National Aeronautics and Space Administration

# Orbital Debris Quarterly News

Volume 12, Issue 3

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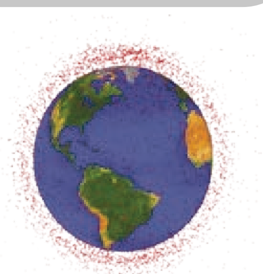
## Inside...





A publication of

The NASA Orbital Debris Program Office

## The Multiple Fragmentations of Cosmos 2421

Late in the first quarter of 2008, the U.S. Space Surveillance Network (SSN) detected a significant fragmentation of Cosmos 2421 (International Designator 2006-026A, U.S. Satellite Number 29247), which produced approximately 300 detectable debris (see ODQN, Vol. 12, Issue 2). Two more fragmentation events of the same spacecraft during April-June added another 200 or more large debris (greater than 5 cm) to the near-Earth space environment, once again raising questions about the peculiar nature of this satellite class.

Cosmos 2421 is the 50$^{th}$ member of a class of spacecraft which debuted in 1974 and which normally operate in nearly circular orbits between 400 and 450 km at an inclination of 65 degrees. The vehicles are often referred to as EORSATs for Electronic Intelligence Ocean Reconnaissance Satellites. Nearly half (22 out of 50) of the spacecraft have fragmented at least once, typically within a few months of the end of their primary missions. During the past ten years, four of five EORSATs have fragmented within a month of the cessation of normal orbit maintenance.

Each spacecraft is essentially cylindrical with two large solar arrays and a nadir-facing cross-antenna (Figure 1). The mass of the vehicle is approximately three metric tons, and the spacecraft recently have demonstrated operational lifetimes of about two years. Normally the debris are relatively short-lived, although during the 1980's three spacecraft (Cosmos' 1220, 1260, and 1461) were maneuvered into higher orbits before undergoing fragmentations, leading to longer-lived debris.

Some debris from the first fragmentation of Cosmos 2421 on 14 March 2008 were thrown into orbits with apogees up to 300 km higher than the pre-event orbit of 400 km by 420 km and perigees as low as 200 km. A little more than six weeks later on 28 April, a new cloud of debris from Cosmos 2421 was observed with some fragments now reaching above 900 km at apogee. By early June more than 50 cataloged debris from the two events had already

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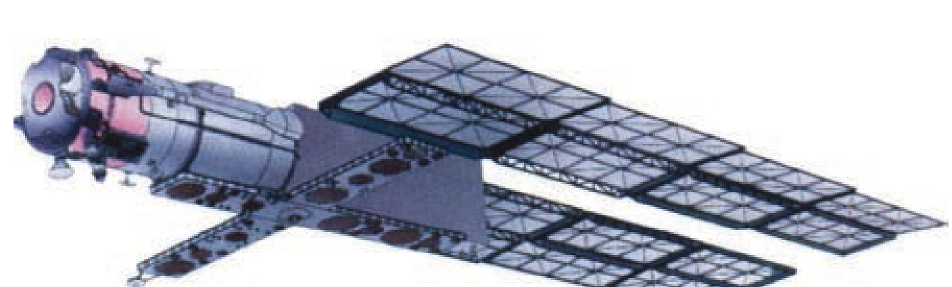

*Figure 1. General configuration of Cosmos 2421-class spacecraft.*

# Cosmos 2421

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fallen back to Earth, but more than 300 debris were still in orbit, being tracked by the U.S. SSN (Figure 2).

The third and thus far final fragmentation event occurred on 9 June when the orbit of the main element of the Cosmos 2421 had decayed slightly to 390 km by 415 km. Once again, more than 100 new debris were observed by the SSN, bringing to 500 or more the assessed total number of debris created as a result of the three fragmentation events.

The root cause of the many EORSAT fragmentations remains unknown, and at this time Cosmos 2421 is the only member of its class still in orbit. ♦

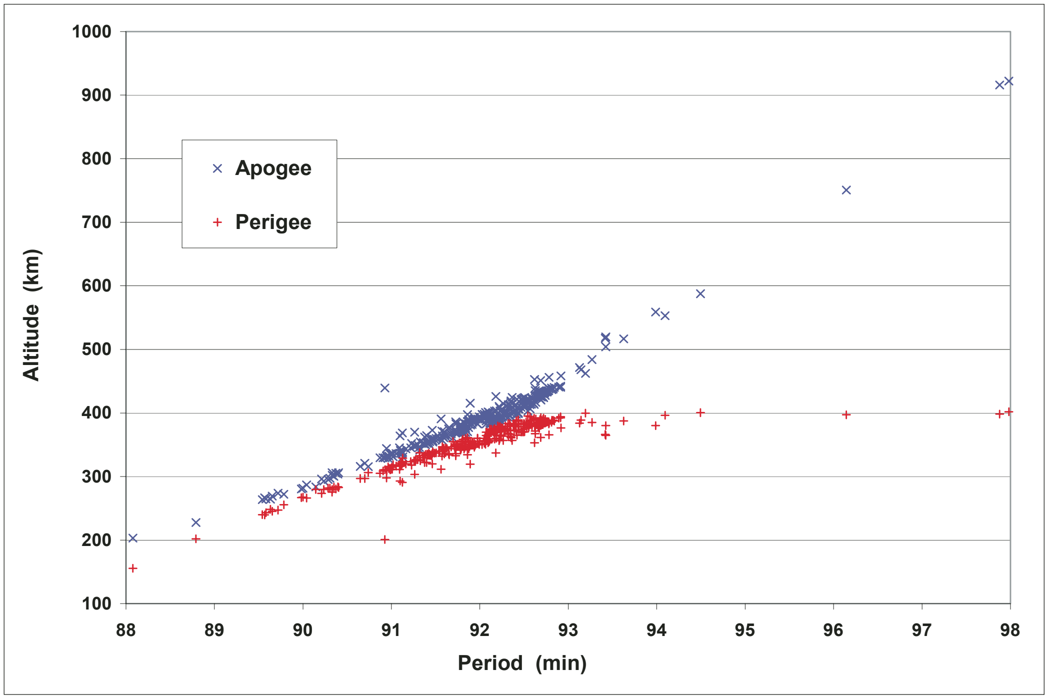
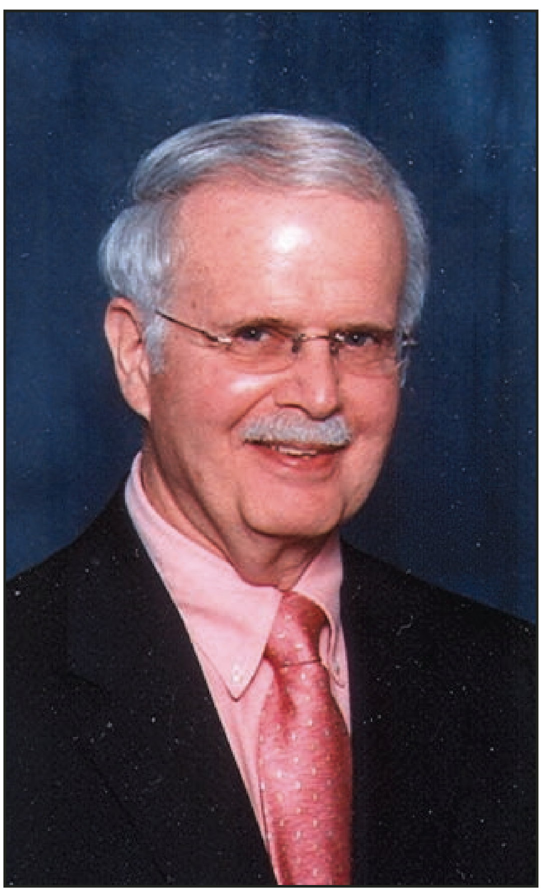



*Figure 2. More than 300 debris from the first two fragmentations of Cosmos 2421 were still in orbit when the third event occurred on 9 June 2008.*

# William (Bill) C. Rochelle – *(15 May 1937 - 7 May 2008)*



The orbital debris community lost a valued colleague on 7 May when Dr. William C. Rochelle passed away after a year-long illness.

Bill, a Texas native, was in the aerospace industry since the Apollo program. He received a BS in Aerospace Engineering from the University of Texas at Austin and an MS in Mechanical Engineering from the California Institute of Technology. His career began as a captain in the U.S. Army stationed at the Marshall Space Flight Center working on Saturn rockets. During his long career, he worked in various areas such as arc-jet testing, Space Shuttle re-entry, and plume impingement for the International Space Station. Since the late 1990s, he had led the Orbital Debris Re-Entry Survivability Team at Lockheed Martin and later at ESCG/Jacobs Technology in support of the NASA Orbital Debris Program Office.

Under his leadership, the team analyzed re-entries of low Earth orbit satellites, space telescopes, rocket bodies, Space Shuttle Columbia fragments, and Martian meteorites. His team completed various updates to ORSAT, the standard NASA re-entry survivability analysis tool, and published several conference papers. Bill's team also collaborated with international partners to further enhance predictions for the re-entry survivability of objects. His experience in the aerospace industry, including orbital debris re-entry, was vast and irreplaceable.

Bill was recognized throughout his career for outstanding service and received many awards. He recently received the JSC Center Director's Award for 40 years of exemplary service to NASA. Bill also earned a Lifetime Achievement Award from the Orbital Debris Program Office for his outstanding contributions to the development of reentry physics and risk assessment and for the living legacy he leaves in the next generation of scientists and engineers he had nurtured and trained.

Both his work and work ethic were of the highest standard. He was often the first person in the office and one of the last to go home at night. Outside of being a superb engineer, Bill was also an excellent teacher. His mentoring benefited many individuals (young and now old) who work with NASA in a variety of different fields.

Bill will be greatly missed by the Orbital Debris community. ♦

# PROJECT REVIEWS

## International Space Station Hand Rail and Extravehicular Activity Tool Impact Damage

J. HYDE, A. DAVIS, AND
E. CHRISTIANSEN

Hypervelocity impact damage sites were observed on an International Space Station (ISS) handrail and an extravehicular activity (EVA) tool during the first two shuttle missions of 2008 (STS-122 and 123).

During the first spacewalk on STS-122 (1E), a crater was observed by an EVA crewmember on airlock hand rail 0506 (Figure 1). The rail material in this location is composed of 7075-T7351 aluminum. During a subsequent spacewalk on the same mission, high resolution images of the site were acquired (Figure 2) for photogrammetric analysis by the NASA/JSC Image Science and Analysis Group. Results of the analysis provided an estimated crater diameter of 1.78 ±0.25 mm. The approximate crater depth was 1.27 ± 0.76 mm and the crater lip height was estimated to be 0.25 ± 0.13 mm. Since the density of the impacting micrometeoroid (MM) or orbital debris (OD) particle is not known, a diameter of approximately 0.7 mm was calculated assuming the impactor was aluminum. The damage site has been flagged so that future EVA traffic will not contact the area; avoiding the potential for cuts to EVA crewmember gloves.

The initial spacewalk of STS-123 (1J/A) also resulted in a report of an MMOD crater on an EVA tool that was exposed to MMOD particle flux in the area of a work site. The EVA D-handle tool, stored in the Z1 port tool caddy (Figure 3), was needed for the assembly of the Canadian Special Purpose Dexterous Manipulator (Dextre) later in the mission. At the end of EVA-1, the tool was brought back inside the ISS to be inspected and photographed (Figure 4). A procedure was developed during the mission to repair the damaged area and the tool was returned to service. As with the airlock hand rail mentioned above, the EVA D-handle tool is composed of 7075-T7351 aluminum material and has the same cross-sectional dimensions as a hand rail at the location of the impact. Analysis of the images provided by the crew indicates that the crater produced by the impact has a diameter of about 5 mm. In addition to the crater produced by the initial entry of the projectile into the aluminum D-handle, the impact also produced backside spall damage on the opposite surface (Figure 4). Since the density of the impacting

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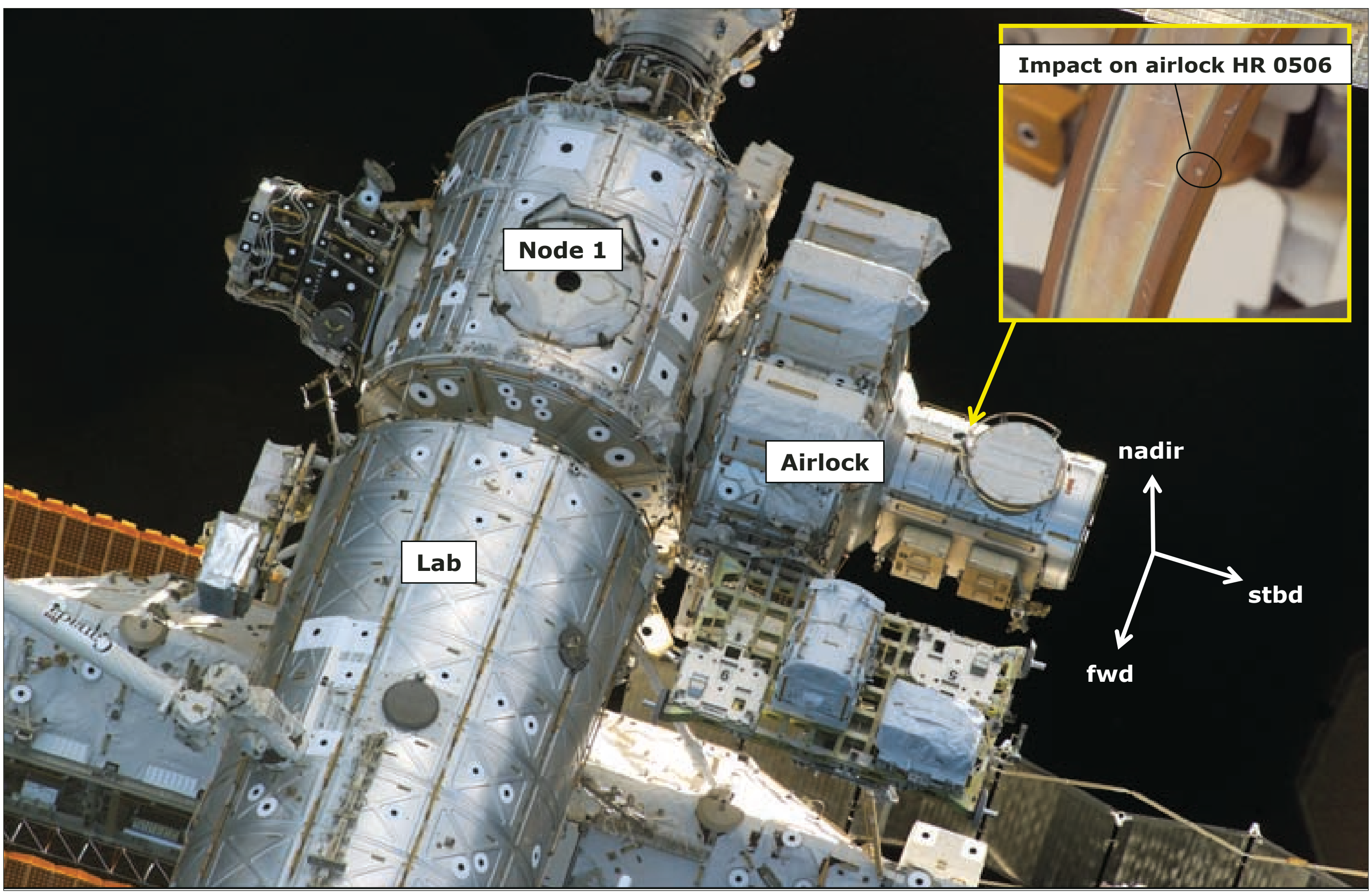


*Figure 1. Location of MMOD impact on airlock hand rail.*


Figure 2. Detail of MMOD impact on airlock hand rail.

# Impact Damage

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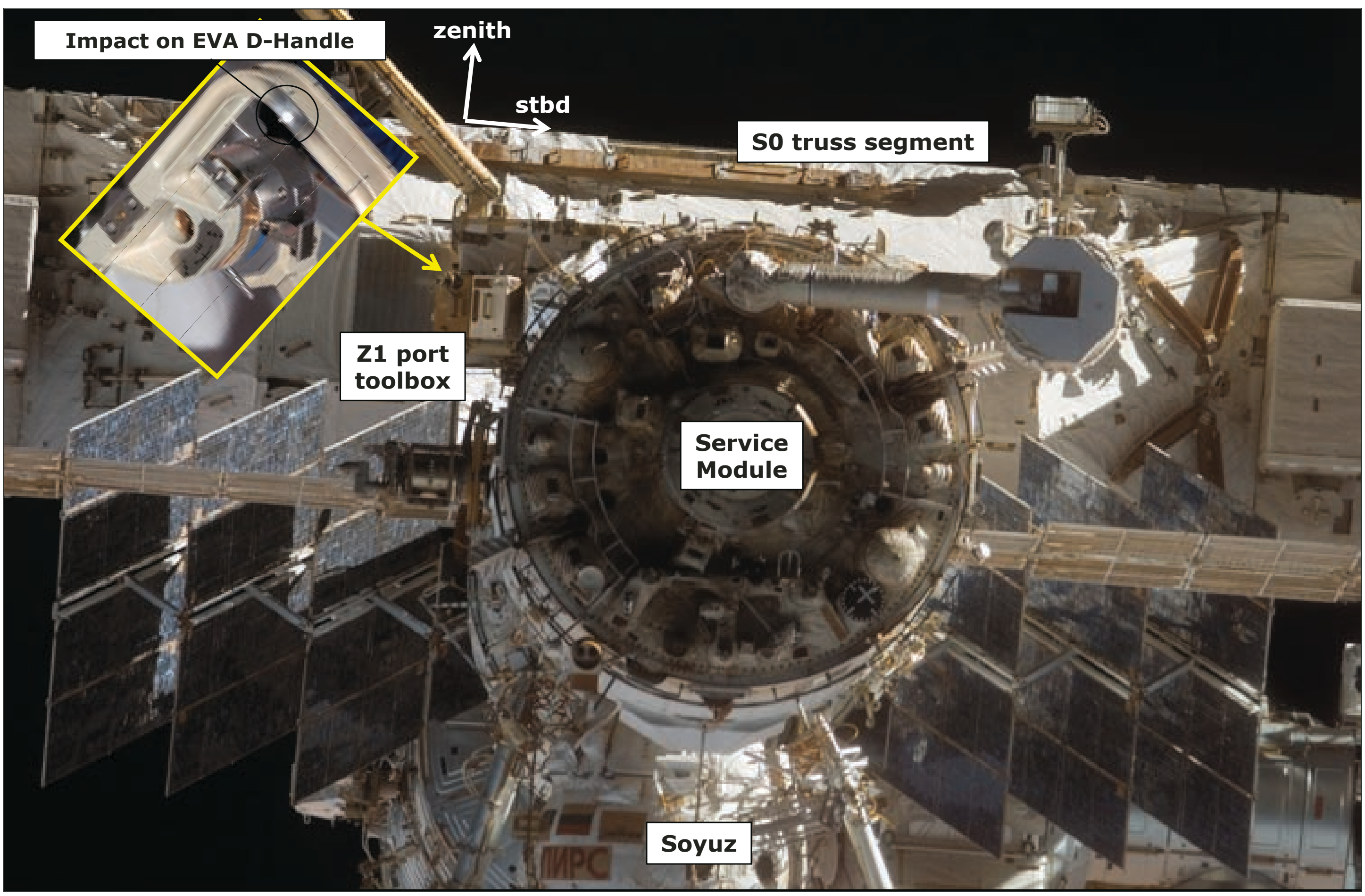


Figure 3. Location of MMOD impact on EVA D-Handle.

# Impact Damage

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particle is not known, a diameter of approximately 1.1 mm was calculated assuming an aluminum OD particle caused the damage.

A hypervelocity impact test program has been undertaken at the NASA/JSC Hypervelocity Impact Technology Facility (HITF) in Houston, supported by the White Sands Test Facility in Las Cruces, in an effort to gain understanding of the cratering effects of small particles. This program involves tests using 0.7 mm to 2 mm diameter aluminum and steel particles at 6.5 km/s to 7.5 km/s at various impact locations and orientations on hand rail samples. The results of test number HITF-8075 (Figure 5) are provided as an example. The test projectile was a 1 mm-diameter aluminum sphere impacting at 7.06 km/s. A 4.5 mm x 4.0 mm diameter crater occurred on the front, with a spall bump 6.0 mm diameter and 1.3 mm high occurring to the backside of the handrail. The frontside crater was 2.3 mm deep and had a raised lip that was 0.9 mm long. The damage in Figure 5 is slightly smaller than the impact damage observed on the D-handle EVA tool. Another result, from test number HITF-8091, is shown in Figure 6. The projectile was a 0.7 mm-diameter aluminum sphere impacting at 6.86 km/s at an impact angle normal to the target ($0^{o}$). The crater diameter resulting from this test is 2.8 mm, which is greater than the observed hand rail damage measuring 1.78 mm. An oblique impact with the same projectile diameter is currently planned that should result in a smaller crater. ♦

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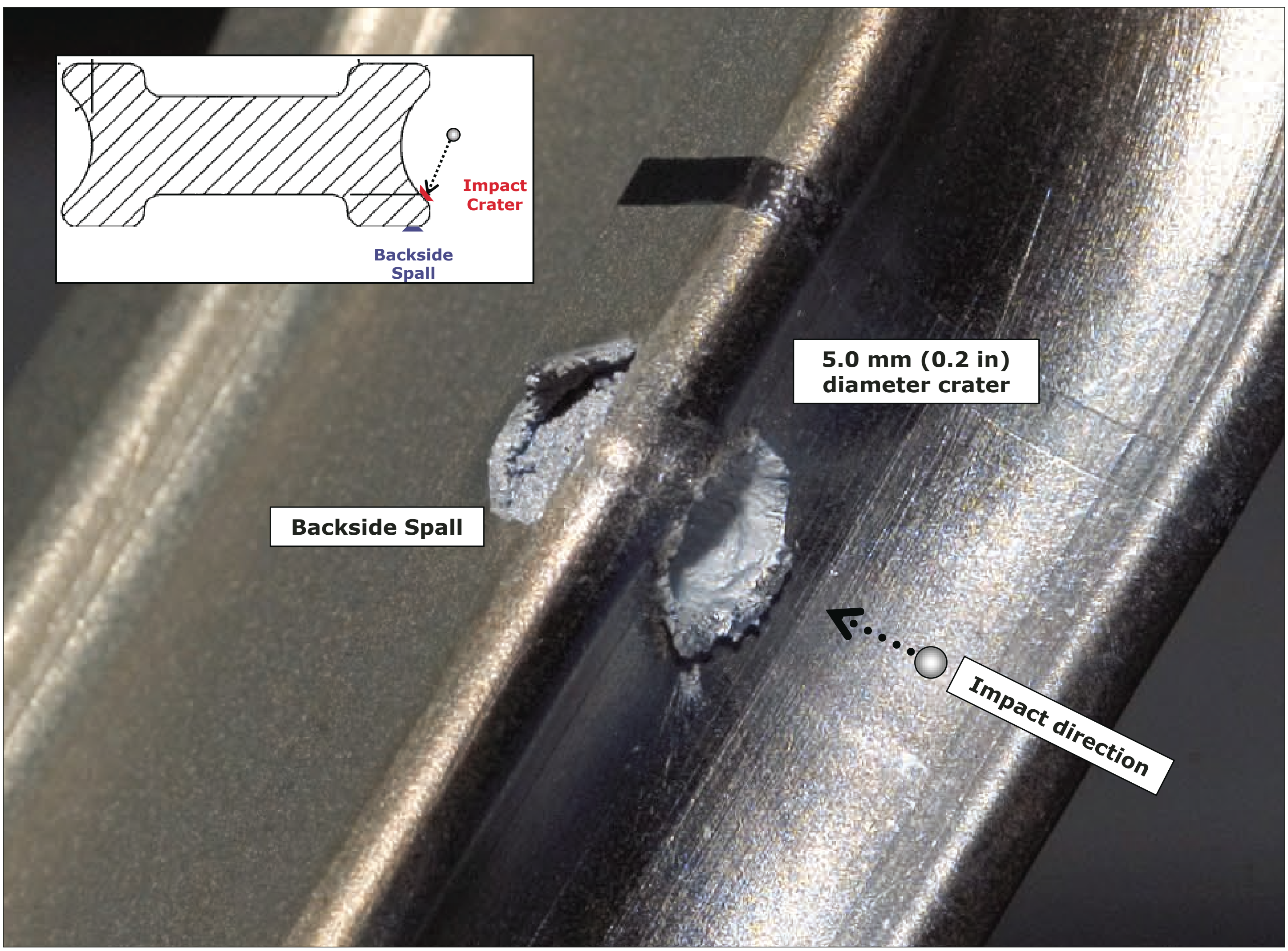


*Figure 4. Detail of MMOD impact on EVA D-Handle.*

# Impact Damage

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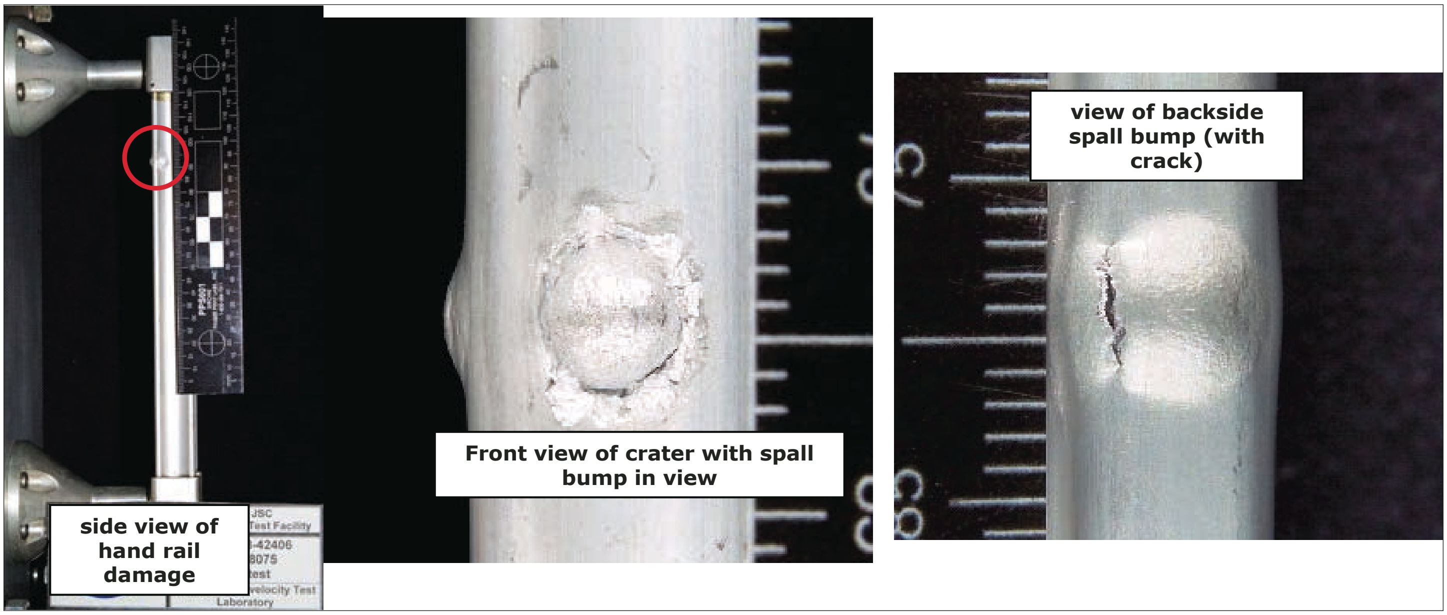


*Figure 5. Results from ground test number HITF-8075: 1 mm-diameter aluminum spherical projectile impacting at 7.06 km/s.*

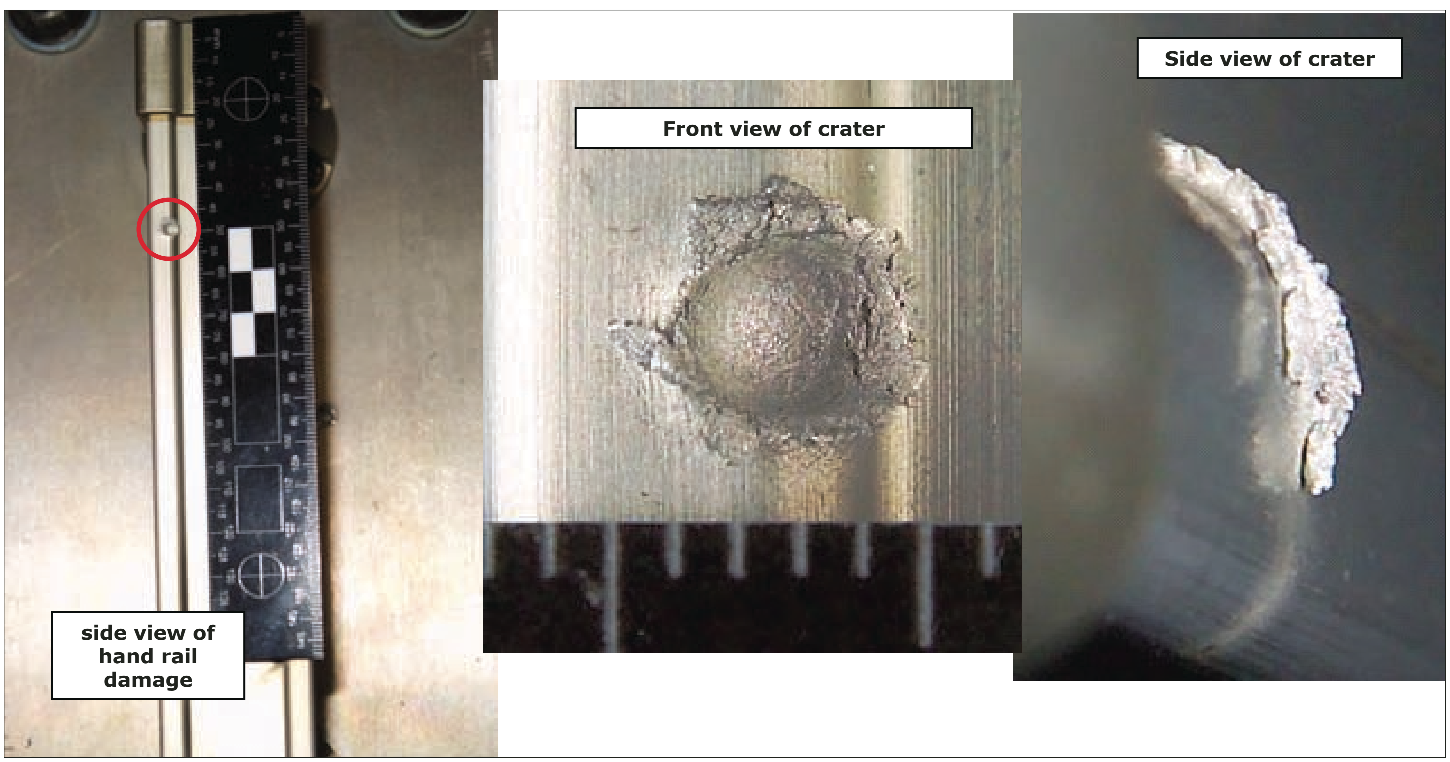


*Figure 6. Results from ground test number HITF-8091: 0.7 mm-diameter aluminum sphere impacting at 6.86 km/s.*

# Haystack Radar Observations of Debris from the Fengyun-1C Antisatellite Test

C. STOKELY AND M. MATNEY

The intentional destruction of the Fengyun-1C satellite (International Designator 1999-025A, U.S. satellite number 25730) by China on 11 January 2007 marked the single largest breakup event in the entire history of space exploration. As of June 2008, the Space Surveillance Network was tracking nearly 2800 objects with effective sizes approximately 10 cm or greater that are attributed to this antisatellite (ASAT) test (see ODQN, Vol. 11, Issues 2 and 3).

The Fengyun-1C meteorological satellite was in a nearly circular sun-synchronous orbit with a mean altitude of 850 km and an inclination of 98.8°. This ASAT test has created significant concern about debris risk to space assets since this altitude region already had the highest spatial density of debris and number of operational satellites of any altitude region. Moreover, debris in orbits at 850 km altitude can remain in orbit for decades before reentry.

The Haystack radar observed the remnants of the Fengyun-1C breakup using an inertial point tracking mode and a traditional staring mode. Haystack has been NASA's primary source of data for centimeter-sized debris since 1990. It can observe debris with sizes down to 1 cm throughout its range window. Its very high sensitivity is a trade-off with its very narrow 0.058° half-power beam-width. Haystack is able to make accurate measurements of an object's radar cross section, range, and Doppler range-rate along the radar boresight. However, measurement of velocity perpendicular to the beam is not as accurate, especially for low signal-to-noise detections. Therefore debris orbits are best determined statistically.

Approximately 24 hours after the break-up, the Haystack radar was tasked to observe the debris cloud using an inertial point tracking operational mode. This consisted of pointing the radar at an inertial point of the estimated debris orbit plane by changing the azimuth and elevation pointing angles to compensate for the rotation of the Earth. The inertial point of the orbit plane was estimated by propagating the last two-line element set of the parent spacecraft prior to the breakup. The orbit plane was observed for ~1.9 hours. The orbital period of the parent spacecraft was ~1.7 hours.

The inertial point tracking mode provided significant challenges to processing the raw radar data since the count rate was nearly 400 detections per hour, whereas the normal detection rate is less than 20 detections per hour at the pointing angles used. The high detection rate ensures that a vast majority of the detections are not debris from other sources. The analysis of this data is on-going, and the results will not be discussed here.

In the first few hours after a breakup, the debris cloud is grouped together in both orbital plane as well as in mean anomaly. However, as time passes, the differential orbital periods of the debris cause the cloud to wrap upon itself, so that eventually the entire cloud is randomized in mean anomaly that forms a "ring" of debris in the orbit plane. After 24 hours, the Haystack data showed that debris had spread throughout the orbit plane although there was still visible "clumping" of detections. The orbit plane stays together for a much longer time before differential precession of the right ascension of ascending node causes it to disperse. In the case of polar orbits like the Fengyun-1C breakup, this can last many months.

Once the mean anomalies have become thoroughly randomized, the best way to use Haystack is in a beam-park mode. The beam is pointed in a particular direction (typically eastward at 75° elevation) and is used to count objects as they cross the beam. Because the Haystack beam is very narrow, this means that any particular object has only a small chance of being detected. However, as the rotation of the Earth causes the radar beam to sweep through the debris plane, it is able to statistically sample the entire cloud.

The detection rate, or number of detections per hour, was calculated for each half hour in the day and is shown in Figure 1 (see ODQN, Vol. 12, Issues 1 and 2). This was for data collected in the first few months after the breakup. The background detection rate for times not in the vicinity of the Fengyun-1C orbit plane passage was 12.4 detections per hour, whereas the peak detection rate for the Fengyun-1C debris was 75 detections per hour for the half hour containing the plane passage.

As the debris cloud evolves over time, there tend to be distinctive "patterns" in the Haystack range and Doppler range-rate data that represent "slices" of the debris orbits in time. The best way to analyze these patterns is to use a model of the debris cloud to predict when and where debris from the breakup cloud will appear in the Haystack beam.

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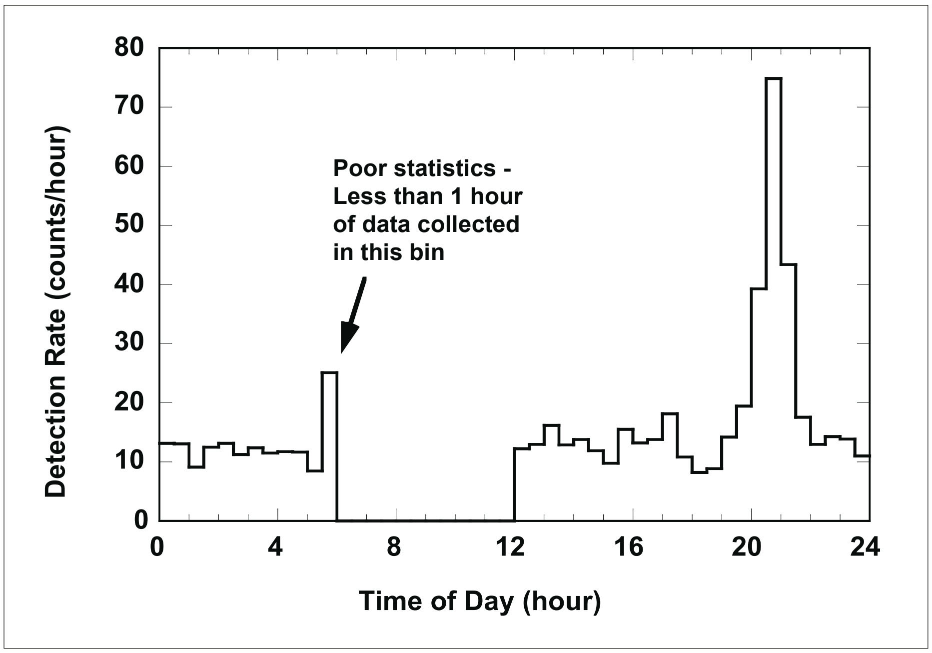


*Figure 1. Detection rate for the Haystack 75° east-staring data in the months following the Fengyun-1C breakup.*

# Haystack

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For this analysis, we use the NASA Standard Breakup Model to simulate the Fengyun-1C cloud. This model uses a Monte Carlo method to predict the population of debris as a function of size, as well as the distribution in delta-velocity. A Monte Carlo cloud is created using the actual Fengyun-1C orbit and time of breakup and each sample particle is propagated to the time of the Haystack observations. This information is used to predict the probability of detection for each computer-created debris object, given the times and pointing directions of the actual Haystack observations. The distribution of the predicted cloud in time, range, and Doppler range-rate can be compared directly to the data to see how close the detected cloud particles come to the predicted distribution. In addition, Haystack observes other debris objects unrelated to the Fengyun-1C breakup. By noting the time, range, and range-rate of these objects, most of these "interlopers" can be removed from the database so that we are left with a set of detections that can be assigned with a high degree of confidence to the Fengyun-1C cloud. As a check of this, the shapes of the cumulative size distribution from the inertial point tracking data agree with the staring data.

Data gathered on day-of-year 53, 87, and 93 of year 2007 had excellent coverage of the Fengyun-1C cloud in time and range at the optimal 75° east-pointing mode. Comparisons between the measured cloud distribution in time, range, and Doppler range-rate agree very well with the predicted cloud, indicating that the NASA Standard Breakup Model is giving us very good delta-velocity distributions, at least to first order. However, the model underpredicts the total number of objects seen by the radar in the centimeter size regime. This indicates that the predicted size distribution underestimates the population of the actual Fengyun-1C cloud. Using the assumption that the model velocity distributions are accurate, the population of the predicted model cloud can be adjusted until an approximate size distribution can be estimated. Data from all three observation days give consistent size distributions that can be combined into a composite size distribution that we believe accurately estimates the size distribution of the actual Fengyun-1C cloud, as shown in Figure 2. Note that the cumulative number of debris near 10 cm obtained from the tracked population and the Haystack radar are consistent with each other.

1. Johnson, N.L., et al., *The Characteristics and Consequences of the Break-up of the Fengyun-1C Spacecraft*, Acta Astronautica, 63, 128-135, 2008.

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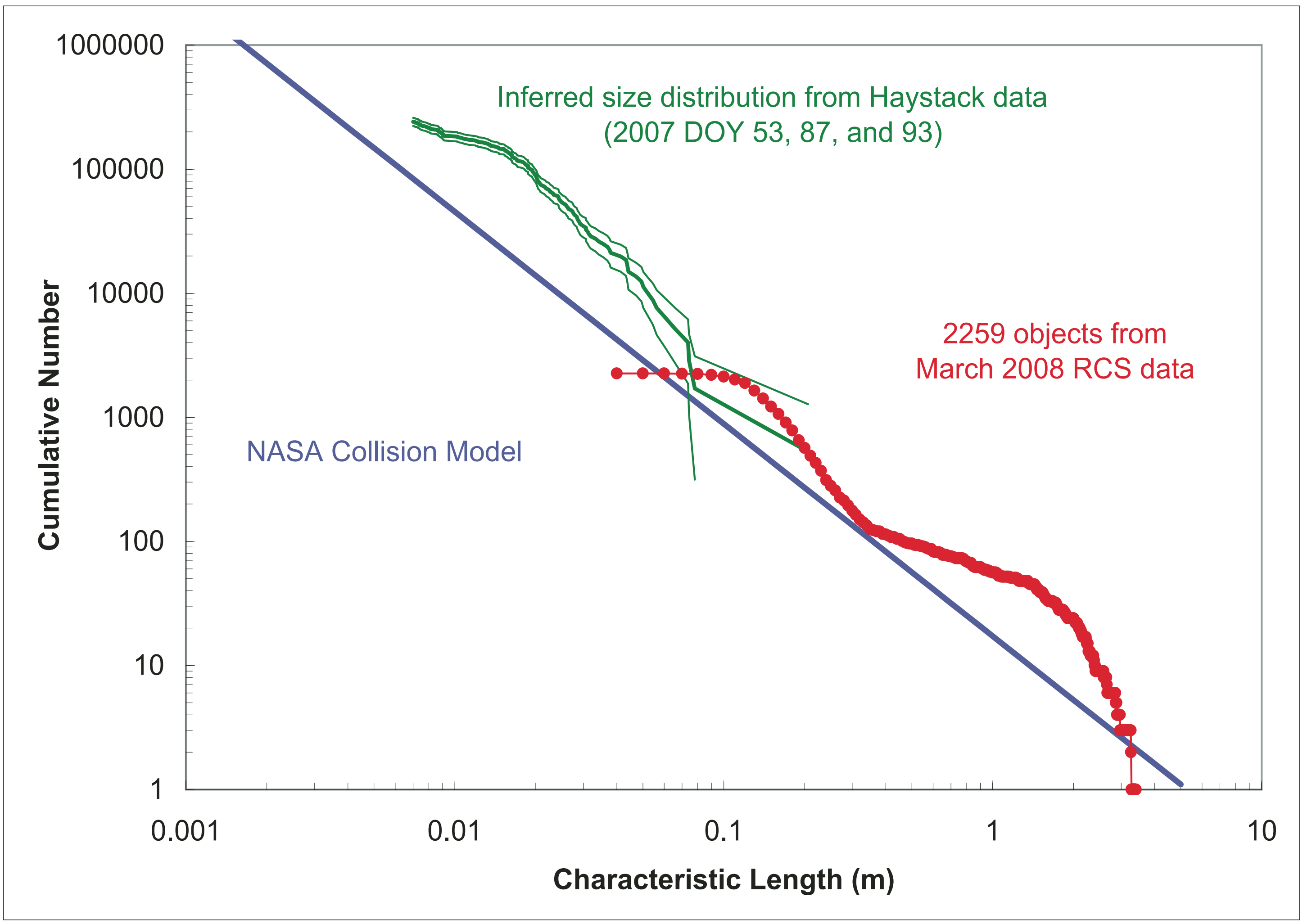
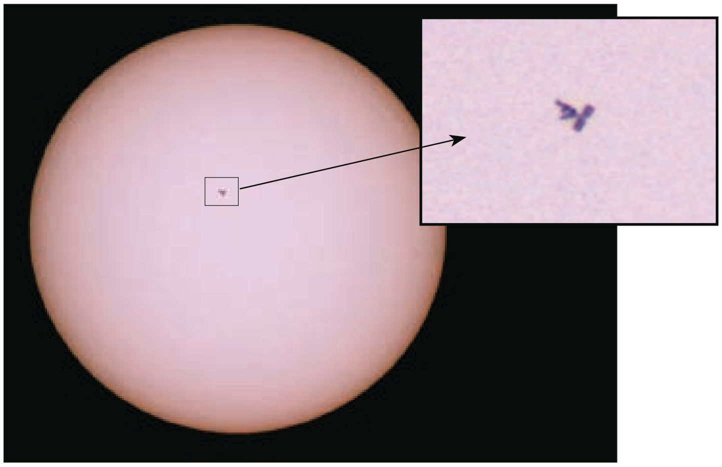



*Figure 2. The Fengyun-1C cumulative number of debris objects in orbit versus effective size with data from catalogued data from the Space Surveillance Network and Haystack radar staring mode data.*



*ISS Transit of Sun. Acquired May 31, 2008 from Texas City, TX. Canon 400D using 1300 mm focal length, 100 mm aperture refractor with Baader filter, 1/3200 sec, ISO 200. Credit: Mulrooney and Stansbery (Image contrast enhanced for print publication).*

*Sagittarius Milky Way Rising at Cerro Tololo Inter-American Observatory (CTIO). MODEST 0.6 m Curtis Schmidt and 4 m Blanco Telescopes in foreground. Acquired during NASA sponsored GEO data acquisition campaign on March 5th, 2008. Canon 400D w/ 10 mm f/3.5 lens, 116 sec, ISO 1600. Credit: Mulrooney and Barker. (Image contrast enhanced for print publication).*

# ABSTRACTS FROM THE NASA ORBITAL DEBRIS PROGRAM OFFICE

## AIAA Houston Annual Technical Symposium (ATS)
## 9 May 2008, Houston, Texas

### Orbital Debris: Past, Present, and Future

H.M. RODRIGUEZ AND J.-C. LIOU

With the first man-made satellite launched in 1957, no one expected the event would be the beginning of a growing environmental issue for the space community today. The combination of almost 5000 launches and 200 on-orbit fragmentations of spacecraft and rocket bodies since then have created an orbital debris issue. Approximately 17,000 objects are currently tracked in orbit by the U.S. Space Surveillance Network (SSN). The majority of these objects are 10 cm (softball size) and larger. There are even more objects smaller in size that cannot be detected by the SSN sensors, yet they present potential threats to operating satellites.

To address the debris issue, the space community has developed mitigation measures to limit the growth of the debris population in the future. However, these mitigation measures will not stop the population growth, only slow it down. The ongoing space activities and continued on-orbit fragmentation events will require additional efforts to stabilize the future debris populations.

This presentation provides a summary of the history of orbital debris, means to measure and characterize the debris populations, an assessment of the current environment, and the challenges for the community to preserve the near-Earth space for future generations. ♦

## 37th COSPAR Scientific Assembly
## 13- 20 July 2008, Montréal, Canada

### Outcome of Recent Satellite Impact Experiments

T. HANADA, J.-C. LIOU, T. NAKAJIMA, AND E. STANSBERY

This paper summarizes three satellite impact tests completed in early 2007 through collaboration between Kyushu University and the NASA Orbital Debris Program Office. The previous experiments completed in late 2005 aimed to compare low- and hyper-velocity impacts on identical target satellites, whereas the new tests used larger satellites as targets and aimed to investigate the effects of impact directions. Three identical micro satellites equipped with fully-functional electronic devices were prepared as targets. Their dimensions were 20 cm by 20 cm by 20 cm, and the mass of each was approximately 1.3 kilograms. Aluminum alloy solid spheres, with diameters of 3 cm and masses of 39 grams were prepared as projectiles. The impact velocity was approximately 1.7 km/s. The impact tests were carried out at the two-stage light gas gun facility at the Kyushu Institute of Technology. All three target satellites were completely fragmented, but there were noticeable differences among the three sets of fragments due to the different impact directions. More than 1000 fragments from each test were collected, measured, photographed, and documented with material descriptions. The analysis of the fragments is currently in progress. Preliminary results of the new data and comparisons with previous data will be included in the paper. ♦

## Empirical Accuracies of U.S. Space Surveillance Network Reentry Predictions

N.L. JOHNSON

The U.S. Space Surveillance Network (SSN) issues formal satellite reentry predictions for objects which have the potential for generating debris which could pose a hazard to people or property on Earth. These prognostications, known as Tracking and Impact Prediction (TIP) messages, are nominally distributed at daily intervals beginning four days prior to the anticipated reentry and several times during the final 24 hours in orbit. The accuracy of these messages depends on the nature of the satellite's orbit, the characteristics of the space vehicle, solar activity, and many other factors. Despite the many influences on the time and the location of reentry, a useful assessment of the accuracies of TIP messages can be derived and compared with the official accuracies included with each TIP message. This paper summarizes the results of a study of numerous uncontrolled reentries of spacecraft and rocket bodies from nearly circular orbits over a span of several years. Insights are provided into the empirical accuracies and utility of SSN TIP messages. ♦

## Characterization of the Catalog Fengyun-1C Fragments and Their Long-Term Effect on the LEO Environment

J.-C. LIOU AND N. JOHNSON

The intentional breakup of Fengyun-1C on 11 January 2007 created the most severe orbital debris cloud in history. More than 2500 large fragments were identified and tracked by the U.S. Space Surveillance Network by the end of the year. The altitude where the event occurred was probably the worst location for a major breakup in the low Earth orbit (LEO) region, since it was already highly populated with operational satellites and debris generated from previous breakups. The addition of so many fragments not only poses a realistic threat to operational satellites in the region, but also increases the instability (*i.e.*, collision cascade effect) of the debris population there.

Preliminary analysis of the large Fengyun-1C fragments indicates that their size and area-to-mass ratio (A/M) distributions are very different from those of other known events. About half of the fragments appear to be composed of light-weight materials and more than 100 of them have A/M values exceeding 1 $m^2/kg$, consistent with thermal blanket pieces. In addition, the orbital elements of the fragments suggest non-trivial velocity gain by the fragment cloud during the impact. These important characteristics were incorporated into a numerical simulation to assess the long-term impact of the Fengyun-1C fragments to the LEO debris environment. The main objectives of the simulation were to evaluate (1) the collision probabilities between the Fengyun-1C fragments and the rest of the catalog population and (2) the collision activities and population growth in the region in the next 100 years. ♦

## Optical Studies of Orbital Debris at GEO Using Two Telescopes

P. SEITZER, K.J. ABERCROMBY, H.M. RODRIGUEZ, AND E. BARKER

Beginning in March 2007, optical observations of debris at geosynchronous orbit (GEO) were commenced using two telescopes simultaneously at the Cerro Tololo Inter-American Observatory (CTIO) in Chile.

The University of Michigan's 0.6/0.9-m Schmidt telescope MODEST (for **M**ichigan **O**rbital **DE**bris **S**urvey **T**elescope) was used in survey mode to find objects that potentially could be at GEO. Because GEO objects only appear in this telescope's field of view for an average of 5 minutes, a full six-parameter orbit can not be determined. Interrupting the survey for follow-up observations leads to incompleteness in the survey results. Instead, as objects are detected on MODEST, initial predictions assuming a circular orbit are done for where the object will be for the next hour, and the objects are reacquired as quickly as possible on the CTIO 0.9-m telescope. This second telescope then follows-up during the first night and, if possible, over several more nights to obtain the maximum time arc possible, and the best six parameter orbit.

Our goal is to obtain an initial orbit for *all* detected objects fainter than R = $15^{th}$ in order to estimate the orbital distribution of objects selected on the basis of two observational criteria: magnitude and angular rate. Objects fainter than $15^{th}$ are largely uncataloged and have a completely different angular rate distribution than brighter objects. Combining the information obtained for both faint and bright objects yields a more complete picture of the debris environment rather than just concentrating on the faint debris. One objective is to estimate what fraction of objects selected on the basis of angular rate are not at GEO. A second objective is to obtain magnitudes and colors in standard astronomical filters (BVRI) for comparison with reflectance spectra of likely spacecraft materials.

This paper reports on results from two 14-night runs with both telescopes: in March and November 2007:

- A significant fraction of objects fainter than R = $15^{th}$ have eccentric orbits ($e > 0.1$).
- Virtually all objects selected on the basis of angular rate are in the GEO and GTO regimes.
- Calibrated magnitudes and colors in BVRI were obtained for many objects fainter than R = $15^{th}$ magnitude.

This work is supported by NASA's Orbital Debris Program Office, Johnson Space Center, Houston, Texas, USA. ♦

## The Effect of a Potentially Low Solar Cycle #24 on Orbital Lifetimes of Fengyun 1-C Debris

D. WHITLOCK, N. JOHNSON, M. MATNEY, AND P. KRISKO

The magnitude of Solar Cycle #24 will have a non-trivial impact on the lifetimes of debris pieces that resulted from the intentional hypervelocity impact of the Fengyun 1-C satellite in January 2007. Recent solar flux measurements indicate Solar Cycle #24 began near the end of 2007 and will continue until approximately 2019. While there have been differing opinions on whether the intensity of this solar cycle will be higher or lower than usual, the Space Weather Prediction Center within the National Oceanic and Atmospheric Administration (NOAA/SWPC) has forecast unusually low solar activity for the cycle, which will result in longer

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### *Low Solar Cycle*

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orbital lifetimes. Understanding the longevity of the Fengyun 1-C debris cloud will affect collision probabilities for both operational spacecraft and large derelict objects over the next century and beyond. Using models for both the breakup of Fengyun 1-C and the propagation of the resultant debris cloud, the Orbital Debris Program Office at NASA Johnson Space Center conducted a study to better understand the impact of the solar cycle on lifetimes for Fengyun debris. The orbits of nearly 2 million, simulated Fengyun debris pieces, of sizes 1 mm and larger, were propagated for up to 200 years. By comparing a normal (*i.e.* average) solar cycle with that of the NOAA/SWPC forecast "low" cycle, as well as a potential "high" cycle, the effect of the solar flux on the lifetimes of the debris pieces was evaluated. The modeling of the low Solar Cycle #24 shows, by 2019, an additional debris count of 12% for pieces larger than 10 cm, when compared to the resultant debris count using an average cycle. The difference becomes more pronounced (over 15%) for debris count in the smaller size regimes. Within 50 years, however, the models predict the differences in debris count from differing models of Solar Cycle #24 to be less than 10% for all size regimes, with less variance in the smaller sizes. ♦

### Modeling of LEO Orbital Debris Populations in ORDEM2008

Y.-L. XU, M. HORSTMAN, P. KRISKO, J.-C. LIOU, M. MATNEY, E.G. STANSBERY, C. STOKELY, AND D. WHITLOCK

The NASA Orbital Debris Engineering Model, ORDEM2000, has been updated to a new version: ORDEM2008. The data-driven ORDEM covers a spectrum of object size from 10 microns to greater than 1 meter, and ranging from LEO (low Earth orbit) to GEO (geosynchronous orbit) altitude regimes. ORDEM2008 centimeter-sized populations are statistically derived from Haystack and HAX (the Haystack Auxiliary) radar data, while micron-sized populations are estimated from shuttle impact records. Each of the model populations consists of a large number of orbits with specified orbital elements, the number of objects on each orbit (with corresponding uncertainty), and size, type, and material assignment for each object. This paper describes the general methodology and procedure commonly used in the statistical inference of the ORDEM2008 LEO debris populations. Major steps in the population derivations include data analysis, reference-population construction, definition of model parameters in terms of reference populations, linking model parameters with data, seeking best estimates for the model parameters, uncertainty analysis, and assessment of the outcomes. To demonstrate the population-derivation process and to validate the Bayesian statistical model applied in the population derivations throughout, this paper uses illustrative examples for the special cases of large-size (≥1 m, ≥32 cm, and ≥10 cm) populations that are tracked by SSN (the Space Surveillance Network) and monitored by Haystack and HAX radars operating in a staring mode. ♦

# MEETING REPORT

## 26th International Symposium on Space Technology and Science (ISTS)
## 2 - 6 June, 2008, Hamamatsu City, Japan

The 26th International Symposium on Space Technology and Science (ISTS) was held 2-6 June 2008, in Hamamatsu City, Japan. Two orbital debris sessions, a total of twelve papers, were presented during the symposium. Papers presented in the debris sessions included optical observations, environment modeling, debris removal technique using electrodynamic tethers, satellite fragment characterization, and hypervelocity impact tests. In addition, several debris and micrometeoroid in-situ experiments papers were presented during a separate space environment session. ♦

# UPCOMING MEETINGS

**29 September - 3 October, 2008: The 59th International Astronautical Congress, Glasgow, Scotland**

A Space Debris Symposium is planned for the 2008 IAC. Five sessions are scheduled for the Symposium to address various technical issues of space debris, including measurements, modeling, risk assessments, reentry, hypervelocity impacts, protection, mitigation, and standards. Additional information about the symposium is available at <http://www.iac2008.co.uk/>.

**16-19 September 2008: 2008 Advanced Maui Optical and Space (AMOS) Surveillance Technologies Conference, Wailea, Maui, Hawaii, USA.**

The 9th annual AMOS Conference will offer pre-conference tutorials, optional technical tours, and a broad range of presentations on topics such as adaptive optics, astronomy, imaging, lasers, metrics, non-resolved object characterization, orbital debris, space weather, Pan-STARRS, SSA programs and systems, and telescopes and sensors. The abstract submission deadline is 18 April 2008. Additional information on the conference is available at <http://www.amostech.com>.

## SATELLITE BOX SCORE

(as of 25 June 2008, as cataloged by the U.S. SPACE SURVEILLANCE NETWORK)

| Country/ Organization | Payloads | Rocket Bodies & Debris | Total |
|---|---|---|---|
| CHINA | 66 | 2684 | 2750 |
| CIS | 1370 | 3202 | 4572 |
| ESA | 39 | 38 | 77 |
| FRANCE | 46 | 326 | 372 |
| INDIA | 36 | 108 | 144 |
| JAPAN | 104 | 71 | 175 |
| US | 1086 | 3164 | 4250 |
| OTHER | 416 | 95 | 511 |
| TOTAL | 3163 | 9688 | 12851 |

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## 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
## 03 April – 30 June 2008

| International Designator | Payloads | Country/ Organization | Perigee Altitude (KM) | Apogee Altitude (KM) | Inclination (DEG) | Earth Orbital Rocket Bodies | Other Cataloged Debris |
|---|---|---|---|---|---|---|---|
| 2008-015A | SOYUZ-TMA 12 | RUSSIA | 336 | 343 | 51.6 | 1 | 0 |
| 2008-016A | ICO G-1 | USA | 35773 | 35800 | 5.9 | 1 | 0 |
| 2008-017A | C/NOFS | USA | 406 | 851 | 13.0 | 1 | 0 |
| 2008-018A | VINSAT 1 | VIETNAM | 35786 | 35789 | 0.0 | 1 | 1 |
| 2008-018B | STAR ONE C2 | BRAZIL | 35780 | 35792 | 0.0 | | |
| 2008-019A | CTDRS | CHINA | 35767 | 35806 | 0.4 | 1 | 0 |
| 2008-020A | GIOVE B | ESA | 23101 | 23246 | 56.0 | 1 | 0 |
| 2008-021A | CARTOSAT 2A | INDIA | 622 | 645 | 98.0 | 1 | 1 |
| 2008-021B | CANX-6 | CANADA | 615 | 638 | 98.0 | | |
| 2008-021C | CUTE 1.7 & AOD 2 | JAPAN | 614 | 636 | 98.0 | | |
| 2008-021D | IMS-1 | INDIA | 620 | 638 | 98.0 | | |
| 2008-021E | COMPASS 1 | GERMANY | 613 | 636 | 98.0 | | |
| 2008-021F | AAUSAT CUBESAT 2 | DENMARK | 614 | 635 | 98.0 | | |
| 2008-021G | DELFI C3 | NETHERLANDS | 614 | 636 | 98.0 | | |
| 2008-021H | CANX-2 | CANADA | 614 | 636 | 98.0 | | |
| 2008-021J | SEEDS | JAPAN | 614 | 637 | 98.0 | | |
| 2008-021K | RUBIN 8 | INDIA | 619 | 662 | 98.0 | | |
| 2008-022A | AMOS 3 | ISRAEL | 35784 | 35790 | 0.0 | 1 | 0 |
| 2008-023A | PROGRESS-M 64 | RUSSIA | 336 | 343 | 51.6 | 1 | 0 |
| 2008-024A | GALAXY 18 | INTELSAT | 35773 | 35799 | 0.0 | 1 | 0 |
| 2008-025A | YUBILEINY | RUSSIA | 1480 | 1508 | 82.5 | 1 | 0 |
| 2008-025B | COSMOS 2437 | RUSSIA | 1480 | 1510 | 82.5 | | |
| 2008-025C | COSMOS 2438 | RUSSIA | 1477 | 1508 | 82.5 | | |
| 2008-025D | COSMOS 2439 | RUSSIA | 1479 | 1509 | 82.5 | | |
| 2008-026A | FENGYUN 3A | CHINA | 826 | 828 | 99.0 | 1 | 0 |
| 2008-027A | STS 124 | USA | 336 | 343 | 51.6 | 0 | 0 |
| 2008-028A | CHINASAT 9 | CHINA | 35775 | 35799 | 0.0 | 1 | 0 |
| 2008-029A | GLAST | USA | 542 | 561 | 25.6 | 1 | 0 |
| 2008-030A | SKYNET 5C | UK | 35777 | 25803 | 0.8 | 1 | 1 |
| 2008-030B | TURKSAT 3A | TURKEY | 35766 | 35802 | 0.1 | | |
| 2008-031A | QUICK LAUNCH 1 | USA | 661 | 672 | 48.4 | 1 | 0 |
| 2008-031B | QUICK LAUNCH 2 | USA | 661 | 672 | 48.4 | | |
| 2008-031C | QUICK LAUNCH 3 | USA | 661 | 672 | 48.4 | | |
| 2008-031D | QUICK LAUNCH 4 | USA | 661 | 672 | 48.4 | | |
| 2008-031E | QUICK LAUNCH 5 | USA | 661 | 672 | 48.4 | | |
| 2008-031F | CGCD | USA | 661 | 672 | 48.4 | | |
| 2008-032A | JASON 2 | FRANCE | 1324 | 1334 | 66.0 | 1 | 0 |
| 2008-033A | COSMOS 2440 | RUSSIA | EN ROUTE TO GEO | | | 2 | 3 |