GPS CONSTELLATION

SVN	PRN	CLOCK	LAUNCHED	USABLE	PLANE/SLOT	NOTES
TYPE: Block IIA						
34	18	Rb	10-26-93	3-20-18	D6	A
TYPE: Block IIR						
43	13	Rb	7-23-97	1-31-98	F6	
46	11	Rb	10-7-99	1-3-00	D2-F	
51	20	Rb	5-11-00	6-1-00	E4	B
44	28	Rb	7-16-00	8-17-00	B3	
41	14	Rb	11-10-00	12-10-00	F2-F	
54	18		1-30-01	2-15-01		C
56	16	Rb	1-29-03	2-18-03	B1-A	
45	21	Rb	3-31-03	4-12-03	D3	
47	22	Rb	12-21-03	1-12-04	E6	
59	19	Rb	3-20-04	4-5-04	C5	
60	23	Rb	6-23-04	7-9-04	F4	
61	02	Rb	11-6-04	11-22-04	D1	
TYPE: Block IIR-M						
53	17	Rb	9-26-05	12-16-05	C4	
52	31	Rb	9-25-06	10-12-06	A2	
58	12	Rb	11-17-06	12-13-06	B4	
55	15	Rb	10-17-07	10-31-07	F2-A	
57	29	Rb	12-20-07	1-2-08	C1	
48	07	Rb	3-15-08	3-24-08	A4	
50	05	Rb	8-17-09	8-27-09	E3	
TYPE: Block IIF						
62	25	Rb	5-28-10	8-27-10	B2	
63	01	Rb	7-16-11	10-14-11	D2-A	
65	24	Cs	10-4-12	11-14-12	A1	
66	27	Rb	5-15-13	6-21-13	C2	
64	30	Rb	2-21-14	5-30-14	A3	
67	06	Rb	5-17-14	6-10-14	D4	
68	09	Rb	8-2-14	9-17-14	F3	
69	03	Rb	10-29-14	12-12-14	E1	
71	26	Rb	3-25-15	4-20-15	B1-F	
72	08	Cs	7-15-15	8-12-15	C3	
73	10	Rb	10-31-15	12-9-15	E2	
70	32	Rb	2-5-16	3-9-16	F1	

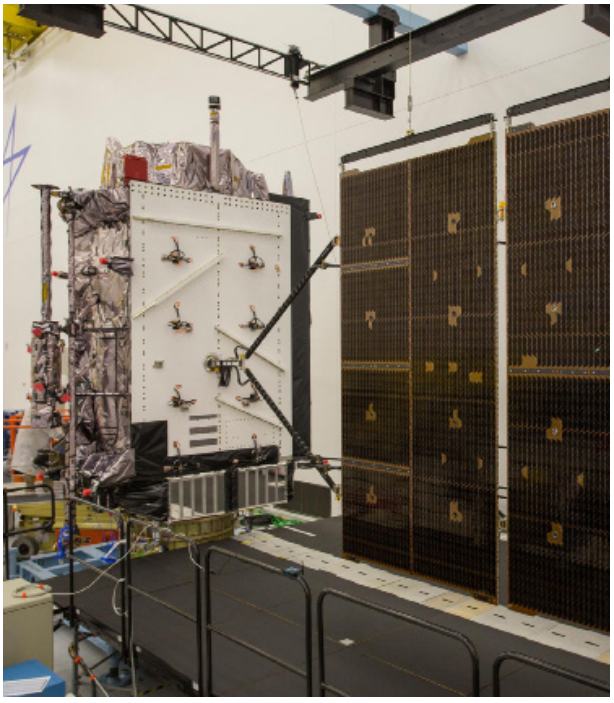
ABOUT THESE TABLES

- *GPS World* believes this information to be correct as of press time. However, because of the evolving nature of satellite constellations, readers should refer to the online version of this Almanac for more current data.
- Dr. Richard Langley of the University of New Brunswick provided the satellite status information and compiled the notes.
- For supplemental notes on the constellations, additional satellite and system information and other GNSS resources, see the online GNSS Almanac at gpsworld.com/the-almanac/.

For more information, see the online GNSS Almanac at gpsworld.com/the-almanac/.

GPS SATELLITE & SYSTEM INFORMATION

- GPS.gov
- National Executive Committee for Space-Based Positioning, Navigation & Timing: www.gps.gov/governance/excom/
- DoD GPS Operations Center and 2SOPS Constellation Status (military only): https://gps.afspc.af.mil/gpsoc/; https://gps.afspc.af.mil/gps/
- U.S. Coast Guard Navigation Center Navigation Information Service (NIS): www.navcen.uscg.gov



LOCKHEED MARTIN'S **GPS III SV03, shown with its solar panels. (Photo: Lockheed Martin)**

GPS NOTES

1. "SV Number" refers to space vehicle number. "PRN Number" refers to the satellite's unique pseudorandom noise code.
2. Clock: Rb = rubidium; Cs = cesium.
3. "Launched" and "Usable" dates are based on Universal Time.
4. The current active GPS constellation consists of 1 Block IIA, 11 Block IIRs, 7 Block IIR-Ms and 12 Block IIFs for a total of 31 satellites and is under FOC (Full Operational Capability). The constellation is in the 24+3 (or "Expandable 24") configuration with satellites occupying the fore and aft bifuracted slots in the B, D and F planes. There are currently 2 reserve satellites, SVNs, 36 and 38, and one test satellite, 49, near slots, C2, A2 and B1-F, respectively. SVN36 transmitted L-band signals as PRN04 between July 20 and Nov. 28, 2017. SVN38 transmitted L-band signals as PRN04 between May 19 and July 14, 2017. SVN49 transmitted L-band signals as PRN04 again starting Dec. 1, 2017. For these test transmissions, the satellites are not set healthy and not included in broadcast almanacs.
5. The Block IIF-1 through IIF-12 satellites have nicknames Polaris, Sirius, Arcturus, Vega, Canopus, Rigel, Capella, Spica, Deneb, Antares, Altair and Betelgeuse respectively.
6. SVN35 and 36 carry onboard corner-cube reflectors for satellite laser ranging (SLR). SLR tracking of the satellites permitted analysts to differentiate between onboard clock errors and satellite ephemeris errors in GPS tracking.
7. Selective availability (SA) was set to zero on all satellites by presidential order on May 2, 2000 at approximately 4:00 UT. Previous Almanacs provide a history of SA status.
8. Antispoofing (AS) was activated on Jan. 31, 1994, on all Block IIs. AS is occasionally off for testing and other purposes. Previous Almanacs provide a history of AS status.
9. The design life and mean-mission duration goals of the Block IIA, IIR, and IIF satellites are 7.5 and 6 years, 10 and 7.5 years, and 12 and 9.9 years, respectively.
10. The launch of the first Block III (GPS III) satellite is expected no earlier than October 2018.

PERFORMANCE NOTES

A. SVN34, previously a reserve satellite, was reactivated to replace SVN54. It started to transmit L-band signals as PRN18 on March 8, 2018, and was set usable on March 20, 2018.

B. SVN51/PRN20's slot designation has been changed from E7 to E4 in GPSOC daily Operational Advisories and on the NavCen website coinciding with the decommissioning of SVN54.

C. SVN54/PRN18 was set unusable on Jan. 23, 2018, and decommissioned from the active constellation on March 5, 2018.

GLONASS CONSTELLATION

GLONASS NUMBER	KOSMOS NUMBER	LAUNCHED	USABLE	ALMANAC/ SLOT	CHANNEL	ORBIT PLANE	NOTES
102 (716)	2425	12-25-06	10-12-07	15	0	2	
103 (717)	2426	12-25-06	4-3-07	10	-7	2	
105 (719)	2432	10-26-07	11-27-07	20	2	3	
106 (720)	2433	10-26-07	11-25-07	19	3	3	
107 (721)	2434	12-25-07	2-8-08	13	-2	2	
109 (723)	2436	12-25-07	1-22-08	12	-1	2	A
116 (730)	2456	12-14-09	1-30-10	1	1	1	
117 (733)	2457	12-14-09	1-24-10	6	-4	1	B
118 (734)	2458	12-14-09	1-10-10	5	1	1	
119 (731)	2459	3-1-10	3-28-10	22	-3	3	
120 (732)	2460	3-1-10	3-28-10	23	3	3	
121 (735)	2461	3-1-10	3-28-10	24	2	3	
122 (736)	2464	9-2-10	10-4-10	16	-1	2	
125 (701)	2471	2-26-11		(20)	-5	3	C
126 (742)	2474	10-2-11	10-25-11	4	6	1	
127 (743)	2475	11-4-11	3-5-13	8	6	1	
128 (744)	2476	11-4-11	12-8-11	3	5	1	
129 (745)	2477	11-4-11	12-23-11	7	5	1	
131 (747)	2485	4-26-13	7-4-13	2	-4	1	
132 (754)	2492	3-24-14	4-13-14	18	-3	3	
133 (755)	2500	6-14-14	8-3-14	21	4	3	
134 (702)	2501	11-30-14	2-15-16	9	-2	2	
135 (751)	2514	2-7-16	2-28-16	17	4	3	
136 (753)	2516	5-19-16	6-27-16	11	0	2	
137 (752)	2522	9-22-17	10-16-17	14	-7	2	
138 (756)	2527	6-7-18				1	D

GLONASS-M satellite 138 is rolled out for launch. (Photo: Russian Ministry of Defense)

GLONASS NOTES

1. The first GLONASS satellite was launched Oct. 12, 1982.
2. The GLONASS numbering scheme used in this table includes the eight "dummy" satellites orbited as ballast along with "real" satellites on the first seven GLONASS launches. The second number (in parentheses) in the "GLONASS Number" column is that assigned by the Russian Space Forces.
3. The Russian Federation designated the "Kosmos Number."
4. GLONASS numbers 1–101 have been withdrawn from service.
5. All operational satellites are GLONASS-M satellites, except GLONASS 125 and 134, which are GLONASS-K1 satellites. GLONASS 133 includes an L3 transmitter.
6. All launch and usable dates are based on Moscow Time (Universal Time + 3 hours).
7. Almanac/slot numbers in parentheses indicate the physical orbital slot of reserve/test satellites or those in maintenance and not in the almanac.
8. Channel number "k" indicates L1 and L2 carrier frequencies: L1 = 1,602 + 0.5625 k (MHz); L2 = 1,246 + 0.4375 k (MHz).
9. All GLONASS satellites use cesium atomic clocks.
10. Twenty-four GLONASS satellites are currently set healthy.
11. New GLONASS channel allocations were introduced September 1993 to reduce interference to radio astronomy. Note the use of the same channel on pairs of antipodal satellites.
12. GPS World believes this information to be correct as of press time. However, because of the satellite constellation's evolving nature, we encourage readers to contact the GLONASS sources listed on these pages for more current information.

GLONASS SYSTEM INFORMATION

The Information and Analysis Center for Positioning, Navigation and Timing (IAC PNT) of the Russian Space Agency publishes official information about GLONASS status and plans as well as consultation, information and scientific-method services to increase GLONASS applications efficiency. It provides current constellations, Earth maps of the current and daily navigation availabilities, results of GNSS navigation field monitoring in the Moscow area in a real-time mode, and other data.

For more information: IAC PNT Center, Central Research Institute for Machine Building, Federal State Unitary Enterprise, www.glonass-iac.ru/en/, email: ianc@glonass-iac.ru

PERFORMANCE NOTES

A. L2 transmissions appear to be impaired.

B. L2 transmissions appear to be impaired.

C. GLONASS 125, the first GLONASS-K1 satellite, is currently in flight test mode near physical orbital slot 20. When not in the active constellation, the satellite typically identifies itself as satellite 26 in its broadcast ephemeris.

D. GLONASS 138 was launched into Plane 1 on June 7, 2018, from the Plesetsk Cosmodrome and is drifting to its intended orbital slot.

GNSS INTERNET RESOURCES

See more at gpsworld.com/the-almanac/

UNITED STATES AND CANADA

Canadian Space Geodesy Forum
www2.unb.ca/gge/Resources/CANSPACE.html
This University of New Brunswick service presents daily GPS constellation status reports, ionospheric disturbance warnings, and news and discussion about GPS and other space-based positioning systems by way of electronic mail. Downloadable files are also available. To subscribe, email the one-line message [sub CANSPACE your_name] to listserv@UNB.CA. For more information: Terry Arsenault or Richard Langley, phone (506) 453-4698, fax (506) 453-4943, email se@unb.ca.

GPS.gov
The U.S. government provides the GPS.gov website to educate the public about the Global Positioning System and related topics. Information includes content for the general public, Congress, international citizens, professionals and students. The site is maintained by the National Coordination Office for Space-Based Positioning, Navigation, and Timing in coordination with multiple federal agencies.

DoD GPS Operations Center (military only)
https://gps.afspc.af.mil/gpsoc/

2SOPS Constellation Status (military only)
https://gps.afspc.af.mil/gps/
The U.S. Department of Defense (DoD) GPS Operations Center and the 2nd Space Operations Squadron (2SOPS), U.S. Air Force, maintain Internet sites for military and DoD users. The GPS Operations Center provides DOP predictions, GPS performance assessments, anomaly impact analysis, GPS FAQs, and other services to meet the needs of GPS users in the field. 2SOPS operates a GPS Constellation Status site with scheduled outages, user advisories, almanac data, electronic mail,and downloadable files. Military: Contact GPS Operations Center at DSN 560-2541 or Commercial (719) 567-2541.

National Executive Committee (EXCOM) for Space-Based Positioning, Navigation & Timing (PNT)
www.gps.gov/governance/excom/
The EXCOM advises U.S. government leadership and coordinates with federal agencies about policy matters concerning GPS. The deputy secretaries of Defense and Transportation jointly chair the EXCOM. Membership includes officials from NASA, the departments of State, Commerce, Homeland Security, Agriculture, Interior, and the Joint Chiefs of Staff. The National Space-Based PNT Advisory Board operates in an independent advisory capacity for the EXCOM. email pnt.office@gps.gov.

National Geospatial-Intelligence Agency (NGA)
Precise GPS Orbit Information and Earth Orientation Parameter Predictions (EOPP): http://earth-info.nga.mil/GandG/sathtml/
The NGA Global Positioning System Division/Ephemeris Support and Analysis Team maintains a website for Department of Defense and civilian users with precise GPS orbit and clock information based on tracking data collected from NGA, U.S. Air Force and IGS stations. Daily and weekly precise ephemeris and clock estimate data, both center-of-mass (pedata) and antenna phase center (apcpe) are calculated on a 15-minute interval. email: gps@nga.mil.

Natural Resources Canada, Canadian Spatial Reference System
www.nrcan.gc.ca/earth-sciences/geomatics/geodetic-reference-systems/9052
Canadian Geodetic Survey operates the Canadian Active Control System (CACS), a national network of continuously operating GNSS tracking stations. Products derived from CACS include GNSS observation data, precise GNSS orbits and precise GNSS clock corrections. (343) 292-6617; email nrcan.geodeticinformationservices.rncan@canada.ca.

Continued on page 46 >>

BEIDOU CONSTELLATION

SATELLITE	NORAD ID	PRN	LAUNCHED	ORBIT	NOTES
TYPE: BeiDou-2					
BeiDou M1	31115	C30	4-13-07	MEO period 12.89 hours	A
BeiDou G2	34779	N/A	4-14-09	GEO drifting	B
BeiDou G1	36287	C01	1-16-10	GEO 140° E	C
BeiDou G3	36590	C03	6-2-10	GEO 110.5° E	D
BeiDou IGSO1	36828	C06	7-31-10	IGSO 118° E, 55° incl.	
BeiDou G4	37210	C04	10-31-10	GEO 160° E	
BeiDou IGSO2	37256	C07	12-17-10	IGSO 118° E, 55° incl.	
BeiDou IGSO3	37384	C08	4-9-11	IGSO 118° E, 55° incl.	
BeiDou IGSO4	37763	C09	7-26-11	IGSO 95° E, 55° incl.	
BeiDou IGSO5	37948	C10	12-1-11	IGSO 95° E, 55° incl.	
BeiDou G5	38091	C05	2-24-12	GEO 58.75° E	
BeiDou M3	38250	C11	4-29-12	MEO slot 1-7	E
BeiDou M4	38251	C12	4-29-12	MEO slot 1-8	E
BeiDou M5	38774	C13	9-18-12	MEO slot 2-3	E, F
BeiDou M6	38775	C14	9-18-12	MEO slot 2-4	E
BeiDou G6	38953	C02	10-25-12	GEO 80° E	
BeiDou IGSO6	41434	C13	3-29-16	IGSO 95° E, 55° incl.	G
BeiDou G7	41586	C17	6-12-16	GEO 144.5° E	
BeiDou IGSO7	43539	C16	7-9-18	IGSO	H
TYPE: BeiDou-3					
BeiDou I1-S	40549	C16	3-30-15	IGSO 95° E, 55° incl.	I
BeiDou M1-S	40749	C33	7-25-15	MEO slot 1-1	E
BeiDou M2-S	40748	C34	7-25-15	MEO slot 1-6	E
BeiDou I2-S	40938	C18	9-29-15	IGSO 95° E, 55° incl.	J
BeiDou M3-S	41315	C35	2-1-16	MEO slot 2-1	E
BeiDou-3 M1	43001	C19	11-5-17	MEO slot 2-7	E
BeiDou-3 M2	43002	C20	11-5-17	MEO slot 2-8	E
BeiDou-3 M7	43107	C27	1-11-18	MEO slot 1-4	
BeiDou-3 M8	43108	C28	1-11-18	MEO slot 1-5	
BeiDou-3 M3	43208	C21	2-12-18	MEO slot 2-5	
BeiDou-3 M4	43207	C22	2-12-18	MEO slot 2-6	
BeiDou-3 M9	43245	C29	3-29-18	MEO slot 1-2	
BeiDou-3 M10	43246	C30	3-29-18	MEO slot 1-3	

BEIDOU NOTES

Website: http://en.beidou.gov.cn/

IGSO node longitudes are nominal values. Nodes are allowed to drift ±3 degrees or so.

A. Inactive.

B. Initially achieved geostationary orbit at a longitude of about 84.5° E, but appears to have become uncontrollable shortly thereafter. Librating about the 75° E libration point.

C. GEO, formerly at 144.5° E, shifted to 140° E between about June 30 and July 9, 2011.

D. GEO, formerly at 84° E, shifted to 110.5° E between about Nov. 7 and Nov. 23, 2012.

E. The MEO satellites are in a 24-satellite three-orbit-plane Walker constellation with orbit planes spaced by 120° with 55° inclination and orbital period of 12.89 hours.

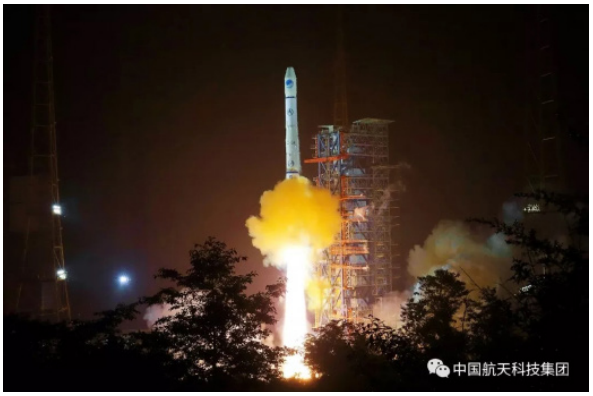
F. Satellite is not currently transmitting standard signals.

G. Satellite switched PRN from C15 to C13 on Oct. 11, 2016.

H. Commissioning. Drifting to assigned node longitude.

I. PRN switched from C31 to C16 on April 24, 2018.

J. PRN switched from C32 to C18 on June 7, 2018.



China launched a Beidou-2 backup navigation satellite on July 9. (Photo: Xinhua.net)

BEIDOU SATELLITE & SYSTEM INFORMATION

Website:
http://en.beidou.gov.cn/

China fielded a demonstration regional satellite-based navigation system known as BeiDou (Chinese for the "Big Dipper" asterism and pronounced "bay- dough") following a program of research and development that began in 1980.

The initial constellation of three geostationary Earth orbit (GEO) satellites was completed in 2003. A fourth GEO satellite was launched in 2007.

The initial regional BeiDou system (BeiDou-1) has been replaced by a global system known as BeiDou-2 (or simply BeiDou and, formerly, Compass). It will eventually include five GEO satellites, 27 medium Earth orbit (MEO) satellites, and five inclined geosynchronous orbit (IGSO) satellites.

BeiDou-2 was declared operational for use in China and surrounding areas on Dec. 27, 2011. FOC for this area was declared on Dec. 27, 2012. In March 2015, China began launching test satellites for a global version of BeiDou, called BeiDou-3 and in November 2017, began launching operational BeiDou-3 satellies. These satellites are transmitting test signals. When completed, BeiDou-3 will consist of five GEO satellites, 27 MEO satellites and three IGSO satellites. The system is expected to provide global coverage by 2020.

GNSS INTERNET RESOURCES

See more at gpsworld.com/the-almanac/

<< CONTINUED FROM PAGE 45.

Scripps Orbit and Permanent Array Center (SOPAC)
GPS Orbits, Real-Time GNSS Data, Coordinate Information, and Data Archive
California Spatial Reference Center (CRSC): http://sopac-csrc.ucsd.edu/
California Real Time Network (CRTN): http://sopac.ucsd.edu/crtn.shtml
The Scripps Institution of Oceanography maintains SOPAC, providing precise orbits and data archiving services for the International GNSS Service. Online applications include SCOUT (a global ITRF2014 coordinates generator), SECTOR (epoch-date ITRF2014 and NAD83 coordinates), Online Map Interface (SOMI) and the GPS Explorer data portal with JPL. SOPAC archives 24-hour RINEX data from about 3,000 continuous GNSS stations from more than 20 scientific networks around the world. SOPAC maintains the CSRC, which provides California's geodetic framework for scientific, engineering, and geographical information systems. SOPAC operates CRTN for the CSRC, providing NTRIP data streams in RTCM3 format from over 600 hundred stations in the western U.S., available through a subscription service. The 1 Hz RINEX data are archived at SOPAC. Email archive@gpsmail.ucsd.edu.

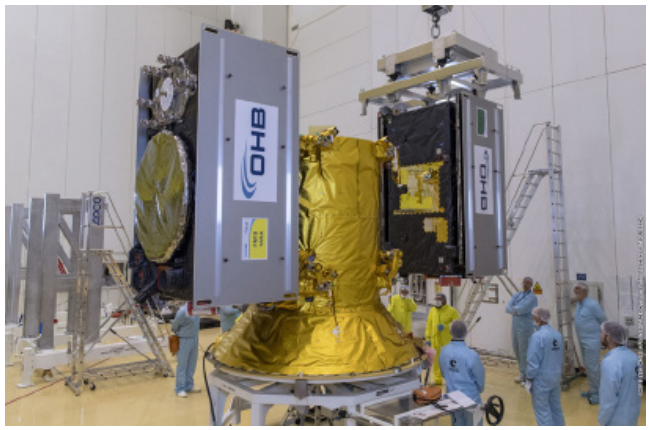
U.S. Coast Guard Navigation Center: www.navcen.uscg.gov
This site offers GPS constellation status, scheduled outage updates, user advisories, and almanac data as well as Differential GPS and Coast Guard Local Notice to Mariners information. Contact the NIS Watchstander, 24 hours a day, at phone (703) 313-5900, or email tis-pf-nisws@uscg.mil.

U.S. National Geodetic Survey (NGS) GPS Orbit Information
www.ngs.noaa.gov/CORS/
NOAA's National Geodetic Survey (NGS) manages a network of Continuously Operating Reference Stations (CORS) that provide GPS data to support three-dimensional positioning, meteorology, space weather and geophysical applications throughout the United States, its territories and a few foreign countries. email ngs.cors@noaa.gov.

CONTINUED ON PAGE 47 >>

GALILEO CONSTELLATION

SATELLITE	NORAD ID	LAUNCHED	L-BAND ACTIVE	OPERATIONAL	SLOT	PRN	CLOCK	NICKNAME	NOTES
GIOVE-A	28922	12-28-05							A
GIOVE-B	32781	4-26-08							B
PFM (GSAT0101)	37846	10-21-11	12-10-11	12-10-11	B5	E11	Rb	Thijs	
FM2 (GSAT0102)	37847	10-21-11	1-9-12	1-16-12	B6	E12	H	Natalia	
FM3 (GSAT0103)	38857	10-12-12	12-1-12	12-1-12	C4	E19	H	David	
FM4 (GSAT0104)	38858	10-12-12	12-12-12	12-12-12	C5	E20	Rb	Sif	C
FOC-FM1 (0201)	40128	8-22-14	11-29-14		Ext 1	E18	H	Doresa	D,F
FOC-FM2 (0202)	40129	8-22-14	3-17-15		Ext 2	E14	H	Milena	E,F
FOC-FM3 (0203)	40544	3-27-15	5-24-15	12-3-15	B8	E26	H	Adam	
FOC-FM4 (0204)	40545	3-27-15	5-21-15	12-4-15	B3	E22	Rb	Anastasia	G
FOC-FM5 (0205)	40889	9-11-15	11-9-15	1-28-16	A8	E24	H	Alba	
FOC-FM6 (0206)	40890	9-11-15	11-9-15	1-28-16	A5	E30	H	Oriana	
FOC-FM7 (0207)	41859	11-17-16	3-2-17	5-29-17	C6	E07	H	Antonianna	
FOC-FM8 (0208)	41174	12-17-15	2-16-16	4-22-16	C7	E08	H	Andriana	
FOC-FM9 (0209)	41175	12-17-15	2-18-16	4-22-16	C2	E09	H	Liene	
FOC-FM10 (0210)	41550	5-24-16	8-17-16	12-1-16	A2	E01	H	Danielè	
FOC-FM11 (0211)	41549	5-24-16	8-20-16	12-1-16	A6	E02	H	Alizée	
FOC-FM12 (0212)	41860	11-17-16	4-22-17	8-1-17	C8	E03	H	Lisa	
FOC-FM13 (0213)	41861	11-17-16	4-22-17	8-9-17	C3	E04	H	Kimberley	
FOC-FM14 (0214)	41862	11-17-16	3-3-17	5-29-17	C1	E05	H	Tijmen	
FOC-FM15 (0215)	43055	12-12-17	5-1-18		A3	E21		Nicole	H
FOC-FM16 (0216)	43056	12-12-17	4-13-18		A7	E25		Zofia	H
FOC-FM17 (0217)	43057	12-12-17	5-8-18		A4	E27		Alexandre	H
FOC-FM18 (0218)	43058	12-12-17	5-7-18		A1	E31		Irina	H



TWO OUT OF FOUR GALILEO satellites are attached to the dispenser pre-launch. (Photo: ESA)

GALILEO NOTES

Websites:

- European GNSS Agency, www.gsa.europa.eu
- European Space Agency, www.esa.int

A. Navigation signals from GIOVE-A were switched off on June 30, 2012, and the satellite decommissioned for ESA use.

B. Navigation signals from GIOVE-B were switched off on July 23, 2012, and the satellite decommissioned for ESA use.

C. Payload power problem beginning May 27, 2014. Subsequently transmitted only an E1 signal. Stopped transmitting on July 17, 2018.

D. Orbit perigree raised by about 3500 kilometers in November 2014.

E. Orbit perigree raised by about 3500 kilometers in January–February 2015.

F. Satellites launched into wrong orbits. Testing underway.

G. Transmission outage beginning Dec. 12, 2017, due to constellation management.

H. Undergoing commissioning.

GALILEO INFORMATION

Galileo is a joint initiative of the European Commission (EC, **ec.europa.eu**) and the European Space Agency (ESA, **www.esa.int**).

The first two full-operational-capability (FOC) satellites, manufactured by OHB Systems GmbH (Bremen, Germany, **www.ohb-system.de**) and Surrey Satellite Technology Ltd. (Guildford, United Kingdom, **www.sstl.co.uk**), were launched on Aug. 22, 2014, into wrong orbits due to an upper rocket stage anomaly. Eighteen FOC satellites have been launched to date.

Galileo Initial Open Service was declared operational on Dec. 15, 2016.

GNSS INTERNET RESOURCES

See more at gpsworld.com/the-almanac/

U.S. Naval Observatory
www.usno.navy.mil/USNO/time/gps
The U.S. Naval Observatory (USNO) provides GPS timing data and status information. Email Stephen.j.mitchell1@navy.mil.

INTERNATIONAL

International GNSS Service (IGS): www.igs.org
The foundation of IGS is a global network of more than 400 permanent, continuously operating, geodetic-quality GPS and GPS/GLONASS sites. Ten analysis centers process the data and contribute products to the analysis center coordinator, who produces the official IGS combined orbit and clock products. Timescale, ionospheric, and tropospheric products are analogously formed by specialized coordinators for each. email cb@igs.org.

Australia: www.ga.gov.au
Geoscience Australia provides geoscience information, services and capability to the Australian government, industry and stakeholders. It is responsible for the development of Australia's Satellite-Based Augmentation System (SBAS). It is the national focal point for coordination of geodetic information and data, and maintains a national network of observatories which forms part of a global observatory network. Users can download RINEX data from

Australian Government
Geoscience Australia

continuously operating GNSS observatories via a public FTP server (ftp://ftp.ga.gov.au) or connect to GNSS data streams in real-time via the AUSCORS Ntrip Broadcaster (http://auscors.ga.gov.au). email geodesy@ga.gov.au.

Czech Republic
http://radio.feld.cvut.cz/RSRDC/doku.php?id=almanacs
The Czech Technical University offers historical constellation status and almanac data for both GPS and GLONASS systems. email pavel.puricer@fel.cvut.cz, vejrazka@fel.cvut.cz.

Denmark: www.sdfe.dk
The Danish Agency for Data supply and Efficiency provides GNSS raw carrier-phase data by request. The service is based on the permanent reference station network, operated by the Danish Agency for Data supply and Efficiency (SDFE). Contact the Geodetic Office, SDFE, Rentemestervej 8, DK-2400 Copenhagen NV, Denmark; phone +45 72 54 50 00, email: grf@sdfe.dk.

India: www.isro.gov.in/irnss-programme
The Indian Space Research Organisation (ISRO) manages the Indian Regional Navigation Satellite System (IRNSS), also known as NavIC. IRNSS is an independent regional navigation satellite system designed to provide accurate position information service to users in India as well as the region extending up to 1500 kilometers from its boundary. An interface control document is available.

Japan: http://qzss.go.jp/en/
The Quasi-Zenith Satellite System (QZSS) website provides technical information on QZSS and other global satellite positioning systems as well as Japanese space policy and related events. View numerous videos and download informational pamphlets.

Russia: www.glonass-iac.ru/en/
The Information and Analysis Center for Positioning, Navigation and Timing (IAC PNT) of the State Space Corporation "Roscosmos" publishes official information about GLONASS status and plans as well as consultation, information and scientific-method services to increase GLONASS applications efficiency. It provides current constellations, Earth maps of the current and daily navigation availabilities, results of GNSS navigation field monitoring in the Moscow area in a real-time mode, and other data. email ianc@glonass-iac.ru.

IRNSS CONSTELLATION

SATELLITE	NORAD ID	LAUNCHED	ORBIT	NOTES
IRNSS-1A	39199	7-1-13	IGSO 55° E	A
IRNSS-1B	39635	4-4-14	IGSO 55° E	
IRNSS-1C	40269	10-15-14	GEO 83° E	
IRNSS-1D	40547	3-28-15	IGSO 111.75° E	
IRNSS-1E	41241	1-20-16	IGSO 111.75° E	
IRNSS-1F	41384	3-10-16	GEO 32.5° E	
IRNSS-1G	41469	4-28-16	GEO 129.5° E	
IRNSS-1I	43286	4-11-18	IGSO 55° E	B

IRNSS NOTES

A. Decommissioned.

B. Commissioning.

IRNSS SATELLITE & SYSTEM INFORMATION

www.isro.gov.in/irnss-programme

According to the Indian Space Research Organisation (ISRO), the Navigation with Indian Constellation (NavIC), also known as the Indian Regional Navigation Satellite System (IRNSS), consists of three GEO satellites located at 32.5°E, 83°E, and 129.5°E as well as two pairs of IGSO satellites with their nodes at longitudes of 55°E and 111.75°E with an orbital inclination of 29°. The satellites transmit signals at 1176.45 and 2492.028 MHz.

All three rubidium atomic clocks on IRNSS-1A have failed. A replacement satellite, IRNSS-1H, was launched on Aug. 31, 2017, but was not successfully deployed. A further replacement satellite, IRNSS-1I, was launched on April 11, 2018.

A REPLACEMENT SATELLITE **for NavIC was launched April 11. (Photo: ISRO)**

QZSS

http://qzss.go.jp/en/

The Quasi-Zenith Satellite System is operated by the Japan Aerospace Exploration Agency (JAXA). It is a four-satellite regional time-transfer system and satellite-based augmentation system that will be receivable within Japan.

The first IGSO satellite, QZS-1 (named Michibiki), was launched Sept. 11, 2010. The second IGSO satellite, QZS-2 also known as Michbiki No. 2, was launched on June 1, 2017, followed by a GEO satellite on Aug. 19, 2017, and an IGSO satellite (QZS-4, or Michibiki No. 4) on Oct. 9, 2017.

The constellation of three IGSO satellites and one GEO satellite is expected to be operational in 2018.

QZSS transmits six signals compatible with GPS and Galileo signals at the L1, L2, L5 and E6 frequencies, including augmentation signals (see SBAS table).

SATELLITE-BASED AUGMENTATION SYSTEMS

SBAS	SATELLITE	ORBIT LONGITUDE	PRN	SIGNALS	NOTES
EGNOS	Inmarsat-3-F2/AOR-E	15.5° W	120	L1	A
	Astra 5B	31.5° E	123	L1/L5	B
	Artemis				C
	Inmarsat-4-F2				D
	SES-5	5° E	136	L1/L5	E
GAGAN	GSAT-8	55° E	127	L1/L5	F, I
	GSAT-10	83° E	128	L1/L5	G, I
	GSAT-15	93.5° E	132	L1/L5	H, I
GATBP	Inmarsat 4F1/PAC-W	143.5° E	122	L1/L5	J
MSAS	MTSAT-1R				K
	MTSAT-2	145° E	129/137	L1	K
NSAS	NigComSat-1R	42.5° E	147	L1/L5	L
QZSS	QZS-1	135° E	183	L1	M
	QZS-2	136° E	184/196	L1/L5	M, N
	QZS-3	127° E	189/197	L1/L5	M, N
	QZS-4	136° E	185/200	L1/L5	M, N
SDCM	Luch-5A	167° E°	140	L1	O
	Luch-5B	16° W	125	L1	P
	Luch-5V	95° E	141	L1	Q
WAAS	Intelsat Galaxy 15 (CRW)	133° W	135	L1/L5	R, T
	TeleSat Anik F1R (CRE)	107.3° W	138	L1/L5	S, T
	Inmarsat-4-F3 (AMR)				U
	Eutelsat 117W B	117° W	131	L1/L5	V
	SES-15	129° W	133	L1/L5	W

SBAS NOTES

A. Inmarsat 3-F2 began Safety-of-Life Service on March 2, 2011, and is transmitting message type 2.

B. Astra 5B was launched on March 22, 2014. On March 20, 2017, it became an operational satellite and is transmitting message type 2.

C. Decomissioned for EGNOS use. Satellite sold to Britain's Avanti Communications.

D. Inmarsat-4-F2 began Safety-of-Life Service on March 22, 2012. It has been retired.

E. SES-5 (also known as Sirius 5 and Astra 4B) was launched on July 9, 2012 and was an operational satellite transmitting message type 2. On March 21, 2017, SES-5 became a test satellite.

F. GSAT-8 was launched on May 20, 2011.

G. GSAT-10 was launched on Sept. 28, 2012.

H. GSAT-15 was launched on Nov. 10, 2015. Its SBAS transponder is in reserve. Transmits test signals.

I. GAGAN was certified for enroute navigation and non-precision approaches on Dec. 30, 2013, and for precision approaches on April 21, 2015.

J. Geoscience Australia Test-Bed Project. Transmitting message type 0; not for safety-of-life use. L1 transmissions began on May 31, 2017.

K. MSAS commissioned for aviation use on Sept. 27, 2007. MTSAT-1R has been decommissioned. MTSAT-2 began transmitting both PRN signals on Dec. 10, 2015.

L. Nigerian Satellite Augmentation System. L1 tests.

M. QZS-1 (nicknamed Michibiki) transmits an L1 augmentation signal using PRN code 183. That signal is in test mode. QZS-2 transmits L1 and L5 augmentation signals using PRNs 184 and 196. Central longitudes of satellites can vary by ± 5° or more from nominal value.

N. On June 2, 2018, QZS-3 suffered a signal amplifier switch failure. During trouble shooting, all test signals from QZS-2, QZS-3 and QZS-4 have been temporally halted since June 4, 2018.

O. Luch-5A was launched on Dec. 11, 2011. Initially positioned at 58.5° E, it was shifted to 95° E between about May 30 and June 28, 2012, then shifted to 167° E between about Nov. 30 and Dec. 22, 2012. Transmissions as PRN 140 began on July 12, 2012. Transmitted occasional, non-coherent code/carrier test signals.

P. Luch-5B was launched on Nov. 2, 2012, and started transmitting test signals on Jan. 17, 2013.

Q. Luch-5V was launched on April 28, 2014. Testing may have started using PRN 140, not 141.

R. Galaxy 15 ranging supports enroute through precision approach modes. Switched to backup satellite oscillator on Jan. 6, 2012.

S. Anik F1R ranging supports enroute through precision approach modes.

T. The Galaxy 15 and and Anik F1R payloads, operated by Lockheed Martin for the FAA, are known as LMPRS-1 and LMPRS-2, respectively.

U. As of July 18, 2015, Inmarsat-4-F3 indefinitely discontinued non-precision approach ranging service. The satellite transponder was retired in November 2017.

V. Eutelsat 117W B began service on March 28, 2018, supporting enroute through precision approach modes.

W. SES-15 was launched on May 18, 2017, and began transmitting test signals on Dec. 18, 2017.

GNSS CONFERENCES AND ORGANIZATIONS

GPS Innovation Alliance, www.gpsalliance.org
The alliance recognizes the ever increasing importance of GPS and other GNSS technologies to the global economy and infrastructure and is firmly committed to furthering GPS innovation, creativity and entrepreneurship. The alliance also seeks to protect, promote and enhance the use of GPS.

Institute of Navigation, www.ion.org
ION is a non-profit professional society dedicated to the advancement of the art and science of positioning, navigation and timing. ION hosts numerous conferences throughout the year, including the annual ION GNSS+ Meeting in September, sponsored by the Satellite Division.

Royal Institue of Navigation, www.rin.org.uk
RIN increases public awareness of the art and science of navigation. It aims to advance the art, science and practice of navigation and promote knowledge in navigation and its associated sciences, including positioning, timing, tracking and conduct of a journey, whether on, in, over or under land, sea, air or space.

Munich Satellite Navigation Summit
www.munich-satellite-navigation-summit.org
This summit of high-ranking worldwide speakers from industry, science and governments provides the participants with a broad overview and different perspectives on the latest developments in GNSS. The summit is part of the efforts of the Bavarian government and the cluster on aerospace and satellite navigation to stimulate applications and services in this high-tech field.

European Navigation Conference, enc2019.eu/
Organized annually by the European Group of Institutes of Navigation, the conference focus is on innovations in positioning, navigation and timing technologies and applications at land, sea and air. The 2019 conference will be held in Warsaw, Poland.

Galileo Service, www.galileo-services.org
Galileo Services is a non-profit organization designed to be a major partner for the Galileo downstream technology and business development.

European GNSS Agency (GSA), www.gsa.europa.eu
The GSA's mission is to support European Union objectives and achieve the highest return on European GNSS investment, in terms of benefits to users and economic growth and competitiveness.