National Aeronautics and Space Administration

Orbital Debris Quarterly News

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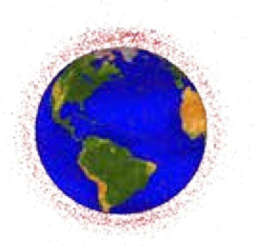
Inside...



A publication of
the NASA Orbital
Debris Program Office

U.S. Launch Vehicle Components Land in Africa

On 14 July, a 38-year-old Delta 1 stage reentered the atmosphere over the Atlantic Ocean and scattered debris across Zimbabwe. Fortunately, no person was injured, and no property damage was reported.

The second stage of the Delta 1 launch vehicle (International Designator 1975-077B, U.S. Satellite Number 08133) was part of a mission to place the Franco-German Symphonie 2 satellite into a geosynchronous transfer orbit. The stage, with a dry mass in excess of 800 kg, was left in an orbit of 410 km by 2020 km, which slowly decayed. The influence of the 11-year solar cycle can be seen in the stair-step decrease of apogee in Figure 1.

As reentry of the stage neared, the U.S. Space Surveillance Network increased tracking and issued predictions for a time and location. Atmospheric interface occurred while the stage was traveling high over the Atlantic Ocean near the equator at about 0600 GMT, 14 July. The intense heating and deceleration forces broke the stage apart with most components burning up completely.

However, the large propellant tank and at least two much smaller spheres continued along the stage's trajectory, surviving to impact in Zimbabwe to the south and southwest of the capital city of Harare (Figures 2 and 3).

Prior to this reentry, 33 other spacecraft and rocket bodies and nearly 200 other debris had already fallen back to Earth in an uncontrolled manner during 2013. In all of 2012, more than 400 uncontrolled reentries, accounting for a total mass in excess of 100 metric tons, were recorded.

Normally, these objects do not possess components which are capable of reaching the surface of the planet, and those components which do survive usually land in an ocean or a sparsely populated region. Since the first satellite reentry in 1957, more than 20,000 cataloged objects have reentered uncontrollably without a single confirmed injury. On average, only about one reentry a year results in the recovery of an identifiable fragment. ♦

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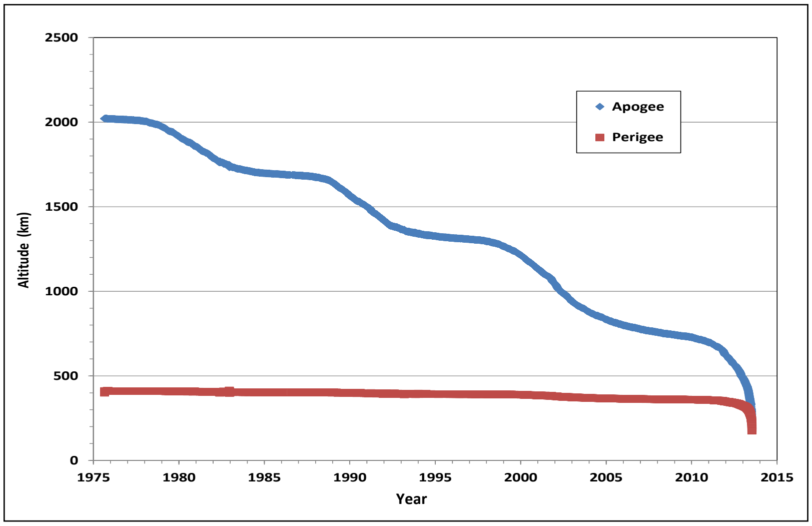

Figure 1. Orbital decay of Delta 1 stage, U.S. Satellite Number 08133.

Components Land in Africa

continued from page 1

Figure 2. After the Delta 1 second stage reentered the atmosphere over the Atlantic Ocean, it broke apart with pieces falling in Zimbabwe.

Figure 3. The propellant tank of the Delta 1 second stage in Zimbabwe. Photo Credit: NewsdezeZimbabwe.

Agencies Place Two U.S. Earth Observation Satellites in Compliant Disposal Orbits

During June - August the U.S. Geological Survey (USGS) and the National Oceanic and Atmospheric Administration (NOAA) each retired long-serving Earth observation spacecraft, one operating in low Earth orbit (LEO) and one with a mission in geosynchronous orbit (GEO). The pair of satellites, both developed and launched by NASA, were maneuvered into disposal orbits compliant with U.S. and international guidelines.

Launched on 1 March 1984, Landsat 5 (International Designator 1984-021A, U.S. Satellite Number 14780) provided more than 2.5 million images of the planet for nearly 29 years. Following the transmission of its final image on 6 January 2013, the spacecraft began a 5-month decommissioning process. The first phase occurred during 15-23 January when the USGS commanded Landsat 5 to execute two maneuvers, lowering its orbit about 25 km from a height of 705 km. This maneuver ensured that the spacecraft could not interfere with an international flotilla of Earth observation vehicles operating at its former altitude.

Before Landsat 5, with a dry mass of 1400 kg, could be formally decommissioned and turned-off, the spacecraft had to be passivated, *i.e.*, all sources of energy that might lead to a future explosion had to be expended or released. Beginning in mid-April, Landsat 5 began a series of maneuvers to burn residual propellant, lowering the perigee of its orbit with each firing (see figure). By late May, all propellants had been depleted, and the spacecraft was in an orbit of 540 km by 675 km. Equally important, the remaining orbital lifetime of Landsat 5 had been reduced from several decades to less than 25 years, the maximum recommended time for a disposal in LEO. By lowering perigee only in phase 2 instead of seeking a lower circular orbit, the

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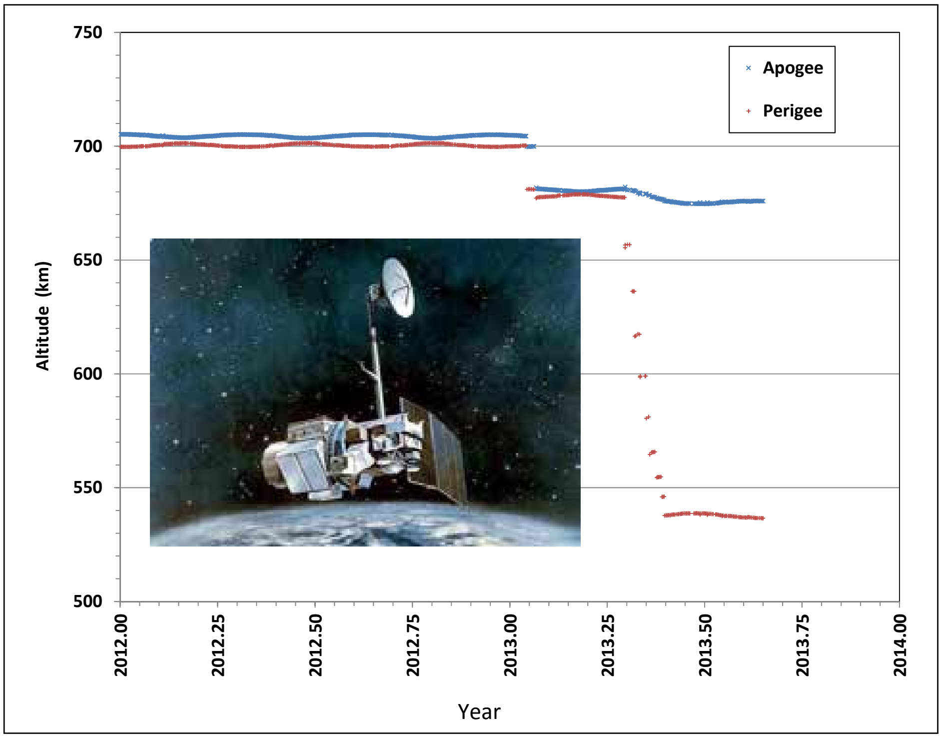

The disposal of Landsat 5 was conducted over a multi-month span.

Earth Observation Satellites

continued from page 2

residual time in Earth orbit was minimized.

After more than 10 years of service providing critical meteorological data, NOAA's GOES 12 spacecraft (International Designator 2001-031A, U.S. Satellite Number 26871) was decommissioned in August 2013. In accordance with long-standing recommendations for the disposal of GEO spacecraft, the 1-metric-ton spacecraft maneuvered into a disposal orbit ranging from 305 km to 340 km above GEO. Removal of spacecraft from the operational geosynchronous region (GEO +/- 200 km) eliminates the possibility of a future collision with other resident GEO space objects and the subsequent creation of new, long-lived orbital debris. Following the disposal maneuvers, GOES 12 was passivated. ♦

West Ford Needles: Where are They Now?

Fifty years ago, the U.S. attempted to create a short-lived band of hundreds of millions of tiny wires about the Earth to test passive communications techniques. Communications satellites quickly obviated the need for such concepts, but some remnants of the two test missions remain today.

Under the name Project West Ford, two Atlas Agena launch vehicles – one on 21 October 1961 and one on 9 May 1963 – carried special canisters of densely packaged, very thin wires to act as dipole reflectors of X-band transmissions. The first mission (International Designator 1961-28, U.S. Satellite Number 00192) reached its intended orbit of approximately 3500 km by 3750 km with an inclination of 95.9 degrees, but due to design characteristics and unanticipated thermal effects, the dipoles did not dispense individually. Eventually, only seven small debris (0.06 - 0.6 m^2 radar cross-section), which are believed to be associated with the experiment, were cataloged by the U.S. Space Surveillance Network (SSN). All are still in orbit.

The second Project West Ford mission (International Designator 1963-14, U.S. Satellite Number 00574) was partially successful and released an estimated 120-215 million copper wires (aka needles) with a length of 1.8 cm and a diameter of only 0.00178 cm (Figure 1) into an initial orbit of 3600 km by 3680 km with an inclination of 87.4 degrees [1]. The orbit and design of the individual needles were chosen to promote rapid orbital decay and reentry into the atmosphere. These needles are believed to have reentered within a few years, largely due to solar radiation pressure effects. The individual needles could not be detected and tracked by the SSN.

During 1963 four additional debris with radar cross-sections ranging from about 0.5 to 1.0 m^2 were cataloged. These are likely the four main dispenser subunits. However, since 1966 the SSN has cataloged 144 small objects associated with the second Project West Ford experiment (two additional objects called "Westford Needles" are assessed to be from a different mission and are miscataloged). A post-mission investigation concluded that only 25-45% of the planned 480 million dipoles dispersed properly. The others were believed to have remained in clumps, which were later discovered by the SSN.

Although still strongly affected by solar radiation pressure, these clumps did not decay as rapidly as the individual needles (Figure 2). Today, 46 clumps remain in Earth orbit (Figure 3). Only nine of the clumps are currently in orbits with perigees below 2000 km.

However, the story does not end there. Since 1989, NASA's Orbital Debris Program Office has been working with the Jet Propulsion Laboratory to detect debris as small as 2-3 mm in low Earth orbit using the 70-m Goldstone radiotelescope and

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Figure 1. The West Ford Needles were individually small, but in a large group they possessed useful radar reflective qualities. For scale, compare the needle sizes in relation to the postage stamp (enlarged to show detail).

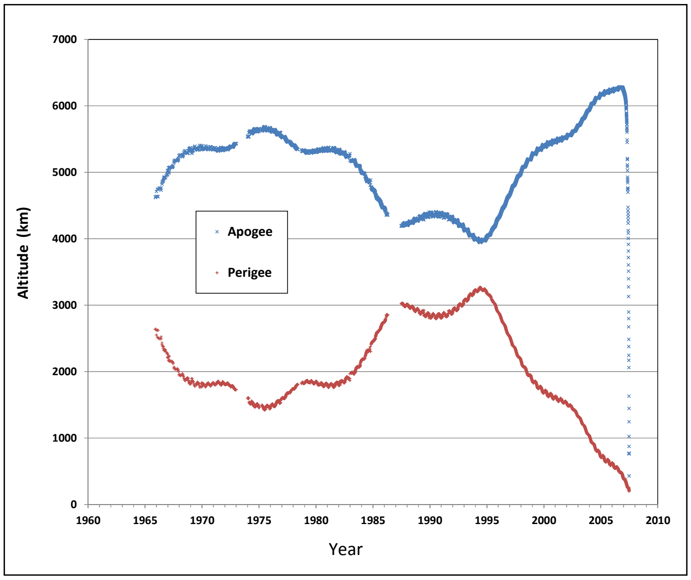

Figure 2. One of the best tracked debris from the second Project West Ford mission was U.S. Satellite Number 02360, which finally reentered in 2007. Solar radiation pressure was responsible for wide fluctuations in orbital eccentricity, as evidenced by the change in apogee and perigee heights.

West Ford Needles

continued from page 3

a nearby smaller dish radar. Data collected during observations in the mid-1990s suggest that a moderate population of small debris resides in orbits above 2500 km. It has been suggested that these debris represent small clumps of needles from the first Project West Ford mission in 1961 [2].

The legacy of Project West Ford can still be found in international policies, including the first major United Nations accord on activities in outer space that calls for international consultations before undertaking an experiment which might cause "potentially harmful interference with activities of other State Parties in the peaceful exploration and use of outer space" [3]. Following the failed first Project West Ford mission, the Committee on Space Research (COSPAR) of the International Council of Scientific Unions (ICSU) established the Consultative Group of Potentially Harmful Effects of Space Experiments. That group evolved into today's Panel on Potentially Environmentally Detrimental Activities in Space (PEDAS), which is the home of COSPAR discussions on orbital debris.

<u>References</u>

1. Waldron, P., *et al.*, "The West Ford Payload", *Proceedings of the IEEE*, May 1964, pp. 571-576.

2. Matney, M., et al., "Recent Results from Goldstone Orbital Debris Radar", Advances in Space Research, Vol. 23, No. 1, 1999, pp. 5-12.

3. *Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and other Celestial Bodies*, United Nations, 1967. ♦

Figure 3. Today only 46 clumps of Project West Ford needles are known to be in orbit. Their orbits are illustrated with this simulated graphic.

PROJECT REVIEW

NASA Develops Report on Radar Observations of Small Debris Populations

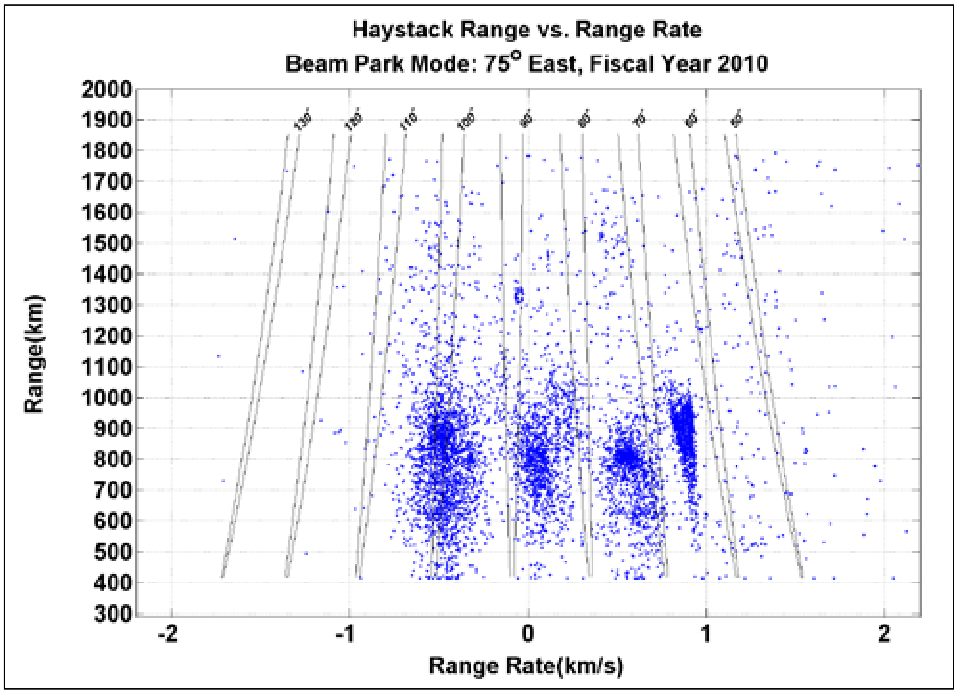

Figure 1. Distribution of Haystack detections over FY 2010 with overlay of circular orbit predictions at 10° increments of inclination.

J. HAMILTON

The Haystack radar, operated by the Massachusetts Institute of Technology Lincoln Laboratory (MIT/LL), has been collecting orbital debris data for the NASA Orbital Debris Program Office (ODPO) since 1990 under an agreement with the U.S. Department of Defense. The NASA ODPO also receives data from the Haystack Auxiliary Radar (HAX) located next to the main Haystack antenna. Both radars operate in a stare mode designed to statistically sample objects in low Earth orbit (LEO) that are smaller than those typically tracked and cataloged by the U.S. Space Surveillance Network (SSN).

Each radar is typically pointed East in azimuth (90°) and at 75° elevation from the local horizon. Since the radars are located at 42.6° latitude, this allows objects with orbital inclinations between 43° and 137° to pass across the beam. The small offset from vertical allows analysts to estimate orbital parameters using a combination of range and range-

continued on page 5

Radar Report

continued from page 4

rate data with only a small decrease in radar detection sensitivity. By staring to the south (180° azimuth) at elevations as low as 10°, the radars can sample lower inclination orbits with the penalty of lower sensitivity due to a longer slant range for a given orbital altitude.

Annually, the MIT/LL collects approximately 1000 hours of debris radar data at random times throughout the year, not including special surveys. The NASA ODPO processes this data and the results are used to improve models that estimate the risk to spacecraft. The MIT/LL's large dish antennae generate narrow beams that are very sensitive but cover a small region of space at any given time. Hundreds of hours are necessary to observe enough objects to reliably measure the small object population for statistical analysis. Although less sensitive than Haystack, the HAX radar operates at a different wavelength (1.8 cm for HAX versus 3 cm for Haystack) and has a wider beam. Normally, data collection would be split between the two radars with 600 hours from Haystack and 400 hours from HAX. When the Haystack radar became unavailable for debris data collection in May 2010, the MIT/LL increased observation hours on HAX to compensate. The Haystack radar is expected to resume debris observations in early 2014.

A report, soon to be published by the NASA ODPO, will cover results from fiscal year (FY) 2006 through FY 2012. Over that period, many events happened that changed the orbital debris environment. Over 1250 payloads, rocket bodies, and operational debris objects were launched worldwide into altitudes less than 2000 km (excluding shuttle and supply vehicles), throwing over 1530 metric-tons of material into LEO or LEO-crossing orbits. An estimated 912 tons of material de-orbited due to drag from the upper atmosphere. More than 40 fragmentations left thousands of cataloged pieces in orbits threatening operational spacecraft in LEO. One of those events was a Chinese anti-satellite test in 2007, which left many pieces of debris throughout LEO (ODQN, April 2007, pp. 2-3; ODQN, January 2013, pp. 4-5). Another major debris-generating event occurred in 2009 when an inactive Russian communication satellite, Cosmos-2251 (International Designator 1993-036A, U.S. Satellite Number 22675), collided with an active U. S. commercial communication satellite, Iridium-33 (International Designator 1997-051C, U.S. Satellite Number 24946), at an altitude of 790 km (ODQN, April 2007, pp. 2-3; ODQN, January 2013, pp. 4-5). The dynamic nature of the environment requires continual monitoring. Also, changes to the radars must be accounted for, including failures that degraded performance and maintenance/upgrades that improved performance.

The upcoming report will include descriptions of the radars, the amount of data collected, and explanations of how the data was processed, calibrated, and validated. The data will be presented in plots and tables allowing for easy year-to-year comparisons. There will be a chapter using parameters in radar-centric terms such as range, range-rate, and radar cross-section (RCS). Figure 1 is a sample of information from the radar-centric chapter, while the table summarizes the observations of each radar. Another chapter will translate those parameters into potentially more useful terms such as detection altitude, orbital inclination, characteristic size, and surface area flux. Surface area flux is a calculated value based on the number of detections, divided by the surface area of the radar beam over an altitude range and divided by the amount of observation time.

Figure 2 shows how surface area flux varies vs. the characteristic size of the detected objects, along with the approximate roll-off in cumulative flux due to the sensitivity of the radar. It is important to remember that these observations are statistical samples that feed models. Although trends are evident in the observations, the real value of the data is in how it allows us to characterize entire populations from the observation samples. ♦

Collection Hours and Number of Detections by Radar

Fiscal Year	HAX Hours of Observation	HAX Number of Detections	Haystack Hours of Observation	Haystack Number of Detections
2006	540	819	350	3304
2007	666	989	401	4249
2008	440	988	332	5272
2009	397	931	547	6959
2010	445	973	657	6368
2011	717	1512	*No Data*	*No Data*
2012	1011	1734	*No Data*	*No Data*

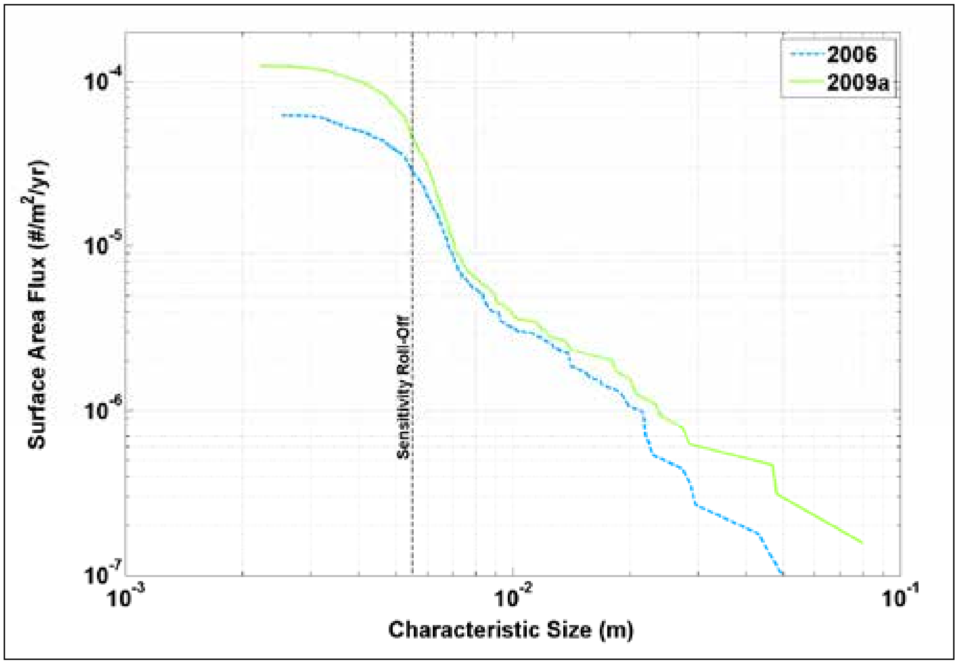

Figure 2. A comparison of surface area flux from an altitude of 800 to 900 km vs. the characteristic size of objects measured by the Haystack radar, with the approximate roll-off below 5 mm due to sensitivity.

ABSTRACTS FROM THE NASA ORBITAL DEBRIS PROGRAM OFFICE

The 14th Advanced Maui Optical and Space Surveillance (AMOS) Technologies Conference
10-13 September 2013, Maui, Hawaii

Observations of Titan IIIC Transtage fragmentation debris

H. COWARDIN, P.SEITZER,
K. ABERCROMBY, E. BARKER,
B. BUCKALEW, T. CARDONA,
P. KRISKO, S. LEDERER

The fragmentation of a Titan IIIC Transtage (1968-081) on 21 February 1992 is one of only two known break-ups in or near geosynchronous orbit. The original rocket body and 24 pieces of debris are currently being tracked by the U. S. Space Surveillance Network (SSN). The rocket body (SSN# 3432) and several of the original fragments (SSN# 25000, 25001, 30000, and 33511) were observed in survey mode during 2004-2010 using the 0.6m Michigan Orbital DEbris Survey Telescope (MODEST) in Chile using a broad R filter. This paper presents a size distribution for all calibrated magnitude data acquired on MODEST. Size distribution plots are also shown using historical models for small fragmentation debris (down to 10 cm) thought to be associated with the Titan Transtage break-up.

In November 2010, visible broadband photometry (Johnson/Kron-Cousins BVRI) was acquired with the 0.9m Small and Moderate Aperture Research Telescope System (SMARTS) at the Cerro Tololo Inter-American Observatory (CTIO) in Chile on several Titan fragments (SSN# 25001, 33509, and 33510) and the parent rocket body (SSN# 3432). Color index data are used to determine the fragment brightness distribution and how the data compares to spacecraft materials measured in the laboratory using similar photometric measurement techniques.

In order to better characterize the break-up fragments, spectral measurements were acquired on three Titan fragments (one fragment observed over two different time periods) using the 6.5-m Magellan telescopes at Las Campanas Observatory in Chile. The telescopic spectra of SSN# 25000 (May 2012 and January 2013), SSN# 38690, and SSN# 38699 are compared with laboratory acquired spectra of materials (e.g., aluminum and various paints) to determine the surface material. ♦

The NASA Meter Class Autonomous Telescope: Ascension Island

S. LEDERER, E. STANSBERY,
H. COWARDIN, P. KERVIN, AND
P. HICKSON

The Meter Class Autonomous Telescope (MCAT) is the newest optical sensor dedicated to NASA's mission to characterize the space debris environment. It is the successor to a series of optical telescopes developed and operated by the JSC Orbital Debris Program Office (ODPO) to monitor and assess the debris environment in (1) Low Earth Orbit (LEO), (2) Medium Earth Orbit (MEO), and (3) Geosynchronous Orbit (GEO), with emphasis on LEO and GEO altitudes.

A joint NASA-Air Force Research Labs project, MCAT is a 1.3 m optical telescope dedicated to debris research. Its optical path and sensor yield a large survey fence at the cutting edge of current detector performance. It has four primary operational observing modes, two of which were not computationally feasible a decade ago. Operations are supported by a sophisticated software suite that monitors clouds and weather conditions, and controls everything from data collection to dome rotation to processing tens of GB of imagery data nightly. With fainter detection limits, precision detection, acquisition and tracking of targets, multi-color photometry, precision astrometry, automated re-acquisition capability, and the ability to process all data at the acquisition rate, MCAT is capable of producing and processing a volume and quality of data far in excess of any current (or prior) ODPO operations. This means higher fidelity population inputs and eliminating the multi-year backlog from acquisition-to-product typical of optical campaigns. All of this is possible given a suitable observing location.

Originally planned for the island of Legan, part of the Kwajalein Atoll Islands, recent developments have led to a change in venue. Specifically, the Ground-based Electro-Optical Deep Space Surveillance, or GEODSS, System of telescopes is the United States' major tracking system for deep space. This network consists of telescopes in Maui, Hawaii; Diego Garcia (Indian Ocean), and Socorro, New Mexico. A fourth optical telescope, though smaller in size, has been operating in conjunction with this effort until recently in Mòron, Spain. With the Mòron site closing, a significant gap in longitude exists between the New Mexico and Diego Garcia sites. This longitudinal gap is well covered by placing a telescope on Ascension Island (7° 58′20” S, 14° 24′ 4”W), in the Atlantic Ocean.

Ascension Island offers the benefits of both location and weather. The near equatorial location affords the opportunity to access under-sampled low-inclination orbits and new GEO longitudes, while simultaneously filling in the GEODSS longitudinal gap. Ascension Island is a volcanic, desert island, receiving only 7″ of rain per year on average. With consistent trade winds blowing from the SSE direction off Africa, the combination of an island location with consistent winds will create the smooth laminar flow sought after by all astronomical sites, which creates stable atmospheric ('seeing') conditions. Finally, this low population island has minimal lighting, resulting in very dark skies, ideal for an observatory. ♦

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

The NASA Orbital Debris Test Populations for the U.S. Air Force Space Fence

P. KRISKO AND A. VAVRIN

The United States Air Force Space Fence is due to begin operation by the end this decade and to be fully capable within the next. The radar system will operate in the S-band frequency range and will detect orbiting objects larger than about 2 cm in Low Earth Orbit to Medium Earth Orbit. One of its duties will be to observe orbital debris in those regions. The NASA Orbital Debris Program Office has created a high fidelity test population of the debris environment of 1 cm and larger in Low Earth Orbit through Geosynchronous Transfer Orbit for the purpose of assisting radar developers in planning and testing of the S-band system. This environment is derived directly from the newest ORDEM model populations which include a background derived from LEGEND, as well as specific events such as the Chinese ASAT test, the Iridium 33/Cosmos 2251 accidental collision, the RORSAT sodium-potassium droplet releases, and other miscellaneous events. It is the most realistic ODPO debris population to date.

In this paper we present the populations in chart form. We describe specific derivations and provide the validation via known and highly used sensor systems. ♦

An Update on the Effectiveness of Postmission Disposal in LEO

J.-C. LIOU AND P. KRISKO

The commonly-adopted orbital debris mitigation measures were developed to reduce the growth of the future debris population. A major component in debris mitigation is postmission disposal (PMD). The key PMD element for LEO satellites is the 25-year rule. It is intended to limit the long-term presence of rocket bodies (R/Bs) and spacecraft (S/C), as well as mission-related debris, in the environment. The effectiveness of PMD has been demonstrated and documented since the development of mitigation measures began in the 1990s. This paper summarizes an updated study, based on the current environment, using the NASA LEGEND model.

The study focused on the ≥10 cm population in LEO. The historical simulation covered 1957 through 2011 and followed the recorded launches and known breakup events. The future projection was carried out for 200 years. An eight-year launch traffic, 2004 – 2011, was repeated during the projection period. An eight-year mission lifetime was assumed for future S/C. No stationkeeping and no collision avoidance maneuvers were implemented. Only objects 10 cm and larger were included in collision consideration. No explosion was allowed for R/Bs and S/C launched after 2011. The 25-year PMD rule success rates were set at 0%, 10%, 50%, 75%, and 95%, respectively, for the 5 study scenarios.

Results of the simulations were analyzed to quantify the differences among the different compliance rates. As expected, the 0% PMD projection followed a rapid and non-linear increase in the next 200 years. The LEO population, on average, more than tripled at the end of the simulations. With a 50% compliance of the 25-year rule, the population growth was reduced approximately by half. However, even with a 95% compliance of the 25-year rule, the LEO debris population would still increase by an average of more than 50% in 200 years. These simulation results provide an updated assessment of the effectiveness of the 25-year rule. It is the first and the most cost-effective defense against future population growth. In addition, the results also confirm the instability of the LEO population and lay the foundation for the need to consider environment remediation in the future. ♦

An Electric Propulsion “Shepherd” for Active Debris Removal that Utilizes Ambient Gas as Propellant

M. MATNEY

There is a growing consensus among the space debris technical community that limiting the long-term growth of debris in Low-Earth Orbit (LEO) requires that space users limit the accumulation of mass in orbit. This is partially accomplished by mitigation measures for current and future LEO systems, but there is now interest in removing mass that has already accumulated in LEO from more than 50 years of space activity (termed “Active Debris Removal”, or ADR).

Many ADR proposals face complex technical issues of how to grapple with uncooperative targets. Some researchers have suggested the use of conventional ion thrusters to gently “blow” on objects to gradually change their orbits, without ever having to come into physical contact with the target. The chief drawback with these methods is the cost per object removed. Typically, a space “tug” or an ion-drive “shepherd” can only remove a few objects per mission due to limited propellant. Unless a cost-effective way that removes tens of objects per mission can be found, it is not clear that any of the ideas so far proposed will be economically viable.

In this paper, a modified version of the ion-drive “shepherd” is proposed that uses ambient atmospheric gases in LEO as propellant for the ion drives. This method has the potential to greatly extend the operational lifetime of an ADR mission, as the only mission limit is the lifetime of the components of the satellite itself, not on its fuel supply.

An ambient-gas ion-drive “shepherd” would enhance the local atmospheric drag on an object by ionizing and accelerating the ambient gas the target would have encountered anyway, thereby hastening its decay. Also, the “shepherd” satellite itself has a great deal of flexibility to maneuver back to high altitude and rendezvous with its next target using the ion drive not limited by fuel supply. However,

continued on page 8

Electric Propulsion

continued from page 7

the amount of available ambient gas is closely tied to the altitude of the spacecraft. It may be possible to use a "hybrid" approach that supplements high-altitude ion-drive operations with stored gas, and transitions to ambient gas at lower altitudes.

This paper will include realistic numbers on the estimated times needed to deorbit objects from different orbit regimes using drives that either partially or completely take advantage of ambient gas. It will conclude with recommendations on whether this is a viable candidate for future ADR efforts. ♦

Optical Reflection Spectroscopy of GEO Objects

P. SEITZER, T. CARDONA, S. LEDERER,
H. COWARDIN, K. ABERCROMBY,
E. BARKER, D. BÉDARD

We report on optical reflection spectroscopy of geosynchronous (GEO) objects in the US Space Surveillance Network (SSN) catalog. These observations were obtained using imaging spectrographs on the 6.5-m Magellan telescopes at the Las Campanas Observatory in Chile. Our goal is to determine the composition of these objects by comparing these spectral observations with ground-based laboratory measurements of spacecraft materials.

The observations are all low resolution (1 nm after smoothing) obtained through a 5 arc-second wide slit and using a grism as the dispersing element. The spectral range covered was from 450 nm to 800 nm. All spectra were flux calibrated using observations of standard stars with the exact same instrumental setup. An effort was made to obtain all observations within a limited range of topocentric phase angle, although the solar incident angle is unknown due to the lack of any knowledge of the attitude of the observed surface at the time of observation.

To date spectral observations of 13 GEO objects have been obtained on Magellan. We concentrated on pieces cataloged as debris in the SSN catalog, along with objects whose characteristics were known prior to launch:

- 5 pieces of debris from the Titan Transtage 3C-4 (1968-081) breakup in 1992: SSN 25000, 38690, 38691, 38699, and 38705.
- 4 other pieces of GEO debris: SSN 08832, 12996, 13753, and 29014
- 1 piece of GEO debris whose pre-launch characteristics are known: SSN 29106, the MSG2 Cooler Cover.
- 3 Initial Defense Communications Satellite Program (IDCSP) satellites whose original surfaces were very simple (solar cells) and known prior to launch: SSN 02653, 02655, and 03287.

Preliminary comparisons have not shown a high correlation between telescopic and laboratory data, with the exception of a few objects. This paper will report on other factors that may skew the results for comparisons and what future work needs to be addressed. ♦

CONFERENCE AND MEETING REPORTS

The 14th Advanced Maui Optical and Space Surveillance Technologies Conference (AMOS)
10-13 September 2013, Maui, Hawaii

The 14th annual Advanced Maui Optical and Space Surveillance Technologies Conference was held 10-13 September. Representatives from 13 countries registered and the conference had the largest abstract submission to date (~130 submissions). Due to budgetary cutbacks, attendance by NASA, Air Force, and other U.S. government officials was severely limited. The first keynote speaker for the event was the commander of Air Force Space Command, General William Shelton, who attended via teleconference due to sequestration. Financial strains and the loss of talent among government entities was a key topic. Collision avoidance, small object detection, and the need to better maintain the Joint Space Operations Center (JSpOC) database was also addressed. Although the Air Force Space Surveillance System, a line of very high frequency radars across the southern United States, was officially closed as of 1 September, Eglin and Cavalier had modified their tracking modes to fill the gap. The new Space Fence will be deployed on Kwajalein and is currently scheduled for calendar year 2018. The second keynote speaker was Douglas Loverro, Deputy Assistant Secretary of Defense for Space Policy, U.S. Department of Defense. Space Situational Awareness (SSA) was briefly discussed, but the focus was on the space policy, specifically how space is governed by the "3 C's": Congested, Competitive, and Contested.

Nine papers were presented during the Orbital Debris session; Dr. Thomas Schildknecht was the session chair. Dr. Heather Cowardin presented results and analysis of observed Titan IIIC fragmentation debris. Other papers in the session included theory on what happened to BLITS, satellite conjunction with debris population, modifying orbital debris orbits using lasers for collision avoidance, using the LaPlace plane as a stable disposal orbit, SSA to support commercial GEO satellite operators, and two papers on space object taxonomy. Dr. Sue Lederer presented a poster discussing NASA's Meter Class Autonomous Telescope.

In addition, other sessions of the conference had orbital debris-relevant talks, particularly in the Non-Resolved Optical Characterization session. Los Alamos National Laboratory presented photometric data from non-resolved objects for space object

continued on page 9

AMOS

continued from page 8

characterization and improved atmospheric modeling. New Mexico Tech University presented a paper on unmixing space object's moderate resolution spectra using the AFRL's Time-domain Analysis Simulation for Advanced Tracking (TASAT) material database.

A panel was held to discuss international SSA Technical Initiatives lead by Lt Col Travis Blake of DARPA and included the following members: Dr. Lauchie Scott (DRDC Ottawa), GPCAPT Cofin Thompson (Australia Royal Air Force), Dr. Thomas Schildknecht (Astronomical Institute at the University of Bern), Dr. Moriba Jah (AFRL), Mr. Richard Tremayne-Smith (Out of Space, UK), Dr. Susumu Yoshitomi (Japan Space Forum). In the space-based assets session, Novarum Tech presented comparative work between NASA ORDEM and ESA MASTER, discussing the need to better understand the uncatalogued debris (small debris) population.

Additional sidebar meetings discussed present and future collaborations. ♦

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

Space debris was a major topic at the 2013 meeting of the International Astronautical Congress (IAC), held in Beijing, China. The longstanding Space Debris Symposium, organized by the International Academy of Astronautics (IAA), hosted a record eight half-day sessions, including 56 oral presentations and over 30 posters. The symposium topics covered the standard debris detection, characterization, and measurements; modeling and risk analysis; hypervelocity impacts; mitigation and standards. New to the symposium were two Active Debris Removal (ADR) sessions, "Issues" and "Concepts"; a session on "Operations in the Space Debris Environment," "Situational Awareness," and "Political, Legal, Institutional and Economic Aspects of Space Debris Mitigation and Removal."

Significant progress was reported in several areas. For example, the International Scientific Optical Network (ISON), a group of small observatories, is expanding toward full longitudinal coverage and beginning the independent cataloging of GEO objects. In modeling, significant upgrades to several tools were reported: ESA DRAMA, CNES STELA, and NASA ORDEM. The ADR concepts, such as throw-nets and tethers for robust space debris capture, have moved past the conceptual and cartoon phase to physical simulation. Also, the subject of the use of CubeSats appeared during presentations, posters, and discussions in the exhibit area. ♦

UPCOMING MEETING

2-10 August 2014: The 40th COSPAR Scientific Assembly, Moscow, Russia

The main theme of the Panel on Potentially Environmentally Detrimental Activities in Space (PEDAS) for the 40th COSPAR is "Space Debris – Responding to a Dynamic Environment." The PEDAS sessions will cover areas such as advances in ground- and space-based observations and methods for their exploitation; in-situ measurement techniques; debris and meteoroid environment models; debris flux and collision risk for space missions; on-orbit collision assessment, re-entry risk assessments, debris mitigation and debris environment remediation techniques and their effectiveness with regard to long-term environment stability; national and international debris mitigation standards and guidelines; hypervelocity accelerator technologies; and on-orbit shielding concepts. Four half-day sessions are planned. The abstract submission deadline is 14 February 2014. Additional details of the 40th COSPAR are available at: <https://www.cospar-assembly.org/>.

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SATELLITE BOX SCORE

(as of 3 October 2013, cataloged by the U.S. SPACE SURVEILLANCE NETWORK)

Country/ Organization	Payloads	Rocket Bodies & Debris	Total
CHINA	152	3599	3751
CIS	1427	4758	6185
ESA	44	46	90
FRANCE	57	445	502
INDIA	52	119	171
JAPAN	124	82	206
USA	1143	3775	4918
OTHER	634	139	773
TOTAL	3633	12963	16596

DAS 2.0 NOTICE

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

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INTERNATIONAL SPACE MISSIONS

1 July 2013 – 30 September 2013

International Designator	Payloads	Country/ Organization	Perigee Altitude (KM)	Apogee Altitude (KM)	Inclination (DEG)	Earth Orbital Rocket Bodies	Other Cataloged Debris
2013-034A	IRNSS R1A	INDIA	35708	35866	27.1	1	0
2013-035A	SJ-11-05	CHINA	688	704	98.1	1	4
2013-036A	MUOS 2	USA	35778	35793	5.0	1	0
2013-037A	PAYLOAD A	CHINA	660	674	98.1	1	4
2013-037B	PAYLOAD B	CHINA	666	674	98.1		
2013-037C	PAYLOAD C	CHINA	558	606	97.7		
2013-038A	ALPHASAT (I-4A F4)	IMMARSAT	35505	35762	0.1	1	1
2013-038B	INSAT 3D	INDIA	35775	35798	0.1		
2013-039A	PROGRESS M-20M	RUSSIA	417	420	51.7	1	0
2013-040A	HTV-4	JAPAN	408	411	51.7	0	0
2013-041A	WGS 6 (USA 244)	USA	33545	38010	0.1	1	0
2013-042A	KOMPSAT 5	SOUTH KOREA	543	563	97.6	1	1
2013-043A	USA 245	USA	NO ELEMS. AVAILABLE			0	0
2013-044A	EUTE 25B	EUTELSAT	35783	35791	0.0	1	1
2013-044B	GSAT 7	INDIA	35756	35817	0.2		
2013-045A	AMOS 4	ISRAEL	35782	35791	0.1	1	0
2013-046A	YAOGAN 17A	CHINA	1082	1099	63.4	1	2
2013-046B	YAOGAN 17B	CHINA	1082	1099	63.4		
2013-046C	YAOGAN 17C	CHINA	1082	1099	63.4		
2013-047A	LADEE	USA	IN LUNAR ORBIT			2	0
2013-048A	GONETS M 05	RUSSIA	1495	1510	82.5	1	0
2013-048B	GONETS M 06	RUSSIA	1493	1508	82.5		
2013-048C	GONETS M 07	RUSSIA	1494	1510	82.5		
2013-049A	SPRINT A	JAPAN	952	1156	29.7	1	1
2013-050A	AEHF 3 (USA 246)	USA	NO ELEMS. AVAILABLE			1	0
2013-051A	CYGNUS	USA	417	420	51.7	1	0
2013-052A	FENGYUN 3C	CHINA	827	828	98.8	1	0
2013-053A	KUAIZHOU 1 (KZ-1)	CHINA	289	300	96.7	0	0
2013-054A	SOYUZ-TMA 10M	RUSSIA	417	420	51.7	1	0
2013-055A	CASSIOPE	CANADA	325	1485	81.0	1	19
2013-055B	CUSAT 1	USA	325	1483	81.0		
2013-055C	DANDE	USA	325	1485	81.0		
2013-055D	POPACS 1	USA	325	1480	81.0		
2013-055E	POPACS 2	USA	324	1482	81.0		
2013-055F	POPACS 3	USA	325	1481	81.0		
2013-055G	CUSAT 2/RB	USA	319	1487	81.0		
2013-056A	ASTRA 2E	LUXEMBOURG	35674	35731	0.1	1	1