National Aeronautics and Space Administration

Orbital Debris
Quarterly News

Volume 13, Issue 4
October 2009

Inside...

A publication of the NASA Orbital Debris Program Office

Thirtieth Anniversary of the NASA Orbital Debris Program Office

Although NASA has conducted research on orbital debris since the 1960s, the NASA Orbital Debris Program Office is now considered to have been established in October 1979, following the recognition by senior NASA officials of orbital debris as a space environmental issue and the allocation by NASA Headquarters' Advanced Programs Office to the Lyndon B. Johnson Space Center (JSC) of funds specifically dedicated for orbital debris investigations. In the 30 years since, the NASA Orbital Debris Program Office has pioneered the characterization of the orbital debris environment and its potential effects on current and future space systems, has developed comprehensive orbital debris mitigation measures, and has led efforts by the international aerospace community in addressing the challenges posed by orbital debris.

In 1967 the Flight Analysis Branch at the Manned Spacecraft Center (renamed the Lyndon B. Johnson Space Center in 1973) evaluated the risks of collisions between an Apollo spacecraft and orbital debris. Three years later the same group calculated collision risks for the forthcoming Skylab space station, which was launched in 1973. By 1976, the nucleus of NASA's yet-to-be-formed orbital debris research efforts, including Andrew Potter, Burton Cour-Palais, and Donald Kessler, was found in JSC's Environmental Effects Office, examining the

continued on page 2

Figure 1. Back row (l to r): Eugene Stansbery, Program Manager, Orbital Debris Program Office; Dr. Mark Mulrooney; John Opiela; Dr. Mark Matney; Mechelle Brown; Dr. Phillip Anz-Meador; Dr. J.-C. Liou; Matt Horstman; Dr. Jim Benbrook; and Nicholas Johnson, NASA Chief Scientist for Orbital Debris. Front row (l to r): Nicole Hill; Dr. Yu-Lin Xu; Dr. Paula Krisko; Robert Kelley; Peter Urschel; Heather Cowardin; Debra Shoots; and Quanette Juarez.

Anniversary

continued from page 1

potential threat of orbital debris to large space platforms, in particular the proposed Solar Power Satellites (SPS).

Initially, JSC Director Christopher Kraft, a proponent of the concept of using satellites to beam concentrated energy to the Earth, did not believe that orbital debris constituted a significant threat to SPS. However, by late 1978, the seminal work on satellite collision frequency by Kessler and Cour-Palais[1] and the results of a special radar observation of small debris convinced Kraft that further study of orbital debris was warranted. Kraft brought the issue of orbital debris to the attention of John Yardley, NASA Associate Administrator for Space Transportation Systems, which in turn led to the initial Headquarters' funding of orbital debris research at JSC.

The accomplishments of the NASA Orbital Debris Program Office are many and varied: the first engineering models of the orbital debris population, the first detailed evolutionary models of the debris environment, the identification of the major sources of orbital debris, the development of the first detailed orbital debris mitigation guidelines, and the assessments of reentry survivability, to name but a few.[2,3] In conjunction with the US Department of Defense, NASA's Orbital Debris Program Office developed the US Government Orbital Debris Mitigation Standard Practices, as cited in the President's National Space Policy.[4]

Under the direction of NASA Headquarters' Office of Safety and Mission Assurance, today the Orbital Debris Program Office supports all NASA space programs and projects, serves as the national center of expertise on orbital debris, and represents the US on orbital debris issues in the international community, including the Inter-Agency Space Debris Coordination Committee (IADC) and the United Nations. The men and women of the Orbital Debris Program Office continue to conduct leading-edge research into all aspects of orbital debris research for the benefit of the global space community.

1. Kessler, D. J. and Cour-Palais, B. G. *"Collision Frequency of Artificial Satellites: The Creation of a Debris Belt,"* Journal of Geophysical Research, Vol. 83, No. A6, p. 2637-2646, 1978.

2. Portree, D. S. F. and Loftus, Jr., J. P. *Orbital Debris: A Chronology*, NASA TP 1999-208856, January 1999.

3. *Orbital Debris Quarterly News*, NASA Johnson Space Center, 1996 to present; see www.orbitaldebris.jsc.nasa.gov/newsletter/newsletter.html.

4. Bush, G. W. *US National Space Policy*, 31 August 2006. ♦

International Conference on Orbital Debris Removal

For many years, spacefaring nations and organizations have recognized the mounting risk to space operations posed by orbital debris. The collision of the Iridium 33 and Cosmos 2251 spacecraft in February 2009 underscored the consequences of those risks not only to operational spacecraft, but also to the near-Earth space environment as a whole. Orbital debris mitigation measures have now been adopted by the United Nations, the Inter-Agency Space Debris Coordination Committee (IADC), and by many national space agencies. However, even with complete compliance with all these mitigation measures, the orbital debris population about the Earth will continue to grow through normal space operations, accidents, and inadvertent collisions.

To address this increasingly hazardous population of debris, NASA and the Defense Advanced Research Projects Agency (DARPA) will co-host an international conference on the removal of debris from Earth orbit. The conference, to be held 8-10 December 2009 in the Washington, DC, vicinity, will be dedicated to discussing issues, challenges, and specific concepts involved with removing man-made debris from Earth orbit. Debris of all sizes and in all orbits are of interest.

Topics open for discussion during the conference include ground-, air-, and space-based debris removal technologies; solutions appropriate for removing small debris (fragments) and large debris (spacecraft and launch vehicle stages); special considerations for low Earth orbits (LEO) and high Earth orbits, particularly the geosynchronous regime (GEO); international policy and legal concerns; safety issues; and economic constraints.

The conference will be held at the Westfields Marriott Hotel in Chantilly, Virginia, just 13 km from the Washington Dulles International Airport. Registration information can be found at https://www.enstg.com/signup, code INT11415. ♦

Old Spacecraft Suffers Minor Fragmentation

A nearly 42-year-old Soviet spacecraft released as many as 20 trackable debris following an event of unknown cause on 30 August 2009. Cosmos 192 (International Designator 1967-116A, US Satellite Number 3047) was launched in November 1967 by the former Soviet Union as the first of more than 150 low altitude navigation spacecraft. The latest descendent of Cosmos 192 was launched in July 2009 under the name Cosmos 2454.

Cosmos 192 was a pressurized, cylindrical spacecraft with a tall boom extending from its top for gravity-gradient stabilization and with a mass of approximately 800 kg. From its initial orbit of 745 by 760 km at an inclination of 74 degrees, the spacecraft gradually dropped to an orbit of 710 km by 715 km at the time of its fragmentation.

The most likely cause of the fragmentation was either a collision with a small, untracked particle or a breach of the spacecraft's pressure vessel due to fatigue after exposure to the harsh environment of space for more than four decades. This incident underscores the current NASA requirement and international guideline to limit the orbital lifetime of spacecraft and launch vehicle orbital stages to no more than 25 years after the end of mission. ♦

Two Old Spacecraft Successfully Retired

NASA, US, and international orbital debris mitigation guidelines call for the responsible disposal of spacecraft to prevent post-mission fragmentations and to remove the vehicle in a timely fashion from regions of special importance to operational space systems. Spacecraft operating in low Earth orbit should be left in orbits with lifetimes of less than 25 years and should be passivated, i.e., all energy sources should be removed.

For older spacecraft that were launched before these recommendations were widely accepted, compliance with the disposal guidelines can be a challenge due to design constraints and system degradations after many years of operations. In 2001 the 19-year-old US Landsat spacecraft was moved from its 705-km orbit to a compliant disposal orbit below 600 km (*Orbital Debris Quarterly News*, July 2001, p. 4). In 2005 NASA decommissioned two spacecraft, ERBS and UARS, which had been in space for 21 and 14 years, respectively. Both vehicles, which were already operating in relatively low orbits below 600 km, were maneuvered into even lower orbits to accelerate their returns to Earth and to ensure compliance with the 25-year lifetime guideline (*Orbital Debris Quarterly News*, January 2006, pp. 1-2).

During the past 12 months, two elderly spacecraft in much higher operational orbits were coaxed into compliant disposal orbits and passivated. The first was the US Navy's GEOSAT Follow-On (GFO) spacecraft (International Designator 1998-007A, US Satellite Number 25157), launched in 1998 into an orbit of 800 km for oceanographic research. The GFO presented exceptional challenges due to a temperature sensitive reaction control wheel and a degraded electrical storage system. A series of eight burns in November 2008 dropped GFO's orbit to 455 km by 785 km, from which reentry is expected within less than 25 years. A detailed and fascinating summary of the trials and tribulations of the disposal operations was presented at the AIAA Space 2009 conference.[1]

In July, the French SPOT 2 spacecraft (International Designator 1990-005A, US Satellite Number 20436) completed a 19-year Earth observation mission at an altitude of 825 km. Like its predecessor SPOT 1, which was maneuvered into a lower disposal orbit in November 2003, SPOT 2, over a span of 2 weeks, executed 11 maneuvers to enter a final disposal orbit of 575 km by 795 km, from which reentry should occur within the 25-year objective.

The successful disposals of the six spacecraft cited above demonstrate both the technical expertise and the commitment of operators of older spacecraft to satisfy international orbital debris mitigation standards, even when those standards were set after launch.

1. Monheim, A. L., et al. *"GFO: Disposal of a Power-Challenged Satellite with an Attitude (Control) Problem,"* AIAA Space 2009 Conference, 14-17 September 2009, Pasadena, California. ♦

Figure 1. GFO spacecraft.

ORDEM2010 Beta Release

The multi-year development of the NASA Orbital Debris Engineering Model 2010 (ORDEM2010) has passed a significant milestone with the release of the Beta version for testing. Like its predecessors in the ORDEM series of engineering models, ORDEM2010 is an empirically derived model that includes assessments of the orbital debris environment as a function of altitude, latitude, and debris size. It provides a state-of-the-art description of the environment, in terms of debris flux onto spacecraft surfaces or the debris detection rate observed by ground-based sensors. The ORDEM2010 model represents a major improvement over the existing ORDEM2000, with significant advances in several fundamental areas described in this article.

Debris data detections that form the basis of the model have been extended through as many as 6 years of data collection. This provides much better statistics than had been available to previous ORDEM model developments. A new approach to the analysis of the data below geosynchronous orbits (GEO) utilizes Bayesian statistics. The data, which is composed of object detections and ephemeris, is compared to the debris populations of several NASA debris environment models. Model results are processed to be compatible with the data in orbital regions where the data is collected. Consequently, model results are extrapolated

continued on page 4

ORDEM2010

continued from page 3

to regions where no data exists. The resulting debris population in the 10 µm to 10 cm size range serves as an input to the ORDEM2010 model. The GEO debris population, included in an ORDEM model for the first time, also is derived from NASA debris environment models and by slight extrapolation of GEO measurement data to smaller sizes with the NASA Standard Breakup Model (see article in this newsletter).

The resulting input population files contain two other quantities for the first time in an ORDEM model. The first is material density for debris smaller than 10 cm. These objects include non-breakup debris for which the compounds are known (e.g., sodium potassium droplets), and breakup fragments, for which low-, medium-, or high-density (i.e., plastics, aluminum, steel) are assigned based on noted ground collision test results. The second, newly included quantity is the population error, which includes measurement, future projection, and modeling uncertainties. Population errors are converted to flux errors in the final calculations of the spacecraft mode.

Unlike ORDEM2000, which uses only the debris velocity component in the local spacecraft or detector beam horizontal velocity direction, ORDEM2010 includes horizontal as well as radial velocity components in the flux calculations. For example, in the spacecraft mode incoming debris flux is no longer calculated from debris velocity components in the horizontal orbit plane, but instead is calculated within surface elements of a virtual sphere encompassing the satellite.

The new quantities such as flux errors and three-dimensional debris flux calculations are supported by an updated graphical user interface (GUI) package designed for ORDEM2010. The anticipated release of the ORDEM2010 package is early 2010. ♦

PROJECT REVIEWS

The 2006 Geosynchronous (GEO) Environment for ORDEM2010

P. H. KRISKO

The NASA Orbital Debris Program Office is updating its Orbital Debris Engineering Model (ORDEM2010) to be the first of the series to include the capability of estimating debris flux in the geosynchronous (GEO) region of Earth orbit. The derived GEO debris population includes objects of sizes larger than 10 cm. This is well below the minimum estimated size of ~70 cm routinely cataloged and tracked by the US Space Surveillance Network (SSN) in the GEO region.

The 2006 GEO population forms the basis of all other yearly populations within the 1995 to 2035 timeframe for ORDEM2010. Two main data sources are combined to derive this 2006 population. The first, the SSN GEO two-line element set (TLE) data, compiles high fidelity orbital elements of objects of sufficient cross-sectional area to be detected and tracked by ground-based sensors. Detected objects include known intacts (spacecraft, rocket bodies, mission-related debris) and a few large fragments from two verified explosive events. The second source is survey data from NASA's 0.6-meter Michigan Orbital Debris Survey Telescope (MODEST) for the years 2004 through 2006. This set includes a population of dim, untracked objects clumped near GEO regions also populated by cataloged intacts.

Use of this data in ORDEM2010, as well as extrapolation of the data to 10 cm, requires size and orbital element estimates. The TLE object physical dimensions are not explicitly noted in the TLEs themselves, though SSN radar sensitivities yield a minimum size to be ~70 cm. To derive this data reliably, The NASA Orbital Debris Program Office researches characteristics of specific rocket bodies and spacecraft (i.e., intact objects) such as wet and dry mass, average cross-sectional area, and rudimentary shape by various means. These include company and government websites, technical publications, and professional contacts. Physical dimensions of cataloged debris, which make up less than 1% of the GEO TLE catalog, are estimated from long-term radar cross-section (RCS) measurements from SSN stations. These data are compiled by NASA and converted to median diameters or characteristic lengths with the NASA Size Estimation Model (SEM). Uncorrelated targets (UCTs) observed by MODEST, which has a sensitivity of ~17th absolute magnitude, are estimated to be larger than ~30 cm.[1] Consideration of these objects as fragmentation debris, from as yet unidentified breakups, is bolstered by the character of the MODEST UCT data. At absolute magnitudes above 15, UCTs increase in number as brightness decreases. Translating absolute magnitude to size shows a log-log slope of cumulative UCT number vs. estimated size consistent with that of the –1.6 slope for explosive fragmentation debris seen from LEO rocket bodies (Figure 1).[2] The figure illustrates the means of extrapolating the MODEST population to fragment sizes from 30 cm to 10 cm. The ORDEM2010 GEO numbers vs. size of fragments from 10 cm to 30 cm are based directly on this curve.

The TLE data contains high quality orbital elements for all tracked objects. However, MODEST data consists of single observations of objects moving through the telescope field-of-view at rates near those of GEO orbits. These give high quality absolute magnitude, orbital inclination, and right ascension of ascending node (RAAN). Eccentricity and mean motion, however, are assigned by the standard practice of assuming a circular orbit.[3] The short arcs of observation within the GEO rate box do not permit any better estimate of these two elements via single telescope observations (argument of perigee is randomized in near GEO orbits.). The extrapolated MODEST

continued on page 5

2006 GEO Environment

continued from page 4

data, of course, contains no orbital elements.

The judicious assignment of the unknown orbital elements for MODEST and extrapolated MODEST data sets is accomplished by comparing the population from NASA's long-term environment model, LEGEND, to the MODEST data. A standard GEO run of LEGEND to 2006 would include the deposit of yearly intact objects and known breakup fragments from the two known explosions. However as Figure 1 suggests, through the number of objects larger than 10 cm, several unrecorded explosions have likely occurred in the GEO region.

Assuming that GEO exploding spacecraft and rocket bodies behave in the same manner as do their LEO counterparts, it is reasonable to consider the GEO fragments as remnants of 7 to 9 rocket body propulsion-related explosions. To account for these events, LEGEND is edited to run in a 'historical random breakup mode.' That is, explosions and collisions are set to occur by two means, through the historical database files (standard historical modeling), and through random happenstance, which is based on predefined event probabilities (standard projection modeling).

Figure 2 is an example of GEO fragment orbital elements (here, inclination vs. RAAN) extracted from the 2006 population with an average of 8 random rocket body explosions and zero collisions. This population density chart is derived from 100 Monte Carlo simulations. The scale is in $\log_{10}$ space. Inclination and RAAN of uncontrolled objects in GEO orbits are dominated by luni-solar perturbations. They follow a 53-year cycle in inclination (0 to 14 to 0 degrees) and RAAN (90 to 0 to 360 to 90 degrees). The initial ΔV of breakup fragments will cause them to deviate somewhat from this path, as evidenced by the wide (8°) band in inclinations.

The results such as the orbital elements presented here are used as probability distribution functions (PDFs) and are applied to the MODEST and extrapolated MODEST data sets. Orbital elements consistent with those of this simulated environment are the result. The application of this method is displayed in Figure 3. The MODEST data shown in Figure 3a is of objects of greater than 15th absolute magnitude, which are surmised to be breakup

continued on page 6

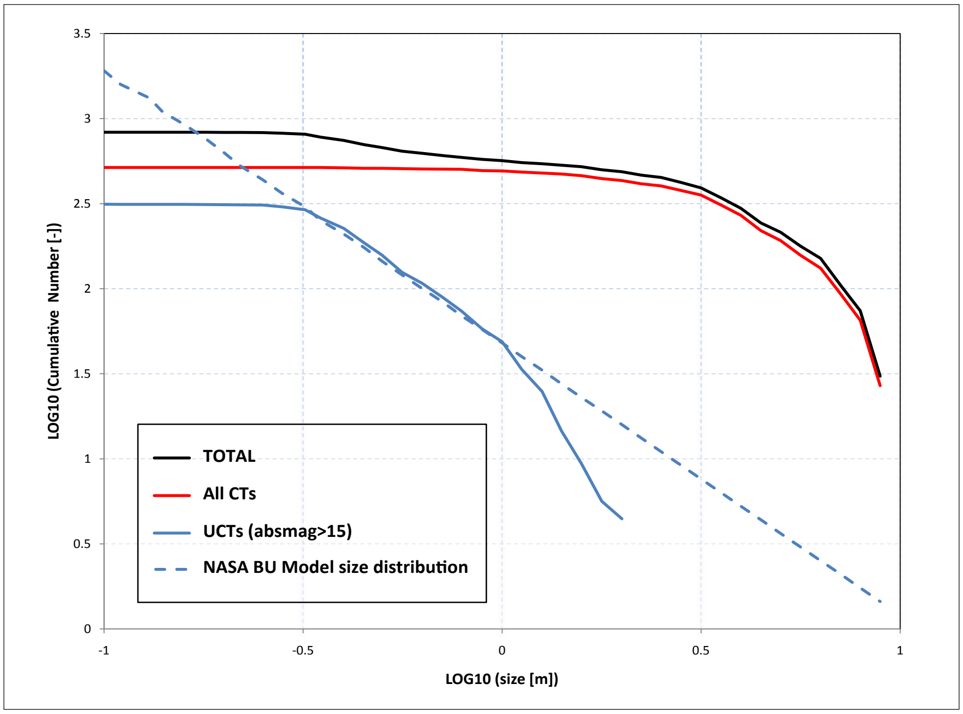


Figure 1. Cumulative size of UCTs vs. NASA Standard Breakup Model Distribution.

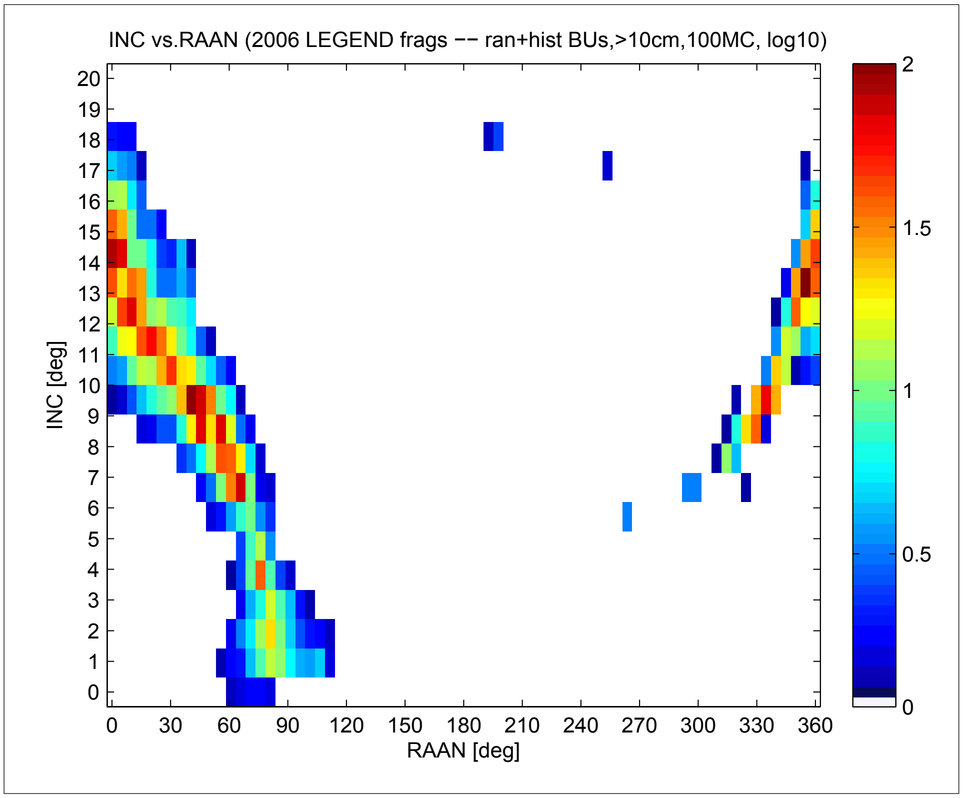


Figure 2. The 2006 LEGEND GEO fragment environment population density chart for inclination vs. RAAN (in log10 density space) in the historical random breakup mode.

2006 GEO Environment

continued from page 5

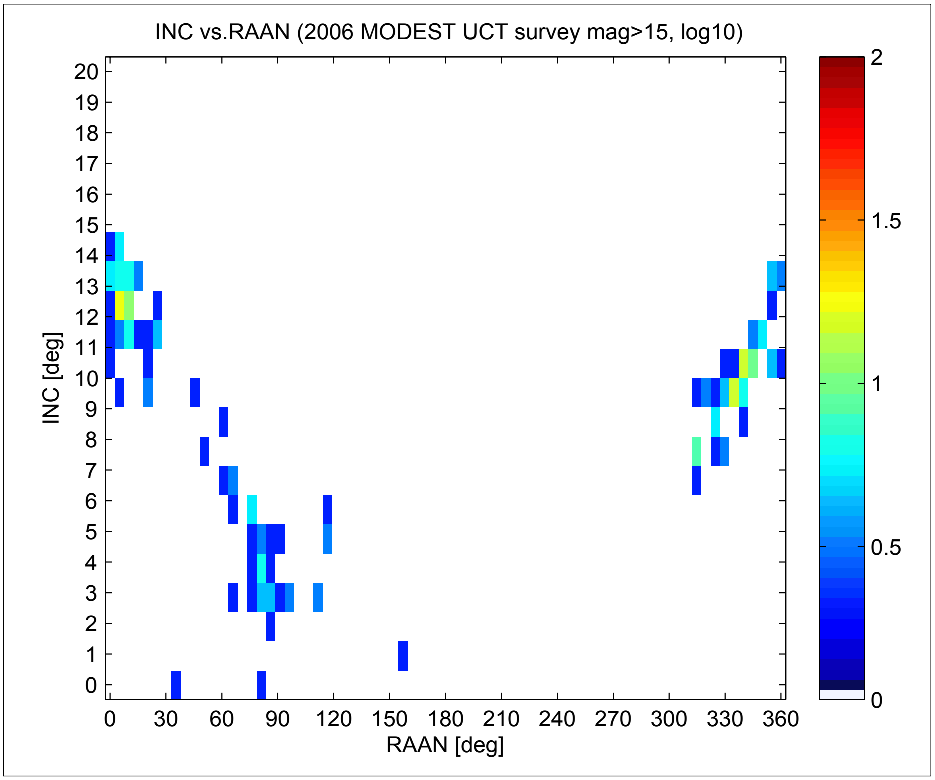


Figure 3a. MODEST 2004-2006 survey data population density with greater than 15th absolute magnitudes (i.e., assumed breakup fragments).

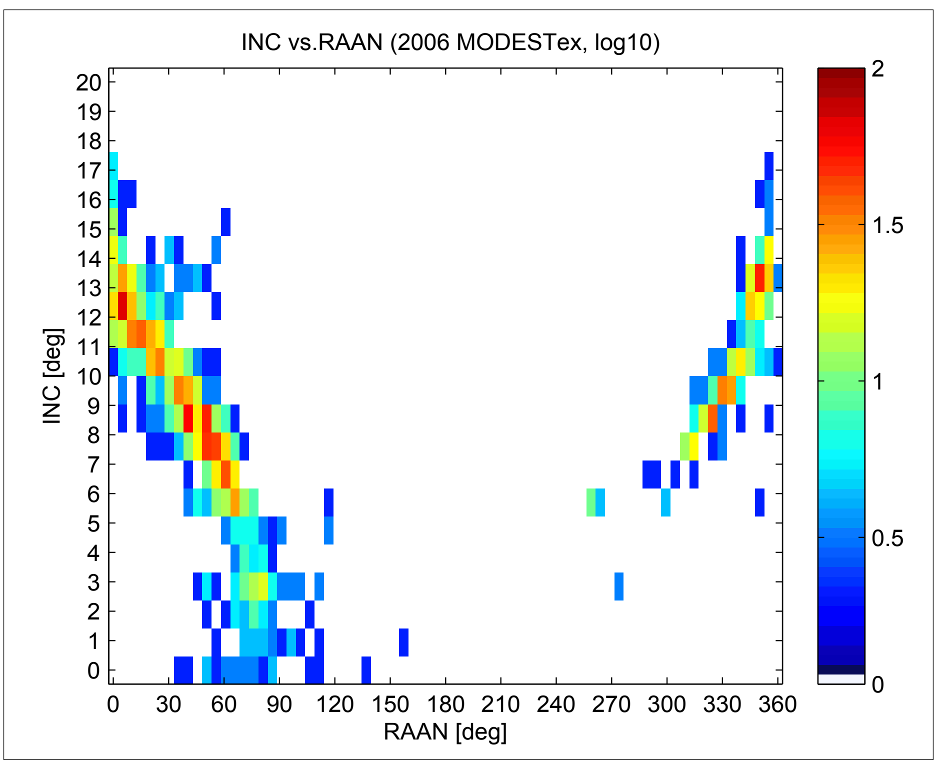


Figure 3b. Population density of MODEST 2004-2006 survey data from Figure 3a plus the extrapolated MODEST data with derived inclination vs. RAAN from the LEGEND PDFs.

fragments. Figure 3b displays the data of Figure 3a plus extrapolated MODEST calculated inclination vs. raan values, derived by applying the RAAN PDFs to the extrapolated data.

The entire ORDEM2010 GEO population for 2006 includes tracked objects from TLEs and untracked fragments derived from the methods described above. All other years of ORDEM2010 GEO are derived from this population.

1. Mulrooney, M. and Matney, M. *"Derivation and Application of a Global Albedo Yielding an Optical Brightness to Physical Size Transformation Free of Systematic Errors,"* 2007 AMOS Technical Conference, Kihei, HI, September 2007.

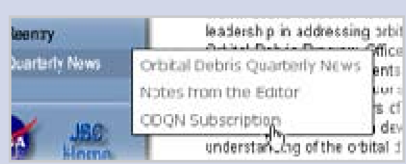
2. Johnson, N. L., Krisko, P. H., Liou J.-C., et al. *NASA'S new breakup model of EVOLVE 4.0*, Advances in Space Research, 28(9), p. 1377-1384, 2001.

3. Abercromby, K. J., Seitzer, P., Barker, E. S., et al. *Michigan Orbital Debris Survey Telescope (MODEST) Observations of the Geosynchronous Orbital Debris Environment Observing Years: 2004-2006*, July 2009. ♦

HOW TO SUBSCRIBE...

To receive email notification when the latest newsletter is available, please fill out the ODQN Subscription Request Form located on the NASA Orbital Debris Program Office website at www.orbitaldebris.jsc.nasa.gov.

To access this form, click on "Quarterly News" in the blue, Quick Links area of the website and select "ODQN Subscription" from the pop-up box that appears.



A 3-Year Summary of GEO "Survey and Chase" and Photometric Measurements with Two-Telescope Observations

H. COWARDIN, K. ABERCROMBY, P. SEITZER, E. BARKER, G. FOREMAN, M. MULROONEY, AND M. HORSTMAN

Beginning in early 2001, the Michigan Orbital DEbris Survey Telescope (MODEST), located at the Cerro Tololo Inter-American Observatory (CTIO), began observations of geosynchronous orbits in survey mode. Using an assumed circular orbit (ACO), the following orbital parameters can be determined: inclination, right ascension of ascending node (RAAN), mean motion, and absolute magnitude.[1,2,3] The final set of survey data is sent to the NASA Johnson Space Center (JSC) to further analyze whether the detected objects were correlated targets (CT) or uncorrelated targets (UCTs). CTs are objects tracked by the U S Space Surveillance Network (SSN), whereas UCTs are not catalogued by the SSN. In an effort to better define the orbital elements of objects, a new program began in 2007 using two telescopes to 1) survey the GEO environment and 2) "chase" or follow-up on faint objects for longer time arcs.

In this two-telescope mode of operation, MODEST is set in standard survey mode using a broad R filter, while a 0.9-m aperture telescope operated by the Small- and Medium-Aperture Research Telescope System (SMARTS) Consortium at CTIO (hereafter noted as the CTIO 0.9 m), is used to reacquire an object. Thus, multiple objects, with different rates, are tracked consecutively during the night without interrupting the survey mode. This method has been termed survey and chase because MODEST continues the survey while the CTIO 0.9 m conducts the object chase. The goal is to follow-up on all objects detected fainter than R =15th magnitude, thus providing an orbital distribution of objects selected on the basis of two observational criteria: magnitude and angular rate. Objects with this magnitude criterion are presumed to be UCTs and most likely to represent the orbital debris population, as well as exhibit different orbit distributions and angular rates than that of bright objects.[1,2,3]

MODEST has a field-of-view (fov) of 1.3° x 1.3°, compared to the CTIO 0.9 m, which has a much smaller fov of 0.21° x 0.21°. Due to its smaller fov, the reacquisition success via the CTIO 0.9 m is sensitive to the buildup of positional errors in the propagation of the orbit, thereby requiring a rapid turnover from survey mode positions to the chase mode. After acquisition, generally 30 minutes of observations on the CTIO 0.9 m telescope are required before an orbit with a plausible eccentric solution can be obtained. On the following night, a minimum of 4 hours of tracking data is needed to reacquire the eccentric object. The success rate with handovers and follow-ups, weather aside, has been nearly 85% with failures primarily being due to objects outside the CTIO 0.9 m fov, which are likely eccentric orbits or objects that drift too far east/west of the telescope range.[2] The following paragraphs will discuss the statistics of the past survey and chase campaigns from March 2007, November 2007, March 2008, July/August 2008, October 2008, February 2009, and June 2009.

In Table 1, the average time for handovers from MODEST to CTIO 0.9 m and the number of successful handovers (acquired at least once on the CTIO 0.9 m), is shown. Based on experience acquired over several observing runs, we empirically determined if the time difference between the last acquisition on MODEST and the first attempt to follow-up on CTIO 0.9 m was too large. If the time is longer than ~ 30 minutes, the risk of not acquiring the object increases and objects that are in eccentric orbits will be out of the CTIO 0.9 m fov due to the error inherent in an ACO-predict position. As shown, the average handover time for reacquiring an object is less than 30 minutes. The success rate shows the number of objects successfully

continued on page 8

Table 1. Observing run handover time and success rate

Observation Campaign	Average Time Between Handovers (minutes)	Handovers Success Rate (success/total)
March 2007	18	———
November 2007	13	37/38 (97%)
March 2008	17	21/32 (66%)
July/August 2008	21	25/29 (86%)
October 2008	16	17/20 (85%)
February 2009	13	24/28 (86%)
June 2009	12	15/16 (94%)

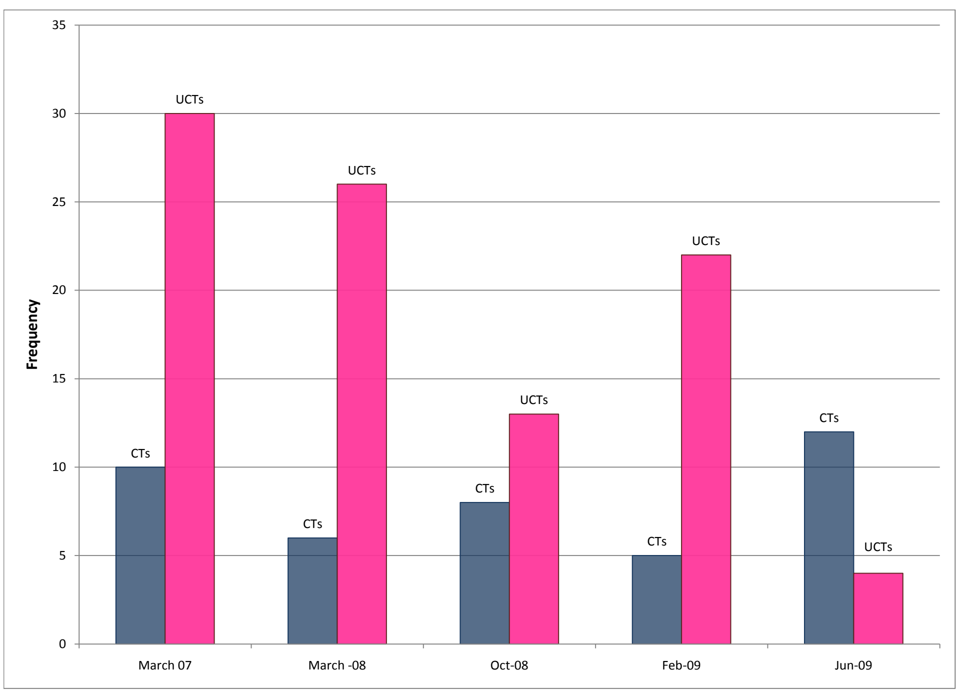


Figure 1. Frequency of CTs and UCTs per observing run.

Survey and Chase

continued from page 7

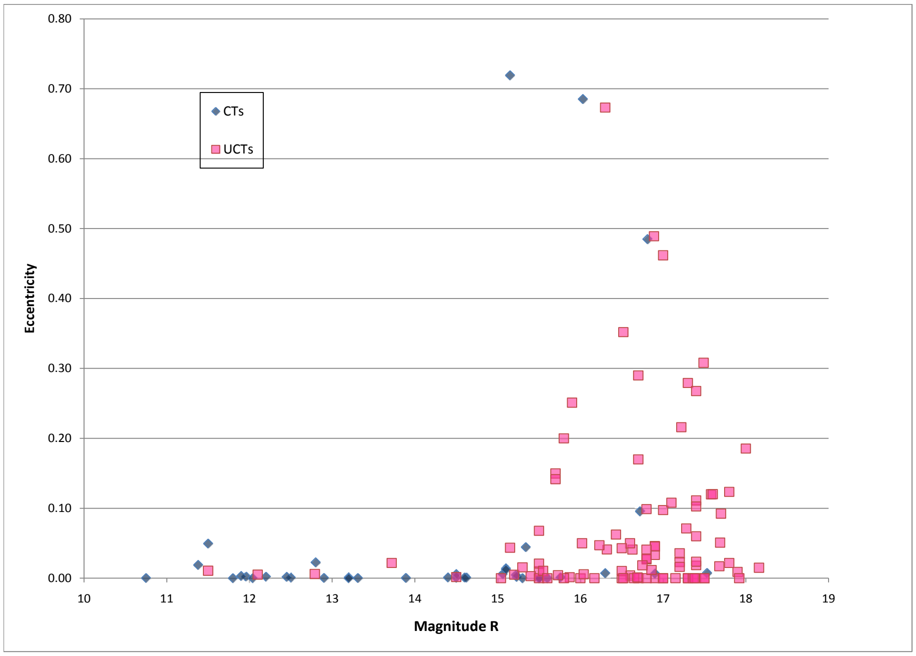


Figure 2. Eccentricity vs. magnitude.

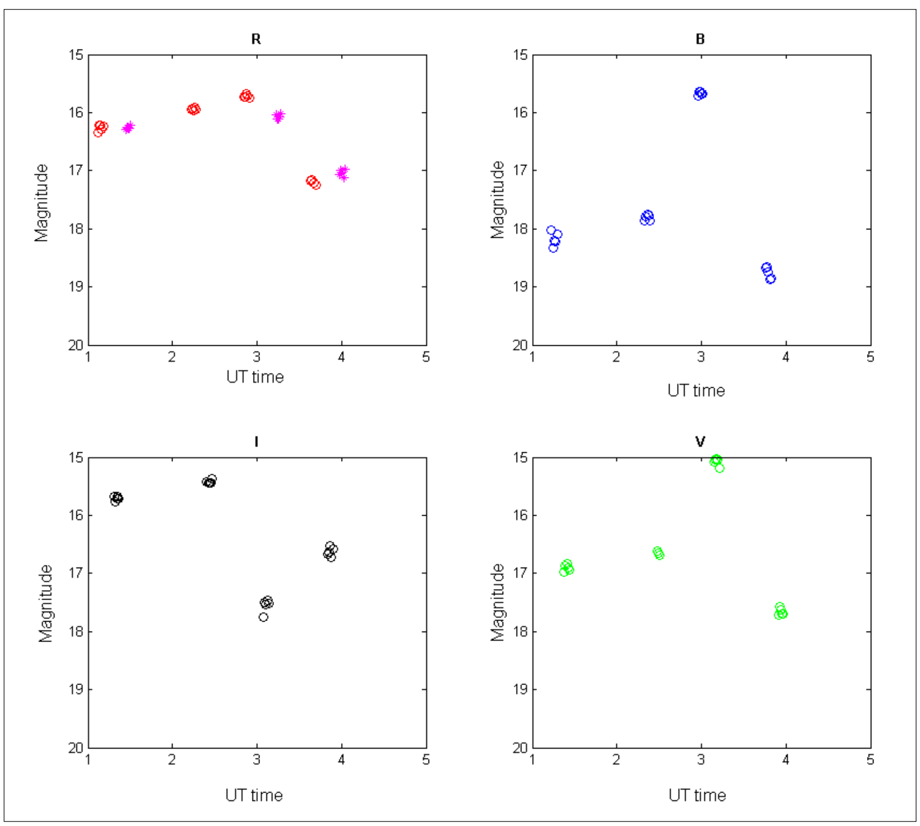


Figure 3. Photometric data for UCT taken in the following –. R, B, I, V, R; always starting and finishing the sequence with the red filter to investigate any systematic change over the time period of the entire observation set. The initial red filter measurement is shown in red and the last red filter measurement is shown in magenta..

acquired over the number attempted per night. Since the value could be skewed by circumstances out of the observer's control, the success rate over multiple nights is not shown. Very seldom has weather been the reason behind unsuccessful handovers. At the start of the survey and chase program in March 2007, the process was not well developed; therefore, the success rate will not be reported. The total number of attempted handovers is dependent on the strip of sky observed, so as the pointing moves further from the geosynchronous belt where most CTs and UCTs are found, the probability of detecting faint debris and, specifically, CTs <15th magnitude is reduced.

Two of the past seven runs are still being processed for correlations and will not be reported at this time. Out of the remaining observing runs, the majority of objects tracked were UCTs, as shown in Figure 1. Not all CTs are active or functional satellites; some of the CTs tracked were nonfunctional satellites, rocket bodies, or catalogued debris. In the last observing campaign, 16 objects were tracked, four UCTS and the rest all CTs. Of the 12 CTs: two were actual debris objects, three were rocket bodies, and the final seven were functional satellites.

Figure 2 shows the observed R magnitude versus the orbital eccentricity for all processed data. The CTs are shown as blue diamonds and the UCTs as pink squares. A large population is grouped between 0 and 0.02. Objects with eccentricities >0.05 are predominately UCTs. For objects with a magnitude >15, the object eccentricities begin to stray from the low eccentricity zones and can be seen near 0.5 and higher. The two CTs near eccentricity of 0.7 were confirmed to be objects in geosynchronous transfer orbits (GTOs).

Another aspect aiding in object identification involves using filter photometry with standard astronomical filters (B, V, R, I). Calculating the filter ratio or color index (i.e., blue to red) shows whether an object has a stronger response in the blue wavelengths (e.g., solar cells) or in the red wavelengths (e.g., Kapton from multi-layered insulation).

Figure 3 shows an example of a UCT from a photometric sequence taken four different times over one night during the October 2008 campaign. This object shows very small brightness and color variations in all filters for

continued on page 9

Survey and Chase

continued from page 8

all short time scales (5 - 20 minutes), suggesting we are seeing just one aspect of this piece of debris. However, on longer timescales, both brightness and colors change significantly (note the behavior near 3 hours UT), where the object brightens in B by three magnitudes (15 x), yet becomes fainter in I by about the same amount.

To better understand the nature of the changes in different colors, additional observations for simultaneous measurements (of the same object) in two different filters have been conducted. The CTIO 0.9 m observes in B, while MODEST observes in R. The MODEST CCD camera is electronically synced to the CTIO 0.9 m CCD camera, enabling both exposures to have the same start time and duration to better than 50 milliseconds. Details of these experiments were reported at the AMOS 2009 Technical Conference.[4,5]

1. Abercromby, K., et al., *A Summary of Five Years of Michigan Orbital Debris Survey Telescope (MODEST) Data*, 2008 International Astronautical Congress, Glasgow, Scotland, October 2008.
2. Seitzer, P., et al., *Optical Studies of Orbital Debris at GEO Using Two Telescopes*, Proceedings of AMOS 2008 Technical Conference, Maui, Hawaii, 2007.
3. Abercromby, K., et al., *Survey and Chase: A New Method of Observations for the Michigan Orbital Debris Survey Telescope (MODEST)*, Acta Astronautica 65, p. 103-111, 2009.
4. Cowardin, H., et al., *An Assessment of GEO Orbital Debris Photometric Properties Derived from Laboratory-Based Measurements*, Proceedings of AMOS 2009 Technical Conference, Maui, Hawaii, 2009.
5. Seitzer, P., et al., *Photometric Studies of GEO Debris*, Proceedings of AMOS 2009 Technical Conference, Maui, Hawaii, 2009. ♦

ABSTRACTS FROM THE NASA ORBITAL DEBRIS PROGRAM OFFICE

NLSI Lunar Science Forum 2009
21-23 July 2009, NASA Ames Conference Center, Moffett Field, California

Large Area Lunar Dust Flux Measurement Instrument

R. CORSARO, F. GIOVANE, J.-C. LIOU, M. BURCHELL, E. STANSBERY, AND N. LAGAKOS

The instrument under development is designed to characterize the flux and size distribution of the lunar micrometeoroid and secondary ejecta environment. When deployed on the lunar surface, the data collected will benefit fundamental lunar science as well as enable more reliable impact risk assessments for human lunar exploration activities. To perform this task, the instrument requirements are demanding. It must have as large a surface area as possible to sample the very sparse population of the larger, potentially damage-inducing micrometeoroids. It must also have very high sensitivity to enable it to measure the flux of small (<10 micron) micrometeorite and secondary ejecta dust particles. To be delivered to the lunar surface, it must also be very low mass, rugged, and stow compactly.

The instrument designed to meet these requirements is called FOMIS. It is a large-area, thin film under tension (i.e., a drum) with multiple, fiber optic displacement (FOD) sensors to monitor displacements of the film. This sensor was chosen because it can measure displacements over a wide dynamic range: 1 cm to sub-Angstrom. A prototype system was successfully demonstrated using the hypervelocity impact test facility at the University of Kent (Canterbury, UK). Based on these results, the prototype system can detect hypervelocity (~5 km/s) impacts by particles as small as 2 microns in diameter. Additional tests using slow speeds find that it can detect secondary ejecta particles (which do not penetrate the film) with momentums as small as 15 pico-gram -m/s, or nominally, 5 microns diameter at 100 m/s. ♦

An Impact Sensor System for the Characterization of the Micrometeoroid and Lunar Secondary Ejecta Environment

J.-C. LIOU, M. BURCHELL, R. CORSARO, F. GIOVANE, E. STANSBERY, J. BLUM, WILLIAM COOKE, AND V. PISACANE

The Impact Sensor for Micrometeoroid and Lunar Secondary Ejecta (IMMUSE) project aims to apply and integrate previously demonstrated impact sensing subsystems to characterize the micrometeoroid and lunar secondary (MMSE) environment on the surface of the Moon. Once deployed, data returned from IMMUSE will benefit:

1. Fundamental Lunar Science: providing data to improve the understanding of lunar cratering processes and dynamics of the lunar regolith.
2. Lunar Exploration Applied Science: providing an accurate MMSE environment definition for reliable impact risk assessments, cost-effective shielding designs, and mitigation measures for long-term lunar exploration activities.
3. Planetary Science: providing micrometeoroid data to aid the

continued on page 10

Impact Sensor System
continued from page 9

understanding of asteroidal collisions and the evolution of comets. A well-established link between micrometeoroid impacts and lunar regolith is also key to understanding other regolith-covered bodies from remote-sensing data.

The IMMUSE system includes two components: (1) a large area (≥1 m^2) micrometeoroid detector based on acoustic impact and fiber optic displacement sensors and (2) a 100 cm^2 lunar secondary ejecta detector consisting of dual-layer laser curtain and acoustic impact sensors. The combinations of different detection mechanisms will allow for a better characterization of the MMSE environment, including flux, particle size/mass, and impact velocity.

IMMUSE is funded by the NASA Lunar Advanced Science and Exploration Research (LASER) Program through 2012. The project's goal is to reach a Technical Readiness Level of 4 in preparation for a more advanced development beyond 2012. Several prototype subsystems have been constructed and subjected to low impact and hypervelocity impact tests. The presentation will include a status review and preliminary test results. ♦

Advanced Maui Optical and Space Surveillance Technology (AMOS) Conference 1-4 September 2009, Maui, Hawaii, USA

An Assessment of GEO Orbital Debris Photometric Properties Derived from Laboratory-based Measurements

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

Optical observations of orbital debris offer insights that differ from radar measurements (specifically the size parameter and wavelength regime). For example, time-dependent photometric data yield light curves in multiple bandpasses that aid in material identification and possible periodic orientations. This data can also be used to help identify shapes and optical properties at multiple phase angles. Capitalizing on optical data products and applying them to generate a more complete understanding of orbital space objects, is a key objective of NASA's Optical Measurement Program, and a primary driver for creation of the Optical Measurements Center (OMC). The OMC attempts to emulate space-based illumination conditions 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, a CCD camera with standard Johnson/Bessel filters, and a robotic arm to rotate objects in an effort to simulate an object's orbit/rotational period. A high-resolution, high bandwidth (350 nm-2500 nm) Analytical Spectral Devices (ASD) spectrometer is also employed to baseline various material types.

Since observation of GEO targets are generally restricted to the optical regime (due to radar limitations), analysis of their properties is tailored to those revealed by optical data products. A small population of GEO debris was recently identified that exhibits the properties of high area-to-mass (A/m) objects (>0.9 m^2/kg), such as variable eccentricities and inclinations, a dynamic characteristic that usually results from variations in solar radiation pressure. In this connection, much attention has been directed towards understanding the light curves of orbital debris and their associated A/m value. Materials, such as multi-layered insulation (MLI) and solar panels, are two examples of materials with high area-to-mass ratios. Light curves for such objects can vary greatly, even for the same object under different illumination conditions. For example, specular reflections from multiple facets of the target surface (e.g., Mylar or Aluminized Kapton), can lead to erratic, orientation-dependent light curves.

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. The specific materials investigated (known to exist in GEO) are: an intact piece of MLI, separated layers of MLI, and multiple solar cell materials. Using the data acquired over specific rotational angles through different filters (B, V, R, I), a color index is acquired (B-R, R-I). As a secondary check, the spectrometer is used to define color indexes for the same material. Using these values and their associated light curves, this laboratory data is compared to observational data obtained on the 1 m telescope of the Astronomical Institute of the University of Bern (AIUB) and 0.9 m operated by the Small- and Medium-Aperture Research Telescope System (SMARTS) Consortium at Cerro Tololo Inter-American Observatory (CTIO); hereafter noted as the CTIO 0.9 m.

We will present laboratory generated light curves with color indexes of the high A/m materials alongside telescopic data of targets with high A/m values. We will discuss the relationship of laboratory to telescope data in the context of classification of GEO debris objects. ♦

Photometric Studies of GEO Debris

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

The photometric signature of a debris object can be useful in determining the physical characteristics of a piece of debris. We report on optical observations in multiple filters of debris at geosynchronous Earth orbit (GEO).

Our sample is taken from GEO objects discovered in a survey with the University of Michigan's 0.6-m aperture Schmidt telescope MODEST (for Michigan Orbital DEbris Survey Telescope), and then followed up in real-time with the 0.9 m operated by the Small- and Medium-Aperture Research Telescope System (SMARTS) Consortium at Cerro Tololo Inter-American Observatory (CTIO); hereafter noted as the CTIO 0.9 m, for orbits and photometry. Our goal is to determine 6 parameter orbits

continued on page 11

Photometric Studies
continued from page 10

and measure colors for all objects fainter than R = 15th magnitude that are discovered in the MODEST survey. At this magnitude the distribution of observed angular rates changes significantly from that of brighter objects.

There are two objectives:

1. Estimate the orbital distribution of objects selected on the basis of two observational criteria: brightness (magnitude) and angular rates.
2. Obtain magnitudes and colors in standard astronomical filters (BVRI) for comparison with reflectance spectra of likely spacecraft materials. What is the faint debris likely to be?

In this paper we report on the photometric results.

For a sample of 50 objects, more than 90 calibrated sequences of R-B-V-I-R magnitudes have been obtained with the CTIO 0.9 m. For objects that do not show large brightness variations, the colors are largely redder than solar in both B-R and R-I. The width of the color distribution may be intrinsic to the nature of the surfaces, but also could be 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 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. ♦

American Physical Society (APS) Shock Compression of Condensed Matter 2009
28 June – 3 July 2009, Nashville, TN

Development of the Next Generation of Meteoroid and Orbital Debris Shields

S. J. RYAN, E .L. CHRISTIANSEN, AND D. M. LEAR

The novel structure of metallic foams is of interest in the design of next-generation debris shields as it introduces physical mechanisms that are advantageous to hypervelocity impact shielding (e.g., increased fragmentation/melt/vaporization, energy dissipation, etc.). Preliminary investigations have shown improved shielding capability over traditional spacecraft primary structures. In this paper, the results of a current hypervelocity impact test program on metallic open-cell foam core sandwich panels are reported. A preliminary ballistic limit equation has been derived from the experimental results, and is presented in a form suitable for implementation in risk assessment software codes. ♦

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

Geosynchrous Environment for Ordem2010

P. H. KRISKO, Y.-L. XU, M. MATNEY, AND K. ABERCROMBY

The new version of the NASA Orbital Debris Engineering Model (ORDEM2010) requires accurate populations as input template files to be used in the calculation of orbital debris fluxes on chosen spacecraft or within telescope/radar fields-of-view. Populations in ORDEM2010 are derived from a consortium of data and modeling. Geosynchronous (GEO) satellites and debris form a distinct ORDEM2010 population that is applied to the distinct analysis of GEO fluxes. Low Earth orbit (LEO) populations are derived by combining modeling results with ground-based data, primarily from radar systems and in-situ data. In contrast, the GEO region has not been as well observed. The distance between orbiting objects and ground-based instruments precludes the wide usage of radar as a means of observation. Instead, optical instruments dominate in the study of GEO. Of these, the NASA-sponsored Michigan Orbital Debris Survey Telescope (MODEST) has provided 4 years of surveys of the region detecting cataloged objects (correlated targets) and non-cataloged objects (uncorrelated targets) to an estimated minimum size of 30 cm.

This paper describes the methods of combining NASA launch database and satellite breakup and orbital propagation modeling with MODEST 2004-to-2006 uncorrelated target data to attain a GEO environment to 10 cm. Assuming that MODEST uncorrelated targets are breakup debris allows for the extension of the debris survey data to smaller sizes with the NASA Standard Breakup model. Each orbit within the total resulting GEO population is marked by a random argument of perigee and nearly constant mean anomaly, eccentricity, inclination, and node over the nearly 3 years of observation. Lack of published references of past breakups in GEO is mitigated by the orbital propagation of MODEST extended data to 1995 (the beginning epoch of ORDEM2010). ♦

Honeycomb vs. Foam: Evaluating Potential Upgrades to ISS Module Shielding

S. J. RYAN, T. HEDMAN, AND E. L. CHRISTIANSEN

A series of 19 hypervelocity impact tests has been performed on ISS-representative structure walls to evaluate the effect on micrometeoroid and orbital debris (MMOD) protective capability caused by replacing honeycomb sandwich panel cores with metallic open-cell foam. In the experiments, secondary impacts on individual foam ligaments were found to raise the thermal state of projectile and bumper fragments, inducing break-up and melt at lower impact velocities

continued on page 12

Impact Sensor System
continued from page 10

than the baseline honeycomb configuration. A ballistic limit equation is derived for the foam-modified configuration and, in comparison with the honeycomb baseline, a performance increase of 3-15% at normal incidence was predicted. With increasing impact obliquity, the enhancement in protective capability provided by the modification is predicted to further increase. The reduction in penetration and failure risk posed by MMOD impacts is achieved by the foam-modified configuration without a significant decrease in mechanical or thermal performance, and with no additional weight. As such, it is considered a promising upgrade to MMOD. ♦

MEETING REPORTS

Advanced Maui Optical and Space Surveillance Technology (AMOS) Conference
1-4 September 2009, Maui, Hawaii, USA

The 2009 Advanced Maui Optical and Space Surveillance Technologies Conference was conducted from 1-4 September 2009 in Wailea, Maui. More than 600 participants interested in all aspects of space surveillance attended the conference. Thomas Schildknecht chaired the orbital debris session, which consisted of several papers and posters. The highlights follow.

Vladimir Agapov, from the Keldysh Institute of Applied Mathematics in Russia, provided an analysis of the situation in the GEO protected region. His talk involved the current state and population of the protected GEO region and the close encounters that have occurred between spacecraft. Also from the Keldysh Institute of Applied Mathematics in Russia, Igor Molotov presented a study of faint, deep space debris observations with the international scientific optical observation network (ISON). His presentation showed the many characteristics of ISON's different ground-based telescopes and the magnitude distribution, area-to mass distribution, and number of new fragments identified by this network. Thomas Kelecy, with Boeing LTS in Maui, presented an analysis of orbit prediction sensitivity to thermal emissions acceleration modeling for high area-to-mass ratio objects. The model involved the time-varying, area-to-mass calculation that leads to error and uncertainties in orbit determination and the need to include the Earth shadow and related thermal variations in orbit determination. Pat Seitzer, from the University of Michigan, gave a talk on photometric studies of GEO debris. The presentation showed filter measurements for multiple objects tracked using the two-telescope system at the Cerro Tololo Inter-American Observatory in Chile. Also presented was the first set of synchronous photometry filter data on a non-catalogued GEO object using the two-telescope system.

Thomas Schildknecht, from the University of Bern, discussed the reflectance spectra of space debris in GEO, focusing on high area-to-mass objects. He discussed the use of grisms (grating and prism technology) to acquire spectral data and showed comparisons of reflectance spectra with solar panels and multi-layered insulation materials taken in a laboratory. Heather Cowardin, with ESCG/Jacobs, presented an assessment of GEO orbital debris photometric properties derived from laboratory-based measurements. The data showed multiple laboratory targets with their associated lightcurves and blue-red color index as a function of rotation angle, as well as a preliminary correlation to material type using telescope photometry data.

There were three posters presented on orbital debris as well. Jason Kent, with the US Air Force, presented a poster on the space elevator, orbital debris, and space situational awareness. The paper addressed issues involved with building a carbon nanotube tether between Earth and the GEO environment, such as the need to detect 1 cm debris and larger, debris mitigation, and the result a collision with a piece of debris would cause to the tether. Carolin Früh, from the Astronomical Institute, University of Bern, Switzerland, showed a comparison of different methods of ephemeris retrieval for correlation of observations. Comparison with different orbital positions, from observed positions to the latest TLE files, varied on the order of 1 km and more. Toshifumi Yanagisawa, from the Japan Aerospace Exploration Agency (JAXA), displayed recent activities of JAXA's innovative technology center on space debris. He discussed the recent development of a technology that allows stacking optical data to detect faint orbital debris that would otherwise go undetected by optical telescopes or human inspection. ♦

Academy of Program/Project and Engineering Leadership (APPEL) Masters Forum 19
30 September – 2 October, 2009, San Francisco, California

NASA's Office of the Chief Engineer, through the Academy of Program/Project and Engineering Leadership (APPEL), sponsors semi-annual Masters Forums: highly interactive and informative 3-day events where project managers and engineers engage, share, and learn from fellow practitioners. The subject of the most recent Masters Forum, held in San Francisco during 30 September – 2 October, was green engineering. One of the topics of the forum was orbital debris.

Nicholas Johnson of the Orbital Debris Program Office made a presentation entitled "Preserving the Near-Earth Space Environment with Green Engineering and Options." Following a short summary of the historical growth of the orbital debris population and its effects on space vehicles, domestic and international orbital debris mitigation policies were addressed. Examples of how simple engineering designs and operational changes have curtailed the generation of new debris were described. Safety issues associated with the reentry of orbital debris were also covered. Finally, results from NASA's LEGEND model were shown to illustrate potential forecasts of the long-term satellite population with and without continued implementation of mitigation measures, including active removal of large resident space objects.

Orbital debris mitigation represents a significant success story in modifying both national and international behaviors essential to the sustainability of space operations for many years to come. ♦

SATELLITE BOX SCORE
(as of 30 Sept. 2009, as cataloged by the US SPACE SURVEILLANCE NETWORK)

Country/ Organization	Payloads	Rocket Bodies & Debris	Total
CHINA	80	3073	3153
CIS	1389	4176	5565
ESA	39	44	83
FRANCE	47	415	462
INDIA	39	132	171
JAPAN	115	73	188
USA	1121	3659	4780
OTHER	449	116	565
TOTAL	3279	11688	14967

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

Visit the NASA Orbital Debris Program Office Website

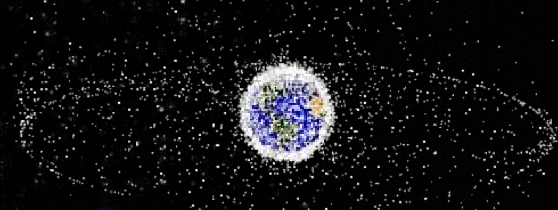
www.orbitaldebris.jsc.nasa.gov

INTERNATIONAL SPACE MISSIONS
01 July – 30 September 2009

International Designator	Payloads	Country/ Organization	Perigee Altitude (KM)	Apogee Altitude (KM)	Inclination (DEG)	Earth Orbital Rocket Bodies	Other Cataloged Debris
2009-035A	TERRESTAR-1	USA	35783	35790	5.9	1	0
2009-036A	COSMOS 2451	RUSSIA	1499	1507	82.5	1	0
2009-036B	COSMOS 2452	RUSSIA	1498	1506	82.5		
2009-036C	COSMOS 2453	RUSSIA	1496	1505	82.5		
2009-037A	RAZAKSAT	MALAYSIA	665	690	9.0	1	0
2009-038A	STS 127	USA	344	354	51.6	0	3
2009-038B	DRAGONSAT	USA	325	332	51.6		
2009-038E	ANDE POLLUX SPHERE	USA	327	332	51.6		
2009-038F	ANDE CASTOR SPHERE	USA	328	333	51.6		
2009-039A	COSMOS 2454	RUSSIA	918	944	83.0	1	0
2009-039B	STERKH	RUSSIA	917	944	83.0		
2009-040A	PROGRESS-M 67	RUSSIA	344	354	51.6	1	0
2009-041A	DEIMOS 1	SPAIN	635	677	98.1	1	2
2009-041B	DUBAISAT 1	UAE	666	682	98.1		
2009-041C	DMC 2	UK	625	677	98.1		
2009-041D	APRIZESAT 4	USA	607	677	98.1		
2009-041E	NANOSAT 1B	SPAIN	587	677	98.1		
2009-041F	APRIZESAT 3	USA	566	677	98.1		
2009-042A	ASIASAT 5	ASIASAT CORP	35778	35795	0.0	1	1
2009-043A	NAVSTAR 64 (USA 206)	USA	20142	20220	55.1	2	0
2009-044A	JCSAT 12	JAPAN	35780	35794	0.0	1	1
2009-044B	OPTUS D3	AUSTRALIA	35775	35797	0.0		
2009-045A	STS 128	USA	344	354	51.6	0	0
2009-046A	PALAPA D	INDONESIA	35780	35793	0.1	1	1
2009-047A	USA 207	USA	NO ELEMS. AVAILABLE			1	0
2009-048A	HTV-1	JAPAN	344	354	51.6	1	2
2009-049A	METEOR-M	RUSSIA	817	821	98.8	1	0
2009-049B	STERKH 2	RUSSIA	815	820	98.8		
2009-049C	FREGAT/IRIS	RUSSIA	491	504	97.4		
2009-049D	TATIANA 2	RUSSIA	815	822	98.8		
2009-049E	UGATUSAT	RUSSIA	815	823	98.8		
2009-049F	SUMBANDILA	SOUTHAFRICA	490	504	97.4		
2009-049G	BLITS	RUSSIA	817	823	98.8		
2009-050A	NIMIQ 5	CANADA	35775	35788	0.0	1	1
2009-051A	OCEANSAT 2	INDIA	722	726	98.3	1	0
2009-051B?	BEESAT	GERMANY	714	723	98.3		
2009-051C?	UWE-2	GERMANY	713	721	98.3		
2009-051D?	ITUpSAT	TURKEY	713	720	98.3		
2009-051E?	SWISSCUBE	SWITZERLAND	714	724	98.3		
2009-051F	PSLV/RUBIN 9.1/9.2	GERMANY	716	795	98.3		
2009-052A	STSS DEMO 1 (USA 208)	USA	NO ELEMS. AVAILABLE			1	0
2009-052B	STSS DEMO 2 (USA 209)	USA	NO ELEMS. AVAILABLE				
2009-053A	SOYUZ-TMA 16	RUSSIA	344	354	51.6	1	0

International Conference on Orbital Debris Removal

December 8-10, 2009



Chantilly, Virginia
USA

Numerous fora have been held in the past to discuss issues related to orbital debris. However, this first of its kind conference, co-hosted by the National Aeronautics and Space Administration (NASA) and the Defense Advanced Research Projects Agency (DARPA), will bring government and industry together to address the issues and challenges involved with removing manmade orbital debris from Earth orbit.

Registration

Register on-line prior to November 23, 2009 at

https://www.enstg.com/signup. Enter code: INT11415

A $300 (USD) conference fee applies. Registration includes:

- Attendance at the two-and-a-half day conference
- Continental breakfast each morning
- Luncheons Tuesday & Wednesday

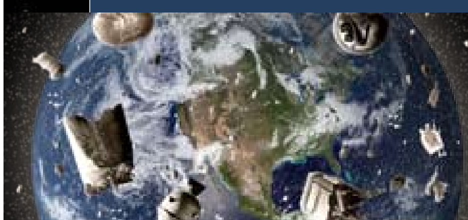
Hotel reservations can be made at the conference location while rooms last:

Westfields Marriott
14750 Conference Center Drive
Chantilly, VA 20151
Phone: 800-635-5666 (Reference: Orbital Debris Removal)
Or online at: **http://www.westfieldsmarriott.com**
Group code: CODCODA

Room rate for conference attendees is $149 (USD).

Call for Presentations

Attendees wishing to present an appropriate technical or scholarly briefing consistent with the conference topics may submit a 250 word abstract in English via e-mail to the selection committee at: orbitaldebrisconference@darpa.mil. Submissions must be received by October 30, 2009, and include a title and the author's name and affiliation. If your abstract is selected for presentation you will be asked to submit a full presentation prior to November 30, 2009.



The Growing Risk from Orbital Debris

Since the advent of the space age, more than thirty-five thousand man-made objects have been cataloged by the U.S. Space Surveillance Network. Nearly fifteen thousand of those objects remain in orbit today, ninety-four percent of which are non-functioning orbital debris. These figures do not include the hundreds of thousands of objects too small to be cataloged, but still large enough to pose a threat to operational satellites in orbit around the Earth. In addition, collisions between orbital objects could potentially lead to a continuously growing debris population, thus further increasing the risk to operational satellites.

For several years space-faring nations have recognized the mounting risk posed by orbital debris. Mitigation measures to minimize the generation of debris, such as limiting debris released during normal operations, minimizing the potential for on-orbit breakups, and planning for post mission disposal, have been adopted by many countries in an attempt to slow the growth of the orbital debris population, with some success. However, current analysis and two recent, significant debris-generating events indicate that debris mitigation alone will not be sufficient to prevent continued growth of the debris population.

Several studies and lab experiments on debris removal have been conducted over the past several years. However, only now have technology and an operational imperative come together to make debris removal a realistic international objective.

International Conference on Orbital Debris Removal

December 8-10, 2009

Location: Westfields Marriott, Chantilly, VA, USA. Conveniently located just 8 miles (13 km) from Washington Dulles International Airport (IAD).

Topics: Topics covered during the two-and-a-half day conference will include:

- Understanding the orbital debris problem, including growth projections and risk assessments
- Debris tracking
- Ground-based removal concepts and technologies
- Small debris (fragments) removal concepts and technologies
- Large debris (spacecraft and rocket bodies) removal concepts and technologies
- Solutions appropriate for Low Earth Orbit (LEO)
- Solutions appropriate for Geostationary Earth Orbit (GEO)
- International policy and cooperation requirements
- Safety issues and other risks
- Legal and economic issues – constraints and incentives

Keynote Speakers: **Bryan O'Connor**, NASA's Chief of Safety and Mission Assurance (confirmed) and **Nicholas Johnson**, NASA's Chief Scientist for Orbital Debris (confirmed), will provide NASA's perspective on debris removal. **Heiner Klinkrad**, head of the European Space Operations Centre's Space Debris Office (confirmed) will provide ESA's perspective on orbital debris.

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

www.nasa.gov