

1

Introduction to Satellites and their Applications

The word ‘Satellite’ is a household name today. It sounds so familiar to everyone irrespective of educational and professional background. It is no longer the prerogative of a few select nations and not a topic of research and discussion that is confined to the premises of big academic institutes and research organizations. It is a subject of interest and discussion not only to electronics and communication engineers, scientists and technocrats; it fascinates hobbyists, electronics enthusiasts and to a large extent everyone.

In the present chapter, the different stages of evolution of satellites and satellite launch vehicles will be briefly discussed, beginning with the days of hot air balloons and sounding rockets of the late 1940s/early 1950s to the contemporary status in the beginning of the 21st century.

1.1 Ever-expanding Application Spectrum

What has made this dramatic transformation possible is the manifold increase in the application areas where the satellites have been put to use. The horizon of satellite applications has extended far beyond providing intercontinental communication services and satellite television. Some of the most significant and talked about applications of satellites are in the fields of remote sensing and Earth observation. Atmospheric monitoring and space exploration are the other major frontiers where satellite usage has been exploited a great deal. Then there are the host of defence related applications, which include secure communications, navigation, spying and so on.

The areas of application are multiplying and so is the quantum of applications in each of those areas. For instance, in the field of communication related applications, it is not only the long distance telephony and video and facsimile services that are important; satellites are playing an increasing role in newer communication services such as data communication, mobile communication, etc. Today, in addition to enabling someone to talk to another person thousands of miles away from the comfort of home or bringing live on television

screens cultural, sporting or political events from all over the globe, satellites have made it possible for someone to talk to anyone anywhere in the world, with both people being able to talk while being mobile. Video conferencing, where different people at different locations, no matter how far the distance is between these locations, can hold meetings in real time to exchange ideas or take important decisions, is a reality today in big establishments. The Internet and the revolutionary services it has brought are known to all of us. Satellites are the backbone of all these happenings.

A satellite is often referred to as an ‘orbiting radio star’ for reasons that can be easily appreciated. These so-called orbiting radio stars assist ships and aircraft to navigate safely in all weather conditions. It is interesting to learn that even some categories of medium to long range ballistic and cruise missiles need the assistance of a satellite to hit their intended targets precisely. The satellite-based global positioning system (GPS) is used as an aid to navigate safely and securely in unknown territories.

Earth observation and remote sensing satellites give information about the weather, ocean conditions, volcanic eruptions, earthquakes, pollution and health of agricultural crops and forests. Another class of satellites keeps watch on military activity around the world and helps to some extent in enforcing or policing arms control agreements.

Although mankind is yet to travel beyond the moon, satellites have crossed the solar system to investigate all planets except Pluto. These satellites for astrophysical applications have giant telescopes on board and have sent data that has led to many new discoveries, throwing new light on the universe. It is for this reason that almost all developed nations including the United States, the United Kingdom, France, Japan, Germany, Russia and major developing countries like India have a full fledged and heavily funded space programme, managed by organizations with massive scientific and technical manpower and infrastructure.

1.2 What is a Satellite?

A satellite in general is any natural or artificial body moving around a celestial body such as planets and stars. In the present context, reference is made only to artificial satellites orbiting the planet Earth. These satellites are put into the desired orbit and have a payload depending upon the intended application.

The idea of a geostationary satellite originated from a paper published by Arthur C. Clarke, a science fiction writer, in the *Wireless World* magazine in the year 1945. In that proposal, he emphasized the importance of this orbit whose radius from the centre of Earth was such that the orbital period equalled the time taken by Earth to complete one rotation around its axis. He also highlighted the importance of an artificial satellite in this orbit having the required instrumentation to provide intercontinental communication services because such a satellite would appear to be stationary with respect to an observer on the surface of Earth. Though the idea of a satellite originated from the desire to put an object in space that would appear to be stationary with respect to Earth’s surface, thus making possible a host of communication services, there are many other varieties of satellites where they need not be stationary with respect to an observer on Earth to perform the intended function.

A satellite while in the orbit performs its designated role throughout its lifetime. A communication satellite (Figure 1.1) is a kind of repeater station that receives signals from ground, processes them and then retransmits them back to Earth. An Earth observation satellite (Figure 1.2) is a photographer that takes pictures of regions of interest during its periodic motion.



Figure 1.1 Communication satellite

A weather satellite (Figure 1.3) takes photographs of clouds and monitors other atmospheric parameters, thus assisting the weatherman in making timely and accurate forecasts.

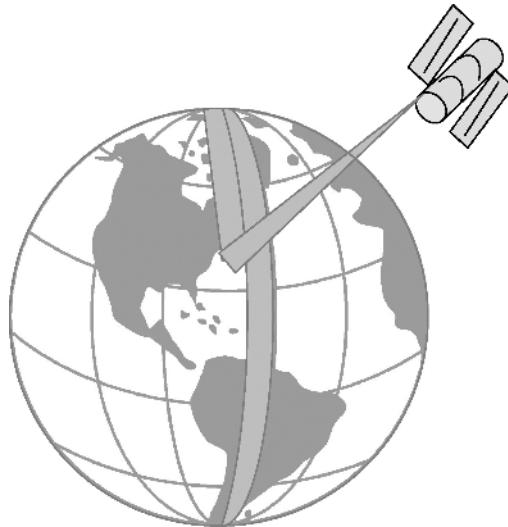


Figure 1.2 Earth observation satellite

A satellite could effectively do the job of a spy in the case of some military satellites (Figure 1.4) meant for the purpose or of an explorer when suitably equipped and launched for astrophysical applications (Figure 1.5).

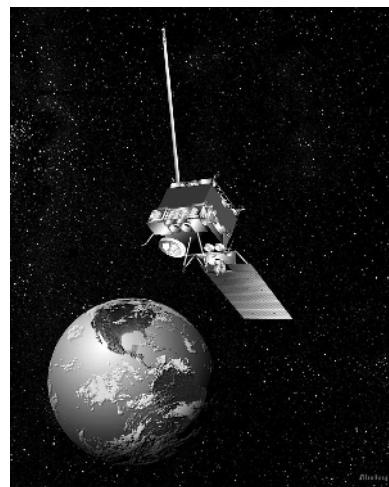


Figure 1.3 Weather forecasting satellite (Courtesy: NOAA and NASA)

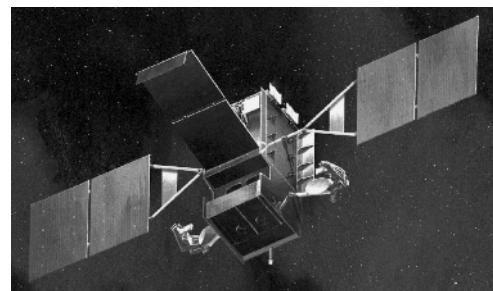


Figure 1.4 Military satellites (Courtesy: Lockheed Martin)

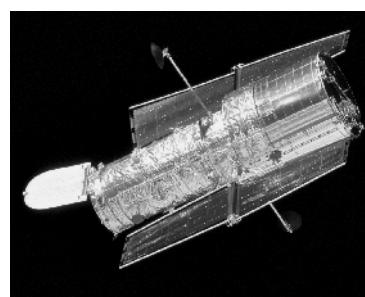


Figure 1.5 Scientific satellites (Courtesy: NASA and STScl)

1.3 History of the Evolution of Satellites

It all began with an article by Arthur C. Clarke published in October 1945 issue of *Wireless World*, which theoretically proposed the feasibility of establishing a communication satellite in a geostationary orbit. In that article, he discussed how a geostationary orbit satellite would look static to an observer on Earth within the satellite's coverage, thus providing an uninterrupted communication service across the globe. This marked the beginning of the satellite era. The scientists and technologists started to look seriously at such a possibility and the revolution it was likely to bring along with it.

1.3.1 Era of Hot Air Balloons and Sounding Rockets

The execution of the mission began with the advent of hot air balloons and sounding rockets used for the purpose of aerial observation of planet Earth from the upper reaches of Earth's atmosphere. The 1945–1955 period was dominated by launches of experimental sounding rockets to penetrate increasing heights of the upper reaches of the atmosphere. These rockets carried a variety of instruments to carry out their respective mission objectives.

A-4 (V-2) rockets used extensively during the Second World War for delivering explosive warheads attracted the attention of the users of these rockets for the purpose of scientific investigation of the upper atmosphere by means of a high altitude rocket. With this started the exercise of modifying these rockets so that they could carry scientific instruments. The first of these A-4 rockets to carry scientific instruments to the upper atmosphere was launched in May 1946 (Figure 1.6). The rocket carried an instrument to record cosmic ray flux from an altitude of 112 km. The launch was followed by several more during the same year.



Figure 1.6 First A-4 rocket to be launched (Courtesy: NASA)

The Soviets, in the meantime, made some major modifications to A-4 rockets to achieve higher performance levels as sounding rockets. The V-2A rocket (the Soviet version of the

modified A-4 rocket), the last of these, made its appearance in 1949. It carried a payload of 860 kg and attained a height of 212 km.

1.3.2 Launch of Early Artificial Satellites

The United States and Russia were the first two countries to draw plans for artificial satellites in 1955. Both countries announced their proposals to construct and launch artificial satellites. It all happened very quickly. Within a span of just two years, Russians accomplished the feat and the United States followed quickly thereafter.

Sputnik-1 (Figure 1.7) was the first artificial satellite that brought the space age to life. Launched on 4 October 1957 by Soviet R7 ICBM from Baikonur Cosmodrome, it orbited Earth once every 96 minutes in an elliptical orbit of $227\text{ km} \times 941\text{ km}$ inclined at 65.1° and was designed to provide information on density and temperature of the upper atmosphere. After 92 successful days in orbit, it burned as it fell from orbit into the atmosphere on 4 January 1958.

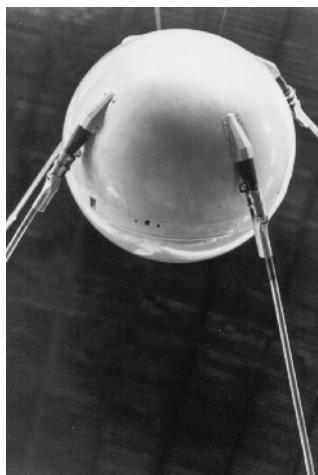


Figure 1.7 Sputnik-1 (Courtesy: NASA)

Sputnik-2 and Sputnik-3 followed Sputnik-1. Sputnik-2 was launched on 3 November 1957 in an elliptical orbit of $212\text{ km} \times 1660\text{ km}$ inclined at 65.33° . The satellite carried an animal, a female dog named Laika, in flight. Laika was the first living creature to orbit Earth. The mission provided information on the biological effect of the orbital flight. Sputnik-3 was a geophysical satellite that provided information on Earth's ionosphere, magnetic field, cosmic rays and meteoroids. The orbital parameters of Sputnik-3 were 217 km (perigee), 1864 km (apogee) and 65.18° (orbital inclination).

The launches of Sputnik-1 and Sputnik-2 had both surprised and embarrassed the Americans as they had no successful satellite launch to their credit till then. They were more than eager to catch up. Explorer-1 (Figure 1.8) was the first satellite to be successfully launched by the United States. It was launched on 31 January 1958 by Jupiter-C rocket from

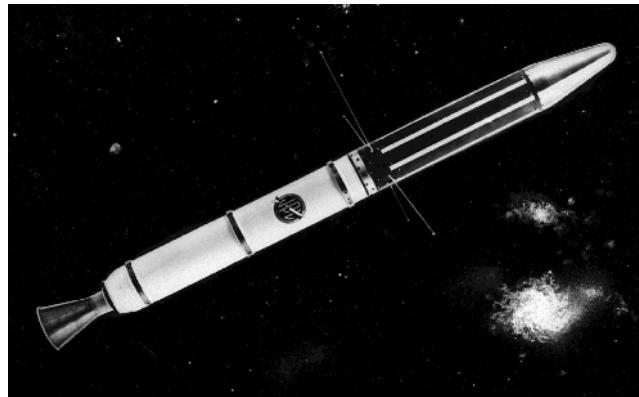


Figure 1.8 Explorer-1 (Courtesy: NASA/JPL-Caltech)

Cape Canaveral. The satellite orbital parameters were 360 km (perigee), 2534 km (apogee) and 33.24° (orbital inclination). Explorer's design was pencil-shaped, which allowed it to spin like a bullet as it orbited the earth. The spinning motion provided stability to the satellite while in orbit. Incidentally, spin stabilization is one of the established techniques of satellite stabilization. During its mission, it discovered that Earth is girdled by a radiation belt trapped by the magnetic field.

After the successful launch of Explorer-1, there followed in quick succession the launches of Vanguard-1 on 5 February 1958, Explorer-2 on 5 March 1958 and Vanguard-1 (TV-4) on 17 March 1958 (Figure 1.9). The Vanguard-1 and Explorer-2 launches were unsuccessful. The Vanguard-1 (TV-4) launch was successful. It was the first satellite to employ solar cells

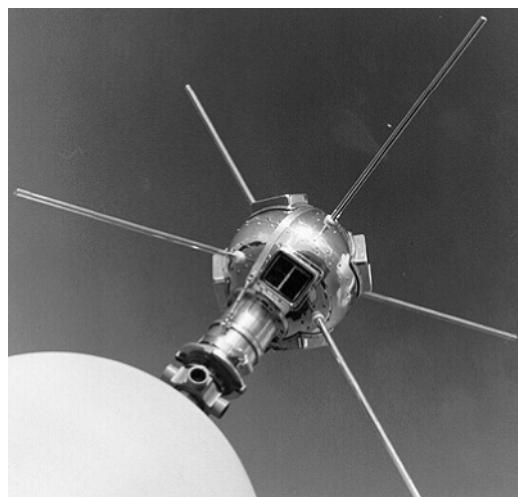


Figure 1.9 Vanguard-1 (Courtesy: NASA)

to charge the batteries. The orbital parameters were 404 km (perigee), 2465 km (apogee) and 34.25° (orbit inclination). The mission carried out geodetic studies and revealed that Earth was pear-shaped.

1.3.3 Satellites for Communications, Meteorology and Scientific Exploration – Early Developments

Soviet experiences with the series of Sputnik launches and American experiences with the launches of the Vanguard and Explorer series of satellites had taken satellite and satellite launch technology to sufficient maturity. The two superpowers by then were busy extending the use of satellites to other possible areas such as communications, weather forecasting, navigation and so on. The 1960–1965 period saw the launches of experimental satellites for the above-mentioned applications. 1960 was a very busy year for the purpose. It saw the successful launches of the first weather satellite in the form of TIROS-1 (television and imaged observation satellite) (Figure 1.10) on 1 April 1960, the first experimental navigation satellite Transit-1B on 13 April 1960, the first experimental infrared surveillance satellite MIDAS-2 on 24 May 1960, the first experimental passive communications satellite Echo-1 (Figure 1.11) on 14 August 1960 and the active repeater communications satellite Courier-1B (Figure 1.12) on 4 October 1960. In addition, that year also saw successful launches of Sputnik-5 and Sputnik-6 in August and December respectively.



Figure 1.10 TIROS-1 (Courtesy: NASA)

While the satellite TIROS-1 with two vidicon cameras on board provided the first pictures of Earth, the Transit series of satellites was designed to provide navigational aids to the US Navy with positional accuracy approaching 160 m. The Echo series of satellites, which were aluminized Mylar balloons acting as passive reflectors to be more precise, established how two distantly located stations on Earth could communicate with each other through a space-borne passive reflector was followed by Courier-1B, which established the active repeater concept. The MIDAS (missile defense alarm system) series early warning satellites established beyond any doubt the importance of surveillance from space-borne platforms to



Figure 1.11 Echo-1 (Courtesy: NASA)



Figure 1.12 Courier-1B (Courtesy: US Army)

locate and identify the strategic weapon development programme of an adversary. Sputnik-5 and Sputnik-6 further studied the biological effect of orbital flights. Each spacecraft had carried two dog passengers.

1.3.4 Nongeosynchronous Communication Satellites: Telstar and Relay Programmes

Having established the concept of passive and active repeater stations to relay communication signals, the next important phase in satellite history was the use of nongeostationary satellites for intercontinental communication services. The process was initiated by the American

Telephone and Telegraph (AT&T) seeking permission from the Federal Communications Commission (FCC) to launch an experimental communications satellite. This gave birth to the Telstar series of satellites. The Relay series of satellites that followed the Telstar series also belonged to the same class.

In the Telstar series, Telstar-1 (Figure 1.13), the first true communications satellite and also the first commercially funded satellite, was launched on 10 July 1962, followed a year later by Telstar-2 on 7 May 1963. Telstar-2 had a higher orbit to reduce exposure to the damaging effect of the radiation belt. The Telstar-1 with its orbit at 952 km (perigee) and 5632 km (apogee) and an inclination of 44.79° began the revolution in global TV communication from a nongeosynchronous orbit. It linked the United States and Europe.

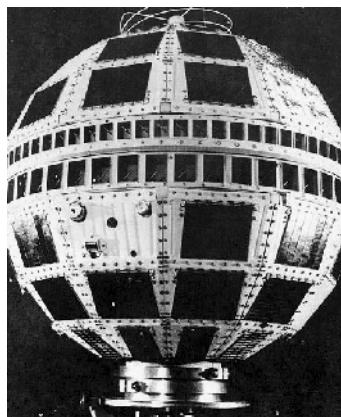


Figure 1.13 Telstar-1 (Courtesy: NASA)

Telstar-1 was followed by Relay-1 (NASA prototype of an operational communication satellite) launched on 13 December 1962. Relay-2, the next satellite in the series, was launched on 21 January 1964. The orbital parameters of Relay-1 were 1322 km (perigee), 7439 km (apogee) and 47.49° (inclination). The mission objectives were to test the transmissions of television, telephone, facsimile and digital data.

It is worthwhile mentioning here that both the Telstar and Relay series of satellites were experimental vehicles designed to discover the limits of satellite performance and were just a prelude to much bigger events to follow. For instance, through Telstar missions, scientists came to discover how damaging the radiation could be to solar cells. Though the problem has been largely overcome through intense research, it still continues to be the limiting factor on satellite life.

1.3.5 Emergence of Geosynchronous Communication Satellites

The next major milestone in the history of satellite technology was Arthur C. Clarke's idea becoming a reality. The golden era of geosynchronous satellites began with the advent of

the SYNCOM (an acronym for synchronous communication satellite) series of satellites at the Hughes Aircraft Company. This compact spin-stabilized satellite was first shown at the Paris Air Show in 1961. SYNCOM-1 was launched in February 1963 but the mission failed shortly thereafter. SYNCOM-2 (Figure 1.14), launched on 26 July 1963, became the first operational geosynchronous communication satellite. It was followed by SYNCOM-3, which was placed directly over the equator near the international date line on 19 August 1964. It was used to broadcast live the opening ceremonies of the Tokyo Olympics. That was the first time the world began to see the words ‘live via satellite’ on their television screens.



Figure 1.14 SYNCOM-2 (Courtesy: NASA)

Another significant development during this time was the formation of INTELSAT (International Telecommunications Satellite Organization) in August 1964 with COMSAT (Communication Satellite Corporation) as its operational arm. INTELSAT achieved a major milestone with the launch of the Intelsat-1 satellite, better known as ‘Early Bird’ (Figure 1.15), on 5 April 1965 from Cape Canaveral. Early Bird was the first geostationary communications satellite in commercial service. It went into regular service in June 1965 and provided 240 telephone circuits for connectivity between Europe and North America. Though designed for an expected life span of only 18 months, it remained in service for more than three years.

While the Americans established their capability in launching communications satellites through launches of SYNCOM and Early Bird during the 1960–1965 era, the Soviets did so through their Molniya series of satellites beginning April 1965. The Molniya series of satellites (Figure 1.16) were unique in providing uninterrupted 24 hours a day communications services without being in a conventional geostationary orbit. These satellites pursued highly inclined and elliptical orbits, known as the Molniya orbit (Figure 1.17),

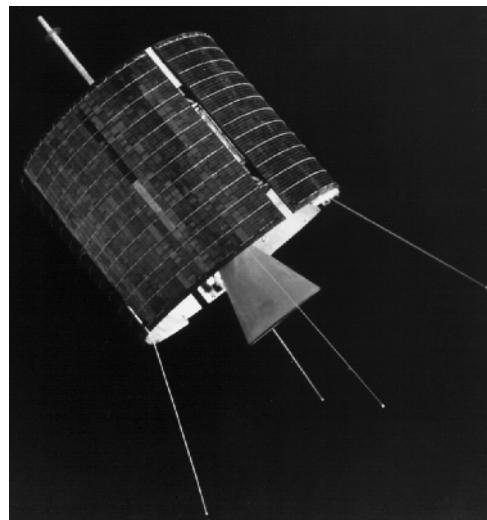


Figure 1.15 Intelsat-1 (Reproduced by permission of Intelsat)

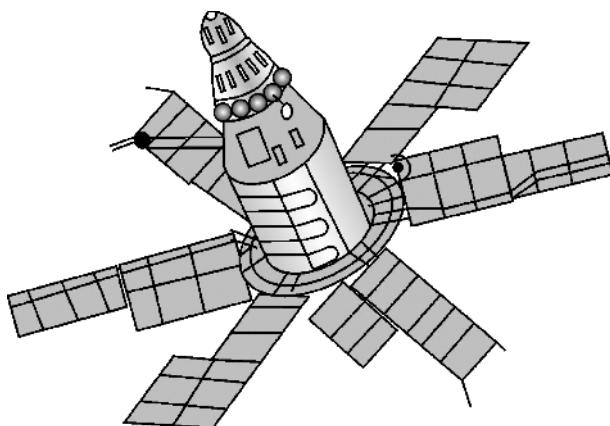


Figure 1.16 Molniya series satellite

with apogee and perigee distances of about 40 000 and 500 km and orbit inclination of 65°. Two or three such satellites spaced equally apart in the orbit provided uninterrupted service. Satellites in such an orbit with a 12 hour orbital period remained over the countries of the former Soviet bloc in the northern hemisphere for more than 8 hours. The Molniya-1 series was followed later by the Molniya-2 (in 1971) and the Molniya-3 series (in 1974).

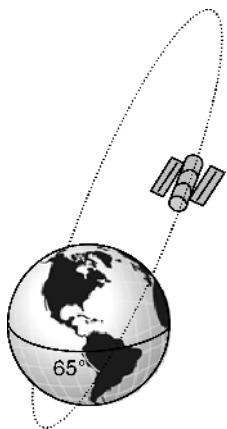


Figure 1.17 Molniya orbit

1.3.6 International Communication Satellite Systems

The Intelsat-1 satellite was followed by the Intelsat-2 series of satellites. Four Intelsat-2 satellites were launched in a span of one year from 1966 to 1967. The next major milestone *vis-à-vis* communication satellites was achieved with the Intelsat-3 series of satellites (Figure 1.18) becoming fully operational. The first satellite in the Intelsat-3 series was launched in 1968. These satellites were positioned over three main oceanic regions, namely the Atlantic, the Pacific and the Indian Oceans, and by 1969 they were providing global coverage for the first time. The other new concept tried successfully with these satellites was the use of a de-spun antenna structure, which allowed the use of a highly



Figure 1.18 Intelsat-3 (Reproduced by permission of Intelsat)

directional antenna on a spin-stabilized satellite. The satellites in the Intelsat-1 and Intelsat-2 series had used omnidirectional antennas.

The communication satellites' capabilities continued to increase with almost every new venture. With the Intelsat-4 series (Figure 1.19), the first of which was launched in 1971, the satellite capacity got a big boost. Intelsat-4A also introduced the concept of frequency re-use. The frequency re-use feature was taken to another dimension in the Intelsat-5 series with the use of polarization discrimination. While frequency re-use, i.e. use of the same frequency band, was possible when two footprints were spatially apart, dual polarization allowed the re-use of the same frequency band within the same footprint. The Intelsat-5 satellites (Figure 1.20), the first of which was launched in 1980, used both C band and

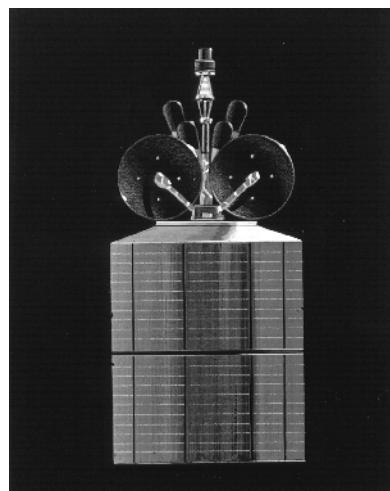


Figure 1.19 Intelsat-4 (Reproduced by permission of Intelsat)



Figure 1.20 Intelsat-5 (Reproduced by permission of Intelsat)

Ku band transponders and were three-axis stabilized. The satellite transponder capacity has continued to increase through the Intelsat-6, Intelsat-7 and Intelsat-8 series of satellites during the 1980s and 1990s. The FOS-2 (Follow-on satellites) series beginning in the year 2000 is the latest from the United States.

The Russians have also continued their march towards development and launching of communication satellites after their success with the Molniya series. The Raduga series (International designation: Statsionar-1), the Ekran series (international designation: Statsionar-T), shown in Figure 1.21, and the Gorizont series (international designation: Horizon) are the latest in communication satellites from the Russians. All three employ the geostationary orbit.

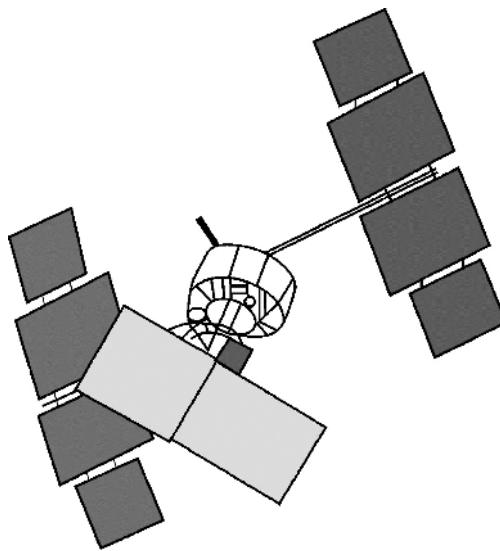


Figure 1.21 Ekran series

1.3.7 Domestic Communication Satellite Systems

Beginning in 1965, the Molniya series of satellites established the usefulness of a domestic communications satellite system when it provided communications connectivity to a large number of republics spread over the enormous land-mass of the former Soviet Union. Such a system was particularly attractive to countries having a vast territory. Canada was the first non-Soviet country to have a dedicated domestic satellite system with the launch of the Anik-A series of satellites (Figure 1.22), beginning in 1972. The capabilities of these satellites were subsequently augmented with the successive series of Anik satellites, named Anik-B (beginning 1978), Anik-C (beginning 1982), Anik-D (also beginning 1982), Anik-E (beginning 1991) and Anik-F (beginning 2000).

The United States began its campaign with the launch of Westar in 1974, Satcom in 1975 and Comstar in 1976. Satcom was also incidentally the first three-axis body-stabilized



Figure 1.22 Anik-A (Courtesy: Telesat)

geostationary satellite. These were followed by many more ventures. Europe began with the European communications satellite (ECS series) and followed it with the Eutelsat-II series of satellites (Figure 1.23).



Figure 1.23 Eutelsat-II (Reproduced by permission of Eutelsat)

Indonesia was the first developing nation to recognize the potential of a domestic communication satellite system and had the first of the Palapa satellites placed in orbit in 1977 to link her scattered island nation. The Palapa series of satellites have so far seen three generations named Palapa-A (beginning 1977), Palapa-B (beginning 1984) and Palapa-C (beginning 1991).

India, China, Saudi Arabia, Brazil, Mexico and Japan followed suit with their respective domestic communication satellite systems. India began with the INSAT-1 series of satellites in 1981 and has already entered the fourth generation of satellites with the INSAT-4 series. INSAT-4A (Figure 1.24), the latest in the series, was launched in December 2005. Arabsat, which links the countries of the Arab League, has also entered the third generation with the Arabsat-3 series of satellites.



Figure 1.24 INSAT-4A (Courtesy: ISRO)

1.3.8 Satellites for other Applications also make Rapid Progress

The intention to use satellites for applications other than communications was very evident, even in the early stages of development of satellites. A large number of satellites were launched mainly by the former Soviet Union and the United States for meteorological studies, navigation, surveillance and earth observation during the 1960s.

Making a modest beginning with the TIROS series, meteorological satellites have come a long way both in terms of the number of satellites launched for the purpose and also advances in the technology of sensors used on these satellites. Both low Earth as well as geostationary orbits have been utilized in the case of satellites launched for weather forecasting applications. Major nongeostationary weather satellite systems that have evolved over the years include the TIROS (television and infrared observation satellite) series and the Nimbus series beginning around 1960, the ESSA (Environmental Science Service Administration) series (Figure 1.25) beginning around 1966, the NOAA (National Oceanic and Atmospheric Administration) series beginning in 1970, the DMSP (Defense Meteorological Satellite Program) series initiated in 1965 (all from the United States), the Meteor series beginning in 1969 from Russia and the Feng Yun series beginning 1988 from China. Major meteorological satellites in the geostationary category include the GMS (geostationary meteorological satellite) series from Japan since 1977, the GOES (geostationary operational environmental satellite) series from the United States (Figure 1.26) since 1975, the METEOSAT (meteorological satellite) series from Europe since 1977 (Figure 1.27), the INSAT (Indian satellite) series from India since 1982 (Figure 1.28) and the Feng Yun series from China since 1997.

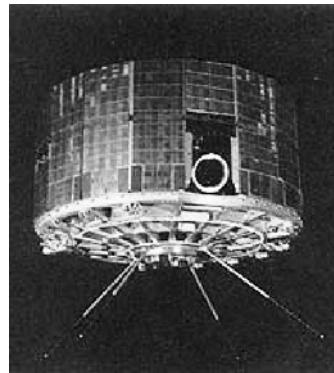


Figure 1.25 ESSA satellites (Courtesy: NASA)

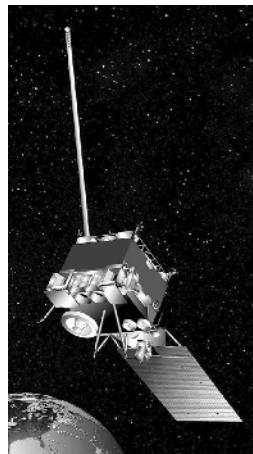


Figure 1.26 GOES satellite (Courtesy: NOAA and NASA)

Sensors used on these satellites have also seen many technological advances, both in types of sensors used as well as in performance levels. While early TIROS series satellites used only television cameras, a modern weather satellite has a variety of sensors with each one having a dedicated function to perform. These satellites provide very high resolution images of cloud cover and Earth in visible and infrared parts of the spectrum and thus help generate data on cloud formation, tropical storms, hurricanes, likelihood of forest fires, temperature profiles, snow cover and so on.

Remote sensing satellites have also come a long way since the early 1970s with the launch of the first of the series of Landsat satellites that gave detailed attention to various aspects of observing the planet Earth from a spaced platform. In fact, the initial ideas of having satellites for this purpose came from the black and white television images of Earth beneath the cloud cover as sent by the TIROS weather satellite back in 1960, followed by

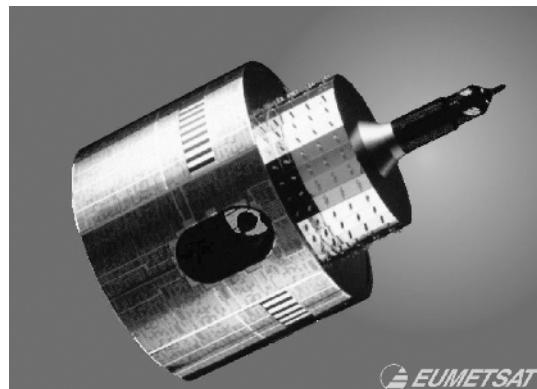


Figure 1.27 METEOSAT series (Reproduced by permission of Copyright 2005 © EUMETSAT)

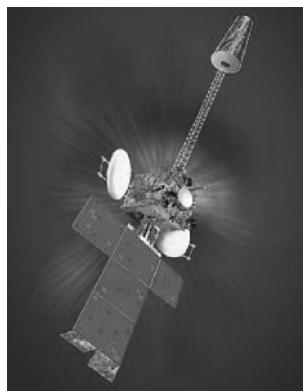


Figure 1.28 INSAT series (Courtesy: ISRO)

stunning observations revealed by Astronaut Gordon Cooper during his flight in a Mercury capsule in 1963 when he claimed to have seen roads, buildings and even smoke coming out of chimneys from an altitude of more than 160 km. His claims were subsequently verified during successive exploratory space missions.

Over the years, with significant advances in various technologies, the application spectrum of Earth observation or remote sensing satellites has expanded very rapidly from just terrain mapping called cartography to forecasting agricultural crop yield, forestry, oceanography, pollution monitoring, ice reconnaissance and so on. The Landsat series from the United States, the SPOT (satellite pour l'observation de la terre) series from France and the IRS (Indian remote sensing satellite) series from India are some of the major earth observation satellites. The Landsat programme, beginning with Landsat-I in 1972, has at the time of writing this book progressed to Landsat-7 (Figure 1.29) as the latest in the series, which was launched in 1999. The SPOT series has also come a long way, beginning with SPOT-1

in 1986 to SPOT-5 (Figure 1.30) launched 2002. The IRS series launches began in 1988 with the launch of IRS-1A, with the most recent in the series being IRS-P5, called Cartosat, launched in 2002, and IRS-P6, called Resourcesat (Figure 1.31), launched in 2003. Sensors on board modern Earth observation satellites include high resolution TV cameras, multispectral

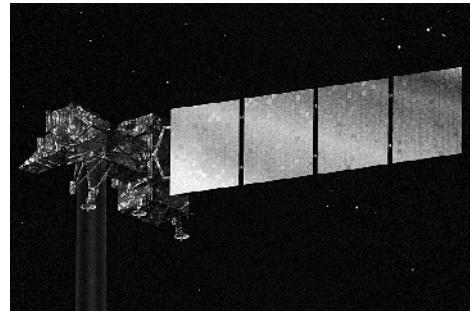


Figure 1.29 Landsat-7 (Courtesy: NASA)



Figure 1.30 SPOT-5 (© CNES/ill. D. DUCROS, 2002)



Figure 1.31 Resourcesat (Courtesy: ISRO)

scanners (MSSs), very high resolution radiometers (VHRRs), a thematic mapper (TM) and a synthetic aperture radar (SAR).

1.4 Evolution of Launch Vehicles

Satellite launch vehicles have also seen various stages of evolution in order to meet launch demands of different categories of satellites. Both smaller launch vehicles capable of launching satellites in low Earth orbits and giant sized launch vehicles that can deploy multiple satellites in geostationary transfer orbit have seen improvements in their design over the last four decades of their history. The need to develop launch vehicles by countries like the United States and Russia was in the earlier stages targeted to acquire technological superiority in space technology. This led them to use the missile technology developed during the Second World War era to build launch vehicles. This was followed by their desire to have the capability to launch bigger satellites to higher orbits. The next phase was to innovate and improve the technology to an extent that these vehicles became economically viable, which meant that the attainment of mission objectives justified the costs involved in building the launch vehicle. The technological maturity in launch vehicle design backed by an ever-increasing success rate led to these vehicles being used for offering similar services to other nations who did not possess them.

The situation in different countries involved in developing launch vehicles is different. On the one hand, there are nations keen to become self-reliant and attain a certain level of autonomy in this area; there are others whose commercial activities complement a significant part of their national activity.

Beginning with a one-stage R-7 rocket (named Semyorka) that launched Sputnik-1 into its orbit in 1957, Russia has developed a large number of launch vehicles for various applications. Some of the prominent ones include the Vostok series, the Molniya series (Figure 1.32), the Soyuz series, the Proton series (Figure 1.33), the Zenit series and Energia (Figure 1.34). Energia is capable of placing a payload of 65 to 200 tonnes in a low Earth orbit.

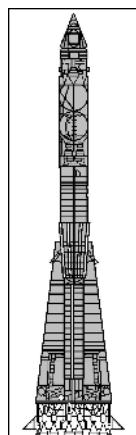


Figure 1.32 Molniya series (Reproduced by permission of Mark Wade)



Figure 1.33 Proton series (Courtesy: NASA)

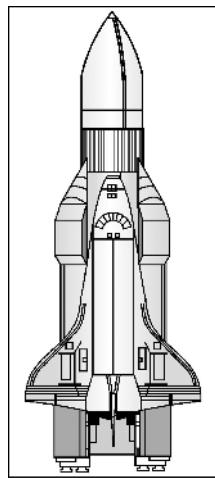


Figure 1.34 Energia series (Reproduced by permission of Mark Wade)

Important launch vehicles developed by the United States include the Delta series (Figure 1.35), the Atlas series, the Titan series (Figure 1.36), the Pegasus series and the re-usable famous Space Shuttle (Figure 1.37). Buran (Figure 1.38) from Russia is another re-usable vehicle similar in design and even dimensions to the American Space Shuttle. The main difference between the two lies in the fact that Buran does not have its own propulsion system and is launched into orbit by Energia. The Ariane launch vehicle from the European Space Agency (ESA) has entered the fifth generation of satellites with the Ariane-5 heavy

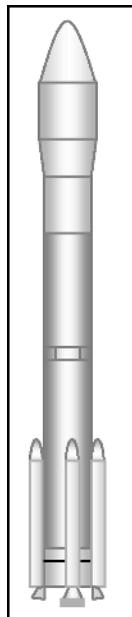


Figure 1.35 Delta series



Figure 1.36 Titan series (Courtesy: NASA/JPL-Caltech)



Figure 1.37 Space Shuttle (Courtesy: NASA)

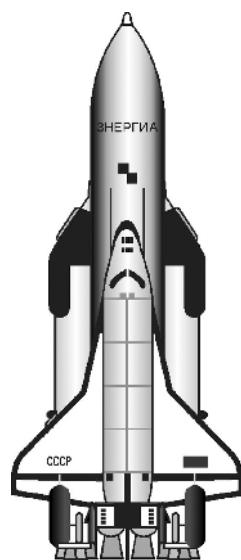


Figure 1.38 Buran series

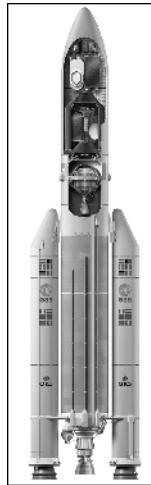


Figure 1.39 Ariane-5ECA (Courtesy: ESA-D.DUCROS)

launch vehicle, with Ariane-5 ECB (Enhanced Capability-B) (Figure 1.39) having a capacity of 12 tonnes to the geostationary transfer orbit.

Long March (Figure 1.40) from China, the PSLV (polar satellite launch vehicle) and the GSLV (geostationary satellite launch vehicle) (Figure 1.41) from India and the H-2 series from Japan are some of the other operational launch vehicles.

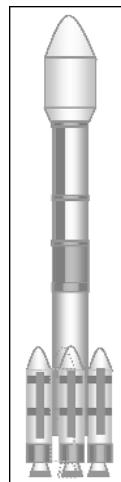


Figure 1.40 Long March



Figure 1.41 GSLV (Courtesy: ISRO)

Further Reading

Labrador, V. and Galace, P. (2005) *Heavens Fill with Commerce: A Brief History of the Communications Satellite Industry*, Satnews Publishers, California.

Internet Sites

1. <http://electronics.howstuffworks.com/satellite.htm/printable>
2. <http://www.aero.org/publications/gilmore/gilmore-1.html>
3. http://www.thetech.org/exhibits_events/online/satellite/home.html
4. www.intelsat.com
5. www.isro.org
6. www.nasa.gov

Glossary

Ariane: European Space Agency's launch vehicle

Astronaut: A space traveller, i.e. a person who flies in space either as a crew member or a passenger

Astrophysics: Study of the physical and chemical nature of celestial bodies and their environs

Buran: A re-usable launch vehicle, Russian counterpart of a space shuttle

Early Bird: Other name for Intelsat-1. First geostationary communications satellite in commercial service

Explorer-1: First successful satellite from the United States

Footprint: The area of coverage of a satellite

Geostationary orbit: An equatorial circular orbit in which the satellite moves from west to east with a velocity such that it remains stationary with respect to a point on the equator. Also known as the Clarke orbit after the name of the science fiction writer who first proposed this orbit

GPS: An abbreviation for the global positioning system. It is a satellite-based navigation system that allows you to know your position coordinates with the help of a receiver anywhere in the world under any weather condition

GSLV: Abbreviation for geostationary satellite launch vehicle. Launch vehicle from India

INTELSAT: Acronym for International Telecommunications Satellite Consortium operating satellites internationally for both domestic and international telecommunication services

Landsat: First remote sensing satellite series

Molniya orbit: A highly inclined and elliptical orbit used by Russian satellites with apogee and perigee distances of about 40 000 and 500 km and an orbit inclination of 65°. Two or three such satellites spaced equally apart in the orbit provide an uninterrupted communication service

Multispectral scanner (MSS): A multispectral scanning device that uses an oscillating mirror to continuously scan Earth passing beneath the spacecraft

NASA: National Aeronautics and Space Administration

Palapa: First domestic communication satellite from a developing country

Payload: Useful cargo-like satellite being a payload of a launch vehicle

Satellite: A natural or artificial body moving around a celestial body

Sounding rocket: A research rocket used to obtain data from the upper atmosphere

Space shuttle: A re-usable launch vehicle from the United States

Spin-stabilized satellite: A satellite whose attitude stabilization is achieved by the spinning motion of the satellite. It employs the gyroscopic or spinning top principle

Sputnik-1: First artificial satellite launched by any country. Launched on 4 October 1957

Thematic mapper: A type of scanning sensor used on Earth observation satellites

Three-axis stabilized satellite: A satellite whose attitude is stabilized by an active control system that applies small forces to the body of the spacecraft to correct any undesired changes in its orientation

TIROS: First series of weather forecast satellites

Transponder: A piece of radio equipment that receives a signal from the Earth station at the uplink frequency, amplifies it and then retransmits the same signal at the downlink frequency

Westar: First domestic communication satellite from the United States

