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Satellite Communications: The Indian Scenario

Dr. Ranjit Singh, FIETE
Department of Electronics Communications Engineering, Ajay Kumar Garg Engineering College, 27 KM stone, NH-24, Ghaziabad 201009 UP

Abstract
India has launched as many as 73 Indian satellites as of today since its first attempt in 1975. Besides serving traditional markets of telephony and broadcasting, satellites are on the frontiers of advanced applications as telemedicine, distance learning, environment monitoring, remote sensing, and so on. Satellite systems are optimized for services such as Internet access, virtual private networks and personal access. Costs have been coming down in recent years to the point where satellite broadband is becoming competitive.
This article is an attempt to view this important topic from Indian perspective. India's Project GAGAN, GPS Aided Geo Augmented Navigation is discussed.
Keywords*:* Communication satellites, Broadband, ISRO, GSLV, Project GAGAN, Cryogenic engine

I. INTRODUCTION

SUNDAY, 5th January 2014 will perhaps be remembered as a Red Letter day in the country's march towards self-reliance in Satellite communications, when ISRO launched a geosynchronous satellite powered by *indigenous* cryogenic engine. Last year in November, ISRO launched a satellite for the Mission MARS. another significant milestone in India's space journey,

In today's world of wireless communications, high-definition television and global access to the Internet, satellites also support all forms of communications that range from simple point-of-sale validation to bandwidth-intensive multimedia applications. Satellite solutions are highly flexible and can operate independently, or as part of a larger network. Satellites of course serve traditional markets — telephony and broadcasting — covering large geographical areas using single-beam transmission.

Satellites are on the frontiers of such advanced applications as remote sensing, telemedicine, distance learning, environment monitoring, Voice over Internet Protocol (VoIP) and video on demand (VOD). Mobile satellite services using a constellation of satellites provide communication services to portable devices such as cellular phones and global positioning systems.

As a result of rising aspirations, there is demand for two-way broadband access over large geographical areas not served by telecom-infrastructure. Satellite providers can offer local-loop services in such areas. The recent report by ITU entitled "Regulation of global broadband satellite communications" explains why satellite broadband technology is vital for expanding multimedia services and applications around the world.

Figure1. The cryogenic engine CE-20 developed by ISRO to propel GSLV rocket. America had forced Russia to deny this technology to India.

Costs have been coming down in recent years to the point where satellite broadband is becoming competitive with other broadband options. A new generation of applications with high throughput requirements has emerged, and satellites are meeting these high throughput needs.

Satellite systems are optimized for services such as Internet access, virtual private networks and personal access. Globally, the number of subscribers to satellite broadband is expected to cross 6 million in 2020.

Interestingly, India has launched as many as 73 Indian satellites as of today since its first attempt in 1975.

II. BACKGROUND

Way back in 1945, British RAF officer, Arthur C. Clarke, wrote an article in *Wireless World* describing the use of manned satellites in 24-hour orbits high above the earth to distribute television programs. During the 1960s and 1970s, advances in satellite performance came quickly and a global industry began to develop. Satellites were mainly used at first for international and long-haul telephone traffic and distribution of select television programming.

Today, satellite communications has profound effect on the life of common man. Those living in remote regions around the world who cannot obtain high speed Internet access from a terrestrial provider are relying on satellite communications. Satellite technology is a solution for some of the most complicated access problems, connecting cities across a large landmass, where copper or fiber would be cost-prohibitive, bringing broadband to the “last mile” of residences and businesses.

Satellite communications feature superior Reliability. When terrestrial outages occur from man-made and natural events, satellite connections remain operational. Satellite is unmatched for broadcast applications like television. For two-way IP networks, the speed, uniformity and end-to-end control of today's advanced satellite solutions are resulting in greater use of satellite by corporations, governments and consumers. Indeed, Satellite communications is the only truly commercial space technology--generating enormous revenues annually in sales of products and services.

III. OPERATIONAL BASICS

Communications data passes through the satellite using a signal path known as a ”transponder.” Today’s satellites have between 24 and 72 transponders. A single transponder is capable of handling up to 155 million bits of information per second. With this immense capacity, communication satellites are an ideal medium for transmitting and receiving almost any kind of content, from simple voice or data to the most complex and bandwidth-intensive video, audio and Internet content. Satellites have an expected life of 10-15 years.

Satellite broadband services are offered in five basic technology categories:

- C-band (4–6 GHz) fixed-satellite service (FSS)
- Ku-band (11–14 GHz) fixed-satellite service (FSS)
- Ka-band (20–30 GHz) bent pipe (with no on-board processing in the satellite)
- Ka-band (20–30 GHz) with on-board processing in the satellite
- L-band (1.5–1.6 GHz) mobile-satellite service (MSS).

First generation satellite broadband, in the late 1990s, made use of the Ku-band fixed-satellite service to provide two-way connections using a single satellite beam. It met with limited success because of the high cost of space segment and subscriber terminals, and the less than optimal network throughput and operational performance.

New generation Ka-band broadband systems deploy spot beam technology, where satellite downlink beams illuminate an area of the order of hundreds (rather than thousands) of kilometres. Coverage looks like a honeycomb or cellular pattern. This enables frequency reuse, resulting in a dramatic increase in the overall capacity of the satellite. New generation satellite broadband is being customized for target markets, to reduce bandwidth costs and increase capabilities to keep pace with the growth in the subscriber population. The system capacity is 30 to 60 times that of the Ku-band fixed-satellite service approach.

Satellites also use commercial frequency bands of C- and Ku-band. Generally C-band operates in the 4-6 GHz range and is mostly used for fixed services such as PSN, Internet Trunking and mobile feeder links. Ku-band in 11 to 14 GHz serves Internet trunking and video distribution applications. Over the next several years, the use of a new frequency band known as Ka-band is expected to increase. Ka-band operates in the 18-30 GHz range largely for broadband applications.

Attenuation and scintillation effects of atmospheric gas, clouds and rain — causing signal fading — become more pronounced with increase in frequency above 1 GHz, and particularly affect the Ka and higher bands. But fade mitigation techniques are implemented to overcome the problem.

The footprint of a satellite does not match national borders. This makes it necessary to regulate satellite usage through international agreements such as those reached under the auspices of ITU.

IV. INDIA’s PROJECT GAGAN

India is becoming known for low-cost innovation in diverse fields such as healthcare and education. Last November’s Mars mission is an example of the ingenuity that produces technology at stupendously low prices. The price tag on Mangalyaan has stirred the global space community.

Phones that pick up signals from orbiting U.S. Global Positioning System (GPS) satellites are now commonplace. The phone uses that information to work out the location and display it on a map.

An important way to meet the demands of civil aviation has been through what is known as a Satellite-Based Augmentation System (SBAS). Satellites in geostationary orbit, where they match the earth's rotation and therefore remain over the same place on the globe, are used to supplement the GPS signals. India is establishing its own system, the 'GPS Aided Geo Augmented Navigation' (GAGAN), a joint effort by the Indian Space Research Organisation and the Airports Authority of India.

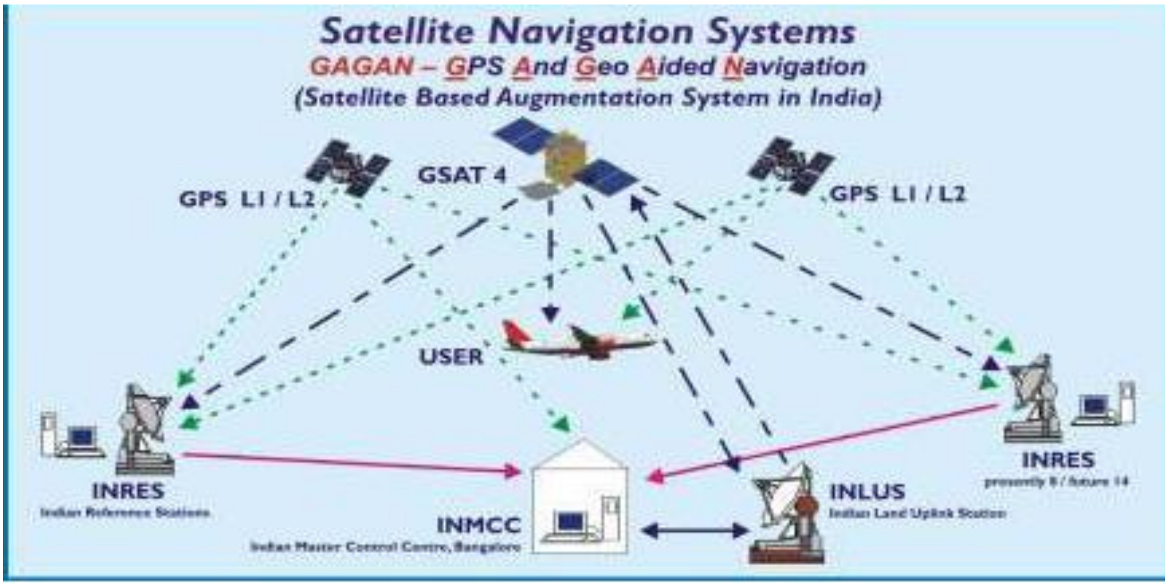

Figure 2. Architecture of the Project GAGAN.

In March 2011, Cabinet Committee on Economic Affairs (CCEA) approved one-time grant of Rs. 378 crore from the Government Budgetary Support for implementation of Gagan project over Indian airspace for seamless navigation. CCEA approved a total project cost of Rs. 774 crore, of which AAI was expected to contribute Rs. 604 crore and ISRO was expected to contribute Rs. 170 crore.

GAGAN is compatible with other Space Based Augmentation System such as the Wide Area Augmentation System of the U.S., the European Geostationary Navigation Overlay Service and the Multi-functional Satellite Augmentation System of Japan and will provide seamless air navigation service across regional boundaries. India would become the fourth country in the world to adopt this system.

The ground segment for GAGAN, which has been put up by the U.S. company Raytheon, has 15 reference stations scattered across the country. Two mission control centres, along with associated uplink stations, have been set up at Kundalahalli in Bangalore. One more control centre and uplink station is at Delhi.

The GAGAN payload is on the GSAT-8 communication satellite. The reference stations pick up signals from the orbiting GPS satellites. These measurements are immediately passed on to the mission control centres that then work out the necessary corrections that must be made.

Messages carrying those corrections are sent via the uplink stations to the satellites in geostationary orbit that have the GAGAN payload. Those satellites then broadcast the messages. SBAS receivers are able to use those messages and apply the requisite corrections to the GPS signals that they receive, thereby establishing their position with considerable accuracy.

The cost savings in using GAGAN accrue from the fact that its ground system does not need to be duplicated for each runway, as is the case for an ILS. The GPS signals, as well as the correcting deltas, can be made available to aircraft for any runway within the network using satellite based communication.

The GAGAN system has a full complement of the SBAS inclusive of ground and onboard segment. It was built in phases.

The first phase was completed in August 2007 and served as a technology demonstrator. Final operation phase implementation started in June 2009 and completed in September 2013. The space borne segment of GAGAN consists of payloads onboard Indian geostationary satellites GSAT-8P, GSAT-10 and GSAT-15.

The GSAT-8P was successfully launched using Ariane 5 on May 21, 2011 and is positioned in geosynchronous orbit at 55 degrees E longitude.

After the launch of GSAT-8, In-Orbit Test and Test and Evaluation of GAGAN navigation payload were carried out and the satellite integrated with Bangalore INLUS-West. Stability test were conducted, following which GAGAN signal without certification became available for users.

GSAT-10 was launched on September 29, 2012 and integrated with Bangalore INLUS-East. Also, GSAT-8 was integrated with New Delhi INLUS. Final System Acceptance Test was scheduled for June 2012 followed by system certification during July 2013.

An on-orbit spare GAGAN transponder will be flown on GSAT-15. GAGAN can function with one Geo stationary satellite. The other two satellites serve as in-orbrit back-ups.

Gagan is intended for use in aviation sector and help in navigation over Indian airspace. Other applications include all weather national infrastructures to be be used by defense services, security agencies, Railways, surface transport, shipping, telecom industry and personal users of position location based services.

V. ISRO's Pride

Last month, ISRO successfully launched a GSLV rocket with indigenous cryogenic engine that placed Rs.145 crore two-ton communication satellite GSAT-14 precisely in the intended orbit. ISRO will confidently look for heavy satellite carriage contracts from foreign parties after it successfully launches one more Geosynchronous Satellite Launch Vehicle.

Figure 3. India developed GSLV to launch its satellites indigenously without dependence on foreign aid. GSLV has attempted eight launches to date, since its first launch in 2001.

GSAT-14 is the twenty third geostationary communication satellite of India built by ISRO. The main objectives of GSAT-14 mission are:

i) To augment the In-orbit capacity of Extended C and Ku-band transponders
ii) To provide a platform for new experiments.

The payloads of GSAT-14 are:

- Six extended C-band transponders for Indian mainland and island coverage with 36 dBW Edge Of Coverage- Effective Isotropic Radiated Power (EOC-EIRP)
- Six Ku-band transponders covering the mainland India with 51.5 dBW EOC-EIRP
- Two Ka-band Beacons operating at 20.2 GHz and 30.5 GHz to carry out attenuation studies.

Some of the new technologies being tested on GSAT-14 are:

- Ka band beacon propagation studies
- Fiber Optic Gyro
- Active Pixel Sun Sensor
- Thermal control coating experiments.

TABLE 1 - SALIENT FEATURES OF GSAT-14 SATELLITE

Mass at Lift-off	1982 kg
Overall size	2.0m x 2.0m x 3.6m
Power	2600 W
Attitude and Orbit Control System	Momentum based 3-axis stabilised
Propulsion System	Mono Methyl Hydrazine mixed oxides of nitrogen
Antennae	One 2m and one 2.2m single shell shaped reflector Antennae
Launch Vehicle	GSLV-D5
Orbit	Geostationary, 74 deg E longitude
Mission life	12 years
Launch site	SHAR

Table 2 -- LIST OF SATELLITES LAUNCHED BY INDIA

India has launched 73 Indian satellites as of 5 January 2014 of many types since its first attempt in 1975. The Table below provides the complete list.

NAME	LAUNCH DATE	APPLICATION/ REMARKS
Aryabhata	19 April 1975	Provided technological experience in building and operating a satellite system.
Bhaskara-I	7 June 1979	First experimental remote sensing satellite. Carried TV and microwave cameras.
Rohini Technology Payload	10 August 1979	Intended for measuring in-flight performance of first experimental flight of SLV-3, the first Indian launch vehicle. Did not achieve orbit.
Rohini RS-1	18 July 1980	Used for measuring in-flight performance of second experimental launch of SLV-3.
Rohini RS-D1	31 May 1981	Used for conducting some remote sensing technology studies using a landmark sensor payload.Launched by the first developmental launch of SLV-3.
Ariane Passenger Payload Experiment	19 June 1981	First experimental communication satellite. Provided experience in building and operating a payload experiment three-axis stabilised communication satellite.
Bhaskara-II	20 November 1981	Second experimental remote sensing satellite; similar to Bhaskara-1. Provided experience in building and operating a remote sensing satellite system on an end-to-end basis.
INSAT-1A	10 April 1982	First operational multipurpose communication and meteorology satellite. Procured from USA. Worked for only six months.
Rohini RS-D2	17 April 1983	Identical to RS-D1. Launched by the second developmental launch of SLV-3.
INSAT-1B	30 August 1983	Identical to INSAT-1A. Served for more than design life of seven years.
Stretched Rohini Satellite Series(SROSS-1)	24 March 1987	Carried payload for launch vehicle performance monitoring and for gamma ray astronomy. Did not achieve orbit.

NAME	LAUNCH DATE	APPLICATION/ REMARKS
IRS-1A	17 March 1988	Earth observation satellite. First operational remote sensing satellite.
Stretched Rohini Satellite Series(SROSS-2)	13 July 1988	Carried remote sensing payload of German space agency in addition to Gamma Ray astronomy payload. Did not achieve orbit.
INSAT-1C	21 July 1988	Same as INSAT-1A. Served for only one-and-a-half years.
INSAT-1D	12 June 1990	Identical to INSAT-1A. Still in service. A third stage motor landed from its launch, landed in Australia in 2008.[2]
IRS-1B	29 August 1991	Earth observation satellite. Improved version of IRS-1A.
INSAT-2DT	26 February 1992	Launched as Arabsat 1C. Procured in orbit from Arabsat in January 1998.
Stretched Rohini Satellite Series(SROSS-C)	20 May 1992	Carried gamma ray astronomy and aeronomy payload.
INSAT-2A	10 July 1992	First satellite in the second-generation Indian-built INSAT-2 series. Has enhanced capability over INSAT-1 series. Still in service.
INSAT-2B	23 July 1993	Second satellite in INSAT-2 series. Identical to INSAT-2A. Still in service.
IRS-1E	20 September 1993	Earth observation satellite. Did not achieve orbit.
Stretched Rohini Satellite Series(SROSS-C2)	4 May 1994	Identical to SROSS-C. Still in service.
IRS-P2	15 October 1994	Earth observation satellite. Launched by second developmental flight of PSLV.Mission accomplished after 3 years of service in 1997.
INSAT-2C	7 December 1995	Has additional capabilities such as mobile satellite service, business communication and television outreach beyond Indian boundaries. Still in service.
IRS-1C	29 December 1995	Earth observation satellite. Launched from Baikonur Cosmodrome.
IRS-P3	21 March 1996	Earth observation satellite. Carries remote sensing payload and an X-ray astronomy payload. Launched by third developmental flight of PSLV.
INSAT-2D	4 June 1997	Same as INSAT-2C. Inoperable since 1997-10-04 due to power bus anomaly.
IRS-1D	29 September 1997	Earth observation satellite. Same as IRS-1C.
INSAT-2E	3 April 1999	Multipurpose communication and meteorological satellite.
Oceansat-1 (IRS-P4)	26 May 1999	Earth observation satellite. Carries an Ocean Colour Monitor (OCM) and a Multifrequency Scanning Microwave Radiometer (MSMR).
INSAT-3B	22 March 2000	Multipurpose communication: business communication, developmental communication, and mobile communication.
GSAT-1	18 April 2001	Experimental satellite for the first developmental flight of Geosynchronous Satellite Launch Vehicle, GSLV-D1.
Technology Experiment Satellite (TES)	22 October 2001	Experimental satellite to test technologies such as attitude and orbit control system, high-torque reaction wheels, new reaction control system, etc.
INSAT-3C	24 January 2002	Designed to augment the existing INSAT capacity for communication and broadcasting and provide continuity of the services of INSAT-2C.
Kalpana-1(METSAT)	12 September 2002	First meteorological satellite built by ISRO. Originally named METSAT. Renamed after Kalpana Chawla who perished in the Space Shuttle Columbia.
INSAT-3A	10 April 2003	Multipurpose satellite for communication, broadcasting, and meteorological services along with INSAT-2E and Kalpana-1.
GSAT-2	8 May 2003	Experimental satellite for the second developmental test flight of Geosynchronous Satellite Launch Vehicle (GSLV)
INSAT-3E	28 September	Communication satellite to augment the existing INSAT System.

NAME	LAUNCH DATE	APPLICATION/ REMARKS
	2003	
RESOURCESAT-1 (IRS-P6)	17 October 2003	Earth observation/remote sensing satellite. Intended to supplement and replace IRS-1C and IRS-1D.
EDUSAT	20 October 2004	Also designated GSAT-3. India's first exclusive educational satellite.
HAMSAT	5 May 2005	Microsatellite (42.5 kilograms) for providing satellite-based amateur radio services to the national as well as the international community.
CARTOSAT-1	5 May 2005	Earth observation satellite. Provides stereographic in-orbit images with a 2.5-meter resolution.
INSAT-4A	22 December 2005	Advanced satellite for direct-to-home television broadcasting services.
INSAT-4C	10 July 2006	Geosynchronous communications satellite. Did not achieve orbit.
CARTOSAT-2	10 January 2007	Advanced remote sensing satellite carrying a panchromatic camera capable of providing scene-specific spot images.
Space Capsule Recovery Experiment(SRE-1)	10 January 2007	Experimental satellite intended to demonstrate the technology of an orbiting platform for performing experiments in microgravity conditions. Launched as a co-passenger with CARTOSAT-2. SRE-1 was de-orbited and recovered successfully after 12 days over Bay of Bengal.
INSAT-4B	12 March 2007	Identical to INSAT-4A. Further augments the INSAT capacity for direct-to-home (DTH) television services and other communications. On the night of 7 July INSAT-4B experienced a power supply glitch which led to switching 'off' of 50 per cent of the transponder capacity (6 Ku and 6 C-Band transponders).
INSAT-4CR	2 September 2007	Identical to INSAT-4C. It carried 12 high-power Ku-band transponders designed to provide direct-to-home (DTH) television services, Digital Satellite News Gathering etc.
CARTOSAT-2A	28 April 2008	Earth observation/remote sensing satellite. Identical to CARTOSAT-2.
IMS-1 (Third World Satellite – TWsat)	28 April 2008	Low-cost microsatellite imaging mission. Launched as co-passenger with CARTOSAT-2A.
Chandrayaan-1	22 October 2008	Unmanned lunar probe. Carries 11 scientific instruments built in India, USA, UK, Germany, Sweden and Bulgaria.
RISAT-2	20 April 2009	Radar imaging satellite used to monitor India's borders and as part of anti-infiltration and anti-terrorist operations. Launched as a co-passenger with ANUSAT.
ANUSAT	20 April 2009	Research microsatellite designed at Anna University. Carries an amateur radio and technology demonstration experiments.
Oceansat-2 (IRS-P4)	23 September 2009	Gathers data for oceanographic, coastal and atmospheric applications. Continues mission of Oceansat-1.
GSAT-4	15 April 2010	Communications satellite technology demonstrator. Failed to reach orbit due to GSLV-D3 failure.
CARTOSAT-2B	12 July 2010	Earth observation/remote sensing satellite. Identical to CARTOSAT-2A.
StudSat	12 July 2010	First Indian pico-satellite (weighing less than 1 kg). Developed by a team from seven engineering colleges from Karnataka and Andhra Pradesh.
GSAT-5P /INSAT-4D	25 December 2010	C-band communication satellite, failed to reach orbit due to GSLV-F06 failure.
RESOURCESAT-2	20 April 2011	RESOURCESAT-2, ISRO's eighteenth remote-sensing satellite, followed RESOURCESAT-1. PSLV-C16 placed three satellites with a total payload mass of 1404 kg – RESOURCESAT-2 weighing 1206 kg, the Indo-Russian YOUTHSAT weighing 92 kg and Singapore's X-SAT weighing 106 kg – into an 822 km polar Sun Synchronous Orbit (SSO).
Youthsat	20 April 2011	Indo-Russian stellar and atmospheric satellite with the participation of university students. It weighed 92 kg
GSAT-8 / INSAT-4G	21 May 2011	Communications satellite carries 24 Ku-band transponders and 2 channel GAGAN payload operating in L1 and L5 band.
GSAT-12	15 July 2011	GSAT-12 communication satellite built by ISRO, weighs about 1410 kg at lift-off. GSAT-12 is configured to carry 12 Extended C-band transponders to meet the country's growing demand for transponders in a short turn-around-time.The 12 Extended C-band transponders of GSAT-12 will augment the capacity in the INSAT system for various communication services like Tele-education, Telemedicine and for Village Resource Centres (VRC).Mission life About 8 Years.

NAME	LAUNCH DATE	APPLICATION/ REMARKS
Megha-Tropiques	12 October 2011	Megha-Tropiques weighs about 1000 kg Lift-off Mass, developed jointly by ISRO and the French Centre National d'Etudes Spatiales(CNES). PSLV-C18 is configured to carry four satellites in which, one satellite, developed by India and France, will track the weather, two were developed by educational institutions, and the fourth is from Luxembourg.
Jugnu	12 October 2011	Nano-satellite weighing 3 kg developed by IIT Kanpur
RISAT-1	26 April 2012	RISAT-1, first indigenous all-weather Radar Imaging Satellite (RISAT-1), whose images will facilitate agriculture and disaster management weighs about 1858 kg.
SRMSAT	26 April 2012	Nano-satellite weighing 10.9 kg developed by SRM University.
GSAT-10	29 September 2012	GSAT-10, India's advanced communication satellite, is a high power satellite being inducted into the INSAT system. Weighing 3400 kg at lift-off.
SARAL	25 February 2013	SARAL, The *S*atellite with *AR*GOS and *AL*TIKA (SARAL) is a joint Indo-French satellite mission for oceanographic studies.
IRNSS-1A	1 July 2013	IRNSS-1A is the first satellite in the Indian Regional Navigation Satellite System (IRNSS). It is one of the seven satellites constituting the IRNSS space segment.
INSAT-3D	26 July 2013	INSAT-3D is the meteorological Satellite with advanced weather monitoring payloads.
GSAT-7	30 August 2013	GSAT-7 is the advanced multi-band communication satellite dedicated for military use.
Mars Orbiter Mission (MOM)	5 November 2013	The Mars Orbiter Mission (MOM), informally called Mangalyaan is India's first Mars orbiter.
GSAT-14	5 Jan' 14	GSAT-14 is the twenty third geostationary communication satellite of India to augment the In-orbit capacity of Extended C and Ku-band transponders.

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Dr Ranjit Singh obtained B.Tech, M.Tech. and Ph.D degrees all from the Indian Institute of Technology, Kanpur in 1969, 1971 and 1976 respectively. He specialized in the area of Electronic communication circuits and devices.
Published large number of technical papers in IETE journals in addition to in-depth technology-reviews covering emerging trends in Communications and information technology.

Since last six years, he is teaching at Ajay Kumar Garg Engineering College where, he is a Professor in the Department of Electronics and Communication Engineering.
He has abiding passion for teaching and research. Currently guiding M. Tech and PhD scholars besides supervising B.Tech projects. He is Life Fellow of the IETE and attended international Technical conferences held in France, Singapore, USA, Hong Kong and Nepal. Daily practices advanced Art-of-Living meditation.