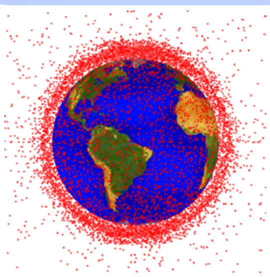
National Aeronautics and Space Administration

Orbital Debris
Quarterly News

Volume 18, Issue 4
October 2014

Inside...



A publication of
the NASA Orbital
Debris Program Office

International Space Station Performs Third Debris Avoidance Maneuver of 2014

In mid-July, the International Space Station (ISS) performed a maneuver to avoid the close approach of a debris fragment from a Breeze-M upper stage that exploded in 2012 (ODQN, Vol. 17, Issue 1, pp. 1-2). This was the 19th ISS collision avoidance maneuver since 1999, and the third performed in 2014 (ODQN, Vol. 18, Issue 2, p. 1). The offending fragment (International Designator 2012-044BJ, U.S. Strategic Command [USSTRATCOM] Space Surveillance Network [SSN] catalog number 38925), was about 15-20 cm in size based on its radar cross section, but had a decay rate estimated to be about 250 times greater than the ISS's decay rate, making predictions very difficult. The time of closest approach was 23 July 2014 at 13:16 GMT. The probability of collision without the maneuver was estimated to be about 1 in 500.

This was a rare retrograde maneuver. Most debris avoidance maneuvers are posigrade and take the place of orbit maintenance maneuvers that the ISS must periodically do to counteract atmospheric drag. However, the launch of Progress 56P was scheduled less than 1 day later and the retrograde maneuver made subsequent ISS operations more straight-forward. ♦

Three Additional Breakups Mar 2014

The first half of 2014 saw seven small fragmentations (ODQN, Vol. 18, Issue 3, pp. 1-2). Three additional small breakups occurred in the following quarter. On 6 July, Haiyang 2A (International Designator 2011-043A, SSN# 37781), a Chinese weather satellite, was observed to shed four objects. None of these entered the U.S. catalog. The satellite was in a circular orbit of 965 km with an inclination of 99° at the time of the event.

The other two breakups were both auxiliary motor (sistema obespecheniya zapuska [SOZ]) units from separate Proton Block DM fourth stages (see Figures 1 and 2). These motors have a long history of fragmentations. These were the 42nd and 43rd breakups of this class of object over its history and the 3rd and 4th to breakup just this year alone. The SOZ provide three-axis control and ullage to the Block DM during coast, and are routinely ejected after the Block DM stage ignites for the final time.

On 9 July, an SL-12 Aux motor (International Designator 2010-007G, SSN# 36406) fragmented

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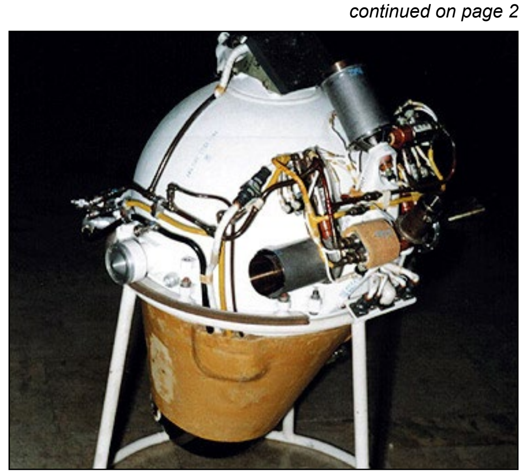

Figure 1. A SOZ unit with its 11D79 engine. Photo credit: RKK Energya/Kosmonavtika.com.

Additional Breakups

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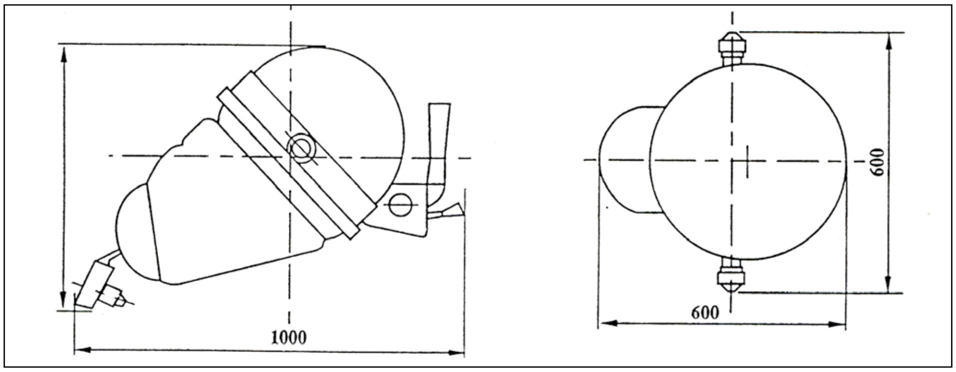

Figure 2. Plan views of a SOZ unit; all dimensions are in millimeters. Dry mass is 56 kg. Illustration from N. L. Johnson, "History of Soviet/Russian Satellite Fragmentations - A Joint US-Russian Investigation," Kaman Sciences Corporation, USA, October 1995, p. 19.

into at least 16 pieces. The motor was in a highly elliptical 770 x 18,750 km orbit at 65° inclination at the time of the breakup.

The second motor (International Designator 2007-052F, SSN# 32280) fragmented into about 70 pieces on 13 August. It was in a 730 x 18,790 km, 65° orbit when it fragmented.

Both SOZ motors had been part of launches that delivered Russian global positioning navigation system (GLONASS) satellites to medium Earth orbit (MEO). ♦

Former ODPO Chief Scientist Nicholas Johnson Receives Order of Gagarin Award

Many team members of the Orbital Debris Program Office (ODPO) have received external recognition due to their efforts to measure, model, and mitigate the risk posed by orbital debris to the safe navigation of space. Mr. Nick Johnson, former NASA Chief Scientist for Orbital Debris, was recently honored with a unique award—that of the Russian Order of Gagarin.

The Russian Federation and its predecessor states have long used Orders to recognize and celebrate civil or military service to the state, with occasional presentation of Orders or medals to foreign citizens. The Federation of Cosmonautics of Russia awarded Mr. Johnson the Order of Gagarin on 27 February 2014 for many achievements over his 35 years of active work in orbital debris and, in particular, for his efforts to broaden and foster debris mitigation standards among the international space-faring community of nations. Dr. Mark Matney accepted the Order on behalf of Mr. Johnson from Mr. Alexander Kokorin, the permanent representative of Roscosmos in Beijing, at the 32nd meeting of the Inter-Agency Space Debris Coordination Committee in May. The Order package has since been delivered to Mr. Johnson.

The Order consists of a medal and accompanying certificate and award booklet. The medal bears the likeness of its namesake, Cosmonaut Col. Yuri Gagarin, on a gilt and silver star and is the 665th award of the Order in its history. ♦

Figure 1. Award booklet with the Order of Gagarin medal.

Figure 2. Order of Gargarin certificate.

PROJECT REVIEW

Recent Impact Damage Observed on International Space Station

E. L. CHRISTIANSEN, D. M. LEAR AND J. L. HYDE

The International Space Station (ISS) crew has photographed several large areas of damage on radiators and solar arrays that were the result of hypervelocity impacts by micrometeoroids and orbital debris (MMOD).

Figures 1 and 2 show a hole found on the P4 Photovoltaic Radiator (PVR) in June 2014. The Image Science and Analysis Group indicated the hole measured 13 cm long by 10 cm wide. A review of available photography of the P4 PVR determined the damage occurred between 12 May 2014 and 20 June 2014. Edges of the hole are petalled back, which is typical of exit damage from hypervelocity impacts on honeycomb panels.

There is damage to the opposite side of the radiator panel (Figure 3) that appears as an area where the paint has been removed (spalled). After image enhancement, a 1.8 cm by 1.3 cm hole was revealed within the paint spall area which is typical of entry damage (that is, it is smaller than the exit hole).

Flow tubes are positioned about every 6.6 cm throughout the panel to carry coolant through the radiator panel. There is a radiator flow tube visible in the damaged area (Figure 2), but no leak of ammonia coolant was noted from the flow tube. The ISS flow tubes were designed with features that make them less likely to fail (i.e., leak) from MMOD impacts compared to previous radiator designs such as used on the Space Shuttle. Even so, it was fortunate that the trajectory of this particular impact appeared to "miss" the flow tubes for the most part, or else a coolant leak might have occurred.

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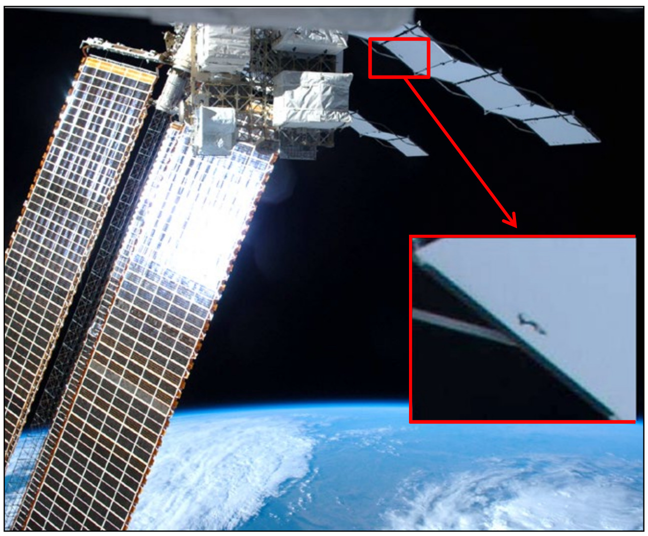

Figure 1. Location of P4 PVR damage.

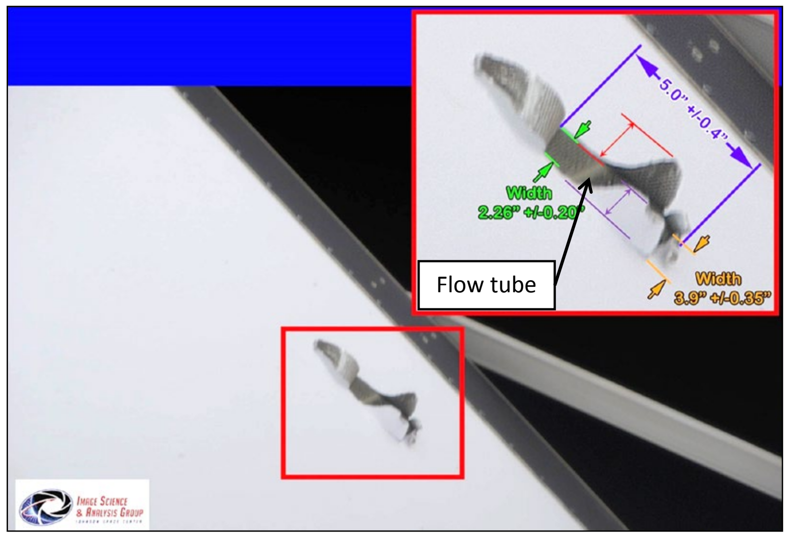

Figure 2. Close-up of exit damage.

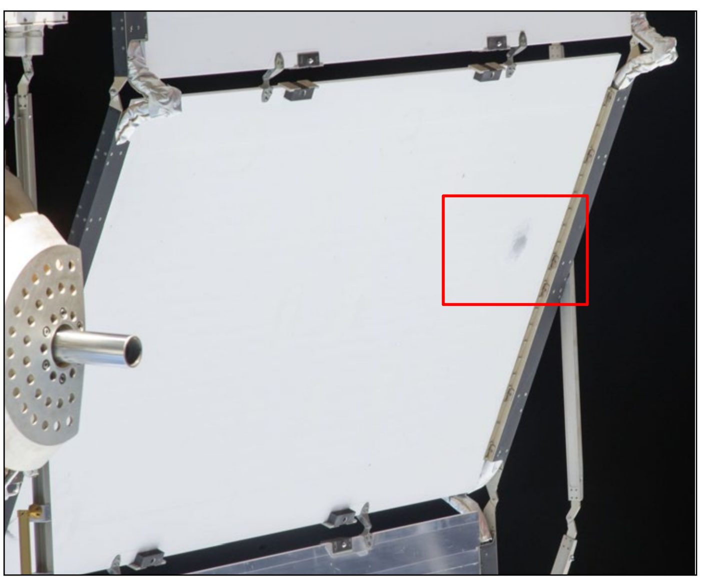

Figure 3. Damage on opposite side of panel.

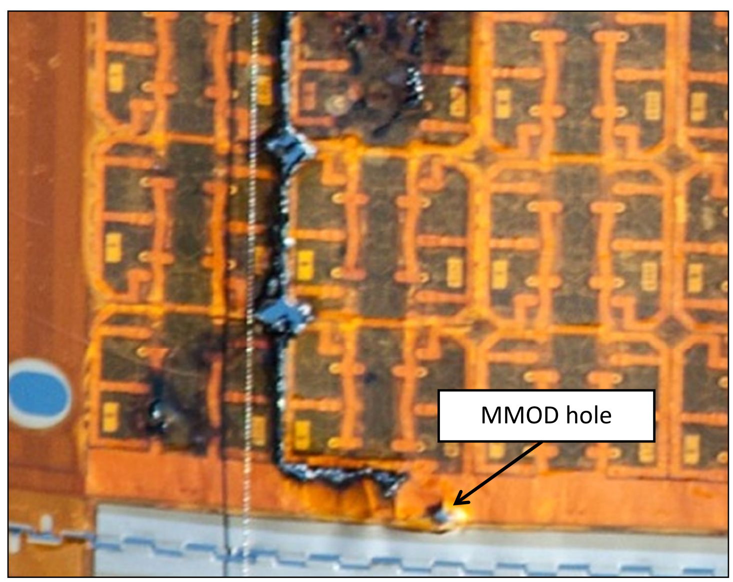

Figure 4. Back of ISS Solar Array 3A, panel 58.

Impact Damage on ISS

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Figures 4 and 5 show an area of damage on the photovoltaic cells of the ISS 3A solar array wing (SAW). A 7-mm-sized MMOD perforation of the solar array panel broke a bypass diode. Major overheating of the solar array occurred in the vicinity of the MMOD impact damage due to the broken bypass diode, causing a nearly 36-cm-long U-shaped burn or tear in the Kapton backing. This damage caused complete failure of one of the 400-cell strings in the 3A solar array wing. However, no appreciable loss of power occurred due to this failure, because there are 82 strings per SAW containing 32,800 solar cells, and 8 SAWs on ISS.

Another 400-cell string was lost under similar circumstances on the 2A SAW, where an MMOD impact caused the bypass diode to be disconnected resulting in an overheated cell and loss of the string (Figure 6). Other burned areas of the solar arrays have been discovered but photo resolution has not been adequate to determine if MMOD impact damage is present and can be associated with these burn areas (Figure 7). ♦

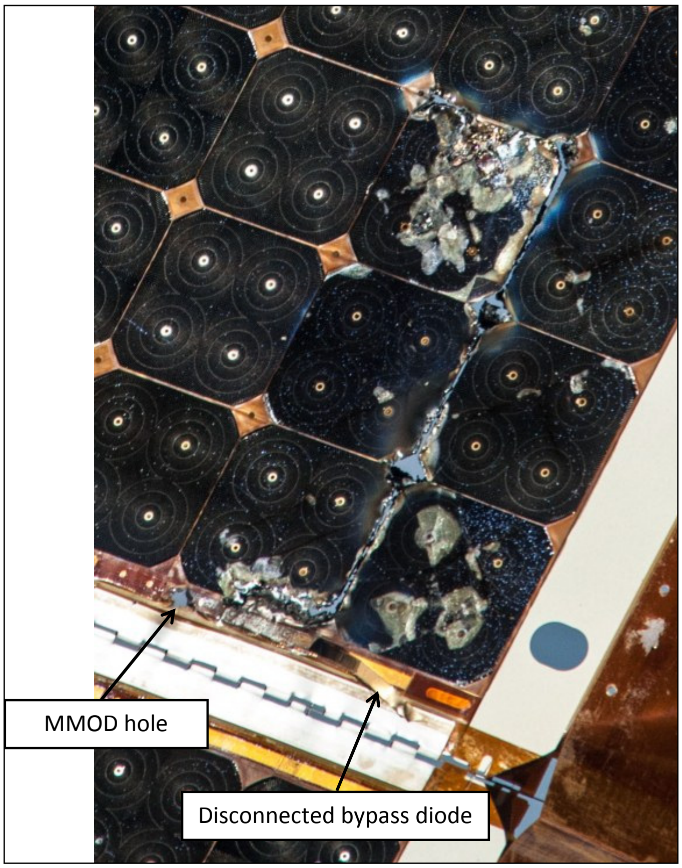

Figure 5. ISS Solar Array 3A damage (front of panel 58).

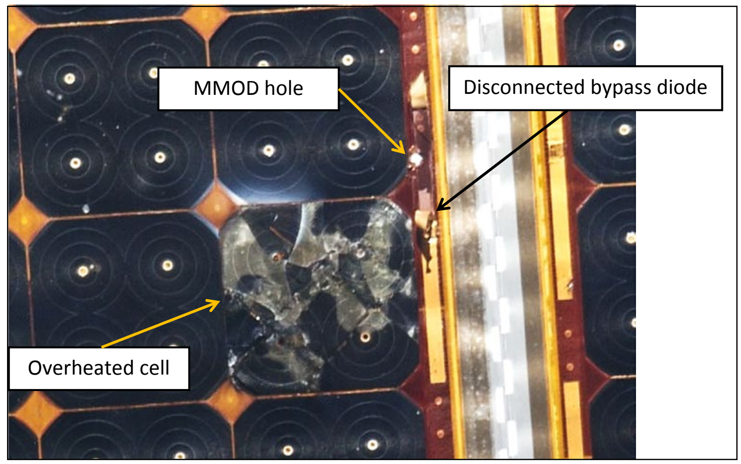

Figure 6. ISS Solar Array 2A, panel 66 damage.

Figure 7. Another burned area in ISS Solar Array 3A (panel 42).

Comet Siding Spring's Shift from Impact Hazard to Science Opportunity

A. MOORHEAD, NASA METEOROID ENVIRONMENT OFFICE

On 19 October 2014, Comet C/2013 A1 (Siding Spring) will pass within 140,000 km of Mars, making a closer approach to the red planet than any comet has to Earth in recorded history (the closest known approach to Earth by a comet was made by comet Lexell at 2.3 million kilometers – more than 15 times the distance). Comet Siding Spring was discovered in early 2013 by Robert McNaught and named after its discovery site, Siding Spring Observatory [1]. These discovery images, combined with prediscovery images from the Catalina Sky Survey and subsequent observations, enabled Jet Propulsion Laboratory scientists to rule out a "nightmare scenario" in which the comet nucleus hits Mars within a few months of the comet's discovery.

Missing the comet nucleus, however, does not alone remove the danger posed to the Martian system. The nucleus will be embedded

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Comet Shift

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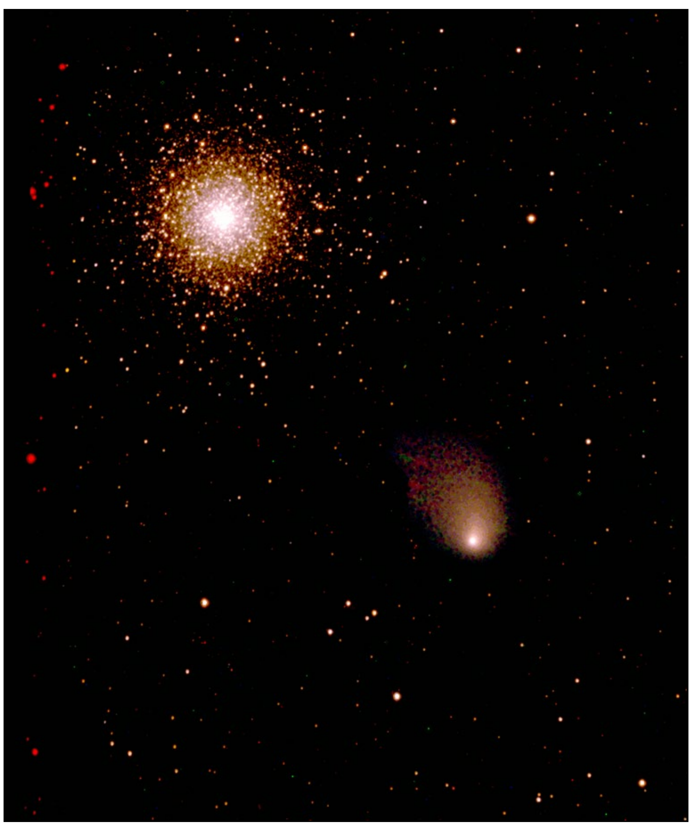
in a coma of gas and dust particles, all of which will be moving 56 km/s (125,000 mph) relative to Mars. Depending on if and how deeply Mars penetrates the coma, its orbiting manmade satellites could be impacted and possibly damaged by high velocity dust grains, or micrometeoroids. Thus, determining whether Mars passes through the coma is critical for assessing the level of meteoroid impact risk posed to Mars Atmosphere and Volatile Evolution (MAVEN), Mars Reconnaissance Orbiter (MRO), and other orbiters.

Early observations of the comet revealed little information about it other than its brightness, but the comet's similarities to fellow Oort-cloud comet Hale-Bopp gave some cause for concern. Both Siding Spring and Hale-Bopp are comets on near-parabolic orbits making their first passage through the inner Solar System. Both comets showed signs of early activity: Hale-Bopp was active out at 7.2 AU (between the orbits of Jupiter and Saturn) while Siding Spring was active out at 7.8 AU. Hale-Bopp produced a coma that grew to millions of kilometers in size – were Siding Spring to follow Hale-Bopp's example, Mars would certainly pass within its coma.

For this reason, several groups made early attempts at modeling the particle flux near Mars during the close encounter. A group led by NASA's Meteoroid Environment Office produced the earliest model: a spherically-symmetric coma that borrowed dust properties from Giotto measurements of Halley's coma and matched brightness measurements of Siding Spring from early 2013 [2]. The largest uncertainty in this model was the assumed comet radius; the group adopted a value of 200,000 km, which is comparable to Halley's coma radius and significantly less than Hale-Bopp's radius.

This coma radius was comparable to that resulting from early computer simulations of the comet produced by Paul Wiegert and Jeremie Vaubaillon [2], [3]. These early measurements predicted a significant risk to spacecraft; roughly every 10 square meters of vehicle area would be hit by a potentially hazardous meteoroid (approximately 0.1 mm or larger). In the 90 minutes it would take for Martian spacecraft to pass through the comet's coma, they would be exposed to 300 times the equivalent risk from spending a year in low Earth orbit. The event at Mars would also have been significant; the resulting meteor shower on Mars would be orders of magnitude stronger than any seen from Earth and was dubbed a "meteor hurricane" [3].

In response to this prospective threat, the Mars program office selected several comet and small body astronomers, including Tony Farnham, Pasquale Tricarico, Davide Farnocchia, and Jian-Yang Li, to undertake a second observation and modeling effort. Images of Siding Spring taken with the Hubble Space Telescope in late 2013 and early 2014 showed that the comet was much more compact than initial estimates, indicating that dust was being ejected at velocities about a factor of 50 lower than assumed in earlier models [4]. Newer models, taking this low ejection velocity into account, predicted that the coma would miss Mars entirely, driving the risk down by five to six orders of magnitude [5], [6], [7]. A similar but independent study led by Quanzhi Ye reported similar findings [8]. Current expectations are that the comet poses less meteoroid impact risk to spacecraft than the sporadic meteoroid background flux. Furthermore, this risk is confined to a region in the comet's tail containing only a few, millimeter-sized particles, which will pass by Mars within half an hour [9]. The expected effect on the Martian atmosphere is also reduced; the meteor hurricane has become a shower.



This composite image of Comet Siding Spring was produced from observations taken with the T30 telescope (part of the iTelescope network) at Siding Spring Observatory, New South Wales, Australia, over the course of two nights. The large star cluster in the top-left corner of this image is the globular cluster NGC 362, in the constellation Tucana.

Although the risk to spacecraft is now projected to be quite low, the Mars program office has opted to further reduce the risk to Odyssey, MRO, and MAVEN by phasing their orbits to use Mars as a shield. This strategy takes advantage of the risk window's short duration (30 minutes) compared to the spacecraft's orbital periods. High voltage components may also be shut down during the encounter in order to reduce the possibility of electric anomalies from high velocity dust particles, which have been hypothesized to cause problems for the Earth-orbiting satellites OLYMPUS and Landsat 5 [10], [11].

Now that the potential impact risk posed to spacecraft has been substantially reduced and mitigation strategies selected, the community is turning its attention to the science opportunity this comet encounter offers. At the Comet Ison Observing Campaign (CIOC) workshop on 11 August, Mars Program scientists reported that all four of its operational spacecraft, including MAVEN, will attempt to observe Comet Siding Spring. The combination of these Mars-based observations with Earth-based and space-based observations will produce a wealth of information on the comet. The result will be a valuable, detailed characterization of an Oort-cloud comet and its meteoroid tail and the validation or refutation of model predictions.

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Comet Shift

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Thus, what first appeared to be a possible hazard to Martian spacecraft has instead turned out to be an exciting opportunity for Mars scientists and comet and meteor astronomers.

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ABSTRACTS FROM THE NASA ORBITAL DEBRIS PROGRAM OFFICE

The 40th Committee on Space Research (COSPAR) Scientific Assembly
2-10 August 2014, Moscow, Russia

New Laboratory-Based Satellite Impact Experiments for Breakup Fragment Characterization

J.-C. LIOU, N. FITZ-COY, R. DIKOVA, M. WILSON, T. HUYNH, C. GRIFFICE, M. SORGE, P. SHEAFFER, G. RADHAKRISHNAN, J. OPIELA, H. COWARDIN, P. KRISKO, R. RUSHING, M. NOLEN, AND B. ROEBUCK

A consortium consisting of the NASA Orbital Debris Program Office, U.S. Air Force's Space and Missile Systems Center, The Aerospace Corporation, and University of Florida is planning a series of hypervelocity impact experiments on mockup targets at the U.S. Air Force's Arnold Engineering Development Complex (AEDC) in early 2014. The target for the first experiment resembles a rocket upper stage whereas the target for the second experiment represents a typical 60-cm/50-kg class payload that incorporates modern spacecraft materials and components as well as exterior wrap of multi-layer insulation and three solar panels. The projectile is designed with the maximum mass that AEDC's Range G two-stage light gas gun can accelerate to an impact speed of 7 km/sec. The impact energy is expected to be close to 15 MJ to ensure catastrophic destruction of the target after the impact. Low density foam panels are installed inside the target chamber to slow down and soft-catch the fragments for post-impact processing. Diagnostic instruments, such as x-ray and high speed optical cameras, will also be used to record the breakup process.

The main goal of this "DebriSat" project is to characterize the physical properties, including size, mass, shape, and density distributions, of orbital debris that would be generated by a hypervelocity collision involving an upper stage or a modern satellite in the low Earth orbit environment. In addition, representative fragments will be selected for laboratory optical and radar measurements to allow for better interpretation of data obtained by telescope and radar observations. This paper will provide a preliminary report of the impact results and the plans to process, measure, and analyze the fragments. ♦

AIAA SPACE 2014 Conference and Exposition
4-7 August 2014, San Diego, California, USA

The New NASA Orbital Debris Engineering Model ORDEM 3.0

P. H. KRISKO

The NASA Orbital Debris Program Office (ODPO) has released its latest Orbital Debris Engineering Model, ORDEM 3.0. It supersedes ORDEM 2000, now referred to as ORDEM 2.0. This newer model encompasses the Earth satellite and debris flux environment from altitudes of low Earth orbit (LEO) through geosynchronous orbit (GEO). Debris sizes of 10 µm through larger than 1 m in non-GEO and 10 cm through larger than 1 m in GEO are available. The inclusive years are 2010 through 2035.

The ORDEM model series has always been data driven. ORDEM 3.0 has the benefit of many more hours of data from existing sources and from new sources than past ORDEM versions. The object data range in size from 10 µm to larger than 1 m, and include in situ and remote measurements. The in situ data reveals material characteristics of small particles. Mass densities are grouped in ORDEM 3.0 in terms of 'high-density', represented by 7.9 g/cc, 'medium-density' represented by 2.8 g/cc and 'low-density' represented by 1.4 g/cc.

Supporting models have also advanced significantly. The LEO-to-GEO ENvironment Debris model (LEGEND) includes an historical and a future projection component with yearly populations that include launched and maneuvered intact spacecraft and rocket bodies, mission related debris, and explosion and collision event fragments. LEGEND propagates objects with ephemerides and physical characteristics down to 1 mm in size. The full LEGEND yearly population acts as an a priori condition for a Bayesian statistical model. Specific populations are added from sodium potassium droplet releases, recent major accidental and deliberate collisions, and known anomalous debris events.

This paper elaborates on the upgrades of this model over previous versions. Sample validation results with remote and in situ measurements are shown, and the consequences of including material density are discussed as it relates to heightened risks to crewed and robotic spacecraft. ♦

The 15th Advanced Maui Optical and Space Surveillance Technologies Conference (AMOS)
9-12 September 2014, Maui, Hawaii

NASA's Optical Measurement Program 2014

H. COWARDIN, S.M. LEDERER,
E. STANSBERY, P. SEITZER,
B. BUCKALEW, K. ABERCROMBY, AND
E. BARKER

The Optical Measurements Group (OMG) within the NASA Orbital Debris Program Office (ODPO) addresses U.S. National Space Policy goals by monitoring and characterizing debris. Since 2001, the OMG has used the Michigan Orbital Debris Survey Telescope (MODEST) at Cerro Tololo Inter-American Observatory (CTIO) in Chile for general orbital debris surveys. The 0.6-m Schmidt MODEST provides calibrated astronomical data of GEO targets, both catalogued and uncatalogued debris, with excellent image quality. The data are utilized by the ODPO modeling group and are included in the Orbital Debris Engineering Model (ORDEM) v. 3.0. MODEST and the CTIO/SMARTS (Small and Moderate Aperture Research Telescope System) 0.9 m are both employed to acquire filter photometry data as well as synchronously observe targets in selected optical filters. Obtaining data synchronously yields data for material composition studies as well as longer orbital arc data on the same target without time delay or bias from a rotating, tumbling, or spinning target.

Observations of GEO orbital debris using the twin 6.5-m Magellan telescopes at Las Campanas Observatory in Chile for deep imaging (Baade) and spectroscopic data (Clay) began in 2011. Through the data acquired on Baade, debris has been detected that reaches ~3 magnitudes fainter than detections with MODEST, while the spectral data from Clay provide better resolved information used in material characterization analyses.

To better characterize and model optical data, the Optical Measurements Center (OMC) at NASA/JSC has been in operation since 2005, resulting in a database of comparison laboratory data. The OMC is designed to emulate illumination conditions in space using equipment and techniques that parallel telescopic observations and source-target-sensor orientations.

Lastly, the OMG is building the Meter Class Autonomous Telescope (MCAT) at Ascension Island. The 1.3-m telescope is designed to observe GEO and LEO targets, using a modified Ritchey-Chrétien configuration on a double horseshoe equatorial mount to allow tracking objects at LEO rates through the dome's keyhole at zenith.

Through the data collection techniques employed at these unique facilities, NASA's ODPO has developed a multi-faceted approach to characterize the orbital debris risk to satellites in various altitudes and provide insight leading toward material characterization of debris via photometric and spectroscopic measurements. Ultimately, the data are used in conjunction with in-situ and radar measurements to provide accurate data for models of our space environment and for facilitating spacecraft risk assessment. ♦

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SpinSat Mission Ground Truth Characterization

A. NICHOLAS, T. FINNE, I. GALYSH,
A. MAI, J. YEN, W. SAWKA, J. RANSDELL,
S. WILLIAMS, H. COWARDIN,
A. BARJATYA, AND F. GASDIA

The SpinSat flight is a small satellite mission proposed by the Naval Research Laboratory and Digital Solid State Propulsion (DSSP) LLC to demonstrate and characterize the on-orbit performance of electrically controlled solid propellant technology in space. Launch is expected in summer of 2014. This is an enabling technology for the small satellite community that will allow small satellites to perform maneuvers. The mission consists of a spherical spacecraft fitted with Electrically Controlled Solid Propellant thrusters and retro-reflectors for satellite laser ranging (SLR). The spacecraft will be deployed from the International Space Station. This paper presents a mission overview, ground truth characterization and unique SSA observation opportunities of the mission. ♦

NASA's Newest Orbital Debris Ground-based Telescope Asset: UKIRT

S. M. LEDERER, J. M. FRITH,
H. M. COWARDIN, AND B. BUCKALEW

In 2014, NASA's Orbital Debris Program Office (ODPO) gained access to the United Kingdom Infrared Telescope (UKIRT). This will extend our spectral coverage into the near- (0.8-5 μm) and mid- to far-infrared (8-25 μm) regime. UKIRT is a 3.8 m telescope located on Mauna Kea on the big island of Hawaii. At nearly 14,000-feet and above the atmospheric inversion layer, this is one of the premier astronomical sites in the world and is an ideal setting for an infrared telescope. An unprecedented one-third of this telescope's time has been allocated to collect orbital debris data for NASA's ODPO over a 2-year period.

UKIRT has several instruments available to obtain low-resolution spectroscopy in both the near-IR and the mid/far-IR. Infrared spectroscopy is ideal for constraining the material types, albedos and sizes of debris targets, and potentially gaining insight into reddening effects caused by space weathering. In addition, UKIRT will be used to acquire broadband photometric imaging at Geosynchronous Earth Orbit (GEO) with the Wide Field Camera (WFCAM) for studying known objects of interest as well as collecting data in survey-mode to discover new targets. Results from the first stage of the debris campaign will be presented.

The combination of this ground-based telescope with NASA's optical assets will yield spectral coverage ranging from 0.3 – 25 μm, allowing orbital debris to be studied in depth across a wider wavelength range in the visible and IR than ever previously studied by ODPO. By expanding the methods for surveying, detecting, and characterizing orbital debris, we can better model the debris environment and ultimately gain insight into how to mitigate potential collisions for future missions. ♦

Bi-static Optical Observations of GEO Objects

P. SEITZER, E. S. BARKER, H. COWARDIN,
S. M. LEDERER, AND B. BUCKALEW

A bi-static study of objects at Geosynchronous Earth Orbit (GEO) was conducted using two ground-based wide-field optical telescopes. The University of Michigan's 0.6-m MODEST (Michigan Orbital Debris Survey Telescope) located at the Cerro Tololo Inter- American Observatory in Chile was employed in a series of coordinated observations with the U.S. Naval Observatory's (USNO) 1.3-m telescope at the USNO Flagstaff Station near Flagstaff, Arizona, USA.

The goals of this project are twofold:

1. Obtain optical distances to known and unknown objects at GEO from the difference in the observed topocentric position of objects measured with respect to a reference star frame. The distance can be derived directly from these measurements, and is independent of any orbital solution. The wide geographical separation of these two telescopes means that the parallax difference is larger than ten degrees.

2. Compare optical photometry in similar filters of GEO objects taken during the same time period from the two sites. The object's illuminated surfaces presented different angles of reflected sunlight to the two telescopes.

During a four-hour period on the night of 22 February 2014 (UT), coordinated observations were obtained for eight different GEO positions. Each coordinated observation sequence was started on the hour or half-hour, and was selected to ensure the same cataloged GEO object was available in the field of view of both telescopes during the thirty minute observing sequence. GEO objects were chosen to be both controlled and uncontrolled at a range of orbital inclinations, and the objects were not tracked. Instead both telescopes were operated with all drives off in GEO survey mode to discover un-cataloged objects at GEO.

The initial photometric results from this proof-of-concept observing run will be presented, with the intent of laying the foundation for future large-scale bi-static observing campaigns of the GEO regime. ♦

The 65th International Astronautical Congress (IAC)
29 September - 3 October 2014, Toronto, Canada

ORDEM 3.0 AND MASTER-2009 Modeled Small Debris Population Comparison

P. H. KRISKO, S. FLEGEL, M. J. MATNEY, D. R. JARKEY, AND V. BRAUN

The latest versions of the two premier orbital debris engineering models, NASA's ORDEM 3.0 and ESA's MASTER-2009, have been publically released. Both models have gone through significant advancements since inception, and now represent the state-of-the-art in orbital debris knowledge of their respective agencies. The purpose of these models is to provide satellite designers/operators and debris researchers with reliable, and timely, estimates of the artificial debris environment in near-Earth orbit. The small debris environment within the critical size range of 1 mm to 1 cm is of particular interest to both human and robotic spacecraft programs. These objects are much more numerous than larger trackable debris and are still large enough to cause significant, if not catastrophic, damage to spacecraft upon impact. They are also small enough to elude routine detection by existing observation systems (radar and telescope). Without reliable detection the modeling of these populations has always coupled theoretical origins with supporting observational data in different degrees.

This paper offers the first cooperative comparison of the two models. No attempt to review model internal populations or compare subsystems or supporting data sets is made (e.g., propagation of fragments, A/m and ΔV distributions). The models are simply run for four test cases representing four orbital regimes (ISS, Polar, Elliptical, GEO). Debris cumulative fluxes at three debris sizes (1 m, 10 cm, and a "critical size range" of 1 cm to 1 mm) are compared. At 1 m there is a very good match between ORDEM and MASTER fluxes, as would be expected. The 10 cm fluxes do not match as well, indicating different treatment of uncatalogued objects, which must be investigated in a future comparison study. Within the critical size range it is noted that ORDEM flux overtakes that of MASTER as debris size decreases in all test cases.

In the analysis of separate model populations, the disparate usage of debris source populations (MASTER) versus debris material density populations (ORDEM) is unresolved. Undoubtedly more in-depth collaborations will follow. ♦

Hypervelocity Impact Testing of DebriSat to Improve Satellite Breakup Modeling

M. RIVERO, I. EDHLUND, N. FITZ-COY, J.-C. LIOU, M. SORGE, T. HUYNH, J. OPIELA, H. COWARDIN, AND P. KRISKO

An effort by NASA and DoD is underway to update the standard break up model in the form of a hypervelocity impact test on DebriSat. DebriSat is a 50 kg class satellite designed to comprehensively represent modern LEO satellites. Instrument and material selections were based on a study of 50 satellite missions with data available in the public domain. The chosen missions formed a representative distribution by dry mass of satellite missions, creating a manageable group from which to collect data on the prevalence of instruments and materials used in satellites ranging from 1 kg to 5000 kg.

Analyzing the distribution of technologies utilized for different subsystems, the team included instruments that were common in most mass categories. For example, in the attitude determination and control subsystem, sun sensors and magnetometers were common across most satellites while gyroscopes and inertial measurement units were more prevalent with increasing satellite mass. Star trackers were also widely used technologies in the mid-range satellites. These instruments are represented in DebriSat based on these findings. A similar instrument identification approach was used for the payload, propulsion, command and data handling, and other subsystems within DebriSat. Common materials found in modern satellites and utilized in the fabrication of DebriSat include aluminum 6061-T6, stainless steel 316, titanium, aluminum 5052 honeycomb, M55J composite, and multi-layer insulation.

The DebriSat design is intended to be representative of the materials, instruments, and assembly processes involved in modern satellite construction. Throughout the design and assembly phases, subject matter experts from NASA, DoD, and The Aerospace Corporation were consulted for guidance and recommendations. As with any flight hardware, strict guidelines were followed to ensure that the final product met all the qualifications of a flight ready satellite (sans software). DebriSat was also subjected to appropriate environmental testing including vibration, thermal, and bakeout, to ensure flight readiness.

This paper describes the design, fabrication, and hypervelocity impact test of DebriSat, and test results obtained to date. ♦

CONFERENCE AND WORKSHOP REPORTS

The 11th Annual CubeSat Developers' Workshop, 23-25 April 2014, Cal Poly San Luis Obispo, California

The 11th Annual CubeSat Developer's Workshop was held 23-25 April at California Polytechnic University in San Luis Obispo, California. The overall focus of the event was technical developments and lessons learned from previous missions. In addition to being the primary topic of one paper, debris mitigation guidelines were briefly mentioned in a few presentations either indirectly or as secondary topics. ♦

The 40th Committee on Space Research (COSPAR) Scientific Assembly 2-10 August 2014, Moscow, Russia

The 40th Scientific Assembly of the Committee on Space Research (COSPAR) took place at the beautiful campus of the Lomonosov Moscow State University in Moscow, Russia, 2-10 August 2014. Space debris sessions were once again organized under the Potentially Environmentally Detrimental Activities in Space (PEDAS) Panel. The sessions included 31 oral presentations and 6 posters. More than 50 international participants, including Professor Walter Flury, attended the sessions. Highlights of the debris sessions included presentations on recent optical measurements in LEO and GEO, hypervelocity impact testing and protection, and orbit modeling. A PEDAS business meeting was also conducted during COSPAR. Key activities of the meeting included discussions on the topics and format of the debris sessions for the 2016 COSPAR and the election of Professor Thomas Schildknecht to serve a second 4-year term as the main scientific organizer of the PEDAS Panel. There was also a proposal to change the name of the panel to better reflect orbital debris but it did not receive enough votes from the meeting participants to pass. ♦

The 28th Annual American Institute of Aeronautics and Astronautics/Utah State (AIAA/USU) Conference on Small Satellites, 2-7 August 2014, Logan, Utah

The 28th Annual American Institute of Aeronautics and Astronautics/Utah State University Conference on Small Satellites was held 2-7 August in Logan, Utah. The conference hosted more than 1400 participants and 130 exhibitors from more than 25 countries. The topic of this year's conference was the "Commerce of Small Satellites." Many of the topics presented focused on recently developed or upcoming technologies focused on small satellites with little mention of debris mitigation. A number of the commercial exhibitors did advertise the fact that their products were designed with NASA OD mitigation guidelines in mind. ♦

The AIAA Space and Astronautics Forum and Exposition (SPACE 2014) 4-7 August 2014, San Diego, California

The annual event, hosted by the American Institute of Aeronautics and Astronautics (AIAA) and cohosted by the American Astronautical Society (AAS), was held 4-7 August in San Diego, California. SPACE 2014 included four conferences, the AIAA SPACE Conference, the AIAA/AAS Astrodynamics Specialist Conference, the 32nd AIAA International Communication Satellites Systems Conference (ICSSC), and the AIAA Complex Aerospace Systems Exchange (CASE). The Exposition included exhibits from twenty aerospace companies, AIAA groups, and NASA.

Participants included international attendees and presenters from commercial, academic, and government aerospace. The Technical Program hosted over 400 oral presentations on current work covering a wide range of space-related activities. Highlighted topics included orbital physics (e.g., optimization methods, dynamics, perturbations, stability, attitude, control, rendezvous, orbital determination, and tracking), orbital safety (e.g., orbital debris, collision avoidance, and space situational awareness), infrastructure (e.g., commercial space ports and launcher design), satellite design (e.g., LEO communications, large space structures, tethers, constellations, and nanosatellites), mission design (e.g., interplanetary and earth orbital mission design and mission cost), crewed mission planning (e.g., asteroid capture, Mars, Moon, space settlement), and space policy.

Five Plenary Session and 16 Forum 360 panel discussions included high-level talks on such topics as Mars exploration, human spaceflight, and the satellite industry and its future. ♦

The 15th Advanced Maui Optical and Space Surveillance (AMOS) Technologies Conference 10-12 September 2014, Maui, Hawaii

The Advanced Maui Optical and Space Surveillance Technologies Conference was held 10-12 September. The keynote speaker for the event was Natalie Crawford, Senior Fellow with the RAND Corporation. Ms. Crawford touched on many areas of Space Situational Awareness, including orbital debris.

Six papers were presented during the Orbital Debris session; Thomas Schildknecht was the session chair. The first session speaker, Rick Kendrick, discussed light curves of near GEO satellites and debris using the wide field camera system on the United Kingdom Infra-Red Telescope (UKIRT) in J, H, and K bands. Schildknecht then gave a talk about the current state of CMOS detectors for optical telescopes compared to CCDs. Next, Barry Geldzahler provided the latest status and plans for the KaBOOM communications and radar array. Mathew Wilkins discussed automated methods for classifying resident space objects in order to determine the most efficient observation techniques to employ. Jan Stupl presented the results of a simulation that showed the percentages of close orbital conjunctions that could be prevented by their LightForce technique of adjusting orbits using lasers. Finally, the last paper in the session by Aleksander Lidtke, discussed target selection for Active Debris Removal.

Although there were only six papers in the Debris Session, there were many other orbital debris related talks in other sessions. There was a panel discussion and session on conjunction assessments. During the Non-Resolved Optical Characterization session, Pat Seitzer presented results from simultaneous observations of GEO satellites and debris from the MODEST telescope in Chile and the U.S. Naval Observatory's telescope at Flagstaff, AZ. He also briefly discussed simultaneous measurements made with the 4-m Blanco telescope in Chile and the 3.5-m Space Surveillance Telescope in New Mexico.

Two poster papers from NASA ODPO were also presented. Sue Lederer and James Frith presented preliminary results from spectral measurements using the UKIRT telescope and status of the Meter Class Autonomous Telescope, which recently broke ground on Ascension Island. Heather Cowardin provided a poster on NASA's current optical measurements program for orbital debris.

Attached to the AMOS conference was a separate SSA forum keynoted by the Air Force Space Command Commander, Gen. John Hyten. There were also four technical short courses that were available from the conference. One of these was on orbital debris and was presented by NASA's Gene Stansbery. ♦

UPCOMING MEETINGS

20-22 October 2014: The 7th International Association for Advancement of Space Safety (IAASS) Conference, Friedrichshafen, Germany

The 7th IAASS Conference, "Space Safety Is No Accident," is an invitation to reflect and exchange information on a number of topics in space safety and sustainability of national and international interest. The 2014 conference will dedicate a set of specialized sessions on orbital debris, including space debris remediation, reentry safety, space situational awareness and international space traffic control, and commercial human spaceflight safety. Additional details of the Conference are available at: <http://iaassconference2014.space-safety.org/>.

4-10 July 2015: The 30th International Symposium on Space Technology and Science (ISTS), Kobe-Hyogo, Japan

The 30th ISTS will be a joint conference with the International Electric Propulsion Conference (IEPC) and the Nano-Satellite Symposium (NSAT). The 19 technical sessions planned for the 2015 ISTS include one on Space Environment and Debris. The abstract submission deadline is 20 November 2014. Additional information is available at: <http://www.ists.or.jp/2015/>.

12-16 October 2015: The 66th International Astronautical Congress (IAC), Jerusalem, Israel

The Israel Space Agency will host the 66th IAC Conference with a theme of "Space – The Gateway for Mankind's Future." Like the previous IAC Conferences, the 2015 Congress will include a Space Debris Symposium to address the complete spectrum of technical issues of space debris measurements, modeling, risk assessments, reentry, hypervelocity impacts and protection, mitigation and standards, and space situational awareness. These topics will be covered in nine oral sessions and one poster session. For conference information as it is posted, visit the IAF conference webpage at: <http://iac2015.org>.

SATELLITE BOX SCORE

(as of 1 October 2014, cataloged by the U.S. SPACE SURVEILLANCE NETWORK)

Country/ Organization	Payloads	Rocket Bodies & Debris	Total
CHINA	166	3619	3785
CIS	1450	4935	6385
ESA	50	46	96
FRANCE	60	445	505
INDIA	55	119	174
JAPAN	130	72	202
USA	1248	3780	5028
OTHER	698	121	819
TOTAL	3857	13137	16994

Visit the NASA Orbital Debris Program Office Website

www.orbitaldebris.jsc.nasa.gov

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INTERNATIONAL SPACE MISSIONS

1 July 2014 – 30 September 2014

International Designator	Payloads	Country/ Organization	Perigee Altitude (KM)	Apogee Altitude (KM)	Inclination (DEG)	Earth Orbital Rocket Bodies	Other Cataloged Debris
2014-035A	OCO 2	USA	702	703	98.2	1	0
2014-036A	GONETS M 08 (M18)	RUSSIA	1471	1518	82.5	1	0
2014-036B	GONETS M 09 (M19)	RUSSIA	1476	1512	82.5		
2014-036C	GONETS M 10 (M20)	RUSSIA	1477	1512	82.5		
2014-037A	METEOR M2	RUSSIA	819	827	98.8	1	1
2014-037B	MKA PN2 (RELEK)	RUSSIA	623	819	98.4		
2014-037C	DX 1	RUSSIA	624	637	98.4		
2014-037D	SKYSAT 2	USA	625	634	98.4		
2014-037E	DUMMY SAT	RUSSIA	625	633	98.4		
2014-037F	UKUBE 1	UK	624	631	98.4		
2014-037G	AISSAT 2	NORWAY	623	632	98.4		
2014-037H	TDS 1	UK	623	633	98.4		
2014-038A	O3B FM3	O3B	8061	8070	0.0	1	0
2014-038B	O3B FM7	O3B	8062	8070	0.0		
2014-038C	O3B FM6	O3B	8062	8069	0.0		
2014-038D	O3B FM8	O3B	8060	8071	0.0		
2014-039A	CYGNUS ORB-2	USA	386	407	51.6	1	0
2014-040A	ORBCOMM FM 109	USA	637	728	47.0	0	0
2014-040B	ORBCOMM FM 107	USA	629	736	47.0		
2014-040C	ORBCOMM FM 106	USA	633	733	47.0		
2014-040D	ORBCOMM FM 111	USA	620	735	47.0		
2014-040E	ORBCOMM FM 104	USA	635	730	47.0		
2014-040F	ORBCOMM FM 103	USA	639	727	47.0		
2014-041A	FOTON M4	RUSSIA	248	524	64.9	1	2
2014-042A	PROGRESS-M 24M	RUSSIA	413	416	51.6	1	0
2014-043A	USA 253	USA	NO ELEMS. AVAILABLE			1	0
2014-043B	USA 254	USA	NO ELEMS. AVAILABLE				
2014-043C	USA 255	USA	NO ELEMS. AVAILABLE				
2014-044A	ATV 5	ESA	413	416	51.6	0	0
2014-045A	NAVSTAR 71 (USA 256)	USA	20169	20197	55.0	1	0
2014-046A	ASIASAT 8	ASIASAT	35779	35793	0.0	1	0
2014-047A	YAOGAN 20A	CHINA	1084	1096	63.4	1	2
2014-047B	YAOGAN 20B	CHINA	1084	1096	63.4		
2014-047C	YAOGAN 20C	CHINA	1084	1096	63.4		
2014-048A	WORLDVIEW 3	USA	612	614	98.0	1	0
2014-049A	GAOFEN 2	CHINA	618	637	98.0	1	0
2014-049B	BRITE-PL 2	POLAND	607	635	98.0		
2014-050A	GALILEO 5 (261)	ESA	13724	25923	49.7	1	0
2014-050B	GALILEO 6 (262)	ESA	13705	25914	49.7		
2014-051A	LING QIAO	CHINA	777	809	98.5	1	0
2014-051B	CHUANG XIN 1-04	CHINA	777	811	98.5		
2014-052A	ASIASAT 6	ASIASAT	35773	35803	0.0	1	0
2014-053A	YAOGAN 21	CHINA	484	500	97.4	1	0
2014-053B	TIANTUO 2	CHINA	475	494	97.4		
2014-054A	OPTUS 10	AUSTRALIA	35775	35797	0.0	1	1
2014-054B	MEASAT 3B	MALAYSIA	35783	35790	0.0		
2014-055A	USA 257	USA	NO ELEMS. AVAILABLE			1	0
2014-056A	DRAGON CRS-4	USA	413	416	51.6	0	2
2014-057A	SOYUZ-TMA 14M	RUSSIA	413	416	51.6	1	0
2014-058A	OBJECT A	RUSSIA	35588	35765	0.0	1	1
2014-059A	SJ-11-07	CHINA	686	706	98.1	1	1

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