National Aeronautics and Space Administration

Orbital Debris
Quarterly News

Volume 12, Issue 2

April 2008

Inside...

A publication of

The NASA Orbital Debris Program Office

Satellite Breakups During First Quarter of 2008

A total of six satellite fragmentations were detected by the U.S. Space Surveillance Network (SSN) during the first three months of 2008, but fortunately all produced short-lived debris, unlike the two severe satellite breakups in the first quarter of 2007 (ODQN, April 2007, pp. 2-3). Only a small portion of debris from one of these latest events is expected to be still in orbit by year's end.

The first three breakups occurred during a month's span between mid-January and mid-February and involved one spacecraft and two launch vehicle upper stages which were experiencing catastrophic orbital decay from highly elliptical orbits with very low perigees. In all cases, the debris detected by the SSN decayed very rapidly, before official cataloging could be accomplished.

Cosmos 2105 (International Designator 1990-099A, U.S. Satellite Number 20941) shed about six pieces on 16 January when its perigee altitude had dropped well below 100 km. The spacecraft decayed approximately 9 hours after the release, and the debris is assessed to have also reentered that day.

On 27 January the third stage of the CZ-3A launch vehicle (International Designator 2007-051B, U.S. Satellite Number 32274), which lifted China's first lunar probe into a temporary Earth orbit on 24 October 2007, reportedly broke-up into 30-40 fragments in an orbit of 80 km by 6035 km. The stage fell back to Earth the following day, and no debris is believed to have remained in orbit for very long.

The third event involved the final stage of the launch vehicle (International Designator 1994-051D, U.S. Satellite Number 23214) which placed the Molniya 3-46 communications satellite into orbit on 23 August 1994. Only two debris were detected as the stage decayed through an orbit of 115 km by 5530 km on 17 February. Reentry of the stage occurred early on 19 February.

On 14 February the U.S. Government announced its intention to attempt to destroy the propellant tank of the USA-193 spacecraft (International Designator 2006-057A, U.S. Satellite Number 29651) at a very low altitude, shortly before the vehicle would naturally reenter the atmosphere. Since the spacecraft had failed immediately after

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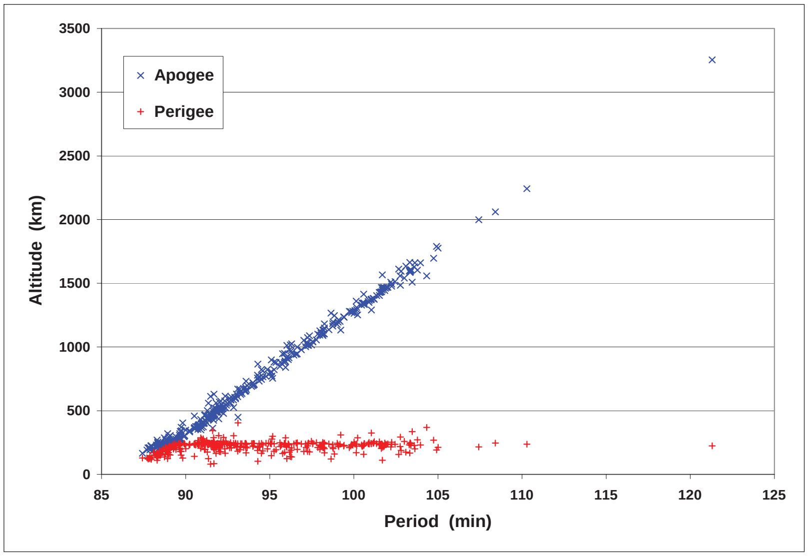

Figure 1. This Gabbard diagram depicts the orbits of 360 debris (5 cm and larger) from USA-193 as of 22 February 2008.

Breakups

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reaching Earth orbit, the tank's hydrazine contents remained unused and in a frozen state. Detailed reentry survivability analyses indicated that the tank and its contents would survive a natural reentry and might pose a threat of human casualty if people encountered the hydrazine cloud released by the tank after impact.

USA-193 was engaged on 21 February (UTC) at an altitude just below 250 km and was severely fragmented via a hypervelocity collision. The majority of the debris fell to Earth within an hour of the break-up, and the remaining debris were left in short-lived orbits. Figure 1 indicates the distribution of 360 orbital debris on 22 February. By the end of March only a small percentage of the original debris were still in orbit, and the reentry of the last fragment was expected this summer.

The next fragmentation occurred on 14 March when Cosmos 2421 (International Designator 2006-026A, U.S. Satellite Number 29247) shed upwards of 300 debris. The vehicle was the 50th of a class of spacecraft which debuted in 1974 and marked the 22nd breakup in the series. At the time of the breakup, Cosmos 2421 was in an orbit of approximately 400 km by 420 km with an inclination of 65 degrees. The spacecraft appeared to have terminated its mission in mid-February and was in a state of natural orbital decay at the time of breakup. The cause of the numerous fragmentations of this class of satellites has not been revealed by the Russian Federation.

The final breakup of the quarter took place on 21 March and involved another rocket body experiencing an early, atmospheric-induced breakup while undergoing catastrophic orbital decay from a highly eccentric orbit. The Atlas 5 Centaur upper stage (International Designator 2007-046B, U.S. Satellite Number 32259) was in an orbit with a perigee altitude of less than 100 km at the time of the event. The primary remnant and all debris were assessed to have reentered by the following day. ♦

Annual Space Debris Meeting at the United Nations

The Scientific and Technical Subcommittee (STSC) of the United Nations' Committee on the Peaceful Uses of Outer Space (COPUOS) held its annual meeting during 11-22 February 2008 in Vienna, Austria. For the 15th consecutive year, space debris was an official agenda topic.

In 2007, after a multi-year effort, the STSC officially adopted a set of Space Debris Mitigation Guidelines (ODQN, Apr 2007, p. 1). These guidelines were accepted by the full COPUOS during its meeting in June 2007. In turn, the UN General Assembly endorsed the guidelines at its 62nd session. In its session report, the General Assembly

> "Agrees that the voluntary guidelines for the mitigation of space debris reflect the existing practices as developed by a number of national and international organizations, and invites Member States to implement those guidelines through relevant national mechanisms;
>
> "Considers that it is essential that Member States pay more attention to the problem of collisions of space objects, including those with nuclear power sources, with space debris, and other aspects of space debris, calls for the continuation of national research on this question, for the development of improved technology for the monitoring of space debris and for the compilation and dissemination of data on space debris, also considers that, to the extent possible, information thereon should be provided to the Scientific and Technical Subcommittee, and agrees that international cooperation is needed to expand appropriate and affordable strategies to minimize the impact of space debris on future space missions;"
>
> (UN Document A/RES/62/217, paragraphs 27 and 28, dated 10 January 2008)

Several technical presentations on space debris were presented during the meeting of the STSC. The U.S. provided a general overview of space activity, including new launches, satellite fragmentations, satellite reentries, and satellite disposals, during 2007. ♦

11th NASA-DoD Orbital Debris Working Group Meeting

The 11th meeting of the NASA/DoD Orbital Debris Working Group was hosted by the NASA Orbital Debris Program Office in Houston, Texas on 26 February 2008. The Working Group, formed in 1997, is an outgrowth of a recommendation from the White House Office of Science and Technology Policy. Its primary purpose is to exchange information on space surveillance activities that contribute to a common understanding of the orbital debris environment.

Air Force Space Command (AFSPC) reported on the status of the Space Surveillance Network, including the anticipated launch of the Space-Based Space Surveillance (SBSS) Block 10 satellite in December 2008. The current list of "lost" satellites was discussed, along with the possible causes for recent increases in lost objects and potential improvements in maintaining the SSN catalog of orbiting objects.

Reorganization of the roles and responsibilities inside AFSPC and the Air Force Safety Center related to orbital debris was also discussed.

A special presentation was made by the Department of Energy and the Air Force Research Laboratory on a photon-counting camera they had developed that could be used to detect orbital debris. The capabilities and limitations of the technique were contrasted with conventional charge-coupled devices (CCDs).

NASA summarized debris-related activities in the Inter-Agency Space Debris Coordination Committee (IADC) and the United Nations' Committee on the Peaceful Uses of Outer Space – Scientific and Technical Subcommittee (UN COPUOS STSC). A set of Space Debris Mitigation Guidelines was approved by the full COPUOS and noted in General Assembly

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NASA-DoD

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Resolution 62/217 on 10 January 2008. NASA also showed the presentation made to the STSC on the planned interception of USA-193 just prior to the event.

In addition, NASA updated a recent analysis of the Fengyun-1C debris cloud that resulted from the Chinese ASAT test in January 2007. Results from the analysis of Haystack radar data were presented which support the assessment that the 1-cm and larger population in low Earth orbit approximately doubled from this single breakup. Also, small asymmetries were found in the distribution of orbital elements within the cataloged fragments from this breakup cloud.

A preview of the upcoming ORDEM2008 Engineering Model also was presented by NASA. The new model will cover all altitudes up to geosynchronous altitudes, and will provide more information on debris sources, debris material density, and population uncertainties.

Other topics of discussion included the recent approval of the new NASA Procedural Requirements for Limiting Orbital Debris (NPR 8715.6), the new NASA Standard 8719.14, *Process for Limiting Orbital Debris*, the release Version 2.0 of the Debris Assessment Software which supports the Standard, and the potential need to update the U.S. Orbital Debris Mitigation Standard Practices. Finally, the need to modernize the SATRAK orbital analysis toolkit to make it compatible with modern (and future) versions of the Windows operating system was discussed.

The next meeting of the Working Group will be held in Colorado Springs during the first quarter of 2009. ♦

Publication of the Final and Yearly CDT Reports

NASA observed the geosynchronous environment (~36,000 km altitude) with the 0.32 m Charged Coupled Device (CCD) Debris Telescope (CDT) at Cloudcroft, New Mexico, between January 1998 and December 2001. The CDT was operated in a staring mode reaching a limiting V magnitude of approximately 17th, which corresponds to a diameter for a ~60 cm sphere (assuming a specular reflection and a 0.2 albedo). Observational and reduction techniques have improved over the duration of the study. The first years of operations have been previously published.[1,2,3] The last two calendar years have recently been published as NASA technical memorandums.[4,5]

The entire CDT dataset has now been uniformly corrected for observed range, phase angle, and solar distance. In addition, the orbit predictions were made using every observation of the object instead of the prior method, wherein only the first and last detection were used. The datasets have been analyzed on a year-to-year basis; the final report was published as a NASA technical publication[6] and inter-compares the yearly datasets to examine similarities and differences on an annual basis. The complete geosynchronous orbit (GEO) dataset for the CDT is presented in the context of distributions such as inclination, Right Ascension of the Ascending Node (RAAN), mean motion, and magnitude (size).

In general, all 4 years of CDT UCT (UnCorrelated Target) data show similar distributions in inclination, eccentricity, RAAN, mean motion, and magnitude, thereby indicating a general uniformity in the UCT environment between 1998 and 2002 for objects brighter than 17th magnitude. Overall, the conclusions of the CDT survey of GEO were:

- The inclination distribution of nonfunctional CTs (Correlated Targets) is similar to the distribution seen for UCTs.
- Analysis of the repeatability of nonfunctional CTs within each observing year provided evidence that each unique UCT is seen ~5.5 times a year, which reduces the total number of unique UCTs to about 100 per year.
- UCTs and CTs show the same amount of drift in the inclination versus RAAN plot between calendar years, confirming the same behavior related to gravitational perturbations of their orbital planes.
- The ratio of UPY (Unique per Year) UCTs to UPY CTs is similar over the 4 years.
- The absolute magnitudes of the UCTs are one to two magnitudes fainter than the nonfunctional CTs for all 4 years.
- If a Lambertian phase function is used instead of a specular phase function to convert the observed magnitudes into characteristic sizes, the resulting size is a factor of 1.63 smaller. The detection limit of 60 cm (specular assumption) for the CDT becomes 35 cm when a diffuse Lambertian sphere is used.
- Probability charts show that the CDT had good coverage for most RAAN values with inclinations less than 15°.

After retirement in December 2001, NASA transferred the CDT to the Aerospace Engineering and Physics Departments of the Embry-Riddle University in Arizona, where it is being used as a teaching tool.

1. Africano, J., et al. *CCD Debris Telescope Observations of the Geosynchronous Orbital Debris Environment*, JSC 28884, 2000.

2. Jarvis, K., et al. *CCD Debris Telescope Observations of the Geosynchronous Orbital Debris Environment, Observing Year: 1998*, JSC 29537, 2001.

3. Jarvis, K., et al. *CCD Debris Telescope Observations of the Geosynchronous Orbital Debris Environment, Observing Year: 1999*, JSC 29712, 2002.

4. Jarvis, K., et al. *CCD Debris Telescope Observations of the Geosynchronous Orbital Debris Environment, Observing Year: 2000*, NASA-TM-214772, 2008a.

5. Jarvis, K., et al. *CCD Debris Telescope Observations of the Geosynchronous Orbital Debris Environment, Observing Year: 2001*, NASA-TM-214773, 2008b.

6. Abercromby, K.J., et al. *The Geosynchronous Earth Orbit Environment as Determined by the CCD Debris Telescope Observations between 1998 and 2002: Final Report*, NASA-TP-14774, 2008. ♦

Debris Assessment Software (DAS) Update

An update to NASA's Debris Assessment Software, DAS 2.0.1, has been released to incorporate two modifications to the original DAS 2.0 program. The first modification corrected an error in the rocket body mass and area-to-mass ratio value when transferred from the Mission Editor to the assessment routines for evaluation of Requirements 4.7-1 and 4.8-1. The second modification revised specific heat (Cp) values in one temperature range for the materials nickel and MP35N® (a non-magnetic, nickel-cobalt-chromium-molybdenum alloy).

DAS users are encouraged to install the new version 2.0.1. The new version will install over the previous version, or users may remove the previous version using the Windows Control Panel "Add/Remove Software" feature.

Members of the ODQN mailing list have been notified of the software update, and the DAS web page (http://www.orbitaldebris.jsc.nasa.gov/mitigate/das.html) now includes a link that may be used to sign up for future update notices. ♦

Publication of the 14th Edition of the History of On-Orbit Satellite Fragmentations

The 14th edition of the *History of On-Orbit Satellite Fragmentations* has been completed. The book details the 194 known fragmentations and 51 anomalous events of on-orbit objects from the first known breakup, on 29 June 1961, through 31 August 2007. This edition of the book discusses LEO and GEO spatial density, in-orbit and decayed object analysis by country of origin, and a comprehensive categorization of breakups and debris by cause, year, and parent object type. Several color graphs, tables, and figures are included to illustrate information related to these topics.

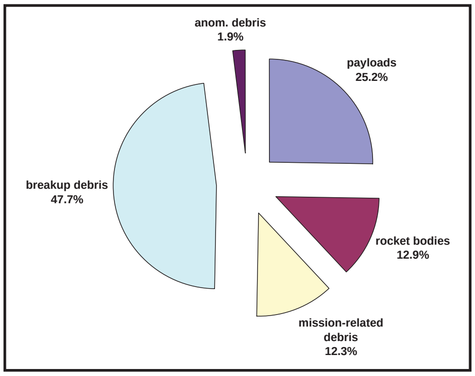

Figure 1. Relative segments of the catalogued inorbit Earth satellite population as of 1 August 2007.

Each object associated with a fragmentation is outlined in a two-page format. The first page consists of information pertinent to the breakup, such as a physical description and orbital parameters of the parent object prior to the breakup, breakup event epoch, altitude and location, assessed cause, and reference documents for those desiring more information. For objects experiencing more than one fragmentation, information about each event is presented on this first page. The second page consists of a Gabbard diagram for the debris cloud (when data were available). Each anomalous event is described on one page, with some basic information about the object and event, as Gabbard diagrams are not included for anomalous events because of the typically low debris count. Twenty-four additional objects experienced a fragmentation as a result of aerodynamic effects. The pertinent information of these events are presented in tabular format, as well.

The 14th edition will be available in Adobe PDF format on the Orbital Debris Program Office web site (http://www.orbitaldebris.jsc.nasa.gov/library/SatelliteFragHistory/fraghistory.html). The *History of On-Orbit Satellite Fragmentations* has been published since 1984. ♦

PROJECT REVIEWS

Physical Properties of the Large Fengyun-1C Breakup Fragments

J.-C. LIOU AND N. L. JOHNSON

The intentional breakup of Fengyun-1C (FY-1C) on 11 January 2007 created the most severe orbital debris cloud in history. Approximately 2700 large fragments were identified and tracked by the U.S. Space Surveillance Network (SSN) by the end of March 2008. Since the event occurred at an altitude of 860 km, the long-term effect of the fragments to the environment must be carefully evaluated. This article provides a preliminary analysis of the physical properties of the FY-1C fragments, as observed by the SSN sensors. The results will be used for a comprehensive assessment that will be presented at the 37th COSPAR Scientific Assembly in July 2008.

The data for the analysis include the orbital elements, preliminary radar cross section (RCS) measurements as of March 2008, and the Two-Line-Element (TLE) history of each object. The NASA Size Estimation Model[1] is used to convert the observed RCS to the average size of each object. Figure 1 shows the preliminary cumulative-size distribution of the fragments (red). Since not all fragments have good RCS data, only 2259 objects are included in the figure. For comparison purposes, the prediction from the NASA Standard Breakup Model[2] for collisions is also shown (green).

The NASA model is designed to describe the average distributions of typical breakups for long-term environment studies, therefore, it is not surprising that there are some discrepancies when the model is compared with a specific event. A typical collision would produce, as indicated by the NASA prediction, less than 900 orbital fragments larger than 10 cm. The level-off of the FY-1C fragment cumulative-size distribution below 13 cm is likely caused by the sensitivity limit of the SSN sensors, since a similar level-off also exists for other fragments in the environment. Separate analysis of data from the more sensitive Haystack radar also supports the assessment that the FY-1C breakup produced more debris than an average hypervelocity impact of a similarly-sized vehicle.

Another unusual characteristic of the FY-1C size distribution is the deviation from

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the single power-law distribution. This may be an indication of multiple components in the fragments – one dominates the 40 cm and larger regime, while the other dominates the smaller regime.

The area-to-mass ratio (A/M) of each fragment can be empirically determined from its TLE history. An iterative curve-fit routine, including orbit propagation based on actual solar flux record, was applied to the TLE history until an A/M value converged to fit the data. At the end of the data processing, good A/M solutions were obtained for 2189 FY-1C fragments. The A/M distribution of those in the apparent 10-to-20 cm size regime is shown in Figure 2. The NASA model prediction for fragments from a typical collision with similar initial conditions is also shown in green. The normalized distributions are shown in Figure 3.

As stated earlier, the FY-1C breakup generated more fragments than what would be expected from a typical collision. An important feature of the FY-1C fragment distribution is the abundance of high A/M pieces. Since the spacecraft[3] had two large solar panels (1.5 m × 4 m each), and was covered with approximately 13 m^2 of Multi-Layer Insulation (MLI), it is very likely that the high A/M component of the fragments consists, at least in part, of solar panel and MLI pieces. By contrast, the two previous, significant hypervelocity impact events, Solwind in 1985 and Delta-180 in 1986, did not possess extensive solar arrays or amounts of MLI. In the end, the shorter-lived but more numerous debris essentially yield an equivalent environmental effect when compared to the NASA Standard Breakup Model results.

1. Stansbery, E.G., et al., *Haystack Radar Measurements of the Orbital Debris Environment; 1990-1994*, JSC-27436, 1996.

2. Johnson, N.L., et al., *NASA's new breakup model of EVOLVE 4.0*, Adv. Space Res. 28, p. 1377, 2001.

3. Johnson, N.L., et al., *The characteristics and consequences of the break-up of the Fengyun-1C spacecraft*, IAC-07-A6.3.01, 2007.

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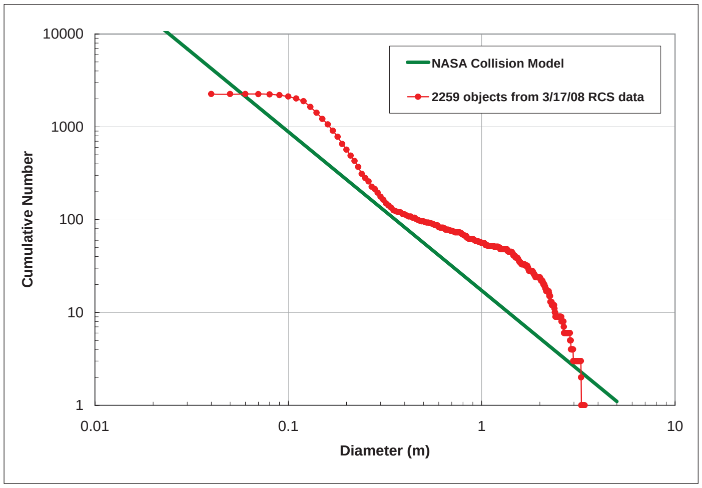

Figure 1. Preliminary cumulative size distribution of the cataloged FY-1C fragments (red). The green line is the NASA model prediction for a typical collision.

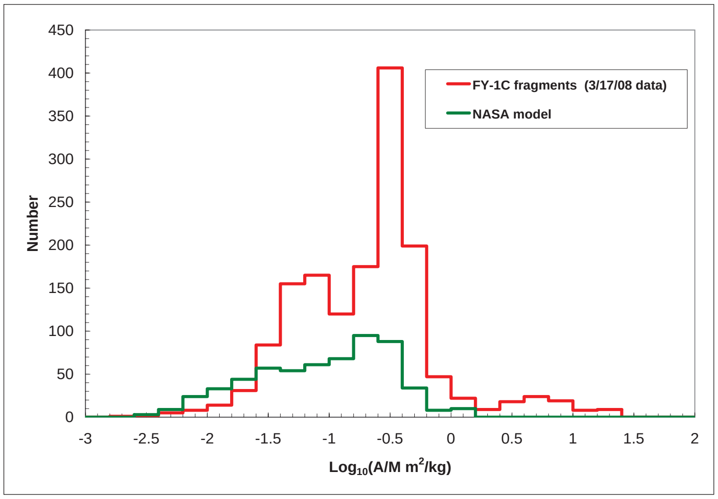

Figure 2. The A/M distributions of the FY-1C fragments (red) and the NASA model prediction for fragments form a typical collision (green). Both curves represent the apparent 10-20 cm debris population.

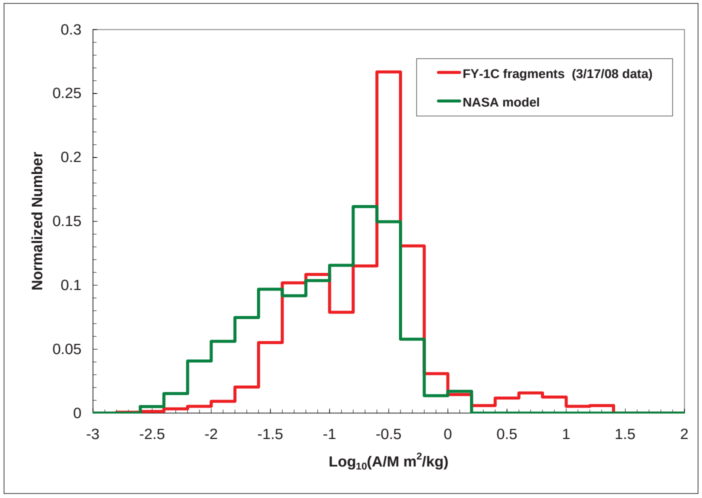

Figure 3. The normalized A/M distributions of the FY-1C fragments (red) and the NASA model prediction for fragments form a typical collision (green). Both curves represent the apparent 10-20 cm debris population.

NASA's New Engineering Model ORDEM2008

M. MATNEY

NASA engineering models are tools for estimating the orbital debris populations in such a way that they can be used to predict the debris environment in Earth orbit. The models are designed to be "user-friendly" and provide the user accurate results in a timely fashion. These models have been used historically by spacecraft designers and operators as well as debris observers.

Spacecraft designers are interested in understanding the flux of particles that can damage or perforate sensitive surfaces of their spacecraft. Because damage equations for different surface types are functions of an impactor's size, relative velocity, and direction with respect to the spacecraft surface element, an engineering model should provide debris flux broken down by size, velocity, and directionality. Programs like NASA's BUMPER construct a computer model of a spacecraft

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using finite elements. Each of these elements has an associated damage equation and can be compared against the engineering model environment to compute total probability of failure.

Because of the long lead times in new satellite designs, engineering models need to be able to estimate the long-term behavior of the debris environment over a satellite life cycle. In addition, because the orbital debris populations are distributed in altitude and latitude, the environment a spacecraft encounters is unique to the orbit of the spacecraft. Thus, an accurate model of the debris flux needs to be able to compute the unique flux dependent on the particular orbital characteristics of the spacecraft.

In the case of a ground-based observer, results will be dependent upon the inclination distribution of resident space objects visible from the observer's latitude. It would also be desirable to show the dependence upon the instrument pointing azimuth and elevation.

In order to satisfy the needs of the various users, any engineering model must include an accurate assessment of the orbital debris environment as it is distributed in altitude, latitude, debris size, and time. The best way to accomplish this is to create populations that are first distributed in orbital elements to reflect the actual distributions around the Earth or, at least, our best approximation to this distribution. Next, the model needs a tool that maps these orbital distributions into spacecraft or instrument flux.

In the past, NASA's ORDEM series of engineering models have included assessments of the orbital debris environment that run on a standard PC. In the years since ORDEM2000 was released, NASA has taken new data and developed new analysis techniques, such as mappings of debris in GEO using Michigan Orbital Debris Survey Telescope (MODEST) data, progress in determining the orbital distributions of spacecraft materials, the evolution of data analysis techniques to estimate population uncertainties, and the advent of generation models for specific populations (e.g, the RORSAT sodium potassium (NaK) coolant droplets).

These advances are mirrored in the specific requirements of the new model, ORDEM-2008, which will supercede ORDEM2000. Table 1 compares the ORDEM2008 requirements to those of ORDEM2000.

Table 1. ORDEM2000 vs. ORDEM2008.

Parameter	ORDEM2000	ORDEM2008
Spacecraft and Telescope/Radar analysis modes	Yes	Yes
Time range	1991 to 2030	1995 to 2035
Altitude range with minimum debris size	200 to 2000 km (>10 µm)	200 to 600 km (>10 µm) 600 to 2000 km (>1 mm) 2000 to 33,000 km (>1 cm) 34,000 to 38,000 km (>10 cm)
Model population breakdown	No	Intacts Low-density fragments Medium-density fragments and degradation/ejecta High-density fragments SRM Al_2O_3 slag (medium-density) RORSAT NaK coolant droplets
Material density breakdown	No	Low-density (<2 g/cc) Medium-density (2-6 g/cc) High-density (>6 g/cc) RORSAT NaK coolant (0.9 g/cc)
Model cumulative size thresholds	10 µm, 100 µm, 1 mm, 1 cm , 10 cm, 1 m	10 µm, 31.6 µm, 100 µm, 316 µm, 1 mm, 3.16 mm, 1 cm, 3.16 cm, 10 cm, 31.6 cm, 1 m
Population uncertainties	No	Yes
Total input file size	13.5 MB	128 MB
Meteoroids	No	No

Input populations in ORDEM-2008, which determine the debris fluxes in Earth orbit, are derived via data analysis coupled with modeling. Available data sets listed in Table 2 span the altitude and size regimes required in Table 1. Computer models, when verified through data (Table 3), yield reliable object populations. These populations are generally restricted to regions in space and in object size where measurement data is available.

Table 2. Contributing data sets.

Observational Data	Role	Region/Size
SSN catalog (radars, telescopes)	Intacts & large fragments	LEO > 10 cm, GEO > 70 cm
Cobra Dane (radar)	Compare with SSN	LEO > 4 cm
Haystack (radar)	Statistical populations	LEO > 1 cm
Goldstone (radar)	Compare with Haystack	LEO >2 mm
STS windows and radiators (returned surfaces)	Statistical populations	LEO < 1 mm
HST solar panels (returned surfaces)	Compare with STS	LEO < 1 mm
MODEST (telescope)	Only GEO data set	GEO > 30 cm

Table 3. Contributing models (with corroborative data).

Model	Usage	Corroborative Data
LEGEND	LEO fragments > 1 cm GEO fragments > 10 cm	Haystack, SSN, MODEST
NaK module	NaK droplets > 1 cm	Haystack
SRM Slag model	Slag > 1 cm	Haystack (TBD)
Degradation/Ejecta model	Degradation/Ejecta > 10 µm	STS windows, STS radiators

ORDEM2008 differs from its predecessor in that the debris populations are stored

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as orbit distributions rather than as spatial distributions. Because ORDEM2008 extends past LEO, the radial velocity becomes important. (This can be effectively ignored in LEO, and was ignored in ORDEM2000.) This also results in a greatly increased number of altitude bins needed to extend to GEO. A plus with this approach is that the uncertainties in the populations are fundamentally linked to the orbit distributions themselves, so they can be stored along with the populations. The populations are stored in orbit element bins of perigee altitude, eccentricity, and inclination, with the assumption of randomized ascending nodes and arguments of perigee (note, these assumptions are not applicable to the GEO regime; therefore, for that region a special alternative population is used). In addition, the populations are broken out by type (corresponding to mass density), size (at half-decade intervals), and time (1 year resolution).

The drawback with this approach is that computer storage is traded for computation time. When the user inputs a spacecraft orbit or observation geometry, the computer uses numerical integration to compute a matrix that maps the orbit distributions to a flux rate. Such integrations can be time-consuming and introduce numerical error. However, for ORDEM2008, these numerical errors are tracked and propagated to the final flux values – a tool that has been lacking in previous versions.

The computations are done in an "igloo" space – a coordinate system centered on the spacecraft or position in the telescope "beam" that defines sub-units for integration. For a spacecraft, the "igloo" space is a binned sphere around the spacecraft divided into "latitude"/"longitude" bins (analogous to yaw/pitch bins) and velocity bins in the spacecraft frame. This is analogous to the BUMPER formulation of

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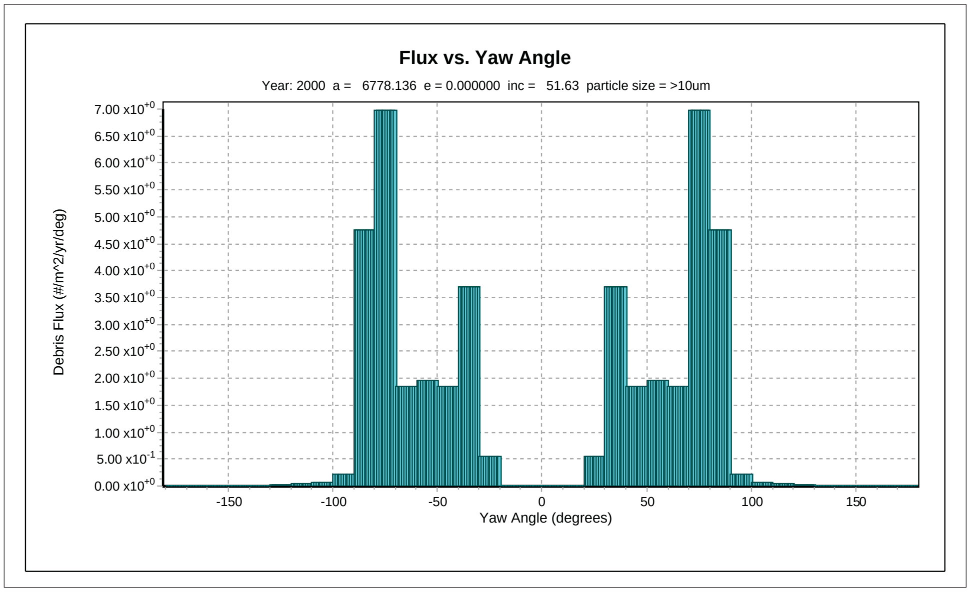

Figure 1. Spacecraft assessment skyline butterfly graph.

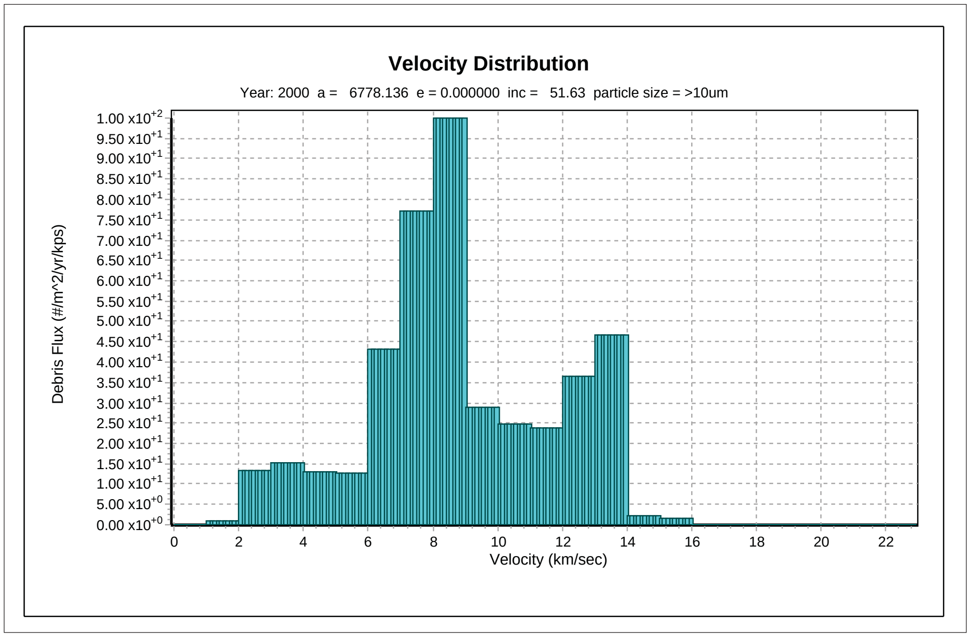

Figure 2. Spacecraft assessment velocity flux distribution.

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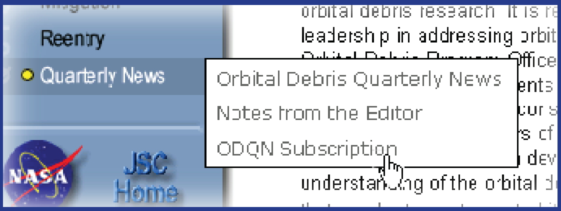

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"threat directions" that subdivide the directional flux. The mapping of orbital distribution to flux is carried out for each of these bins and summarized in tables by the program. The telescope igloo is much simpler. The telescope "beam" is subdivided into altitude/range segments. In order to integrate the flux, the full velocity direction "igloo" is integrated internally within ORDEM, but the output flux is simplified into a surface area flux for each segment of the telescope "beam".

Integrated with the software is an upgraded graphical user interface (GUI), which uses project-oriented organization and provides the user with graphical representations of numerous output data products. These include flux distributions by "collapsed" direction and velocity (Figures 1 and 2), and color-contoured, two-dimensional (2-D), directional flux diagrams (Figure 3), all in the local spacecraft frame. ♦

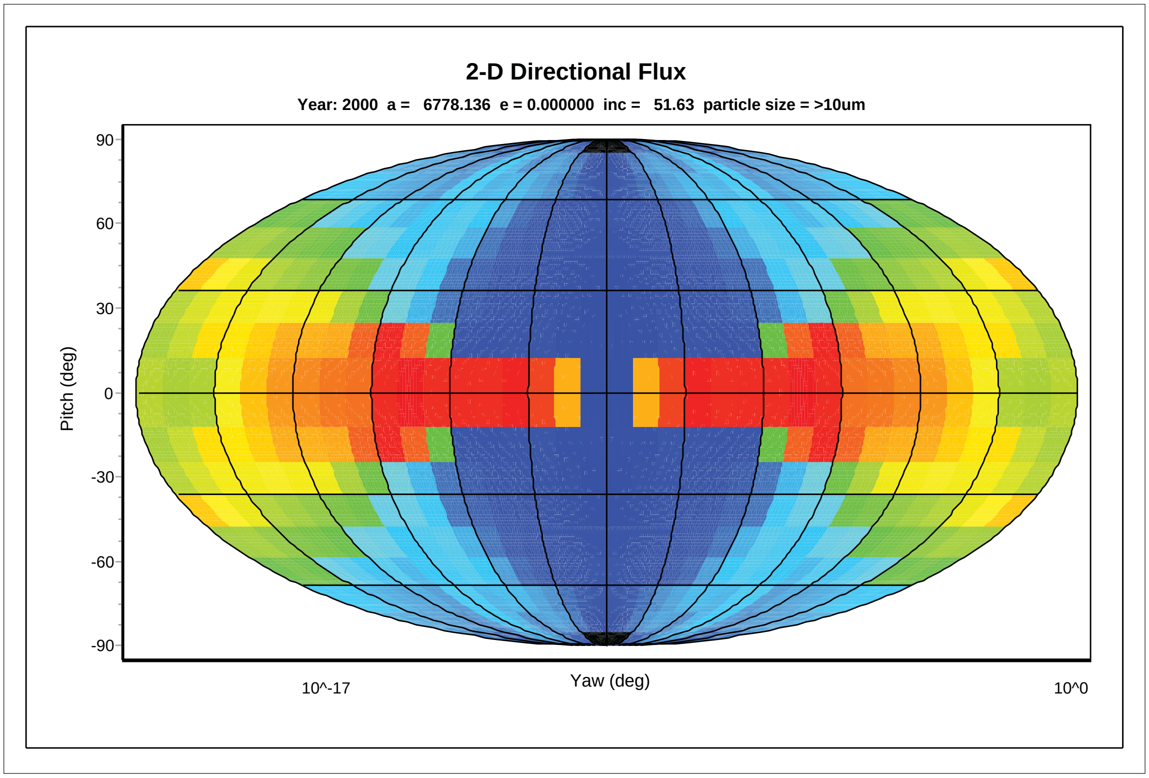

Figure 3 Spacecraft assessment 2-D directional flux projection.

ABSTRACTS FROM THE NASA ORBITAL DEBRIS PROGRAM OFFICE

211th Meeting of the American Astronomical Society
7-11 January 2008, Austin, Texas, USA

An Optical Survey for Space Debris in Geosynchronous Orbit

P. SEITZER, K. ABERCROMBY, H. RODRIGUEZ, AND E. BARKER

The University of Michigan's Curtis-Schmidt telescope at Cerro Tololo Inter-American Observatory is dedicated to an optical survey for faint space debris at geosynchronous orbit (GEO) for NASA. In the public catalog in or near the GEO regime, there are over 250 active spacecraft, and more than 500 large inactive spacecraft and debris pieces. The purpose of the Schmidt GEO survey is to statistically estimate the debris population of objects too faint to be in the catalog. One result is that objects fainter than 15th R magnitude have a very different angular-rate distribution than bright objects. One possibility for some of this difference is that an unknown fraction of the faint objects has a high area-to-mass (A/M) ratio, whose orbital eccentricity and inclination are changed by solar radiation pressure. Such behavior is predicted by theoretical models (Anselmo and Pardini 2005, Liou and Weaver 2005) and seen in European observations of GEO debris (Schildknecht, et al. 2005).

Our goal is to determine orbits for a complete sample of survey objects fainter than 15th R magnitude. However, the Schmidt survey observations only provide data for 5 minutes, which is not a long enough arc to fit a full six-parameter orbit on GEO objects (mean period = 1436 min). Therefore, in March 2007, the Schmidt was used simultaneously with the CTIO 0.9-m. The Schmidt was constantly in survey mode, and as faint objects were detected, they were followed-up in real-time on the CTIO 0.9-m for orbit determination. Objects with full six-parameter orbits show a range of eccentricities, inclination, and mean motion. We will discuss this result, as well as a summary of conclusions from the Schmidt GEO survey. This project is supported by grants to the University of Michigan from NASA's Orbital Debris Program Office. ♦

INTERNATIONAL SPACE MISSIONS
01 January – 31 March 2008

International Designator	Payloads	Country/ Organization	Perigee Altitude (KM)	Apogee Altitude (KM)	Inclination (DEG)	Earth Orbital Rocket Bodies	Other Cataloged Debris
2008-001A	THURAYA 3	UAE	35764	35811	6.1	1	0
2008-002A	TECSAR	ISRAEL	405	579	41.0	1	0
2008-003A	EXPRESS AM-33	RUSSIA	35780	35793	0.0	1	1
2008-004A	PROGRESS-M 63	RUSSIA	339	340	51.6	1	0
2008-005A	STS 122	USA	329	343	51.6	0	0
2008-006A	THOR 2R	NORWAY	35758	35815	0.0	0	1
2008-007A	WINDS (KIZUNA)	JAPAN	35772	35801	0.0	1	0
2008-008A	ATV 1 (Jules Verne)	ESA	339	340	51.6	1	0
2008-009A	STS 123	USA	341	346	51.6	0	0
2008-010A	USA 200	USA	NO ELEMS. AVAILABLE			1	0
2008-011A	AMC 14*	USA	774	35575	49.0	1	0
2008-012A	NAVSTAR 62 (USA 201)	USA	20147	20218	55.1	2	0
2008-013A	DIRECTV 11	USA	EN ROUTE TO GEO			1	0
2008-014A	SAR-LUPE 4	GERMANY	469	507	94.4	1	0

* Launch vehicle malfunctioned

SATELLITE BOX SCORE

(as of 02 April 2008, as cataloged by the U.S. SPACE SURVEILLANCE NETWORK)

Country/ Organization	Payloads	Rocket Bodies & Debris	Total
CHINA	63	2687	2750
CIS	1367	2993	4360
ESA	38	36	74
FRANCE	45	322	367
INDIA	34	106	140
JAPAN	103	70	173
US	1085	3195	4280
OTHER	400	93	493
TOTAL	3135	9502	12637

Technical Editor
J.-C. Liou

Managing Editor
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UPCOMING MEETINGS

13 - 20 July 2008: The 37th COSPAR Scientific Assembly, Montréal, Canada.

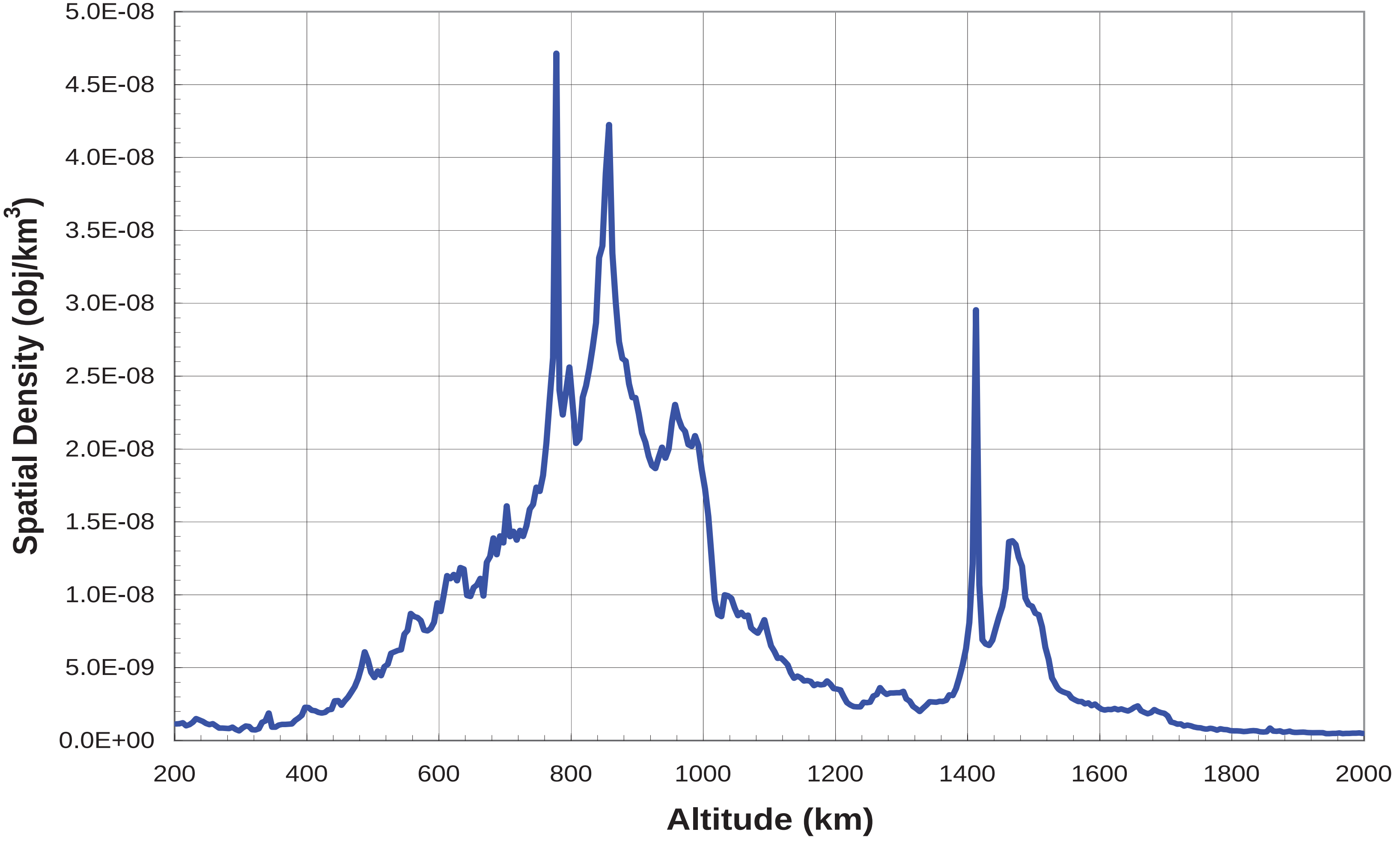
Four debris sessions are planned for the conference. They will address advances in ground-based and in-situ measurement techniques; debris and meteoroid environment models and related collision risk estimates for space missions; on-orbit collision avoidance; re-entry risk assessments; debris mitigation measures and their effectiveness for long-term environment stability; national and international debris mitigation standards and guidelines; hypervelocity impact technologies; and on-orbit shielding concepts. Additional information for the conference is available at <http://www.cospar2008.org/index.html>.

16-19 September 2008: 2008 Advanced Maui Optical and Space (AMOS) Surveillance Technologies Conference, Wailea, Maui, Hawaii, USA.

The 9th annual AMOS Conference will offer pre-conference tutorials, optional technical tours, and a broad range of presentations on topics such as adaptive optics, astronomy, imaging, lasers, metrics, non-resolved object characterization, orbital debris, space weather, Pan-STARRS, SSA programs and systems, and telescopes and sensors. The abstract submission deadline is 18 April 2008. Additional information on the conference is available at <http://www.amostech.com>.

29 September - 3 October, 2008: The 59th International Astronautical Congress, Glasgow, Scotland.

A Space Debris Symposium is planned for the 2008 IAC. Five sessions are scheduled for the Symposium to address various technical issues of space debris, including measurements, modeling, risk assessments, reentry, hypervelocity impacts, protection, mitigation, and standards. Additional information about the symposium is available at <http://www.iac2008.co.uk/>.



Spatial density distribution of objects tracked by the U.S. Space Surveillance Network as of 17 March 2008. The altitude bin resolution is 5 km.

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