National Aeronautics and Space Administration

Orbital Debris Quarterly News

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Inside...

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Upper Stage Explosion Places LEO Satellites at Risk

The explosion of a failed launch vehicle upper stage on 16 October created thousands of new debris which pose collision risks to hundreds of satellites operating in low Earth orbit (LEO), including the International Space Station (ISS). Fortunately, the threat will be relatively short-lived with the majority of the debris expected to reenter the atmosphere within one year.

The explosion of the Proton Briz-M stage (International Designator 2012-044C, U.S. Satellite Number 38746) occurred just a day after the publication of the October 2012 issue of the *Orbital Debris Quarterly News*, which contained an article describing the potential for just such a breakup (ODQN, October 2012, pp. 2-3). The stage (Figure 1), with a dry mass of 2.6 metric tons, had been stranded in an elliptical orbit of about 265 km by 5015 km with an estimated 10 metric tons of propellant, following a launch malfunction on 6 August.

The massive fragmentation occurred at an altitude of 290 km as the stage approached perigee. Although as many as 700 large debris were detected by the U.S. Space Surveillance Network (SSN), only 111 had been officially cataloged by the end of December. Figure 2 indicates the altitude distribution of more than 200 debris as of 25 October. The number of debris potentially hazardous to operational spacecraft was estimated to be much more numerous.

To ascertain the population of small debris from the Briz-M breakup, the Orbital Debris Program Office requested special observations of the debris cloud by the Haystack Auxiliary radar operated by the Massachusetts Institute of Technology's Lincoln Laboratory and by the Jet Propulsion Laboratory's Goldstone radars in California. These radars can detect centimeter- and millimeter-class objects at the Briz-M debris perigee altitudes. The observations did indicate a much larger debris population than could be tracked by the SSN.

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Figure 1. The Briz-M upper stage contains a central engine and propellant surrounded by an auxiliary propellant tank, which is ejected part-way through the mission.

Upper Stage Explosion

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Since the ISS was in a nearly circular orbit at 415 km, all the Briz-M debris passed through the altitude of the station twice each revolution. Figure 3 illustrates that the orbital planes of ISS and the Briz-M debris were nearly perpendicular at the time of the explosion, giving rise to high relative velocities (Figure 4). However, the higher precession rate of the plane of the ISS gradually led to a closer alignment of the orbital planes in December, leading to lower relative velocities and a tendency of potential impacts to occur near the aft end of the ISS. Technical assessments found the risk to the ISS from the Briz-M debris to be a small fraction of the risk from the normal background debris environment.

Since 2007, a total of three failed Briz-M stages have exploded, each creating large amounts of hazardous orbital debris. Two other Briz upper stages remain in orbits passing through LEO: a Briz-KM stage (International Designator 2011-005B) and a Briz-M stage (International Designator 2011-045B).

Yet another Briz-M stage (International Designator 2012-70C) failure occurred on 8 December 2012, when the main engine cut-off prematurely during the final burn. The stage and its payload were left in unplanned, elliptical orbits with perigee near 3,000 km and apogee near geosynchronous altitude. International Launch Source (ILS) officials have stated that the two remaining Briz-M stages were passivated after their anomalous flights and do not pose an explosion hazard. ♦

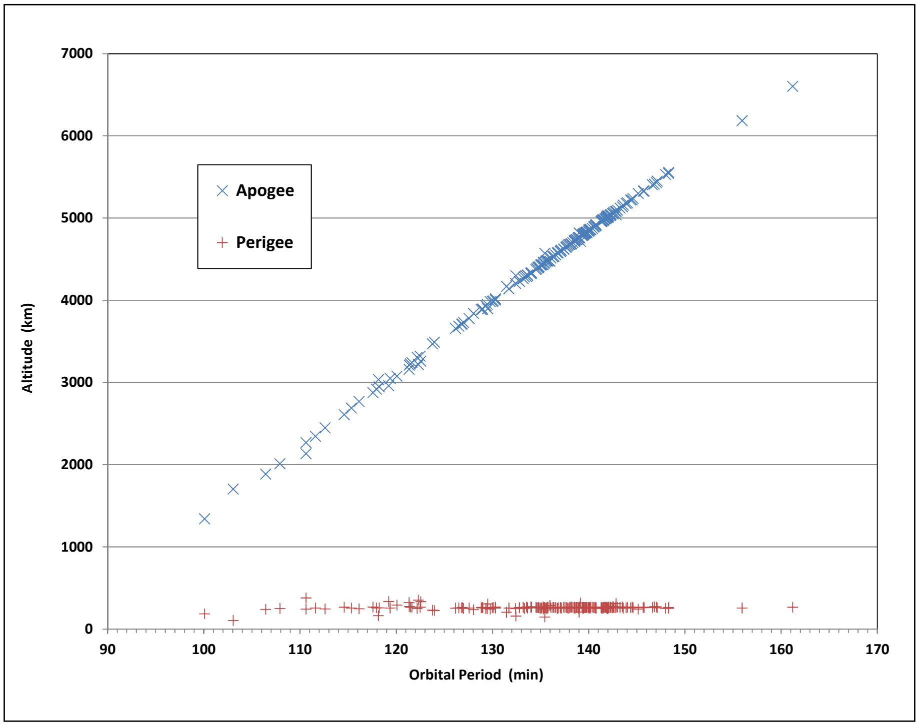


Figure 2. Distribution of more than 200 tracked Briz-M debris as of 25 October 2012.

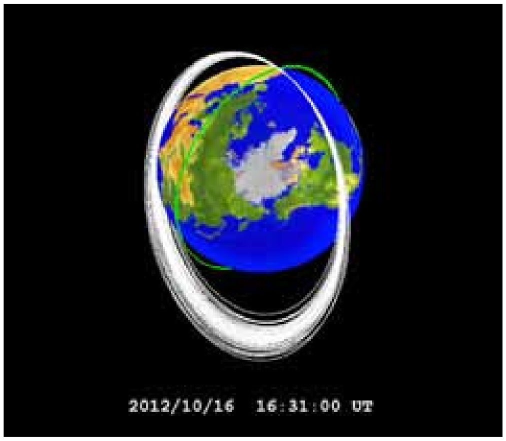


Figure 3. Orbital planes of the International Space Station (green) and the Briz-M debris (white) at the time of the breakup.

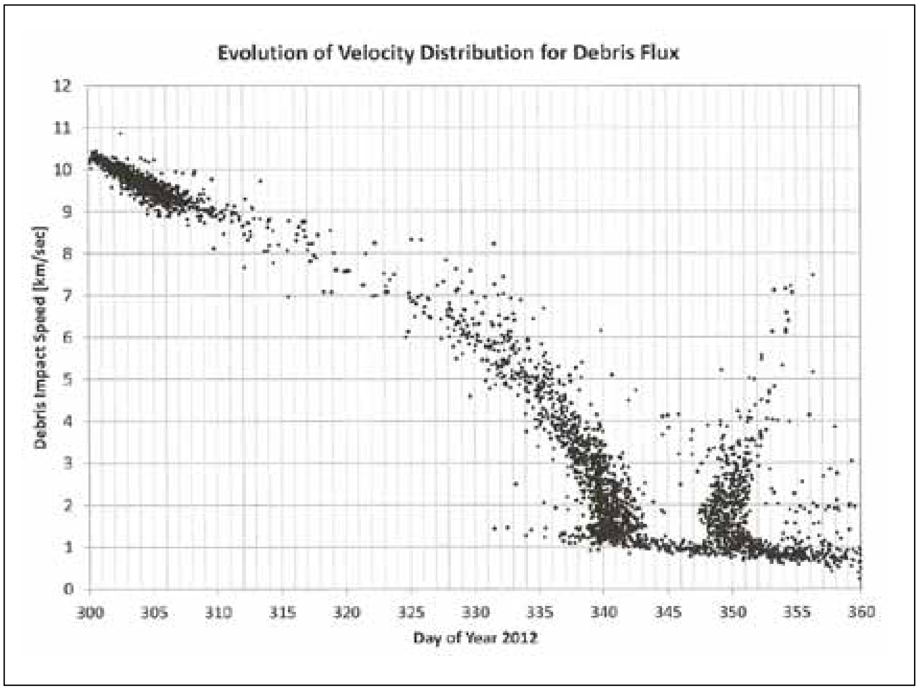
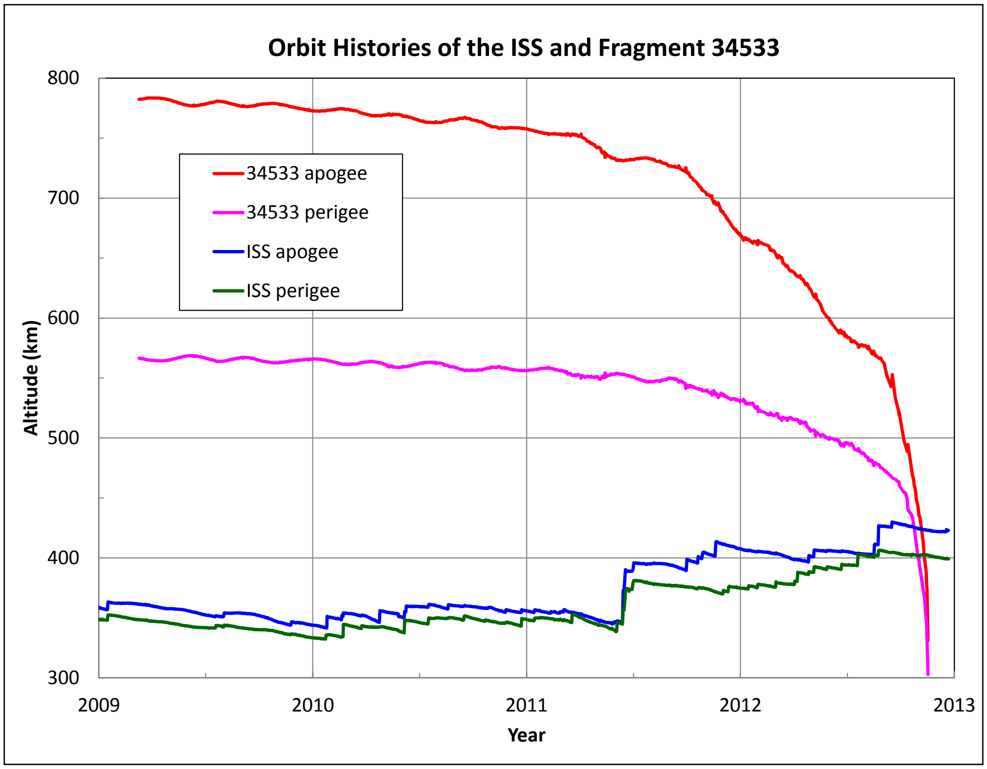


Figure 4. The relative velocity between the Briz-M debris cloud and the International Space Station was initially near 10 km/s, but as the orbital planes more closely aligned, the relative velocity decreased significantly.

Another Debris Avoidance Maneuver for the ISS

The International Space Station (ISS) conducted another debris avoidance maneuver (DAM) on 31 October 2012. The object to be avoided was an Iridium 33 fragment generated from the collision between Iridium 33 and Cosmos 2251 in 2009. This small fragment (International Designator 1997-051JA, U.S. Satellite Number 34533) had a radar cross- section of approximately 0.01 m^2. It had an orbit of 438 × 399 km, with an inclination of 86.2 degrees at that time. The tracking data and conjunction assessments provided by the Joint Space Operations Center (JSpOC) indicated that this object would have repeated conjunctions with the ISS, with collision probabilities exceeding the acceptable threshold of 1 in 10,000 around 31 October – 1 November. Because of the assessments, a 0.31 m/s burn was executed for the ISS at 23:08 GMT on 31 October to avoid the fragment. After the ISS DAM, this small fragment continued its rapid decay and finally reentered on 16 November.



The apogee and perigee altitude histories of the ISS and fragment 34533.

Two major breakup events (the Fengyun-1C ASAT test and the Iridium 33 – Cosmos 2251 collision) and an increase in solar activity will likely result in an increased frequency of debris conjunctions for the ISS for the next few years. All three ISS DAMs performed during 2012 were caused by debris from Fengyun-1C or Iridium 33. Notification of another conjunction – this time with a fragment from Cosmos 2251 in March 2012 – was received too late for a DAM, requiring the ISS crew to retreat temporarily to their Soyuz spacecraft (ODQN, April 2012, pp.1-2). ♦

APPEL Releases Orbital Debris iBook

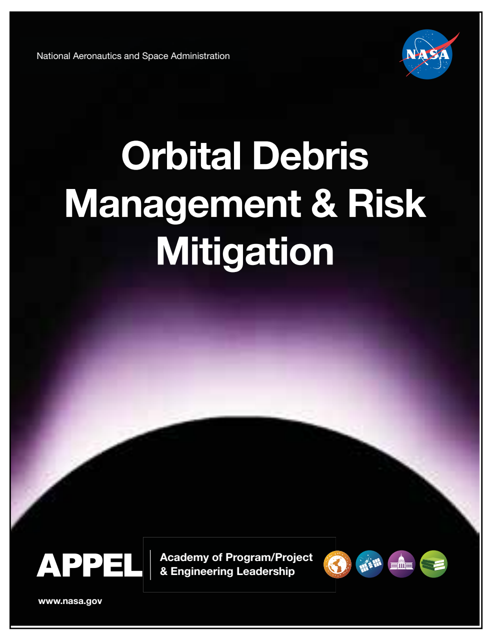
The NASA Academy of Program/ Project & Engineering Leadership (APPEL) has announced the public release of Orbital Debris Management and Risk Mitigation, its first publication of NASA training materials using the iBook format. This new electronic book platform enables the seamless integration of text with videos, 3-D models, image galleries, and interactive graphics.

APPEL's Orbital Debris Management and Risk Mitigation (ODM) training course provides mission-critical knowledge that helps NASA missions implement the agency's overarching strategic goals and the U.S. National Space Policy goals for long-term sustainability in space. The new iBook supplements the existing course taught by Nicholas L. Johnson, NASA Chief Scientist for Orbital Debris. These supplementary materials are now freely available to anyone.

The book was produced using iBooks Author, a free software. Since iBooks are designed to function on an iPad, APPEL has also released a PDF of the complete text and all multimedia materials for readers using other technologies or e-readers.

Both the iBook and the PDF can be downloaded from

<http://www.nasa.gov/offices/oce/appel/knowledge/publications/appel-releases-ibook.html>. ♦



An update of the FY-1C, Iridium 33, and Cosmos 2251 Fragments

The beginning of the year 2013 marks the sixth anniversary of the destruction of the Fengyun-1C (FY-1C) weather satellite as the result of an anti-satellite test conducted by China in January of 2007 and the fourth anniversary of the accidental collision between Cosmos 2251 and the operational Iridium 33 in February of 2009. These two events represent the worst satellite breakups in history. A total of 5579 fragments have been cataloged by the U.S. Space Surveillance Network (SSN) and almost 5000 of them still remain in orbit as of January 2013 (see the table on page 5). In addition to these cataloged objects, hundreds of thousands (or more) of fragments down to the millimeter size regime were also generated during the breakups. These fragments are too small to be tracked by the SSN, but still large enough to be a safety concern for human space activities and robotic missions in low Earth orbit (LEO, the region below 2000 km altitude). Just like their cataloged siblings, many of them remain in orbit today.

These two breakup events dramatically changed the landscape of the orbital debris environment in LEO. The spatial density of the January 2013 cataloged objects is shown as the top blue curve in Figure 1. The combined FY-1C, Iridium 33, and Cosmos 2251 fragments (black curve) account for about 50% of the cataloged population below 1000 km altitude. They are also responsible for the concentrations at 770 and 850 km altitudes. The impacts of the FY-1C, Iridium 33, and Cosmos 2251 fragments will continue to be felt for decades to come (Figure 2). In general, the Iridium 33 and Cosmos 2251 fragments will decay faster than the FY-1C fragments because of their lower altitudes. Between the Iridium 33 and Cosmos 2251 fragments, the former have much shorter orbital lifetimes than the latter. This is because lightweight composite materials were heavily used in the construction of the Iridium vehicle, leading to higher area-to-mass ratios of the fragments (ODQN, July 2009, p. 5-6). ♦

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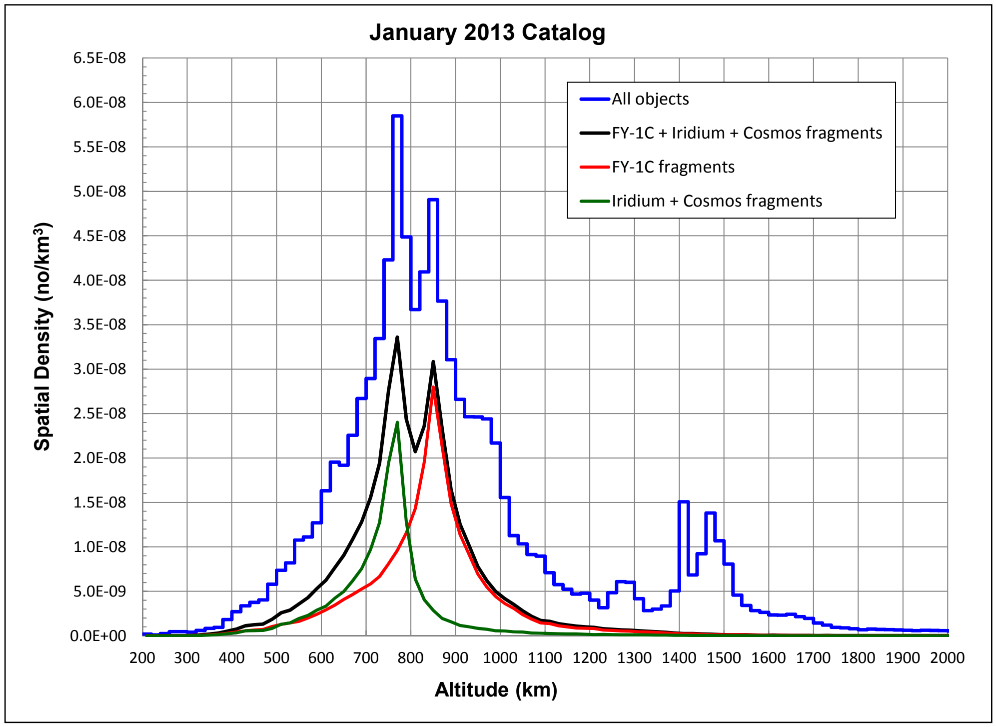

Figure 1. Spatial density distribution of the cataloged objects as of January 2013.

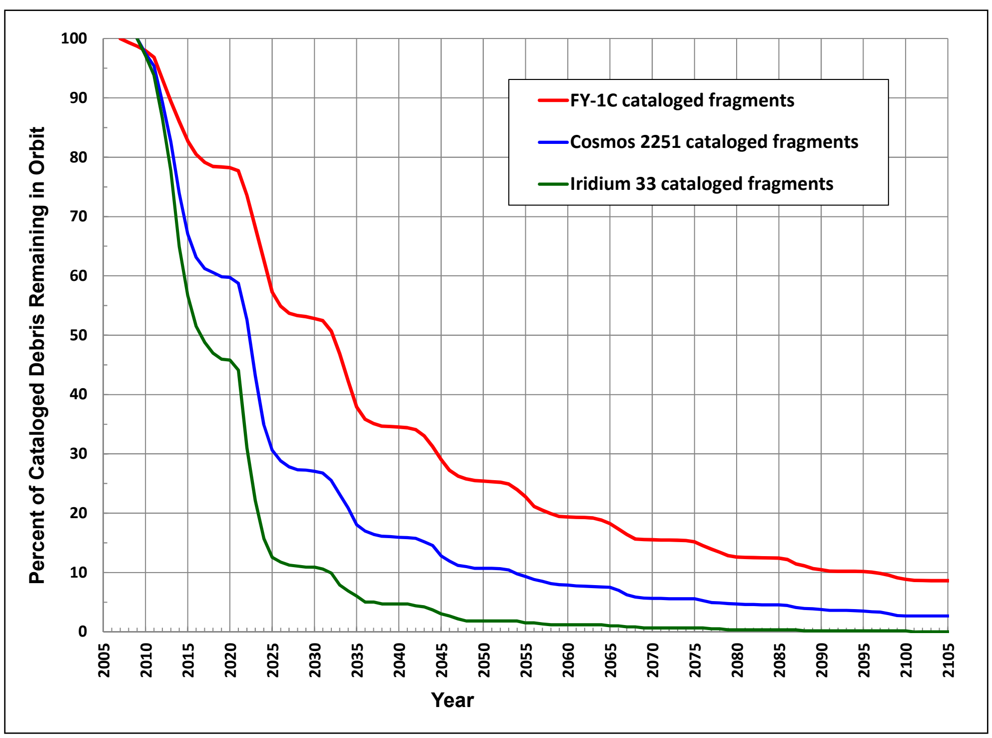

Figure 2. Projected decay of the cataloged FY-1C, Iridium 33, and Cosmos 2251 fragments. Projection assumes a return to normal solar activity beginning in 2020.

Update

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A Summary of the FY-1C, Cosmos 2251, and Iridium 33 Cataloged Fragments (as of January 2013)

Name	Cataloged Debris	Debris Decayed	Debris in Orbit
FY-1C	3378	302	3076
Cosmos 2251	1603	261	1342
Iridium 33	598	119	479
Total	5579	682	4897

GRAIL Spacecraft Impact Moon in Accordance with Orbital Debris Mitigation Requirements

Two NASA Gravity Recovery and Interior Laboratory (GRAIL) spacecraft completed their year-long mission in orbit about the Moon on 17 December 2012 when they were sent on a controlled impact into a lunar mountain. This disposal action was in compliance with recommendations in NASA Procedural Requirements for Limiting Orbital Debris, NPR 8715.6A, designed to protect historic and scientifically valuable lunar surface sites.[1]

Affectionately known as Ebb and Flow (Figure 1), the two 200-kg dry-mass spacecraft entered lunar orbit on New Year's Eve 2011 and New Year's Day 2012, respectively, and worked primarily from a 55-km altitude science orbit. As their reservoirs of hydrazine propellant dwindled, plans were made to target their crash onto the lunar surface rather than let them fall randomly.

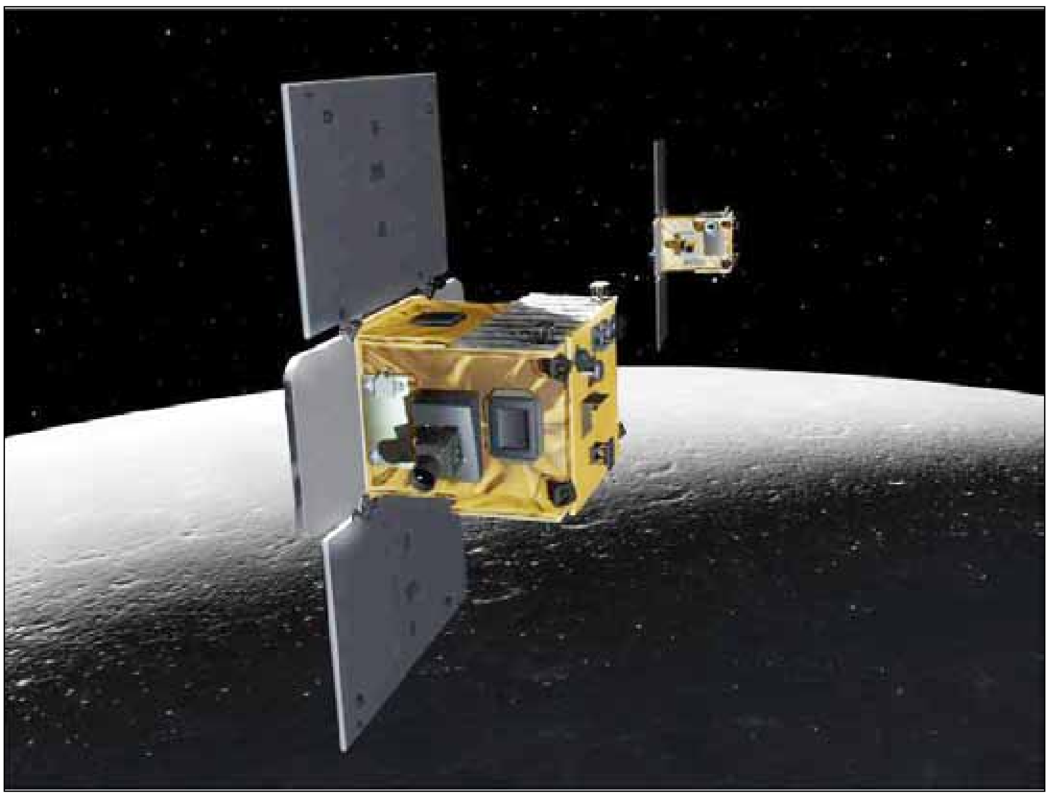

Figure 1. Artist's view of the two GRAIL satellites flying in close formation in lunar orbit.

Although NASA's original orbital debris mitigation policies and safety standard during the 1990s did not address orbits beyond the Earth, NPR 8715.6, issued in 2007, for the first time addressed objects in orbits about the Moon. NPR 8715.6A, issued in 2009, states that NASA program and project managers "shall not plan to leave objects in lunar orbit unless a documented need is stated in the ODAR" (Orbital Debris Assessment Report).

For the disposal of the two GRAIL spacecraft a trajectory was selected to carry the spacecraft toward an unnamed lunar mountain near the north pole (Figures 2 and 3). The final resting place for the two GRAIL spacecraft has been named for the late Sally Ride, the first U.S. woman in space and a proponent of the Moon KAM (Moon Knowledge Acquired by Middle School Students) cameras carried by the GRAIL spacecraft.

Reference

NASA Procedural Requirements for Limiting Orbital Debris, NPR 8715.6A, 14 May 2009, Section 3.3.3. ♦

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GRAIL

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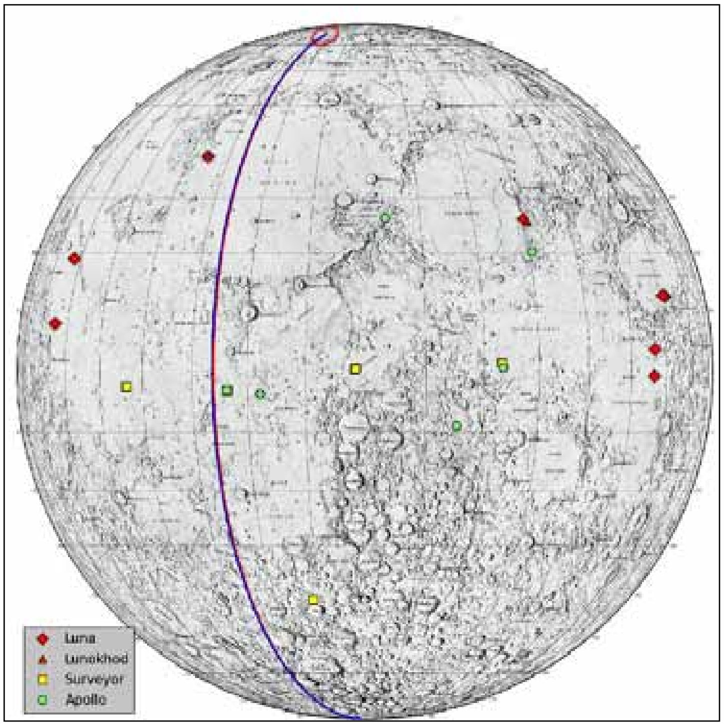

Figure 2. The final groundtrack of the two GRAIL spacecraft.

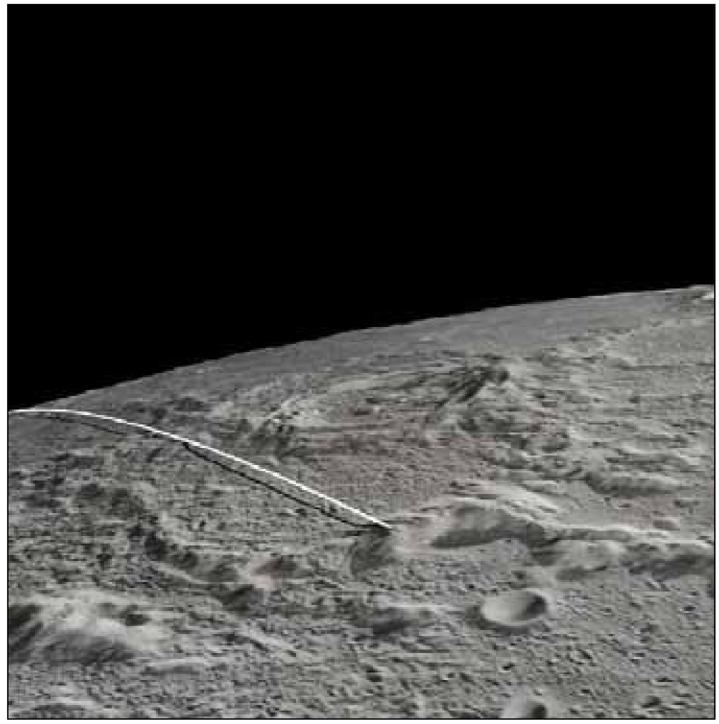

Figure 3. The two GRAIL spacecraft struck the lunar surface just 30 seconds apart at a speed of nearly 2 kilometers per second.

UPCOMING MEETINGS

22-25 April 2013: 6th European Conference on Space Debris, Darmstadt, Germany

This major international conference will cover all disciplines in space debris research, including radar, optical, and in-situ measurements; space surveillance and catalogs; debris environment modeling; on-orbit and reentry risk assessments; orbit prediction and determination; debris mitigation and remediation; hypervelocity impacts and shielding; standardization and policies. In addition, the conference will include a special theme on the topic of active debris removal, in support of orbital debris environment remediation to ensure a long-term sustainability of near-earth space activities. Additional information about the conference is available at: <http://www.congrexprojects.com/13a09>.

21-23 May 2013: The 6th IAASS Conference, Montreal, Canada

The main theme of the 6th International Association for the Advancement of Space Safety (IAASS) is "Safety is not an option." The objective of the 2013 conference is to reflect and exchange information on a number of topics in space safety and sustainability of national and international interest. Among the topics to be included in the event are "Space debris and space debris removal" and "Spacecraft re-entry safety." More information on the conference is available at: <http://iaassconference2013.spacesafetyfoundation.org>.

23-27 September 2013: 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>.

INTERNATIONAL SPACE MISSIONS
1 October 2012 – 31 December 2012

International Designator	Payloads	Country/ Organization	Perigee Altitude (KM)	Apogee Altitude (KM)	Inclination (DEG)	Earth Orbital Rocket Bodies	Other Cataloged Debris
2012-053A	NAVSTAR 67 (USA 239)	USA	20171	20195	55.0	1	0
2012-054A	DRAGON CRS-1	USA	402	425	51.6	1	3
2012-054B	ORBCOMM OG2	USA	145	204	51.6		
2012-055A	GALILEO-FM3	ESA	23220	23224	55.3	1	0
2012-055B	GALILEO-FM4	ESA	23221	23224	55.3		
2012-056A	SJ-9A	CHINA	621	651	98.0	1	5
2012-056B	SJ-9B	CHINA	623	651	98.0		
2012-057A	INTELSAT 23	INTELSAT	35780	35792	0.0	1	1
2012-058A	SOYUZ-TMA 6M	RUSSIA	400	422	51.6	1	0
2012-059A	BEIDOU G6	CHINA	35776	35796	1.7	1	0
2012-060A	PROGRESS-M 17M	RUSSIA	400	422	51.6	1	0
2012-061A	LUCH 5B	RUSSIA	35768	35803	0.3	1	1
2012-061B	YAMAL 300K	RUSSIA	35782	35794	0.1		
2012-062A	STARONE C3	BRAZIL	35776	35798	0.1	1	1
2012-062B	EUTELSAT 21B	EUTELSAT	35776	35796	0.0		
2012-063A	MERIDIAN 6	RUSSIA	1005	39349	62.8	1	0
2012-064A	HJ-1C	CHINA	489	503	97.4	1	4
2012-064B	FENGNIAO 1 (FN-1)	CHINA	487	500	97.4		
2012-064C	XINYAN 1 (XY-1)	CHINA	488	501	97.4		
2012-065A	ECHOSTAR 16	USA	35729	35738	0.0	1	1
2012-066A	YAOGAN 16A	CHINA	1086	1095	63.4	1	2
2012-066B	YAOGAN 16B	CHINA	1086	1095	63.4		
2012-066C	YAOGAN 16C	CHINA	1086	1095	63.4		
2012-067A	CHINASAT 12	CHINA	35904	35908	0.1	1	0
2012-068A	PLEIADES 1B	FRANCE	688	690	98.2	0	0
2012-069A	EUTELSAT 70B	EUTELSAT	35785	35786	0.1	1	0
2012-070A	YAMAL 402	RUSSIA	35784	35789	0.1	1	1
2012-071A	OTV 3 (USA 240)	USA	NO ELEMS. AVAILABLE			0	0
2012-072A	KMS 3-2	NORTH KOREA	498	582	97.4	1	2
2012-073A	GOKTURK 2	TURKEY	669	690	98.2	1	0
2012-074A	SOYUZ-TMA 7M	RUSSIA	400	423	51.6	1	0
2012-075A	SKYNET 5D	UK	35775	35800	0.2	1	1
2012-075B	MEXSAT 3	MEXICO	35784	35791	0.1		

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.

SATELLITE BOX SCORE
(as of 1 January 2013, cataloged by the U.S. SPACE SURVEILLANCE NETWORK)

Country/ Organization	Payloads	Rocket Bodies & Debris	Total
CHINA	140	3638	3778
CIS	1425	4864	6289
ESA	42	45	87
FRANCE	56	437	493
INDIA	48	125	173
JAPAN	124	82	206
USA	1125	3811	4936
OTHER	606	118	724
TOTAL	3566	13120	16686

Visit the NASA Orbital Debris Program Office Website

www.orbitaldebris.jsc.nasa.gov

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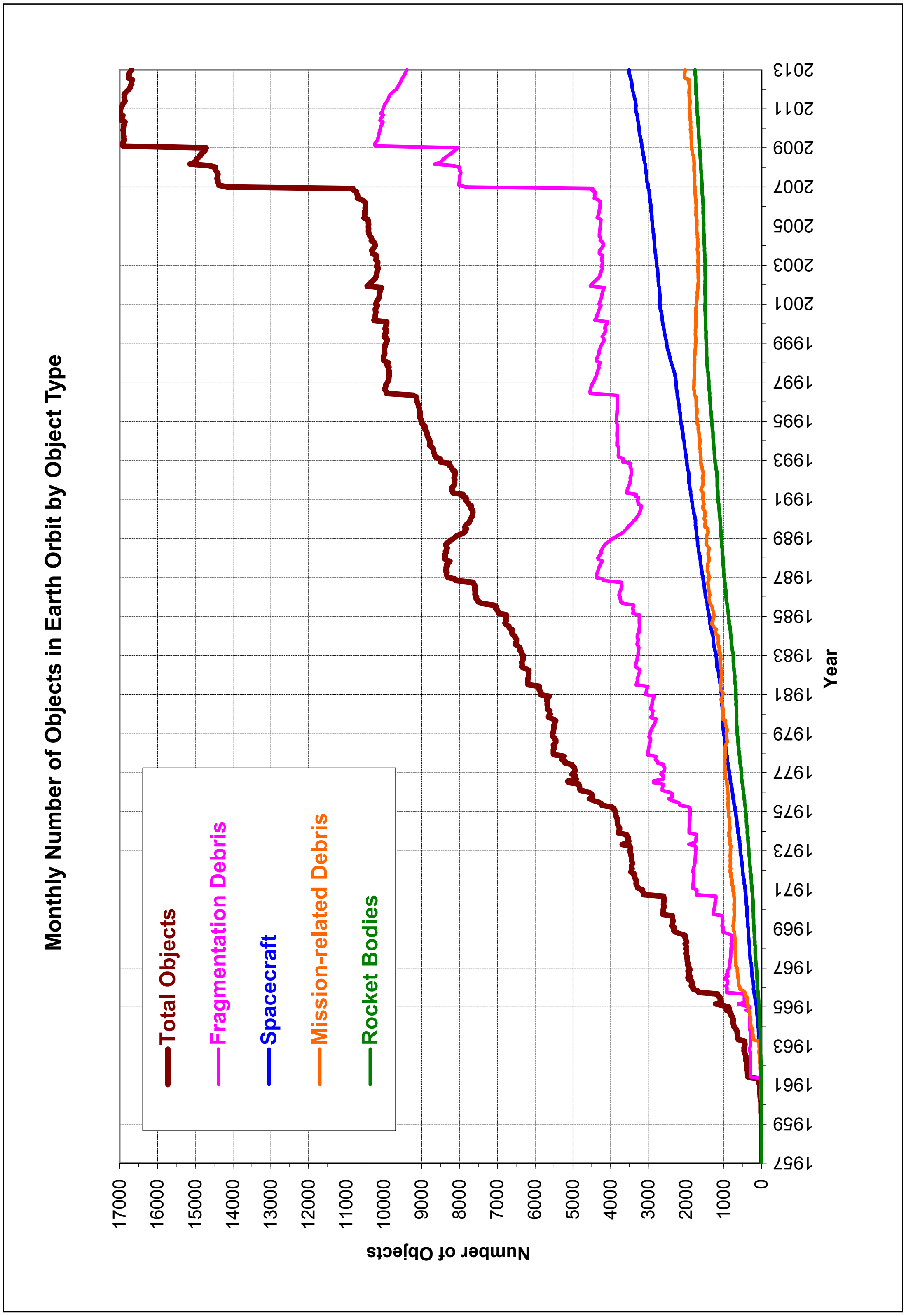

Monthly Number of Cataloged Objects in Earth Orbit by Object Type: This chart displays a summary of all objects in Earth orbit officially cataloged by the U.S. Space Surveillance Network. “Fragmentation debris” includes satellite breakup debris and anomalous event debris, while “mission-related debris” includes all objects dispensed, separated, or released as part of the planned mission.

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