Space Activities in 2016

Jonathan McDowell
planet4589@gmail.com

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Preface

In this paper I present some statistics characterizing astronautical activity in calendar year 2016. In the 2014 edition of this review, I described my methodological approach and some issues of definitional ambguity; that discussion is not repeated here, and it is assumed that the reader has consulted the earlier document, available at http://planet4589.org/space/papers/space14.pdf (This paper may be found as space16.pdf at the same location).

An earlier version of this paper incorrectly included some satellites launched in 2015 and deployed in 2016 in tables 4,5 and 6.

Orbital Launch Attempts

During 2016 there were 85 orbital launch attempts. Table 1 categorizes them by launching state (the state owning the launch vehicle: therefore, Arianespace flights count as French).

Table 1: Orbital Launch Attempts

		2009-2013 Average	2014	2015	2016
USA		19.0	24	20	22
Russia		30.2	32	26	17
China		14.8	16	19	22
	France		*11*	*12*	*11*
	Japan		*4*	*4*	*4*
	India		*4*	*5*	*7*
	Israel		*1*	*0*	*1*
	N Korea		*0*	*0*	*1*
	S Korea		*0*	*0*	*0*
	Iran		*0*	*1*	*0*
Other		15.0	20	22	24
Total		79.0	92	87	85

There were two Arianespace-managed Soyuz launches from French Guiana which are counted as French. Two launches failed to reach orbit (one Chinese, one Russian).

2016 saw the first flight of China's heavy CZ-5 rocket, which, with its YZ-2 upper stage, placed the SJ-17 satellite in geostationary orbit.

Also with its first launch was the redesigned Antares vehicle, with new engines on its first stage.

Launch failures

There were two orbital launch failures during the year, tabulated below. To evaluate average launch vehicle reliability I allocate each launch a score between 0.0 (total failure) and 1.0 (success). Failures which nevertheless reach orbit get an intermediate score; the final Chinese launch of the year is in this category.

A old-model Soyuz-U launched on Dec 1 carrying a new-model Progress-MS cargo ship failed to reach orbit on Dec 1. (This contrasts with the 2015 failure involving incompatibility between a new-model Soyuz-2-1A and an old-model Progress M-M cargo ship). Initial reports suggest that the payload prematurely separated from the final stage which then collided with it twice, but an official failure report is still pending at this writing. The debris fell in the Tuva Republic.

A Chang Zheng 4C rocket failed to reach orbit on Aug 31; the third stage is rumoured to have failed. On Dec 28 a Chang Zheng 2D rocket apparently had problems during first stage burn that led to it reaching orbit with a slight underspeed of about 100 m/s, leaving its payloads in a lower than planned orbit. The primary payloads used their own propulsion to reach the target orbit but the secondary payload, a small amateur radio cubesat, is likely to have a shortened life. For statistical purposes (see http://planet4589.org/space/jsr/back/news.669) I score an off-nominal but usable orbit as a success with weight 0.75 instead of 1.0.

In addition, a SpaceX Falcon 9, with the Israeli-owned Amos 6 communications sat on top of it, was destroyed on its launch pad during a static test at 1307 UTC Sep 1. I don't count such prelaunch accidents in the statistics of launch successes and failures but it is noted here for reference. For a catalog of prelaunch on-pad explosions from 1956 to 2016, see http://planet4589.org/space/misc/pe.txt

Table 2: 2016 Orbital Launch Failures

Designation	Date	LV State	LV	Payload	Type of failure	Launch Score
2016-F01	Aug 31	China	Chang Zheng 4C	Gaofen 10	Stage 3 failure	0.00
2016-E01	Sep 1	USA	Falcon 9	Amos 6	Prelaunch test	Not counted
2016-F02	Dec 1	Russia	Soyuz-U	Progress MS-04	Payload premature separation?	0.00
2016-083	Dec 28	China	Chang Zheng 2D	Gaojing 1/2	Underperformance	0.75

Commercial Launches

Of the 85 orbital launch attempts, 46 were carried out by governments; 21 by commercial companies under contract to their host governments, and 18 for commercial customers, including foreign governments.

I count the CZ-11 launches as Chinese government launches; their payloads were mostly small unversity-developed satellites, but the management and funding appears to have been as part of government space programs.

Table 3: Commercial versus government launches

Launch provider	Launches	Type	Customers
US Launch providers			
ULA/Boeing Delta 4	4	CSP	US Gov
ULA/LM Atlas 5	8	CSP/FC	6 US Gov, 2 Comm
SpaceX Falcon 9	8	FCS/FC	3 US Gov, 5 Comm
Orbital Antares	1	FCS	1 US Gov
Orbital Pegasus	1	CSP	1 US Gov
European Launch providers			
Arianespace Vega	2	FC?	2 comm./foreign
Arianespace Ariane 5	7	FCS/FC	1 Eur gov, 6 comm/for.
Arianespace Soyuz	2	FCS	2 Eur gov
Russian Launch providers			
ILS Proton	3	FC	2 Comm, 1 foreign gov
Khrunichev Rokot	2	GOV	1 Ru.gov, 1 for.
Roskosmos Soyuz	9	GOV	9 Ru.gov (civil)
VVKO Soyuz	3	GOV	3 Ru.gov (military)
Chinese Launch providers			
CALT CZ-3A/B/C	6	GOV	5 Chinese gov,1 foreign
CALT CZ-5	1	GOV	Chinese gov
CALT CZ-7	1	GOV	Chinese gov
CALT CZ-11	1	GOV	Chinese gov
CALT CZ-2F	2	GOV	Chinese gov
SBA CZ-2D/4B/4C	11	GOV	Chinese gov
Other Launch providers			
MHI H-IIA/B	3	CSP	3 Japan gov
JAXA Epsilon	1	GOV	1 Japan gov
ISA Shaviyt	1	GOV	1 Israeli gov
ISRO/Antrix PSLV/GSLV	7	GOV	6 Indian gov
NADA Kwangmyongsong	1	GOV	1 North Korean gov

Here GOV = Government; CO = Commercial operation; CM = Commercial manufacture; CSP = Commercial service provision to government; FCS = Fully commercial service (but customers may include govt); FC = Fully commercial (no govt involved); A = Amateur, academic, non-profit. See the 2014 document for full discussion.

Satellite Launch Statistics

2013 and 2014 saw a dramatic increase in the numbers of satellites deployed, thanks to the launch of several clusters of cubesats. The 221 satellites launched in 2016 include 110 with masses above 100 kg.

Failures to reach orbit are not included here. 19 satellites launched in 2015 and deployed from ISS in 2016 are counted in the 2015 totals. 14 satellites currently aboard ISS awaiting deployment are included in the 2016 totals. The BEAM module is counted as a payload, but the IDA-2 docking fixture is not.

Table 4: Payloads launched per year

	2012	2013	2014	2015	2016
USA	35	85	110	94	94
Russia	22	29	34	27	15
China	25	17	26	43	41
Other	50	75	85	55	71
Total	132	206	255	219	221

Let us break this down by class for 2016 (first the launch powers, then other countries). In 2016 the satellites launched were owned by 27 countries and two European organizations: ESA and the European Union.

Satellite ownership by country

Table 5: 2016 payloads launched, by owner country and class

	A Academic/ NonProfit	B Business/ Commercial	C Civil	D Defense	Total Number	Total Mass (tonne)
USA	0	70	12	12	94	115
China	4	7	24	6	41	57
Japan	9	3	4	0	16	35
Russia	3	0	9	3	15	58
India	4	0	8	0	12	12
ESA/EU/EUM	0	0	10	0	10	
B Belgium	1	0	0	0	1	
D Germany	0	1	1	0	2	
DK Denmark	1	0	0	0	1	
E Spain	1	0	0	0	1	
F France	0	2	2	0	4	
I Italy	2	0	0	0	2	
UK	0	1	0	0	1	
Total Europe					22	31
AR Argentina	0	2	0	0	2	
AU Australia	0	1	0	0	1	
BR Brazil	1	1	0	0	2	
BY Belarus	0	1	0	0	1	
CA Canada	2	0	0	1	3	
DZ Algeria	0	0	3	0	3	
ID Indonesia	0	1	1	0	2	
IL Israel	0	0	0	1	1	
KP N Korea	0	0	1	0	1	
MX Mexico	0	1	0	0	1	
PE Peru	0	0	0	1	1	
PH Phillipines	0	0	1	0	1	
T Thailand	0	1	0	0	1	
TR Turkey	0	0	0	1	1	
Total Other					21	30
Total	28	92	76	25	221	338

Satellite manufacture by country

Most countries build only very small (cubesat) satellites, purchasing their larger satellites from one of the main space powers. Here I tabulate the manufacturers of 2016 satellites with masses of 100 kg or more. HSF is 'Human spaceflight', including related robotic missions such as cargo ships to support ISS. 'Surv.' is surveillance, including early warning and space debris surveillance; visible and radar imaging recon satellites and weather sats are under 'Imaging'. Microgravity research and planetary probes are included under Sci (Science). Satellites built in the UK, France, Germany, Italy, Spain and the Netherlands are lumped together as 'Europe' to reflect the integration of the western European aerospace industry.

Table 6: 2016 payloads by manufacturer country - 100 kg and up only

	HSF	Comms	Imaging	Nav	SIGINT	Surv.	Sci	Tech	Total
USA	5	19	8	1	1	2	1	0	37
China	3	3	7	3	1	0	1	8	26
Europe	0	2	7	6	0	0	4	0	19
Russia	6	0	3	2	0	0	2	0	13
India	0	1	3	3	0	0	1	0	8
Japan	1	0	1	0	0	0	2	0	4
Indonesia	0	0	1	0	0	0	0	0	1
Israel	0	0	1	0	0	0	0	0	1
N Korea	0	0	1	0	0	0	0	0	1

Scientific Space Programs

2016 saw the launch of Europe's Exomars Trace Gas Orbiter and Schiaparelli Lander towards Mars, and the NASA OSIRIS-REX asteroid sample return misison. Exomars-TGO is now in orbit around Mars, but Schiaparelli's landing attempt was not successful.

The long-awaited Hitomi (ASTRO-H) X-ray observatory was launched from Japan in February but the satellite failed while being checked out, spinning up until it broke apart. A Japanese geospace science mission, Akase, was launched in December. In November China launched an experiment to perfom navigation using natural X-ray signals from pulsars, and in December the TanSat mission which will study global carbon dioxide distribution. NASA's CYGNSS mission, consisting of eight small satellites, will study the wind speeds in the centers of hurricanes.

Military Space Activities

Military satellites include navigation, communications, and technology development missions in addition to the intelligence gathering activities that I report here.

Space surveillance

The third and fourth US GSSAP satellites were placed in secret geosynchronous orbits to carry out surveillance of objects at GEO altitudes.

Reconnaissance and Signals Intelligence

Launches of spy satellites by the major space powers appear to have been at a relatively low ebb this year. The US NRO launched the TOPAZ 4 radar spy satellite and an ORION geostationary signals intelligence satellite. Russia launched the Bars-M (Kosmos-2515) military cartographic satellite; and China launched the Yaogan 30 imaging satellite.

In contrast, there are starting to be more reconnaissance satellites from smaller countries. This year both Peru and Turkey procured the launch of European-manufactured spy satellites, and Israel launched the 11th in the Ofeq series.

Orbital Debris and Orbital Decay

At the end of 2016 there were 17027 cataloged objects in orbit and the total known mass in orbit increased to 8830 tonnes. The figures for past years given here are a bit different from last year's report, mostly because deep space objects are no longer included. I'm still working on getting that properly accounted for, so the figures may change a little again.

Table 7: Debris in orbit 2014-2016

	Debris 2014		Debris 2015		Debris 2016	
	Number	Mass (t)	Number	Mass(t)	Number	Mass(t)
Active Payloads	1301	1586	1429	1692	1551	1804
Dead Payloads	2575	3476	2591	3576	2619	3680
Rocket bodies	1859	3033	1899	3140	1933	3222
Operational debris	1678	110	1653	117	1653	121
PRC ASAT/FY-1C debris	2945	-	2880	-	2863	-
Strela/Iridium debris	1600	-	1492	-	1452	-
Other fragment debris	5068	-	5517	-	5542	-
Spurious catalog entry	1	-	1	-	1	-
Total cataloged	17189	8114	17106	8199	17427	8687

Reentries

Table 8 gives statistics on reentries in 2016, not including deliberate deorbit and landing.

Table 8: Uncontrolled Reentries 2016

	Number	Mass (t)
Active Payloads	38	1.8
Dead Payloads	15	9.1
Rocket bodies	35	95.8
Operational debris	44	2.5
PRC ASAT/FY-1C debris	17	-
Strela/Iridium debris	40	-
Other fragment debris	41	-

Controlled deorbits and landings

In addition to natural reentries, there were 9 controlled landings and 7 controlled deorbitings of spacecraft during 2016, representing the safe removal of around 140 tonnes from the orbital environment. 4 Russian Soyuz ships landed in Kazakhstan. and two Dragon spacecraft splashed down in the Pacific near California. Three Chinese spacecraft were also recovered: Shenzhou 11, Shi Jian 10 and the DFFC experimental spacecraft.

Six ISS cargo ships (three Cygnus and three Progress) were deorbited over the South Pacific east of New Zealand. One Chinese YZ-1A stage was deorbited over the Pacific after several days of orbital tests.

Twelve objects reentered and burned up on controlled trajectories associated with landings of spacecraft (Soyuz orbital and propulsion modules, Dragon trunks, Shenzhou propulsion module.)

In addition, 16 rocket stages were deorbited after only one or two Earth orbits (two Centaur, two Delta 4, 3 Falcon 9, 2 Vega AVM, Japanese H2, two Chinese CZ-2D, two Soyuz, a Volga and a Fregat). Only three of these were assigned catalog numbers. A further 16 rocket stages were inserted into slightly suborbital trajectories that ensured controlled disposal without the need for a deorbit burn (Ariane EPC, Vega Z9A, Proton stage 3, PSLV stage 3, some Soyuz-2 stage 3).

Table 9: Most massive reentries, 2016

COSPAR	Spacecraft	Date	Mass/kg	Location	Coords	Type
2015-074C	Zenit 2SB80.4	2016 Jan 1 2335	9300	Vietnam	99E 15 N	Reentry
2016-042E	CZ-7 Y1	2016 Jul 28 0440	6000	Utah		Reentry
2016-057B	CZ-2F T2	2016 Sep 29 1900?	5500	Pacific		Reentry
2016-061B	CZ-2F Y11	2016 Nov 3 2254	5500	Sudan	27E 13N	Reentry
2009-035B	Ariane ESC-A 547	2016 Oct 31 1511	5000?	Indian Ocean	76E 6S	Reentry
Landings and deorbits, 2016						
2016-023A	Shi Jian 10 RV	2016 Apr 18 0830	850?	Siziwan, China		Landing
2016-042	Duoyongtu feichuan fanhui cang	2016 Jun 26 0741	2600	China		Landing
2016-061A	Shenzhou 11	2016 Nov 18 0559	3240	China	112 42E 42 20N	Landing
2015-043A	Soyuz TMA-18M	2016 Mar 2 0425	2910	Kazakhstan	47 21N 69 42E	Landing
2015-076A	Soyuz TMA-19M	2016 Mar 2 0425	2910	Kazakhstan	47 21N 69 42E	Landing
2016-018A	Soyuz TMA-20M	2016 Sep 7 0113	2885	Kazakhstan	47 18N 69 38E	Landing
2016-044A	Soyuz MS-01	2016 Oct 30 0358	2885	Kazakhstan		Landing
2016-024A	Dragon CRS-8	2016 May 11 1851	5600?	Pacific	120.2W 31.45N	Landing
2016-046A	Dragon CRS-9	2016 Aug 26 1547	4522?	Pacific	120.7W 27.5N?	Landing
2015-055A	Progress M-29M	2016 Apr 8 1416?	5500?	S Pacific	139 46W 42 28S	Deorbited
2015-080A	Progress MS-01	2016 Jul 3 0750	5500?	S Pacific	128 33W 49 36S	Deorbited
2016-022A	Progress MS-02	2016 Oct 14 1339	5500?	S Pacific		Deorbited
2015-072A	Cygnus OA-4	2016 Feb 20 1553	7300?	S Pacific		Deorbited
2016-019A	Cygnus OA-6	2016 Jun 22 1329	5300?	S Pacific		Deorbited
2016-062A	Cygnus OA-5	2016 Nov 27 2336	5000?	S Pacific		Deorbited
2016-029B	CZ-2D Stage 2	2016 May 15 0320?	4000?	Antarctic?		Deorbited
2016-051D	CZ-2D Stage 2	2016 Aug 15 1820?	4000?	Antarctic?		Deorbited
2016-010B	Delta 359	2016 Feb 10 1402	3450?	S Ocean	118E 53S	Deorbited
2016-075B	Delta 376	2016 Dec 8 1100?	3450?	Philippine Sea?		Deorbited
2016-076	H-2B-F6	2016 Dec 9 1540?	3400?	S Pacific	115W 48S?	Deorbited
2016-019	Centaur AV-064	2016 Mar 23 0400?	2020?	S Ocean		Deorbited
2016-047	Centaur AV-065	2016 Jul 28 2106?	2020?	Pacific	160W 12N?	Deorbited
2016-058	Vega VV07 AVUM	2016 Sep 16 0409?	660?	Indian Ocean		Deorbited
2016-073B	Vega VV08 AVUM	2016 Dec 5 1630?	660?	S Ocean		Deorbited
2016-002	Falcon 9-019 Stage 2	2016 Jan 17 2030?	3000?	N Pacific		Deorbited
2016-024	Falcon 9-023 Stage 2	2016 Apr 8 2145?	3000?	S Ocean	124E 48S?	Deorbited
2016-046	Falcon 9-027 Stage 2	2016 Jul 18 0545?	3000?	S Ocean		Deorbited
2016-026E	Volga No. 6	2016 Apr 28 0900?	1120	Pacific		Deorbited
2016-025	Fregat 133-08	2016 Apr 26 0132?	1000	S Atlantic		Deorbited
2016-042A	YZ-1A	2016 Jun 27	2100?	Pacific		Deorbited

Retirements in the GEO belt

During 2016 14 satellites were retired to the graveyard above the GEO: EUTELSAT 115 West A (Satmex 5), EUTELSAT 70D (HotBird 6), Ekspress AM-2, Intelsat IS-7, GOES 3, XM Radio 1, Inmarsat 3 F4, Telstar 7, Insat 3A, NATO 4B, DSP 16, Turksat 2A, Palapa C2, and Intelsat 702.

The YZ-2 upper stage that delivered China's SJ-17 satellite is in an elliptical orbit whose perigee passes through the GEO belt.

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