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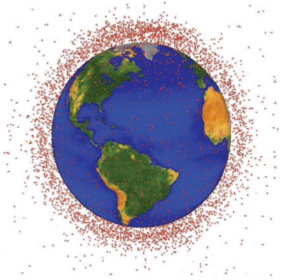
Inside...



A publication of

The NASA Orbital
Debris Program Office

Orbital Debris Mitigation Re-emphasized in the New U.S. National Space Policy

On 31 August 2006, President Bush signed the new U.S. National Space Policy, almost exactly ten years after President Clinton approved the previous such policy. The new policy again specifically addresses the topic of orbital debris, reflecting the progress made both nationally and internationally during the past decade.

The first U.S. National Space Policy to mention orbital debris was signed by President Reagan on 5 January 1988 and affirmed that "All space sectors will seek to minimize the creation of space debris. Design and operations of space tests, experiments and systems will strive to minimize or reduce accumulation of space debris consistent with mission requirements and cost effectiveness." Two years later the George H. W. Bush Administration issued a new National Space Policy (16 November 1989) and expanded the section on orbital debris with the following additional statement: "The United States Government will encourage other spacefaring nations to adopt policies and practices aimed at debris minimization."

One of the direct consequences of the 1989 National Space Policy was the formation of separate bilateral working groups between NASA and the space agencies of Europe, Russia, and Japan. These working groups were merged in 1993 to form the Inter-Agency Space Debris Coordination Committee (IADC). Today, the IADC has grown to eleven members and is actively engaged in a variety of joint research and information sharing (www.iadc-online.org).

The Clinton-era National Space Policy (14 September 1996) reiterated the essential elements of the previous policy and called upon NASA, the Department of Defense (DoD), and the U.S. intelligence community to work with the private sector to "develop design guidelines for future government procurements of spacecraft, launch vehicles, and services." In 1997 NASA and DoD prepared draft U.S. Government Orbital Debris Mitigation Standard Practices, which were officially accepted in February 2001 after consultations with industry.

The 2006 National Space Policy recognizes these standard practices and the related commercial regulations which have been developed by other U.S. Government entities since 1996:

> "Orbital debris poses a risk to continued reliable use of space-based services and operations and to the safety of persons and property in space and on Earth. The United States shall seek to minimize the creation of orbital debris by government and non-government operations in space in order to preserve the space environment for future generations. Toward that end:
>
> - Departments and agencies shall continue to follow the United States Government Orbital Debris Mitigation Standard Practices, consistent with mission requirements and cost effectiveness, in the procurement and operation of spacecraft, launch services, and the operation of tests and experiments in space;
> - The Secretaries of Commerce and Transportation, in coordination with the Chairman of the Federal Communications Commission, shall continue to address orbital debris issues through their respective licensing procedures; and
> - The United States shall take a leadership role in international fora to encourage foreign nations and international organizations to adopt policies and practices aimed at debris minimization and shall cooperate in the exchange of information on debris research and the identification of improved debris mitigation practices."

Orbital debris mitigation remains a high priority for the U.S., which continues to promote scientific research and the implementation of practical countermeasures on a world-wide basis, especially in coordination with the United Nations and the IADC. ♦

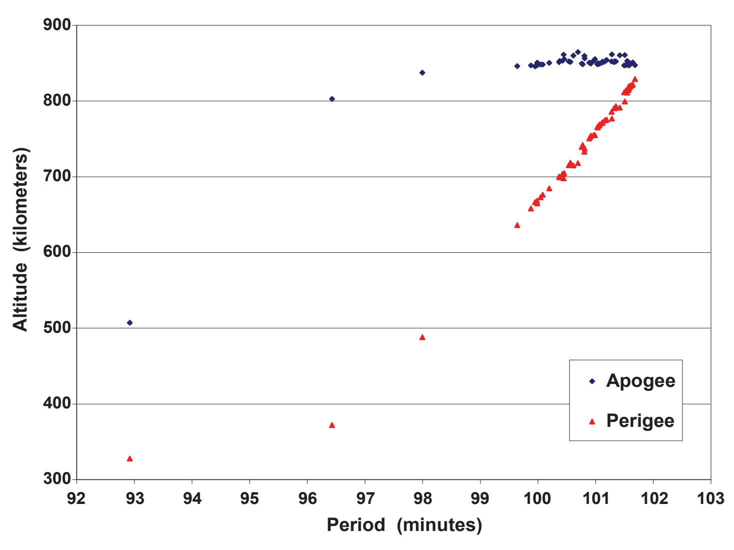
Significant Increase in Satellite Breakups During 2006

Although no satellite breakups were detected for nearly a year during the period from June 2005 to the first of May 2006, the remainder of 2006 witnessed eight satellite breakups for a rate of one per month. Not since 1993 had so many breakups occurred in one year. Half of these breakups occurred in the final quarter of the year and included one Japanese and two U.S. rocket bodies and one Russian spacecraft. Fortunately, the debris from these latest four satellites, with ages ranging from less than one hour to more than 17 years, should be relatively short-lived.

On 14 September 2006 the Russian Federation launched Cosmos 2423 (International Designator 2006-039A, U.S. Satellite Number 29402), the eighth of a series of Earth observation spacecraft which began in 1989 with Cosmos 2031. The nearly 7-metric-ton spacecraft normally operate between an altitude of 200 km and 350 km for periods of up to four months. A distinctive feature of this class of spacecraft is an apparent detonation of the vehicle at the end of mission. Debris clouds with as many as 180 members, with apogees as high as 1100 km, have been detected. Fortunately, the low altitude of these spacecraft at the time of fragmentation leads to very limited orbital lifetimes for the debris.

After a flight of 64 days, Cosmos 2423 completed its mission on 17 November and generated numerous debris, of which 28 were quickly cataloged by the U.S. Space Surveillance Network (SSN) (Satellite Numbers 29604-29631) before reentering the atmosphere. Some debris were thrown into orbits with apogees of more than 850 km, but all known debris had fallen out of orbit within 30 days.

While the fragmentation of Cosmos 2423 had been expected, the release of at least 62 debris by a Delta IV second stage (International Designator 2006-050B, U.S. Satellite Number 29523) soon after launch on 4 November was not. As reported on page 3 in this issue, this rocket body successfully completed a controlled reentry burn about an hour and a half after delivering its payload into a 850 km, sun-synchronous orbit. However, sometime after orbital insertion and before the de-orbit maneuver, the stage ejected all the aforementioned debris in a retrograde direction (see figure).



All debris from the Delta IV second stage was ejected in a retrograde direction. The graph above depicts the orbits of 60 cataloged debris ten days after the event. The lowest period piece has already experienced significant orbital decay.

The nature of the debris and the cause of their release are not yet understood, but an investigation is underway. The primary objective is to identify the debris generation mechanism and to implement any necessary countermeasures to prevent a reoccurrence on future Delta IV missions. Although the two debris thrown into the lowest orbits decayed quickly, the orbital longevity of the remaining debris might be significantly greater, particularly under the current low level of solar activity.

The surprise of the rapid fragmentation of the Delta IV second stage was matched by the 3 December breakup of a Delta II second stage which had been dormant in a low Earth orbit for 17 years. Moreover, the stage (International Designator 1989-089B, U.S. Satellite Number 20323), which had been used to launch NASA's COBE spacecraft, had been passivated at the end of its mission and, therefore, should not have contained any energy sources that could have caused the breakup. At the time of the event, the ~900 kg stage was in an orbit of 685 km by 790 km with an inclination of 97.1°.

By the end of December, no debris had been officially cataloged by the U.S. SSN, but more than 30 debris were being tracked. On a positive note, the debris were decaying rapidly, despite their moderate altitude. Such behavior suggests that the debris possess a high area-to-mass ratio. Observations of the stage after the event indicated that it was tumbling rapidly. Potential reasons for the breakup, including impact by a small object, are under evaluation.

The final satellite breakup of 2006 involved the second stage of an H-2A launch vehicle (International Designator 2006-037B, U.S. Satellite Number 29394), which had been in orbit for less than four months. At the time of the event, the rocket body was in an orbit of 430 km by 490 km with an inclination of 97.2°. Less than 20 debris were detected by the U.S. SSN. The breakup bore several similarities with the fragmentation of another H-2A second stage in August (*Orbital Debris Quarter News*, 10-4, p. 1). All the debris were expected to reenter within a relatively short time. ♦

2006 NASA Orbital Debris Colloquium

The NASA Orbital Debris Program Office at Johnson Space Center hosted a NASA Orbital Debris Colloquium on 14-15 November 2006 attended by about 30 government and contractor personnel. The primary topic of the meeting was a discussion of the emerging NASA Procedural Requirements (NPR) document, 8715.DRAFT, *NASA Procedural Requirements for Limiting Orbital Debris* (currently under NODIS [NASA Online Directives Information System] review), the new NASA Technical Standard (NS), NASA-STD-8719.14, *Process for Limiting Orbital Debris*, and the accompanying Debris Assessment Software (DAS) 2.0.

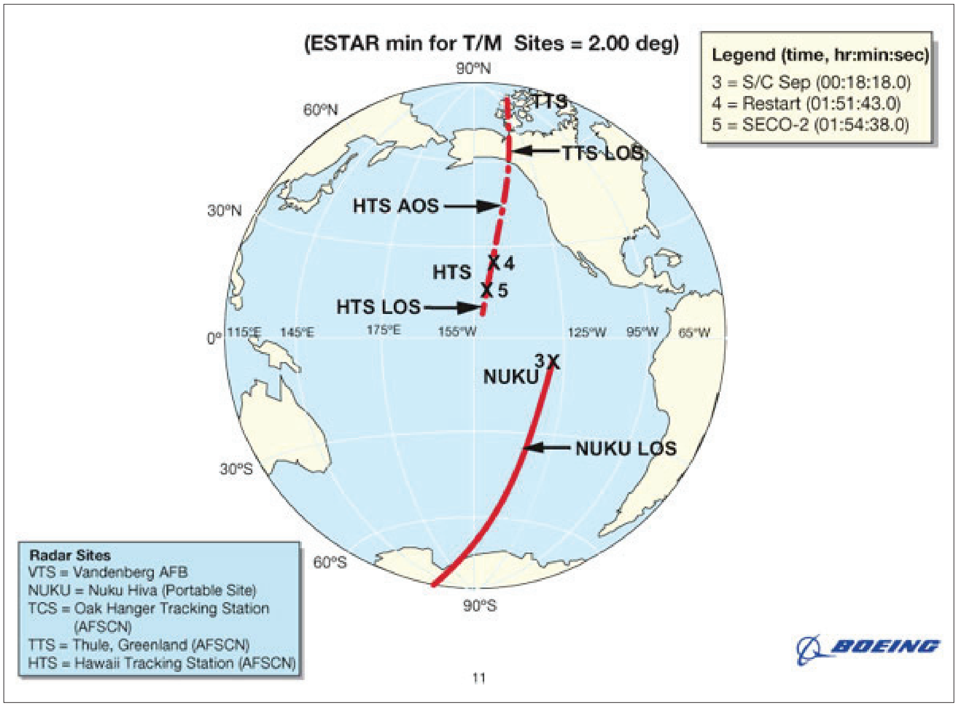
After a brief introduction and some real world examples of operational debris concerns presented by Gene Stansbery, Nicholas Johnson presented a review of national and international policies on orbital debris. John Lyver then led the discussion on the NPR and NS. Two special topics were presented to lead off the second day of the colloquium. Jim Anderson from Goddard Space Flight Center presented "Design to Demise" efforts by the Global Precipitation Measurement (GPM) project. In order to meet the 1 in 10,000 reentry risk threshold, GPM has developed designs for a completely demisable reaction wheel and propulsion tank. The second presentation by Lauri Newman, also from Goddard, showcased procedures for "Close Approach Evaluation and Avoidance Process for the Earth Science Constellation Missions."

Following these presentations, David Whitlock discussed the requirements and formats for the Orbital Debris Assessment Reports (ODAR) and End-of-Mission Plans (EOMP) required by the new NPR. The meeting wrapped up with a presentation on the new DAS 2.0 software tool by J.-C. Liou and a demonstration of the software by John Opiela. DAS 2.0 will be released after approval and release of the new NPR and NS documents. ♦

Delta IV Performs Successful Controlled Reentry

The latest flight of the Delta IV launch vehicle has demonstrated a new capability to execute a controlled reentry of the second stage from a relatively high orbit. The operation not only removed the vehicle from a long-lived orbit, where it might have been a later source for collision-induced debris, but also eliminated any risk of injury or property damage which might have followed an uncontrolled reentry.

The Delta IV launch system was introduced in 2002 and through October 2006 had been used on six missions to a variety of Earth orbits. The seventh mission, carrying a U.S. meteorological spacecraft (DMSP 5D-3 F17), called for a direct insertion of the second stage and the payload into a sun-synchronous orbit near an altitude of 850 km. Fifteen minutes after launch from Vandenberg Air Force Base on 4 November, the spacecraft and the Delta IV second stage reached the target orbit and were separated about three minutes later.



This map shows the rocket's upper stage during its fuel depletion burn and atmospheric reentry. Credit: Boeing

After coasting for another hour and a half, the second stage was restarted for a final three-minute burn. Without its payload, the stage was able to fly an extremely steep trajectory and reenter the atmosphere only a few minutes later, rather than the leisurely 30-plus minutes normally seen with other satellite reentries. Consequently, the debris impact footprint over an uninhabited region of the Pacific Ocean was substantially reduced.

This demonstration proved that, given adequate residual propellants, the Delta IV second stage has sufficient electrical power and attitude control accuracy following payload release to conduct a controlled reentry. This capability is of particular interest since reentry risk assessments for both types of Delta IV second stages (with nominal dry masses of either 2.9 or 3.5 metric tons) have indicated that the amount of debris expected to survive an uncontrolled reentry would pose a human casualty risk in excess of the value of 1 in 10,000 set forth in the U.S. Government Orbital Debris Mitigation Standard Practices. ♦

Publication of the 2003 Haystack and HAX Radar Report

The fiscal year 2003 Haystack and Haystack Auxiliary (HAX) radar report has been recently published. This JSC report, *Haystack and HAX Radar Measurements of the Orbital Debris Environment; 2003* (JSC-62815), provides a detailed presentation of the processing and analysis of debris data for debris as small as 5 mm.

There were many differences in the fiscal year 2003 data compared to previous years. The fiscal year 2003 data were taken with a redesigned data acquisition system in which large segments of the real time processing were converted from analog to digital. The system supports longer transmitted pulses and faster pulse repetition rates, providing enhanced detection capability. The range window of the radar has also been extended significantly. All of the 633.3 hours of Haystack data and the 541.8 hours of HAX data were taken in the 75° elevation East staring mode. The long data collection time provides the best orbital debris statistics ever obtained in a single year.

Data analysis described in the report revealed discrepancies in the data that indicated problems with the data acquisition at the radars. As a result of this analysis, the Massachusetts Institute of Technology Lincoln Laboratory (MIT/LL) later discovered and resolved software errors in the data buffering system and various quantization errors; however, these problems were resolved after the fiscal year 2003 data collection. These malfunctions in the data acquisition system reduced the capability of the Haystack radar to detect debris less than 1 cm, and the HAX radar to detect debris less than 4 cm. Despite the limitations of the radars imposed by these data acquisition system problems, the excellent statistics for Haystack and HAX data during fiscal year 2003 have greatly helped in characterizing the small debris environment.

The increased debris statistics in fiscal year 2003 allow debris breakup clouds to be apparent. The report includes the analysis of an interesting cloud of debris in a near-circular debris ring in a polar orbit associated with the nuclear powered SNAPSHOT satellite. ♦

New Program Manager for the NASA Orbital Debris Program Office

In November, Mr. Gene Stansbery was appointed the new Program Manager for the NASA Orbital Debris Program Office at Johnson Space Center, having served as the Acting Program Manager since July. Gene has supported the NASA Orbital Debris Program Office for 20 years with emphasis on ground-based and *in situ* debris measurement activities. For many years he served as the Lead Scientist for Orbital Debris Measurements.

The recent appointment recognized the growing responsibilities of the Program Manager and the NASA Chief Scientist for Orbital Debris and the need for dedicated support for each portfolio. Nicholas Johnson, who served in both roles from 1997 until July 2006, continues his Chief Scientist duties. ♦

PROJECT REVIEWS

A New Analysis on the Size Estimation Model Pieces

R. MADLER

An initial analysis for shape determination of the Size Estimation Model (SEM) pieces was performed. This was part of a broader study to review the feasibility of a shape parameter for use by the orbital debris community. A driving requirement for a shape parameter is relevance to modeling, measurement, and hazard analysis. This initial review was limited to a parameter that could be measured on fragments from debris tests with the intention of correlating that measurement with radar observations. Finding a shape parameter that can be estimated with radar data is the key to utilizing shape for debris hazard assessment. A subset of the objects used to create the radar SEM was used for this initial analysis.

Initial shape parameterization focused on using ratios of the characteristic lengths of the fragments. A review of the literature on size and shape estimation shows a rich history of using characteristic lengths for shape estimation. However, there were several ways of measuring the sizes and many definitions for shape, most of which are not practical for debris use. A review of the size measurements of the Satellite Orbital Debris Characterization Impact Test (SOCIT) and SEM fragments taken by different groups revealed that, even in the debris community, there is not a consistent method of measuring debris size. NASA is taking steps to ensure that a consistent size measurement methodology is used for all future size measurements and that the measurement methods for prior tests are understood before using the data.

In 1990 and 1991, NASA sponsored a series of static radar cross section (RCS) measurements to characterize hypervelocity impact fragments. Thirty-nine objects from this series were used to create a SEM so that debris size could be estimated from the radar signal. The majority of the 39 objects came from two hypervelocity impact shots conducted at the Arnold Engineering Development Center (AEDC). The two shots were identified as 6470 and 6472. The processing and results are documented in several XonTech reports. This model has been extended to create the Statistical Size Estimation Model (SSEM). This note will focus on the use of a subset of these 39 objects, first for size comparison and then to examine shape characteristics.

Size of debris fragments has classically involved assessing three orthogonal measurements, which we will call X, Y, and Z. A comparison of the XYZ measurements from a subset of the 39 objects (the ones from shot 6470) was possible because two groups, in addition to XonTech, had performed measurements on these objects. The XonTech XYZ measurements compared well for one of the groups, while the other group had obviously used a different measurement methodology. Even between the two similar measurement sets, there was a discrepancy for a couple oddly shaped objects such as the one shown in Figure 1. This operator variance has been well documented in the size estimation literature.

Figure 1. Image of Fragment 2 from the 6470 test. This is an example of a large crumpled fragment.

Figure 2 shows a shape classification method based on the XYZ size measurements that groups more spherical objects toward the upper right corner. The figure also identifies groups of objects with similar size ratios and labels them with rough shape classifications. All of these objects have been imaged extensively and distinct differences in cross sectional area distributions between crumpled and blade or plate-like objects have been shown. However, deducing the shape of an object based on cross-section distribution would take multiple measurements at different angles and could be difficult to use for on-orbit debris objects.

Since a useful shape parameter must be discernible from radar measurements in order to be measured for on-orbit debris, the static RCS measurements used in the SEM were compared for objects with different shapes based upon their XYZ measurements. It was expected that the orthogonal polarization radar signal would have some correlation with shape. This characteristic is already used to identify spherical low Earth orbit (LEO) objects based on radar return from the Haystack radar.

Currently, several radars can determine the average ratio between principle and orthogonal

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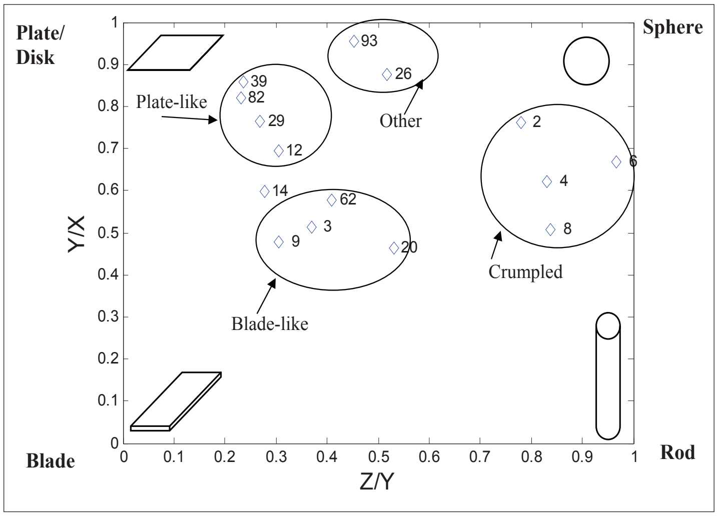

Figure 2. An example of using size ratio for shape characterization. X, Y, and Z correspond to the largest to smallest orthogonal dimensions on a fragment. The shapes and names by the corners correspond to idealized shapes. Most debris fragments group toward the center of the figure, but have been grouped here according to a qualitative descriptor for shape.

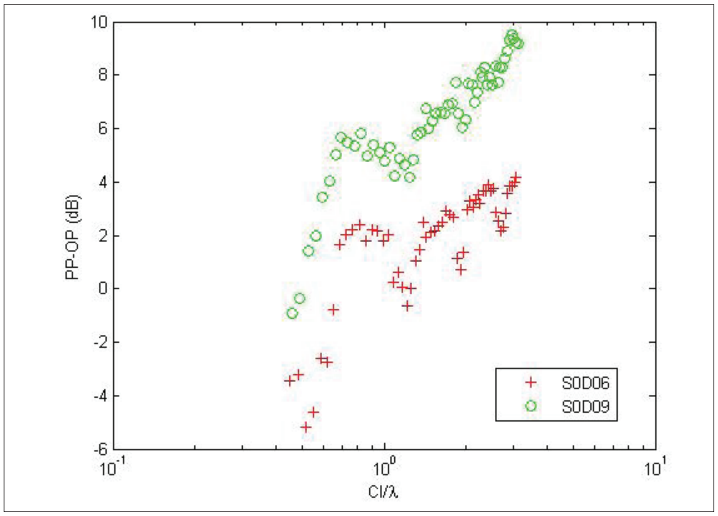

Figure 3. PP-OP comparison between crumpled piece 6 (S0D06) and blade-like piece 9 (S0D09). The PP-OP values (in dB) were determined over a range of wavelengths. The x-axis is the characteristic length for the object divided by the wavelength. The characteristic length is the average of the XYZ size measurements.

Risk to LEO Spacecraft Due to Small Particle Impacts

P. KRISKO

Many long-term studies have been completed on the subject of the future collisional risk to spacecraft from objects larger than 10 cm passing through low Earth orbit (LEO). Objects of this size limit were chosen because their fragmentation has been deemed most likely to generate large fragments that would themselves become dangerous impactors, and also because their modeled numbers over time have been computationally manageable. But recent work at the NASA Orbital Debris Program Office has indicated that, by the methods of statistical analysis, a reasonable number of non-catastrophic collisions involving small impactors (< 10 cm) and larger targets (≥ 10 cm) have already taken place[1]. These events would by their nature be unlikely to be routinely detected, as the result would be a destruction of the small untracked impactor and a cratering of the larger target. Evidence of slight ephemeris changes in large resident space objects, however, could be evidence of such collisions[2].

That work is extended to the near-future with attention paid to all events involving larger than 1 cm objects passing through LEO; both non-catastrophic and catastrophic. LEGEND, NASA's 3-dimensional long-term debris evolutionary model, is modified for this study. The standard version of the model includes the 2001 NASA Breakup Model and an 8-year traffic cycle (1998-2005) for the projection period. Added for this study are the NASA sodium potassium (NaK) deposit model and an extension of the collision calculations to objects larger than 1 cm.

Time period	Total period 1957 through 2035 (79 years)
Ave # collisions Target ≥ 10 cm, Impactor ≥ 10 cm Target ≥ 10 cm, Impactor < 10 cm Target < 10 cm, Impactor < 10 cm	 5 102 1
Ave # collisions (All) Catastrophic	108 (StDev 30) 7 (StDev 7)
Ave # collisions (Target ≥ 10 cm, Impactor < 10 cm) Catastrophic	102 (StDev 28) 2 (StDev 2)
Ave # collisions (both objects ≥ 10 cm) Catastrophic	5 (StDev 3) 3 (StDev 2)
Ave # collisions (NaK) Catastrophic	21 (StDev 5) 1 (StDev 1)

Table 1. Test summary events with standard deviations.

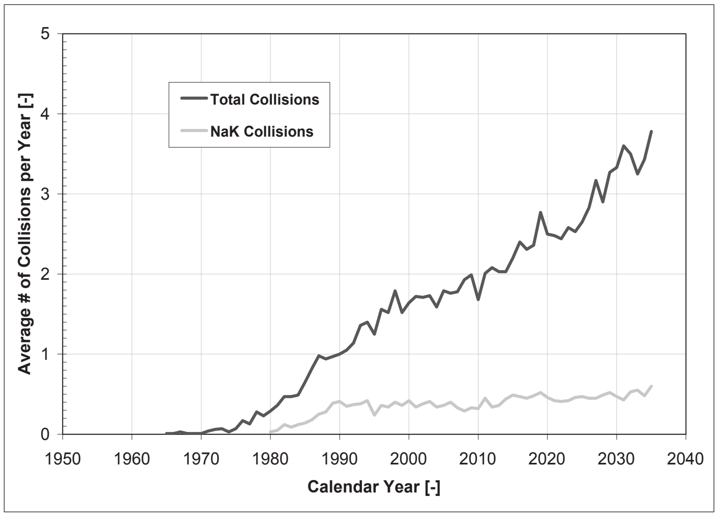

Figure 1. Modeled average collision rate over time during analysis period (1957 through 2035).

The sources of orbiting objects, therefore, include active spacecraft, fragments from explosions and collisions, NaK droplets, mission-related debris, and spent spacecraft and upper stages. Solid rocket motor slag is not added since NASA does not have a validated model for this source presently; however, when slag particles are included they may increase the 1 cm collision rate by a noticeable amount.

The analysis period chosen is 1957 through 2035. This provides a smooth transition between the known past environment and the projected future, and therefore, brings confidence to the entire modeling process. The end-year 2035, is chosen to be before any stringent mitigation practices could be implemented (*e.g.*, active removal of objects from LEO). Therefore, this analysis period should give a reasonable representation of the true growth of the LEO debris environment, reflected by the models.

The analysis includes 200 Monte Carlo iterations of the LEO environment throughout the modeling period. The results displayed in Table 1 represent the averages and standard deviations of those iterations.

Result highlights are as follows,

- the number of collisions among the modeled population of 1 cm and larger objects passing through LEO is nontrivial,
- approximately 95% of all collisions occur between impactors that are smaller than 10 cm in size and targets that are larger than 10 cm in size, and 98% of these collisions are non-catastrophic,
- NaK droplets account for between 19% and 25% of collisions, with the rate stabilizing over time of the study
- nearly three quarters of all impactors are fragments,
- collision events between objects larger than 10 cm occur sparingly in the past with a rate that does not contradict the actual confirmed rate of three in the last 49 years,
- the projected rate of catastrophic collision events between objects larger than 10 cm is in line with previous NASA studies,
- and nearly 30% of catastrophic events involve impactors smaller than 10 cm and targets larger than 10 cm throughout the analysis period.

The modeled overall collision rate continually increases over time towards a rate of four

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New Analysis

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polarizations for on-orbit objects. Since this ratio is known to be a function of shape, it holds promise for on-orbit debris shape estimation. The initial review of the radar measurements on two debris fragments from the 6470 test, which had distinct shapes based on their size ratios, supports this hypothesis. Figure 3 shows a comparison of the principle to orthogonal polarization (PP-OP) between a crumpled object (S0D06) and a blade-like object (S0D09). The crumpled object (more spherical) appears to have more similar principle and orthogonal polarizations than the blade-like object. While this apparent difference between the two objects should not be surprising, no attempt to quantify the effect of shape has been undertaken.

This initial study confirms the supposition that the static RCS measurements of the SEM fragments contains shape information, yet did not quantify a shape parameter based upon the radar polarization. Further theoretical study into the radar response of various shapes as well as further radar measurements will be necessary to quantify a shape parameter that can be used by the measurement community. In parallel, this radar-determined shape parameter must be related to the physical size, area, and shape characteristics of the fragment for use by the modeling and hazard analysis communities. ♦

Risk to LEO Spacecraft

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events per year by the end of the analysis period (Figure 1). The NaK collision rate appears to stabilize after the final deposit of droplets in 1989 to a constant rate through the remainder of the analysis period. According to this study, a rate of one NaK impact every two to three years would be expected at least through 2035.

Figures 2 and 3 further categorize the modeled activity by LEO altitude in snapshot for the study years 2005 and 2035. Regions of high population are the most active collisionally. NaK droplets account for over 20% of all events by the end of the year 2005 and are of course found in the altitude regions 800 km through 1050 km where the droplets are clustered at that date. The overall collision rate within the altitude range 950 km through 1050 km is greatly increased due to the NaK. By the end of the year 2035, modeled collision events have increased nearly fourfold and spread in altitude range. NaK droplets, in particular, continue to affect the collision rates of lower altitudes as they decay out of orbit.

Catastrophic collisions that involve small impactors and larger targets are of special note. As stated previously, nearly 30% of all catastrophic events throughout the analysis period belong to this class with most of these events occurring between the numerous population of debris fragments from past explosion and collision events. But over 10% of the modeled activity within this class occurs between small untrackable impactors and large intact spacecraft. This would indicate a very small but growing danger of catastrophic impact between objects < 10 cm and spacecraft in LEO over this century.

Though the numerical results of this analysis are highly dependent on the current NASA Breakup Model and the 8-year launch cycle, the study does reveal noteworthy trends in LEO environmental collision activity and growth due to the activity.

1. Krisko, P.H. *Historical collisions in low Earth orbit*, IAC-06-B6.2.5, 57th International Astronautical Congress, Valencia, Spain, 2006.

2. Anon. *A New Collision in Space?*, Orbital Debris Quarterly News, 7-3, p. 1, 2002. ◆

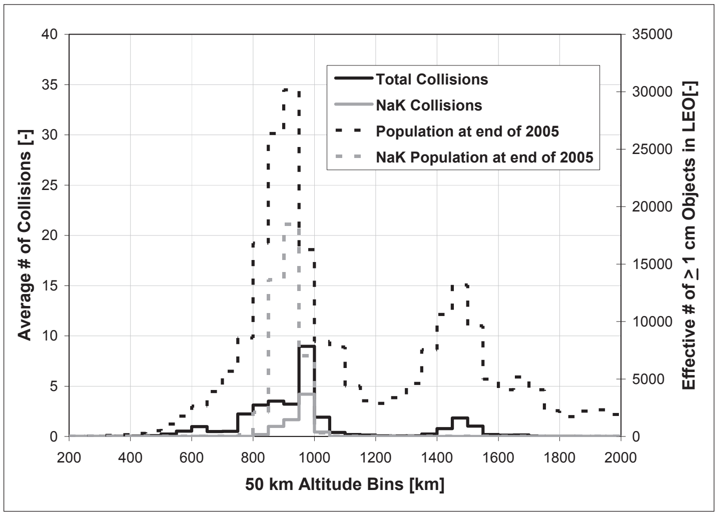

Figure 2. Modeled average number of collisions by altitude bin at the end of the historical period, 2005, compared to the effective population of 1 cm and larger objects in the LEO altitude bins. (Effective number is defined as the portion of the orbit that passes through the altitude range.)

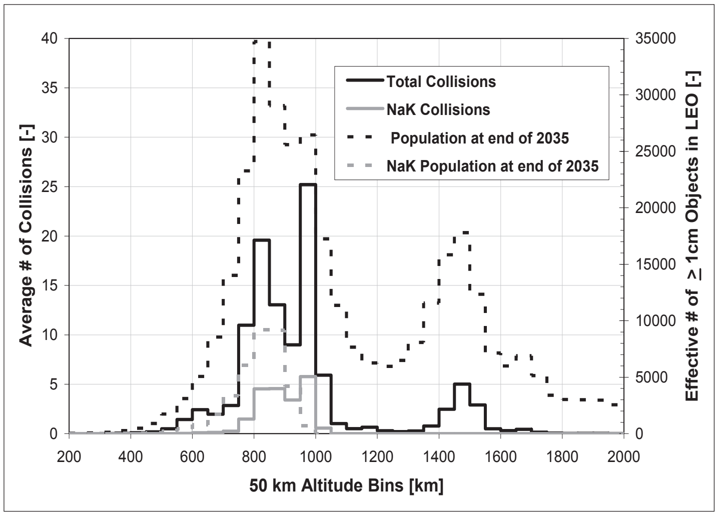

Figure 3. Modeled average number of collisions by altitude bin at the end of the analysis period, 2035, compared to the effective population of 1 cm and larger objects in the LEO altitude bins. (Effective number is defined as the portion of the orbit that passes through the altitude range.)

UPCOMING MEETINGS

14-16 May 2007: The 2nd International Association for the Advancement of Space Safety (IAASS) Conference, Chicago, Illinois, USA.

The conference is an invitation to reflect and exchange information on a number of topics in space safety that are of national and international interest. Among the topics to be discussed are space debris environment and spacecraft reentry. Additional information is available at http://www.congrex.nl/07a02/.

10-14 September 2007: 2007 Advanced Maui Optical and Space (AMOS) Surveillance Technologies Conference, Wailea, Maui, Hawaii, USA.

The 2007 AMOS Conference will cover various topics in adaptive optics, astronomy, imaging, lasers, metrics, non-resolved object characterization, orbital debris, Pan-STARRS, SSA programs and systems, and telescopes and sensors. Additional information on the conference is available at http://www.amostech.com.

23-27 September 2007: Hypervelocity Impact Symposium (HVIS), Wiliamsburg, Virginia, USA.

This biennial symposium is dedicated to enabling and promoting an understanding of the basic physics of high velocity impact and related technical areas, including spacecraft shielding design and orbital debris environment. More information can be obtained at http://hvis.org/HVIS_07/index.html.

24-28 September 2007: The 58th International Astronautical Congress, Hyderabad, India.

A Space Debris Symposium is planned for the congress. The three scheduled sessions will address the complete spectrum of technical issues of space debris, including measurements and space surveillance, modeling, risk assessment, reentry, hypervelocity impacts, protection, mitigation, and standards. Additional information on the Congress is available at http://www.iac2007.org.

INTERNATIONAL SPACE MISSIONS
25 September - 27 December 2006

International Designator	Payloads	Country/ Organization	Perigee (KM)	Apogee (KM)	Inclination (DEG)	Earth Orbital Rocket Bodies	Other Cataloged Debris
2006-042A	NAVSTAR 58 (USA 190)	USA	20014	20349	55.0	2	0
2006-043A	DIRECTV 9S	USA	35775	35798	0.0	1	1
2006-043B	OPTUS D1	AUSTRALIA	35772	35802	0.0		
2006-043C	LDREX 2	JAPAN	261	35568	7.0		
2006-044A	METOP-A	ESA	820	821	98.7	1	0
2006-045A	PROGRESS-M 58	RUSSIA	325	357	51.6		
2006-046A	SJ-6C	CHINA	594	599	97.7	1	3
2006-046B	SJ-6D	CHINA	598	600	97.7		
2006-047A	STEREO A	USA	HELIOCENTRIC			1	1
2006-047B	STEREO B	USA	HELIOCENTRIC				
2006-048A	SINOSAT 2	CHINA	EN ROUTE TO GEO			1	0
2006-049A	XM-4	USA	35783	35790	0.1	1	0
2006-050A	DMSP 5D-3 F17	USA	840	856	98.8	1	66
2006-051A	ARABSAT 4B	RUSSIA	35763	35809	0.0	1	1
2006-052A	NAVSTAR 59 (USA 192)	USA	20205	20367	55.1	2	0
2006-053A	FENGYUN 2D	CHINA	35782	35789	2.6	2	0
2006-054A	WILDBLUE 1	FRANCE	35780	35794	0.0	1	1
2006-054B	AMC-18	FRANCE	35784	35790	0.0		
2006-055A	STS 116	USA	314	339	51.6	0	3
2006-055B	MEPSI	USA	308	328	51.6		
2006-055C	RAFT	USA	312	331	51.6		
2006-055D	MARSCOM	USA	312	332	51.6		
2006-055F	ANDE SPHERE 1	USA	313	336	51.6		
2006-055J	ANDE SPHERE 2	USA	312	336	51.6		
2006-056A	MEASAT-3	MALAYSIA	35774	35798	0.1	1	1
2006-057A	USA 193	USA	NO ELEMS. AVAILABLE			1	0
2006-058A	TACSAT 2	USA	412	424	40.0	1	0
2006-058C	GENESAT	USA	412	424	40.0		
2006-059A	ETS 8 (KIKU 8)	JAPAN	EN ROUTE TO GEO			1	0
2006-060A	SAR LUPE 1	GERMANY	468	505	98.2	1	0
2006-061A	MERIDIAN 1	RUSSIA	1031	39752	98.2	1	0
2006-062A	COSMOS 2424	RUSSIA	19078	19134	64.8	2	1
2006-062B	COSMOS 2425	RUSSIA	19138	19155	64.8		
2006-062C	COSMOS 2426	RUSSIA	19121	19140	64.8		
2006-063A	COROT	FRANCE	894	908	90.0	1	0

ORBITAL BOX SCORE

(as of 27 DEC 2006, as cataloged by US SPACE SURVEILLANCE NETWORK)

Country/ Organization	Payloads	Rocket Bodies & Debris	Total
CHINA	57	334	391
CIS	1364	2913	4277
ESA	37	36	73
FRANCE	47	314	361
INDIA	31	105	136
JAPAN	100	68	168
USA	1049	3103	4152
OTHER	364	27	391
TOTAL	3049	6900	9949

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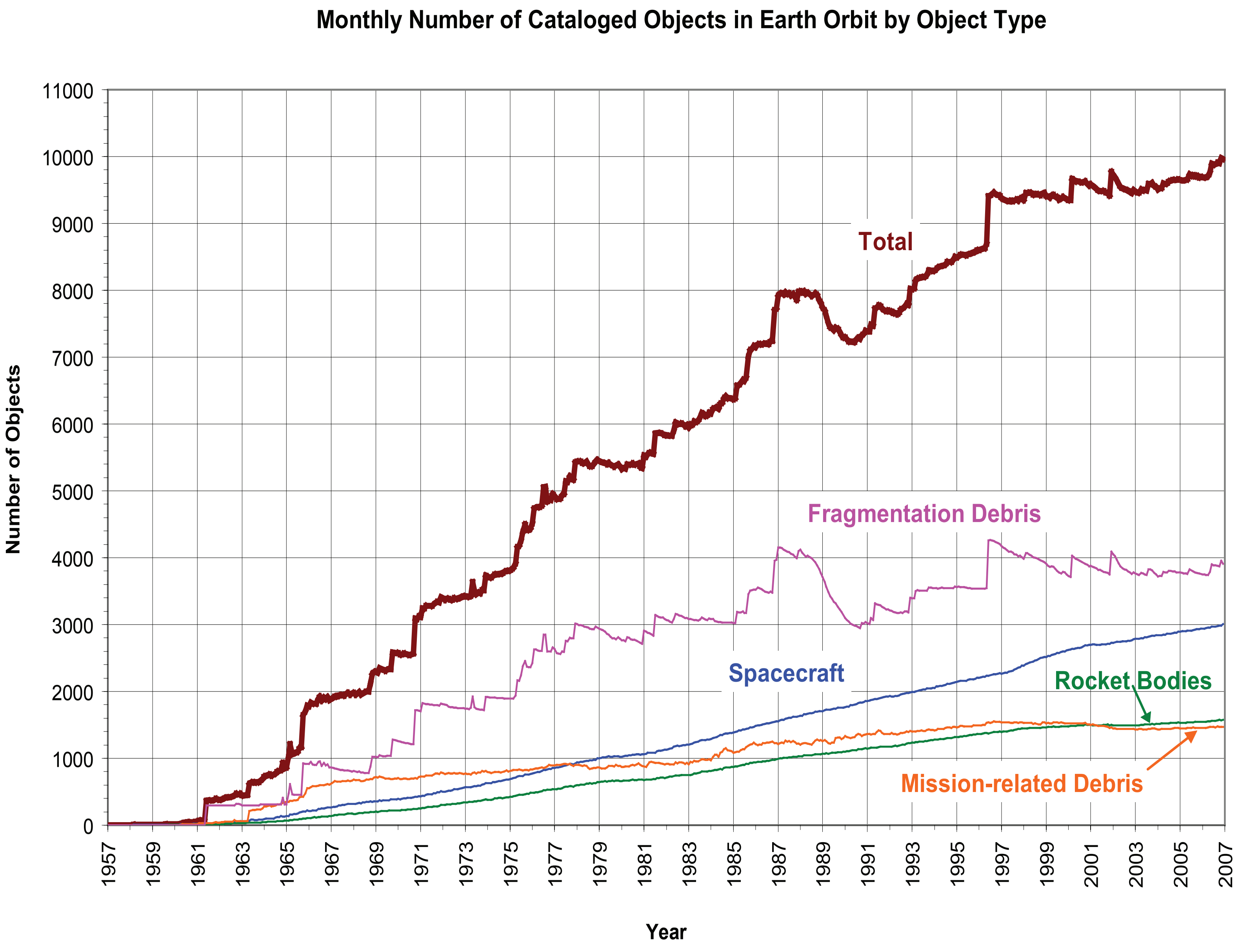
MEETING REPORT

57th International Astronautical Congress
2-6 October 2006, Valencia, Spain

The 57th International Astronautics Congress (IAC) was held in Valencia, Spain from 2 – 6 October 2006. The Space Debris Symposium was coordinated by Christophe Bonnal (CNES), Walter Flury (ESA), and Nicholas Johnson (NASA). It spanned two days with four paper sessions (with 40 papers presented) – Measurements and Space Surveillance, Risk Analysis and Modeling, Hypervelocity Impacts and Protection, and Mitigation and Standards -- and two poster sessions (with 15 posters presented). Recent research was reported and included measurements of the near geosynchronous orbit environment from optical systems, progress in debris cataloging programs, statistical determination of populations based on radar and optical measurements, small particle populations and collision risk to intact spacecraft, impact tests and responses of spacecraft materials, impact modeling, shielding, tethers as active deorbiters of intact spacecraft, and mitigation policies. ♦



Monthly Number of Cataloged Objects in Earth Orbit by Object Type: This chart displays a summary of all objects in Earth orbit officially cataloged by the U.S. Space Surveillance Network. "Fragmentation debris" includes satellite breakup debris and anomalous event debris, while "mission-related debris" includes all objects dispensed, separated, or released as part of the planned mission.

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