National Aeronautics and Space Administration

Orbital Debris
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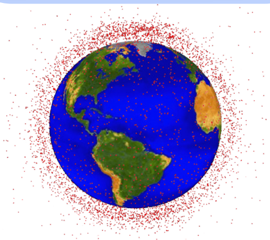
Inside...



A publication of
the NASA Orbital
Debris Program Office

United Nations Discusses Space Debris and Long-Term Sustainability of Activities in Outer Space

Space Debris has been an agenda item for each annual meeting of the Scientific and Technical Subcommittee of the United Nations' Committee on the Peaceful Uses of Outer Space (COPUOS) since 1994. In 1999 the Subcommittee produced its first major assessment on the topic, Technical Report on Space Debris (Orbital Debris Quarterly News, April 1999, pp. 7, 9), followed in 2007 with the establishment of space debris mitigation guidelines (Orbital Debris Quarterly News, April 2007, pp. 1-2).

During its 48th session in February 2011, the Subcommittee continued its deliberations on space debris with numerous special presentations, including those by the United States, France, the Russian Federation, the European Space Agency (ESA), and the Inter-Agency Space Debris Coordination Committee (IADC). Nicholas Johnson, NASA Chief Scientist for Orbital Debris, made a presentation on behalf of the United States, entitled USA Space Debris Environment, Operations, and Policy Updates (http://www.oosa.unvienna.org/pdf/pres/stsc2011/tech-31.pdf). The status of debris from Fengyun-1C, Cosmos 2251, and Iridium 33 was provided, as was information on the disposal of NASA satellites in LEO and GEO.

One common theme was the increasing numbers of collision avoidance maneuvers conducted in the previous year to prevent potentially catastrophic encounters among resident space objects. NASA reported seven such maneuvers by its fleet of robotic satellites and one for the International Space Station, while France and ESA acknowledged 13 and 9 maneuvers, respectively, for spacecraft under their control.

In 2010 the subject of long-term sustainability of activities in outer space was added to the Subcommittee's agenda, and a working group was formed under a multi-year work plan. At the 2011 meeting of the Subcommittee, terms of reference for the working group were established. The objective of the Working Group will be "to examine and propose measures to ensure the safe and sustainable use of outer space for peaceful purposes, for the benefit of all countries. The Working Group will prepare a report on the long-term sustainability of outer space activities containing a consolidated set of current practices and operating procedures, technical standards and policies associated with the safe conduct of space activities. On the basis of all the information collected, the Working Group will produce a set of guidelines which could be applied on a voluntary basis by international organizations, non-governmental entities, individual States and States acting jointly to reduce collectively the risk to space activities for all space actors and to ensure that all countries are able to have equitable access to the limited natural resources of outer space."

Topics for examination by the working group include space debris, space weather, space operations, tools to support collaborative space situational awareness, regulatory regimes, and guidance for actors in the space arena. Under the terms of reference, an exchange of views on these topics is envisioned among the UN Member States, intergovernmental organizations, and private sector entities. An international workshop will be held in 2013, and a final report will be published in 2014. ♦

14th NASA/DoD Orbital Debris Working Group Meeting

The Orbital Debris Program Office (ODPO) hosted the 14th NASA/DoD Orbital Debris Working Group (ODWG) meeting in Houston on 1 March 2011. The genesis of the ODWG comes from recommendations by interagency panels, which reviewed U.S. Government OD activities in the late 1980s and 1990s. The 1-day meeting viewed activities and research in OD with a common interest to both NASA and DoD. During the morning, the NASA ODPO presented six topics: 1) United Nations and IADC Updates, 2) Plans for the Meter Class Autonomous Telescope and Potential Coordinated Measurements with Kwajalein Radars, 3) ORDEM 2010, NASA's Orbital Debris Engineering Model, 4) Debris Resistive/Acoustic Grid Orbital Navy Sensor (DRAGONS), 5) SSN RCS Time History Analyses, and 6) Potential Collaboration on Satellite Impact Tests and Model Improvements. In addition, Dr. Bill Cooke from NASA's Meteoroid Environment Office at Marshall Space Flight Center presented "The 2011 Draconid Meteor Outburst/Storm."

After lunch, representatives of the Department of Defense made nine presentations: 1) Status of the Space Surveillance Network (SSN), Status of MOA Between AFSPC/NASA, and the Sensor Integration Process, 2) Disposal Orbit Recommendations, 3) Improving C2/SSA Capabilities Through Improved Calibration & RCS, 4) Haystack Ultra-wideband Satellite Imaging Radar (HUSIR), 5) Pan-STARRS Status, 6) Thermal IR Spectroscopic and Visible Time-Domain Observational Methods and Plans for Space Debris Observations at AMOS, 7) Bei Dou G4 Debris, 8) High Area to Mass Ratio Satellites, and 9) The Space Fence Program. Presentations by both NASA and DoD concerning radar cross section (RCS) measurements were of particular interest.

Two additional topics were discussed. First, an old action item concerning potential changes to the U.S. Orbital Debris Mitigation Standard Practices was discussed, along with options to complete the action. Second, the new National Space Policy directs both NASA and DoD to "pursue research and development of technologies and techniques, …to mitigate and remove on-orbit debris, reduce hazards, and increase understanding of the current and future debris environment…" Although it was concluded that research into active debris removal was outside the scope of the ODWG, it was decided that the group would monitor activities until more formal cooperation between NASA and DoD was established. ♦

NASA/DoD Meeting on Active Debris Removal

The NASA Orbital Debris Program Office arranged for and hosted a special meeting with representatives from various Department of Defense (DoD) organizations to focus on the subject of Active Debris Removal (ADR) in Houston on 2 March 2011. It was the first attempt to reach out to a broader community and to establish a coordinated dialogue between NASA and DoD on ADR after the new U.S. National Space Policy was released in June of 2010, where NASA and DoD were directed to pursue research and development of technologies and techniques to remove on-orbit debris.

Four presentations were given at the beginning of the meeting, followed by a roundtable discussion. The presentations included an overview of the engineering and technological challenges for ADR operations, a summary of commonly-proposed ADR concepts, a review of a Navy and Air Force collaborative effort on the development of ADR systems, and reviews of ADR activities within NASA and DoD. All participants recognized the enormous challenges, both technical and non-technical, to mature feasible and low-cost technologies to enable routine ADR operations for environment remediation. A decision was made at the end of the meeting to continue communications and coordination among the participating organizations before the 2012 NASA/DoD Orbital Debris Working Group meeting. ♦

Kessler Receives the 2011 Dirk Brouwer Award

Kessler receives the 2010 Brouwer Award from Professor Dan Scheeres, Chairman of the AAS Dirk Brouwer Award committee.

The American Astronautical Society (AAS) presented the Dirk Brouwer Award to Donald J. Kessler during the 21st AAS/AIAA Space Flight Mechanics Meeting in New Orleans in February. This award was established by the AAS to honor significant technical contributions to space flight mechanics and astrodynamics. It is the most prestigious award presented by the AAS. The award to Kessler reads "For first recognizing, then defining and researching the Earth's orbital debris hazard during an illustrious half-century career in astrodynamics."

Kessler is considered by many to be the father of orbital debris research. His early efforts in understanding the orbital debris problem led to the establishment of the NASA Orbital Debris Program Office at the Johnson Space Center in 1979. The collision between Iridium 33 and Cosmos 2251 in 2009 underlined the potential collision cascade effect, commonly known as the "Kessler Syndrome," based on his pioneer work in modeling the near-Earth orbital debris environment in 1978. For half a century, Kessler dedicated his research to various aspects of the orbital debris problem, from measurements to modeling, at both national and international levels. He was awarded the NASA Medal for Exceptional Scientific Achievement in 1989. He retired from NASA in 1996 as the Senior Scientist for Orbital Debris. Kessler is also the recipient of many other awards, including the 2008 IAASS Jerome Lederer Space Safety Pioneer Award. ♦

Russian Launch Vehicle Stage Reenters Over U.S.

In January 2011 the Russian Federation successfully tested a new launch vehicle to insert its next generation of meteorological spacecraft into geosynchronous orbit. The Zenit-3 SLBF launch vehicle left two stages in Earth orbit: one in a short-lived, low Earth parking orbit and one in a sub-geosynchronous orbit.

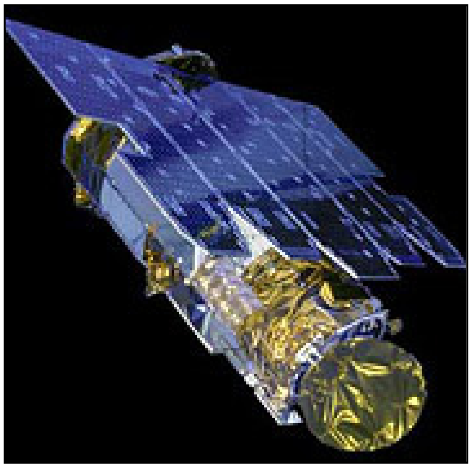
The former, the Zenit 8900-kg second stage, rapidly fell back to Earth from an initial orbit of 178 km by 640 km with an inclination of 51.3 degrees, reentering at an altitude of about 80 km over Los Angeles on 19 March 2011. The stage's northeasterly trajectory carried the debris over Utah and the extreme northwestern corner of Colorado.

On 22 March the Sheriff's office of Moffat County, Colorado, contacted the NASA Orbital Debris Program Office about a discovery the day before of a metallic sphere with a diameter of approximately 30 inches. The timing and location of the discovery and Cyrillic markings on the tank have led to a tentative association with the Zenit reentry. The tank appears to have been part of a pressurization system. Efforts are underway to confirm the tank's identity and to locate any other debris which might have survived to reach the ground. ♦

Pressurant tank found in Colorado in March 2011 and tentatively linked to a Zenit launch vehicle stage.

U.S. Commercial Earth Observation Spacecraft Executes Controlled Reentry

Following U. S. government recommendations for the responsible disposal of satellites in low Earth orbit, Geoeye Imagery Collection Systems Incorporated commanded its Orbview-3 remote sensing satellite to a fiery reentry over the Pacific Ocean on 13 March 2011 after nearly 8 years in orbit. The successful disposal operation involved numerous maneuvers over a span of nearly 3 months and was carefully designed to avoid any risk to the International Space Station or the STS-133 mission of the Space Shuttle Discovery.



Orbview-3 spacecraft.

The 300-kg Orbview-3 (International Designator 2003-030A, U.S. Satellite Number 27838) was inserted into orbit on 26 June 2003 by a Pegasus rocket. The spacecraft operated at a mean altitude near 455 km until March 2007, when its principal payload became inoperable. Control of Orbview-3 was still maintained, and by December 2010 its orbit had decayed to about 435 km.

The disposal plan was divided into two phases. The first phase consisted of four maneuvers during December 2010 and early January 2011 that brought Orbview-3 into a temporary orbit below that of the International Space Station, i.e., below 350 km. The spacecraft remained in this orbit until early March when a final series of four maneuvers culminated in the safe reentry of the vehicle over the eastern Pacific Ocean in the early morning hours (GMT) of 13 March, 4 days after the return of STS-133.

Although Orbview-3 would have naturally fallen back to Earth well within the recommended 25 years following end of mission, this controlled reentry significantly reduced the spacecraft's remaining time in orbit and eliminated the possibility of collisions with either small or large resident space objects [1].

Reference

1. U.S. Government Orbital Debris Mitigation Standard Practices, 2001 (http://www.orbitaldebris.jsc.nasa.gov/library/USG_OD_Standard_Practices.pdf). ♦

New Chapter on Space Waste

Gene Stansbery, Program Manager for NASA's Orbital Debris Program Office, contributed Chapter 26 on "Space Waste" to the recently published book *Waste: A Handbook for Management*. The new book (ISBN: 978-0-12-381475-3), published by Academic Press, was edited by Trevor M. Letcher & Daniel A. Vallero. The chapter on Space Waste discusses the current orbital debris environment, comprising the number, distribution, and sources of orbital debris; counter measures, which include shielding against orbital debris, collision avoidance, and mitigation policies and practices; and the future orbital debris population, involving active debris removal. According to the book jacket synopsis, *Waste* "offers scientific and non-biased overviews to ensure credibility in the environmental science and engineering communities; focuses on management and recycling, providing solutions for scientists, engineers, technicians and government leaders; addresses questions about the severity of today's waste situation; and poses management solutions for the future." ♦

PROJECT REVIEW

An Update on LEO Environment Remediation with Active Debris Removal

J.-C. LIOU

The catastrophic collision between Cosmos 2251 and the operational Iridium 33 in 2009 signaled a potential onset of the "Kessler Syndrome" in the environment, predicted by Kessler and Cour-Palais in 1978 [1]. This event also supports the conclusion of several recent modeling studies that, even with a good implementation of the commonly-adopted mitigation measures, the debris population in low Earth orbit (LEO, the region below 2000 km altitude) will continue to increase [2]. The population growth is driven by fragments generated via accidental collisions among existing satellites. Therefore, to remediate the environment, active debris removal (ADR) should be considered. The need of ADR is also highlighted in the National Space Policy of the United States released in June 2010 where, under the Section of "Preserve the Space Environment," NASA and the Department of Defense are directed to pursue research and development of technologies and techniques to remove on-orbit debris.

There are many technical and non-technical challenges for ADR. If the objective is to remediate the environment, then the most effective approach is to target the root cause of the problem – objects that have the greatest potential of generating the highest amount of fragments in the future. These are objects with the highest mass and collision probability products [3]. Figure 1 shows the mass distribution in LEO. It is obvious that the major mass reservoirs are located around 600, 800, and 1000 km altitudes. The 600 km region is dominated by spacecraft (S/Cs) while the other two regions are dominated by spent rocket bodies (R/Bs). Note the operational spacecraft accounts for only approximately 10% of the mass in LEO. Since the 800 to 1000 km region also has the highest spatial density in LEO, it is expected that many of the potential ADR targets will be R/Bs in that region. Figure 2 depicts the LEO number and mass breakdowns in terms of object sources.

A key element for any ADR planning is the ability to quantify the requirements of the operations and the benefits to the environment. Figure 3 shows the latest results from the NASA Orbital Debris Program Office on LEO environment remediation [4]. Simulations were carried out with the NASA long-term debris evolutionary model, LEGEND. The future projection part of the top curve assumes a nominal launch cycle and a 90% compliance of the postmission disposal (PMD) measures (e.g., the 25-year rule). The average of 100 Monte Carlo LEGEND runs indicates that the LEO population will continue a steady increase in the next 200 years. With the addition of ADR operations of two objects per year, starting from the year 2020 (the middle curve), the population growth is approximately reduced by half. If the ADR rate is increased to five objects per year, then the LEO population in the next 200 years can be maintained at a level similar to the current environment (bottom curve). However, if the objective is to restore the environment back to the level prior to 1 January 2007, then a

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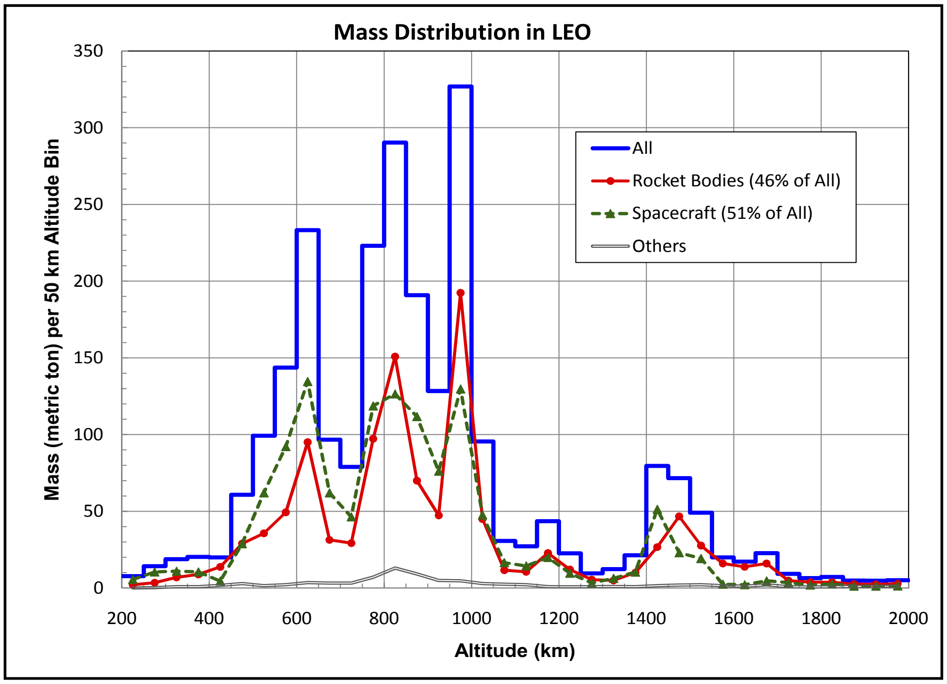

Figure 1. Mass distribution in LEO. The environment is dominated by R/Bs and S/Cs. Note the International Space Station, with a mass of ~350 tons, is not included in the distribution.

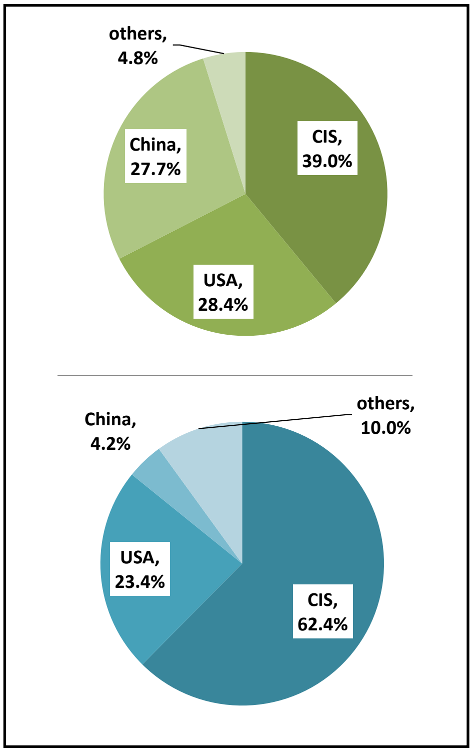

Figure 2. Sources of LEO debris in terms of number (top) and in terms of mass (bottom). The breakdown is based on objects in the SSN catalog. More than 99% of the mass in orbit is in objects in the catalog. CIS denotes the Russian Federation.

ADR

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removal rate of more than five objects per year must be implemented.

The predicted collision activities in LEO from the three scenarios are shown in Figure 4. The top three curves indicate the total numbers of "all" collisions – catastrophic and non-catastrophic collisions. The bottom three curves show just the catastrophic collisions. A catastrophic collision occurs when the ratio of impact energy to target mass exceeds 40 J/g. The outcome of a catastrophic collision is the total fragmentation of the target, whereas a non-catastrophic collision only results in minor damage to the target and generates a small amount of debris that has minimal contribution to population growth. Table 1 provides additional details of the catastrophic collisions predicted by the three scenarios. Collisions are separated into three categories – those involving two intact objects (i-i), those involving one intact and one fragment (i-f), and those involving two fragments (f-f). Each number is the average of 100 MC runs. In general, an intact-intact collision will generate more debris than an intact-fragment collision.

The ADR target selection criterion used in the LEGEND simulations was the [mass × collision probability] value of each object. This criterion can be applied to objects in the current environment to identify potential targets for removal in the near future. The altitude-versus-inclination distribution of the top 500 objects identified via this selection criterion is shown in Figure 5. The prograde group is dominated by several well-known classes of vehicles: SL-3 R/Bs (Vostok second stages; 2.6 m diameter by 3.8 m length; 1440 kg dry mass), SL-8 R/Bs (Kosmos 3M second stages; 2.4 m diameter by 6 m length; 1400 kg dry mass), SL-16 R/Bs (Zenit second stages, 4 m diameter by 12 m length; 8900 kg dry mass), and various Meteor-series and Cosmos S/Cs (masses ranging from 1300 to 2800 kg). The fact that many of the SL R/Bs are high on the list is not surprising, based on the mass distribution in the environment (see also Figures 1 and 2). Below 1100 km altitude, the total mass of all SL-3, SL-8, and SL-16 R/Bs is about 500 tons, which accounts for about 20% of the total mass in LEO. Objects in the retrograde region are more diverse. They include, for example, Ariane R/Bs (1700 kg dry mass), CZ-series R/Bs (1700–3400 kg dry mass), H-2 R/Bs (3000 kg dry mass), SL-16 R/Bs, and S/Cs such as Envisat (8000 kg) and

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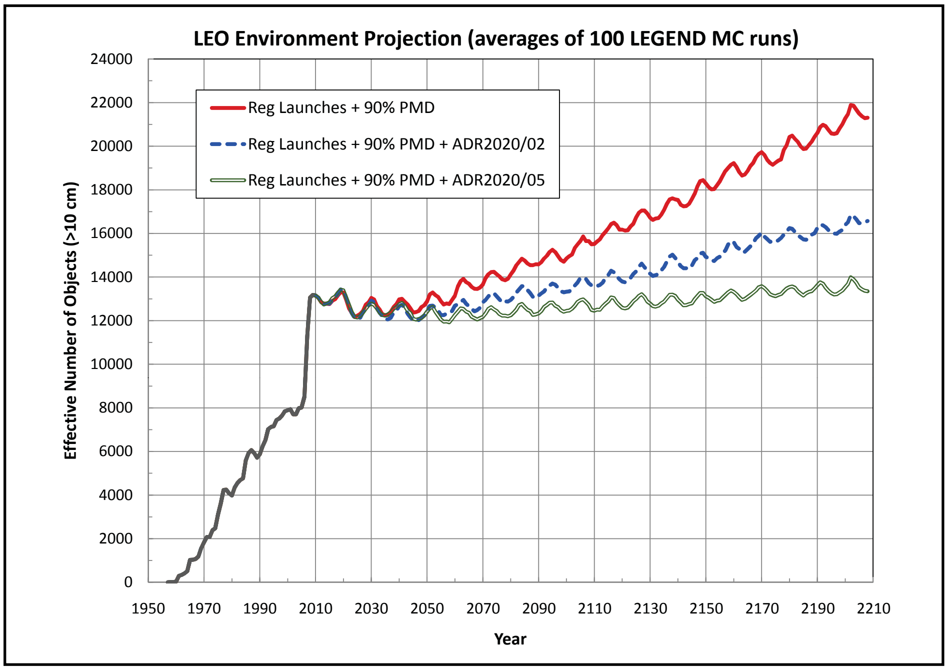

Figure 3. The benefits of using ADR to better limit the growth of the future LEO population. Each future projection is the average of 100 LEGEND Monte Carlo (MC) runs. An ADR of five objects per year can stabilize the future environment in LEO.

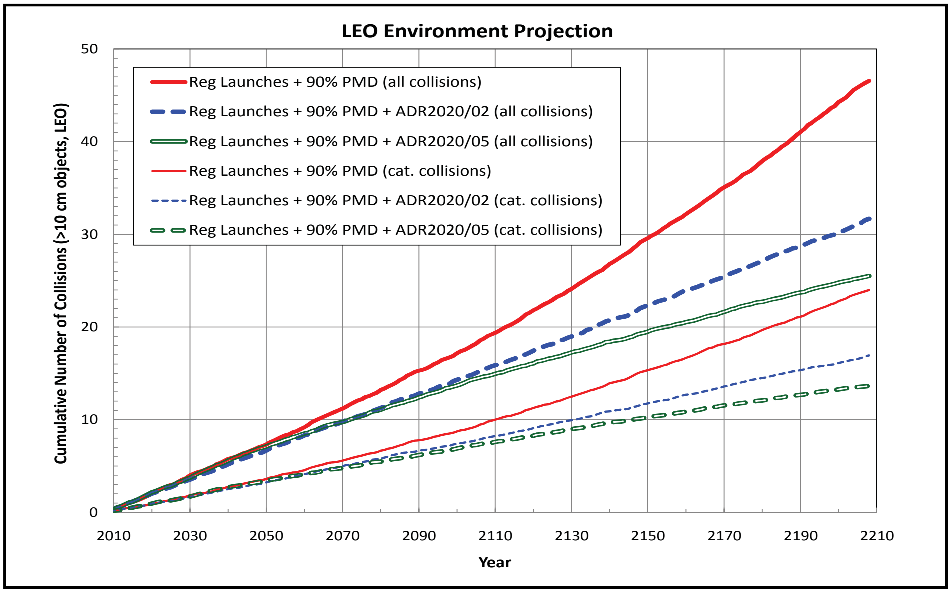

Figure 4. Projected LEO collision activities in the next 200 years. Even with an ADR of 5 objects per year, a total of 14 catastrophic collisions are expected in the next 200 years.

Table 1 – Predicted LEO catastrophic collisions in the next 200 years.

	i-i collisions	i-f collisions	f-f collisions	Total
90% PMD	10.2	10.9	3.0	24.1
90% PMD+ADR2020/2	8.2	7.0	1.9	17.1
90% PMD+ADR2020/5	6.5	5.5	1.8	13.8

ADR

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meteorological satellites from various countries.

If ADR is to be conducted in the near future, objects in Figure 5 should be high on the target list for removal. In general, R/Bs ought to be considered first because they have simple shapes and structures, and belong to only a few classes. However, some of the R/Bs may carry leftover propellant in pressurized containers. Any capture operations of those R/Bs will have to be carefully conducted. A potential problem to capture and remove objects shown on Figure 5 is the non-trivial tumble rates of the targets. New ground-based observations on those objects are needed in the near future to identify their tumble states. As the international community gradually reaches a consensus on the need for ADR, the focus will shift from environment modeling to technology development, engineering, and operations. It is clear that major cooperation, collaboration, and contributions at the national and international levels will be needed to move forward to implement ADR for environment remediation.

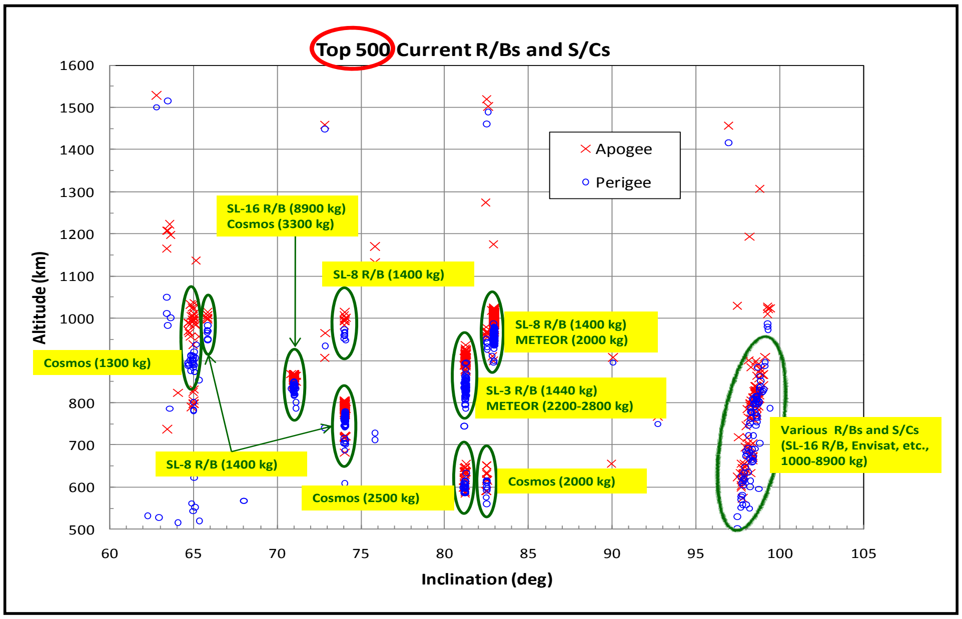

Figure 5. Objects with the highest [mass × collision probability] in the current environment. Major classes are identified, including the dry mass of each vehicle.

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1. Kessler, D.J. and Cour-Palais, B.G. Collision frequency of artificial satellites: The creation of a debris belt, JGR, 83, A6, 2637-2646, (1978).

2. Liou, J.-C. and Johnson, N.L. Risks in space from orbiting debris, Science, 311, 340-341, (2006).

3. Liou, J.-C., et al. Controlling the growth of future LEO debris populations with active debris removal, Acta Astronautica, 66, 648-653, (2010).

4. Liou, J.-C. An active debris removal parametric study for LEO environment remediation. J. Adv. Space Res. (2011), doi:10.1016/j.asr.2011.02.003. ♦

Simulation of Micron-Sized Debris Populations in Low Earth Orbit

Y.-L. XU, E. CHRISTIANSEN,
J. HYDE, M. MATNEY, T. PRIOR

The update of ORDEM2000, the NASA Orbital Debris Engineering Model, to its new version – ORDEM2010, is nearly complete. ORDEM models require a number of input debris populations across a wide range of object sizes, including micro-debris (greater than 10 µm and smaller than 1 mm in size) populations. The development of the micro-debris populations follows the general approach to deriving other ORDEM2010 required model populations for various components and types of debris. It includes the following key steps:

1. Data analysis,
2. Construction of reference populations,
3. Definition of model parameters in terms of the reference populations,
4. Linking model parameters with data,
5. Searching for best estimates of the model parameters based on data; updating reference populations using the best estimated parameters, and
6. Assessment of the modeling results and repeating the above two steps until satisfactory results are obtained.

Principal data used in the modeling of the micron-sized debris populations are in-situ hypervelocity impact records that are accumulated in post-flight damage surveys of the space-exposed surfaces of returned spacecraft. In spite of the limited quantity of the available space transportation systems (STS) impact data, the population-derivation process is satisfactorily stable and effective. Final modeling results obtained from shuttle window and radiator impact data are reasonably convergent, especially for the debris populations with object-size thresholds at 10 and 100 µm.

Whenever time permits prior to an upcoming flight, NASA conducts post-flight inspections on the space-exposed surfaces of a returned shuttle orbiter to identify damage caused by hypervelocity impacts from micrometeoroids and orbital debris. When possible, the source of a projectile and its material type is identified by analyzing chemical compositions of the projectile remnant found at the impact site. The STS impactors are split into two material groups: medium and high densities (MD and HD). The HD group consists of steel, copper, and silver, whereas the MD group includes all other materials. Figure 1 shows the cumulative crater depth and

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Simulation

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size distributions for three dominant window-impactor groups: aluminum (Al), paint, and steel. It is interesting that Al and paint are similar not only in the total number of impacts, but also in both crater depth and diameter distributions. Similarly, Fig. 2 shows thermal tape hole-diameter distributions of the damage from Al, paint, and steel impacts to the STS radiator. Note that the Al data shown in Fig. 2 includes 20 extra impacts extracted from the impacts classified as "unknowns."

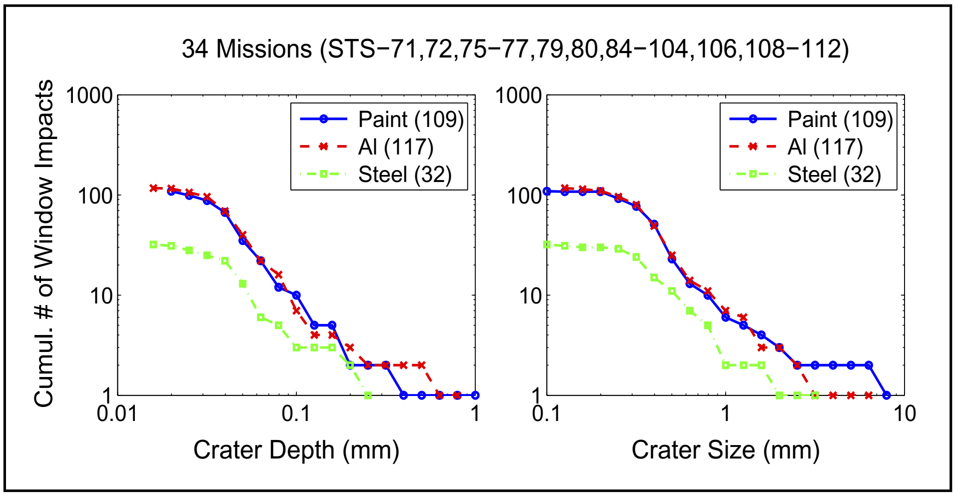

Figure 1. Cumulative crater depth and size (diameter) distributions of STS window impacts from debris impactors of paint, aluminum (Al), and steel as identified in post-flight surveys of 34 missions (STS-71, 72, 75-77, 79, 80, 84-104, 106, 108-112).

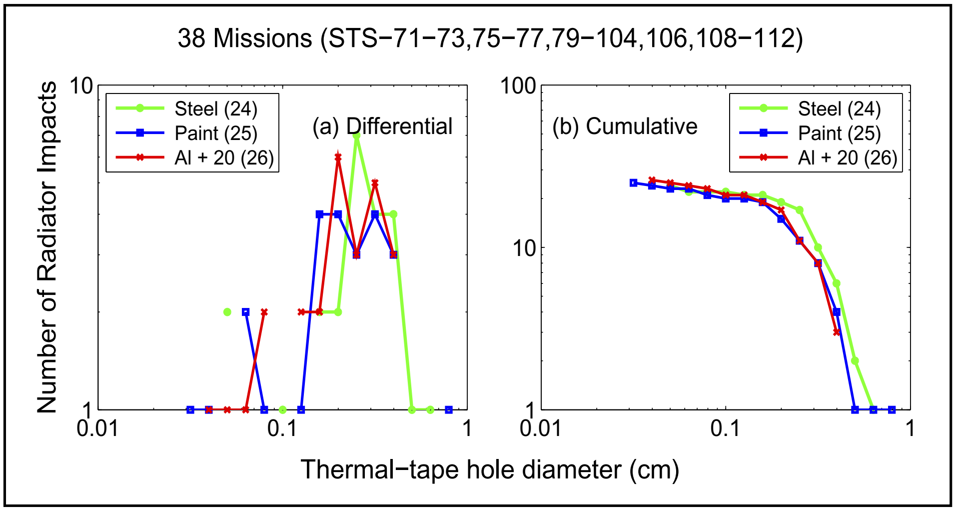

Figure 2. STS radiator thermal-tape damage size (diameter) distributions of paint, aluminum, and steel impactors as identified in the post-flight surveys of 38 missions (STS-71-73, 75-77, 79-104, 106, 108-112). Note that the data shown include 20 extra Al impacts extracted from "unknowns."

An ORDEM model debris population consists of a large group of representative orbits. It is not feasible to obtain such a model micro-debris population from the STS impact data directly, given the low data count and the huge number of micro-debris objects in the environment. An appropriate source model that simulates the orbital distribution and the dynamic evolution, over time, of the debris objects is necessary to provide reference populations for the statistical derivations. It must be based on our best understanding of physical and dynamical debris properties and generation mechanisms. Then the statistical inference is used to test and refine the reference populations by minimizing the differences between data and model predictions.

A critical step in the statistical inference process of the ORDEM model populations is to link model populations with data. This step simply makes predictions of STS impacts from model populations, which demands three crucial elements. First, damage equations (or damage laws) are required to provide estimates for impact damage characteristics, given the physical size and material density of a projectile and impact conditions. Second, detailed information is indispensable on STS flight timelines and the space-exposed area-time/directionality of each window and radiator element of a shuttle orbiter for each of the involved space missions. Third, detailed directional debris fluxes on the orbits of every involved mission from model populations must be pre-calculated.

When data and reference populations are available and the connection between data and model populations are established, adequate model parameters can be defined in terms of reference populations to allow the statistical model to search for the best estimates of the parameters based on the compiled data. A model parameter is usually a subset of a group of orbits in the reference populations. During the modeling process, orbital elements, including semi-major axis (or perigee height), eccentricity, and inclination of each orbit remain unchanged. The model parameters defined in this way are the easiest to handle in practical calculations. It is the object numbers of a subset orbit that are actually adjusted. As a requirement of ORDEM2010, model populations in the micron size regime need to provide the four size thresholds at 10, 31.6, 100, and 316 μm. Thus, for each of the two material types of medium and high mass-densities, we use four parameters in the micro-debris population estimation. Figure 3 shows the comparison of model predictions based on the best-estimated final populations with data for the two material types of MD and HD combined. It refers to the four orbital groups defined by the object sizes of 10-31.6, 31.6-100, 100-316, and ≥316 μm, respectively. Note that STS impact records do not contain sufficient data for a reliable inference of ≥316 μm populations. Our results for the 8-parameter model are obtained by coupling with the results of millimeter- and centimeter-sized debris populations inferred from radar data.

In summary, both STS window and radiator impact data are used simultaneously in the estimation of ORDEM2010 micro-debris populations. A degradation/ejecta model

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Simulation

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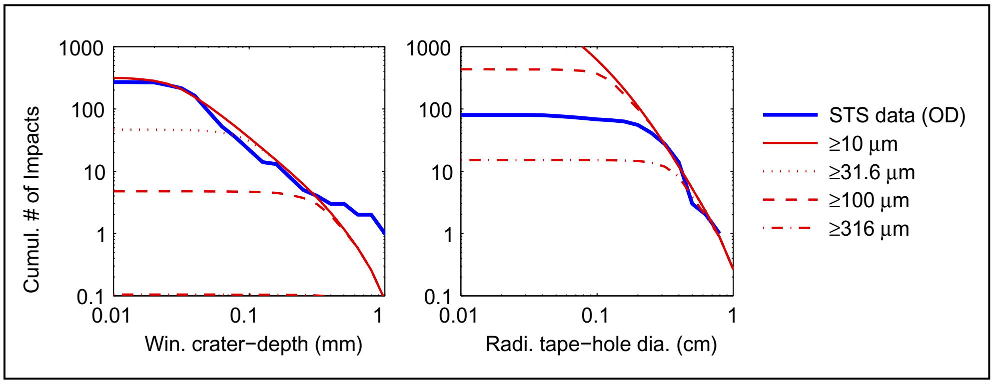

Figure 3. Comparison between model predictions based on best-estimated micro-debris populations (red) with STS impact data (blue) for the two material types of MD and HD combined. Model predictions are shown for the four groups of ≥316, ≥100, ≥31.6, and ≥10 µm objects. For the radiator panel, the ≥31.6 µm curve is above the range and is not visible.

provides reference populations for the initial step of the statistical population-derivation process. The initial step of the statistical inference process provides a set of best estimates for the model parameters needed to update the initial reference populations. Necessary, subsequent iterations continue to update reference populations until no further adjustment is needed. The statistical inference process simply refines a reference debris population in terms of data. In Bayesian terminology, the observed results change a given prior distribution into a posterior distribution. Further work and possible improvements are anticipated on the micro-debris environment modeling. ♦

UPCOMING MEETINGS

5-12 June 2011: The 28th International Symposium on Space Technology and Science (ISTS), Okinawa, Japan

The main theme of the 2011 ISTS is "Exploring Humans, Earth, and Space." The Symposium will include several plenary sessions with invited speakers, panel discussions on human exploration in space, and 17 technical subjects including propulsion; astrodynamics; navigation, guidance, and control; space utilization; satellite communications; explorations; and space environment and debris. A total of eight debris sessions are planned. In addition, a panel discussion on "Observation and Characterization of Space Debris for Orbital Safety" is scheduled during the Symposium. Additional information about the 28th ISTS is available at: <http://www.ists.or.jp/2011/>.

4-8 July 2011: The 4th European Conference for Aerospace Sciences (EUCASS), Saint Petersburg, Russia

EUCASS is a high-level European forum aimed at aerospace scientific advances, innovation, research, and technology development. The conference in 2011 will include three sessions related to space debris – environment modeling, debris removal, and reentry. Additional information of the conference is available at: <http://eucass.ru>.

3-7 October 2011: The 62nd International Astronautical Congress (IAC), Cape Town, South Africa

The theme for the 62nd International Astronautical Congress is "African Astronaissance." The dates have been chosen to coincide with World Space Week. The Congress will include a Space Debris Symposium to address various technical issues of space debris. Six sessions are planned for the Symposium: "Measurements," "Modeling and Risk Analysis," "Hypervelocity Impacts and Protection," "Mitigation and Standards," "Space Debris Detection and Characterization," and "Removal and Legal Issues." Additional information on the conference is available at: <http://www.iac2011.com>.

17-19 October 2011: The 5th International Association for the Advancement of Space Safety (IAASS) Conference, Versailles-Paris, France

The 5th IAASS Conference "A Safer Space for a Safer World" is an invitation to reflect and exchange information on a number of topics in space safety and sustainability of national and international interest. The conference is also a forum to promote mutual understanding, trust, and the widest possible international cooperation in such matters. The conference will include two orbital debris-related topics – "Space Debris Remediation" and "Spacecraft Re-entry Safety." Additional information on the conference is available at: <http://www.congrex.nl/11a03/>.

INTERNATIONAL SPACE MISSIONS
1 January 2011– 31 March 2011

International Designator	Payloads	Country/ Organization	Perigee Altitude (KM)	Apogee Altitude (KM)	Inclination (DEG)	Earth Orbital Rocket Bodies	Other Cataloged Debris
2011-001A	ELEKTRO-L	RUSSIA	35780	35793	0.3	2	5
2011-002A	USA 224	USA	NO ELEMS. AVAILABLE			0	0
2011-003A	HTV 2	JAPAN	351	354	51.6	0	0
2011-004A	PROGRESS M-09M	RUSSIA	351	354	51.6	1	0
2011-005A	GEO IK 2	RUSSIA	304	1050	99.5	1	0
2011-006A	USA 225	USA	NO ELEMS. AVAILABLE			1	2
2011-007A	ATV 2	ESA	351	354	51.6	1	0
2011-008A	STS-133	USA	318	355	51.6	0	0
2011-009A	COSMOS 2471 (GLONASS)	RUSSIA	19113	19146	64.8	1	0
2011-010A	OTV 2 (USA 226)	USA	NO ELEMS. AVAILABLE			0	0
2011-011A	USA 227	USA	NO ELEMS. AVAILABLE			1	0

SATELLITE BOX SCORE
(as of 30 March 2011, cataloged by the U.S. SPACE SURVEILLANCE NETWORK)

Country/ Organization	Payloads	Rocket Bodies & Debris	Total
CHINA	100	3374	3474
CIS	1406	4635	6041
ESA	40	44	84
FRANCE	49	431	480
INDIA	41	130	171
JAPAN	114	72	186
USA	1142	3679	4821
OTHER	487	111	598
TOTAL	3379	12476	15855

DAS 2.0 NOTICE

Attention DAS 2.0 Users: an updated solar flux table is available for use with DAS 2.0. Please go to the Orbital Debris Website (http://www.orbitaldebris.jsc.nasa.gov/mitigate/das.html) to download the updated table and subscribe for email alerts of future updates.

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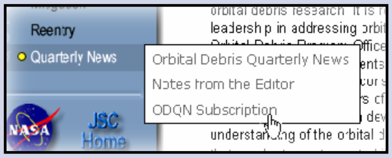

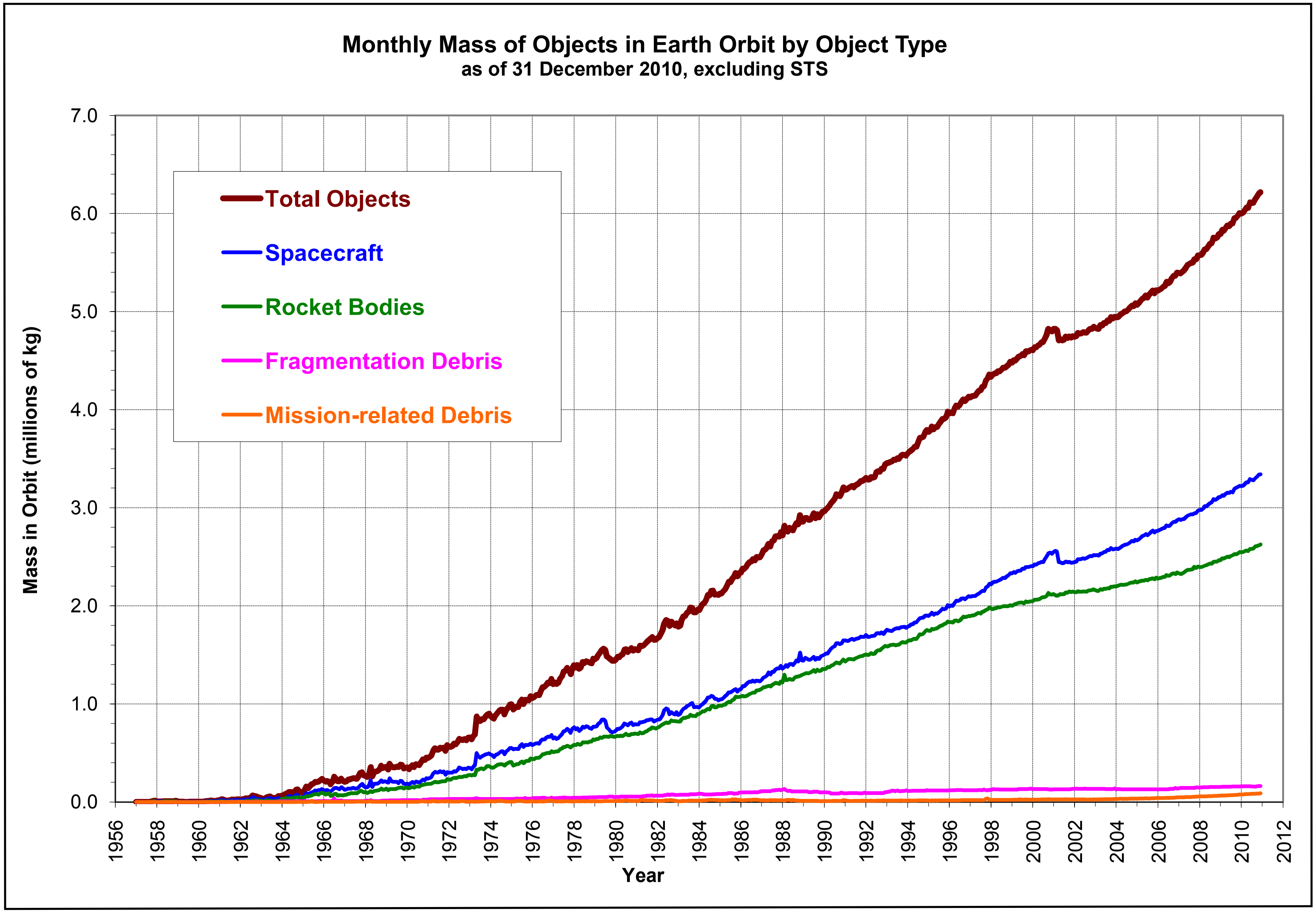

Monthly Mass of Cataloged Objects in Earth Orbit by Object Type: This chart displays a summary of all objects in Earth orbit officially cataloged by the U.S. Space Surveillance Network. "Fragmentation debris" includes satellite breakup debris and anomalous event debris, while "mission-related debris"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

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