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Orbital Debris Quarterly News

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Inside...

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Only a Few Minor Satellite Breakups in 2011

The year 2011 ended with the least number of identified satellite breakups since 2002. Moreover, the number of long-lived, 10 cm and larger debris appears to have been only a few dozen – good news for the satellite operator community.

Only three standard satellite breakups were detected by the U.S. Space Surveillance Network (SSN) during the year, two involving small auxiliary motors associated with the Russian Proton Block-DM upper stage. On 18 August 2011, a small (~55 kg) ullage motor (International Designator 2007-065G, U.S. Satellite Number 32399) used for the deployment of the Cosmos 2434-2436 navigation satellites in late December 2007, fragmented in an orbit of 540 km by 18,965 km. Although some small debris were initially observed by the SSN, by year's end none had been officially cataloged.

A similar situation existed with another ullage motor (International Designator 1990-045F, U.S. Satellite Number 20630) flown in May 1990 on the Cosmos 2079-2081 mission. This engine unit broke-up on 17 November 2011 in an orbit of 420 km by 18,620 km. Again, none of the originally seen debris have yet been officially cataloged. These two events represent the 38th and 39th known fragmentations of Block-DM ullage motors.

Within a few days of its launch on 19 December, a Chinese CZ-3B/E launch vehicle third stage (International Designator 2011-077B, U.S. Satellite Number 38015) fragmented into as many as a few dozen debris. The stage was in a geosynchronous transfer orbit of 230 km by 41,715 km with an inclination of 24.3 degrees. Fragmentations had been noted with similar upper stages in February 2007 and November 2010. Due to their low perigees, the debris from this latest breakup appeared to be short-lived.

Three other satellites experienced minor fragmentations just prior to reentry as a result of aerodynamic forces. These breakups occur when the perigee of an elliptical orbit drops to a very low altitude (typically below 120 km) for days or more before the satellite ultimately falls back to Earth. During 2011 such events were seen with Chinese and U.S. rocket bodies (a CZ-3C upper stage in March and an Atlas Centaur upper stage in August) and a Russian Molniya 3K spacecraft in December. Fortunately, debris created in such catastrophic orbital decays are very short-lived. ♦

Two Derelict NOAA Satellites Experience Anomalous Events

In the span of a month two decommissioned NOAA spacecraft, one in low Earth orbit (LEO) and one above geosynchronous orbit (GEO), exhibited anomalies of interest to the orbital debris community. In one case two new debris were created, and in the other a noticeable orbital perturbation occurred.

After more than 16 years of service, NOAA-12 (International Designator 1991-032A, U.S. Satellite Number 21263) was deactivated on 10 August 2007, following a series of power system problems. The passivation process included the depletion of the

continued on page 2

NOAA Satellites

continued from page 1

nitrogen in the attitude control system and of the hydrazine in the orbit adjust system, as well as the disconnection of one of the two nickel-cadmium batteries from the charging circuit. Spacecraft design prevented disconnecting both batteries at the same time. The half-metric ton spacecraft, which had been launched prior to the adoption of requirements to limit post-mission orbital lifetimes in LEO, was then left in an orbit of 800 km by 815 km.

Four years later on 2 October 2011, two small debris separated from NOAA-12 at very low velocities, less than 10 meters per second. The new debris were cataloged with U.S. Satellite Numbers 37831 and 37832. This was the fifth occurrence of a NOAA spacecraft producing debris years after its retirement. NOAA-11 also released two debris in November 2010, more than 6 years after that spacecraft had been abandoned (ODQN, January 2011, p. 3). The cause of these minor fragmentation events remains unknown, but a battery explosion is the leading candidate.

One month before the NOAA-12 incident, the derelict GOES-10 (International designator 1997-019A, U.S. Satellite Number 24786) abruptly fell to a slightly lower orbit in the graveyard region above GEO. The spacecraft was decommissioned on 2 December 2009 after having been transferred to a storage orbit of 335 km by 355 km above GEO and passivated.

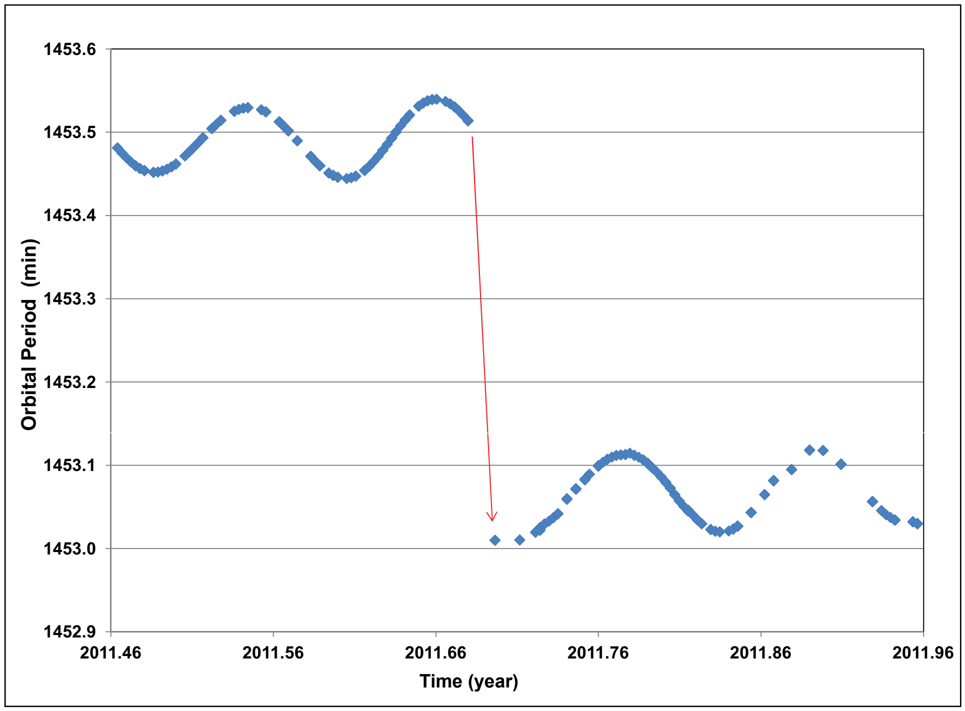

Figure 1. The GOES-10 spacecraft exhibited a distinct change in orbital period on 5 September 2011, despite having been shutdown nearly two years earlier.

Yet on 5 September 2011, the orbit of the spacecraft abruptly dropped 20 km in perigee. Since no known energy sources remained on GOES-10, the cause of the change in orbit might have been from the impact of an unknown object. Any small debris generated in such a collision would likely not be detectable by the U.S. Space Surveillance Network due to system sensitivity limits at such extreme ranges. ♦

Smallsat Deployments Done Right

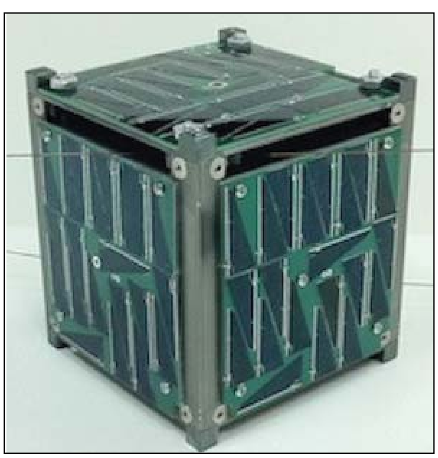

Figure 1. AubieSat 1, a cubesat from Auburn University, which was one of six smallsats launched with the NPP spacecraft.

Smallsats are typically defined as satellites with masses less than 500 kg and can be further categorized by mass as minisats, microsats, nanosats, and picosats. With advanced technologies now permitting smallsats to perform useful functions in space at relatively low costs, their popularity is understandably increasing. Launch costs are also often minimized by accompanying larger payloads into orbit. However, complying with guidelines for the proper disposal of smallsats after the end of their missions can be challenging if the primary payload is inserted into a long-lived orbit.

The recent National Polar-orbiting Operational Environmental Satellite System (NPOESS) Preparatory Project (NPP) serves as a textbook case on how to meet multiple mission objectives while satisfying orbital debris mitigation requirements. As part of a NASA program to support educational smallsats, the NPP spacecraft was to be accompanied into space by six cubesats, a special type of smallsat with a mass of only a few kilograms, developed by multiple universities for a wide variety of studies in space weather, spacecraft technologies, and Earth observation. These cubesats were attached to the second stage of the Delta 2 launch vehicle for deployment after the release of the NPP spacecraft.

The NPP was designed to operate in a nearly circular, sun-synchronous orbit with an altitude near 820 km. From this height most

continued on page 3

Smallsat

continued from page 2

spacecraft will remain in orbit for several decades before dropping out of orbit. The NPP itself was equipped with a propulsion system for a controlled reentry when the multi-year mission comes to an end, but the six cubesats, with projected operational lifetimes measured only in months, had no such maneuvering capability. Working closely with the launch vehicle vendor, NASA Kennedy Space Center personnel devised a plan to ensure that the cubesats had an opportunity to meet their mission goals and at the same time restrict the post-mission orbital lifetimes to less than 25 years, as required by NASA and several other national space agencies.

Following launch on 28 October 2011 into the designed orbit, the NPP spacecraft (International Designator 2011-61A, U.S. Satellite Number 37849) separated as planned from the Delta 2 second stage. After moving away from NPP, the stage was restarted and maneuvered into an elliptical orbit of 460 km by 815 km. The six cubesats were then released from their carriers. In these orbits the cubesats will fall back to Earth within the desired 25-year limit.

To further reduce the orbital lifetime of the Delta 2 second stage, the vehicle's main engine was fired for a final time, leaving the stage in an orbit of only 180 km by 715 km. Reentry occurred over the Pacific Ocean only a month later on 29 November. ♦

TDRS and GOES Spacecraft Sent to Graveyard Orbits

Figure 1. TDRS 4 spacecraft.

After highly successful communications and meteorological missions, NASA and NOAA, respectively, maneuvered two large geosynchronous satellites into higher altitude disposal orbits. In accordance with U. S. and international orbital debris mitigation guidelines, the spacecraft were left in orbits which will not intersect the GEO protected region (GEO +/- 200 km) for well over 100 years.

The fourth of NASA's primary communications relay satellites, TDRS 4 (International Designator 1989-021B, U.S. Satellite Number 19883), was launched on 13 March 1989 as the principal payload of the STS-29 mission. On 28 November 2011 two major burns were executed to lift the 22-year-old TDRS 4 to an initial storage orbit of approximately 300 km by 500 km above GEO. A series of additional maneuvers were then conducted to deplete all residual propellants for the purpose of preventing a future, accidental explosion. This was achieved on 9 December, leaving TDRS 4 in an orbit of 460 km by 560 km above GEO. TDRS 1, the only other TDRS satellite to have been retired to date, was placed in a super-synchronous disposal orbit in June 2010 (ODQN, July 2010, p. 2).

NOAA's GOES 11 satellite (International Designator 2000-022A, U.S. Satellite Number 26352) was replaced on 6 December by GOES 15. Two maneuvers were conducted 10 days later to transfer the spacecraft to a disposal orbit 350 km above GEO. As with TDRS 4, additional small maneuvers were then conducted to deplete all remaining propellants. ♦

Recent Disposal of JAXA Akari Satellite

Figure 1. Illustration of the Akari spacecraft.

Following its own requirements, as well as international recommendations, the Japan Aerospace Exploration Agency (JAXA) has responsibly disposed of a scientific satellite which had been operating in the low Earth orbit (LEO) region. The spacecraft was maneuvered into a lower orbit to limit its remaining time in space, where the vehicle might pose a hazard to operational spacecraft or be the subject of a debris-creating collision by another resident space object. The maneuvers also expended residual propellants to prevent a future accidental explosion.

The Akari infrared astronomical telescope (International Designator 2006-005A, U.S. Satellite Number 28939) was launched by JAXA in February 2006, and inserted into an orbit with a mean altitude near 700 km. Science operations with the observatory ceased in June 2011, leading to preparations for a safe disposal. During November the perigee of the 1-metric-ton spacecraft was reduced to only 440 km to ensure that it did not remain in orbit for more than 25 years following end of mission. ♦

PROJECT REVIEW

Increasing Solar Activity Aids Orbital Debris Environment

N. JOHNSON

Although high levels of solar activity are a bane to spacecraft operators, the consequent increase in the density of the Earth's atmosphere is a welcome, albeit brief, respite from an otherwise growing orbital debris population. The number of cataloged debris in Earth orbit actually decreased during 2011 as solar activity increased toward an anticipated maximum in 2013. Smaller, uncataloged debris are even more affected by the changing atmosphere, causing even greater of their numbers to fall back to Earth.

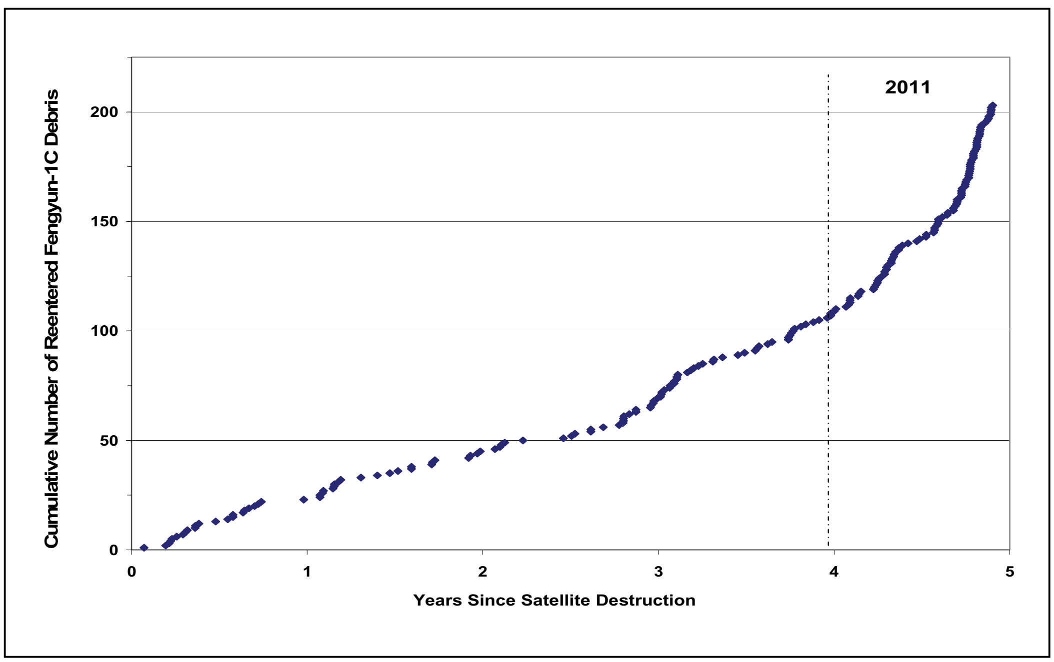

Figure 1. Approximately half of all reentered debris from the Fengyun-1C satellite occurred during the past year due to increasing solar activity.

Figure 1 illustrates how the rate of debris reentries from the Fengyun-1C anti-satellite test of January 2007 increased during the past year. Even though only 6% of the total 3218 cataloged debris from the ill-advised engagement had reentered by the end of 2011, half of these debris fell out of orbit in the past 12 months. Likewise, many debris from the 2009 accidental collision of Cosmos 2251 and Iridium 33 are accelerating their departure from Earth orbit.

In the absence of a new major satellite breakup, the overall orbital debris population should continue to decrease during 2012 and 2013. ♦

On the Probability of Random Debris Reentry Occurring on Land or Water

M. MATNEY

One of the questions that often arises concerning the uncontrolled reentry of satellites is "where will it land?." One of the answers often given is "approximately a 75% chance it will reenter over the ocean, because the Earth's surface is three-fourths water." This is probably a good simple approximation, but a glance at a globe confirms that land and water are not evenly distributed over the Earth's surface. This raises the question whether an object's inclination has an effect on the probability that debris surviving reentry will fall on land or water.

In order to answer this question, a database is needed like that used in population risk calculations that identifies which parts of the Earth's surface are land and which parts are water as a function of latitude and longitude. A number of digital elevation maps (DEMs) have been created over the years, but the most recent (and accurate) DEMS include bathymetry, so it is not always clear whether a point is a land elevation datum or a depth of water datum (e.g., the Jordan River/Dead Sea valley is below sea level, so elevation alone is not an unambiguous identifier).

For the purpose of this calculation, we need a database that clearly identifies land and water. We chose the GTOPO30 database maintained by the U.S Geological Survey (http://eros.usgs.gov/#/Find_Data/Products_and_Data_Available/gtopo30_info). Note that the topography data in this DEM is considered obsolete, but its identification of land/water is not dependent on the accuracy of the topography. The GTOPO30 DEM has elevation information at 30 arc second intervals in both latitude and longitude, covering the entire Earth. Water locations are given a default value, making identification simple.

The entire GTOPO30 DEM was processed to remove the dependence on longitude, based on the usual assumption that random reentry location is random with longitude. Figure 1 shows the distribution of land/water as a function of latitude on the Earth. This graph is interesting because the perceptions obtained by observing a map are now given precise measure. Antarctica near the South Pole stands out as 100% land, while the north polar region is 100% water. There is a general trend toward a higher fraction of land with increasing latitude, peaking at latitudes dominated by the vast regions of Canada and Siberia.

The next step is to introduce the orbit footprint of a satellite. Satellites spend different fractions of their time at different latitudes, and a disproportionate amount of time at the farthest north and farthest south points in their orbits, as determined by the orbit inclination. Using a Kepler orbit approximation, it is straightforward to integrate the land fraction of the Earth weighted by the relative amount of time a satellite spends at each latitude. Figure 2 shows this weighted fraction as a function of satellite inclination. Despite the wide disparity of land fraction as a function of latitude, the average amount of land under a particular satellite orbit is only weakly dependent on inclination, varying between 21% and 34%. The highest land percentages are polar orbits, but these orbits spend a large fraction of the time over the vast uninhabited regions of Antarctica. As can be seen, if Antarctica is excluded (treated as "ocean"), the total land fraction is much more similar to that under the other inclination orbits.

These calculations confirm that the original estimate that a satellite has a 75% chance of landing over the ocean is actually a very good approximation. ♦

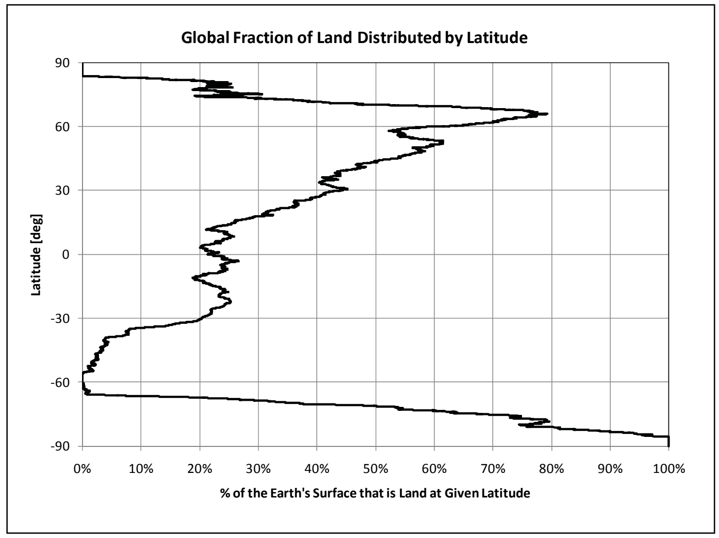

Figure 1. This chart shows the uneven distribution of the fraction of the Earth's surface that is land as a function of latitude (longitude dependence has been averaged out). The high percentage near the South Pole is the land area of Antarctica, and the high percentage near 60° N is due to the vast land areas of Canada and Siberia.

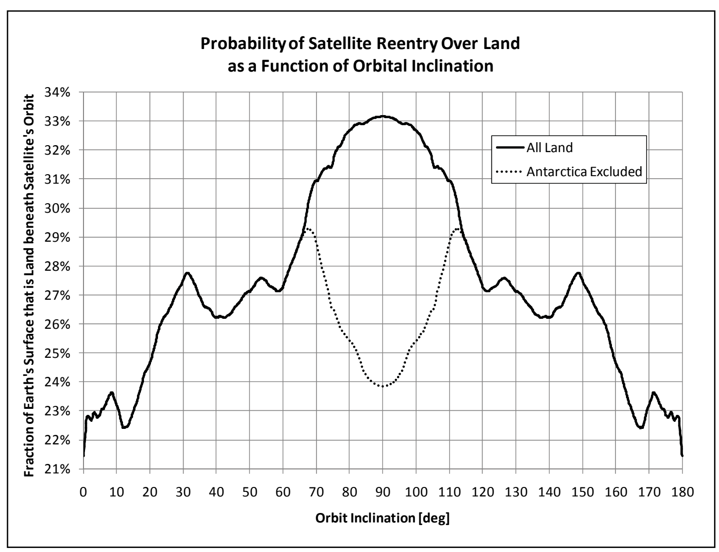

Figure 2. This chart shows the percentage of land beneath the orbit of a satellite as a function of inclination. Longitude dependence has been averaged out. The dotted line shows the same calculation with the land area of Antarctica removed, indicating that much of the enhanced land fraction at the higher inclinations is contributed from that continent. Note that despite the widely varying distribution of land over the Earth's surface, the probability of a satellite reentering over land/water is surprisingly independent of orbit inclination.

MEETING REPORTS

The 62nd International Astronautical Congress (IAC) 3-7 October 2011, Cape Town, South Africa

Space debris was a major topic at the 2011 meeting of the International Astronautical Congress (IAC), the first time this influential annual gathering of aerospace experts was held on the African continent. The longstanding Space Debris Symposium, organized by the International Academy of Astronautics (IAA), hosted a record 6 half-day sessions, including 48 oral presentations and numerous poster papers. The symposium topics covered debris detection, characterization, and measurements; modeling and risk analysis; hypervelocity impacts; mitigation and standards; and removal issues.

For the first time, many of the symposia included a keynote lecture focused on an overview of a discipline or on a special topic. The keynote lecture for the Space Debris Symposium was given by the NASA Chief Scientist for Orbital Debris and was entitled "Space Debris: A 50-Year Retrospective and a Look Forward."

A special session of the Symposium on Space Policy, Regulations, and Economics was devoted to "Assuring the Long Term Sustainability of Outer Space Activities." This topic is the subject of a recently established working group of the Scientific and Technical Subcommittee of the United Nations Committee on the Peaceful Uses of Outer Space.

In addition, the theme of the 26th Scientific-Legal Roundtable, sponsored by the IAA and the International Institute of Space Law (IISL), was "Towards Space Debris Remediation." This 3-hour-long, interdisciplinary roundtable started with five invited presentations, followed by a lively discussion among the presenters and the audience. ♦

The 5th International Association for the Advancement of Space Safety (IAASS) Conference 17-19 October 2011, Versailles-Paris, France

The 5th IAASS Conference was held 17-19 October in Versailles, France. The 3-day conference consisted of forty 2-hour sessions devoted to a number of general space safety issues including three sessions on spacecraft reentry, four sessions on space traffic, two sessions on space debris, one session on debris removal, and one panel on debris removal. Highlights included a number of papers presented by the French space agency (CNES) to discuss a newly developed suite of software to assess compliance with France's recently adopted national space safety policy, as well as a presentation discussing the safety consideration of de-orbiting the International Space Station at its scheduled end-of- life. During the conference gala dinner, recently retired NASA Associate Administrator of Safety and Mission Assurance, Bryan O'Connor, was presented with the Jerome Lederer – Space Safety Pioneer Award 2011 for his lifelong devotion to space safety. ♦

UPCOMING MEETINGS

14-22 July 2012: The 39th COSPAR Scientific Assembly, Mysore, India

The theme for the space debris sessions for the 39th COSPAR is "Steps toward Environment Control." Topics to be included during the sessions are advances in ground- and space-based surveillance and tracking, in-situ measurement techniques, debris and meteoroid environment models, debris flux and collision risk for space missions, on-orbit collision avoidance, 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 impact technologies, and on-orbit shielding concepts. Additional information of the event can be found at <http://www.cospar-assembly.org/>.

16-20 September 2012: The 2012 Hypervelocity Impact Symposium (HVIS), Baltimore, Maryland

This biennial event is organized by the Hypervelocity Impact Society to promote research and development in the high and hypervelocity impact areas. The topics to be covered in the 2012 HVIS include hypervelocity phenomenology, high-velocity launchers, spacecraft micrometeoroid and orbital debris shielding, material response and equation of state, fracture and fragmentation physics, analytical and numerical modeling, advanced and new diagnostics. Additional information of the symposium can be found at <http://hvis2012.org/>.

1-5 October 2012: The 63rd International Astronautical Congress (IAC), Naples, Italy

The theme for the 2012 IAC is "Space science and technology for the needs of all." Just like the previous IACs, a Space Debris Symposium is planned. It will address all aspects of space debris research and technology development. A total of five sessions are scheduled for the Symposium: Measurements, Modeling and Risk Analysis, Hypervelocity Impacts and Protection, Mitigation and Standards, Space Debris Removal Issues. In addition, a joint session with the Space Security Committee on "Political, Economic, and Institutional Aspects of Space Debris Mitigation and Removal" will be held to address the non-technical issues associated with future debris removal. Additional information of the 63rd IAC can be found at <http://www.iac2012.org/>.

INTERNATIONAL SPACE MISSIONS

01 October – 31 December 2011

International Designator	Payloads	Country/ Organization	Perigee Altitude (KM)	Apogee Altitude (KM)	Inclination (DEG)	Earth Orbital Rocket Bodies	Other Cataloged Debris
2011-055A	COSMOS 2474 (GLONASS)	RUSSIA	19110	19149	64.8	1	0
2011-056A	INTELSAT 18	INTELSAT	35778	35794	0.0	1	0
2011-057A	EUTELSAT W3C	EUTELSAT	35779	35796	0.2	1	0
2011-058A	MEGHA-TROPIQUES	INDIA	853	868	20.0	1	0
2011-058B	JUGNU	INDIA	839	866	20.0		
2011-058C	VESSELSAT 1	LUXEMBOURG	847	868	20.0		
2011-058D	SRMSAT	INDIA	850	868	20.0		
2011-059A	VIASAT	USA	35775	35797	0.0	1	1
2011-060A	GALILEO-PRM	ESA	23218	23227	54.7	1	0
2011-060B	GALILEO-FM2	ESA	23215	23229	54.7		
2011-061A	NPP	USA	826	828	98.7	1	0
2011-061B	DICE 1	USA	457	813	101.7		
2011-061C	DICE 2	USA	457	812	101.7		
2011-061D	RAX-2	USA	458	812	101.7		
2011-061E	AUBIESAT-1	USA	455	812	101.7		
2011-061F	M-CUBED/EXP-1 PRIME	USA	456	812	101.7		
2011-062A	PROGRESS-M 13M	RUSSIA	375	407	51.6	1	0
2011-063A	SZ-8	CHINA	333	336	42.8	1	2
2011-064A	COSMOS 2476 (GLONASS)	RUSSIA	19089	19171	64.8	1	1
2011-064B	COSMOS 2477 (GLONASS)	RUSSIA	19093	19166	64.8		
2011-064C	COSMOS 2475 (GLONASS)	RUSSIA	19023	19173	64.8		
2011-065A	PHOBOS-GRUNT	RUSSIA	180	229	88.6	1	6
2011-066A	TX 1	CHINA	475	488	97.4	1	0
2011-066B	YAOGAN 12	CHINA	485	497	97.4		
2011-067A	SOYUZ-TMA 22	RUSSIA	375	407	51.6	1	0
2011-068A	CHUANG XIN 1-03	CHINA	783	805	98.5	1	0
2011-068B	SHIYUAN 4	CHINA	783	804	98.5		
2011-069A	ASIASAT 7	ASIASAT	35784	35793	0.0	1	1
2011-070A	MSL	USA	EN ROUTE TO MARS			0	0
2011-071A	COSMOS 2478 (GLONASS)	RUSSIA	19102	19158	64.8	1	0
2011-072A	YAOGAN 13	CHINA	502	512	97.1	1	4
2011-073A	BEIDOU IGSO 5	CHINA	35708	35864	55.2	1	0
2011-074A	AMOS 5	ISRAEL	35596	36007	0.1	1	1
2011-074B	LUCH 5A	RUSSIA	35778	35794	4.9		
2011-075A	IGS 7A	JAPAN	NO ELEMS. AVAILABLE			1	0
2011-076A	ELISA W11	FRANCE	677	692	98.2	0	1
2011-076B	ELISA E23	FRANCE	676	692	98.2		
2011-076C	ELISA W23	FRANCE	678	692	98.2		
2011-076D	ELISA E12	FRANCE	675	692	98.2		
2011-076E	SSOT	CHILE	623	624	98.0		
2011-076F	PLEIADES 1	FRANCE	697	699	98.2		
2011-077A	NIGCOMSAT 1R	NIGERIA	35785	35787	0.3	1	0
2011-078A	SOYUZ-TMA 3M	RUSSIA	375	407	51.6	1	0
2011-079A	ZY 1	CHINA	774	774	98.6	1	0
2011-080A	GLOBALSTAR OBJ. A	GLOBALSTAR	920	926	52.0	0	0
2011-080B	GLOBALSTAR OBJ. B	GLOBALSTAR	919	927	52.0		
2011-080C	GLOBALSTAR OBJ. C	GLOBALSTAR	917	927	52.0		
2011-080D	GLOBALSTAR OBJ. D	GLOBALSTAR	916	926	52.0		
2011-080E	GLOBALSTAR OBJ. E	GLOBALSTAR	915	927	52.0		
2011-080F	GLOBALSTAR OBJ. F	GLOBALSTAR	919	926	52.0		

SATELLITE BOX SCORE

(as of 04 January 2012, cataloged by the U.S. SPACE SURVEILLANCE NETWORK)

Country/ Organization	Payloads	Rocket Bodies & Debris	Total
CHINA	118	3497	3615
CIS	1417	4670	6087
ESA	41	44	85
FRANCE	54	435	489
INDIA	47	129	176
JAPAN	117	72	189
USA	1158	3692	4850
OTHER	514	112	626
TOTAL	3466	12651	16117

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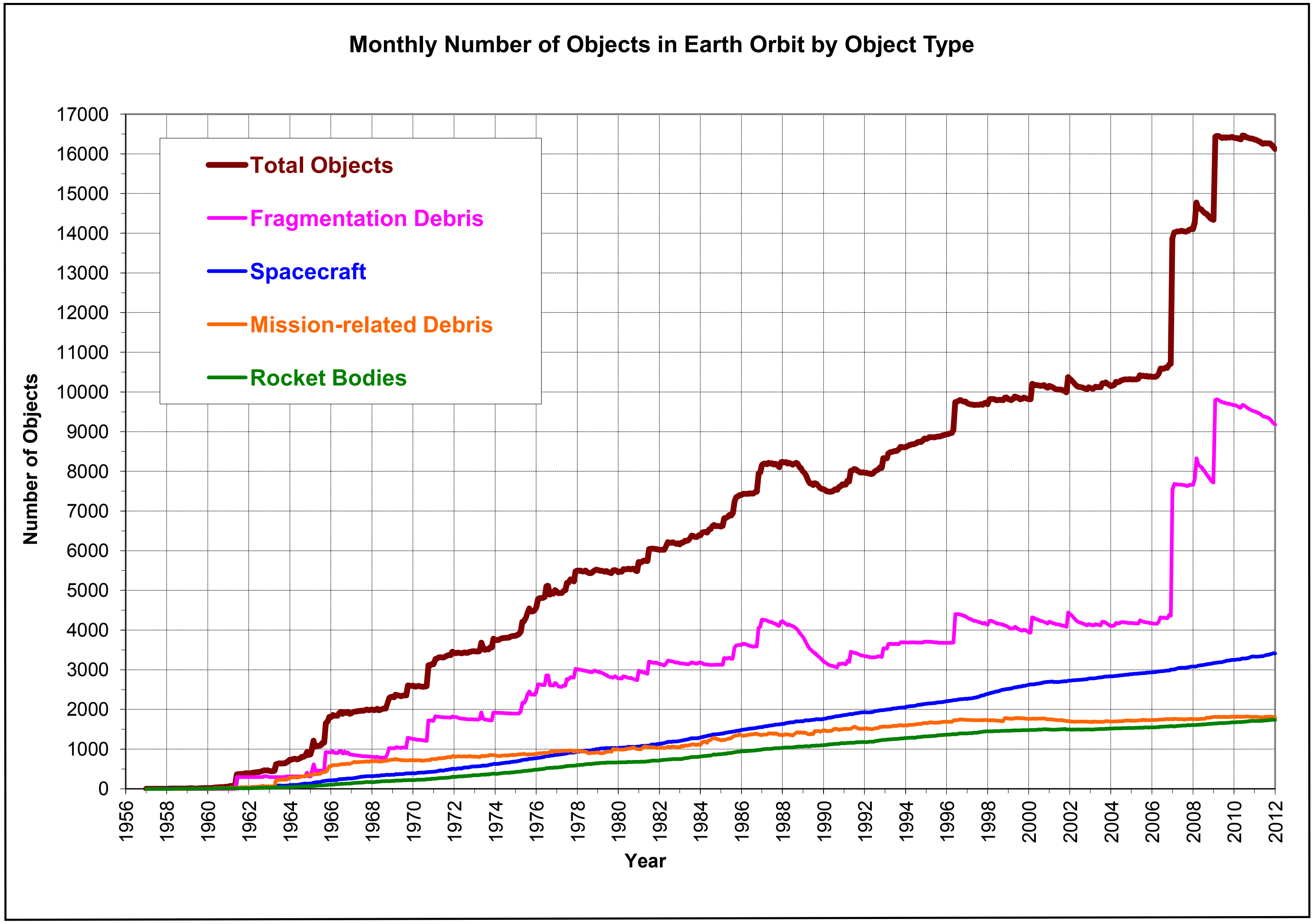

Monthly Number of Cataloged Objects in Earth Orbit by Object Type: This chart displays a summary of all objects in Earth orbit officially cataloged by the U.S. Space Surveillance Network. "Fragmentation debris" includes satellite breakup debris and anomalous event debris, while "mission-related debris"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

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