National Aeronautics and Space Administration

Orbital Debris Quarterly News

Volume 23, Issue 4
November 2019

Inside...

A publication of the NASA Orbital Debris Program Office (ODPO)

The First International Orbital Debris Conference (IOC) is scheduled for December 9–12, 2019 at the Sugar Land Marriott Town Square in Sugar Land (greater Houston area), Texas.

Visit the conference website for registration and logistics information.
https://www.hou.usra.edu/meetings/orbitaldebris2019/

The program and abstracts are available on this website. Register by November 10 for the best conference rates and by November 21 for hotel reservations at the group rate.

ODQN readers are referred to the conference website for the roster of keynote speakers.

Three Recent Rocket Body Breakups

Three breakups of derelict rocket bodies have recently been observed. The first occurred in May 2019, but was not reported until after publication of the ODQN 23-3. The second two occurred in August 2019.

The first event was the Titan IIIC Transtage rocket body (International Designator 1976-023F, U.S. Strategic Command [USSTRATCOM] Space Surveillance Network [SSN] Catalog # 8751) that launched the complex Lincoln Experiment Satellite 8 and 9, and SOLRAD 11A/11B, payload stack. The event is estimated to have occurred at 1902 GMT on 7 May 2019, after over 43 years on-orbit. The rocket body was in a 16.4° inclination, 36889 × 35793 km-altitude orbit. The approximately 1640 kg (dry mass) Transtage No. 30 was the third Transtage launched without a passive or active Heat Rejection System for stage thermal management, and employed a monopropellant, anhydrous hydrazine (N_2H_4) Attitude Control System.

No Transtage No. 30 fragments have, to date, entered the SSN catalog. Additional fragments may be cataloged in the future, and the reader is reminded that cataloging debris in geosynchronous orbit is difficult.

The second event occurred on 13 August 2019 and is associated with the Ariane 42P third stage rocket body (International Designator 1992-052D, SSN # 22079) that launched the TOPEX-Poseidon oceanographic spacecraft and two smaller payloads in Arianespace mission V-52. The approximately 1720 kg (dry mass) third stage was in a 66° inclination, 1404 × 1296 km-altitude orbit at the time of the event. Like other low Earth orbit missions

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Breakups

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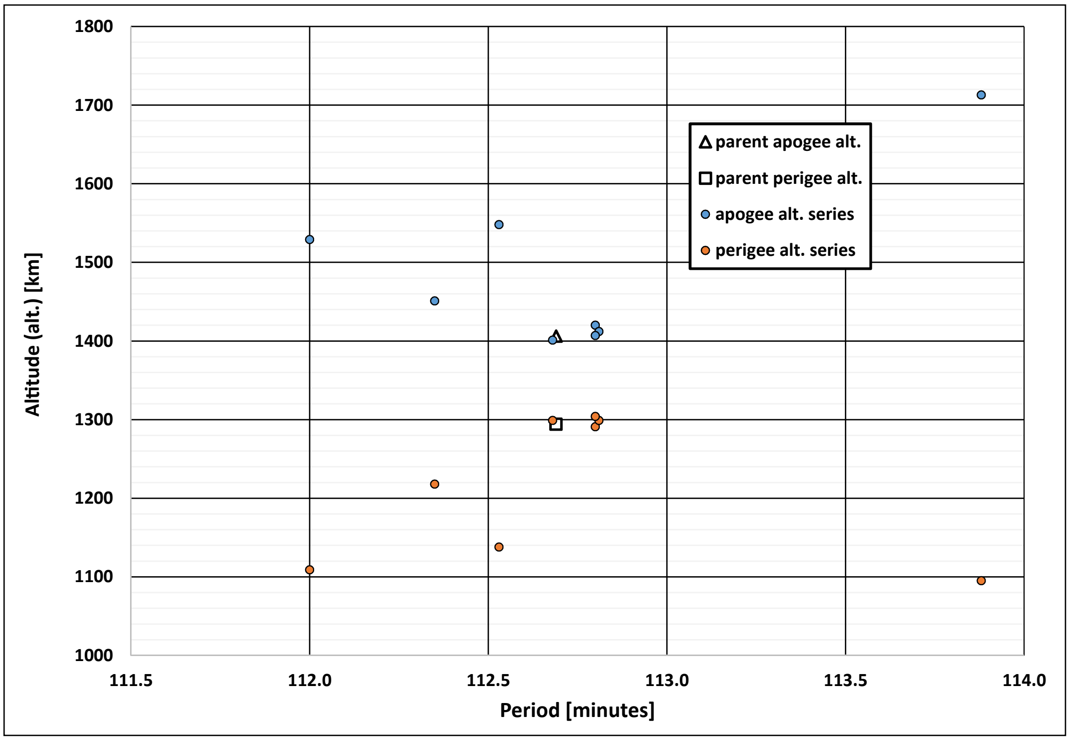

A Gabbard diagram of the 1992-052 third-stage event. Debris was injected into both longer and shorter-period orbits, indicating an energetic event.

after the breakup of the V-16 SPOT-1/Viking mission's third stage in 1986, and before the general implementation of debris mitigation with mission V-60, this stage was passivated at end of mission.

In addition to the rocket body, eight additional debris (piece tags "E" through "M" inclusive) have entered the public satellite catalog. A Gabbard diagram illustrates the breakup in the figure.

A maximum change in period of 1.19 minutes, and in inclination of 0.3°, was observed. At this time, the breakup mechanism is not understood.

The third event was the breakup of a SOZ (*Sistema Obespecheniya Zapuska*) ullage motor, or SL-12 auxiliary motor, from a Proton Block DM fourth stage fragmented at 1358 GMT on 19 August 2019. These motors have a long history of fragmentations, this event being the 50th breakup of this class of object over its program history. A total of 380 SL-12 Auxiliary Motors were cataloged between 1970 and 2012, of which 64 remain on orbit as of 1 October 2019. Of these 64, 34 are now believed to be intact. The remaining 30 have fragmented and remain on-orbit while an additional 20 fragmented parent bodies are no longer on-orbit.

Ullage motors used to provide three-axis control to the Block DM during coast and to settle propellants prior to an engine restart, were routinely ejected after the Block DM stage ignites for the final time. The reader is referred to a prior ODQN (ODQN, Vol. 18, Issue 4, pp. 1-2) for an illustration and engineering drawing of a typical SOZ unit.

This SOZ unit (International Designator 2010-041H, SSN# 37144), is associated with the launch of the Cosmos 2464-2466 spacecraft triplet, members of the Russian global positioning navigation system (GLONASS) constellation. Its sister unit, International Designator 2010-041G, SSN# 37143, had previously fragmented on 3 September 2017 [1].

The motor was in a highly elliptical 18907 × 541 km-altitude orbit at an inclination of 65° at the time of the breakup. Due to difficulties in tracking objects in deep space elliptical orbits, this event may have produced many more fragmentation debris than have been observed to date. This event represents another SOZ unit fragmentation predicted by analysts of the Air Force Space Command 18th Space Control Squadron [2]. Their analysis indicates that SOZ units experience outgassing prior to the fragmentation event; the main body of the SOZ can then exhibit the effects of outgassing for several days after the event. This technique is useful in prompting additional surveillance of a SOZ unit prior to and post-fragmentation and assessing event time for modeling and risk assessment purposes.

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DAS 2.1/3.0 NOTICE

Attention DAS Users: an updated solar flux table is available for use with DAS 2.1 and DAS 3.0. Please go to the Orbital Debris Website at https://www.orbitaldebris.jsc.nasa.gov/mitigation/debris-assessment-software.html to download the updated table and subscribe for email alerts of future updates.

New ODPO Website Update

The Orbital Debris Program Office (ODPO) website located at https://orbitaldebris.jsc.nasa.gov/ has been updated with new content. An improved structure makes navigation through the site easier to follow. Additional images, videos, and links provide a more enjoyable browsing experience, including a carousel of images, as shown in this snapshot of the home page.

Each page has an **Explore Orbital Debris** column on the right. Here you can move from topic-to-topic, as shown in the table on page 9. About ODPO acts as a home button to take you back to the opening page. **Upcoming Events** will bring you the latest ODPO news, such as the upcoming First International Orbital Debris Conference in December 2019.

Subscribing to the Orbital Debris Quarterly News (ODQN) page is now controlled through the NASA mailing list "jsc-orbital-debris-newsletter." This transition verifies emails to minimize interference with normal mail delivery. Existing subscribers will not be impacted. To subscribe, follow the instructions at https://orbitaldebris.jsc.nasa.gov/quarterly-news/newsletter.html .

If you prefer to enter the ODPO webpages from the Astromaterials Research & Exploration Science website (https://ares.jsc.nasa.gov/), select the dropdown choice of Orbital Debris Program Office from the "Safety" tab at the top of the page.

We hope you enjoy the new look. ♦

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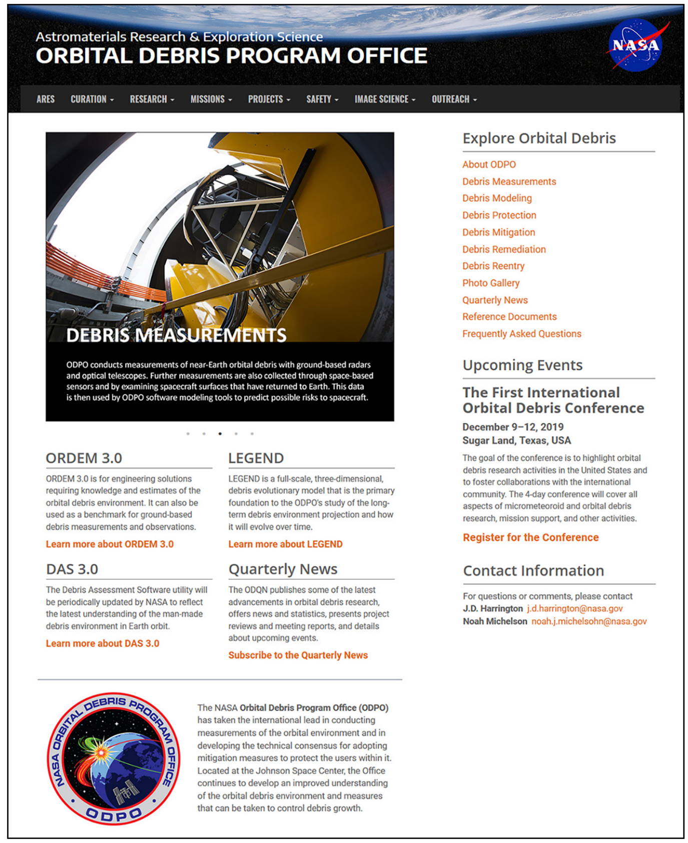

The ODPO website home page located at https://orbitaldebris.jsc.nasa.gov/ .

PROJECT REVIEW

HUSIR Measurements of the OD Environment: 2014 – 2017

T. KENNEDY AND J. MURRAY

The NASA Orbital Debris Program Office (ODPO) recently published a report detailing the orbital debris (OD) measurements and analysis from the Haystack Ultra-wideband Satellite Imaging Radar (HUSIR) covering U.S. Government fiscal years (FY) 2014 – 2017 [1]. This represents the first set of OD measurements and analysis from this sensor since the Haystack radar underwent upgrades starting in 2010, emerging as HUSIR, with orbital debris data collection resuming in early FY14 [2]. This 2014 – 2017 dataset also represents the first set of data from the upgraded HUSIR sensor used in developing and validating populations for the upcoming Orbital Debris Engineering Model (ORDEM) 3.1 model release. An overview of the data collected is given in this review article, which will highlight some of the recent observations related to important orbital debris populations resident in the 2014 – 2017 dataset.

For OD measurement purposes, HUSIR maintains the Haystack standard mode of operating in the well-known fixed beam or staring mode, where the radar is pointed to a particular elevation and azimuth angle, sampling the OD environment by making measurements of OD that travels through the volume of space observed by the radar. Direct measurements from the sensor are range, range-rate and radar cross section (RCS), and an aggregate of these measurements for the case of pointing HUSIR to 75° elevation and due east for all of the years considered are shown in Fig. 1.

Assuming a circular orbit and an elevation and azimuth pointing, in this case 75° E, the inclination of OD traveling through the beam may be approximated from the measured range and range-rate or Doppler information for each object [3]. This enables transformation of the range and range-rate data into altitude and Doppler inclination as shown in Fig. 2. Based on the data in Fig. 2, a number of important orbital debris families are evident; of particular note is the heavily trafficked sun-synchronous family of OD clustered about the sun-synchronous inclinations for circular orbits – indicated by the dashed black curve in Fig. 2 [4]. The well-known sodium potassium (NaK) population is evident for inclination angles between approximately 63 and 67 degrees, and is discussed in more detail later in this article. Also of interest in Fig. 2 are several highlighted on-orbit events – indicated by the red circles. The center of these circles corresponds to the altitude and inclination at the time of the event [5].

Generally, the most populous orbital debris families have stable count rates over the years observed. A comparison of the year-to-year variation in the OD count density is depicted in Fig. 3. This figure is generated by aggregating the raw counts into 2° bins in inclination and 50 km bins in altitude and averaging over the number of observations considered in each year. It is worthwhile to compare the count density between the clusters of objects corresponding to the regions of space associated with the Cosmos 2251 and Iridium 33 debris clouds – see Fig. 2 for the altitude and inclination at the time of the event. It is evident from Fig. 3 that the count density of objects associated with the Iridium 33 debris cloud is less than that

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HUSIR Measurements

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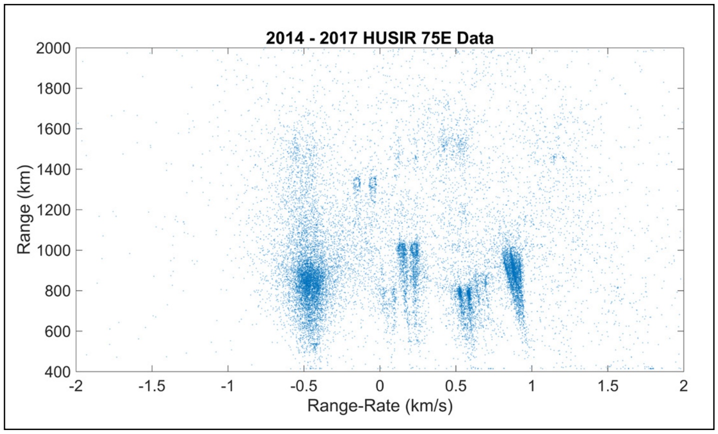

Fig. 1. Range vs. range-rate observations for orbital debris, as measured by HUSIR in U.S. Government FY 2014-2017.

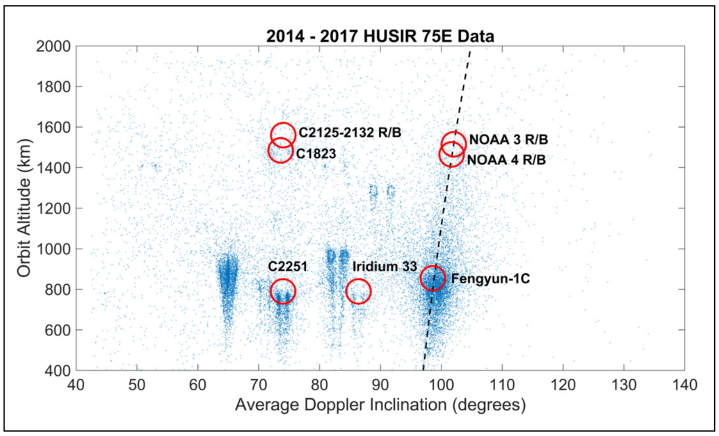

Fig. 2. Conversion of HUSIR range and range-rate measurements into altitude and Doppler-derived inclination. The sun-synchronous condition, assuming a circular orbit, is indicated with the dashed black line.

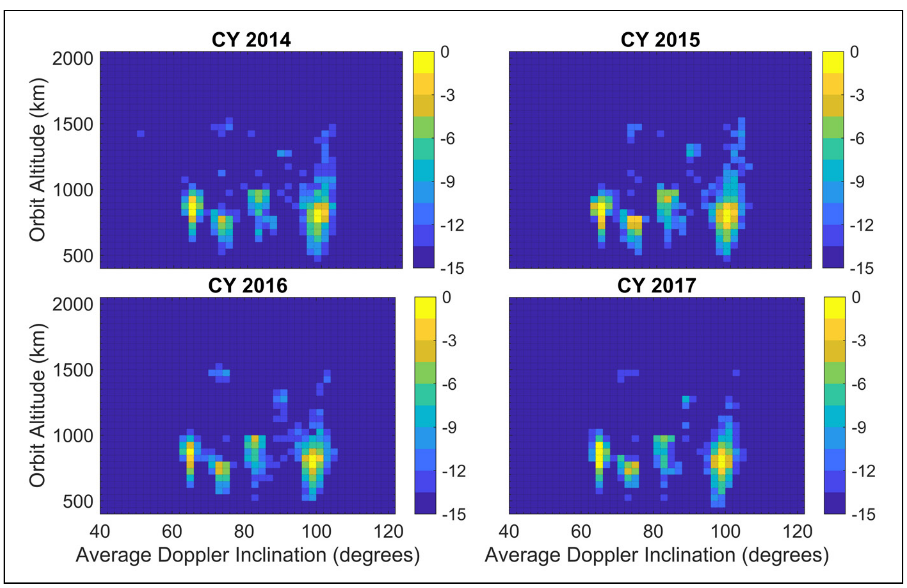

Fig. 3. Orbital debris count density in altitude (km) vs. Doppler-derived inclination (°) space. The color scale is in decibels (dB), hence each 3 dB decrease represents a factor of 2 decrease in count density.

associated with the Cosmos 2251 debris cloud – which may be attributable to the materials and construction used for the Iridium satellite. Iridium 33 was a more modern satellite constructed out of modern light-weight materials that tend to drag out quicker. Understanding orbital debris generated by such a satellite was a key motivator for the DebriSat experiment [6].

To determine the RCS of an object, range measurements are combined with information about the polarization of the backscattered radar signal, the signal-to-noise ratio (SNR), and the path traveled by the object through the radar beam – resulting in a left- and right-handed, circularly polarized RCS for each observation. These may alternately be referred to as the principal polarization (PP) and orthogonal polarization (OP) RCS, respectively. The NASA size estimation model (SEM) is used to infer a characteristic length from the RCS for the OD object [7-8]. The cumulative count rate for a given SEM estimated size, for each calendar year (CY) during the 2014 – 2017 observation period, is relatively stable over the time of observations considered. The count rates shown in Fig. 4 include the shaded 95% confidence intervals – constructed using the Poisson 2σ values – and based on this, the count rates for a given size are statistically equivalent for a given calendar year and for most of the sizes considered in the comparison. It should be noted that differences at the smaller SEM sizes may be attributable, in large part, to a change in sensitivity for HUSIR in a given year, for example in 2017 where the transmitter power was significantly reduced due to multiple amplifier failures.

The completeness of the HUSIR 75E dataset to a given SEM size for altitudes less than 1000 km is approximately 5.5 mm for observation times with nominal sensitivity. Using the completeness constraint for the data in CY2016, a plot of the altitude versus SEM size for HUSIR orbital debris observations is shown in Fig. 5. The approximate data completeness to a given size is indicated by the red curve shown in this plot, where the detection efficiency is observed to decrease rapidly to the left of this curve.

The NaK population has been studied for many years and represents an important class of orbital debris – both due to the size of this population and due to the unique properties of the NaK droplets [9]. The droplets, owing to their formation in the microgravity of orbit, have a spherical shape – which combined with their conductivity make this population an excellent calibration source for radar data [10]. Examination of this population is conducted by initially filtering on altitude and Doppler inclination, corresponding to the source of this population. Since the NaK droplets are spherical and electrically conductive, the reflection of an incident circularly polarized wave is also circularly polarized, however, the reflected energy reverses polarization handedness, *i.e.*, a right-hand, circularly polarized or OP incident wave produces a left-hand, circularly polarized or PP backscattered wave. The right-hand, circularly polarized or OP backscattered wave is ideally zero for the perfectly conducting sphere. Differences arise if the droplets are not perfectly spherical, and at low SNR – equivalently smaller sizes – where in the latter case noise power in the sensor measuring the OP component is such that the polarization appears to be a mix of both right- and left-hand circular polarizations.

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HUSIR Measurements

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In Fig. 6, the radar observations from Fig. 2 – and for CY2014 – are first filtered in altitude and inclination, resulting in a NaK population cluster that is observable in a plot of polarization as a function of RCS. The RCS indicated are for the PP component, which is left-hand circularly polarized since HUSIR transmits right-hand circular polarization. An ad hoc decision boundary, the dashed line in the figure, is constructed by inspection to separate the NaK population from the rest of the objects detected in this altitude and inclination region. Alternately, clustering techniques may be employed that yield similar results as described in [10].

The NaK count rates, after extracting the NaK droplets from the rest of the orbital debris population are shown in Fig. 7 as a function of RCS, along with the Poisson 2σ uncertainties – the uncertainties are indicated by the shaded areas of the same color as the respective count rate for a given calendar year. As noted for the entire orbital debris population, the count rates for the NaK population are stable for the years considered here, and in general are statistically equivalent to each other.

As mentioned previously, the NaK population is an excellent calibration data source, which was used to great effect in preparation of data included in the 2014 – 2017 HUSIR data report. For the HUSIR radar wavelength (3 cm), it is expected that the NaK population has an inflection point in the count rate for particles with an RCS near -35 dB per square meter (dBsm). This increased count rate is due to the clustering of the radar cross section of the NaK particles in the Mie resonance region. The RCS for the case of Mie scattering for a sphere as a function of size (diameter) at the HUSIR wavelength is shown in Fig. 8, where a horizontal line at -35 dBsm is indicated. A more detailed summary of the NaK calibration, and additional data and analysis for other orbital debris populations may be found in the HUSIR 2014 – 2017 orbital debris data collection report [1] and upcoming papers at the 1st International Orbital Debris Conference (IOC) [10, 11].

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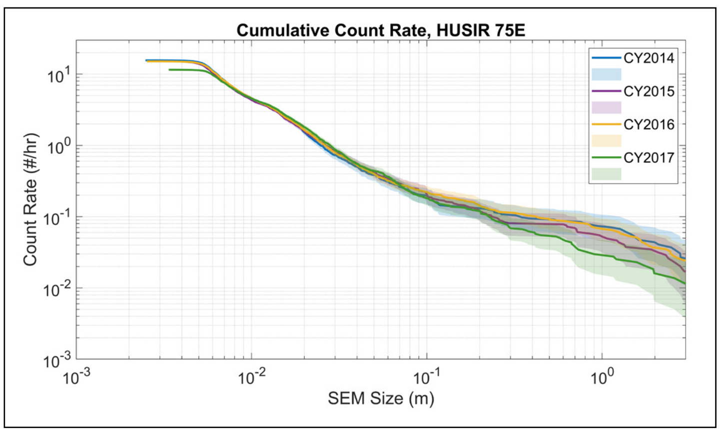

Fig. 4. Cumulative count rate for the orbital debris as a function of NASA SEM size. Shading color corresponds to CY line color.

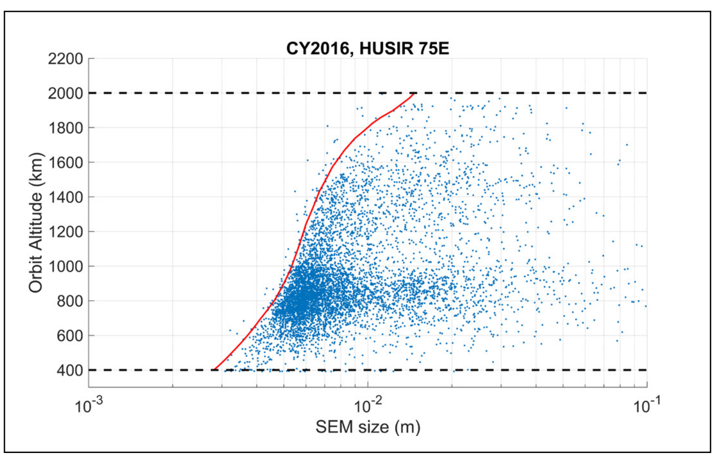

Fig. 5. Orbital debris observations in altitude and SEM-size space for the 2016 HUSIR 75E data. The red curve indicates the altitude and SEM-size sensitivity relationship for the radar in 2016. Dashed black lines indicate approximate altitude limits for the HUSIR orbital debris mode.

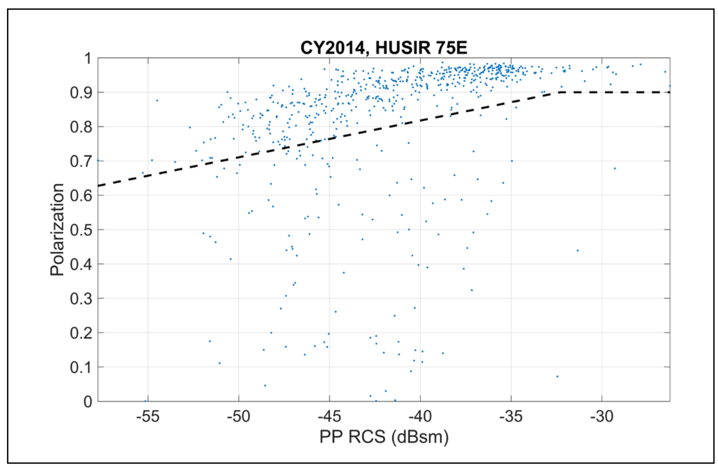

Fig. 6. Identification of the piecewise linear line that separates the NaK from the rest of the orbital debris population with altitudes < 1000 km and Doppler inclinations between 62.9° and 67°. The polarization shown is limited to positive values to highlight the NaK population, which has polarizations near unity.

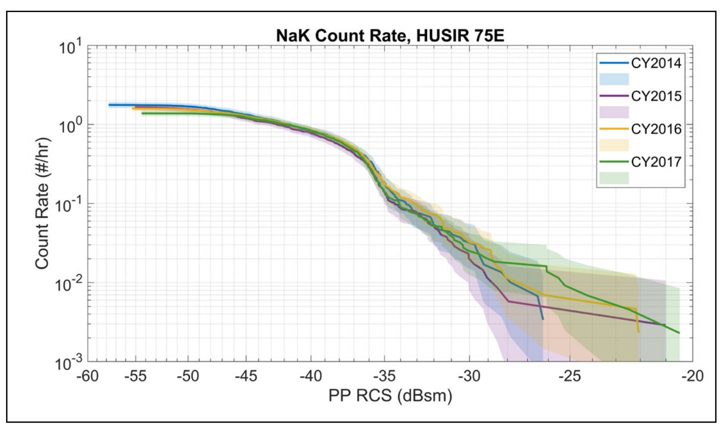

Fig. 7. Count rates for the NaK population for HUSIR 75E. Shading color corresponds to CY line color.

HUSIR Measurements

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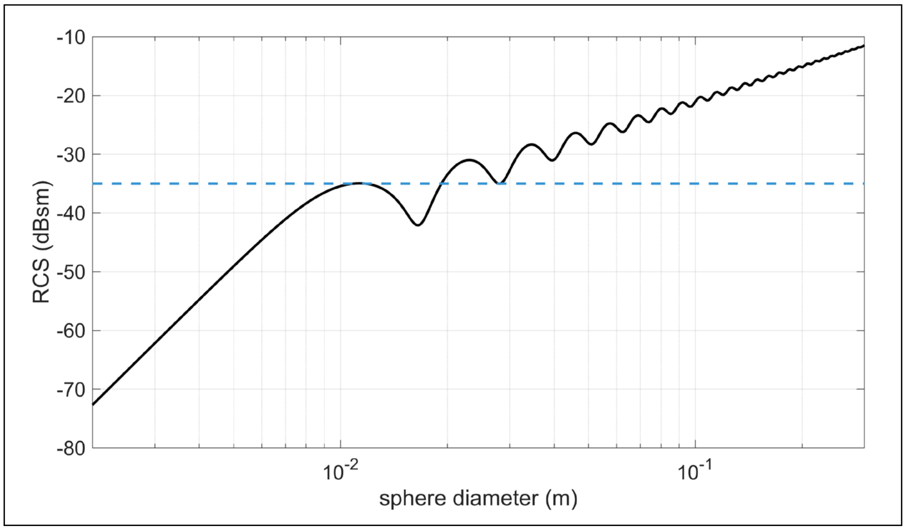

Fig. 8. Mie sphere scattering for the HUSIR X-band wavelength. A reference line at -35 dBsm marks the inflection of the RCS curve where a sudden increase in the NaK cumulative count rate is expected for HUSIR X-band operation.

MEETING REPORTS

The 33rd Annual Small Satellite Conference, 3-8 August 2019, Logan, Utah, USA

The 33rd Annual American Institute of Aeronautics and Astronautics/Utah State University Conference on Small Satellites was held 8-13 August in Logan, Utah. The conference hosted nearly 3500 international participants and 234 exhibitors, both records for this growing annual forum. The topic of this year's conference was "Driving a Revolution," and many papers focused on the emerging problems and opportunities as individual small satellites proliferate, large constellations deploy, and launch opportunities expand, notably with simultaneous deployments of enormous numbers of dissimilar small satellites. There was significant movement in the reported accomplishments and future plans to use small satellites beyond Earth orbit in Solar System exploration.

The NASA Orbital Debris Program Office (ODPO) gave a side meeting presentation: "Orbital Debris Mitigation Policy and Unique Challenges for Small Satellites," which included an overview of the use of ODPO's Debris Assessment Software (DAS) to assure compliance with U.S. Government Agency requirements. The ODPO's representatives discussed orbital debris issues throughout the conference individually with exhibitors and presenters. A total of 48 side meetings complemented the 140 oral papers and 142 posters presented.

Many of the conference topics focused on recently developed or upcoming small satellite technologies with little mention of orbital debris (OD) mitigation. Several commercial exhibitors did advertise that their products were designed with NASA OD mitigation requirements in mind.

A wide variety of compact propulsion units were presented and displayed, showing the fast pace of innovation in that particular area. Although robust, commercial off-the-shelf spacecraft subsystems and busses are evolving, historically only 25% of SmallSat missions have performed 100% of their mission requirements, and comparable numbers fulfill none of them, raising the apprehension that a majority of small satellite missions in orbits with > 25 year natural decay will become long-term debris objects.

The conference keynote from OneWeb founder Greg Wyler included significant focus on — and encouragement to all satellite developers to adhere to — space debris requirements and to be best possible citizens of the common space environment. Mr. Wyler even suggested that stronger regulation (with penalties) might be needed to avoid future risk to the environment, based upon prior history of mission success through to the end-of-mission. ♦

20th Advanced Maui Optical and Space Surveillance Technologies Conference, 17-20 September 2019, Maui, Hawaii, USA

The 20th Advanced Maui Optical and Space Surveillance Technologies (AMOS) Conference was held 17-20 September. This year AMOS broke the previous attendance record with 919 participants, including 127 representing international partners from 18 countries. The opening keynote speaker was General (Ret.) William L. Shelton, Chairman of the Space Foundation and Former Commander of the Air Force Space Command. General Shelton discussed the new threats and increased traffic associated with Space Situational Awareness (SSA) in general, including private investments in space business, "brazen anti-satellite tests," the popularity of CubeSats and SmallSats, and calls for new sensors and new regulatory framework.

Two opening keynote addresses were given by Major General John Shaw, Deputy Commander of the Air Force Space Command and Brigadier General Thomas James, Commander of U.S. Space Command's Joint Task Force Space Defense. The daily keynote addresses, in order, were given by 1) Hirohisa Mori, Director of the National Space Policy Secretariat, who serves in Japan's Cabinet Office; 2) Francesca Letizia, Space Debris Engineer with the European Space Agency's (ESA's) Space Debris Office; and 3) Kevin O'Connell, Director of the Office of Space Commerce at the U.S. Department of Commerce.

Four papers were presented during the Orbital Debris session, co-chaired by Dr. Darren McKnight (Centauri) and Dr. Thomas Schildknecht (Astronomishes Institut Universität Bern). The session's first speaker, Dr. Peter Zimmer (J. T. McGraw and Associates), provided an overview on optical measurements of faint low Earth orbit objects, specifically focused on CubeSats and Fengyun-1C debris. Next, Dr. Jira Silha (Comenius University in Bratislava) presented an overview of filter (blue, red, visible, and infrared) photometric measurements of space debris objects taken using the Astronomical and Geophysical Observatory in Modra, including a comparison with laboratory measurements taken by the NASA Orbital Debris Program Office (ODPO). Dr. Schildknecht then spoke about ESA's recent optical surveys to characterize fragmentation events in geosynchronous orbits and highly elliptical orbits. Lastly, Dr. McKnight engaged the audience with a topic focused on space traffic management, setting the framework for controlling the orbital debris risk.

The Non-Resolved Object Characterization session, co-chaired by Dr. Heather Cowardin (NASA ODPO) and Dr. John Lambert (Cornerstone Defense), focused on attitude stability using radar cross section statistics; attitude estimation using optical measurements and deep learning; shape characterization from random finite set estimations using a LIDAR system; shape estimates from noisy light curves; and using Bayer arrays for synchronous multi-filter photometry.

Two NASA ODPO poster papers also were presented over two-day sessions. Dr. Sue Lederer (NASA ODPO) presented a poster on updates and upgrades to the Eugene Stansbery-Meter Class Autonomous Telescope (ES-MCAT). Dr. Cowardin presented on experimentally derived, bidirectional, reflectance distribution function data acquired in the Optical Measurement Center at the NASA Johnson Space Center.

Ten technical short courses also were offered at the conference. Of these, two courses focused on space debris. Tim Flohrer (ESA/European Space Operations Centre (ESOC) Space Debris Office) and Srinivas Setty (ESA/ESOC GMV Insyen AG) presented space debris risk assessment and mitigation analysis. Dr. Schildknecht presented his course on observing and characterizing space debris. ♦

ABSTRACT FROM THE NASA ORBITAL DEBRIS PROGRAM OFFICE

The 20th Advanced Maui Optical and Space Surveillance Technologies Conference, 17-20 September 2019, Maui, Hawaii, USA

Experimentally Derived Bidirectional Reflectance Distribution Function Data in Support of the Orbital Debris Program Office

J.HOSTETLER AND H. COWARDIN

The NASA Orbital Debris Program Office (ODPO) has used various optical assets to acquire photometric data of Earth-orbiting objects to define the orbital debris environment. To better characterize and model optical data acquired from ground-based telescopes, the Optical Measurements Center (OMC) at NASA Johnson Space Center emulates illumination conditions seen in space using equipment and techniques that parallel telescopic observations and source-target-sensor orientations.

One of the goals of the OMC is to improve the size calculation used for optical data by developing an optical-based Size Estimation Model. The current size estimation requires applying a Lambertian phase function, set albedo value, and range to the observed magnitude. The first step to improving the sampled brightness of laboratory targets is to remove aspect-angle dependencies. Then, the volume of possible object viewing angles is sampled at 21 specified combinations of azimuthal and elevation angles for each solar phase angle. Finally, the acquired images are input into an image processing program that generates approximations for the object's Bidirectional Reflectance Distribution Function (BRDF) and phase function. The BRDF is a radiometric concept that identifies an object's material composition by matching a BRDF approximated with photometric data collected by ground-based telescopes with a BRDF generated experimentally from a known object in the laboratory.

This paper discusses the validation of experimental BRDF and phase function approximations produced in the OMC and how the findings will

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Experimentally Derived BRDF Data - *continued*

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be incorporated into ODPO models. A Lambertian sphere is imaged and the subsequent experimental functions are scrutinized to confirm that they correspond to an object that has an isotropic luminance. With the image processing algorithm validated, test objects with varying optical properties are then imaged to confirm that the produced photometric functions are both unique and repeatable. Once the validation is complete, the OMC will be used to evaluate a subset of fragments from a hypervelocity impact test of a mock-up satellite and assess the appropriate phase function and size estimates using BRDF measurements for a large volume of targets composed of various shapes, sizes, and materials. ♦

UPCOMING MEETINGS

3-4 December 2019: 2019 Spacecraft Anomalies and Failures Workshop (SCAF), Chantilly, VA, USA

The 2019 SCAF Workshop will be hosted by the Centauri Corporation and co-sponsored by NASA and the U.S. National Reconnaissance Office. The SCAF Workshop, organized in moderated discussions between community participants, has three primary goals: establishing enduring relationships between stakeholders that might not normally interface such as space operators, space weather experts, system testers, modelers, etc. and strengthening cross-community ties with academia, government, contractors, and other relevant parties; improving the anomaly root cause attribution processes for the sponsors and the community, in general by characterizing best practices that migrate across organizations in order to prevent future anomalies and failures; and solving complex case studies in cause and effect. The overarching theme is to strive to reduce the ambiguity of space operations which is vitally needed as systems, operators, missions, and environments are increasingly complicated. Attendees must be U.S. citizens to attend the workshop, and additional details are provided at the registration site. Register at https://www.eventbrite.com/e/2019-spacecraft-anomalies-and-failures-scaf-workshop-tickets-70570136177 and the registration deadline is 20 November 2019.

9-12 December 2019: The First International Orbital Debris Conference (IOC), Sugar Land, Texas, USA

The first of this "once-every-4-years" conference series will be initiated 9-12 December 2019 in Sugar Land (greater Houston area), Texas, USA. The conference goal is to highlight orbital debris research activities in the United States and to foster collaborations with the international community. The 4-day conference will cover all aspects of micrometeoroid and orbital debris research, mission support, and other activities. Topics to be covered include radar, optical, in situ, and laboratory measurements; engineering, long-term environment, and reentry modeling; hypervelocity impacts and protection; and mitigation, remediation, policy, and environment management. The abstract submittal deadline passed on 29 April 2019. The conference announcement is available at https://www.hou.usra.edu/meetings/orbitaldebris2019/ .

14-16 January 2020: 2nd IAA Conference on Space Situational Awareness (ICSSA), Washington, D.C., USA

The International Academy of Astronautics (IAA), the American Institute of Aeronautics and Astronautics (AIAA), and the University of Florida's Mechanical and Aerospace Engineering Dept. will convene the 2nd IAA Conference on Space Situational Awareness in Washington, D.C., USA. Technical sessions include, but are not limited to, resident space object and Near Earth Object sensing, identification, forecasting, tracking, proximity operations, risk assessment, debris removal, drag assisted reentry, and deorbiting technologies. The abstract submission passed on 10 October 2019. Additional information about the conference is available at http://reg.conferences.dce.ufl.edu/ICSSA .

22-23 January 2020: 8th Satellites End of Life and Sustainable Technologies Workshop, Paris, France

CNES Headquarters will host the 8th Satellites End of Life and Sustainable Technologies Workshop. The objective of this 2-day workshop is to review the state of the art in end of life technologies, post-mission disposal concepts and lessons learned, measurements, and mission extension; and spacecraft reliability and post-mission disposal success probability, Design for Demise, protection and health monitoring, and Active Debris Removal (ADR) Ready designs and equipment. Attendees are invited to register for the workshop at http://eol-and-t4sc-workshop.evenium.net . Additional information about the conference is available from the ODQN editorial team.

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UPCOMING MEETINGS - Continued

15-17 June 2020: 6th International Workshop on Space Debris Modeling and Remediation, Paris, France

CNES Headquarters will host the 6th International Workshop on Space Debris Modeling and Remediation. Topics are anticipated to include, but are not necessarily limited to, modelling, including specificities coming from small satellites and constellations; high level actions, road-maps, associated to Debris Remediation; Remediation system studies, including those relative to small debris; Design of specific concepts, including new ideas relative to Just-in-time Collision Avoidance and proposals devoted to large constellations and small satellites; concepts derived from current Space Tugs initiatives; GNC aspects, rendezvous sensors and algorithms, de-spin, control during de-boost; and Policy, Economics, Insurance, Intellectual property, national security, and international cooperation aspects of Debris remediation. The abstract submission process will be announced shortly. Additional information about the conference, limited to 140 participants, is available from the ODQN editorial team.

1-6 August 2020: 34th Annual Small Satellite Conference, Logan, UT, USA

Utah State University (USU) and the AIAA will sponsor the 34th Annual AIAA/USU Conference on Small Satellites at the university's Logan campus, Utah, USA. Conference information will be updated as it becomes available hereinafter, and at the organizer's website at https://smallsat.org/.The abstract submission period closes on 4 February 2020.

15-22 August 2020: COSPAR 2020, Sydney, Australia

The 43rd Committee on Space Research (COSPAR) Scientific Assembly will convene in the Sydney International Convention Center on Saturday, 15 August 2020 and runs through Saturday, 22 August. The COSPAR panel Potentially Environmentally Detrimental Activities in Space (PEDAS) will conduct a program entitled "The Science of Human-Made Objects in Orbit: Space Debris and Sustainable Use of Space." PEDAS.1 sessions will include advances in ground- and space-based measurements of the orbital debris environment, micrometeoroid and orbital debris environment modeling, end-of-life concepts, and solutions to fundamental operational challenges. The abstract submission period closes on 14 February 2020. Please see the COSPAR website at https://www.cospar-assembly.org/admin/session_cospar.php?session=953 and the Assembly website https://www.cospar2020.org/ for further information.

New ODPO Website

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Orbital Debris Program Office (ODPO) Website Page Navigation: Topics and Details Found on each Linked Page

Topics	Items Included on Linked Pages
ODPO Homepage	A carousel of slides highlights ODPO's areas of expertise. Includes links to ORDEM 3.0, LEGEND, DAS 3.0 and the Quarterly News.
Debris Measurements	Four divisions include Radar, Optical, and In situ Measurements and the DebriSat project.
Debris Modeling	Learn more about ORDEM 3.0 and LEGEND. View the "Debris Growth" video.
Debris Protection	Includes links to Spacecraft Impact Research and the Hypervelocity Impact Technology Facility. View the "Debris in Motion" video.
Debris Mitigation	Includes links to the *NASA Procedural Requirements for Limiting Orbital Debris*, the *Process for Limiting Orbital Debris (NASA-STD-8719.14)*, the *Handbook for Limiting Orbital Debris (NASA-HDBK-8719.14)*, the *Debris Assessment Software & User's Guide*, and the *U.S. Government Orbital Debris Mitigation Standard Practices*.
Debris Remediation	Explore events that increased the debris population and study debris removal through Orbital Debris Quarterly News (ODQN) article links.
Debris Reentry	Includes links to Debris Assessment Software (DAS) and Object Reentry Survival Analysis Tool (ORSAT) pages.
Photo Gallery	Images are organized on tabs for easy navigation.
Quarterly News	Visit current and previous issues of the ODQN, which can be downloaded directly. Subscribe here to receive email notifications.
Reference Documents	Download key orbital debris documents.
Frequently Asked Questions	Find answers to common questions.

SATELLITE BOX SCORE

(as of 04 October 2019, cataloged by the U.S. SPACE SURVEILLANCE NETWORK)

Country/ Organization	Spacecraft*	Rocket Bodies & Debris	Total
CHINA	369	3720	4089
CIS	1536	5099	6635
ESA	90	57	147
FRANCE	66	507	573
INDIA	96	163	259
JAPAN	180	115	295
USA	1878	4815	6693
OTHER	966	122	1088
TOTAL	5181	14598	19779

** active and defunct*

Visit the NASA

Orbital Debris Program Office Website

www.orbitaldebris.jsc.nasa.gov

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INTERNATIONAL SPACE MISSIONS

01 July – 30 September 2019

Intl.* Designator	Spacecraft	Country/ Organization	Perigee Alt. (KM)	Apogee Alt. (KM)	Incli. (DEG)	Addnl. SC	Earth Orbital R/B	Other Cat. Debris
1998-067	ISS dispensed SC	various	406	412	51.6	7	0	1
2019-038A	METEOR M2-2	RUSSIA	813	815	98.6	20	0	0
2019-039A	COSMOS 2535	RUSSIA	607	624	97.9	0	1	0
2019-039B	COSMOS 2536	RUSSIA	609	624	97.9			
2019-039C	COSMOS 2537	RUSSIA	609	625	97.9			
2019-039D	COSMOS 2538	RUSSIA	607	624	97.9			
2019-040A	SPEKTR RG	RUSSIA	HELIOCENTRIC			0	0	0
2019-041A	SOYUZ MS-13	RUSSIA	411	421	51.6	0	1	1
2019-042A	CHANDRAYAAN 2	INDIA	LUNAR ORBIT			0	1	0
2019-043A	CAS 7B	CHINA	201	217	42.7	0	0	0
2019-044A	DRAGON CRS-18	USA	397	414	51.6	0	0	2
2019-045A	YAOGAN-30 N	CHINA	596	602	35.0	0	1	0
2019-045B	YAOGAN-30 P	CHINA	592	606	35.0			
2019-045C	YAOGAN-30 Q	CHINA	598	599	35.0			
2019-046A	MERIDIAN 8	RUSSIA	1002	39352	62.8	0	1	0
2019-047A	PROGRESS MS-12	RUSSIA	411	421	51.6	0	1	0
2019-048A	COSMOS 2539	RUSSIA	35785	35787	0.0	0	1	1
2019-049A	EDRS-C	ESA	35783	35788	0.1	0	1	1
2019-049B	INTELSAT 39	INTELSAT	35715	35721	0.0			
2019-050A	AMOS 17	ISRAEL	35777	35794	0.1	0	1	0
2019-051A	AEHF 5 (USA 292)	USA	28827	34818	7.5	0	1	0
2019-051B	TDO SPACECRAFT	USA	210	35263	26.2			
2019-052A	OBJECT A	CHINA	530	561	97.6	0	0	0
2019-052B	OBJECT B	CHINA	527	561	97.6			
2019-052C	OBJECT C	CHINA	527	562	97.6			
2019-053A	CHINASAT-18	CHINA	237	35761	28.5	0	1	0
2019-054A	BRO-1	FRANCE	534	548	45.0	0	2	0
2019-054C	PEARL WHITE 1	USA	535	548	45.0			
2019-054D	PEARL WHITE 2	USA	534	548	45.0			
2019-054E	GLOBAL-4	USA	538	549	45.0			
2019-055A	SOYUZ MS-14	RUSSIA	410	421	51.6	0	1	0
2019-056A	NAVSTAR 78 (USA 293)	USA	20185	20193	55.0	0	0	0
2019-057A	COSMOS 2540	RUSSIA	942	944	99.3	0	1	0
2019-058A	XAIOXIANG-1 07	CHINA	592	610	97.8	0	1	0
2019-058B	KX-09	CHINA	592	608	97.8			
2019-059A	ZY-1 02D	CHINA	774	774	98.6	0	1	1
2019-059B	BNU-1	CHINA	732	751	98.6			
2019-059C	TAURUS-1	CHINA	731	751	98.6			
2019-060A	ZHUHAI-1 03A	CHINA	503	523	97.4	0	1	0
2019-060C	ZHUHAI-1 03B	CHINA	506	520	97.4			
2019-060D	ZHUHAI-1 03C	CHINA	494	511	97.4			
2019-060E	ZHUHAI-1 03D	CHINA	493	513	97.4			
2019-060F	ZHUHAI-1 03E	CHINA	491	512	97.4			
2019-061A	BEIDOU 3M23	CHINA	21546	22194	55.0	0	2	0
2019-061B	BEIDOU 3M24	CHINA	21535	22016	55.0			
2019-062A	HTV-8	JAPAN	411	421	51.6	0	0	0
2019-063A	YUNHAI 1-02	CHINA	782	785	98.6	0	1	1
2019-064A	SOYUZ MS-15	RUSSIA	411	421	51.6	0	1	0
2019-065A	COSMOS 2541	RUSSIA	1643	38540	63.8	0	1	0

** Intl. = International; SC = Spacecraft; Alt. = Altitude; Incl. = Inclination; Addnl. = Additional; R/B = Rocket Bodies; Cat. = Cataloged*