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Inside...

Orbital Debris Program Office
Measurements - Modeling
Mitigation - Outreach
30 Year Anniversary
1979 - 2009

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Debris Program Office

Satellite Collision Leaves Significant Debris Clouds

The first accidental hypervelocity collision of two intact spacecraft occurred on 10 February, leaving two distinct debris clouds extending through much of low Earth orbit (LEO). The first indication of the impact was the immediate cessation of signals from one of the satellites. Shortly thereafter, the U.S. Space Surveillance Network (SSN) began detecting numerous new objects in the paths of the two spacecraft. By the end of March, 783 of the larger debris had been identified and cataloged by the SSN with additional debris being tracked, but not yet cataloged. Special ground-based observations confirmed that a much greater number of smaller debris was also generated in the unprecedented event.

Iridium 33, a U.S. operational communications satellite (International Designator 1997-051C, U.S. Satellite Number 24946), and Cosmos 2251, a Russian decommissioned communications satellite (International Designator 1993-036A, U.S. Satellite Number 22675), collided at 1656 GMT as the two vehicles passed over extreme northern Siberia at an altitude of 790 km. Both spacecraft were in nearly circular orbits with high inclinations: 86.4 degrees and 74.0 degrees, respectively. At the time of the collision, the two orbital planes intersected at a nearly right angle, resulting in a collision velocity of more than 11 km/s (Figure 1).

The number of debris created in a collision of this type is dependent upon the masses of the vehicles involved and the manner in which they struck one another. The two complex spacecraft (Figure 2) were of moderate dry

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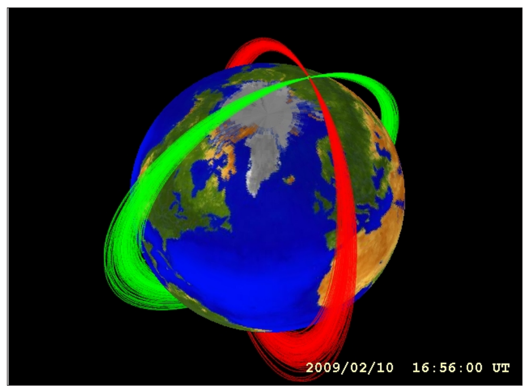

Figure 1. The orbital planes of Iridium 33 and Cosmos 2251 were at nearly right angles at the time of the collision.

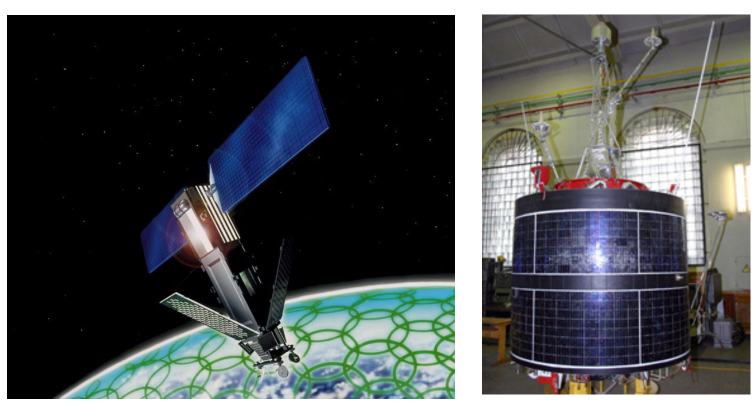

Figure 2. Configurations of an Iridium satellite (left) and the class of Cosmos satellite (right) involved in the collision of 10 February 2009.

Satellite Collision

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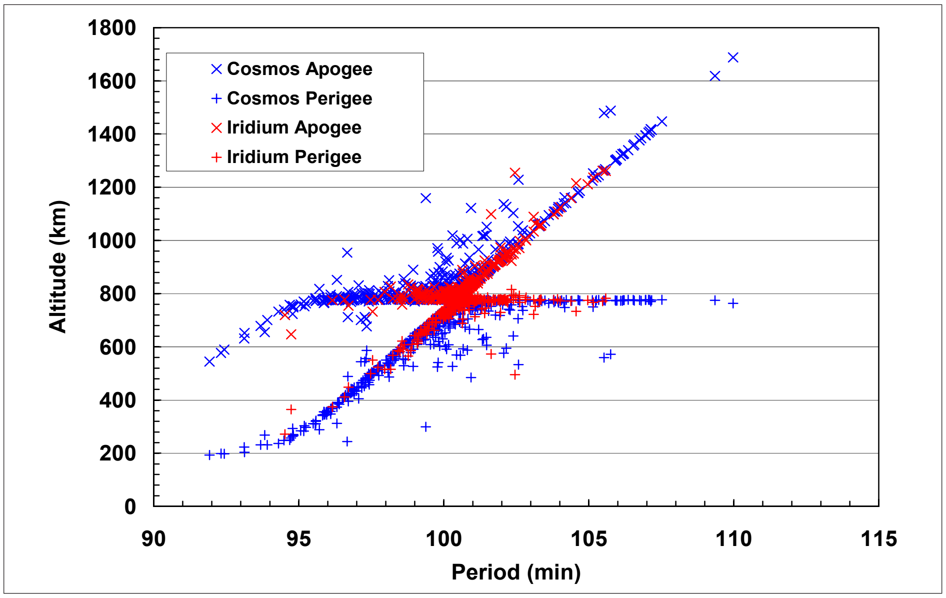

Figure 3. Altitude distribution of 731 cataloged debris on 20 March 2009. An additional piece of cataloged debris had already fallen back to Earth.

mass: 560 kg for Iridium 33 and approximately 900 kg for Cosmos 2251. Although the number of debris tracked by the SSN is high, an even larger amount (~1300) would be expected if the two satellites had hit body-to-body. The larger number and broader spread of ejecta velocities of identified debris originated from the more massive and pressurized Cosmos 2251 (Figure 3).

Due to the differential orbital periods of the debris, their orbital planes will gradually separate and form a shell about the Earth. Figure 4 illustrates the predicted orbital planes six months after the collision. The debris from the Iridium 33 spacecraft will spread more slowly than those from Cosmos 2251 due to their higher inclination. From preliminary assessments, the orbital lifetimes of many of the debris are likely to be measured in decades, posing future collision hazards to other satellites in LEO.

Observations of debris too small to be seen by the SSN were conducted by the Haystack, Haystack Auxiliary, and Goldstone radars. The Haystack and the Haystack Auxiliary radars can reliably detect objects as small as 1 cm in LEO. A pair of radars operated by the Jet Propulsion Laboratory in Goldstone, CA, working in a bistatic mode (one radar acts as a transmitter and one radar acts as a receiver) can detect sub-centimeter debris in low altitudes. These observations confirmed a large number of small debris from both spacecraft.

The collision of Iridium 33 and Cosmos 2251 occurred in a region of relatively high spatial density, *i.e.*, where collisions would be statistically more likely to occur. At the beginning of February 2009, the Iridium constellation itself consisted of 70 satellites in the operational altitude regime. The main body of each satellite is about one meter across by four meters tall, plus two large solar arrays (1.3 m wide by 3.3 m long) and three communications antenna plates. Whizzing through the Iridium constellation altitude regime many times each day are approximately 3,300 additional cataloged objects. Close approaches between these objects and Iridium spacecraft are common occurrences.

This event was the fourth known accidental hypervelocity collision between two cataloged objects (Figure 5). The previous impacts involved an intact spacecraft or launch vehicle orbital stage with a smaller piece of debris and resulted in only a maximum of four cataloged debris being produced per event. ♦

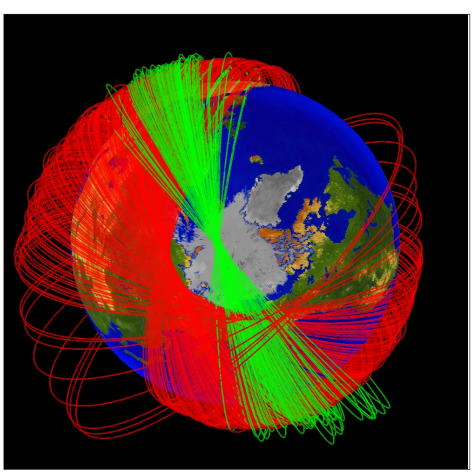

Figure 4 Predicted evolution of the Iridium and Cosmos debris planes six months after the collision.

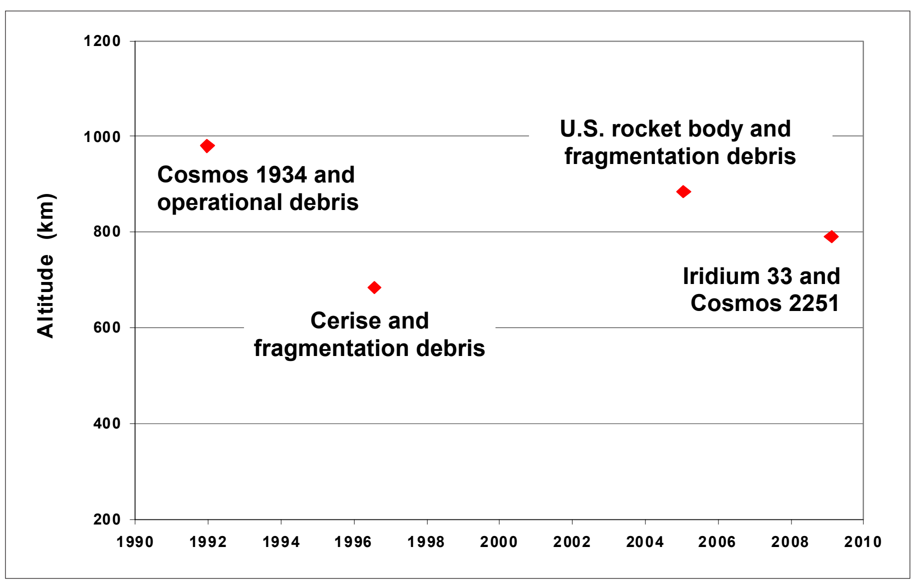

Figure 5. A total of four accidental, hypervelocity collisions have been identified, but only the one on 10 February 2009 involved two intact spacecraft.

ISS Crew Seeks Safe Haven During Debris Flyby

On 12 March the crew of the International Space Station (ISS) temporarily retreated into the safety of their Soyuz TMA-13 spacecraft when a small piece of orbital debris was belatedly projected to come close to the ISS. In the end, the interloping object (International Designator 1993-032D, U.S. Satellite Number 25090) passed ISS at a comfortable distance of almost 4 km.

At the time of the conjunction, ISS was in a nearly circular orbit near 355 km altitude, while the debris, a piece of mission-related hardware from a U.S. Delta 2 third stage, was in a highly elliptical orbit of about 145 km by 4230 km. From radar cross-section observations, the size of the object was determined to be about 13 cm, large enough to inflict serious damage to the ISS in the event of a collision.

To protect the ISS, U.S. Space Surveillance Network personnel perform conjunction assessments thrice daily to identify any object which might come within a volume of 2 km by 25 km by 25 km centered around the space station during the next three days. If an object satisfies that criterion, additional tracking of the object is tasked, and higher precision conjunction assessments are undertaken. Should the subsequently calculated probability of collision exceed a value of 0.0001 (1 in 10,000), then a collision avoidance maneuver is normally executed.

In the case of the 12 March conjunction, the rapidly changing orbit of the debris due to its low perigee led to a delayed recognition of the threat, leaving no time to prepare for a collision avoidance maneuver. In such cases, the crew is instructed to move to their return vehicle and prepare to undock quickly in the unlikely event that the object does impact ISS.

Initial conjunction notifications normally occur a few times per month, although rarely is a collision maneuver or crew re-location required. The number of conjunction notifications increased markedly during 2008 following the break-up of Cosmos 2421 into more than 500 fragments at a point only 60 km above ISS (ODQN, Vol. 12, Issues 2-4). Fortunately, the majority of the Cosmos 2421 debris had already fallen back to Earth by the start of 2009. ♦

Minor March Satellite Break-Up

On 8 March an 18-year-old ullage motor from a Russian Proton launch vehicle broke-up into as many as 20 fragments. At the time of the event, the long dormant object (International Designator 1991-25F, U.S. Satellite Number 21220) was in a highly elliptical orbit of 465 km by 18,535 km with an inclination of 64.9 degrees.

The ullage motor had been separated from the fourth stage of the Proton launch vehicle at the start of the final burn of the stage on a mission to place three navigation spacecraft into a nearly circular orbit near 19,100 km. Each stage carries two ullage motors, and the second ullage motor for this flight (International Designator 1991-25G, U.S. Satellite Number 21226) broke-up on 16 June 2001, after a decade in space. Late in March debris from 1991-25F began to be officially cataloged by the U.S. Space Surveillance Network. This was the 37th identified instance of the on-orbit break-up of a Proton ullage motor. ♦

PROJECT REVIEWS

STS-126 Shuttle Endeavour Window Impact Damage

J. HERRIN, J. HYDE, E. CHRISTIANSEN, AND D. LEAR

During the November 2008 STS-126 mission to the International Space Station, the Endeavour crew observed micrometeoroid or orbital debris impact damage to the outer thermal pane of the rightmost flight deck window (window #6). Figure 1 shows one of the initial on-orbit photos. While five other window impacts occurred during this mission, these were all smaller and were not observed during the mission.

Figure 1. STS-126/OV-105 window #6 on-orbit photo.

The Johnson Space Center (JSC) Astromaterials Research and Exploration Science Directorate Micrometeoroid and Orbital Debris (MMOD) damage inspection team inspected the window damage shortly after Endeavour's return to the Kennedy Space Center. The JSC MMOD inspection team obtained damage measurements, digital microscope photos, and dental-mold impressions of the damage. The dental molds provide detailed surface-damage shapes from which the size and impact depth can be determined. Additionally, the dental molds frequently retain impactor residue that can be subsequently analyzed using a Scanning Electron Microscope (SEM) with Energy Dispersive Spectroscopy (EDS)

Figure 2. STS-126/OV-105 window #6 impact damage location.

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STS-126 Window Damage

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and Raman spectroscopy to determine if the impactor was a micrometeoroid or orbital debris particle. A photograph of the impact location on window #6 is shown in Figure 2. A digital microscope photo of the window damage with scale reference is shown in Figure 3.

Based on measurements taken from the digital microscope photographs, the impact produced subsurface damage spanning 12.4 mm by 10.3 mm (measured parallel to the glass surface). The region of excavated surface glass measured from the dental mold impressions (*i.e.*, the crater diameter) spans 11.45 mm by 9.55 mm (Figure 4), with a maximum crater depth of 0.62 mm. Based on the size of the excavated surface glass, this is the largest shuttle window impact observed. The previous largest

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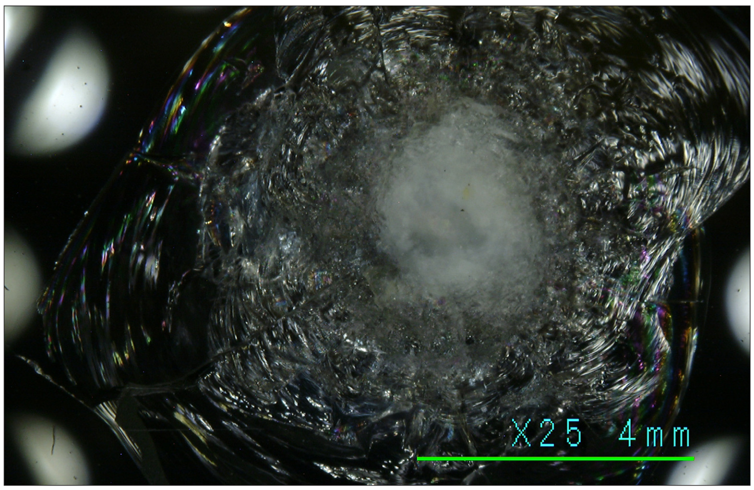

Figure 3. Window impact digital microscope damage measurements.

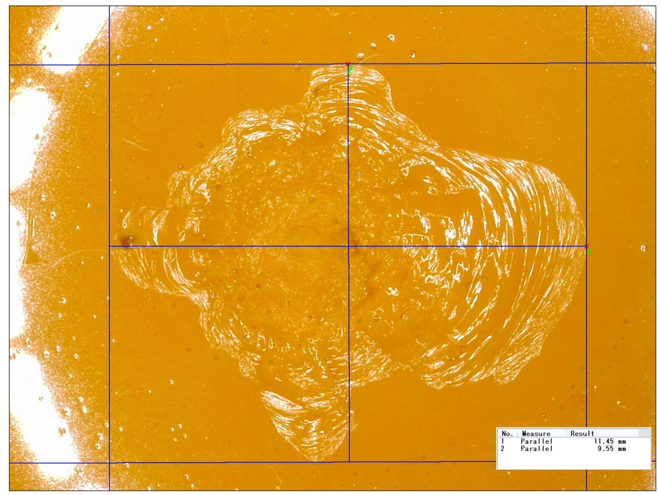

Figure 4. Dental mold digital microscope measurements.

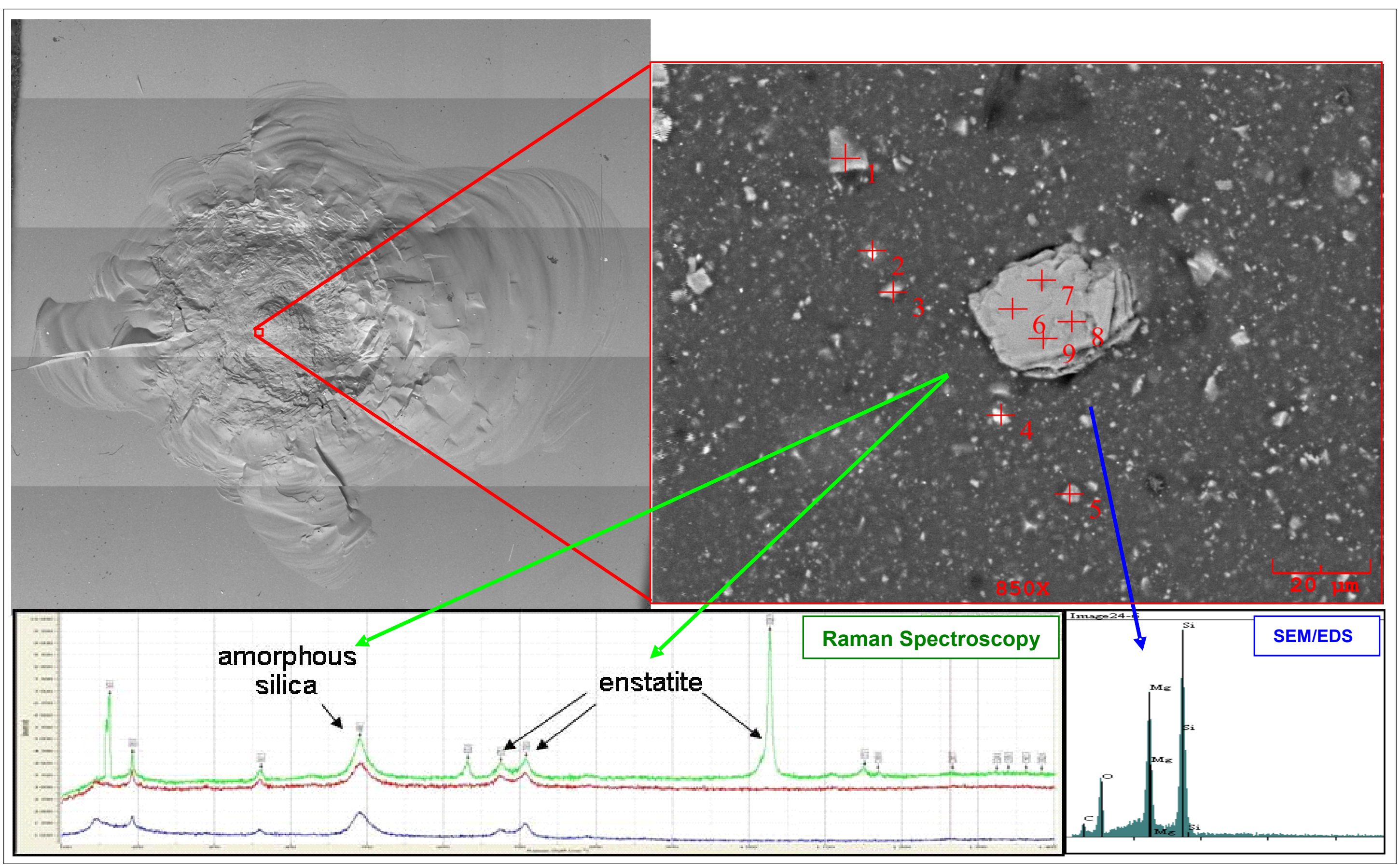

Figure 5. SEM/EDS and Raman spectroscopy results.

STS-126 Window Damage

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impact occurred on the STS-59 hatch window (window #11) during the 1994 mission.

SEM/EDS and Raman spectroscopy were used to determine if the impactor was micrometeoroid or orbital debris (Figure 5). Preliminary analysis suggests that the impactor was a micrometeoroid particle due to the presence of the mineral enstatite fused to amorphous silica glass particles in the central impact area of the dental molds. Enstatite is a magnesium-silicate mineral that is rare on the Earth's surface but is common in interplanetary dust particles. Based on crater depth, this level of damage would be due to a particle on the order of 0.15 mm diameter at typical micrometeoroid velocities and densities of stony meteoroids. This is a preliminary size estimate pending completion of the impactor SEM/EDS analysis. ♦

ABSTRACTS FROM THE NASA ORBITAL DEBRIS PROGRAM OFFICE

The 5th European Conference on Space Debris
30 March - 2 April 2009, Darmstadt, Germany

Reflectance Spectra Comparison of Orbital Debris, Intact Spacecraft, and Intact Rocket Bodies in the GEO Regime

K. J. ABERCROMBY, P. ABELL, AND E. BARKER

A key objective of NASA's Orbital Debris program office at Johnson Space Center (JSC) is to characterize the debris environment by way of assessing the physical properties (type, mass, density, and size) of objects in orbit. Knowledge of the geosynchronous orbit (GEO) debris environment in particular can be used to determine the hazard probability at specific GEO altitudes and aid predictions of the future environment. To calculate an optical size from an intensity measurement of an object in the GEO regime, a 0.175 albedo is assumed currently. However, identification of specific material type or types could improve albedo accuracy and yield a more accurate size estimate for the debris piece. Using spectroscopy, it is possible to determine the surface materials of space objects. The study described herein used the NASA Infrared Telescope Facility (IRTF) to record spectral data in the 0.6 to 2.5 micron regime on eight catalogued space objects. For comparison, all of the objects observed were in GEO or near-GEO. The eight objects consisted of two intact spacecraft, three rocket bodies, and three catalogued debris pieces. Two of the debris pieces stemmed from Titan 3C transtage breakup and the third is from COSMOS 2054. The reflectance spectra of the Titan 3C pieces share similar slopes (increasing with wavelength) and lack any strong absorption features. The COSMOS debris spectra is flat and has no absorption features. In contrast, the intact spacecraft show classic absorption features due to solar panels with a strong band gap feature near 1 micron. The two spacecraft are spin-stabilized objects and therefore have solar panels surrounding the outer surface. Two of the three rocket bodies are inertial upper stage (IUS) rocket bodies and have similar looking spectra. The slopes flatten out near 1.5 microns with absorption features in the near-infrared that are similar to that of white paint. The third rocket body has a similar flattening of slope but with fewer features of white paint – indicating that the surface paint on the SL-12 may be different than the IUS. This study shows that the surface materials of debris appear different spectrally than intact rocket bodies and spacecraft and therefore are not believed to be solar panel material or pristine white paint. Further investigation is necessary in order to eliminate materials as possible choices for the debris pieces. ♦

Shape Distribution of Fragments From Microsatellite Impact Tests

T. HANADA AND J.-C. LIOU

Fragment shape is an important factor for conducting reliable orbital debris damage assessments for critical space assets such as the International Space Station. To date, seven microsatellite impact tests have been completed as part of an ongoing collaboration between Kyushu University and the NASA Orbital Debris Program Office. The target satellites ranged in size from 15 cm by 15 cm by 15 cm to 20 cm by 20 cm by 20 cm. Each target satellite was equipped with fully functional electronics including circuits, battery, and transmitter. Solar panels and multilayer insulation (MLI) were added to the target satellites of the last two tests. The impact tests were carried out with projectiles of different sizes and impact speeds.

All fragments down to about 2 mm in size were collected and analyzed based on their three orthogonal dimensions, x, y, and z, where x is the longest dimension, y is the longest dimension in the plane perpendicular to x, and z is the longest dimension perpendicular to both x and y. Each fragment was also photographed and classified by shape and material composition. This data set serves as the basis of our effort to develop a fragment shape distribution.

Two distinct groups can be observed in the x/y versus y/z distribution of the fragments. Objects in the first group typically have large x/y values. Many of them are needle-like objects originating from the fragmentation of carbon fiber reinforced plastic materials used to construct the satellites. Objects in the second group tend to have small x/y values, and many of them are box-like or plate-like objects, depending on their y/z values. Each group forms the corresponding peak in the x/y distribution. However, only one peak can be observed in the y/z distribution. These distributions and how they vary with size, material type, and impact parameters will be described in detail within the paper. ♦

Micrometeoroid and Orbital Debris Threat Mitigation Techniques for the Space Shuttle Orbiter

J. HYDE, E. CHRISTIANSEN, D. LEAR, AND J. KERR

An overview of significant Micrometeoroid and Orbital Debris (MMOD) impacts on the Payload Bay Door radiators, wing leading edge, reinforced carbon-carbon panels and crew module windows will be presented, along with a discussion of the techniques NASA has implemented to reduce the risk from MMOD impacts. The concept of "Late Inspection" of the Nose Cap and Wing Leading Edge (WLE), Reinforced Carbon Carbon (RCC) regions will be introduced. An alternative mated attitude with the International Space Station (ISS) on shuttle MMOD risk will also be presented. The significant threat mitigation effect of these two techniques will be demonstrated. The wing leading edge impact detection system, on-orbit repair techniques, and disabled vehicle contingency plans will also be discussed. ♦

The International Space Station and the Space Debris Environment: 10 Years on

N. JOHNSON

For just over a decade the International Space Station (ISS), the most heavily protected vehicle in Earth orbit, has weathered the space debris environment well. Numerous hypervelocity impact features on the surface of ISS caused by small orbital debris and meteoroids have been observed. In addition to typical impacts seen on the large solar arrays, craters have been discovered on windows, hand rails, thermal blankets, radiators, and even a visiting logistics module. None of these impacts have resulted in any degradation of the operation or mission of the ISS. Validating the rate of small particle impacts on the ISS as predicted by space debris environment models is extremely complex. First, the ISS has been an evolving structure, from its original 20 metric tons to nearly 300 metric tons (excluding logistics vehicles) ten years later. Hence, the anticipated space debris impact rate has grown with the increasing size of ISS. Secondly, a comprehensive visual or photographic examination of the complete exterior of ISS has never been accomplished. In fact, most impact features have been discovered serendipitously. Further complications include the estimation of the size of an impacting particle without knowing its mass, velocity, and angle of impact and the effect of shadowing by some ISS components. Inadvertently and deliberately, the ISS has also been the source of space debris. The U.S. Space Surveillance Network officially cataloged 65 debris from ISS from November 1998 to November 2008: from lost cameras, sockets, and tool bags to intentionally discarded equipment and an old space suit. Fortunately, the majority of these objects fall back to Earth quickly with an average orbital lifetime of less than two months and a maximum orbital lifetime of a little more than 15 months. The cumulative total number of debris object-years is almost exactly 10, the equivalent of one piece of debris remaining in orbit for 10 years. An unknown number of debris too small to be tracked and cataloged have also been generated, but normally with even shorter orbital lifetimes. Finally, eight collision avoidance maneuvers have been performed to avoid potential collisions between ISS and large, tracked space debris. The most recent such maneuver was accomplished by ESA's Automated Transfer Vehicle, the Jules Verne, just three months before the 10th anniversary of the launch of ISS's first element. ♦

Space Debris Environment Remediation Concepts

N. JOHNSON AND H. KLINKRAD

Long-term projections of the space debris environment indicate that even drastic measures, such as an immediate, complete halt of launch and release activities, will not result in a stable environment of man-made space objects. Collision events between already existing space hardware will, within a few decades, start to dominate the debris population and result in a net increase of the space debris population, also in size regimes which may cause further catastrophic collisions. Such a collisional cascading will ultimately lead to a run-away situation ("Kessler syndrome"), with no further possibility of human intervention. The International Academy of Astronautics (IAA) has been investigating the status and the stability of the space debris environment in several studies by first looking into space traffic management possibilities and then investigating means of mitigating the creation of space debris. In an ongoing activity, an IAA study group looks at ways of active space debris environment remediation. In contrast to the former mitigation study, the current activity concentrates on the active removal of small and large objects, such as defunct spacecraft, orbital stages, and mission-related objects, which serve as a latent mass reservoir that fuels initial catastrophic collisions and later collisional cascading.

The paper will outline different mass removal concepts, *e.g.*, based on directed energy, tethers (momentum exchange or electrodynamic), aerodynamic drag augmentation, solar sails, auxiliary propulsion units, retarding surfaces, or on-orbit capture. Apart from physical principles of the proposed concepts, their applicability to different orbital regimes and their effectiveness concerning mass removal efficiency will be analyzed. The IAA activity on space debris environment remediation is a truly international project which involves more than 23 contributing authors from 9 different nations. ♦

In Situ Measurement Activities at the NASA Orbital Debris Program Office

J.-C. LIOU, M. BURCHELL, R. CORSARO, G. DROLSHAGEN, F. GIOVANE, V. PISACANE, AND E. STANSBERY

The NASA Orbital Debris Program Office has been involved in the development of several particle impact instruments since 2002. The main objective of this development is to eventually conduct in situ measurements to better characterize the small (millimeter or smaller) orbital debris and micrometeoroid populations in the near-Earth environment. In addition, the Program Office also supports similar instrument development to define the micrometeoroid and lunar secondary ejecta environment for future lunar exploration activities.

The instruments include impact acoustic sensors, resistive grid sensors, fiber optic displacement sensors, impact ionization sensors, and laser curtain sensors. They rely on different mechanisms and detection principles to identify particle impacts. A system consisting of these

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In Situ Measurement Activities

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different sensors will provide data that are complementary to each other, and will provide a better description of the physical and dynamical properties (*e.g.*, size, mass, and impact speed) of the particles in the environment. Testing of various prototype units at both low velocity and hypervelocity regimes is underway. Details of the test results and several systems being considered by the Program Office and their intended mission objectives will be summarized in this paper. ♦

Microsatellite Impact Tests to Investigate Multilayer Insulation Fragments

J. MURAKAMI, T. HANADA, J.-C. LIOU, AND E. STANSBERY

This paper summarizes two satellite impact experiments completed in 2008. The objective of the experiments is to investigate the physical properties of satellite fragments, including those originated from multilayer insulation (MLI) and solar panels. The ultimate goal is to use the results to improve the NASA Standard Breakup Model. The targets were two cubic micro-satellites, 20 cm by 20 cm by 20 cm in size, and approximately 1500 g in mass. The main structure of each microsatellite was composed of five layers; the top and bottom layers and three internal layers parallel to the top and bottom layers, plus four side panels. The top layer was equipped with solar cells that were mounted to an aluminum honeycomb sandwich panel with CFRP face sheets. The four side panels and the bottom layer were all covered with MLI.

The two satellite impact experiments were conducted using the two-stage light gas gun at the Kyushu Institute of Technology in Kitakyusyu, Japan. For the first experiment (labeled Shot F), the satellite was oriented in such a way that the solar panel was facing the incoming projectile, a 39.3 g aluminum alloy solid sphere. For the second experiment (labeled Shot R), the satellite was oriented so that the solar panel was on the opposite side of the impact surface. The projectile used in the second shot was a 39.2 g aluminum alloy solid sphere. The impact speeds of Shot F and Shot R were 1.74 km/s and 1.78 km/s, respectively. The ratio of the impact kinetic energy to satellite mass for the two experiments was about 40 J/g. Both target satellites were completely fragmented, although there were noticeable differences in the characteristics of the fragments.

Approximately 1800 fragments were collected from Shot F, but only 1000 fragments were collected from Shot R. This difference primarily comes from the number of needle-like CFRP and MLI fragments. All collected fragments and MLI pieces will be measured and analyzed using the same method as described in the NASA Standard Breakup Model. This paper will present: (1) the area-to-mass ratio, size, and mass distributions of the fragments, and (2) the differences in fragment properties between Shot F and Shot R. ♦

Mitigation of EMU cut glove hazard from micrometeoroid and orbital debris impacts on ISS handrails

S. RYAN, E. CHRISTIANSEN, B.A. DAVIS, AND E. ORDONEZ

During post-flight processing of STS-116, damage to crewmember Robert Curbeam's Phase VI Glove Thermal Micrometeoroid Garment was discovered. This damage consisted of: loss of RTV-157 palm pads on the thumb area on the right glove, a 0.75 inch cut in the Vectran adjacent to the seam and thumb pad (single event cut), constituting the worst glove damage ever recorded for the U.S. space program. The underlying bladder and restraint were found not be damaged by this event. Evaluation of glove damage found that the outer Vectran fibers were sliced as a result of contact with a sharp edge or pinch point rather than general wear or abrasion (commonly observed on the RTV pads). Damage to gloves was also noted on STS-118 and STS-120. One potential source of EMU glove damages are sharp crater lips on external handrails, generated by micrometeoroid and orbital debris (MMOD) impacts.

In this paper, the results of a hypervelocity impact (HVI) test program on representative and actual ISS handrails are presented. These tests were performed in order to characterize impact damage profiles on ISS handrails and evaluate alternatives for limiting risk to future missions. It was determined that both penetrating and non-penetrating MMOD impacts on aluminum and steel ISS handrails are capable of generating protruding crater profiles which exceed the heights required for EMU glove abrasion risk by an order of magnitude. Testing demonstrated that flexible overwraps attached to the outside of existing handrails are capable of limiting contact between hazardous crater formations and crewmember gloves during extravehicular activity (EVA). Additionally, replacing metallic handrails with high strength, low ductility, fiber-reinforced composite materials would limit the formation of protruding crater lips on new ISS modules. ♦

Photometric Studies of Orbital Debris at GEO

P. SEITZER, K. J. ABERCROMBY, H. RODRIGUEZ-COWARDIN, E. BARKER, G. FOREMAN, AND M. HORSTMAN

We report on optical observations of debris at geosynchronous Earth orbit (GEO) using two telescopes simultaneously at the Cerro Tololo Inter-American Observatory (CTIO) in Chile.

The University of Michigan's 0.6/0.9-m Schmidt telescope **MODEST** (for **M**ichigan **O**rbital **DE**bris **S**urvey **T**elescope) was used in survey mode to find objects that potentially could be at GEO. Because GEO objects only appear in this telescope's field of view for an average of 5 minutes, a full six-parameter orbit can not be determined. Interrupting the survey for follow-up observations leads to incompleteness in the survey results. Instead, as objects are detected with **MODEST,** initial predictions assuming a circular orbit are done for where the object will be for the next hour, and the objects are reacquired as quickly as possible on the CTIO 0.9-m telescope. This second telescope follows-up during the first night and, if possible, over several more nights to obtain the maximum time arc possible and the best six-parameter orbit.

Our goal is to obtain an initial orbit and calibrated colors for *all* detected objects fainter than R = 15th in order to estimate the orbital distribution of objects selected on the basis

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Photometric studies

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of two observational criteria: magnitude and angular rate. One objective is to estimate what fraction of objects selected on the basis of angular rate are not at GEO. A second objective is to obtain magnitudes and colors in standard astronomical filters (BVRI) for comparison with reflectance spectra of likely spacecraft materials.

We will report on calibrated BVRI magnitudes and colors for a sample of more than 30 objects observed with the CTIO 0.9-m. Almost all objects are redder than solar in B-R, but show a broad distribution in R-I. The width of the color distribution may be intrinsic to the nature of the surfaces, but also could be due to the circumstance that we are seeing irregularly shaped objects and measuring the colors at different times with just one telescope.

For a smaller sample of objects we have observed with two telescopes simultaneously in different filters. The CTIO 0.9-m observes in B, and MODEST in R. The CCD cameras are electronically linked together so that the start time and duration of observations are the same to better than 50 milliseconds. Thus, the B-R color is a true measure of the surface of the debris piece facing the telescopes for that observation. Any change in color reflects a real change in the debris surface.

We will compare our observations with models and laboratory measurements of selected surfaces.

This work is supported by NASA's Orbital Debris Program Office, Johnson Space Center, Houston, Texas, USA. ♦

MEETING REPORT

12th Meeting of the NASA/DoD Orbital Debris Working Group 16 January 2009, Colorado Springs, Colorado

The 12th meeting of the NASA/DoD Orbital Debris Working Group was hosted by the Air Force Space Command (AFSPC)/A3C on 16 January 2009 in Colorado Springs. The meeting was co-chaired by Lt Col Joe Gambrell for DoD and Mr. Gene Stansbery for NASA. The working group addresses space surveillance and space situational awareness activities contributing to a common understanding of the orbital debris issues of mutual interest to both organizations.

Maj David Oue gave a presentation on the recent AFSPC reorganization related to Space Situational Awareness and Command and Control (SSA&C2) and AFSPC's role in national-level SSA planning including the National SSA Roadmap/Interim Architecture.

NASA reported on its recent activities starting with an annual report on orbital debris activities and plans for the United Nations' Committee on the Peaceful Uses of Outer Space (UNCOPUOS)and Inter-Agency Space Debris Coordination Committee (IADC). NASA then reported on the expected improvements to its upcoming release of the orbital debris engineering model, ORDEM2008, and the status of the Meter Class Autonomous Telescope (MCAT), a collaborative project between NASA and the Maui detachment of the AF Research Laboratory. This was followed by a discussion of Haystack and HAX radar measurements and the need to extend the current agreement covering orbital debris measurements collected by the two radars.

Another cooperative program briefed by NASA is the Debris Resistive/Acoustic Grid Orbital Navy Sensor (DRAGONS). DRAGONS is designed to detect and characterize micrometeoroid and orbital debris populations at 800-to-1000 km altitude. It is a collaborative effort among the NASA Orbital Debris Program Office, U.S. Naval Academy, U.S. Naval Research Lab, University of Kent, and Virginia Tech. There is a possible launch opportunity in 2013 on the GEOSAT Follow-On 2 (GFO-2) satellite

Dr. Ed Barker provided a summary of the multi-aircraft surveillance/data capture performed on the ATV-1 "Jules Verne" reentry. NASA collected and is analyzing video data of the reentry in order to determine the trajectories of as many pieces as possible. Following his talk on the ATV-1 reentry, Dr. Barker discussed current studies at NASA on debris shapes. He described the tools used to scan the surface of debris objects into 3-dimensional computer models which can then be used for various computer simulations.

On the DoD side, Dr. Felix Hoots, from the Aerospace Corporation, provided a briefing to outline Aerospace's Debris Analysis Response Team and their debris risk assessment process. The process has been developed for rapid assessment of satellite breakup debris risk to other resident satellites.

Dr. Paul Kervin, from the Maui detachment of AFRL, presented a briefing on the Panoramic Survey Telescope And Rapid Response System (PanSTARRS), . The PanSTARRS is a large aperture, wide field-of-view astronomical telescope intended to detect Earth-approaching/crossing asteroids and comets. Dr. Kervin reported on preliminary measurements of the orbital debris in the geosynchronous altitude regime. Although preliminary, the results show the great potential of PanSTARRS for these measurements.

DoD also reported on the difficulties meeting its current Casualty Expectation (Ec) requirements. These requirements address the hazard to humans on the ground from reentering spacecraft. After discussion, DoD recommended that it should conduct a survivability analysis of a generic satellite system reentry using the current DoD Aerospace model and then compare the findings to results of previous NASA and the European Space Agency studies.

The meeting was concluded with a discussion on space surveillance data collected after the USA-193 collision and a discussion of spacecraft anomaly databases which might provide clues to satellite failures related to orbital debris impacts. ♦

INTERNATIONAL SPACE MISSIONS
01 January – 31 March 2009

International Designator	Payloads	Country/ Organization	Perigee Altitude (KM)	Apogee Altitude (KM)	Inclination (DEG)	Earth Orbital Rocket Bodies	Other Cataloged Debris
2009-001A	USA 202	USA	NO ELEMS. AVAILABLE			1	0
2009-002A	GOSAT	JAPAN	668	670	98.0	1	1
2009-002B	PRISM	JAPAN	614	641	98.0		
2009-002C	SDS-1	JAPAN	663	667	98.0		
2009-002D	OBJECT D	JAPAN	656	666	98.0		
2009-002E	OBJECT E	JAPAN	659	667	98.0		
2009-002F	OBJECT F	JAPAN	666	671	98.0		
2009-002G	STARS	JAPAN	649	665	98.0		
2009-002H	KKS-1	JAPAN	653	665	98.0		
2009-003A	KORONAS-FOTON	RUSSIA	538	563	82.5	1	0
2009-004A	OMID	IRAN	245	378	55.5	1	0
2009-005A	NOAA 19	USA	846	866	98.7	1	0
2009-006A	PROGRESS-M 66	RUSSIA	349	362	51.6	1	0
2009-007A	EXPRESS AM-44	RUSSIA	35802	35772	0.1	1	1
2009-007B	EXPRESS MD1	RUSSIA	35788	35784	0.1		
2009-008A	NSS 9	NETHER-LANDS	35778	35794	0.0	1	1
2009-008B	HOT BIRD 10	EUTELSAT	35783	35791	0.1		
2009-008C	SPIRALE A	FRANCE	619	35706	2.0		
2009-008D	SPIRALE B	FRANCE	626	35697	2.0		
2009-009A	TELSTAR 11N	CANADA	35777	35798	0.0	1	0
2009-010A	RADUGA 1-8	RUSSIA	35907	35946	1.5	2	3
2009-011A	KEPLER	USA	HELIOCENTRIC			1	1
2009-012A	STS 119	USA	346	357	51.6	0	0
2009-013A	GOCE	ESA	272	288	96.7	1	0
2009-014A	NAVSTAR 63 (USA 203)	USA	EN ROUTE TO SSO			2	0
2009-015A	SOYUZ-TMA 14	RUSSIA	347	360	51.6	1	0

SATELLITE BOX SCORE
(as of 01 April 2009, as cataloged by the U.S. SPACE SURVEILLANCE NETWORK)

Country/ Organization	Payloads	Rocket Bodies & Debris	Total
CHINA	78	2695	2773
CIS	1379	3036	4415
ESA	38	36	74
FRANCE	49	331	380
INDIA	36	111	147
JAPAN	105	69	174
US	1098	3161	4259
OTHER	425	96	521
TOTAL	3208	9535	12743

UPCOMING MEETING

12-16 October 2009: The 60th International Astronautical Congress (IAC), Daejeon, Republic of Korea

The theme of the 2009 IAC is "Space for Sustainable Peace and Progress." A total of five sessions are planned for the Space Debris Symposium. The subjects of the sessions include measurements and space surveillance, modeling and risk analysis, hypervelocity impacts and protection, and mitigation and standards. Additional information of the 2009 IAC is available at <http://www.iac2009.kr/>..

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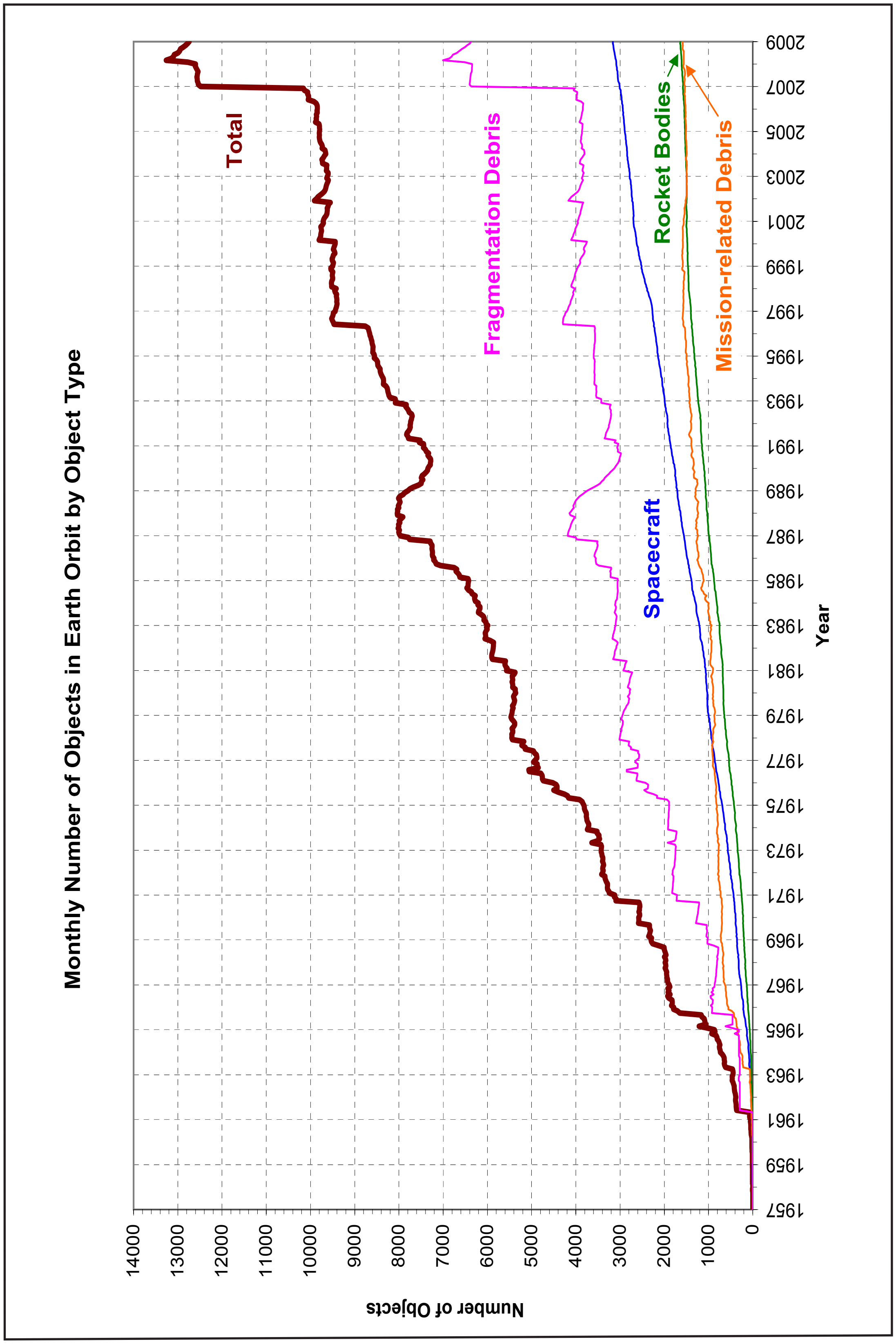

Monthly Number of Cataloged Objects in Earth Orbit by Object Type: This chart displays a summary of all objects in Earth orbit officially.