IADC-12-06

April 2013

Inter–Agency Space Debris Coordination Committee

Space Debris

IADC Assessment Report for 2011

Issued by the IADC Steering Group

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Acronyms

ADR	Active Debris Removal
ASI	Italian Space Agency
CNES	Centre National d'Etudes Spatiales (France)
CNSA	China National Space Agency
CSA	Canadian Space Agency
COPUOS	Committee on the Peaceful Uses of Outer Space, United Nations
DLR	German Aerospace Center
ESA	European Space Agency
GEO	Geosynchronous Orbit region (region near 35,786 km altitude where the orbital period of a satellite matches that of the rotation rate of the Earth)
IADC	Inter-Agency Space Debris Coordination Committee
ISRO	Indian Space Research Organization
ISS	International Space Station
JAXA	Japan Aerospace Exploration Agency
LEO	Low Earth Orbit region (orbital region below 2000 km altitude)
NASA	U.S. National Aeronautics and Space Administration
ROSCOSMOS	Russian Federal Space Agency
SSAU	State Space Agency of Ukraine
STSC	COPUOS Scientific and Technical Subcommittee
UKSA	UK Space Agency

1. Foreword

The Inter-Agency Space Debris Coordination Committee (IADC) is an international forum of space agencies for the worldwide coordination of activities related to the issues of man-made and natural debris in space.

The IADC was formally established in 1993 (1) to promote the exchange of information on space debris research activities between member space agencies, (2) to facilitate opportunities for cooperation in space debris research, (3) to review the progress of ongoing cooperative activities, and (4) to identify debris mitigation options.

As of January 2012, 12 space agencies were members of the IADC:

- ASI (Agenzia Spaziale Italiana)
- CNES (French Centre National d'Etudes Spatiales)
- CNSA (China National Space Administration)
- CSA (Canadian Space Agency)
- DLR (German Aerospace Center)
- ESA (European Space Agency)
- ISRO (Indian Space Research Organization)
- JAXA (Japan Aerospace Exploration Agency)
- NASA (U.S. National Aeronautics and Space Administration)
- ROSCOSMOS (Russian Federal Space Agency)
- SSAU (State Space Agency of Ukraine)
- UKSA (UK Space Agency)

The IADC conducts its activities through a Steering Group and four Working Groups. The specialized working groups are as follows:

- Working Group 1: Measurements
- Working Group 2: Environment and Data Base
- Working Group 3: Protection
- Working Group 4: Mitigation

The IADC Terms of Reference, public documents, and other valuable information and links can be found at the IADC internet website at www.iadc-online.org.

The purpose of this annual report is to highlight the recent events and activities related to space debris research and to provide a current assessment of the state of the Earth artificial satellite population, along with growth trends.

2. IADC Highlights

DLR hosted the 29th meeting of the IADC in Berlin, Germany, during the period 11-14 April 2011. Approximately 100 specialists from all 12 IADC members were in attendance. Following an official welcome from Dr. Gruppe, Member of the DLR Executive Board, each of the heads of delegation made opening statements.

During the opening plenary session, a special presentation by CNES highlighted the events of the 1st European Workshop on Active Debris Removal, which had been held in Paris, France, on 22 June 2010. A total of 120 specialists from 14 countries attended to discuss primarily the technical challenges of removing resident space objects from Earth orbit. Numerous demonstrator vehicle concepts were described, ranging from a 3-kg microsatellite equipped with a solar sail capable of moving 500-kg spacecraft to a much larger, more conventional vehicle capable of handling spacecraft up to 8 metric tons. A second workshop was anticipated to be held in 2012.

During 2011 two IADC Risk Object Reentry Exercises were held in conjunction with the reentry of two major spacecraft: NASA's Upper Atmosphere Research Satellite (UARS) and DLR's Röntgensatellit (ROSAT). The IADC risk object reentry communications network is tested annually by monitoring the natural reentry of a resident space object. The IADC established and first tested this information sharing network in 1998.

Figure 1. Participants at the 29th meeting of the IADC in Berlin, Germany.

Figure 2. Opening plenary session at the 29th meeting of the IADC in Berlin, Germany.

The purpose of the network is to provide a means of sharing both orbital tracking data and reentry predictions among IADC members in the event of the reentry of a satellite which might pose an elevated risk to people and property on Earth due to the mass of the object or due to the presence of specific hazardous materials, *e.g*., radioactive materials. To date, no need has arisen to activate the network for the reentry of an actual risk object.

The 2011 exercises were conducted during 13-24 September for UARS and during 10-23 October for ROSAT with a high degree of participation by IADC members. The two spacecraft reentered without incident over the Pacific and Indian Oceans, respectively. The orbital decay and reentries of the spacecraft were also followed very closely by the international press.

The Steering Group met for the second of its semi-annual meetings on 4 October 2011 in Cape Town, South Africa, in conjunction with the 2011 International Astronautical Congress. CSA graciously offered to host the 30th meeting of the IADC in Montreal, Quebec, Canada, during May 2012.

3. Space Debris Activities in the United Nations

Space debris has been an agenda item for the Scientific and Technical Sub-committee (STSC) of the United Nations Committee on the Peaceful Uses of Outer Space (COPUOS) since 1993. In 1999, after a multi-year effort, the STSC produced the first UN Technical Report on Space Debris. In 2003 the STSC began considering the preparation of a set of space debris mitigation guidelines. This activity was completed in 2007 with subsequent endorsements by the full COPUOS and by the General Assembly.

The IADC is often invited to make a special technical presentation during the annual meeting of the STSC in February of each year. Since 1998, the IADC has delivered 13 presentations at STSC meetings. Each of these presentations can be accessed at the IADC website (www.iadc-online.org).

During the 2011 meeting of the STSC, the IADC provided an overview of the scope of the IADC and its activities. Special technical presentations were also made by Member States France, the Russian Federation, and the United States, as well as by the European Space Agency, a non-governmental organization. A common theme among the presentations was the increase in the number of collision avoidance maneuvers to prevent potentially catastrophic encounters among resident space objects.

Under a new multi-year work plan, the STSC has established the Working Group on the Long-term Sustainability of Outer Space Activities with Dr. Peter Martinez of South Africa serving as the Chairman. In 2011 the Terms of Reference for the working group was adopted with an objective "to examine and propose measures to ensure the safe and sustainable use of outer space for peaceful purposes, for the benefit of all countries."

The new working group has been divided into four Expert Groups to address

(1) sustainable space utilization supporting sustainable development on Earth;

(2) space debris, space operations, and tools to support collaborative space situational awareness;

(3) space weather; and

(4) regulatory regimes and guidance for actors in the space arena.

The objective of the working group is to deliver a set of best practice guidelines for the consideration of the full subcommittee at its February 2014 meeting.

4. Earth Satellite Population

In its Space Debris Mitigation Guidelines, the IADC has defined two protected regions about the Earth (Figure 3). The first region is the low Earth orbit (LEO) protected region which extends from the lowest maintainable orbital altitude up to a height of 2,000 km above the surface of the Earth. The second region is the geosynchronous orbit (GEO) protected region, which includes the volume of space bounded in altitude by +/- 200 km of the geosynchronous altitude (35,786 km) and in inclination by +/- 15 degrees. Note that the GEO protected region represents only a portion of the entire GEO region.

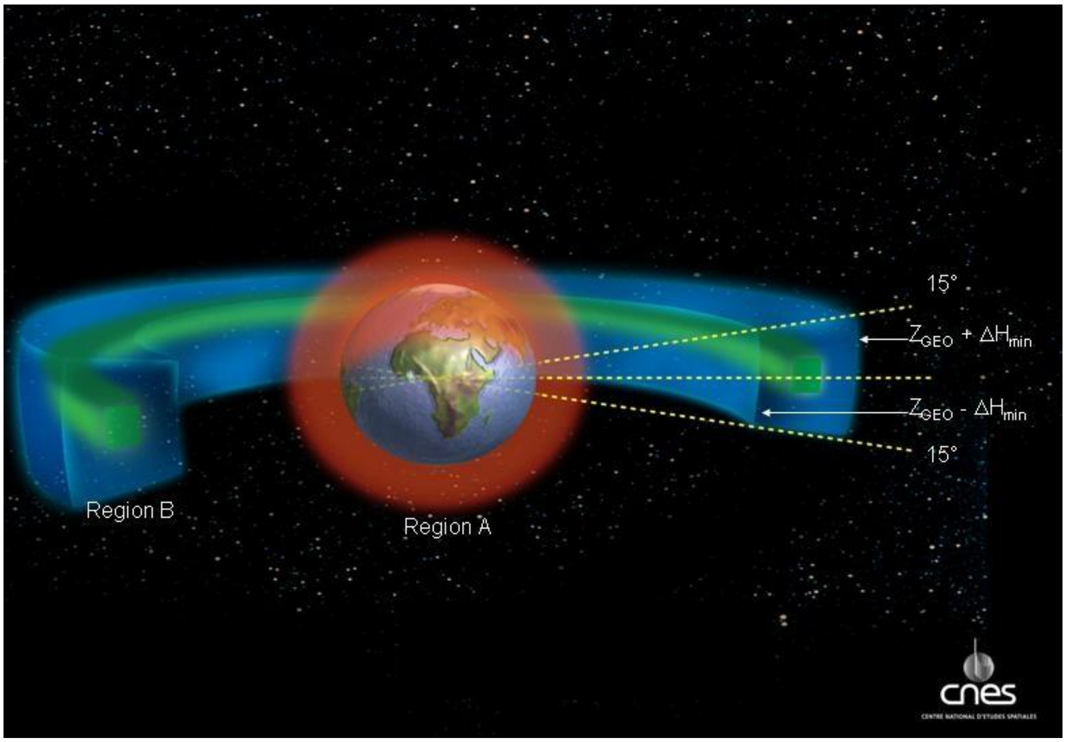

Figure 3. Protected Regions A and B, as defined by the Inter-Agency Space Debris Co-ordination Committee and adopted by the United Nations. (Source: *Support to the IADC Space Debris Mitigation Guidelines*, October 2004)

Knowledge about the population of man-made objects in orbit about the Earth is derived from three main sources as a function of object size:

1. Objects larger than ~10 cm in LEO and larger than ~1 m in GEO: These objects, which include intact spacecraft, launch vehicle stages, mission-related debris, and fragmentation and other debris, are tracked by established space surveillance systems, comprised primarily of terrestrially-based radar and electro-optical sensors, such as the U.S. Space Surveillance Network and the Russian Space Surveillance System. The majority of these objects

have been identified and officially cataloged and are monitored on a frequent basis.

2. <u>Objects between 2 mm and 10 cm in LEO and between 10 cm and 1 m in GEO</u>: These objects typically consist of mission-related or fragmentation debris and are detected by special ground-based sensors. In LEO no attempt is made to maintain discrete orbits for these objects. Instead, data on size, altitude, and inclination are used to develop statistical models of the environment. In GEO some efforts are underway to develop a catalog-like database for these objects.

3. <u>Objects smaller than 2 mm in LEO</u>: The presence of these objects can be inferred by the examination of space vehicle surfaces which have been returned to Earth, *e.g.*, solar arrays of the Hubble Space Telescope.

Figure 4 depicts the most recent assessment of the growth of the Earth satellite population at all altitudes since the launch of Sputnik 1 in 1957. Fragmentation debris has clearly been the dominant component of the population since the 1960s. The dramatic increases of fragmentation debris seen in 2007 and 2009 are due to the breakup induced by the collision of the Fengyun-1C spacecraft and the collision of the Cosmos 2251 and Iridium 33 spacecraft, respectively. Some of these debris are beginning to fall back to Earth at an accelerated rate due to the increase of solar activity as part of the Sun's natural 11-year cycle.

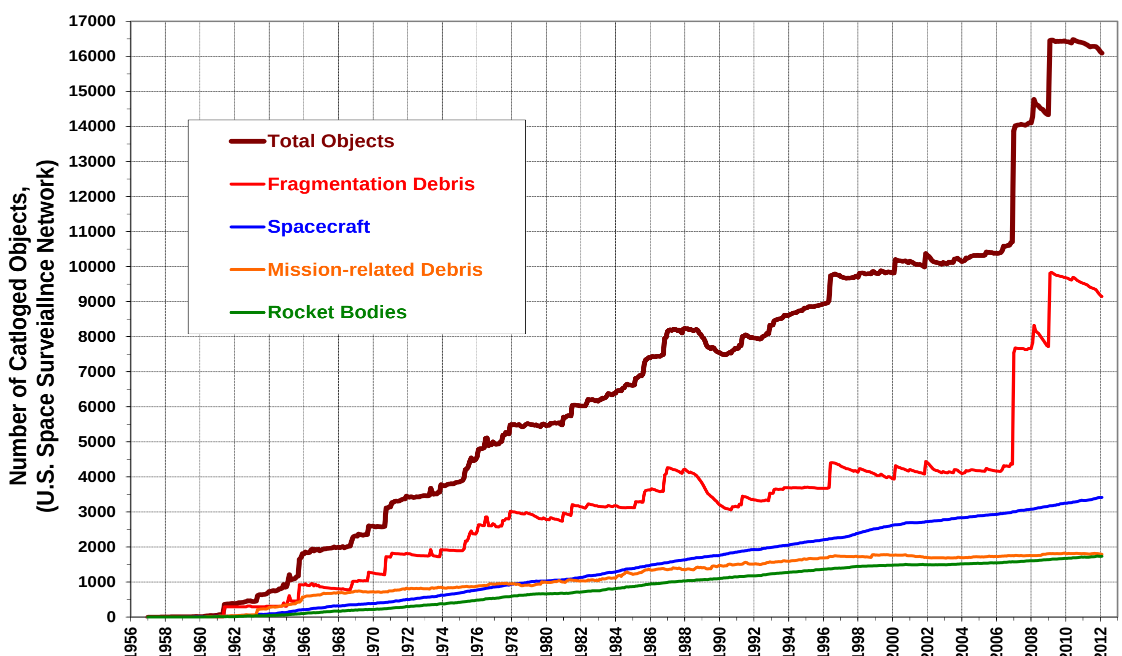

Figure 4. Growth of the cataloged population of objects in Earth orbit.

LEO is the most highly congested region in near-Earth space, containing approximately 75% of all cataloged objects (Figure 5). For objects too small to catalog, the population levels are even greater. For instance, the number of debris between 1 and 10 cm is assessed to be several hundred thousand, and the number between 1 mm and 1 cm is assessed to be in excess of 100 million.

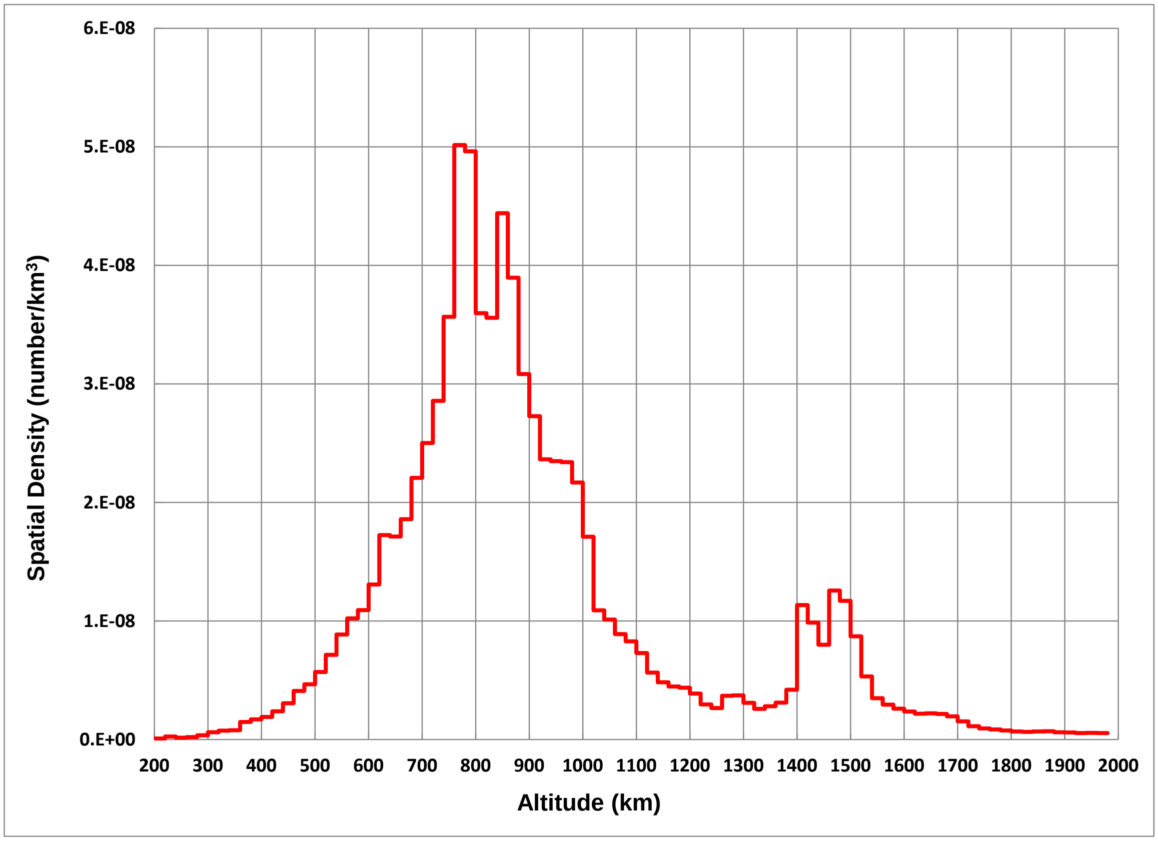

Figure 5. Spatial density of cataloged objects in low Earth orbit at the end of 2011.

The objects in the GEO region are much less numerous than in LEO and reside in about seven times the volume of LEO, but this unique regime is the home to more than 400 operational communications and other spacecraft which serve vital purposes for all countries of the world. The total number of cataloged objects in or near the GEO region is in excess of 1,100. The current number of estimated objects as small as 10 cm in or near the GEO region is on the order of 3,000. Only rough estimates are available for debris smaller than 10 cm at these high altitudes.

Another important measure of the Earth's satellite population is the total mass which is now in orbit. As Figure 6 clearly illustrates, more than six million kilograms have accumulated during the past half century. Not surprisingly, virtually all of this mass arises from intact spacecraft (functional and non-functional) and launch vehicle orbital stages.

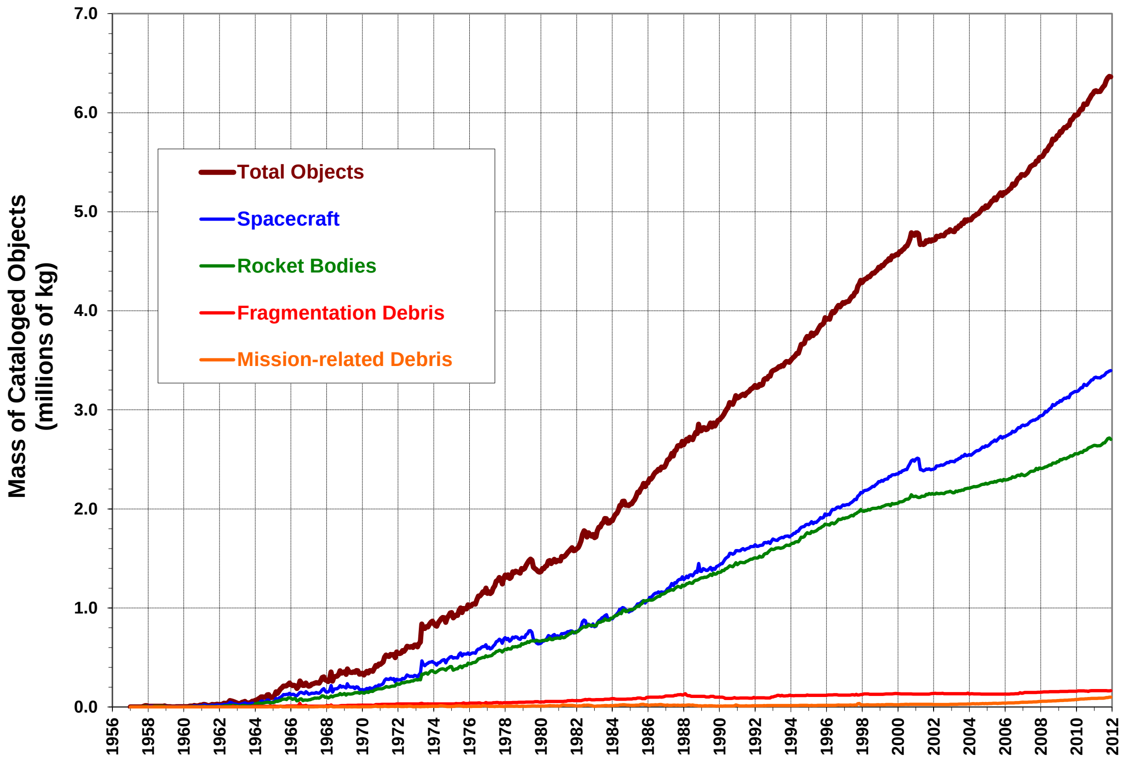

Figure 6. Growth of mass of man-made objects in Earth orbit.

5. Satellite Launches, Reentries, and Retirements

A total of 80 world-wide space launches reached Earth orbit during 2011, the most since the year 2000, but well below the annual launch rates of the 1970s and 1980s (Figure 7). Missions were successfully launched by seven countries: China, France, India, Iran, Japan, the Russian Federation, and the United States. Four attempts to reach Earth orbit (two by the Russian Federation and one each by China and the United States) were unsuccessful.

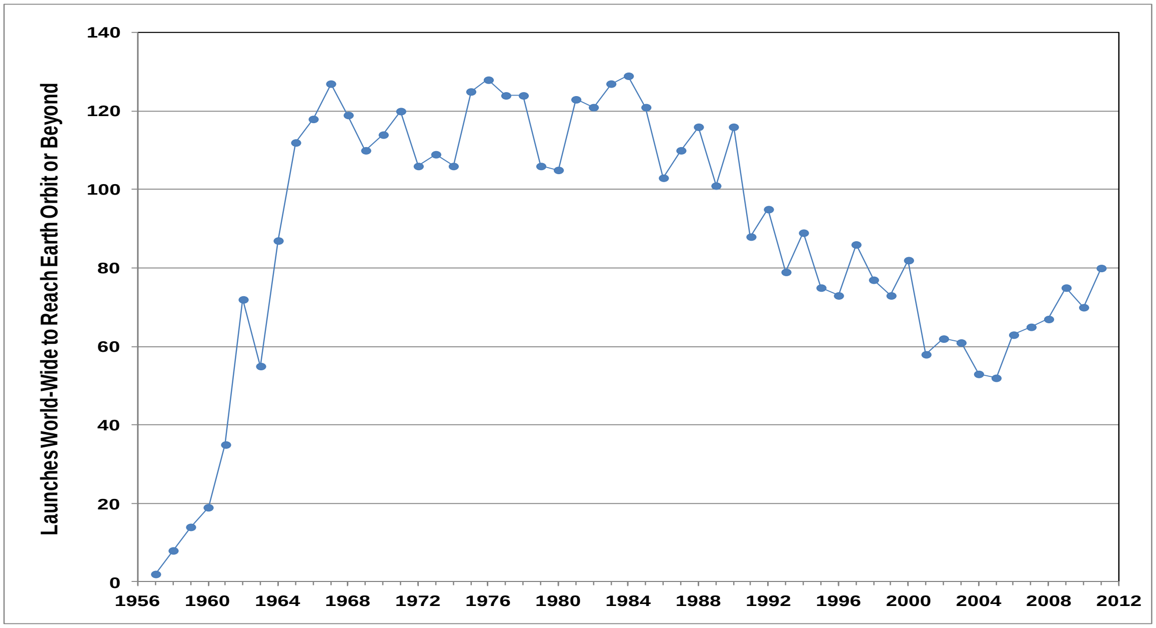

Figure 7. Annual number of space missions to Earth orbit or beyond.

The total amount of mass initially inserted into Earth orbit during 2011 was more than 400 metric tonnes, not including the empty mass of U.S. Space Shuttles. However, more than 170 metric tonnes from these new launches fell back to Earth before the end of the year in either controlled or uncontrolled reentries.

Overall, approximately 500 cataloged objects reentered during 2011, a 25% increase over 2010 due to increased solar activity. Only 25 of the reentries were conducted in a controlled fashion, sixteen of which were associated with logistical flights to the International Space Station. A record total of eight launch vehicle stages executed controlled reentries during the year. The total amount of reentering mass (excluding U.S. Space Shuttles) was approximately 245 metric tonnes, about half of which returned in an uncontrolled manner. Fortunately, no incidents of injury or significant property damage were reported.

After mission operations have been terminated, the IADC Space Debris Mitigation Guidelines specifically address the need to dispose of spacecraft and launch vehicle orbital stages in a responsible manner, especially when operating in the LEO and GEO regions. Vehicles reaching end of life in the LEO region have the options of (1) controlled reentries, (2) being left in reduced-lifetime disposal orbits, *e.g*. leading to natural, uncontrolled reentries within 25 years, (3) direct retrieval, or (4) maneuvering to a disposal orbit above 2,000 km.

In addition to the controlled reentries noted above, several LEO spacecraft were placed in lower altitude disposal orbits to reduce the amount of time they would remain in Earth orbit. One such example was the Japanese Akari scientific satellite. Launched in early 2006, the spacecraft completed its mission in late 2011 and was commanded to lower its perigee approximately 250 km, greatly shortening its stay in space (Figure 8).

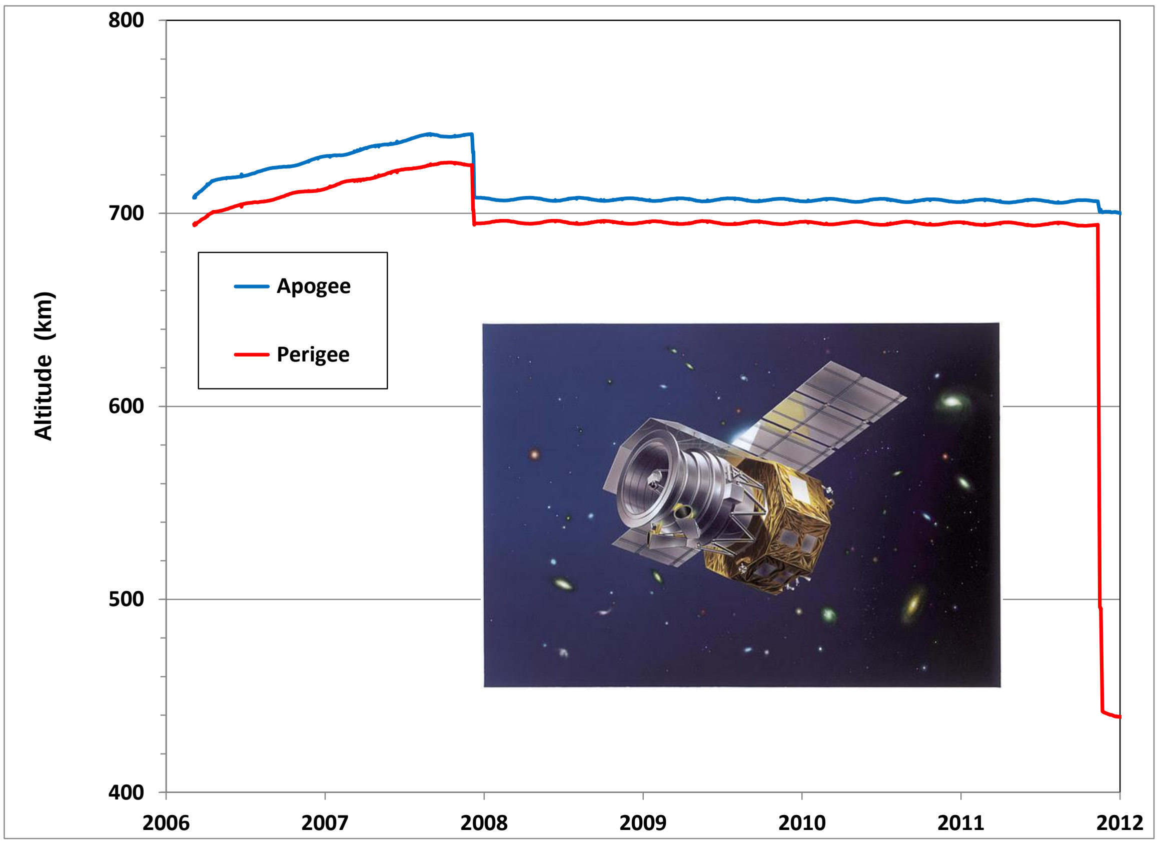

Figure 8. The Akari spacecraft lowered it perigee at end of mission to accelerate its fall back to Earth.

Similarly, ESA's ERS-2 spacecraft, which had been launched before the establishment of IADC space debris mitigation guidelines, completed a 16-year-long mission of Earth observations in 2011 at an altitude near 785 km. With its remaining propellant, the spacecraft lowered both its apogee and perigee to a mean altitude of only 570 km (Figure 9). Reentry from this new orbit is expected to occur within about 15 years.

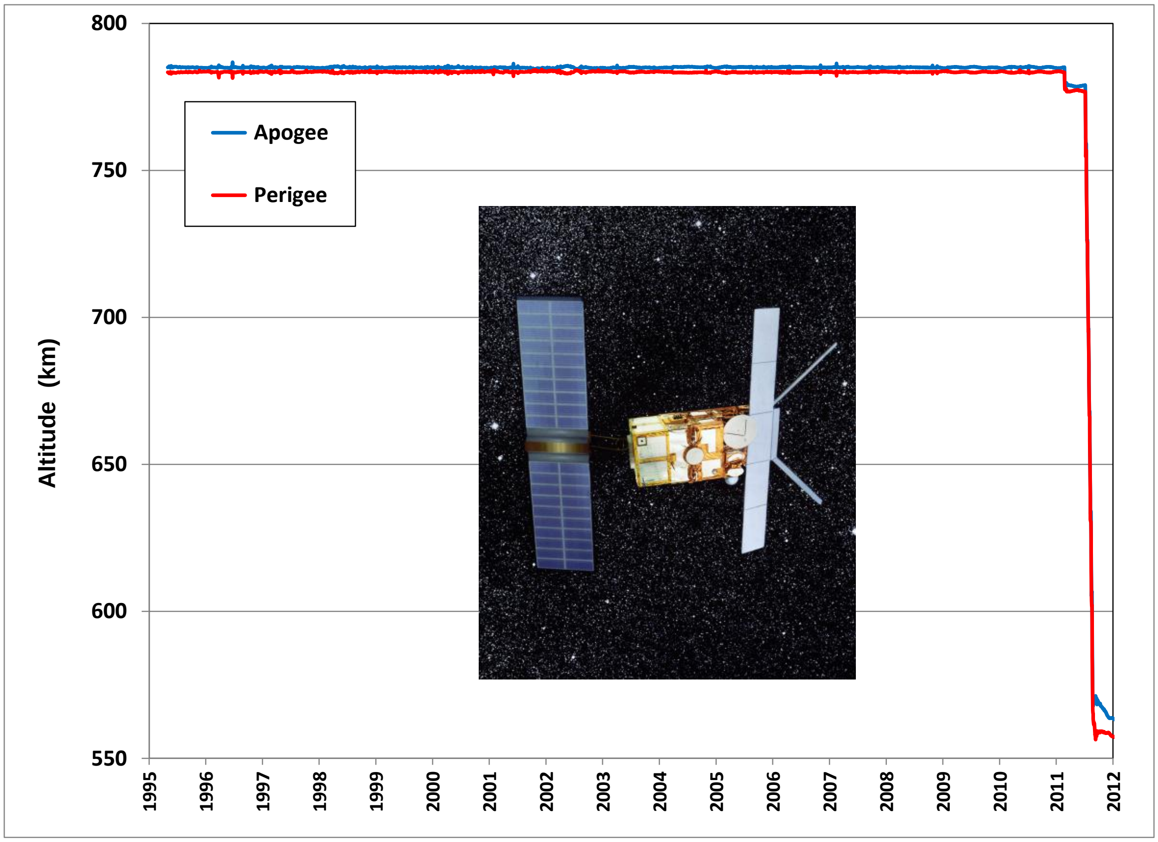

Figure 9. ESA's ERS-2 spacecraft was placed in a much shorter-lived orbit at the end of its mission in 2011.

Also in 2011, France retired two small SPIRALE satellites in highly elliptical orbits. The perigees of both spacecraft were lowered at end of mission to ensure reentry within 25 years. In February and March, CNES lowered the altitude of the DEMETER satellite in order to fulfill the 25-year criterion.

For geosynchronous satellites, reentry into the Earth's atmosphere is not a practical option. Recommendations by the IADC, the United Nations, and the International Telecommunications Union call for maneuvering non-operational geosynchronous satellites into disposal orbits, typically 300 km or more above the geosynchronous altitude. By the end of 2011, more than 325 geosynchronous satellites had been maneuvered into higher altitude disposal orbits.

Whereas 32 new geosynchronous satellites were launched in 2011 (the same number as in 2010), nearly 20 older geosynchronous spacecraft reached their end of mission. All but one of these were maneuvered into new disposal orbits. However, the disposal orbits of four of the spacecraft were insufficiently high to be compliant with international recommendations – the same number of spacecraft with inadequate disposal orbits as seen in 2010.

Table 1. GEO Satellites Retired in 2011

NAME	DISPOSAL MANEUVER	APOGEE (km above GEO)	PERIGEE (km above GEO)
BEIDOU 1	Yes	465	310
BEIDOU 1B	Yes	425	150
BS-3N	Yes	325	305
BSAT-2A	Yes	340	315
ECHOSTAR 4	Yes	410	340
ESTRELA DO SUL / TELSTAR 14	Yes	435	385
GOES 11	Yes	355	340
GORIZONT 32	Yes	70	-5
GSAT 2	Yes	140	100
HOTBIRD 3 / ABS-1B	Yes	-710	-510
INTELSAT 2 / PAS 2	Yes	355	265
INTELSAT 3R / PAS 3R	Yes	380	295
INTELSAT 601	Yes	205	175
INTELSAT 705	Yes	445	290
METEOSAT 6	Yes	385	345
RADUGA 1-7	No		
TDRS 4	Yes	560	460
USA 39	Yes	425	400
USA 158	Yes	490	325

6. Satellite Fragmentations

Since 1961 more than 300 satellite fragmentation events have been identified. They have ranged from the creation of just one new piece of debris (the collision involving the CERISE spacecraft in 1996) to the generation of thousands of debris large enough to be cataloged.

Satellite fragmentations are often categorized as breakups or anomalous events. The former is usually characterized by the destructive disassociation of an orbital spacecraft, rocket body or other structure, often with a wide range of ejecta velocities. The cause of a satellite breakup might be accidental or the result of intentional actions. In contrast, an anomalous event is the unplanned separation, usually at low velocity, of one or more detectable objects from a satellite which remains essentially intact.

Only four resident space objects were involved in satellite fragmentations not associated with reentry during 2011: three breakups of rocket stages or components and one spacecraft anomalous event. Table 2 summarizes these fragmentations, including the number of debris which had been cataloged by the end of the year and the number of debris which are believed to have been created. Overall, very few breakup debris were created during the year.

Two additional rocket bodies and one spacecraft also experienced minor fragmentations shortly prior to reentry. At the time these vehicles were in elliptical orbits with perigees near or below 100 km. These fragmentations are caused by aerodynamic forces and typically occur hours or a few days before reentry. Debris produced in such events are likewise very short-lived.

The International Space Station (ISS) is also sometimes the source of short-lived debris, either accidentally or deliberately. On average, five cataloged debris separate from the ISS annually. For example, in 2008 a tool bag was accidentally lost during a space walk, and in 2007 a large assembly of unneeded ammonia tanks was intentionally jettisoned. Over the course of four space walks during 2011, a total of seven debris separated from ISS. All had fallen back to Earth by the end of the year.

Table 2. Satellite Fragmentations in 2011

COMMON NAME	INTERNATIONAL DESIGNATOR	FRAGMENTATION DATE	PERIGEE	APOGEE	CATALOGED / ASSESSED DEBRIS	CAUSE
Proton Ullage Motor	2007-065G	8 August	540 km	18965 km	1 / No assessment	Propellants
NOAA 12	1991-032A	2 October	800 km	815 km	2 / 2	Unknown
Proton Ullage Motor	1990-045F	17 November	420 km	18620 km	1 / <20	Propellants
CZ-3B Third Stage	2011-077B	21 December	230 km	41715 km	1 / >60	Unknown

Table 3 summarizes the ten worst satellite breakups in terms of total debris cataloged. Note that at least eight of the breakups were accidental.

Table 3. Top Ten Worst Satellite Breakups

COMMON NAME	CATALOGED DEBRIS*	DEBRIS IN ORBIT*	YEAR OF BREAKUP	ALTITUDE OF BREAKUP	CAUSE OF BREAKUP
Fengyun-1C	3216	2987	2007	850 km	Collision
Cosmos 2251	1559	1371	2009	790 km	Collision with Iridium 33
STEP 2 Rocket Body	710	58	1996	625 km	Accidental Explosion
Iridium 33	567	487	2009	790 km	Collision with Cosmos 2251
Cosmos 2421	509	0	2008	410 km	Unknown
SPOT 1 Rocket Body	492	32	1986	805 km	Accidental Explosion
OV 2-1 / LCS 2 Rocket Body	473	35	1965	740 km	Accidental Explosion
Nimbus 4 Rocket Body	375	245	1970	1075 km	Accidental Explosion
TES Rocket Body	370	111	2001	670 km	Accidental Explosion
CBERS 1 Rocket Body	343	178	2000	740 km	Accidental Explosion
Total	**8614**	**5504**			

* As of March 2012. These data are based upon observations by the U.S. SSN only.

7. Collision Avoidance

The large numbers of objects in orbit about the Earth, traveling in a myriad of directions at high speed, inevitably lead to frequent close approaches, called conjunctions. On rare occasions, collisions can occur. Through the end of 2011, four known accidental high-speed collisions between cataloged space objects had occurred. The first three such collisions (in 1991, 1996, and 2005), produced only very small amounts of new debris. However, the collision of the Cosmos 2251 and the Iridium 33 spacecraft in 2009 generated more than 2,000 new large debris spread across nearly the entire LEO region. Following that event, efforts to avoid future collisions were expanded.

On average, 10-30 close approach warning messages are now transmitted daily by the U.S. Joint Space Operations Center to satellite operators around the world. During 2010 an expanded message format, called the Conjunction Summary Message (CSM), was introduced. The CSM contains detailed information on both objects involved in the conjunction, including detailed uncertainty data which can be used to calculate the probability of collision.

In the LEO region, a calculated miss distance of less than 1 km can lead to a collision avoidance maneuver; in the GEO region a miss distance of less than 5 km might also warrant a collision avoidance maneuver. Whenever possible, collision avoidance maneuvers are conducted in a manner which does not waste limited propellant resources, *e.g*., effectively becoming an unplanned station-keeping maneuver. The ISS almost always employs a collision avoidance strategy which raises its mean altitude, an action which must be undertaken several times a year to combat atmospheric drag.

During 2011, the ISS conducted two collision avoidance maneuvers (2 April and 29 September), and on a third occasion (28 June) the ISS crew had to retreat to their return spacecraft when insufficient time was allowed for maneuver preparations. More than 75 collision avoidance maneuvers were executed by robotic spacecraft in LEO and GEO during the year. For example, NASA Earth observation satellites in LEO had to perform collision avoidance maneuvers on 8 separate occasions, and a TDRS communications satellite in GEO also had to avoid being struck by a derelict spacecraft. CNES reported conducting 5 collision avoidance maneuvers during 2011. ASI reported conducting 16 collision avoidance manoeuvres during 2011 on their 4 sun-synchronous satellites for Earth observation at 620 km altitude.

8. Orbital Debris Removal

Since 2006, studies by researchers across the globe have indicated that portions of low Earth orbit have already reached the point where future accidental collisions will produce new debris faster than the debris will fall naturally from orbit, leading to an ever increasing debris population, the well-known Kessler Syndrome (Figure 10). Although concepts for the removal of derelict spacecraft and launch vehicle orbital stages have been proposed for decades, not until recently has the international community as a whole begun to give serious thought to how such operations might be accomplished.

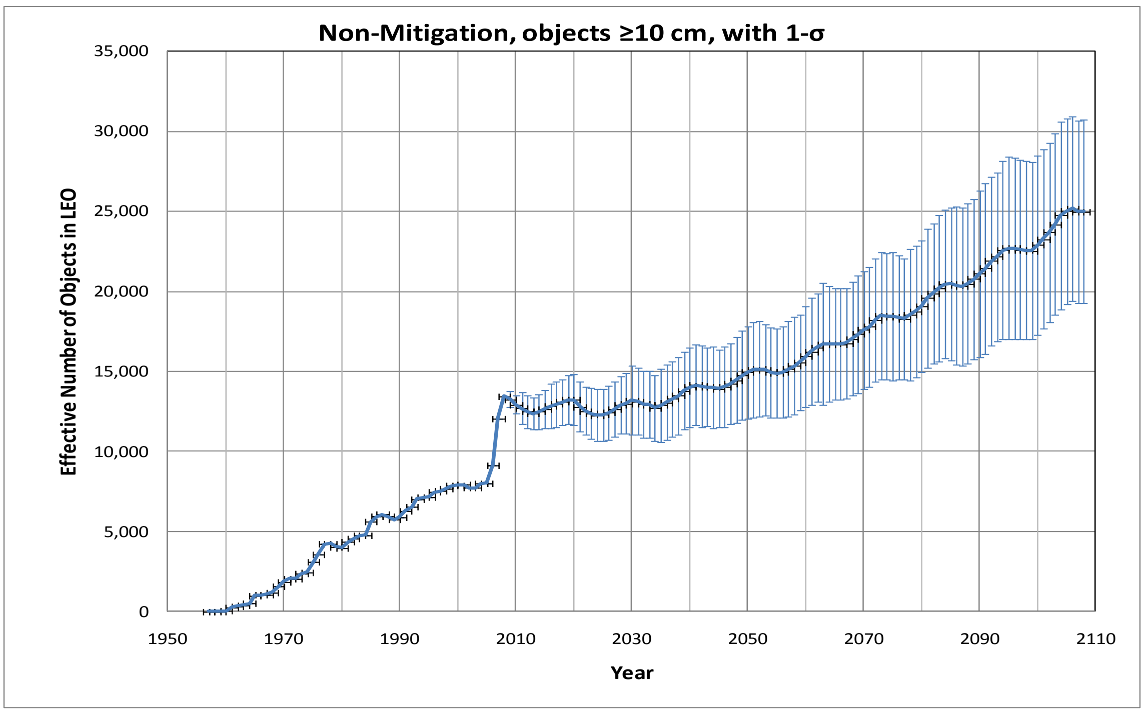

Figure 10. Projected growth of satellite population in low Earth orbit with annual space launches at recent rates and without active debris removal. The blue region indicates a 1-sigma (68%) uncertainty. (Source: NASA).

In late 2006 the International Academy of Astronautics initiated a comprehensive survey of techniques, which offered the potential of removing either small or large debris from either low or high altitude orbits. In December 2009, the first International Conference on Orbital Debris Removal was held near Washington, DC, in the United States. The momentum of this conference carried over into 2010 with the 1st European Workshop on Active Debris Removal, held 22 June in Paris, France. Other national and international meetings have also been held to discuss the feasibility of the remediation of both the LEO and GEO regions.

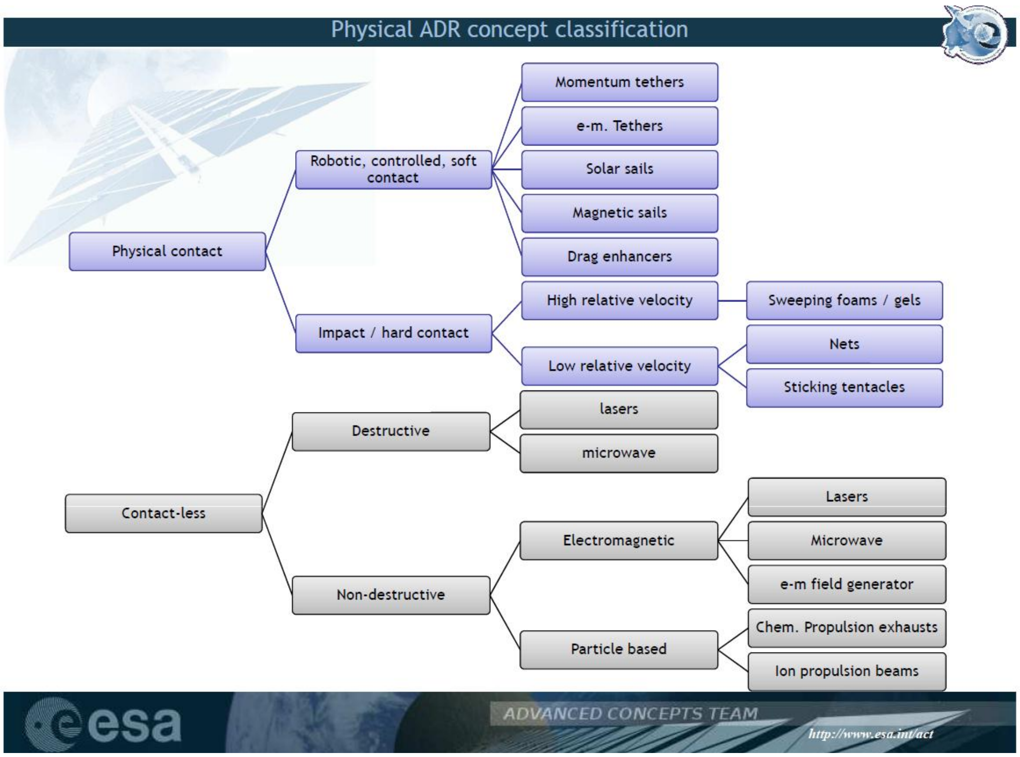

Figure 11. Hierarchy of the principal concepts for active debris removal.

A team from ESA has prepared a hierarchy of the principal active debris removal (ADR) techniques (Figure 11). It is generally agreed that in addition to the technical challenges of debris removal, many economic and legal hurdles also exist.

Several IADC member agencies are now actively working on various orbital debris removal concepts. However, routine operations to remove orbital debris will likely not occur for several years to come.

9. Major Meetings Addressing Space Debris

Many scientific and technical conferences around the world devoted special sessions to the topic of orbital debris during 2011. Hundreds of papers were delivered covering the full spectrum of space debris topics, including measurements, modeling, mitigation, protection, and removal.

Some noteworthy meetings included:

- 48th Session of the Scientific and Technical Subcommittee, Committee on the Peaceful Uses of Outer Space, United Nations, Vienna, Austria, 7-18 February. See Section 3 for details of this session.

- Space Debris Conference, Swiss Re Center for Global Dialogue, Ruschlikon, Switzerland, 24 March.

- 29th Meeting of the Inter-Agency Space Debris Coordination Committee, Berlin, Germany, 11-14 April. See Section 2 for details of this meeting.

- 54th Session of the Committee on the Peaceful Uses of Outer Space, United Nations, Vienna, Austria, 1-10 June.

- 5th International Workshop on Space Situational Awareness, Luxembourg, 28-29 June.

- 12th Advanced Maui Optical and Space Surveillance Technology (AMOS) Conference, Maui, Hawaii, USA, 13-16 September.

- 62nd International Astronautical Congress, Cape Town, South Africa, 3-7 October. This is the preeminent meeting each year for space debris specialists. The Space Debris Symposium consisted of six half-day sessions addressing the principal topics of measurements; modeling and risk analysis; hypervelocity impacts and protection; mitigation, standards, removal, and legal issues; and space situational awareness. A special scientific-legal roundtable on space debris environment remediation was also held.

- 5th International Association for the Advancement of Space Safety Conference, Versailles, Paris, France, 17-19 October.

- 3rd Space Debris Congress, McGill University, Montreal, Quebec, Canada, 11-12 November.

Appendix: Satellite Breakups, 2000-2011

Satellite Name	INTERNATIONAL DESIGNATOR	SATELLITE OWNER	LAUNCH DATE	BREAKUP DATE	APOGEE (KM)	PERIGEE (KM)	INCLINATION (DEG)	ASSESSED CAUSE
CBERS 1/SACI 1 R/B	1999-057C	CHINA	14-Oct-99	11-Mar-00	745	725	98.5	PROPULSION
GORIZONT 29 ULLAGE MOTOR	1993-072E	RF	18-Nov-93	6-Sep-00	11215	140	46.7	PROPULSION
COSMOS 2316-18 ULLAGE MOTOR	1995-037K	RF	24-Jul-95	21-Nov-00	18085	150	64.4	PROPULSION
INTELSAT 515 R/B	1989-006B	FRANCE	27-Jan-89	1-Jan-01	35720	510	8.4	PROPULSION
COSMOS 2139-41 ULLAGE MOTOR	1991-025G	RF	4-Apr-91	16-Jun-01	18960	300	64.5	PROPULSION
GORIZONT 27 ULLAGE MOTOR	1992-082F	RF	27-Nov-92	14-Jul-01	5340	145	46.5	PROPULSION
COSMOS 2367	1999-072A	RF	26-Dec-99	21-Nov-01	415	405	65.0	UNKNOWN
TES R/B	2001-049D	INDIA	22-Oct-01	19-Dec-01	675	550	97.9	PROPULSION
INTELSAT 601 R/B	1991-075B	FRANCE	29-Oct-91	24-Dec-01	28505	230	7.2	PROPULSION
INSAT 2A/EUTELSAT 2F4 R/B	1992-041C	FRANCE	9-Jul-92	Feb-02	26550	250	7.0	PROPULSION
INTELSAT 513 R/B	1988-040B	FRANCE	17-May-88	9-Jul-02	35445	535	7.0	PROPULSION
COSMOS 2109-11 ULLAGE MOTOR	1990-110G	RF	8-Dec-90	21-Feb-03	18805	645	65.4	PROPULSION
COSMOS 1883-85 ULLAGE MOTOR	1987-079H	RF	16-Sep-87	23-Apr-03	18540	755	65.2	PROPULSION
COSMOS 1970-72 ULLAGE MOTOR	1988-085F	RF	16-Sep-88	4-Aug-03	18515	720	65.3	PROPULSION
COSMOS 1987-89 ULLAGE MOTOR	1989-001H	RF	10-Jan-89	13-Nov-03	18740	710	65.4	PROPULSION
COSMOS 2399	2003-035A	RF	12-Aug-03	9-Dec-03	250	175	64.9	DELIBERATE
COSMOS 2383	2001-057A	RF	21-Dec-01	28-Feb-04	400	220	65.0	UNKNOWN
USA 73 (DMSP 5D2 F11)	1991-082A	USA	28-Nov-91	15-Apr-04	850	830	98.7	UNKNOWN
COSMOS 2204-06 ULLAGE MOTOR	1992-047G	RF	30-Jul-92	10-Jul-04	18820	415	64.9	PROPULSION
COSMOS 2392 ULLAGE MOTOR	2002-037F	RF	25-Jul-02	29-Oct-04	840	235	63.6	PROPULSION
DMSP 5B F5 R/B	1974-015B	USA	16-Mar-74	17-Jan-05	885	775	99.1	COLLISION
COSMOS 2224 ULLAGE MOTOR	1992-088F	RF	17-Dec-92	~22-Apr-05	21140	200	46.7	PROPULSION
COSMOS 2392 ULLAGE MOTOR	2002-037E	RF	25-Jul-02	1-Jun-05	835	255	63.7	PROPULSION
COSMOS 1703 R/B	1985-108B	RF	22-Nov-85	4-May-06	640	610	82.5	PROPULSION
COSMOS 2022-24 ULLAGE MOTOR	1989-039G	RF	31-May-89	10-Jun-06	18410	655	65.1	PROPULSION

Satellite Name	INTERNATIONAL DESIGNATOR	SATELLITE OWNER	LAUNCH DATE	BREAKUP DATE	APOGEE (KM)	PERIGEE (KM)	INCLINATION (DEG)	ASSESSED CAUSE
ALOS-1 R/B	2006-002B	JAPAN	24-Jan-06	8-Aug-06	700	550	98.2	UNKNOWN
COSMOS 2371 ULLAGE MOTOR	2000-036E	RF	4-Jul-00	~1-Sep-06	21320	220	46.9	PROPULSION
DMSP 5D-3 F17 R/B	2006-050B	USA	4-Nov-06	4-Nov-06	865	830	98.8	UNKNOWN
COSMOS 2423	2006-039A	RF	14-Sep-06	17-Nov-06	285	200	64.9	DELIBERATE
COBE R/B	1989-089B	USA	18-Nov-89	3-Dec-06	790	685	97.1	UNKNOWN
IGS 3A R/B	2006-037B	JAPAN	11-Sep-06	28-Dec-06	490	430	97.2	UNKNOWN
FENGYUN 1C	1999-025A	CHINA	10-May-99	11-Jan-07	865	845	98.6	COLLISION
BEIDOU 1D R/B	2007-003B	CHINA	2-Feb-07	2-Feb-07	41900	235	25.0	UNKNOWN
KUPON ULLAGE MOTOR	1997-070F	RF	12-Nov-97	14-Feb-07	14160	260	46.6	PROPULSION
CBERS 1	1999-057A	CHINA/BRAZIL	14-Oct-99	18-Feb-07	780	770	98.2	UNKNOWN
ARABSAT 4 BRIZ-M R/B	2006-006B	RF	28-Feb-06	19-Feb-07	14705	495	51.5	PROPULSION
USA 197 R/B	2007-054B	USA	11-Nov-07	11-Nov-07	1575	220	29.0	UNKNOWN
USA 193	2006-057A	USA	14-Dec-06	21-Feb-08	255	245	58.5	COLLISION
COSMOS 2421	2006-026A	RF	25-Jun-06	14-Mar-08	420	400	65.0	UNKNOWN
COSMOS 1818	1987-011A	RF	1-Feb-87	4-Jul-08	800	775	65.0	UNKNOWN
IRIDIUM 33	1997-051C	USA	14-Sep-97	10-Feb-09	780	775	86.4	COLLISION WITH COSMOS 2251
COSMOS 2251	1993-036A	RF	16-Jun-93	10-Feb-09	800	775	74.0	COLLISION WITH IRIDIUM 33
COSMOS 2139-41 ULLAGE MOTOR	1991-025F	RF	4-Apr-91	8-Mar-09	18535	465	64.9	PROPULSION
COSMOS 192	1967-116A	RF	23-Nov-67	30-Aug-09	715	710	74.0	UNKNOWN
YAOGAN 1	2006-015A	CHINA	26-Apr-06	4-Feb-10	630	625	97.9	UNKNOWN
AMC 14 BRIZ-M R/B	2008-011B	RF	14-Mar-08	13-Oct-10	26565	645	48.9	PROPULSION
BEIDOU G4 R/B	2010-057B	CHINA	1-Nov-10	1-Nov-10	35780	160	20.5	UNKNOWN
IGS 4A/4B R/B DEBRIS	2007-005E	JAPAN	24-Feb-07	23-Dec-10	440	430	97.3	UNKNOWN
COSMOS 2434-36 ULLAGE MOTOR	2007-065G	RF	25-Dec-07	18-Aug-11	18965	540	65.0	PROPULSION
COSMOS 2079-81 ULLAGE MOTOR	1990-045F	RF	19-May-90	17-Nov-11	18620	420	65.0	PROPULSION
NIGCOMSAT 1R R/B	2011-077B	CHINA	19-Dec-11	~21-Dec-11	41715	230	24.3	UNKNOWN

1. Breakup date and orbit are for the first event only if multiple events occurred.
2. Does not include satellite anomalous events or fragmentations caused by aerodynamic forces prior to reentry.
3. Russian Federation (RF) ownership includes space objects launched by the former USSR.
4. R/B = rocket body.