National Aeronautics and Space Administration

Orbital Debris Quarterly News

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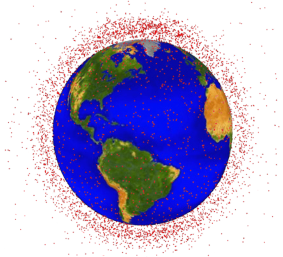
Inside...



A publication of
the NASA Orbital
Debris Program Office

Reentries of GeneSat-1 and ICESat Spacecraft

After successfully completing valuable scientific missions, two NASA spacecraft fell out of orbit harmlessly during August. Although one decayed from orbit naturally, the other was intentionally maneuvered into a very short-lived orbit, after a mission of more than 7 years, to avoid becoming a collision hazard to other resident space objects.

The 5-kg GeneSat-1 (International Designator 2006-058C, U.S. Satellite Number 29655) was launched as a secondary payload, along with the much larger TACSAT 2 satellite, on 16 December 2006 from NASA's Wallops Flight Facility off the coast of Virginia. From an initial altitude of 415 km, the nanosatellite was designed to study the effects of the microgravity environment on biological cultures. The tiny spacecraft (~10 cm by 10 cm by 35 cm, Figure 1) reentered the atmosphere on 4 August at an indeterminate location, with no component expected to survive to the surface of the Earth.

NASA's Ice, Cloud, and land Elevation Satellite (ICESat, International Designator 2003-002A, U.S. Satellite Number 27642) concluded 7 years of environmental monitoring operations, particularly over the polar regions, in February 2010. At its then altitude of approximately 600 km, ICESat would have remained in orbit for 15 or more years. Even though this residual orbital lifetime was compliant with U.S. and international guidelines, a decision was made to greatly accelerate its fall back to Earth. During June and July the

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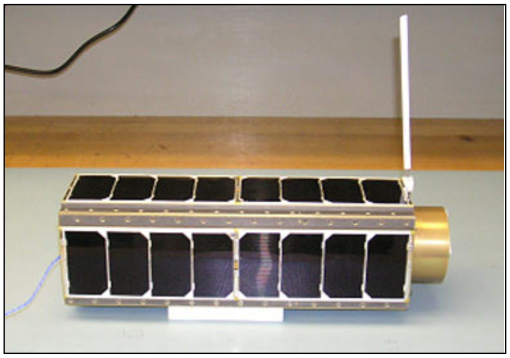

Figure 1. GeneSat-1 was a member of a new class of nanosatellites.

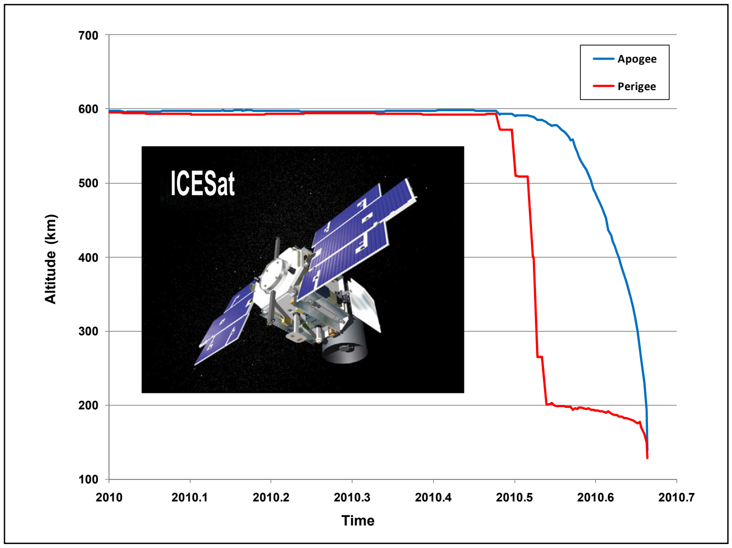

Figure 2. ICESat reentered the atmosphere only 6 weeks after its orbit-lowering maneuvers.

Reentries

continued from page 1

900-kg satellite was commanded to conduct a series of maneuvers which left it in an orbit of only 200 km by 580 km. Reentry occurred 6 weeks later on 30 August over the Barents Sea.

In all, 46 cataloged objects reentered the atmosphere during August for a rate of three every 2 days. As solar activity increases, this reentry rate is expected to double or more. In addition to GeneSat-1 and ICESat, a small sphere released from Space Shuttle Endeavor (STS-127), an upper stage from a U.S. Delta 2 launch vehicle, and the main remnant of the Russian Cosmos 2421 spacecraft (ODQN, July 2008) also reentered during August. However, the majority of the month's reentries were debris from a Russian launch vehicle component which experienced an unusual fragmentation in June (see the following article). ♦

Unusual Satellite Fragmentation

A component of a Russian launch vehicle broke-up in an unusual manner in late June, and the magnitude of the event only became clear as the summer progressed. Fortunately, all the debris were left in short-lived orbits with two-thirds already having reentered the atmosphere by the beginning of September.

Under a commercial contract, Russia launched the Asiasat 5 spacecraft on 11 August 2009, employing a powerful Proton-M launch vehicle equipped with a Breeze-M (aka Briz-M) final stage. This stage is designed to carry a geosynchronous spacecraft from a low altitude parking orbit into a highly elliptical transfer orbit with two burns. The first burn raises the apogee altitude to nearly 36,000 km, followed by a second burn which typically raises perigee several thousand kilometers or more. Before the second burn is initiated, a large (1.3 metric ton dry mass) propellant tank is ejected (Figure 1).

For the Asiasat 5 mission, the Breeze-M tank (International Designator 2009-042C, U.S. Satellite Number 35698) was left in an orbit of 400 km by 35,740 km with an inclination of 49.2 degrees. Over the next 10 months, the tank's orbit gradually decayed until by late 21 June 2010, the orbit had fallen to about 95 km by 1500 km with reentry expected within several hours. However, about 15 minutes after passing through perigee at 2145 GMT, the stage fragmented into a large number of pieces. By mid-September, a total of 85 debris had been officially cataloged by the U.S. Space Surveillance Network.

Such fragmentations are not uncommon for objects decaying rapidly from highly elliptical orbits with perigees below 100 km. Normally, though, the fragmentations appear to occur near perigee (the point of highest stress), which leads to debris reentry within hours or, at most, days. In the case of this Breeze-M propellant tank, the object had climbed to an altitude of nearly 500 km before the breakup event. Figure 2 illustrates the distribution of 42 debris which had been identified by 9 July. ♦

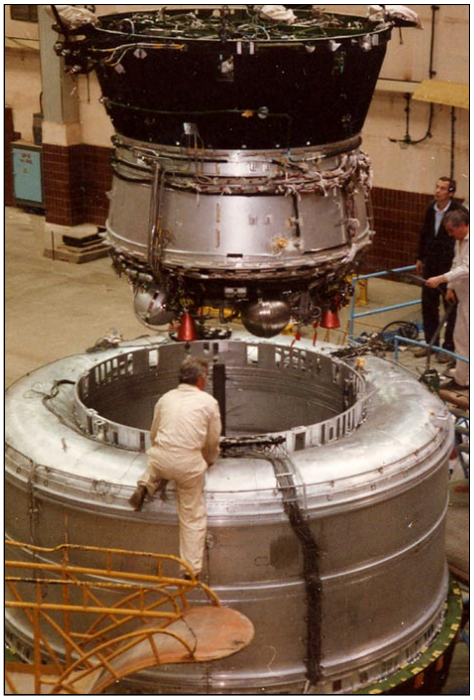

Figure 1. Breeze-M donut-shaped propellant tank and core propulsion system.

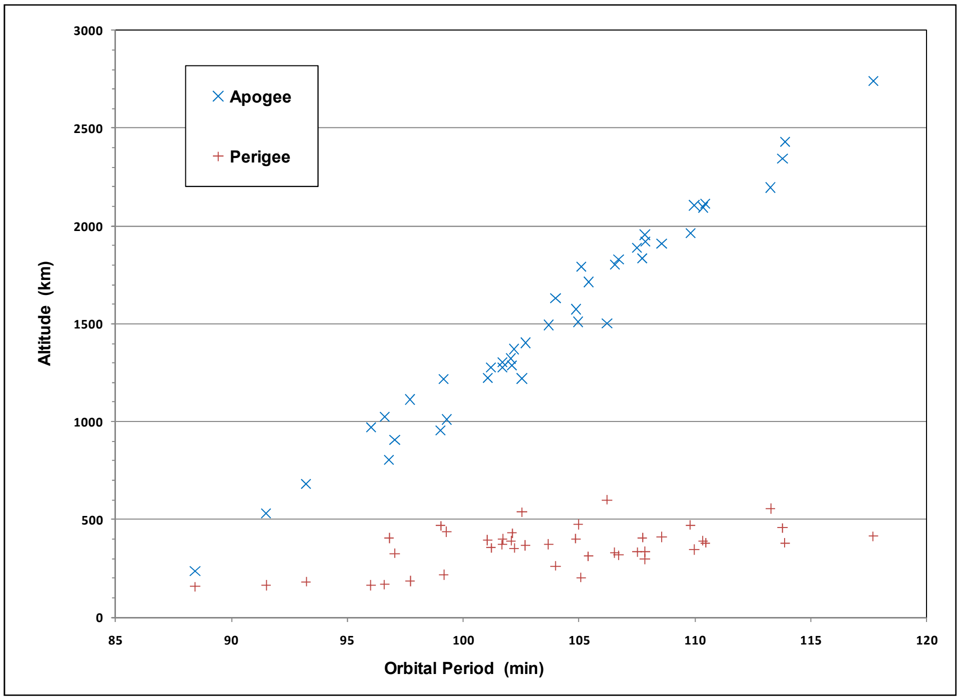

Figure 2. Distribution of Breeze-M tank debris on 9 July 2010.

Chinese Debris Reaches New Milestone

The number of debris officially cataloged from the Chinese antisatellite test of January 2007 (ODQNs April and July 2007; January, April, and July 2008; January and July 2009; April 2010) has now surpassed 3000. By mid-September 2010, the tally had reached 3037, of which 97% remained in Earth orbit more than three and a half years after the test, posing distinct hazards to hundreds of operational satellites (Figure 1). The debris from the Fengyun-1C spacecraft (International Designator 1999-025A, U.S. Satellite Number 25730) now represents 22% of all cataloged objects passing through low Earth orbit, i.e., below 2000 km. ♦

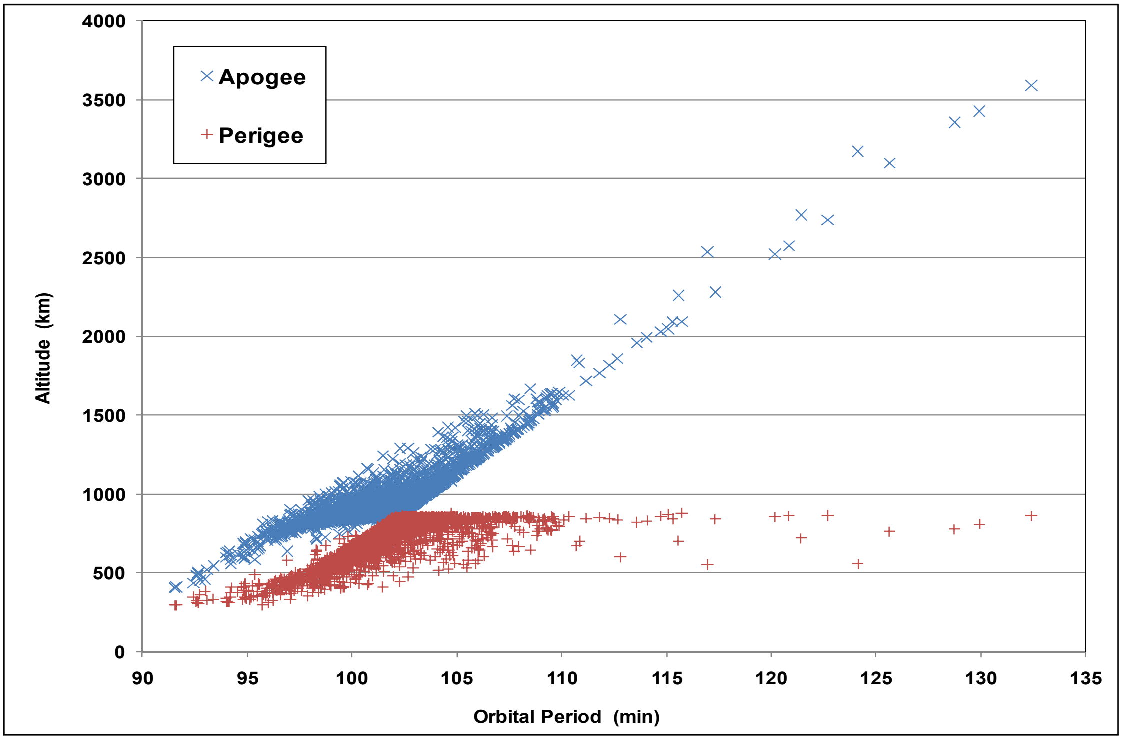

Figure 1. Distribution of the Fengyun-1C breakup debris in September 2010.

New NASA Course on Orbital Debris

A new course on orbital debris mitigation and reentry risk management has been developed for NASA civil servants and contractors. The two-day class is designed to appeal to all levels of personnel from scientists and engineers to program and project managers. Topics covered during the first day include measurement and modeling of the orbital debris environment; probability and consequences of satellite collisions; agency, national and international policies and guidelines on orbital debris mitigation; and NASA's Debris Assessment Software (DAS). Day two is devoted to the challenge of limiting human casualties and property damage from reentering objects, characterization of hazardous reentries, the establishment of risk criteria, reentry risk assessment software tools, and the philosophy of design for demise.

Offered under the curriculum of NASA's Academy of Program/Project and Engineering Leadership (APPEL), the course was first taught at the Goddard Space Flight Center in August 2010. Additional classes will be held at the Johnson Space Center and the Jet Propulsion Laboratory in November. The course is expected to be taught at five or more NASA centers during 2011. ♦

HOW TO SUBSCRIBE...

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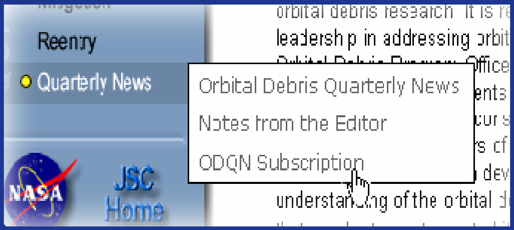

Habitat Particle Impact Monitoring System (HIMS)

The JSC-led Habitat Demonstration Unit (HDU) is a large-scale test bed designed for the testing and demonstration of technologies and processes that will be needed to support the future human exploration missions to the International Space Station, near-Earth asteroids, the Moon, or Mars. The FY2010 configuration of HDU includes a Pressurized Excursion Module (PEM, approximately 6 m in diameter and 4 m in height) and an airlock (see Figure 1). A multi-layer inflatable loft is planned to be installed on top of the PEM in FY2011. The construction of the HDU was completed at the NASA Johnson Space Center (JSC) in the summer of 2010. After a brief dry run at the JSC Rockyard facility, the HDU was shipped to the SP Mountain and the Black Point Lava Flow test sites, approximately 40 miles north of Flagstaff, Arizona, where it was used in a very successful NASA Desert Research and Technology Studies (D-RATS) campaign during 3 weeks in early September.

Figure 1. An image of the HDU in front of the SP Mountain. The larger component to the right is the PEM and the smaller structure to the left is the airlock.

A key requirement to improve the safety of long-term habitat operations is being able to monitor particle impacts that could potentially damage the structure. Sources of the impacting particles include orbital debris and micrometeoroids in the near Earth environment, micrometeoroids and lunar secondary ejecta on the surface of the Moon, and micrometeoroids in interplanetary space. The NASA Orbital Debris Program Office initiated an effort to develop the Habitat particle Impact Monitoring System (HIMS) for the HDU in April 2010. Twelve space-qualified acoustic impact sensors were installed at four different locations and three layers of the Section D wall of the PEM. The four locations are indicated by the red circles in Figure 2a. The PEM wall consists of a fiberglass hard shell with a thickness of about 1 cm and an exterior layer of 10-cm-thick foam insulation. Sensors were attached to both the interior and exterior of the PEM wall, and between the fiberglass shell and foam insulation (Figure 2b). The objective of this year's HIMS project is to demonstrate the capability of detecting particle impact location and the degree of impact penetration. The former is achieved by triangulation analysis using signals received by sensors at different locations. The latter is achieved by analyzing signal strength from sensors located at different layers.

The space-qualified HIMS sensors have been tested on different materials (aluminum plate, Kevlar, multi-layer insulation, etc.) subjected to hypervelocity impacts up to 7 km/sec. For demonstration purposes during the D-RATS campaign, however, hypervelocity impacts on the HDU were not possible. Instead, a 10-pump air rifle was used to simulate particle impacts. The degree of projectile penetration was controlled by varying the number of pumps of the air rifle and the speed of the projectile was measured using a ballistic chronometer. Projectile speed ranged from about 30 m/sec for 1 pump to 150 m/sec for 10 pumps. The transition from partial to full penetration through the foam insulation of the structure occurred around 130 m/sec.

The HIMS team members conducted a very successful impact test series during the 2010 D-RATS campaign. A total of 113 air rifle shots and more than 20 hours of the HDU background acoustics data were collected. The team will analyze the data to optimize the HIMS system parameters in preparation for a full integration of HIMS into the PEM. A feasibility study to investigate adding HIMS sensors to the inflatable loft will also be conducted next year.

♦

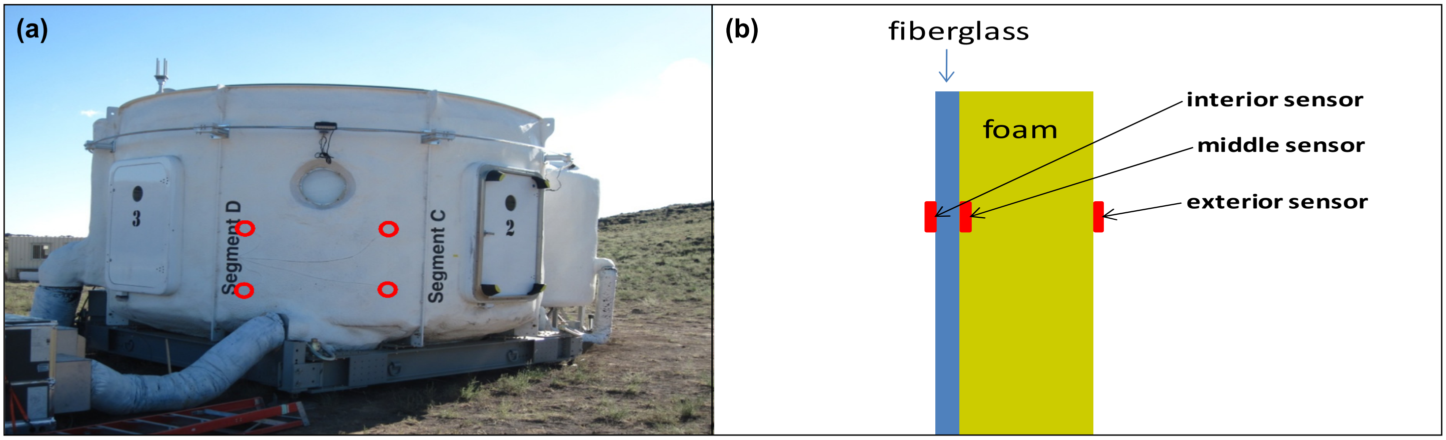

Figure 2. (a) The four red circles indicate the locations of the sensors on the HDU-PEM. (b) An illustration of the cross-section of the PEM wall structure.

PROJECT REVIEW

Comparison of ORSAT and SCARAB Reentry Codes for a Generic Satellite

ROBERT KELLEY, NICOLE HILL, NICHOLAS JOHNSON, AND TOBIAS LIPS

The NASA Object Reentry Survivability Analysis Tool (ORSAT) and the ESA Spacecraft Atmospheric Reentry and Aerothermal Break-up (SCARAB) model serve as standard codes for reentry survivability assessment of reentering spacecraft and rocket bodies. For the purpose of verifying and improving their respective codes, NASA and ESA have undertaken a series of comparison studies during the past 12 years. The most recent study uses "TestSat," a conceptual satellite composed of generic parts and defined to use numerous simple shapes and various materials in order to evaluate consistency in modeling techniques and variables (shown in Figure 1).

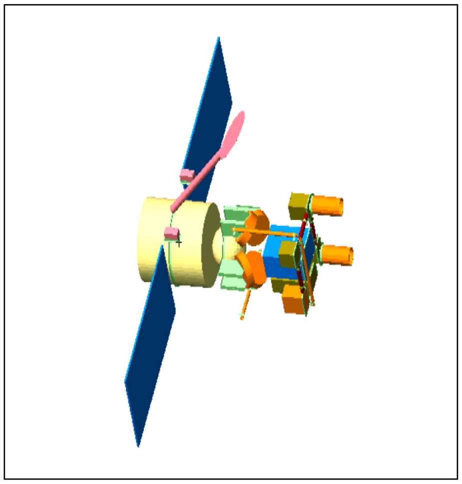

Figure 1. General form of TestSat (Source: HTG).

The design of "TestSat" was determined through collaboration between the ORSAT team at JSC and the SCARAB team of Hypersonic Technology Göttingen (HTG) in Germany. The product is an approximately 400 kg vehicle consisting of simplified models of typical components found in a satellite. These include, but are not limited to, power subsystems (including batteries and solar arrays), attitude control subsystems (including reaction wheels and gyroscopes), and communications subsystems. The design of these objects was constrained using typical mass allowances for each subsystem, while limiting the objects to simple shapes (i.e., spheres, cylinders, and boxes).

Both SCARAB and ORSAT used the same initial trajectory conditions for altitude, longitude, latitude, velocity, flight path angle, and inclination. Of the 33 unique objects modeled, the SCARAB and ORSAT codes yielded very similar results for 31 of them. Five objects (the liquid hydrogen tank and four reaction wheel assembly flywheels) were found to survive with both models. An additional item, a command box, seen below in Figure 2, was found to survive in ORSAT but not in SCARAB. However, ORSAT calculations indicated that the box received >96% of the total energy required to demise. Minor material property or modeling differences could account for the difference in outcomes.

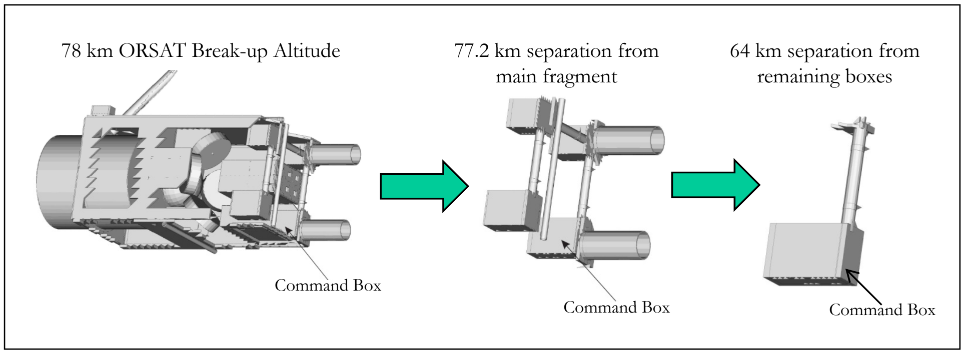

Figure 2. SCARAB break-up history for the command box.

The final category of objects is those which survive in both codes, but do so in a different configuration. The battery box and its components are responsible for most of the difference in the human casualty predictions between the two codes. In ORSAT once the outer portion of the battery box ablates, the inner frame pieces and the battery cells are assumed to reenter individually. SCARAB, on the other hand, assumes the battery box, inner frames, and battery cells to be strongly attached. The result of this, as seen in Figure 3, is that as portions of the battery box demise, the rest of the components remain connected.

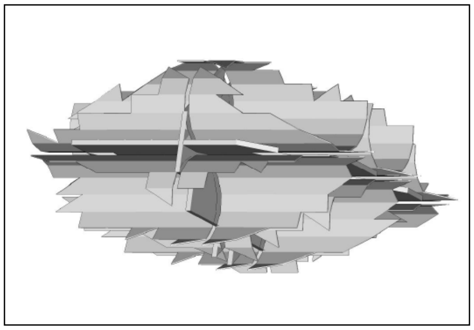

Figure 3 SCARAB model of partial battery cells and frame pieces.

Consequently, for this group of objects, ORSAT predicts 3 aluminum frame pieces and 12 nickel batteries to survive with a total mass of 20.77 kg. For this same group of objects SCARAB predicts only one surviving component with a mass of 17.70 kg.

Overall, this comparison study showed that the ORSAT and SCARAB models produced very similar results. In addition, greater insight into each model was gained, along with greater confidence in the prediction results. ♦

ABSTRACTS FROM THE NASA ORBITAL DEBRIS PROGRAM OFFICE

Advanced Maui Optical and Space Surveillance Technology (AMOS) Conference 14-17 September 2010, Maui, Hawaii, USA

Characterization of Orbital Debris Photometric Properties Derived from Laboratory Based Measurements

H. COWARDIN, K. ABERCROMBY, E. BARKER, P. SEITZER, AND T. SCHILDKNECHT

To better characterize and model optical data acquired from ground-based telescopes, the Optical Measurements Center (OMC) at NASA/JSC attempts to emulate illumination conditions seen in space using equipment and techniques that parallel telescopic observations and source-target-sensor orientations. The OMC uses a 75 watt Xenon arc lamp as a solar simulator, an SBIG CCD camera with standard Johnson/Bessel filters, and a robotic arm to simulate an object's position and rotation. The laboratory uses known shapes, materials suspected to be consistent with the orbital debris population, and three phase angles to best match the lighting conditions of the telescope-based data. The 14 objects studied in the laboratory are fragments or materials acquired through ground-tests of scaled-model satellites/rocket bodies as well as material samples in more or less "flight-ready" condition. All fragments were measured at 10° increments in a full 360° rotation at a 6°, 36°, and 68° phase angle.

This paper will investigate published color photometric data for a series of orbital debris targets and compare it to the empirical photometric measurements generated in the OMC. Using the data acquired over specific rotational angles through different filters (B, V, R, I), a color index is acquired (B-R, R-I). Using these values and their associated lightcurves, this laboratory data is compared to observational data obtained on the 1 m telescope of the Astronomical Institute of the University of Bern, the 0.9 m operated by the Small- and Medium-Aperture Research Telescope System Consortium and the Curtis-Schmidt 0.6 m Michigan Orbital DEbris Survey Telescope (MODEST) both located at Cerro Tololo Inter-American Observatory.

An empirical-based optical characterization model will be presented to provide preliminary correlations between laboratory-based and telescope-based data in the context of classification of GEO debris objects. ♦

Optical Photometric Observations of GEO Debris

P. SEITZER, H. COWARDIN, E. BARKER, K. ABERCROMBY, T. KELECY, AND M. HORSTMAN

We report on a continuing program of optical photometric measurements of faint orbital debris at geosynchronous Earth orbit (GEO). These observations can be compared with laboratory studies of actual spacecraft materials in an effort to determine what the faint debris at GEO might be.

We have optical observations from Cerro Tololo Inter-American Observatory (CTIO) in Chile of two samples of debris:

1. GEO objects discovered in a survey with the University of Michigan's 0.6-m aperture Curtis-Schmidt telescope MODEST (for Michigan Orbital DEbris Survey Telescope), and then followed up in real-time with the CTIO/SMARTS 0.9-m for orbits and photometry. Our goal is to determine 6-parameter orbits and measure colors for all objects fainter than R = 15th magnitude that are discovered in the MODEST survey.
2. A smaller sample of high area to mass ratio (AMR) objects discovered independently, and acquired using predictions from orbits derived from independent tracking data collected days prior to the observations.

Our optical observations in standard astronomical BVRI filters are done with either telescope, and with the telescope tracking the debris object at the object's angular rate. Observations in different filters are obtained sequentially.

We have obtained 71 calibrated sequences of R-B-V-I-R magnitudes. A total of 66 of these sequences have 3 or more good measurements in all filters (not contaminated by star streaks or in Earth's shadow). Most of these sequences show brightness variations, but a small subset has observed brightness variations consistent with that expected from observational errors alone.

The majority of these stable objects are redder than a solar color in both B-R and R-I. There is no dependence on color with brightness.

For a smaller sample of objects we have observed with synchronized CCD cameras on the two telescopes. 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. ♦

The 61st International Astronautical Congress (IAC), 27 September - 1 October 2010, Prague, Czech Republic

Medium Earth Orbits: Is There a Need for a Third Protected Region?

N. JOHNSON

The Inter-Agency Space Debris Coordination Committee (IADC) and the United Nations have adopted the concept of near-Earth regions which should be afforded protection from the accumulation of orbital debris. These regions are low Earth orbit (LEO), which extends up to 2000 km altitude, and geosynchronous orbit (GEO), which includes the volume of space encompassed by 35,786 km +/- 200 km in altitude and +/- 15 degrees in

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Medium Earth Orbits

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latitutde. The region between LEO and GEO is commonly referred to as Medium Earth Orbit (MEO). Although historically a small minority of spacecraft have operated in MEO, the number of such satellites residing in or routinely transiting the zone is increasing. The question thus arises: should MEO be considered an orbital debris protected region?

This paper first reviews the characteristics of space systems now utilizing MEO, as well as those anticipated to join them in the near future. MEO is then contrasted with LEO and GEO, both physically and pragmatically. Recommended orbital debris mitigation guidelines for MEO space vehicles are highlighted, and the challenges of spacecraft and launch vehicle stage disposal are recognized. Note is also made of the principal tenets of the United Nations Outer Space Treaty and of recent trends toward *de facto* partitioning of MEO. Finally, the efficacy and practicality of establishing MEO as a new protected region with regard to orbital debris are addressed. ♦

A Parametric Study on Using Active Debris Removal to Stabilize the Future LEO Debris Environment

J.-C. LIOU

Recent analyses of the instability of the orbital debris population in the low Earth orbit (LEO) region and the collision between Iridium 33 and Cosmos 2251 have reignited the interest in using active debris removal (ADR) to remediate the environment. There are, however, monumental technical, resource, operational, legal, and political challenges in making economically viable ADR a reality. Before a consensus on the need for ADR can be reached, a careful analysis of the effectiveness of ADR must be conducted. The goal is to demonstrate the feasibility of using ADR to preserve the future environment and to guide its implementation to maximize the benefit-cost ratio.

This paper describes a comprehensive sensitivity study on using ADR to stabilize the future LEO debris environment. The NASA long-term, orbital debris evolutionary model, LEGEND, is used to quantify the effects of many key parameters. These parameters include (1) the starting epoch of ADR implementation, (2) various target selection criteria, (3) the benefits of collision avoidance maneuvers, (4) the consequence of targeting specific inclination or altitude regimes, (5) the consequence of targeting specific classes of vehicles, and (6) the timescale of removal. Additional analyses on the importance of postmission disposal and how future launches might affect the requirements to stabilize the environment are also included. ♦

An Analysis of Recent Major Breakups in the Low Earth Orbit Region

J.-C. LIOU AND P. ANZ-MEADOR

Of the 190 known satellite breakups between 1961 and 2006, only one generated more than 500 cataloged fragments. The event was the explosion of the Pegasus Hydrazine Auxiliary Propulsion System in 1996, adding 713 fragments to the U.S. Satellite Catalog. Since the beginning of 2007, however, the near-Earth environment has been subjected to several major breakups, including the Fengyun-1C anti-satellite test and the explosion of Briz-M in 2007, the unusual breakup of Cosmos 2421 in 2008, and the collision between Iridium 33 and Cosmos 2251 in 2009. Combined, these events added more than 5000 large (≥10 cm) fragments to the environment.

Detailed analysis of the radar cross section measurements and orbit histories of the fragments from these major events reveals several unusual characteristics in their size and area-to-mass ratio distributions. The characteristics could be related to the material composition of the parent vehicles, the nature of the breakup, and the composition and physical property of the fragments. In addition, the majority of these fragments are expected to remain in orbit for decades, at least. Their long-term impact to the environment is analyzed using the NASA orbital debris evolutionary model, LEGEND. Descriptions of these analyses and a summary are included in this paper. ♦

Orbital Debris Detection and Tracking Strategies for the NASA/AFRL Meter Class Autonomous Telescope (MCAT)

M. MULROONEY, P. HICKSON,
E. STANSBERY, AND E. BARKER

The Meter-Class Autonomous Telescope (MCAT) is a 1.3m f/4 Ritchey-Chrétien on a double horseshoe equatorial mount that will be deployed in early 2011 to the western Pacific island of Legan in the Kwajalein Atoll to perform orbital debris observations for the National Aeronautics and Space Administration (NASA) and the Air Force Research Lab (AFRL). MCAT will be capable of tracking Earth orbital objects at all inclinations and at altitudes from 200 km to geosynchronous. MCAT's primary objective is the detection of new orbital debris in both low-inclination, low-Earth orbits (LEO) and at geosynchronous orbit (GEO) down to 2 and 10 cm diameters, respectively. MCAT was designed with a fast focal ratio and a large field of view (FOV). The primary detector is a closed-cycle-cooled, 4K x 4K, 15 µm pixel CCD camera that yields a 0.96° diagonal field. For orbital debris detection in widely spaced angular rate regimes, the camera offers low read-noise performance over a wide range of framing rates. MCAT's 4-port camera operates from 100 kHz to 1.5 MHz per port at 2 and 10 electron (e-) read noise, respectively. This enables low-noise multi-second exposures for GEO observations as well as moderate (one frame per second) exposures for LEO. GEO observations will be performed initially using a counter-sidereal time delay integration (CSTDI) technique which NASA has used successfully in the past. For LEO observations two methods will be employed. The first, Stare and Chase Mode (SCM), will perform a static or sidereal stare, then detect, discriminate, acquire, and track objects that enter the MCAT (or its auxiliary telescope) field of view and which satisfy specific rate and brightness criteria. The second, Orbit Survey Mode (OSM), will scan specific orbital inclination and altitude regimes, detect new orbital debris objects against trailed background stars, and adjust the telescope track to follow the detected object. Orbits generated by SCM and OSM will be used for reacquisition by MCAT (and other assets) and as inputs to the orbital object environment definition. All three operational modes, as well as photometric and astrometric reduction, will be fully automated. MCAT, its objectives, and its methods, are described herein. ♦

Data Collected During the Post-Flight Survey of Micrometeoroid and Orbital Debris Impact Features on the Hubble Wide Field Planetary Camera 2

J. OPIELA, J.-C. LIOU, AND
P. ANZ-MEADOR

Over a period of 5 weeks during the summer of 2009, personnel from the NASA's Orbital Debris Program Office and Meteoroid Environment Office performed a post-flight examination of the Hubble Space Telescope (HST) Wide Field Planetary Camera 2 (WFPC-2) radiator. The objective was to record details about all micrometeoroid and orbital debris (MMOD) impact features with diameters of 300 µm and larger. The WFPC-2 was located in a clean room at NASA's Goddard Space Flight Center. Using a digital microscope, the team examined and recorded position, diameter, and depth information for each of 685 craters. Taking advantage of the digital microscope's data storage and analysis features, the actual measurements were extracted later from the recorded images, in an office environment at the Johnson Space Center.

Measurements of the craters included depth and diameter. The depth was measured from the undisturbed paint surface to the deepest point within the crater. Where features penetrated into the metal, both the depth in metal and the paint thickness were measured. In anticipation of hypervelocity tests and simulations, several diameter measurements were taken: the spall area, the area of any bare metal, the area of any discolored ("burned") metal, and the lips of the central crater. In the largest craters, the diameter of the crater at the surface of the metal was also measured. The location of each crater was recorded at the time of inspection. This paper presents the methods and results of the crater measurement effort, including the size and spatial distributions of the impact features. This effort will be followed by taking the same measurements from hypervelocity impact targets simulating the WFPC-2 radiator. Both data sets, combined with hydrocode simulation, will help validate or improve the MMOD environment in low Earth orbit. ♦

ABSTRACTS FROM THE NASA HYPERVELOCITY IMPACT TECHNOLOGY GROUP

The 61st International Astronautical Congress (IAC), 27 September - 1 October 2010, Prague, Czech Republic

Shuttle Post Flight MMOD Inspection Highlights

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

This paper documents four significant micro-meteoroid orbital debris (MMOD) impact events on the shuttle: two perforations of the payload bay door radiator sandwich panels, one crater in the crew module window and another in a wing leading edge reinforced carbon-carbon panel. Evidence from Scanning Electron Microscope/Energy-Dispersive x-ray Spectroscopic (SEM/EDS) analysis of impact residue samples will be presented to identify the source of each impact. Impact site features that indicate projectile directionality are discussed, along with hypervelocity impact testing on representative samples conducted to simulate the impact event. The paper also provides results of a study of impact risks for the size of particles that caused the MMOD damage and the regions of the orbiter vehicle that would be vulnerable to an equivalent projectile. ♦

A Ballistic Limit Analysis Program for Shielding Against Micrometeoroids and Orbital Debris

S. RYAN AND E. CHRISTIANSEN

Ballistic Limit Equations (BLEs) lie at the heart of Micrometeoroid and Orbital Debris (MMOD) risk assessments, yet are often unpublished, loosely validated, or simply open to misinterpretation through insufficient documentation. Furthermore, for common MMOD shields, multiple competing BLEs often exist, each with their own underlying assumptions and predictive biases. In order to provide a more user-friendly means to perform preliminary shield sizing, performance evaluations, and parametric studies, a simple software program has been developed by the Hypervelocity Impact Technology Facility (HITF) at NASA Johnson Space Center. The program is written in Visual Basic for Applications (VBA), and is intended to be freely distributed as an add-in to Microsoft Excel®. BLEs are provided for single wall, dual wall, triple wall, and advanced shield types, along with common thermal protection systems (TPS) and transparent materials. The effects of multi-layer insulation and projectile shape (ellipsoid only) can also be included in the evaluation. In the case of configurations for which multiple approaches exist, e.g., metallic Whipple shields, a competitive evaluation has been performed using a compilation of over 440 experimental data points to identify the most accurate. The software is distributed together with a user manual, which documents and provides validity bounds for each of the program's underlying equations. ♦

MEETING REPORTS

38th Scientific Assembly of COSPAR, 18-25 July 2010, Bremen, Germany

"Space Debris – A Global Challenge" was the main theme for the Panel on Potentially Environmentally Detrimental Activities in Space (PEDAS) at the 38th Scientific Assembly of the 2010 COSPAR. A total of 27 presentations, including two solicited reviews on the design of the European space surveillance network and particle impact damage inspection of the Hubble Wide Field Planetary Camera 2 radiator, were given during four debris sessions dedicated to measurements, modeling, environment characterization, and mitigation and remediation. Several papers were also included in a short poster session. A joint session on "Space Situational Awareness and its Relationship with Science" was co-arranged by PEDAS and the Panel on Space Weather. It included several solicited presentations on radar and optical measurements of the debris environment.

A business meeting was held at the conclusion of PEDAS sessions to review the plan for the next COSPAR in 2012 and other PEDAS-related items. This year's meeting marked the end of the tenure of ESA's Dr. Heiner Klinkrad as the main scientific organizer for PEDAS. Dr. Thomas Schildknecht of the University of Bern in Switzerland was nominated by Dr. Klinkrad and elected by meeting participants to become the new principal scientific organizer, effective immediately. ♦

Advanced Maui Optical and Space Surveillance Technology (AMOS) Conference 14-17 September 2010, Maui, Hawaii, USA

The 11th Advanced Maui Optical and Space Surveillance Technologies (AMOS) Conference was held on 14-17 September 2010. Organized, in part, by the Air Force Research Laboratory and the Maui Economic Development Board, the AMOS conference has become an important forum for Space Situational Awareness (SSA) topics, including many that relate directly or indirectly to orbital debris.

Much of the discussion at the meeting centered around the new U.S. National Space Policy and its emphasis on debris mitigation and removal, and on sharing of SSA data and orbit conjunction warnings.

The session on orbital debris led off the meeting after keynote addresses by Maj. Gen. Helms and Lt. Gen. Sheridan. Session Chair Schildknecht presented the latest ESA findings on faint debris objects in GEO, followed by Seitzer's report on similar objects observed by NASA in Chile. The session also included two talks about potential future observing techniques (using population/motion prediction and laser techniques) by Uetsuhara and Tagawa, respectively. Both are from Kyushu University in Japan.

The next session, on Non-Resolved Object Characterization, was chaired by Hejduk. It included papers on many techniques common to research on intact satellites and fragmentation debris. Hall's paper on multi-band optical observations of satellites showed many parallels to a poster paper by Cowardin on similar measurements of debris. Agapov presented a paper which utilized the large database of measurements collected by the International Scientific Optical Network. Kervin discussed the difficulties and benefits associated with using phase angle information for random tumbling objects such as debris.

Another session which touched on orbital debris topics was integrating diverse data. This session discussed not only integrating different types of data, but taking data from sources outside the traditional Space Surveillance Network. This session included a panel discussion moderated by Kelso and Fletcher.

Other papers included an interesting simulation of a debris collision event by Fasenfest and an overview of optical designs for wide field-of-view telescopes for debris surveys by Ackermann. Reported techniques for observing and characterizing debris ranged from thermal infrared (Dawson and Banston) to optical (Shell) to polarization (Stryjewski).

This year's AMOS conference was attended by 640 participants. ♦

The 61st International Astronautical Congress (IAC), 27 September - 1 October 2010, Prague, Czech Republic

The 61st International Astronautical Congress (IAC) was held in Prague, Czech Republic, from 27 September 2010 to 1 October 2010. The Space Debris Symposium was coordinated by C. Bonnal (CNES) and N. Johnson (NASA). It spanned 5 days with 5 oral sessions (with 44 papers presented) – Measurements; Modeling and Risk Analysis; Hypervelocity Impacts and Protection; Mitigation, Standards, Removal and Legal Issues; and Space Surveillance and Space Situational Awareness. The poster session included seven posters. Recent research was reported and included using optical observations to provide survey measurements and orbital evolution data for high area-to-mass ratio objects, descriptions of optical (NASA's Meter Class Autonomous Telescope) and radar sensors, in-situ measurements (HST WFPC-2, STS inspections), the MASTER-2009 model and populations, hypervelocity impact testing on single and honeycomb sandwiched plates, on-orbit collision avoidance techniques, active debris removal proposals, legal and policy considerations of debris removal, and international space surveillance efforts. ♦

SATELLITE BOX SCORE

(as of 06 October 2010, cataloged by the U.S. SPACE SURVEILLANCE NETWORK)

Country/ Organization	Payloads	Rocket Bodies & Debris	Total
CHINA	98	3395	3493
CIS	1406	4600	6006
ESA	39	44	83
FRANCE	49	426	475
INDIA	41	133	174
JAPAN	113	76	189
USA	1124	3701	4825
OTHER	479	115	594
TOTAL	3349	12490	15839

Visit the NASA Orbital Debris Program Office Website

www.orbitaldebris.jsc.nasa.gov

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INTERNATIONAL SPACE MISSIONS

01 July 2010 – 30 September 2010

International Designator	Payloads	Country/ Organization	Perigee Altitude (KM)	Apogee Altitude (KM)	Inclination (DEG)	Earth Orbital Rocket Bodies	Other Cataloged Debris
2010-034A	ECHOSTAR 15	USA	35776	35798	0.0	1	1
2010-035A	CARTOSAT 2B	INDIA	619	646	98.0	1	1
2010-035B	STUDSAT	INDIA	619	641	98.1		
2010-035C	AISSAT 1	NORWAY	618	637	98.1		
2010-035D	ALSAT 2A	ALGERIA	672	674	98.2		
2010-035E	TISAT 1	SWITZERLAND	617	640	98.1		
2010-036A	BEIDOU IGSO 1	CHINA	35676	35895	55.1	1	0
2010-037A	NILESAT 201	EGYPT	35760	35813	0.0	1	1
2010-037B	RASCOM QAF 1R	AFRICA	35401	36175	0.1		
2010-038A	YAOGAN 10	CHINA	627	630	97.8	1	0
2010-039A	AEHF 1 (USA 214)	USA	EN ROUTE TO GEO			1	0
2010-040A	TIANHUI 1	CHINA	486	505	97.4	0	0
2010-041A	COSMOS 2466 (GLONASS)	RUSSIA	19068	19192	64.8	2	8
2010-041B	COSMOS 2465 (GLONASS)	RUSSIA	19030	19229	64.9		
2010-041C	COSMOS 2464 (GLONASS)	RUSSIA	19082	19178	64.9		
2010-042A	CHINASAT 6A	CHINA	35785	35786	0.4	1	0
2010-043A	COSMOS 2467	RUSSIA	1496	1506	82.5	1	0
2010-043B	GONETS-M	RUSSIA	1499	1509	82.5		
2010-043C	COSMOS 2468	RUSSIA	1498	1507	82.5		
2010-044A	PROGRESS-M 07M	RUSSIA	349	359	51.7	1	0
2010-045A	QZS-1 (MICHIBIKI)	JAPAN	32608	38965	41.0	1	0
2010-046A	USA 215	USA	NO ELEMS. AVAILABLE			0	0
2010-047A	YAOGAN 11	CHINA	624	657	98.0	0	0
2010-047B	ZHEDA PIXING 1B	CHINA	622	657	98.0		
2010-047C	ZHEDA PIXING 1C	CHINA	623	657	98.0		
2010-048A	SBSS (USA 216)	USA	530	539	98.0	1	0
2010-049A	COSMOS 2469	RUSSIA	565	39125	62.8	2	2

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