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Inside...

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High-Speed Particle Impacts Suspected in Two Spacecraft Anomalies

During a span of just 26 hours in May, two spacecraft, one at low altitude and one in geosynchronous orbit, each experienced attitude anomalies that might have resulted from a collision with a small particle.

The first incident occurred on 22 May when NOAA's GOES 13 spacecraft (International Designator 2006-018A, U.S. Satellite Number 29155) suffered an attitude disturbance of unknown origin, causing an attitude drift of at least 2 degrees per hour off nadir pointing. Fortunately, no permanent damage was discovered, and the spacecraft (Figure 1) was returned to normal operations in June.

Figure 1. Artist concept of the GOES 13 satellite (Allan Kung/NASA). .

Although the event is indicative of a small meteoroid or orbital debris particle impact, particularly one on the large solar array, first impressions can be wrong. On 20 November 2005, the NOAA 17 spacecraft (International Designator 2002-032A, U.S. Satellite Number 27453) in low Earth orbit also experienced an instantaneous attitude upset, which was initially attributed to a collision with a small object. The fact that the anomaly occurred during the annual Leonid meteor shower seemed to support the collision hypothesis. Three other failure modes were investigated and found to be unlikely [1]. However, 18 days later a similar anomaly affected NOAA 17. Upon further investigation, a definitive root cause for both events was found to be hydrazine leaks in two different thrusters [2].

The second incident occurred on 23 May and involved the month-old NEE-01 Pegaso satellite (International Designator 2013-018B, U.S. Satellite Number 39151). Representing Ecuador's first venture into space, Pegaso was a simple vehicle with a 10-cm cube main body and two 27-cm long solar

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Figure 2. NEE-01 Pegaso satellite.

Two Spacecraft Anomalies

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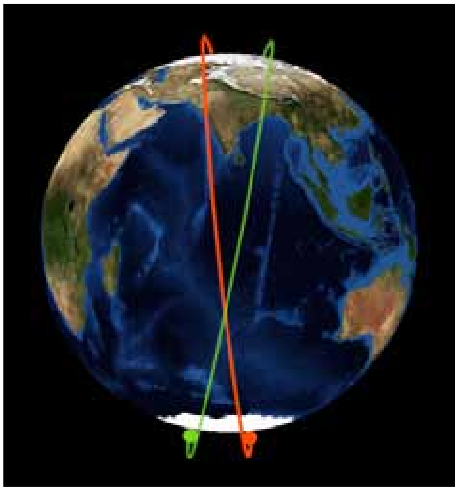

Figure 3. Conjunction of the Pegaso and Soviet rocket body over the Indian Ocean on 23 May 2013.

arrays (Figure 2), circling the Earth in an orbit of approximately 627 km by 654 km.

On the previous day, the U.S. Joint Space Operations Center had notified Ecuador that a 28-year-old Soviet rocket body (International Designator 1985-058B, U.S. Satellite Number 15890) would come close to Pegaso on 23 May as it passed over the Indian Ocean (Figure 3). Both vehicles would be heading south, Pegaso from east to west and the Soviet rocket body from west to east.

In a contact with Pegaso after the conjunction, the Ecuadorian Civil Space Agency noticed that the spacecraft was no longer in a stable attitude. An assumption was made that the Soviet rocket body was somehow responsible for the change in Pegaso's condition. However, detailed post-conjunction assessments indicated that the rocket body passed under Pegaso at a safe distance. In addition, the U.S. Space Surveillance Network detected no new debris from either vehicle, as would be expected if a collision had occurred.

A suggestion was made that small particles from the rocket body might have impacted Pegaso and disrupted its very delicate balance. For many years, orbital debris researchers have been aware that small debris clouds (called debris wakes) accompany some resident space objects. The debris are believed to be formed by degradation of surface materials and impacts by small particles. These debris, though, would normally extend down from the parent satellite, a geometry which would not lead to interactions with Pegaso.

Investigations are underway to determine the actual cause for each event.

References

1. Walters, J. "NOAA-17 Collision With Object/Roll-Yaw Coil Switch," SER-05-P467, (2005).

2. Phenneger, M. and Harvie, E. "NOAA-17 External Momentum Exchange Event," SER-05-P472, (2005). ♦

Orbital Debris Program Office Strategic Plan

In February of this year, NASA's Orbital Debris Program Office (ODPO), located at the Johnson Space Center, submitted its draft Strategic Plan to the NASA Office of Safety and Mission Assurance (OSMA) where it will eventually be included in an overall MMOD Strategic Plan.

The Strategic Plan begins by looking at the history of orbital debris research in a broad thematic perspective from its beginnings in the late 1970s through today. Early efforts concentrated on understanding the environment, its drivers, and historical trends, mainly from the historical catalog of resident space objects produced by the Department of Defense (DoD) using their Space Surveillance Network (SSN). The SSN can only see objects as small as 10 cm in low Earth orbit. Also, efforts were made to educate other U.S. government leaders to the issues with OD.

Later themes included improved measurements, especially statistically measuring debris of smaller size. Modeling of the OD environment improved in fidelity and complexity as more detailed information about the environment from better measurements became available. Sharing findings and understanding of the growing debris environment was an important theme since no single agency or country is responsible for creating debris or for controlling it. Mitigation strategies were developed, first at NASA, and then nationally and internationally. Finally, the 2005 study by Liou and Johnson is discussed, which concludes that the number of 10 cm and larger debris in LEO would continue to grow due to future collisions, even if nothing else is ever launched into space [1].

The Strategic Plan lays out current and future tasks in these major areas: 1) Environment Measurements, 2) Environment Modeling, 3) Risk Assessment, 4) Mitigation, 5) Active Debris Removal, 6) Interagency and International Endeavors, and 7) Outreach. The plan also provides a notional schedule through 2018.

If successfully implemented, the Strategic Plan should allow NASA to improve and refine knowledge of the current and future environment and risks to spacecraft from debris. Continued success in mitigation practice compliance, both nationally and internationally, and the possible development of affordable Active Debris Removal techniques should successfully limit the runaway growth of the orbital debris environment.

Reference

1. Liou, J.-C. and Johnson, N. "Risks in Space from Orbiting Debris," *SCIENCE* 20, **311,** 5759, p. 340-341, (2006). ♦

Fifty Years Ago

At the beginning of July 1963, the U.S. Space Surveillance Network (SSN) had cataloged a total of 616 man-made space objects since the launch of Sputnik 1. However, many of these had already fallen back to Earth and a few had gone on to the Moon or entered orbits around the Sun, leaving a perceived population of only 338 artificial satellites in orbit about the Earth. Today, the SSN database of objects still in Earth orbit exceeds 23,000.

That July 1963 satellite catalog included 76 payloads, 35 rocket bodies, and 227 mission-related or fragmentation debris. As is the case

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Fifty Years Ago

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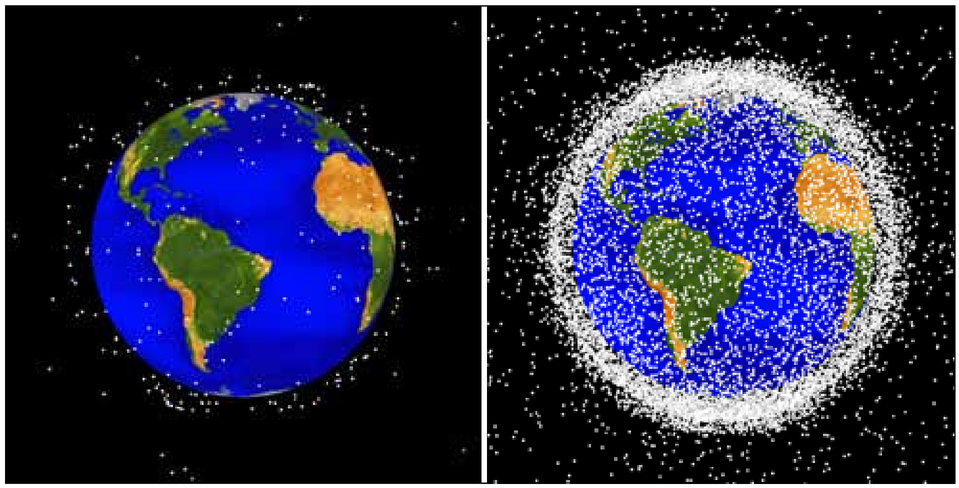
today, only a very small percentage of the total tracked satellite population represented operational spacecraft, since the majority of the payloads were no longer functional.

More than half of all objects then in Earth orbit originated from the June 1961 explosion of a U.S. Ablestar upper stage. The official count at that time was 184, of which only 3 had reentered the atmosphere. Eventually, 296 debris from this breakup would be officially cataloged by the SSN, of which 60% remain in orbit today.

The rapid growth of the Earth's satellite population in less than 6 years since the start of the Space Age had not gone unnoticed. Ernest Peterkin, Head of the Systems Section of the Operational Research Branch at the U.S. Naval Research Laboratory, wrote a memorandum in February 1963 on "Some Characteristics of the Artificial Earth Satellite Population." In this memorandum, Peterkin was one of the first to employ the now standard near-Earth space congestion measure of spatial density, *i.e.*, the average number of objects per unit volume in low Earth orbit.

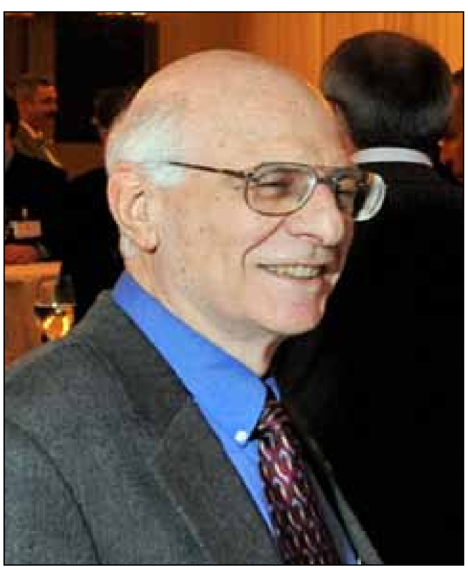
Peterkin also derived potential population growth functions, assuming specific satellite launch rates, operational lifetimes, and satellite fragmentation events. Remarkably, his final equation for the growth of the satellite population yields a value of ~16,500 for the beginning of 2013. This is almost exactly the number of officially cataloged objects in orbit on 1 January 2013, although a few thousand more objects of this size regime are known to exist.

In a separate memorandum three days later, Peterkin advised his organization about the consequences of the increasing satellite population. Of particular note was the stress that a growing population would place on space surveillance systems. Peterkin concluded that efforts should continue "to develop improved methods of detection and data processing to provide a space surveillance capability that can cope with the increasing population." This thought remains just as valid today. ♦



Cataloged objects in orbit about the Earth in 1963 (left) and in 2013 (right).

George Levin, Former OD Program Manager Passes



George M. Levin, Orbital Debris Program Manager from 1991 until his retirement from NASA in 1997, died June 17 after a long battle with lung cancer. During his tenure, George was instrumental in developing international understanding and cooperation in orbital debris research and mitigation. He led the U.S. Delegation to the Interagency Space Debris Coordination Committee (IADC) and was a member of the U.S. Delegation to the Scientific and Technical Subcommittee of the United Nations Committee on the Peaceful Uses of Outer Space. George was admired and respected by the entire international space debris community.

Mr. Levin began his 35-year NASA career in 1962 at the Goddard Space Flight Center. His professional background includes work on the Nimbus weather satellite program, and on the planetary exploration program - including the Pioneer Venus Project. From 1972 to 1981 he managed the development of the Hubble Space Telescope's first five scientific instruments as well as the preparations for mission and science operations. In 1981 he moved to NASA Headquarters where he managed the development of seventeen successful flight demonstrations launched on both the Space Shuttle and Delta II rockets.

Mr. Levin was the recipient of numerous awards, including both NASA's Exceptional Service Medal and the Silver Snoopy, awarded to no more than 1% of eligible NASA employees. In 1987 Mr. Levin was selected by the White House to be a Presidential Exchange Executive. In 1999 he was elected to membership in the International Academy of Astronautics.

In 1997, he retired from NASA and joined the National Academies as Director of the Aeronautics and Space Engineering Board. Mr. Levin retired from the National Academies in 2007. Even in retirement George continued his close association with the Orbital Debris Program Office (ODPO). He continued to attend and provide his advice at the IADC through 2012. He also provided valuable feedback during the development of the ODPO Strategic Plan earlier this year.

Mr. Levin passed away at home surrounded by close family. ♦

PROJECT REVIEW

Characterization of the Wide Field Planetary Camera-2 Radiator's Cored Impact Features at NASA JSC

K. ROSS AND P. ANZ-MEADOR

Hubble Space Telescope's Wide Field Planetary Camera-2 (WFPC-2) was returned to Earth during the STS-125 servicing mission in 2009, after almost 16 years in low Earth orbit. The radiator of WFPC-2 collected numerous impact craters due to exposure to the micrometeoroid and orbital debris (MMOD) environment (ODQN, January 2010, pp. 3-4). These impact features were cored from the radiator (ODQN, July 2012, pp. 4-6) to permit direct examination of the impacted surface and investigation to identify the impactor. Hypervelocity impacts by MMOD are energetic events, with fragmentation, melting, and vaporization of parts of both the impactor and target materials. Thus, residues of the impactor may be rare, fine-grained, and/or dissolved or engulfed in impact-melted target materials.

Four hundred and eighty WFPC-2 cores of impact features have been examined using scanning electron microscopy methods. Approximately half of these samples have been examined in England, at the Natural History Museum and at the University of Surrey's Ion Beam Centre. The NASA Orbital Debris Program Office is investigating the remaining samples using the Astromaterials Research and Exploration Science Directorate lab facility at the Johnson Space Center. Electron microscopy permits high magnification imaging of the impact features, and chemical analysis of target and residues of impactor materials. Bombardment of materials by energetic electrons induces the emission of x-rays, and the x-ray spectrum contains peaks that represent elements abundant in the target region. Each element in the periodic table produces a set of x-ray line energies that are characteristic of that element. Thus, collection of x-ray spectra permits the identification of elements present in the sample, and x-ray line intensities are a function of the abundances of the elements.

Figure 1 shows a cross section through a blank (non-impacted) core. The complex character of the "target" material is shown, with an ~200 micron-thick layer of paint overlying Al-metal. The paint consists of Zinc orthotitanate (Zn_2TiO_4) pigment and the PS7 potassium silicate binder. The paint layer is made up of sub-rounded paint particles and is very porous. The underlying Al-6061 alloy layer encompasses many fine-grained inclusions of Fe-Mn-Cr-Si, as well as less abundant Mg-Si-O-bearing particles. Given the chemical complexity of the target material, impacts that penetrate to the Al layer are particularly difficult to assign to an impactor type because of the additional elements that could be in impact melts of the target.

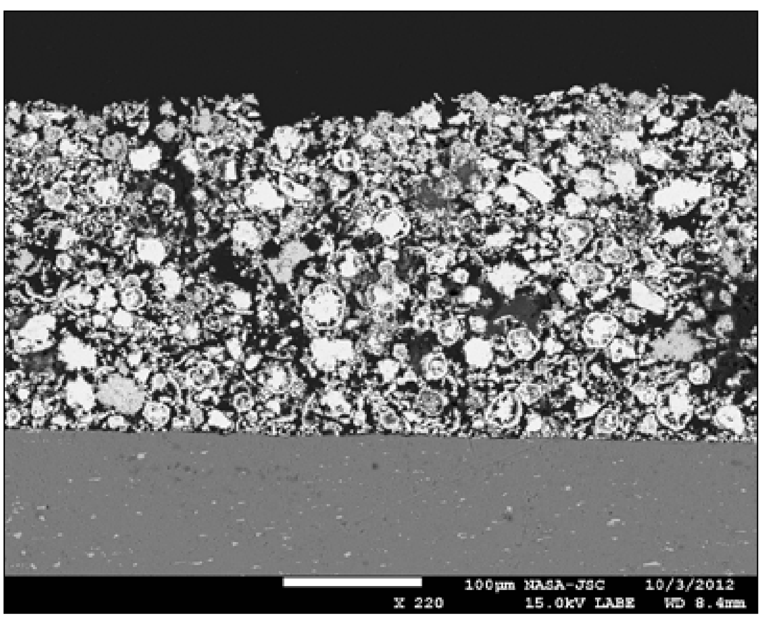


Figure 1. Backscattered electron image of a cross-section of an un-impacted core, showing the overlying, porous paint layer, and the underlying Al-metal substrate, with abundant Fe-rich inclusions.

WFPC-2 impact features were examined using two scanning electron microscopes. A JEOL 7600F scanning electron microscope (SEM), equipped with a ThermoScientific SD (silicon drift) x-ray detector, as well as a JEOL JSM-5910LV SEM, equipped with a ultrathin-window Si(Li) x-ray detector, were used to examine, image, and obtain chemical analyses from the cored impact features. Cores were carbon coated to ensure electrical conductivity. Secondary and backscattered electron images of craters were collected to permit measurement of feature sizes, and to search for unusual compositions. Regions within and near craters were searched in backscattered electron imaging (BSE) mode (which highlighted compositional variations). Phases that were notably different in brightness in BSE mode were characterized for chemistry by collection of x-ray spectra. The complex character of the impacted surface, with Zn-orthotitanate and potassium silicate constituents, as well as substantial porosity, variable volatile element contents, and non-smooth surface topography, resulted in very complex backscattered response.

The best location for searching for impactor residues appears to be the impact melts found in the craters. The critical aspect that makes impact melts the best location is that elements found dissolved in the impact melts must have been present when the impact happened. Particles found on the surface might be from the impactor, but could also be contaminate, unrelated to the impactor. Melts derived from the painted surface always contain Zn, Ti, K, Si and O. We also note that some source of Al is widely present in the paint, and Al is very frequently found as a minor component in melts formed from paint. We have observed Al-rich particles within pore spaces in the paint layer distal from any impact. Thus, the impact melts are chemically complex, and any impactors that consisted of Zn-, Ti-, or Al-bearing materials are unlikely to be recognized, because all of these elements are already present in the target.

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WFPC-2 Impact Features

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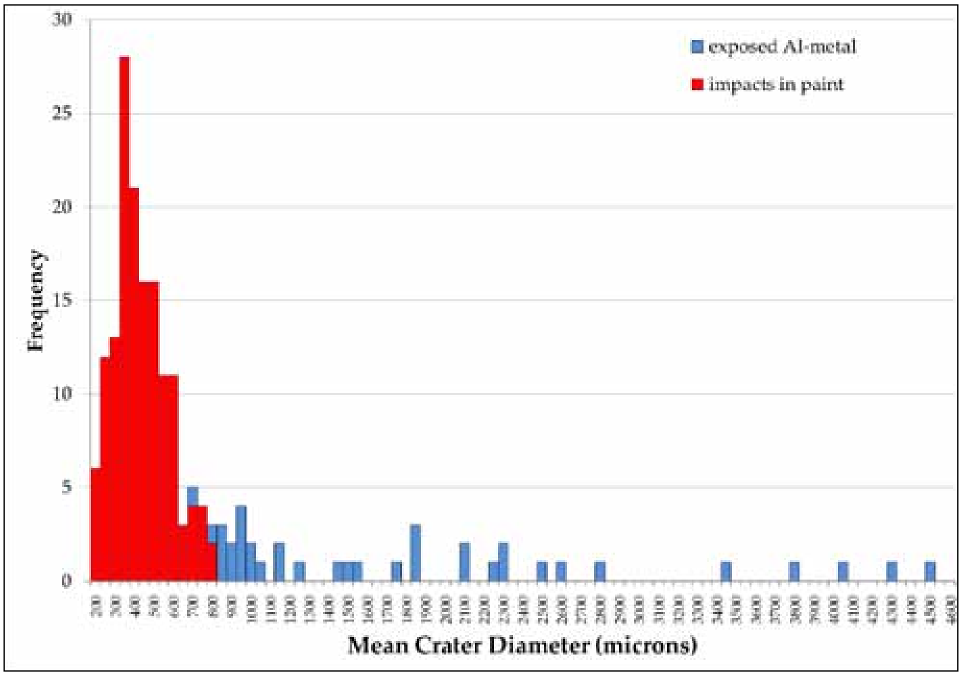

Figure 2. Histogram of the measured mean diameters of impact features.

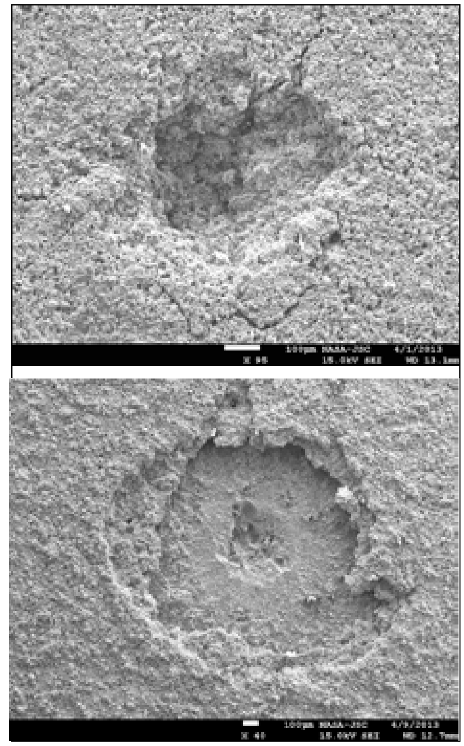

Figure 3. Secondary electron images of impact features WFPC2-81 (top) and WFPC2-34 (bottom). The impact crater at the top penetrated the paint layer only. The larger impact feature at the bottom penetrated to and exposed the underlying Al alloy substrate. A sub-crater is visible in the metal, showing that the impactor energy penetrated to and damaged the metal substrate, as well as removing a large volume of paint.

Observations of the sizes of impact features are presented in Figure 2. The smallest impacts were not cored, so the distribution of impact sizes falls off at small diameters (<300 microns). At larger sizes, the frequency of impacts declines exponentially. Figure 3 shows secondary electron images of examples for both types of craters (those that penetrated only paint, and those that penetrated both paint and underlying metal substrate). Damage equations that relate impact feature size to impactor size, density, and velocity will need to account for the stratified nature of the target, the differing material properties of the two layers, and the weak nature of the interface between the two layers.

The distinctive character of impacts into paint versus more energetic impacts that exposed underlying metal is shown in Figure 3. Impacts that bottomed out in the paint layer have bowl- or cone-shaped floors, and are generally lined with abundant frothy impact melts. Impacts that reached the Al-alloy layer often expose large, flat-bottomed floors, with sub-craters formed in the metal. Impact melts that are rich in Al in the floor of these craters are not frothy, because the Al alloy was not rich in volatiles so no out-gassing occurred from the impact-melted Al. The detachment and excavation of paint from these deeper craters often carried away impact melted paint, perhaps removing the best target material for this study.

Figure 4 shows frothy textures in impact melt of paint in one impact feature. The texture of melted paint is readily distinguishable from unmelted paint. The search for rare impactor residues requires sampling the paint composition, often in many locations, before any likely impactor residues are located. Impactor residues are dissolved in and strongly diluted by the more abundant elements that reside in the paint.

Figure 5 shows an x-ray spectrum from the impact-melted paint shown in Figure 4. The elemental composition of the impact melt is dominated by Zn, Ti, Si, K and O, with minor Al, indicating that this impact melt is made up dominantly of elements derived from the paint layer. The expanded

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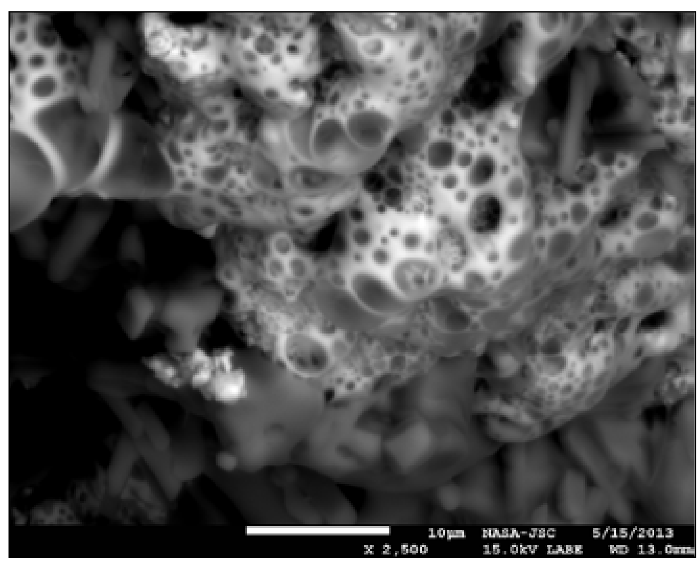

Figure 4. Close-up backscattered electron image of frothy, melted paint in impact core WFPC2-68. The impact-melted paint layer typically contains abundant bubbles formed by outgassing of volatile elements that resided in the paint before impact.

WFPC-2 Impact Features

continued from page 5

view of the spectrum shows that Mg and Fe are also constituents of the impact melt. This impact feature did not penetrate to the underlying metal substrate, so that it appears that the only available source for the Mg and Fe is a micrometeoroid impactor. We note that Si is a major constituent of the paint. While it is very likely that Mg- and Fe-bearing micrometeoroid impactors would be accompanied by Si, we cannot use Si in the paint as an indicator of any impactor type, as it is already present.

This study has partitioned the impacting population into its micrometeoroid and orbital debris components; that portion of the total thus identified can be used to characterize the overall population statistics among those features not identifiable as being micrometeoroids or orbital debris. Damage equations for painted surfaces and the time history of the WFPC-2 orientation are being developed and, coupled with the population identified by this work, shall be used in near- and long-term models of the orbital debris environment in low Earth orbit. A subsequent article will describe the overall results of the examination of WFPC-2. ♦

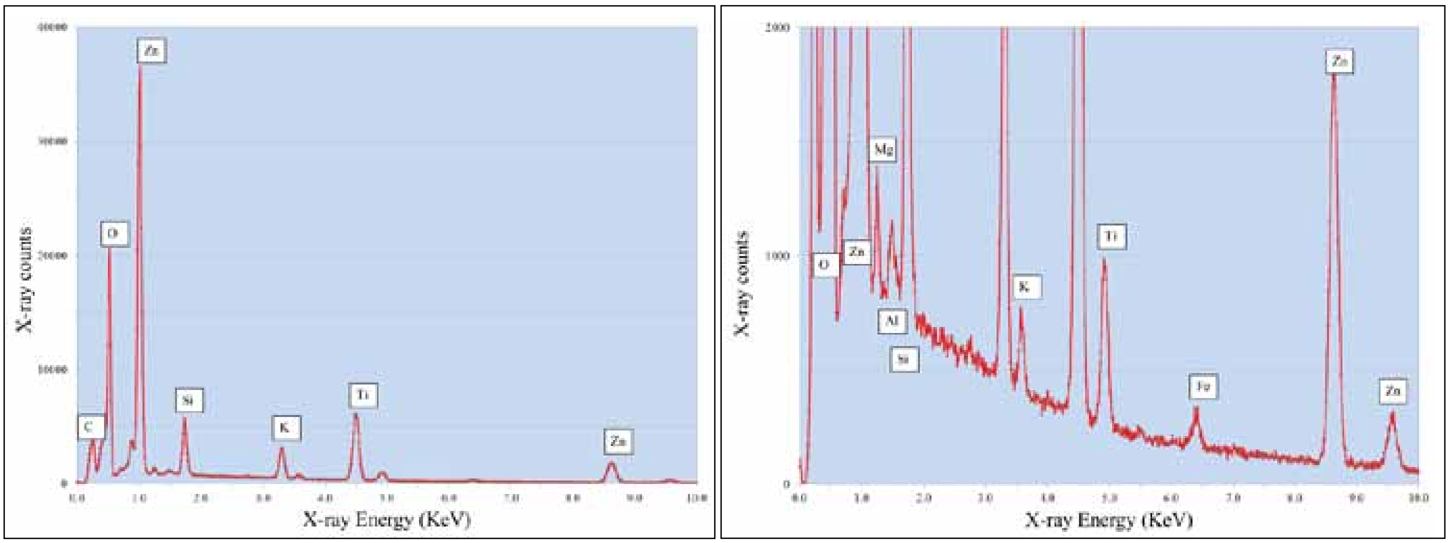

Figure 5. Example x-ray spectrum of melted paint from WFPC2-68. Panel at right shows a vertically-expanded view of the same spectrum, with Mg and Fe in melt. These elements are likely indicators of a micrometeoroid impactor.

MEETING REPORTS

The Sixth European Conference on Space Debris
22-25 April 2013, Darmstadt, Germany

The Sixth European Conference on Space Debris was held 22-25 April in Darmstadt, Germany. This is the world's premier conference on space debris and is held every 4 years at the European Space Operations Center. This year a record 355 participants attended the event from 26 countries. One-hundred and fifteen oral presentations were made, along with a large number of poster presentations.

There were eight sessions held in parallel during the four days. Topics included detection of space debris from the ground using optical and radar methods, in-situ measurements, space surveillance activities, orbit determination methods, re-entry predictions, modeling of the space debris environment, and concepts for debris mitigation & remediation.

Presentations based on work done or supported by the NASA Orbital Debris Program Office included studies of GEO debris with the 6.5-m Magellan telescopes, a planned laboratory-based satellite impact experiment to characterize breakup fragments, interpreting the observed spectra of GEO debris to understand the material makeup, the characteristics of the 2012 breakup of a BRIZ-M upper stage, analysis of impacts on the WFPC-2 radiator after retrieval from the Hubble Space telescope, and the small particle population as used in the forthcoming ORDEM 3.0.

During the opening session there was a summary presentation of the likely future population growth of the orbital debris population in LEO, based on a study conducted by six member agencies of the IADC (ASI, ESA, ISRO, JAXA, NASA, and UKSpace). All model predictions showed an increase in the number of objects in LEO over time, even with a 90% compliance of the 25-year rule and no future explosion.

The concluding press conference stated that there was "an urgent need to undertake active debris removal and employ sustainable strategies for future missions." ♦

Spacecraft Anomalies and Failures Workshop 5-6 June 2013, Chantilly, VA, USA

The Spacecraft Anomalies and Failures Workshop, hosted by Integrity Applications, Incorporated in Chantilly, Virginia on 5-6 June 2013, was perhaps the first time experts from the spacecraft engineering community – both commercial and government – and the space environment community came together to share and discuss information on the challenges of spacecraft anomalies and their relationship to the space environment. The talks ranged from general environment models and laboratory experiments to stories of specific satellite events and how they were diagnosed and corrected.

Day 1 included discussions of the philosophy of spacecraft anomaly analyses, and the importance of "internal" situational awareness, as well as understanding of the space environment. Talks were on the nature of the natural meteoroid environment and laboratory experiments of the electromagnetic effects of impacts at micrometeoroid speeds. There was also a discussion of the anthropogenic orbital debris environment, with specific examples of damage on human-tended spacecraft, including the International Space Station and the Hubble Space Telescope. Discussion also included the challenges imposed by the radiation and space weather environment and by long-term space weathering, as well as effects of unintentional electromagnetic jamming. Interspersed with these environment discussions were specific examples of spacecraft anomalies and their causes, as well as specific actions taken to recover spacecraft operations after an anomaly (often in very creative ways).

An additional discussion topic was how anomaly information – traditionally not shared by satellite operators – might be pooled in such a way as to help the entire satellite community. Also of interest was mining statistical data of past anomalies to identify previously-unrecognized environmental effects and patterns that might shed light on spacecraft risks.

Day 2 included discussions on insurance and policy perspectives, as well as further examples of spacecraft anomalies and their investigations and solutions.

At the end of the 2-day meeting, one of the participants asked when next year's meeting would take place. There was clearly a perception that this meeting filled a gap in the operational community, and that continued sharing in future cross-disciplinary venues would be beneficial. ♦

UPCOMING MEETINGS

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

The technical program of the 14th Advanced Maui Optical and Space Surveillance Technologies Conference (AMOS) will focus on subjects that are mission critical to Space Situational Awareness. The presentations will include detection capability of advanced telescopes, new detection algorithm, techniques to recover previously detected objects, recent development in adaptive optics and imaging, and space-based assets. One of the technical sessions is dedicated to orbital debris. Additional information about the conference is available at <http://www.amostech.com/>.

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

The main theme for the 2013 IAC is "Promoting Space Development for the Benefit of Mankind." A Space Debris Symposium is planned, organized by the International Academy of Astronautics to address the full spectrum of technical issues of space debris. They include measurements, modeling, risk assessments, reentry, hypervelocity impacts and protection, mitigation and standard, and space surveillance. The Symposium will include five oral sessions and one poster session. The abstract submission deadline is 21 February 2013. Additional information for the 2013 IAC is available at: <http://www.iac2013.org>.

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

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

SATELLITE BOX SCORE

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

Country/ Organization	Payloads	Rocket Bodies & Debris	Total
CHINA	143	3595	3738
CIS	1426	4798	6224
ESA	44	47	91
FRANCE	57	441	498
INDIA	51	121	172
JAPAN	125	82	207
USA	1137	3786	4923
OTHER	629	120	749
TOTAL	3612	12990	16602

Visit the NASA Orbital Debris Program Office Website

www.orbitaldebris.jsc.nasa.gov

Technical Editor
J.-C. Liou

Managing Editor
Debi Shoots

Correspondence concerning the ODQN can be sent to:

Debi Shoots
NASA Johnson Space Center
Orbital Debris Program Office
Mail Code JE104
Houston, TX 77058

debra.d.shoots@nasa.gov

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

www.nasa.gov
http://orbitaldebris.jsc.nasa.gov/

INTERNATIONAL SPACE MISSIONS

1 April 2013 – 30 June 2013

International Designator	Payloads	Country/ Organization	Perigee Altitude (KM)	Apogee Altitude (KM)	Inclination (DEG)	Earth Orbital Rocket Bodies	Other Cataloged Debris
2013-014A	ANIK G1	CANADA	35785	35788	0.0	1	1
2013-015A	BION M1	RUSSIA	471	579	64.9	1	0
2013-015B	OSSI 1	SOUTH KOREA	218	348	64.9		
2013-015C	DOVE 2	USA	564	575	64.9		
2013-015D	AIST 2	RUSSIA	564	575	64.9		
2013-015E	BEESAT 3	GERMANY	558	574	64.9		
2013-015F	SOMP	GERMANY	558	574	64.9		
2013-015G	BEESAT 2	GERMANY	558	574	64.9		
2013-016A	BELL	USA	153	161	51.6	1	0
2013-016B	DOVE 1	USA	160	169	51.6		
2013-016C	ALEXANDER	USA	134	152	51.6		
2013-016D	PAYLOAD SIM (CYGNUS)	USA	144	150	51.6		
2013-016E	GRAHAM	USA	161	175	51.6		
2013-017A	PROGRESS-M 19M	RUSSIA	360	418	51.6	1	0
2013-018A	GAOFEN 1	CHINA	628	656	98.1	1	0
2013-018B	NEE 01 PEGASO	EQUADOR	627	654	98.1		
2013-018C	TURKSAT 3U	TURKEY	628	654	98.1		
2013-018D	CUBEBUG 1	ARGENTINA	627	654	98.1		
2013-019A	COSMOS 2485 (GLONASS)	RUSSIA	19084	19176	64.8	1	0
2013-020A	CHINASAT 11	CHINA	35780	35794	0.6	1	0
2013-021A	PROBA V	ESA	814	819	98.7	0	1
2013-021B	VNREDSAT 1	VIETNAM	683	685	98.1		
2013-021C	ESTCUBE 1	ESTONIA	656	672	98.1		
2013-022A	EUTE 3D	EUTELSAT	35776	35797	0.0	1	1
2013-023A	NAVSTAR 68 (USA 242)	USA	20178	20187	55.0	1	0
2013-024A	WGS 5 (USA 243)	USA	EN ROUTE TO GEO			1	0
2013-025A	SOYUZ-TMA 9M	RUSSIA	409	421	51.6	1	0
2013-026A	SES-6	SES	35777	35796	0.1	1	1
2013-027A	ATV-4	ESA	409	421	51.6	1	0
2013-028A	COSMOS 2486	RUSSIA	714	733	98.3	1	0
2013-029A	SZ-10	CHINA	333	337	42.8	1	5
2013-029H	SZ-10 MODULE	CHINA	331	337	42.8		
2013-030A	RESURS P1	RUSSIA	459	473	973	1	0
2013-031A	O3B FM5	O3B	7808	7838	0.0	1	0
2013-031B	O3B FM4	O3B	7820	7838	0.0		
2013-031C	O3B FM2	O3B	7828	7838	0.0		
2013-031D	O3B PFM	O3Ba	7843	8007	0.0		
2013-032A	COSMOS 2487	RUSSIA	497	501	74.7	1	0
2013-033A	IRIS	USA	622	663	97.9	1	0