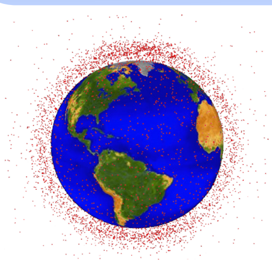
National Aeronautics and Space Administration

Orbital Debris
Quarterly News

Volume 18, Issue 1
January 2014

Inside...



A publication of the NASA Orbital Debris Program Office

Program Announcement: ORDEM 3.0 Released

The latest version of the NASA Orbital Debris Engineering Model, ORDEM 3.0, has been released. The model is appropriate for those engineering solutions requiring knowledge and estimates of the orbital debris environment (debris spatial density, flux, etc.). ORDEM 3.0 can also be used as a benchmark for ground-based debris measurements and observations.

ORDEM 3.0 incorporates significant improvements over its predecessor, ORDEM2000, which was released in 2002. For the first time, ORDEM includes uncertainties in the flux estimates. The model includes material density classes. It has also been extended to describe the orbital debris environment from low Earth orbit past geosynchronous orbit (200 to 38,000 km altitude).

ORDEM 3.0 is based on a large set of observational data (both in-situ and ground-based) that reflect the current debris environment. These data cover the object size range from 10 µm to 1 m. Analytical techniques (such as maximum likelihood estimation and Bayesian statistics) are employed to determine the orbit populations used to calculate population fluxes and their uncertainties. The model output lists fluxes of debris in half-decade size bins by distinct material characteristics (i.e., intact objects, high-, medium-, or low-material density objects, and NaK droplets) either by direction and velocity for an encompassing 'igloo' (for spacecraft) or by range bins (for a sensor beam on the Earth's surface), depending on the user's chosen operational mode.

The program graphical user interface (GUI), executable, data files, and an ORDEM 3.0 User's Guide are included in the package. ORDEM 3.0 has been subjected to extensive verification and validation. Currently, ORDEM 3.0 runs on Windows XP or more recent PC operating systems.

Although approved for public release, NASA regulations require that a software usage agreement must be obtained to acquire a copy of the NASA-developed software, ORDEM 3.0, MSC-25457. To begin the process, please email your request to <jsc-techtran@mail.nasa.gov>.

ORDEM 3.0 was developed by NASA's Orbital Debris Program Office (ODPO) located at Johnson Space Center, Houston, TX. Funding for the ODPO comes from NASA Headquarters' Office of Safety and Mission Assurance. ♦

Large Space Object Population near the International Space Station

Assessing potential close approaches of known space objects to the International Space Station (ISS) has been an integral part of ISS operations since the launch of the first element, the Zarya module, in November 1998. If a predicted conjunction yields a probability of collision greater than 1 in 10,000, official flight rules call for the execution of a collision avoidance maneuver by the ISS unless such a maneuver would lead to an even greater risk to the ISS or its crew. After a record number of four collision threats in 2012, no ISS

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Large Population

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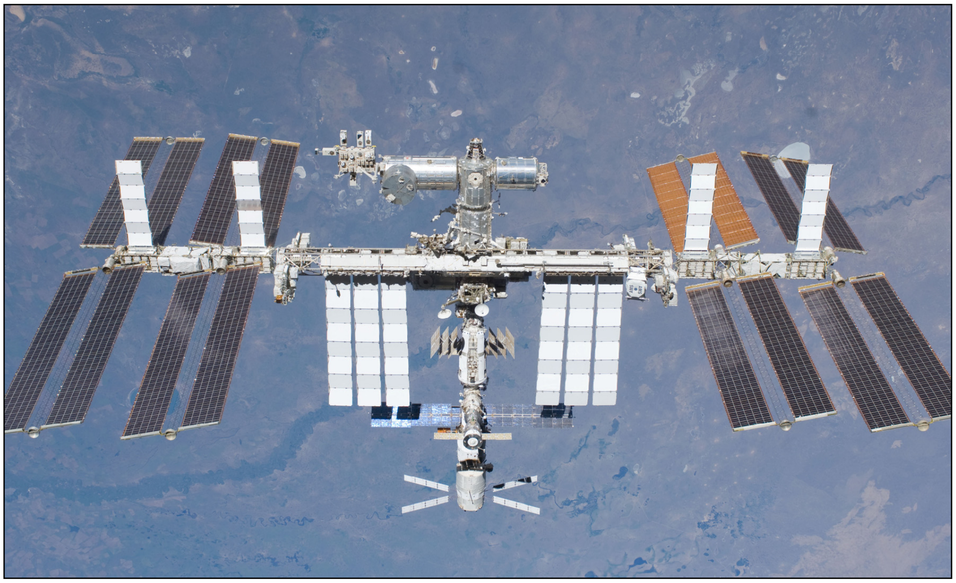

The International Space Station in 2011.

collision avoidance maneuvers were required during 2013, reflecting the chaotic nature of the satellite population.

During its first 15 years of operations, the ISS successfully conducted 16 collision avoidance maneuvers, and on a separate occasion in 1999 a planned maneuver attempt failed. In addition, three incidents arose when insufficient time permitted a collision avoidance maneuver, forcing the crew of the ISS to retreat to the Soyuz return craft during the time of closest approach, where they were prepared to undock from the ISS quickly in the event of a collision. In total, the collision avoidance maneuver threshold level has been reached only 20 times for an average of once per year.

However, the number of known objects that routinely transit the ISS orbital altitude is significant. In October 2013, the number of cataloged objects that posed potential threats to the ISS was in excess of 800, representing an increase of 60% from the population of November 1998 in an altitude region of ~415-420 km. Of these, 10% were spacecraft (operational and non-functional), a third were rocket bodies, and the remainder were miscellaneous debris. Although the individual masses of these objects varied from less than a kilogram to several metric tons, each was capable of inflicting serious damage to the ISS in the event of a collision.

Space objects in circular orbits intersecting the ISS altitude normally drop below the ISS orbit very quickly (days or weeks), although they intersect the ISS orbital plane up to 30 times per day. Objects in moderately or highly elliptical orbits (i.e., eccentricities greater than 0.1) typically present threats over much longer periods (years), but they pose potential collision threats much less often, typically passing through the ISS altitude only a few times per day. More than 80% of the cataloged objects transiting the ISS altitude belong to the latter category. Unfortunately, the accuracies with which these orbits are maintained by the U.S. Space Surveillance Network (SSN) are normally less conducive to high quality conjunction assessments due to fewer tracking opportunities and additional perturbation forces.

In addition to the cataloged satellites, the SSN maintains orbits on a large number (on the order of 5000 or more) of objects which have not yet been officially cataloged. For October 2013, the number of such objects with orbits passing through the ISS altitude regime exceeded 200. Three of the 20 close approaches noted above involved uncataloged objects, resulting in two collision avoidance maneuvers and one crew retreat to Soyuz spacecraft. ♦

Fengyun-1C Debris Cloud Remains Hazardous

The seventh anniversary of the destruction of the Fengyun-1C spacecraft by a Chinese anti-satellite weapon was marked on 11 January 2014. The event represents the worst single debris contamination of low Earth orbit (LEO), placing hundreds of operational spacecraft, including all human space flight missions, at continuing risk.

To date, the U.S. Space Surveillance Network has cataloged nearly 3400 distinct debris from the former meteorological satellite. These debris range in size from 5 cm to nearly a meter. The accompanying graphic indicates that the rate of reentry of these debris has been very slow, due in part to the high altitude of Fengyun-1C at the time of the ill-advised test, i.e., 860 km, and in part to the recent lower-than-normal level of solar activity. Fifty percent of the debris could still be in orbit 20 years after the event [1].

Numerous spacecraft have already been forced to execute evasive maneuvers to avoid potentially catastrophic collisions with debris from Fengyun-1C. The International Space Station conducted such a maneuver in January 2012, as have NASA's Terra, Aqua, and Cloudsat satellites and many other satellites.

Collisions between large intact objects, whether operational or not, and cataloged Fengyun-1C debris are important since they could produce large new debris clouds.

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Fengyun-1C Debris

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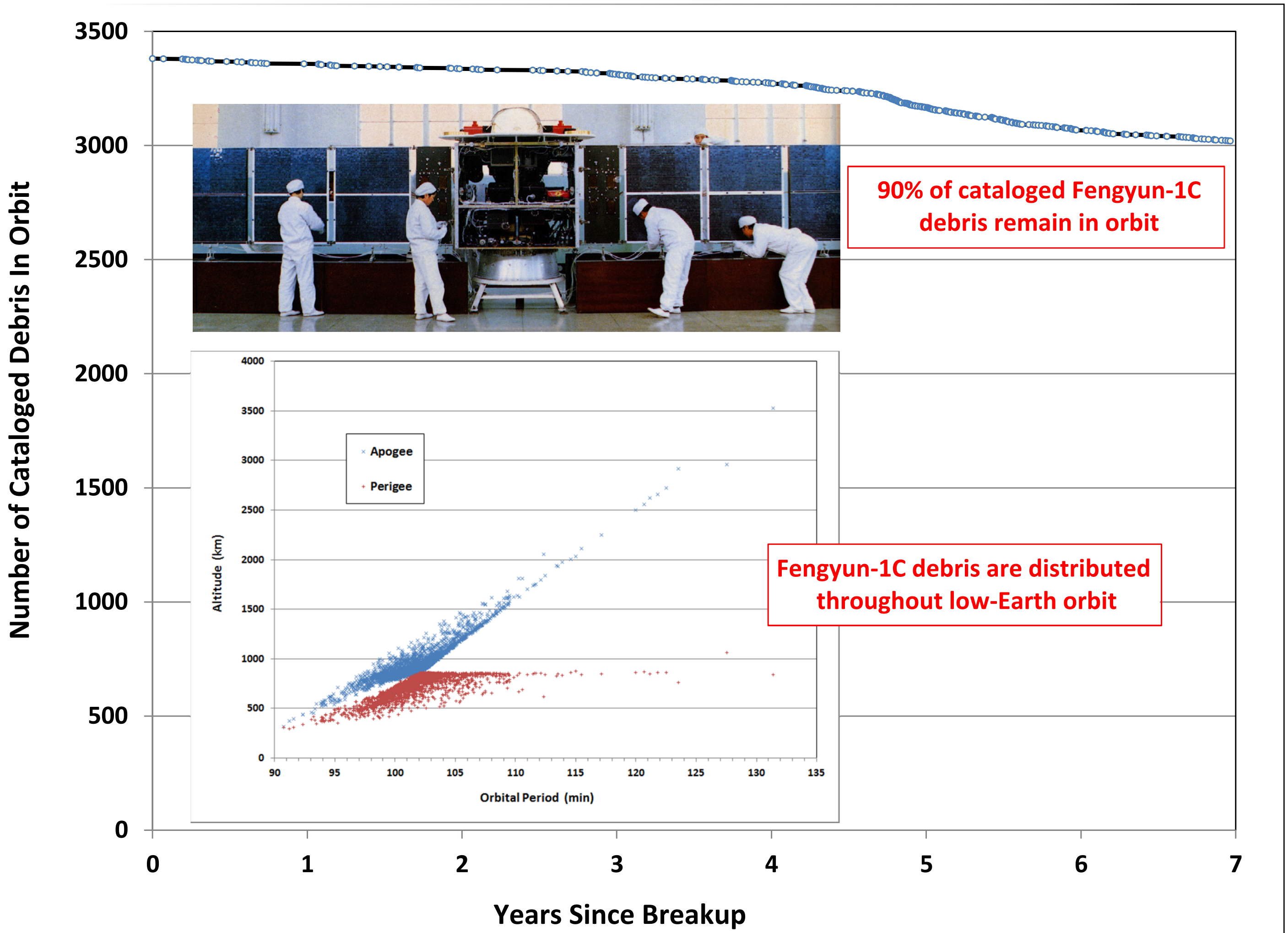
However, the operational risk to spacecraft arises primarily from the vastly larger number of hazardous debris that are too small to be tracked [2].

References

1. Johnson, N., "The Effects of Solar Maximum on the Earth's Satellite Population and Space Situational Awareness," IAC-12.A6.2.9, 63rd International Astronautical Congress, Naples, Italy, October 2012.

2. Johnson, N., et al., "The Characteristics and Consequences of the Break-up of the Fengyun-1C Spacecraft," *Acta Astronautica*, Vol. 63 (2008), pp. 128-135. ♦



More than 3000 cataloged debris from Fengyun-1C continue to pose threats to space operations.

Disposal of Globalstar Satellites in 2013

The Globalstar satellite network is one of the three original low Earth orbit (LEO) commercial communications systems that began deployments in the 1990s. Although no formal U.S. government and international recommendations for the disposal of LEO satellites existed when the original 52 Globalstar satellites were launched during 1998-2000,[1] the spacecraft operators have sought to abide by current disposal guidelines to the greatest extent possible. These efforts continued in 2013.

Unlike its Iridium and Orbcomm sister constellations, the Globalstar network opted for a high-LEO operational orbit 1414 km above the surface of the Earth. From this

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Globalstar

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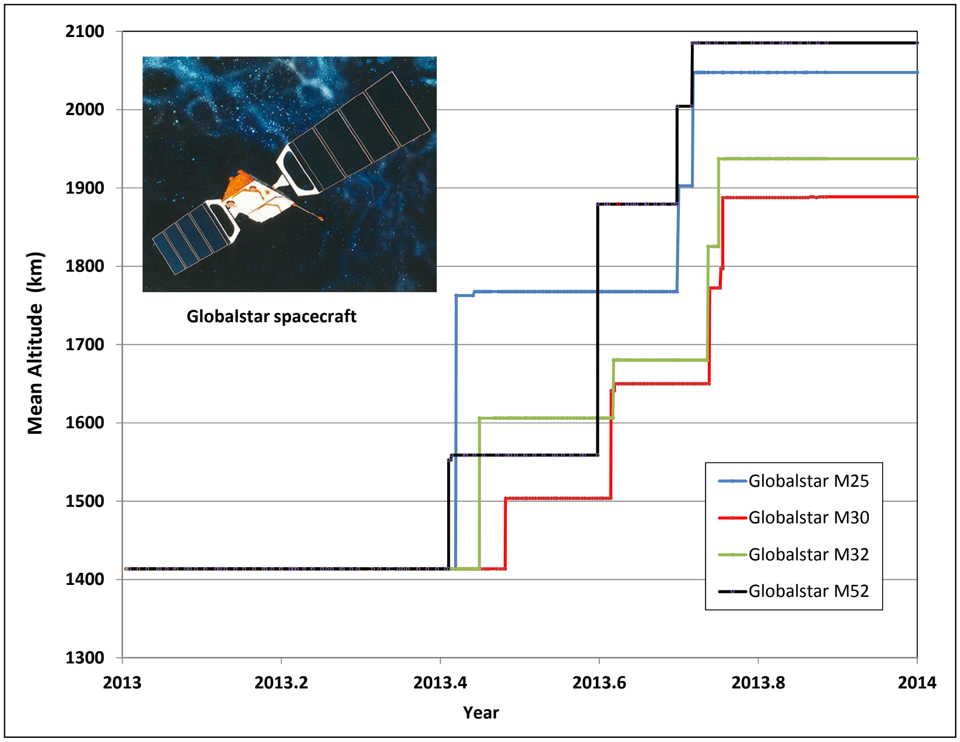
altitude a post-mission maneuver to a storage orbit above 2000 km (the upper limit of LEO) is more energy efficient than a reduction in altitude to ensure an atmospheric reentry within 25 years, which is an acceptable alternative disposal means. Despite not being designed to carry reserve propellant for maneuvering to a disposal orbit 600 km above the operational orbit, many of the retired Globalstar spacecraft have demonstrated a remarkable ability to raise their orbits to near 2000 km or even beyond (ODQN, January 2011, p. 3).

During 2013, four Globalstar spacecraft departed their operational orbits for much higher disposal orbits (see figure). This process can take many months and in some cases even years, as the satellites undergo a variety of tests at various altitudes. Therefore, the orbits indicated in the figure might be raised even further during 2014. A fifth spacecraft, Globalstar M45, also left the operational network in mid-2013, but by the end of the year it had only reached an apparently temporary altitude of 150 km above its operational orbit.

By the end of 2013, 25 of the 37 retired Globalstar spacecraft had been maneuvered into orbits more than 200 km above the network altitude. A dozen of these were in orbits of 1900 km or more above the planet. ♦

Footnote:

1. NASA was the first organization to issue specific recommendations for the responsible disposal of LEO satellites, but these original 1995 guidelines only applied to NASA satellites.



Four Globalstar spacecraft were transferred to higher disposal orbits during 2013.

DebriSat Soft-Catch Panel Impact Tests

The NASA Orbital Debris Program Office is leading an effort, called DebriSat (ODQN, April 2013, p. 8), to generate new laboratory-based, satellite hypervelocity-impact data. The project's ultimate goal is to use the new data to update the satellite breakup model, which provides short- and long-term assessments of the orbital debris environment and impact threats to operational spacecraft. The DebriSat project will also address a key 2011 National Research Council recommendation that NASA "…should expand its efforts to more accurately incorporate data on sources of debris into the Standard Breakup Model, especially … results from hypervelocity impact tests with payloads using newer construction methods and materials, and enhanced data on fragment shape characteristics." DebriSat is co-sponsored by the Air Force's Space and Missile Systems Center. The project team also includes members from the Air Force's Arnold Engineering Development Complex, the Aerospace Corporation, and University of Florida.

Recently, the DebriSat team finalized the design of a soft-catch panel system inside the target chamber for post-impact fragment capture and recovery. These panels will gradually slow down the hypervelocity fragments (generated after the impact on the target), minimize additional damage during the slowdown process, and then capture the fragments before they reach the steel chamber walls. The capture system's configuration is based on the same polyurethane foam material selected for the Satellite Orbital Debris Characterization Impact Test (SOCIT), but with an improved density variation (0.048 to 0.193 g/cm^3) over a wider depth (50.8 cm).

To confirm the new panel design's performance, the DebriSat team worked with the JSC Hypervelocity Impact Technology group to arrange two hypervelocity impact tests on sample foam panels. Figure 1 shows the side view of the test article. The dimensions (excluding the plywood and the backing plate at the bottom) are 45.7 cm × 45.7 cm × 50.8 cm. The thicknesses of the top four panels are 2.54 cm (1 inch) each while the thicknesses of the bottom eight panels are 5.08 cm (2 inches) each. Both hypervelocity impact tests were conducted at the NASA/JSC White Sands Test Facility in November 2013. For the first test, the projectile was an aluminum sphere with a

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DebriSat

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diameter of 3.4 mm (0.058 g mass) travelling at 6.75 km/sec. For the second test, the projectile was a stainless steel sphere with a diameter of 1.4 mm (0.01 g mass) travelling at 6.78 km/sec. The impact angles for both shots were normal to the panel surface.

Figure 2 shows the front of the test article outside the target chamber after the second impact. The entry hole on the front panel is clearly visible to the lower left corner, as indicated by the red arrow. Close post-impact inspection of the test article shows that the actual penetration depths are approximately 18 cm and 22 cm for the first and second shots, respectively. These test results are very close to the pre-test prediction. It is expected that during the DebriSat impact experiment, fragments smaller than the projectiles used in these two tests may speed up to about 10 km/sec. Nevertheless, the designed foam panel configuration should be able to slow down and capture all fragments before any of them reach the chamber walls. ♦

Figure 1. Soft-catch panel test article before impact.

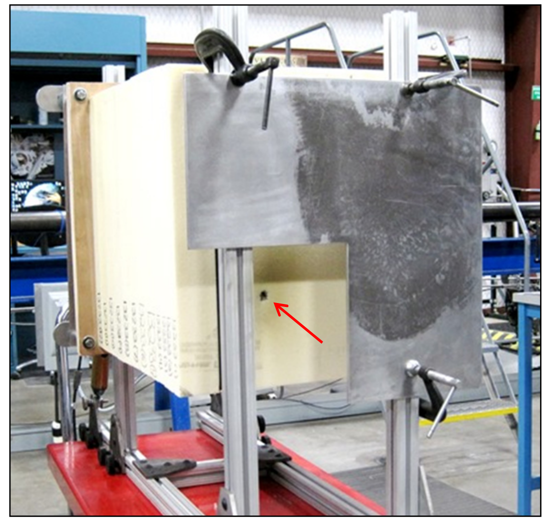

Figure 2. Test article outside the target chamber after the second impact. The entry hole damage is clearly visible to the lower left corner of the front panel, as indicated by the red arrow.

PROJECT REVIEW

New NASA Orbital Debris Engineering Model ORDEM 3.0

P. KRISKO

In the years since the release of the NASA engineering model ORDEM2000 (aka ORDEM 2.0), the NASA Orbital Debris Program Office (ODPO) has devoted tremendous resources toward advances in data collection, both remote and in situ, companion data analysis techniques, computer modeling, and visualization. As the orbital debris populations have evolved, several data sources that were central to ORDEM 2.0 development have been retired (LMT, LDEF, Eureca, HST-SA, SFU, and Mir) and replaced by others that have matured and are a more current reflection of the debris environment (Space Transportation System [STS] impact database, Goldstone radar, and Michigan Orbital Debris Survey Telescope [MODEST]) [1]. The "work horse" radar systems [Space Surveillance Network (SSN), the Haystack radar, and the Haystack Auxiliary (HAX) radar] continue to contribute heavily, with Haystack and HAX typically providing 1250 hours/year of statistical data (> 5 mm and > 3 cm, respectively). In the smaller debris realm, the STS impact database and Satellite Orbital debris Characterization Impact Test (SOCIT) proved vital to understanding the debris populations and compositions.

All of the above data supported the development of a Bayesian statistical model for the ORDEM 3.0 yearly populations, with NASA's LEO-to-GEO, three-dimensional, debris evolutionary model, LEGEND, and the Degradation/Ejecta model serving as *a priori* conditions.

Based on these data and techniques, NASA set a number of mandates for the new engineering model, ORDEM 3.0. With the singular events that occurred near the end of the last decade (the Fengyun 1-C anti-satellite test and the Iridium 33/Cosmos 2251 collision), the mandates for ORDEM 3.0 have expanded to:

- extend the model to geosynchronous orbit (GEO) with the addition of MODEST data and modeling techniques to include GEO objects down to 10 cm,
- investigate and account for Molniya-type orbits with fixed arguments of perigee,
- continue to include radar detections of debris (SSN, HAX, Haystack, and Goldstone) in the model and make use of these larger data sets to apply model fiducial points at half-decade sizes,
- use the NASA Hypervelocity Impact Technology (HVIT) group's STS microdebris impact database (STS 71-135 listing over 600 impacts), which includes crater dimension, chemical composition, and derived damage equations on STS aluminum radiator panels and windows,
- assign small fragment (< 10 cm) material density based on the SOCIT laboratory

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impact test results and on-orbit STS returned surface impactor analysis,

- model the Radar Ocean Reconnaissance SATellite (RORSAT) sodium potassium (NaK) coolant droplet population with radar measurements,
- include specific major debris-producing events that have been thoroughly observed (i.e., the remnants of the Fengyun 1-C anti-satellite test on 11 January 2007 and the accidental collision of Iridium 33 and Cosmos 2251 on 10 February 2009) and add to the general population,
- include long-term, debris-producing events that have been surmised from LEO high-altitude radar data (e.g., Snapshot, Transit, and 56-degree-debris shedding activity) and add to the general population,
- fully develop the Bayesian statistical model for population derivation,
- include debris population uncertainties,
- provide "igloos" with elements of equal-angle and velocity binning (e.g., the 10 x 10 x 1 igloo refers to a cell of 10 deg azimuth by 10 deg elevation by 1 km/s), and
- build the ORDEM 3.0 GUI to accommodate the full-angle views of the large yearly input files.

The new model is the first to tag small debris (< 10 cm) by material density. After several years of studies of spacecraft and rocket body materials from the open literature, returned surfaces, and impact ground tests, the NASA ODPO determined that the percentages of medium- versus high-density (e.g., aluminum/paint versus steel) small debris are about 90% versus 10%, with low-density material (e.g., plastics) as a very minor constituent in the current orbital debris environment [3, 4]. While the relative population of high-density impactors is small, it is on average, more lethal to spacecraft than medium- or low-density impactors. Higher density equates to lower area-to-mass for the same sized debris, which leads to longer time on-orbit. Ballistic Limit Equations (BLE) derived from ground impact testing by HVIT have generally shown a positive correlation between impactor density and penetration depth (separate risk models must be used to determine probability of penetration of any particular satellite.) [5].

Another key feature of ORDEM 3.0 is the extension of the model analysis region to encompass altitudes through GEO. It has the consequence that orbits with eccentricities greater than zero must be fully included in the modeled environment. The ORDEM 2.0 simple, finite element model with a geometric grid (latitude∗longitude∗altitude) excluded the radial velocity of any object in LEO. This was justified by the fact that most LEO orbits have a radial velocity of less than 0.1 km/s while the horizontal components range from about 6 to 11 km/s.

For ORDEM 3.0, this geometric grid system is abandoned for a different orbital

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Table 1. Feature Comparison of ORDEM 2.0 and ORDEM 3.0 [2]

Parameter	**ORDEM 2.0**	**ORDEM 3.0**
Spacecraft & telescope/radar analysis modes	Yes	Yes
Time range	1991 to 2030	2010 to 2035
Altitude range with minimum debris size*	200 to 2000 km (>10 μm) (LEO)	200 to 34,000 km (>10 μm) 34,000 to 38,000 km (>10 cm) (LEO to GEO)
Orbit types	Circular (radial V ignored)	Circular to highly elliptical
Model population breakdown by type & material density	No	Intacts Low-density (<2 g/cc) fragments Medium-density (2-6 g/cc) fragments and microdebris High-density (>6 g/cc) fragments and microdebris RORSAT NaK coolant droplets (0.9 g/cc)
Special model population breakdown	No	Fengyun 1-C and Iridium/Cosmos)
Model cumulative size thresholds (*fiducial points*)	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
Flux uncertainties	No	Yes
Total input file size	13.5 MB	1.25 GB

*Sub-millimeter populations have been validated below ~600 km only. Populations below 10 cm have been validated in LEO only.

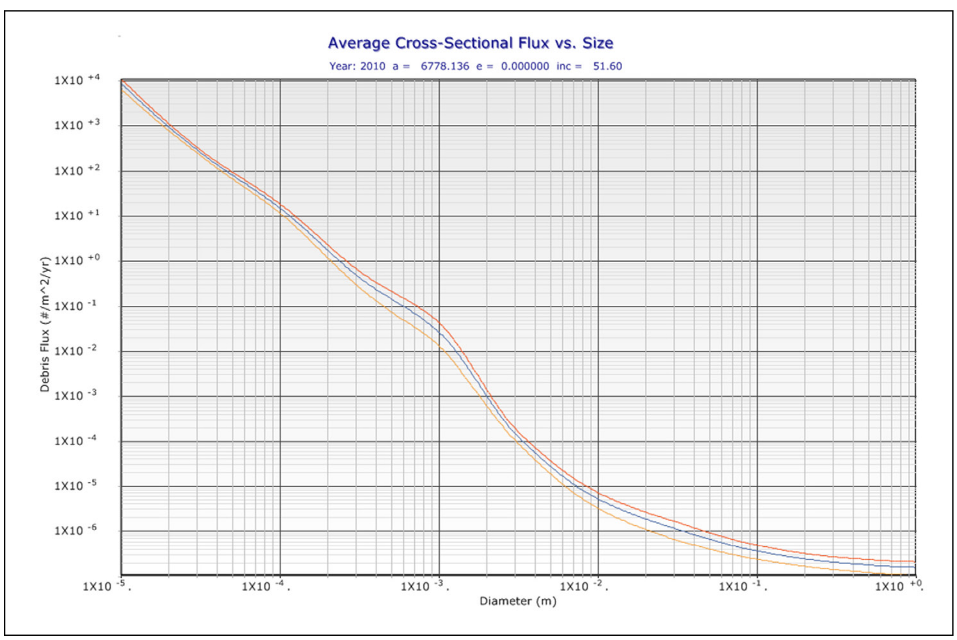

Figure 1. ORDEM 3.0 ISS debris diameter vs. cross sectional flux, with error bars (GUI output).

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binning system (perigee height*inclination *sqrt[eccentricity]) for LEO to GTO and (mean motion*inclination*sqrt[eccentricity]* right ascension of ascending node) for GEO. The input population files must contain the mean number of objects by year, material density, object size (at the half-decade fiducial points in Table 1), orbit bin, and population uncertainties. Though many orbit bins are empty and are not stored, the total size of ORDEM 3.0 input files outstrips that of ORDEM 2.0 by a factor of 100. Program installation requires much more available disk space and the executable requires a longer runtime in general. For example, a flux calculation in the spacecraft mode for the International Space Station (ISS) orbit expands from a fraction of a second (ORDEM 2.0) to five minutes (ORDEM 3.0).

Seven output files are generated for a spacecraft mode run and four for a telescope/radar mode run. These files are used as inputs to the GUI and as analysis guides for ORDEM 3.0 users. Conventional files include average debris size (or altitude bin) vs. flux, direction butterfly/skyline, and velocity distribution used in ORDEM 2.0. A spacecraft mode diameter vs. flux (with model uncertainties) chart is shown in Figure 1 for the ISS in 2010. Given the proven utility of this chart and underlying data, a 'FluxCalculator' is included as an option associated with the spacecraft assessment graphs. This function calculates flux given a particle size value.

The ORDEM 3.0 three-dimensional orbital view must also be accompanied by an appropriate visualization package. The population orbit binning scheme is mapped to a color-contoured, two-dimensional, directional flux diagram in local spacecraft elevation and azimuth. Figure 2 depicts this Mollweide projection for the ISS in 2010 with

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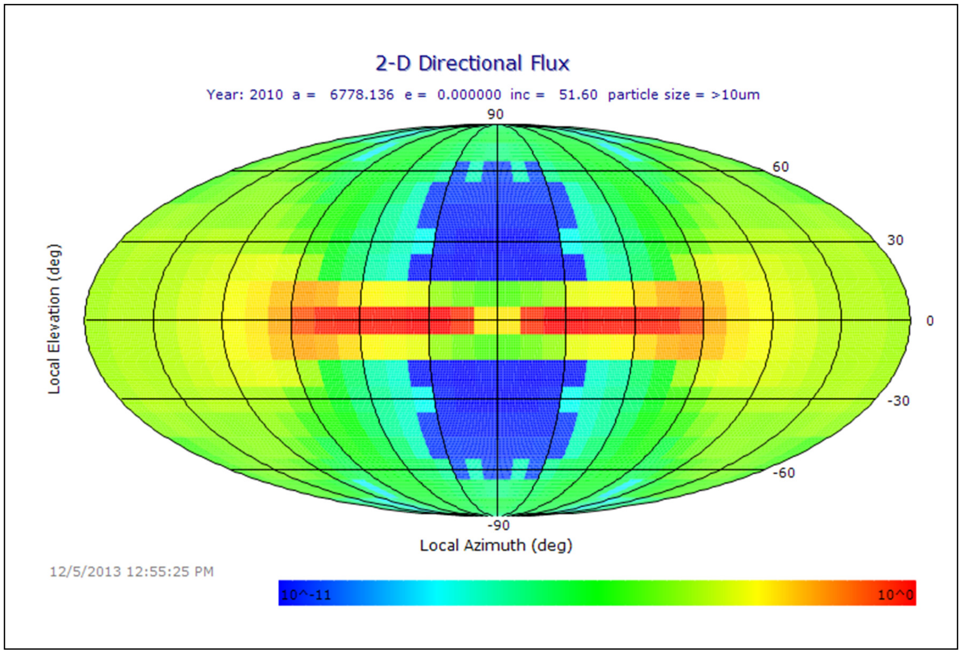

Figure 2. ORDEM 3.0 ISS 2-D flux chart (GUI output). Direction relative to the spacecraft is noted in (Local Azimuth, Local Elevation) coordinates: where Azimuth runs along the horizontal and ranges from [-180°, 180°], and Elevation runs vertically and ranges from [-90°, 90°]. Ram direction is defined by an (Azimuth, Elevation) of (0, 0), wake by (+180, 0), zenith by (Undefined, 90), and nadir by (Undefined, -90).

ORDEM Debris Flux Through Spacecraft 'Igloo'
Igloo: Debris Populations Flux in Bin (no./km^2/yr)
Year: 2010 Elements: 14122 Populations: 55 a = 6778.136 e = 0.00 inc = 51.60

Element	az_low	az_high	el_low	el_high	vel_low	vel_high	---	Flux NK30	Flux LD30	Flux MD30	Flux HD30	Flux IN30	---
-------	--------	--------	--------	--------	--------	--------		-------------	-------------	-------------	-------------	-------------	
1	-180	180	-90	-85	0	1	---	0.00E+00	3.17E-12	1.07E-09	2.20E-09	1.63E-14	---
2	-180	180	-90	-85	1	2	---	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	---
3	-180	180	-90	-85	2	3	---	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	---
---													
5347	-50	-40	5	15	10	11	---	0.00E+00	5.02E-12	3.26E-10	1.90E-10	0.00E+00	---
5348	-50	-40	5	15	11	12	---	0.00E+00	3.21E-09	6.05E-08	5.44E-08	2.77E-12	---
5349	-50	-40	5	15	12	13	---	0.00E+00	6.47E-09	2.70E-07	2.65E-07	2.53E-12	---
5350	-50	-40	5	15	13	14	---	0.00E+00	1.06E-08	7.15E-07	9.03E-07	4.50E-12	---
5351	-50	-40	5	15	14	15	---	0.00E+00	3.16E-09	3.70E-07	5.20E-07	1.52E-12	---
---													
14119	170	180	75	85	19	20	---	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	---
14120	170	180	75	85	20	21	---	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	---
14121	170	180	75	85	21	22	---	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	---
14122	170	180	75	85	22	23	---	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	---

Figure 3. Excerpt from ORDEM 3.0 User's Guide showing output for IGLOOFLUX_SC.OUT from the 1 mm and larger flux population. This run was for the ISS orbit (400 km altitude, 51.60 inclination) for the year 2010. Only the ≥ 1 mm flux column is included for the purposes of this figure. Flux components are defined as NK (NaK), LD (low density), MD (medium density), HD (high density), and IN (intact; objects > 10 cm with a medium (Al) density).

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10º x 10º binning. Here the cumulative flux of debris > 10 µm is presented with the lowest fluxes in blue moving to the highest fluxes in red. A look at the accompanying output file, IGLOOFLUX_SC.OUT (Figure 3), displays another advantage of ORDEM 3.0. The fluxes here are separated by material (NaK, low-, medium-, high-density, large intact), and by cumulative half-decade size bin, giving the user more flexibility in analysis of the orbital debris environment.

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UPCOMING MEETINGS

16-18 June 2014: 3rd European Workshop on Space Debris Modeling and Remediation, Paris, France

The focus of the previous two workshops was on concepts and technology development for active debris removal of large and massive objects. The scope of the third workshop will expand to also include modeling of the future orbital debris environment, removal of millimeter and larger debris, and non-technical aspects of orbital debris environment remediation. The CNES will again organize and host this bi-annual event at its headquarters in Paris. Additional information about the event can be obtained from Dr. Christophe Bonnal at <christophe.bonnal@cnes.fr>.

2-10 August 2014: 40th Committee on Space Research (COSPAR) Scientific Assembly, Moscow, Russia

The main theme of the Panel on Potentially Environmentally Detrimental Activities in Space (PEDAS) for the 40th COSPAR is "Space Debris – Responding to a Dynamic Environment." The PEDAS sessions will cover areas such as advances in ground- and space-based observations and methods for their exploitation; in-situ measurement techniques; debris and meteoroid environment models; debris flux and collision risk for space missions; on-orbit collision assessment, re-entry risk assessments, debris mitigation and debris environment remediation techniques and their effectiveness with regard to long-term environment stability; national and international debris mitigation standards and guidelines; hypervelocity accelerator technologies; and on-orbit shielding concepts. Four half-day sessions are planned. The abstract submission deadline is 14 February 2014. Additional details of the 40th COSPAR are available at: <https://www.cospar-assembly.org/>.

29 Sep - 3 Oct 2014: 65th International Astronautical Congress (IAC), Toronto, Canada

The Canadian Aeronautics and Space Institute will host the 65th IAC with a theme of "Our World Needs Space." Just like the previous IACs, the 2014 Congress will include a Space Debris Symposium to address the complete spectrum of technical issues of space debris measurements, modeling, risk assessments, reentry, hypervelocity impacts and protection, mitigation and standards, and space situational awareness. Seven sessions have been planned to cover these topics. In addition, a joint session with the Space Security Committee on the policy, legal, and economic aspects of space debris will also be held. The deadline for abstract submission is 25 February 2014. Additional details of the Congress are available at: <http://www.iafastro.com/index.php/events/iac/iac-2014>.

20-22 Oct 2014: 7th International Association for Advancement of Space Safety (IAASS) Conference, Friedrichshafen, Germany

The 7th IAASS Conference, "Space Safety Is No Accident," is an invitation to reflect and exchange information on a number of topics in space safety and sustainability of national and international interest. The 2014 conference will dedicate a set of specialized sessions on orbital debris, including space debris remediation, reentry safety, space situational awareness and international space traffic control, and commercial human spaceflight safety. The deadline for abstract submission is 30 May 2014. Additional details of the Conference are available at: <http://iaassconference2014.space-safety.org/>

INTERNATIONAL SPACE MISSIONS
1 October 2013 – 31 December 2013

International Designator	Payloads	Country/ Organization	Perigee Altitude (KM)	Apogee Altitude (KM)	Inclination (DEG)	Earth Orbital Rocket Bodies	Other Cataloged Debris
2013-057A	SJ-16	CHINA	601	614	75.0	1	0
2013-058A	SIRIUS FM-6	USA	35777	35796	0.0	1	1
2013-059A	YAOGAN 18	CHINA	508	512	97.5	1	4
2013-060A	MARS ORBITER MISSION	INDIA	HELIOCENTRIC			1	0
2013-061A	SOYUZ-TMA 11M	RUSSIA	413	420	51.7	1	0
2013-062A	RADUGA 1M-3	RUSSIA	35772	35801	0.1	1	1
2013-063A	MAVEN	USA	HELIOCENTRIC			0	0
2013-064A	STPSAT-3	USA	498	505	40.5	1	0
2013-064	(29 additional payloads)	USA					
2013-065A	YAOGAN 19	CHINA	1201	1208	100.5	1	0
2013-066A	APRIZESAT 7	USA	592	654	97.8	1	2
2013-066C	SKYSAT 1	USA	566	598	97.8		
2013-066D	DUBAISAT 2	UAE	583	604	97.8		
2013-066G	STSAT 3	SOUTH KOREA	591	627	96.9		
2013-066	(28 additional payloads)	(various)					
2013-067A	SWARM B	ESA	493	497	87.6	1	0
2013-067B	SWARM A	ESA	493	497	87.6		
2013-067C	SWARM C	ESA	493	497	87.6		
2013-068A	SHIYUAN 5 (SY-5)	CHINA	737	757	98.0	0	0
2013-069A	PROGRESS M-21M	RUSSIA	413	420	51.7	1	0
2013-070A	CHANG'E 3	CHINA	LUNAR SURFACE			0	0
2013-071A	SES-8	LUXEMBOURG	35783	35791	0.1	1	0
2013-072A	USA 247	USA	NO ELEMS. AVAILABLE			1	0
2013-072	(12 additional payloads)	USA					
2013-073A	INMARSAT 5-F1	INMARSAT	EN ROUTE TO GEO			1	1
2013-074A	GAIA	ESA	HELIOCENTRIC			0	0
2013-075A	TKSAT 1	BOLIVIA	35774	35799	0.3	1	0
2013-076A	COSMOS 2488	RUSSIA	1479	1509	82.5	1	1
2013-076B	COSMOS 2489	RUSSIA	1482	1511	82.5		
2013-076C	COSMOS 2490	RUSSIA	1481	1510	82.5		
2013-077A	EXPRESS AM-5	RUSSIA	EN ROUTE TO GEO			1	1
2013-078A	AIST 1	RUSSIA	600	625	82.4	1	1
2013-078B	SKRL-756A	RUSSIA	600	625	82.4		
2013-078C	SKRL-756B	RUSSIA	600	625	82.4		

SATELLITE BOX SCORE
(as of 1 January 2014, cataloged by the U.S. SPACE SURVEILLANCE NETWORK)

Country/ Organization	Payloads	Rocket Bodies & Debris	Total
CHINA	155	3609	3764
CIS	1439	4737	6176
ESA	46	45	91
FRANCE	58	442	500
INDIA	53	119	172
JAPAN	124	82	206
USA	1174	3787	4961
OTHER	666	119	785
TOTAL	3715	12940	16655

Visit the NASA Orbital Debris Program Office Website

www.orbitaldebris.jsc.nasa.gov

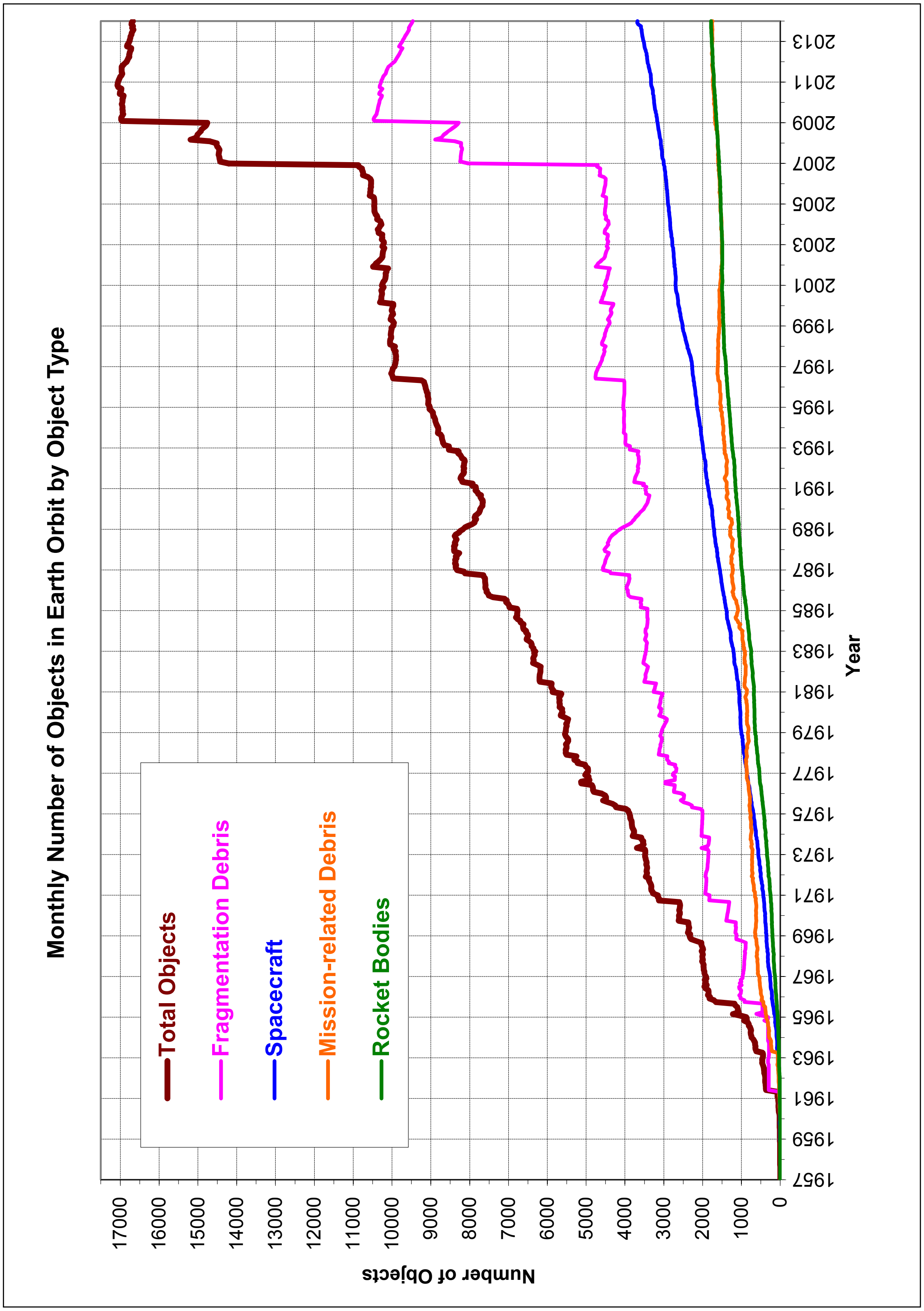
Technical Editor
J.-C. Liou

Managing Editor
Debi Shoots

Correspondence concerning the ODQN can be sent to:

Debi Shoots
NASA Johnson Space Center
Orbital Debris Program Office
Mail Code JE104
Houston, TX 77058

debra.d.shoots@nasa.gov



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.

National Aeronautics and Space Administration
Lyndon B. Johnson Space Center
2101 NASA Parkway
Houston, TX 77058

www.nasa.gov
http://orbitaldebris.jsc.nasa.gov/