National Aeronautics and Space Administration

Orbital Debris
Quarterly News

Volume 17, Issue 2
April 2013

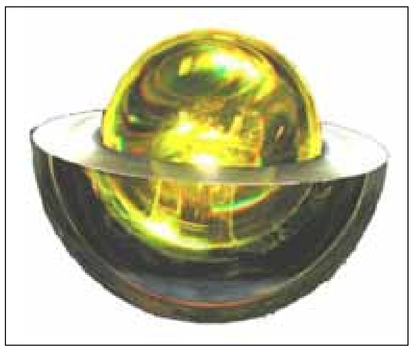
Inside...

A publication of the NASA Orbital Debris Program Office

Small Satellite Possibly Hit by Even Smaller Object

A small Russian geodetic satellite was slightly perturbed from its orbit on 22 January 2013 and shed a piece of debris after apparently being struck by a very small meteoroid or orbital debris. Known as BLITS (Ball Lens In The Space), the satellite (International Designator 2009-049G, U.S. Satellite Number 35871) was circling the Earth at an altitude of 832 km with an inclination of 98.6 degrees at the time of the event.

The BLITS is a completely inert object consisting of a glass sphere encased in another glass sphere with a total mass of 7.53 kg and a full diameter of 17 cm (see figure). The internal sphere contains a retro-reflector, which serves as a target for laser ranging stations to obtain very precise altitude measurements. The satellite was reported to be spinning at a rate of 5.6 seconds prior to the suspected collision and at a rate of only 2.1 seconds afterwards.



Cut-away to show the construction of the BLITS satellite.

The force of the collision reduced the orbital period of BLITS by less than 0.004 minutes. Very soon thereafter, the U.S. Space Surveillance Network (SSN) detected a new object in a similar orbit, but with an orbital period slightly greater (~0.006 min) than the original period of BLITS. This object, with an estimated size of 10 cm, was later cataloged with an International Designator of 2009-049J and a U.S. Satellite Number of 39119. Specialists of the SSN confirmed that BLITS had not been struck by a known object in Earth orbit, notwithstanding some erroneous media reports to the contrary.

Collisions between satellites and very small debris are common, but normally go unnoticed and do not produce new trackable debris. In 2002, Cosmos 539 was apparently struck by a small object and also released a piece with a very high drag characteristic (ODQN, July 2002, p. 1). That same year the JASON-1 spacecraft was struck by a small particle, producing two new small debris (ODQN, July 2011, p. 2). The nature of the fragment from BLITS is still under examination. ♦

Twentieth Year of Space Debris Discussions at the United Nations

For the 20th consecutive year, the agenda of the annual meeting of the Scientific and Technical Subcommittee (STSC) of the United Nations (UN) Committee on the Peaceful Uses of Outer Space (COPUOS) included the topic of space debris. Major accomplishments of the subcommittee to date include the preparation of a *Report on Space Debris* in 1999 and the adoption of a set of comprehensive space debris mitigation guidelines in 2007. Those

continued on page 2

Twentieth Year

continued from page 1

The United Nations Office of Outer Space Affairs (OOSA) is located in the UN complex in Vienna, Austria.

guidelines were later endorsed by the full COPUOS and the UN General Assembly.

During February 2013 at the UN complex in Vienna, Austria, the STSC received seven technical briefings on space debris from Member States and official observers. The U.S., France, and European Space Agency (ESA) summarized their space debris research and operational activities during the previous year, including examples of their compliance with UN space debris mitigation guidelines. The U.S. presentation was made by the NASA Chief Scientist for Orbital Debris and highlighted the current Earth satellite population; satellite breakups, collision avoidance maneuvers, and reentries in 2012; and the results of a study on the effectiveness of post-mission disposal compliance in controlling the satellite population.

The Russian Federation made a presentation on the monitoring of objects in high-altitude Earth orbits, including the geosynchronous region, by the International Scientific Optical Network (ISON). The Inter-Agency Space Debris Coordination Committee (IADC) briefed the results of its recent study confirming the instability of the low Earth orbit satellite population. China presented an overview of its space debris endeavors, including modeling and space operations, during a special workshop on long-term sustainability of outer space activities. Finally, the International Organization for Standardization (ISO) noted its growing number of standards on space debris and related space vehicle operations.

All of the above presentations are available on the website of the UN Office of Outer Space Affairs at <http://www.oosa.unvienna.org/oosa/en/COPUOS/stsc/2013/index.html>.

The STSC working group on long-term sustainability of outer space activities continued its deliberations on the development of best practice guidelines (ODQN, April 2012, p. 2). Space debris is one of the topics being addressed by the working group.

Concurrent with the STSC meeting, the International Astronautical Federation (IAF) sponsored a special, half-day symposium on an overview of studies and concepts for active orbital debris removal. All eight presentations, covering activities in the U.S., Europe, and Asia, are available at the website cited above. Following the formal briefings, a lively question-and-answer period ensued. The majority of participants appeared to agree that the removal of orbital debris remained a serious technical and economic challenge, but one not requiring an urgent undertaking. ♦

Orbital Debris Pioneer William Djinis Dies at the Age of 91

William Djinis, former Program Executive for Orbital Debris at NASA Headquarters, passed away 1 February 2013 at the age of 91. He joined NASA in 1980 and retired in 1991. He led the orbital debris program during the late 1980s until his retirement. One of the key developments during his tenure was the beginning of the Haystack radar measurements of the 1 - 10 cm orbital debris environment, still the cornerstone of the state-of-the-art understanding of the debris population in this size range.

In the 1960s, Mr. Djinis worked for Grumman Aerospace where he oversaw the electronic and avionic systems development for the Lunar Excursion Module (LEM) for Apollo. He also assisted in the safe return of the Apollo 13 crew in 1970. ♦

PROJECT REVIEW

ISS Solves EVA Problems Caused by Small MMOD Impacts

E. CHRISTIANSEN AND D. LEAR

The external handrails used by the International Space Station (ISS) crew during extravehicular activity (EVA) are exposed to micrometeoroid and orbital debris (MMOD) impacts that cause craters that have raised edges, called "crater lips" (Figure 1). These crater lips are often very sharp and represent an EVA cut-glove hazard. There have been several cases of craters reported to ISS handrails. For instance, six craters were observed on a single 34.8-cm (13.7-inch) long handrail from an ISS pump module (PM) returned on the last Space Shuttle mission, STS-135 (Figures 2a and 2b). This PM handrail was exposed to MMOD impacts for 8.7 years. The largest crater on

continued on page 3

Small MMOD Impacts

continued from page 2

the PM handrail measured 1.85 mm diameter (outside) with a 0.33 mm lip height (Figure 3). The size of the other five craters ranged from 0.12 mm to 0.56 mm in diameter, with crater lips that ranged from 0.01 mm to 0.08 mm high. Other damages to handrails and EVA tools (Figures 4-5) have been described in the ODQN, July 2008, pp. 3-6.

If the crater lips from hypervelocity impacts are large enough, they can tear or cut into the materials used in the EVA gloves. Crater lip heights of 0.25 mm (0.01 inch) were found to be sufficient to cut EVA glove materials in ground experiments coordinated by the NASA EVA engineering community. These experiments were performed after there were several incidents of cut gloves reported for EVAs during STS-109, STS-110, STS-116, STS-118, STS-120, STS-125 and other missions. Some of these glove cuts were large enough to result in early termination of the EVA. For instance on STS-118, Rick Mastracchio and Clayton Anderson began the third EVA of the mission. During a routine glove inspection, Mastracchio noticed a possible tear on the thumb of his left glove. To be safe, NASA managers decided to end the spacewalk after about 5.5 hours, and examination and photography of the glove was performed during suit removal (Figure 6). A similar incident occurred during the third EVA of STS-120. MMOD craters are not the only possible cause for these glove damages, but are one of the leading possible causes.

continued on page 4

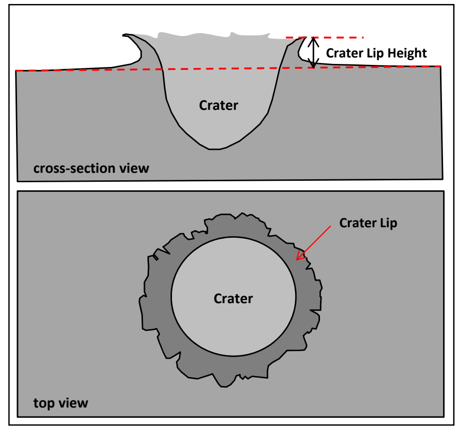


Figure 1. MMOD impact craters in metals typically exhibit raised sharp-edged "crater lips." Top image shows a cross-sectional (side) view of the crater and associated crater lip. Bottom image shows the top view of the crater.

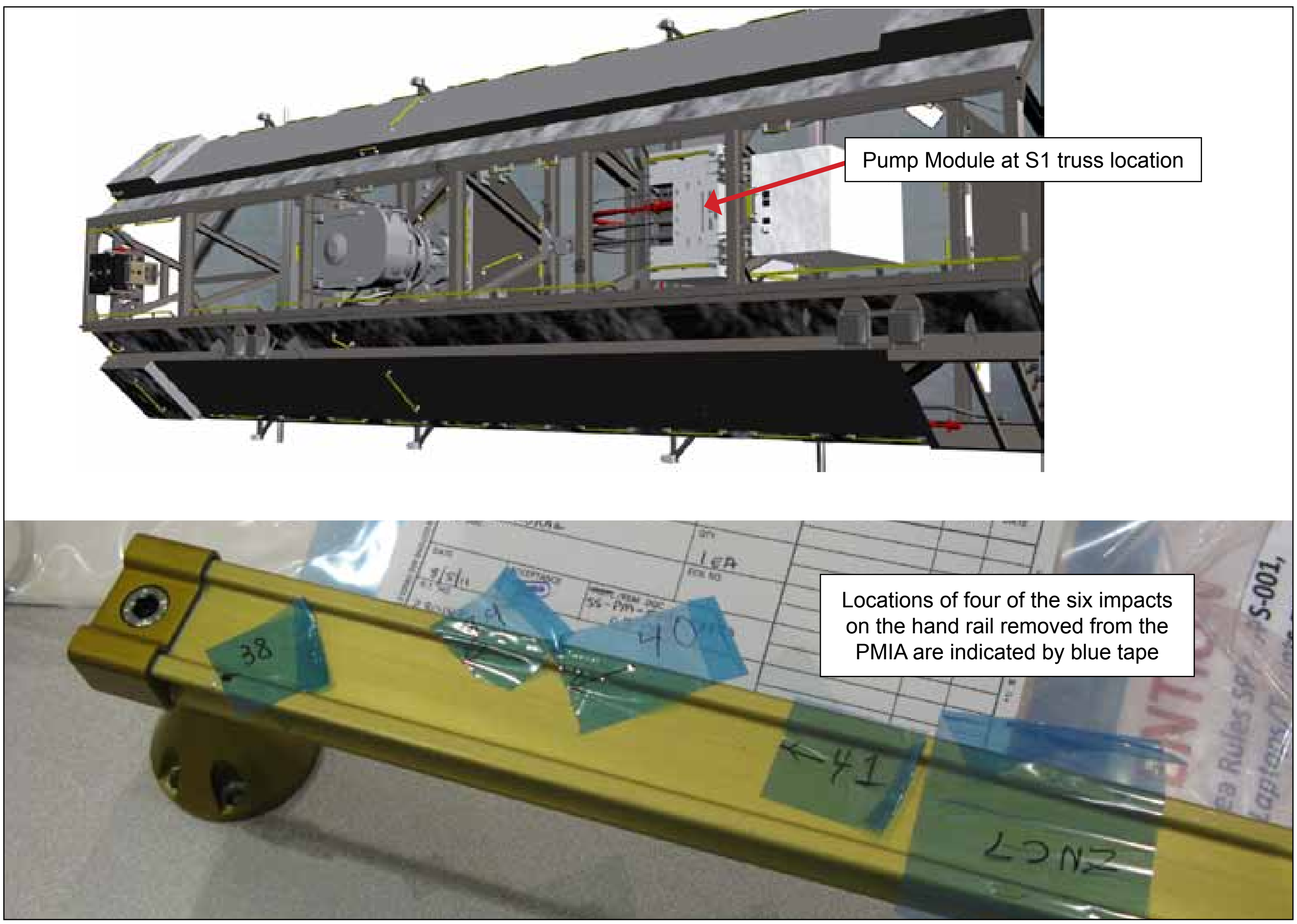


Figure 2a (top). Location of the ISS Pump Module Integrated Assembly (PMIA) on the ISS.
Figure 2b (bottom). Six craters were found by the JSC Hypervelocity Impact Technology Group on one handrail removed from the PMIA and returned on STS-135.

Small MMOD Impacts

continued from page 3

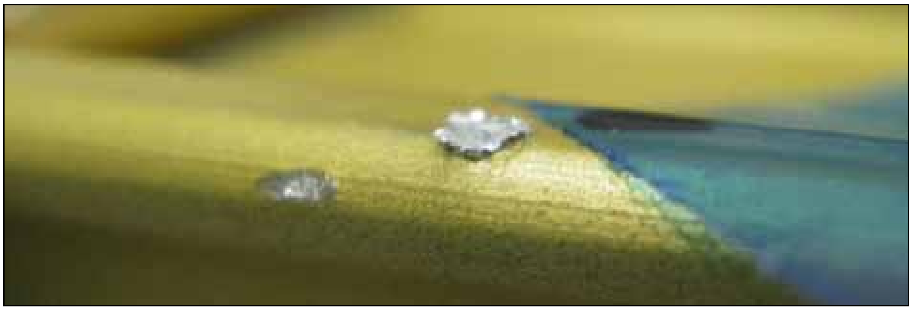


Figure 3. Largest crater found on the PMIA handrail was 1.85 mm diameter with 0.33-mm-high crater lips.

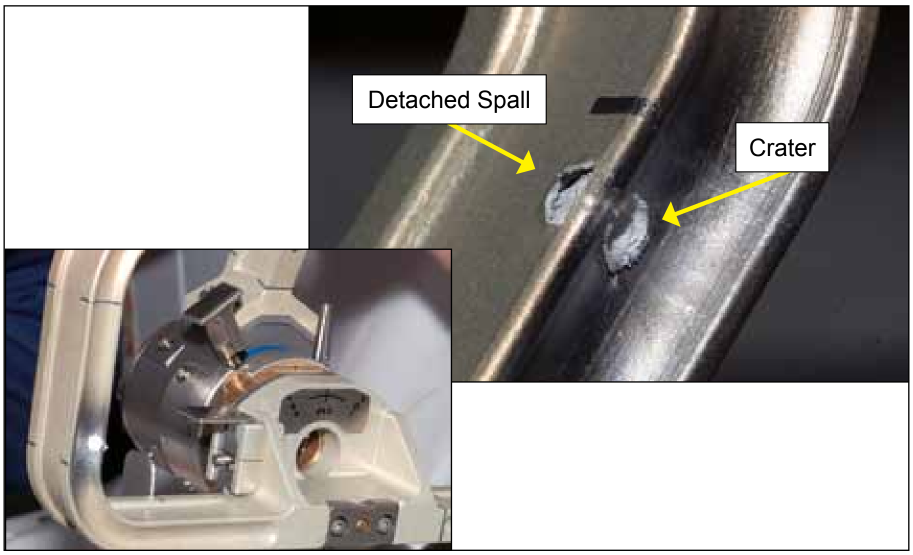


Figure 4. Nearly 5-mm-diameter crater found by ISS crew on the EVA D-handle tool stored externally on ISS, prior to STS-123 EVA. Note that the detached spall from the side opposite the MMOD impact crater also has sharp edges. The D-handle is made from similar materials as typical ISS dog-bone handrails.

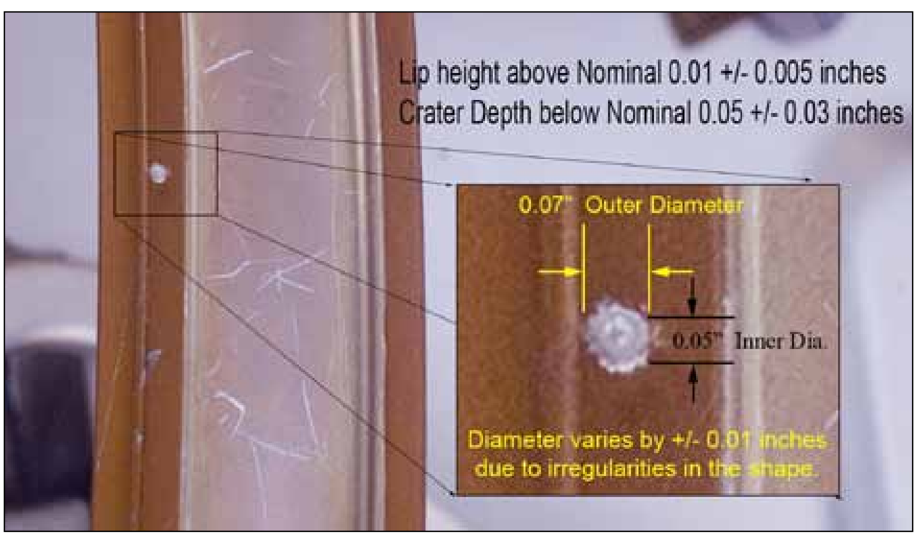


Figure 5. Crater on airlock handrail photographed during an STS-122 EVA measures 1.8 mm (0.07 inch) outside diameter with 0.25 mm (0.01 inch) crater lip height (JSC Image Science and Analysis Group).

To minimize the risk from sharp edges that could cut the EVA gloves, the ISS Program instituted a number of changes to EVA hardware and procedures, including:

- Toughening the gloves by adding additional materials to areas sensitive to cuts.

- Monitoring the status of the handrails for MMOD impacts via photographs and maintaining a database of potential sharp edges on handrails for EVA planning purposes. Currently, the ISS Imagery Inspection Management System (IIIMS) contains over 200 records of MMOD impacts to handrails and other areas that could be contacted during EVA.

- Developing EVA procedures and tools to detect and repair (or cover) sharp edges from MMOD impacts on handrails (Figure 7).

The Johnson Space Center (JSC) Hypervelocity Impact Technology Group provided assessments of the frequency of craters with lip heights that could result in glove damage, and worked with White Sands Test Facility to provide samples of realistic hypervelocity impact damage to handrails to help support development of the tools and procedures used to find and repair damage to handrails. Since the above changes have been incorporated in EVA hardware and procedures, the incidents of cut gloves have been greatly reduced. ♦

continued on page 5

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.

Small MMOD Impacts

continued from page 4

Figure 6. Mastracchio's left glove after STS-118 EVA #3.

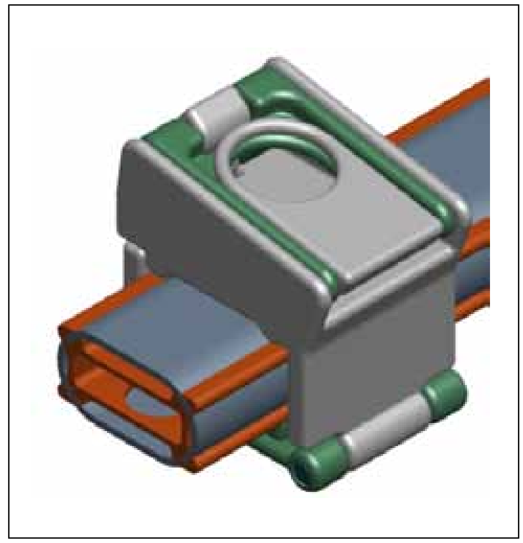


Figure 7. Example of clamp tool to mitigate MMOD damage to handrails.

Reentry of Cataloged Objects

J.-C. LIOU

"What goes up must come down" is a good description for orbital debris with perigees in the altitude regime where the atmospheric drag perturbation is non-negligible. Depending upon the object's ballistic coefficient (or the area-to-mass ratio) and the solar activity, debris in circular orbits below 400 km altitude could decay quickly in several months or less, but debris in circular orbits near 900 km altitude could remain in orbit for centuries or longer. The U.S. Space Surveillance Network (SSN) maintains a catalog of the largest objects in the environment. Most of the cataloged objects in LEO are approximately 10 cm or larger and in GEO are approximately 1 m or larger. The SSN also monitors the reentry of cataloged objects. Figure 1 shows the history of these objects, including controlled and uncontrolled reentries. Other than controlled reentry, the number of reentered objects within each year is a function of the population, distribution of the objects' orbits, and the solar activity.

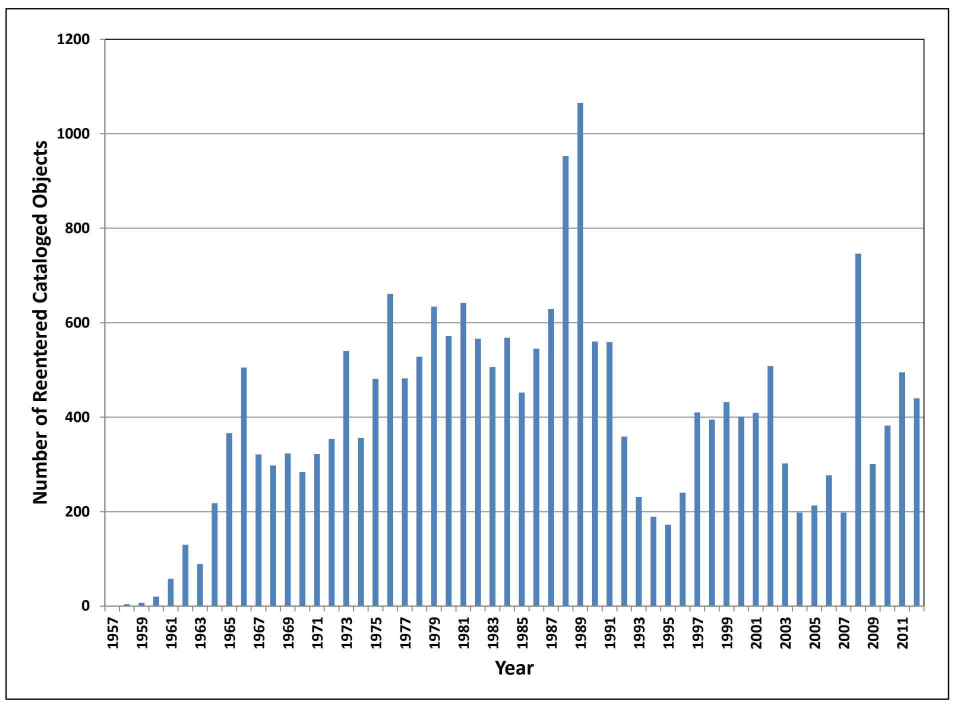


Figure 1. Number of reentered cataloged objects as a function of time.

Two major factors contributed to the high number of reentered objects in 1988-1989. First, that period was near the maximum activity of Solar Cycle 22. Second, the period was a few years after four major breakup events in LEO. Those events were (1) the explosion of Cosmos 1461 (International Designator 1983-044A, U.S. Satellite Number 14064, 890 km × 570 km) in March 1985 where 160 fragments were cataloged; (2) the hypervelocity impact of P-78 Solwind (International Designator 1979-017A, U.S. Satellite Number 11278, 545 km × 515 km) in September 1985 where 285 fragments were cataloged; (3) the explosion of Spot 1 Ariane 3rd stage (International Designator 1986-019C,

continued on page 6

Reentry

continued from page 5

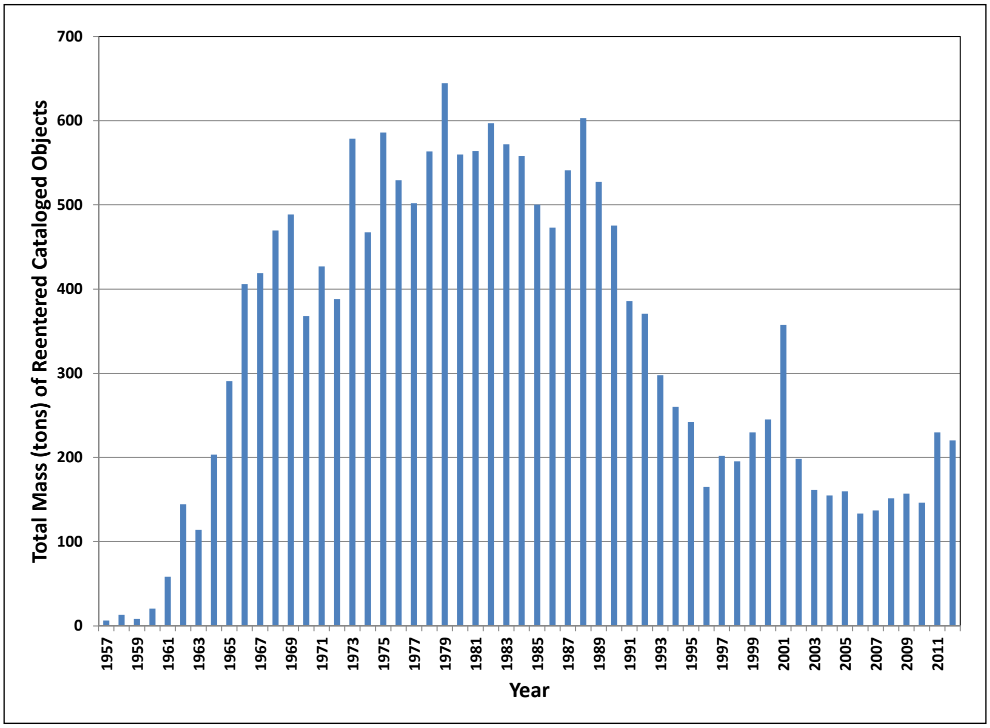


Figure 2. Mass of reentered cataloged objects as a function of time. The STS data was excluded.

Figure 3. An Explorer 8 model.

Figure 4. An Ariane helium pressure tank fell in Brazil in February 2012.

U.S. Satellite Number 16615, 835 km × 805 km) in November 1986 where 489 fragments were cataloged; and (4) the explosion of Cosmos 1813 (International Designator 1987-004A, U.S. Satellite Number 17297, 415 km × 360 km) in January 1987 where 195 fragments were cataloged. In total, 678 cataloged fragments from those four events reentered in 1988-1989.

The spike in 2008 was primarily due to the reentries of 424 Cosmos 2421 fragments. Cosmos 2421 (International Designator 2006-026A, U.S. Satellite Number 29247) was a member of the Russian Electronic Intelligence Ocean Reconnaissance Satellites (EORSATs). More than 20 EORSAT vehicles have suffered fragmentation since 1974 (ODQN, April 2008, pp. 1-2; ODQN, July 2008, pp. 1-2). Three fragmentation events of Cosmos 2421 in March-June 2008 led to the generation of 508 cataloged debris. Because of the low orbit of the vehicle at the time of breakup (420 km × 400 km), most of the debris reentered within the same year. By January 2012, all Cosmos 2421 fragments had reentered.

The anti-satellite test on Fengyun-1C (FY-1C) conducted by China in 2007 and the collision between Iridium 33 and Cosmos 2251 in 2009 generated more than 5500 cataloged fragments. Because of the high orbits of the parent satellites at the time of the breakups, 865 km × 845 km for FY-1C, 780 km × 775 km for Iridium 33, and 800 km × 775 km for Cosmos 2251, less than 700 of the generated cataloged fragments had decayed by January 2013 (ODQN, January 2013, pp. 4-5). More of them are expected to reenter in the next few years as we enter the maximum activity of the current Solar Cycle 24.

The mass history of the reentered objects is shown in Figure 2. Shuttle missions were excluded from the chart. Since rocket bodies and derelict spacecraft dominate the mass distribution of the debris population, the mass history is heavily influenced by launches rather than by breakup events. The oldest satellite among the more than 440 that reentered in 2012 was NASA's Explorer 8. The 41 kg payload had a diameter of 76 cm (Figure 3). It was launched in 1960 to study the ionosphere, with an initial orbit of 2288 km × 417 km. Shown in Figure 4 is a helium pressure tank from the third stage of an Ariane 4 booster that survived reentry in February 2012 and was recovered in Brazil. In addition to the uncontrolled reentries, 14 spacecraft and 11 rocket bodies executed controlled reentries in 2012. The number of controlled stage reentries has increased from three in 2010 to eight in 2011. This is an encouraging trend indicating the willingness of the international space community to follow the commonly adopted reentry guidelines. ♦

ABSTRACTS FROM THE NASA ORBITAL DEBRIS PROGRAM OFFICE

The 6th European Conference on Space Debris, 22-25 April 2013, Darmstadt, Germany

(No NASA personnel, including contractors, will attend the conference in person as a result of a 2013 travel restriction.)

Comparisons of a Constrained Least Squares Model versus Human-in-the-loop for Spectral Unmixing to Determine Material Type of GEO Debris

K. ABERCROMBY, J. RAPP, D. BEDARD, P. SEITZER, T. CARDONA, H. COWARDIN, E. BARKER AND S. LEDERER

Spectral reflectance data through the visible regime was collected at Las Campanas Observatory in Chile using an imaging spectrograph on one of the twin 6.5-m Magellan telescopes. The data were obtained on 1-2 May 2012 on the 'Landon Clay' telescope with the LDSS3 (Low Dispersion Survey Spectrograph 3). Five pieces of Geosynchronous Orbit (GEO) or near-GEO debris were identified and observed with an exposure time of 30 seconds on average. In addition, laboratory spectral reflectance data was collected using an Analytical Spectral Device (ASD) field spectrometer at California Polytechnic State University in San Luis Obispo on several typical common spacecraft materials including solar cells, circuit boards, various Kapton materials used for multi-layer insulation, and various paints.

The remotely collected data and the laboratory-acquired data were then incorporated in a newly developed model that uses a constrained least squares method to unmix the spectrum in specific material components. The results of this model are compared to the previous method of a human-in-the-loop (considered here the traditional method) that identifies possible material components by varying the materials and percentages until a spectral match is obtained. The traditional model was found to match the remotely collected spectral data after it had been divided by the continuum to remove the space weathering effects, or a "reddening" of the materials. The constrained least-squares model also used the de-reddened spectra as inputs and the results were consistent with those obtained through the traditional method. For comparison, a first-order examination of including reddening effects into the constrained least-squares model will be explored and comparisons to the remotely collected data will be examined. The identification of each object's suspected material component will be discussed herein. ♦

Sampling and Analysis of Impact Crater Residues found on the Wide Field Planetary Camera-2 Radiator

P. ANZ-MEADOR, J.-C. LIOU, D. ROSS, G. ROBINSON, J. OPIELA, A. KEARSLEY, G. GRIME, J. COLAUX, C. JEYNES, V. PALITSIN, R. WEBB, T.GRIFFIN, B. REED, AND B. GERLACH

After nearly 16 years on orbit, the Wide Field Planetary Camera-2 (WFPC-2) was recovered from the Hubble Space Telescope in May 2009 during the 12-day shuttle mission designated STS-125. During that exposure to the low Earth orbit environment, the WFPC-2 radiator was struck by approximately 700 impactors producing crater features 300 μm and larger in size. Following an optical inspection of these features in 2009, an agreement was reached for the joint NASA-ESA examination and characterization of crater residues, the remnants of the projectile, in 2011. Active examination began in 2012, with 486 of the impact features being cored at NASA Johnson Space Center's (JSC) Space Exposed Hardware cleanroom and curation facility. The core samples were subsequently divided between NASA and ESA. NASA's analysis was conducted at JSC's Astromaterials Research and Exploration Science (ARES) Division, using scanning electron microscopy (SEM)/ energy dispersive X-ray spectrometry (EDS) methods, and ESA's analysis was conducted at the Natural History Museum (NHM) again using SEM/ EDS, and at the University of Surrey Ion Beam Centre (IBC) using ion beam analysis (IBA) with a scanned proton microbeam.

As detailed discussion of the joint findings remains premature at this point, this paper reports on the coring technique developed; the practical taxonomy developed to classify residues as belonging either to anthropogenic "orbital debris" or micrometeoroids; and the protocols for examination of crater residues. Challenges addressed in coring were the relative thickness of the surface to be cut, protection of the impact feature from contamination while coring, and the need to preserve the cleanroom environment so as to preclude or minimize cross-contamination. Classification criteria are summarized, including the assessment of surface contamination and surface cleaning.

Finally, we discuss the analytical techniques used to examine the crater residues. We employed EDS from either electron excitation (SEM-EDS) and, in a minority of cases for cores assessed as "difficult" targets, proton excitation (IBA). All samples were documented by electron imagery: backscattered electron imagery in the SEM, and where appropriate, secondary electron imagery during IBA. ♦

DebriSat – A Planned Laboratory-based Satellite Impact Experiment for Breakup Fragment Characterization

J.-C. LIOU, S. CLARK, N. FITZ-COY,
T. HUYNH, J. OPIELA, M. POLK,
B. ROEBUCK, R. RUSHING, M. SORGE,
AND M. WERREMEYER

DebriSat is a planned laboratory-based satellite hypervelocity impact experiment. The goal of the project is to characterize the orbital debris that would be generated by a hypervelocity collision involving a modern satellite in low Earth orbit (LEO). The DebriSat project will update and expand upon the information obtained in the 1992 Satellite Orbital Debris Characterization Impact Test (SOCIT), which characterized the breakup of a 1960's U.S. Navy Transit satellite. There are three phases to this project: the design and fabrication of an engineering model representing a modern, 50-cm/50-kg class LEO satellite known as DebriSat; conduction of a laboratory-based hypervelocity impact to catastrophically break up the satellite; and characterization of the properties of breakup fragments down to 2 mm in size. The data obtained, including fragment size, area-to-mass ratio, density, shape, material composition, optical properties, and radar cross-section distributions, will be used to supplement the DoD's and NASA's satellite breakup models to better describe the breakup outcome of a modern satellite. Updated breakup models will improve mission planning, environmental models, and event response.

The DebriSat project is sponsored by the Air Force's Space and Missile Systems Center and the NASA Orbital Debris Program Office. The design and fabrication of DebriSat is led by University of Florida with subject matter experts' support from The Aerospace Corporation. The major milestones of the project include the complete fabrication of DebriSat by September 2013, the hypervelocity impact of DebriSat at the Air Force's Arnold Engineering Development Complex in early 2014, and fragment characterization and data analyses in late 2014. ♦

Stability of the Future LEO Environment – An IADC Comparison Study

J.-C. LIOU, A. K. ANILKUMAR,
B. BASTIDA VIRGILI, T. HANADA,
H. KRAG, H. LEWIS, M. X. J. RAJ,
M. M. RAO, A. ROSSI, AND R. SHARMA

On-going space activities and the increasing orbital debris (OD) population will eventually lead to a collision cascade effect in the near-Earth environment. This "Kessler Syndrome" was predicted by Kessler and Cour-Palais more than 30 years ago. Recent modeling studies of the OD population in low Earth orbit (LEO, the region below 2000 km altitude) suggested that the current LEO environment had already reached the level of instability. Mitigation measures commonly adopted by the international space community, including those of the Inter-Agency Space Debris Coordination Committee (IADC) and the United Nations (UN), may be insufficient to stop the future population growth. If the instability of the LEO debris population is confirmed, additional measures need to be considered to better preserve the near-Earth space environment for future generations.

In response to this new finding, an official IADC modeling study was conducted to assess the stability of the current LEO debris population. Study participants included six IADC member agencies – ASI, ESA, ISRO, JAXA, NASA, and UKSA. The study was coordinated and led by NASA. The goal was to investigate the stability of the LEO debris environment using the six different OD evolutionary models developed by the agencies. The initial population for the numerical simulations consisted of the 10 cm and larger LEO-crossing objects as of 1 May 2009. The future launch cycle was a repeat of the 2001-to-2009 traffic. Both the initial population and the traffic cycle were based on MASTER2009 and provided by ESA. Future spacecraft were assumed to have mission lifetimes of 8 years. No future explosion was allowed and the 25-year postmission disposal rule was applied to rocket bodies and spacecraft, with a 90% success rate. Each agency was asked to use its best models for solar flux projection, orbit propagation, collision probability calculation, and breakups. The future projection was set for 200 years, and 725 Monte Carlo simulations were carried out by the participating agencies.

This IADC study was initiated in 2009 and completed in 2012. Results from the six different models were consistent – even with a 90% compliance of the commonly-adopted mitigation measures, the simulated LEO debris population increased by an average of approximately 30% in the next 200 years. Catastrophic collisions are expected to occur every 5 to 9 years. Remediation measures, such as active debris removal, need to be considered to stabilize the future LEO environment. ♦

Characterization of the 2012-044C Briz-M Upper Stage Breakup

M. MATNEY, J. HAMILTON,
M. HORSTMAN, AND V. PAPANYAN

On 6 August, 2012, Russia launched two commercial satellites aboard a Proton rocket, and attempted to place them in geosynchronous orbit using a Briz-M upper stage (2012-044C, SSN 38746). Unfortunately, the upper stage failed early in its burn and was left stranded in an elliptical orbit with a perigee in low Earth orbit (LEO). Because the stage failed with much of its fuel on board, it was deemed a significant breakup risk. These fears were confirmed when it broke up 16 October, creating a large cloud of debris with perigees below that of the International Space Station.

The debris cloud was tracked by the US Space Surveillance Network (SSN), which can reliably detect and track objects down to about 10 cm in size. Because of the unusual geometry of the breakup, there was an opportunity for NASA Orbital Debris Program Office to use specialized radar assets to characterize the extent of the debris cloud in sizes smaller than the standard debris tracked by the SSN.

This paper will describe the observation campaign to measure the small particle distributions of this cloud, and presents the results of the analysis of the data. We shall compare the data to the modelled size distribution, number, and shape of the cloud, and what implications this may have for future breakup debris models. We shall conclude the paper with a discussion how this measurement process can be improved for future breakups. ♦

The Small Particle Population of ORDEM 3.0

M. MATNEY, P. KRISKO, AND P. ANZ-MEADOR

Over the last several years, the NASA Orbital Debris Program Office has been developing the latest Orbital Debris Engineering Model (ORDEM 3.0). The new model incorporates a number of new features that have presented a variety of challenges. Perhaps the most significant change has been the breakdown of the population into material density types. The inclusion of the "high density" component, which primarily consists of steel debris particles, has shifted the concerns about spacecraft safety from the more common aluminium particles with sizes of a few millimeters down to these steel particles down to sizes around 1 millimeter.

In the intervening years since the last release of the an engineering model (ORDEM 2000), much more *in situ* data has been harvested from returned Space Shuttle missions, and has added considerably to our knowledge of the debris environment below about 600 km for debris below 1 mm in size. Specifically, impacts on the Shuttle radiator give us direct measurements of debris fluxes for both aluminum and steel up to debris sizes very close to and even exceeding 1 mm in size. What these data show is that the size distribution of sub-millimeter debris does not show the kind of sharp turn-down in slope with increasing size as seen in previous models.

In this paper, we shall present the results from the final compilation of *in situ* data from the Shuttle program, and how this data presented a number of challenging modelling issues for the creation of ORDEM 3.0. This paper will summarize the methods used to analyse and interpret these data, and the implication of the results for the safety of space flight. ♦

Observations of GEO Debris with the Magellan 6.5-m Telescopes

P. SEITZER, A. BURKHARDT, T. CARDONNA, S. LEDERER, H. COWARDIN, E. BARKER, AND K. ABERCROMBY

Optical observations of geosynchronous orbit (GEO) debris are important to address two questions:

1. What is the distribution function of objects at GEO as a function of brightness? With some assumptions, this can be used to infer a size distribution.

2. Can we determine what the likely composition of individual GEO debris pieces is from studies of the spectral reflectance of these objects?

In this paper we report on optical observations with the 6.5-m Magellan telescopes at Las Campanas Observatory in Chile that attempt to answer both questions.

Imaging observations over a 0.5 degree diameter field-of-view have detected a significant population of optically faint debris candidates with $R > 19^{th}$ magnitude, corresponding to a size smaller than 20 cm assuming an albedo of 0.175. Many of these objects show brightness variations larger than a factor of 2, suggesting either irregular shapes or albedo variations or both. The object detection rate (per square degree per hour) shows an increase over the rate measured in the 0.6-m MODEST observations, implying an increase in the population at optically fainter levels. Assuming that the albedo distribution is the same for both samples, this corresponds to an increase in the population of smaller size debris.

To study the second issue, calibrated reflectance spectroscopy has been obtained of a sample of GEO and near GEO objects with orbits in the public U.S. Space Surveillance Network catalog. With a 6.5-m telescope, the exposures times are short (30 seconds or less), and provide simultaneous wavelength coverage from 4500 to 8000 Angstroms. If the observed objects are tumbling, then simultaneous coverage and short exposure times are essential for a realistic assessment of the object's spectral signature. We will compare the calibrated spectra with lab-based measurements of simple spacecraft surfaces composed of a single material. ♦

UPCOMING MEETINGS

21-23 May 2013: The 6th IAASS Conference, Montreal, Canada

The main theme of the 6th International Association for the Advancement of Space Safety (IAASS) is "Safety is not an option." The objective of the 2013 conference is to reflect and exchange information on a number of topics in space safety and sustainability of national and international interest. Among the topics to be included in the event are "Space debris and space debris removal" and "Spacecraft re-entry safety." More information on the conference is available at: <http://iaassconference2013.spacesafetyfoundation.org>.

23-27 September 2013: 64th International Astronautical Congress (IAC), Beijing, China

The main theme for the 2013 IAC is "Promoting Space Development for the Benefit of Mankind." A Space Debris Symposium is planned, organized by the International Academy of Astronautics to address the full spectrum of technical issues of space debris. They include measurements, modeling, risk assessments, reentry, hypervelocity impacts and protection, mitigation and standard, and space surveillance. The Symposium will include five oral sessions and one poster session. The abstract submission deadline is 21 February 2013. Additional information for the 2013 IAC is available at: <http://www.iac2013.org>.

SATELLITE BOX SCORE
(as of 3 April 2013, cataloged by the U.S. SPACE SURVEILLANCE NETWORK)

Country/ Organization	Payloads	Rocket Bodies & Debris	Total
CHINA	140	3612	3752
CIS	1427	4830	6257
ESA	42	46	88
FRANCE	56	442	498
INDIA	49	125	174
JAPAN	125	83	208
USA	1134	3804	4938
OTHER	615	119	734
TOTAL	3588	13061	16649

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

INTERNATIONAL SPACE MISSIONS
1 January 2013 – 31 March 2013

International Designator	Payloads	Country/ Organization	Perigee Altitude (KM)	Apogee Altitude (KM)	Inclination (DEG)	Earth Orbital Rocket Bodies	Other Cataloged Debris
2013-001A	COSMOS 2482	RUSSIA	1473	1517	82.5	1	0
2013-001B	COSMOS 2483	RUSSIA	1477	1503	82.5		
2013-001C	COSMOS 2484	RUSSIA	1475	1514	82.5		
2013-002A	IGS 8A	JAPAN	512	514	97.4	1	4
2013-002B	IGS 8B (DEMO)	JAPAN	427	428	97.1		
2013-003A	STSAT 2C	S. KOREA	297	1492	80.3	1	0
2013-004A	TDRS 11	USA	35743	35830	7.0	1	0
2013-005A	GLOBALSTAR M078	USA	1058	1090	52.0	0	0
2013-005B	GLOBALSTAR M093	USA	1069	1109	52.0		
2013-005C	GLOBALSTAR M094	USA	915	927	52.0		
2013-005D	GLOBALSTAR M095	USA	918	929	52.0		
2013-005E	GLOBALSTAR M096	USA	1413	1414	52.0		
2013-005F	GLOBALSTAR M097	USA	1413	1414	52.0		
2013-006A	AMAZONAS 3	SPAIN	35782	35793	0.0	1	1
2013-006B	AZERSPACE 1	AZERBAIJAN	35781	35791	0.0		
2013-007A	PROGRESS-M 18M	RUSSIA	402	418	51.6	1	0
2013-008A	LANDSAT 8	USA	682	693	98.2	0	0
2013-009A	SARAL	INDIA	783	785	98.5	1	1
2013-009B	AAUSAT3	DENMARK	769	788	98.6		
2013-009C	SAPPHIRE	CANADA	771	788	98.6		
2013-009D	NEOSSAT	CANADA	771	787	98.6		
2013-009E	STRAND 1	UK	771	784	98.6		
2013-009F	BRITE-A TUGSAT-1	AUSTRIA	769	784	98.6		
2013-009G	BRITE-U UNIBRITE	AUSTRIA	770	784	98.6		
2013-010A	DRAGON CRS-2	USA	380	409	51.6	1	2
2013-011A	SBIRS GEO 2 (USA 241)	USA	35711	35760	5.6	1	0
2013-012A	SATMEX 8	MEXICO	35768	35798	0.1	1	1
2013-013A	SOYUZ-TMA 8M	RUSSIA	402	418	51.6	1	0

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

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