From the hands of mankind came the Satellites

By Lloyd Butler VK5BR

A multitude of man made Satellites orbit the earth enabling communications, weather forecasting, navigation and many other operations not possible at earth ground level. The article gives a broad picture of the operations of these satellites since they were first introduced in the 1950's and continue today.

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Introduction

A satellite is a moon, planet or machine that orbits a planet or star. For example, Earth is a satellite because it orbits the sun. Likewise, the moon is a satellite because it orbits Earth. Usually, the word "satellite" refers to a machine that is launched into space and moves around Earth or another body in space. Thousands of artificial, or man- made, satellites orbit Earth. The bird's-eye view that a satellite has allows it to see large areas of Earth and relay radio signals between points in that area..

I had no intention of getting into discussion concerning satellites which orbit planets or stars. But I have set out to find out what I could about satellites which have been put into orbit around the earth by mankind and the various functions that those satellites carry out. The article documents information I have obtained from various sources.

The number of man made satellites varies continuously in space with new ones added and others dropping out of service. According to the late 2018 Index of Objects Launched into Outer Space maintained by the United Nations Office for Outer Space Affairs (UNOOSA), there were 4857 satellites currently orbiting the planet. This is an increase of 4.79% compared to the those of the previous year. Of these there were currently 1980 active satellites in orbit, leaving 2877 no longer used as pieces of metal, hurtling around the Earth at high speed.

Mankind has launched satellites to carry out various roles:
.Satellite navigation - The Global Positioning System (GPS) and for Telemetry
.Telephone & TV signals relay
.Weather Forecasting
.General Science for monitoring and Defence
,And 60% of the total are used for communications (including Amateur Radio)

Russia (USSR) launched the first man made satellite, Sputnik 1 which was the size of a basketball. Put into orbit on the 4th of October 1957, it carried a radio beacon transmitting on the frequency of 20.005 MHz. This could be received by a sensitive short wave receiver on the earth. Many people heard the beep-beep-beep sound from this satellite as it orbited around the Earth every 90 minutes or so.

USA followed with the launch of satellite Explorer 1 on January 31, 1958. using its Jupiter C rocket, This was launched by the U.S. Army Ballistic Missile Agency and developed under the direction of German scientist Wernher Von Braun, who had worked on the V-2 missile programme during World War II. This satelitte was twice the size of the Sputnik and it was an important event for the U.S.A., as the Space Race with the Soviet Union was just beginning.

In 1967, The Australian-built Weapons Research Establishment Satellite WRESAT was successfully launched into orbit from Woomera using a Redstone Rocket. This made Australia the third country, after the former USSR and USA, to launch a satellite to orbit from its own territory.

As recorded in 2014, the oldest satellite, still in orbit, was launched in 1958. One report (date not shown) recorded that 50 countries owned satellites. USA had about 502, Russia about 118, and China about 116.

Satellites for different functions orbit at different heights above the earths surface. Here are some general figures:
.Communications - 35,200 Km
.GPS - 19,840 Km
.International Space Station - 416 Km

The Global Positioning System (GPS)

The Global Positioning System, originally Navstar GPS, is a satellite-based radio-navigation system owned by the United States government and operated by the United States Air Force. The GPS project was launched by the U.S. Department of Defense in 1973 for use by the United States military and became fully operational in 1995. It was allowed for civilian use in the 1980s.

The GPS does not require the user to transmit any data, and it operates independently of any telephonic or internet reception. As of early 2015, high-quality radio navigation GPS receivers provided horizontal accuracy at ground locations of better than 3.5 meters. As it stands, Australians generally get uncorrected GPS signals that are accurate to five metres. However, there seems to be moves in hand to improve accuracy to around one metre.

GPS operates in Satellite Constellation, that is, a group of satellites working in concert with synchronized overlap ground coverage. The baseline satellite constellation consists of 24 satellites positioned in six earth-centered orbital planes with four operation satellites and a spare satellite slot in each orbital plane. The system can support a constellation of up to thirty satellites in orbit.

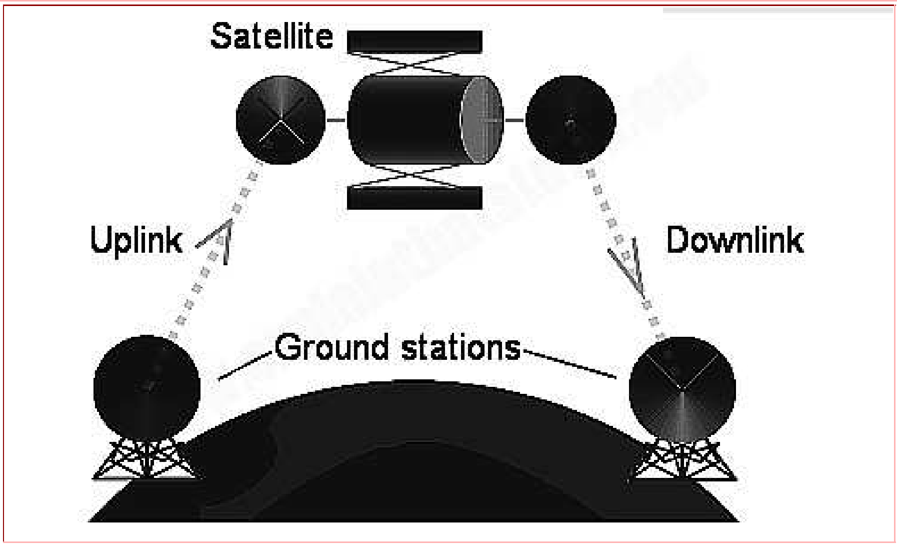
A geosynchronous satellite is a satellite in geosynchronous orbit, with an orbital period the same as the Earth's rotation period. Such a satellite returns to the same position in the sky after each sidereal day, and over the course of a day, traces out a path in the sky that is typically some form of analemma.

In astronomy, an analemma is a diagram showing the position of the Sun in the sky, as seen from a fixed location on Earth at the same man solar time, and as that position varies over the course of a year. The drawn diagram will resemble the figure 8. Sidereal relates to the rotation of Earth relative to the stars rather than the sun.

A special case of geosynchronous satellite is the geostationary satellite, which has a circular geosynchronous orbit directly above the Earth's equator. Another type of geosynchronous orbit used by satellites is the Tundra elliptical orbit. A tundra orbit is a highly elliptical geosynchronous orbit with a high inclination (usually near 63.4°) .

GPS navigation has largely replaced the ships and aircraft radio navigation systems, first developed in the 1930s and 1940s. GPS receivers are now fitted in many modern motor cars, taxis and transport vehicles.

Communications Satellites



Communications via Satellite

As at 2004, 1,107 satellites provided civilian communications and 792 military communications. Some seven hundred of them were placed into geosynchronous orbit. Civilian and military communications satellites represent the most numerous kind of spacecrafts launched.

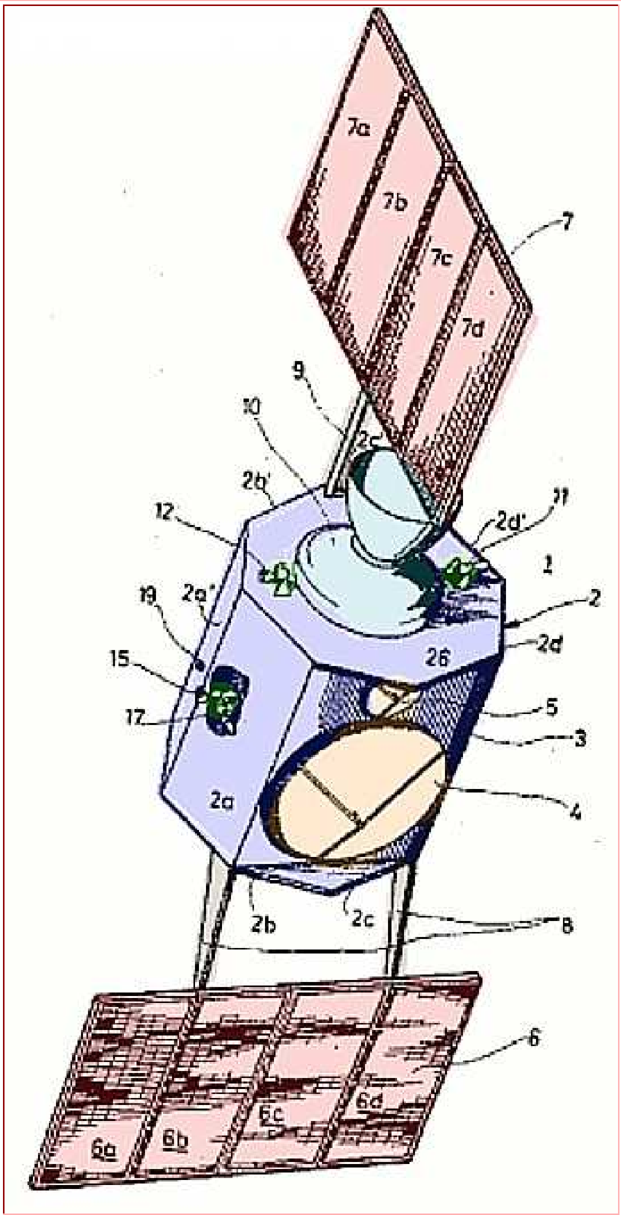
There are two major classes of communications satellites, passive and active. Passive satellites only reflect the signal coming from the source, back to the receiver. With passive satellites, the reflected signal is not amplified at the satellite, and only a very small amount of the transmitted energy actually reaches back to the receiving location. Since the satellite is so far above Earth, the radio signal is attenuated due to free-space path loss, and the signal received back to Earth is very weak. Active satellites, on the other hand, amplify the received signal before re-transmitting it back. Passive satellites were the first communications satellites, but are little used now.

The diameter of the earth is around 12,700 km. At an orbit some 35,000 km from the earth's surface, the communications satellite is able to get close to line of sight signal back, on VHF/UHF channels, over almost half the earth's surface.

Because of the large path distance to the satellite and the weak signal received on return, digital encoded signals are desirable for reliable communication. (The digital signal, with quite a limited mark to space level ratio, can be decoded at levels barely above the receiving noise floor).

The following drawing shows a typical communications satellite. This one was designed by German engineer Hans Sass who filed a patent for it in 1968. (Ref, 4). The writer of Ref. 4 included a legend of components as follows:

4: Large parabolic dish antenna for sending/receiving signals.
5: Small parabolic dish antenna for sending/receiving signals.
6: Lower solar "battery" of four solar panels.
7: Upper solar "battery" of four more solar panels.
8: Supports fold out the lower solar panels once the satellite is in orbit.
9: Supports fold out the upper solar panels.
10: Main satellite rocket motor.
11, 12, 15, 17: Small control engines keep the satellite in its precision position, spin, and orbit.



A Communications Satellite
(From Reference 4)

Weather Forecasting Satellites

Weather satellites are put into one of two kinds of orbits around the Earth, each of which has advantages (and disadvantages) for weather monitoring. The first is a "geostationary" orbit, with the satellite at a very high altitude (about 36,000 km) and orbiting over the equator at the same rate that the Earth turns.

The other orbit type is called near-polar, sun-synchronous (or just "polar"), where the satellite is put into a relatively low altitude orbit (around 800 km) that carries the satellite near the North Pole and the South Pole approximately every 100 minutes. Unlike the geostationary orbit, the polar orbit allows complete Earth coverage as the Earth turns beneath it.

Only a few countries : Canada, China, India, Japan, Russia, the Republic of Korea and U.S.A., or groups of countries, e.g. Europe, operate meteorological satellites. However, since weather does not adhere to political boundaries, there is a high level of international co-operation in collecting and sharing satellite data among many regions and countries of the world.

National Aeronautics and Space Administration (NASA)

The NASA Kennedy Space Centre, California

NASA stands for National Aeronautics and Space Administration. NASA was started on October 1, 1958, as a part of the United States government. NASA is in charge of U.S. science and technology that has to do with airplanes or space. In 2018, NASA turned 60 years old!

NASA is involved with numerous operations, including constructing satellites. The satellites help scientists learn more about Earth. NASA sends probes into space and scientists study things in the solar system and even further distant. A new program will again send humans to explore the Moon and perhaps one day to Mars. NASA also shares what they learn with others such as their new inventions.

NASA Headquarters is in Washington, D.C. There are 10 NASA centers across the United States and also seven smaller NASA work places where they test and study Earth and space. Thousands of people work for NASA including engineers, scientists and astronauts. Astronaut Ed White was the first American to walk in space.

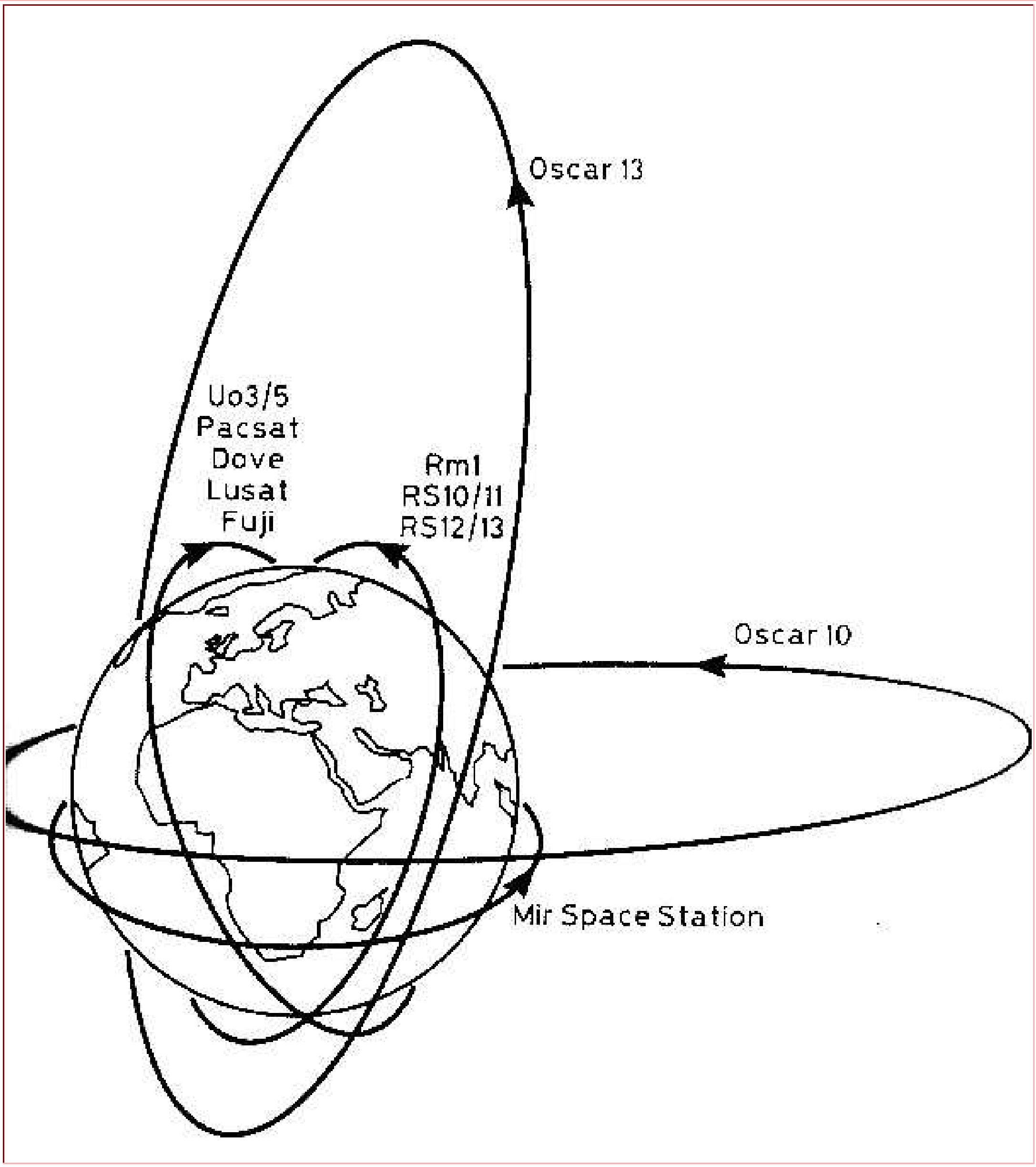
NASA initially began to plan for human spaceflight. The Mercury, Gemini and Apollo programs helped NASA learn about flying in space. This led to the first human landing on the Moon in 1969 and NASA has astronauts living and working on the International Space Station. NASA space probes have also visited every planet in the solar system and scientists have looked far into space using telescopes.

Amateur Radio Satellites

An amateur radio satellite is an artificial satellite built and used by amateur radio operators for use in the Amateur Satellite service. These satellites use amateur radio frequency allocations to facilitate communication between amateur radio stations.

A California group of Amateur Radio operators, calling itself Project OSCAR, built the first Amateur Radio satellite in 1961. The OSCAR designation is an acronym for Orbiting Satellite Carrying Amateur Radio. Since the first satellite, many following on have also been called OSCAR. The designation is assigned by AMSAT, an organization which promotes the development and launch of amateur radio satellites. Because of the prevalence of this designation, amateur radio satellites are often referred to as OSCARs.

AMSAT is a name for amateur radio satellite organizations worldwide, but in particular the Radio Amateur Satellite Corporation (AMSAT-NA) with headquarters at Kensington, Maryland, near Washington, D.C. AMSAT organizations design, build, arrange for launches, and then command the operation of satellites carrying amateur radio payloads, including the OSCAR series of satellites. Other informally affiliated national organizations exist, such as AMSAT Germany (AMSAT-DL) and AMSAT Japan (JAMSAT).



Typical Amateur Radio Satellite Orbits
(From 'Space Communications' 1989 ARRL Handbook}

Amateur satellites can be used by licensed amateur radio operators for voice (FM, SSB) and data communications (AX.25, packet radio, APRS). Currently, over 18 fully operational amateur satellites in orbit are acting as repeaters, linear transponders, or store and forward digital relays.

Throughout the years, radio amateurs who have experimented with amateur satellites, have helped develop new techniques in the science of satellite communications. A few advancements include the launch of the first satellite voice transponder (OSCAR 3), the development of highly advanced digital "store-and- voice transponder (OSCAR 3), and the development of highly advanced digital "store-and- forward" messaging transponder techniques. Around 70 Amateur Radio Satellites have been launched over four decades.

The information presented regarding functional satellites is outdated quickly as the Amateur Radio Satellite community has become very active in building new satellites and making use of educational secondary cargo launch opportunities. For current information, visit AMSAT for North America at https://www.amsat.org/ and AMSAT-UK for Europe

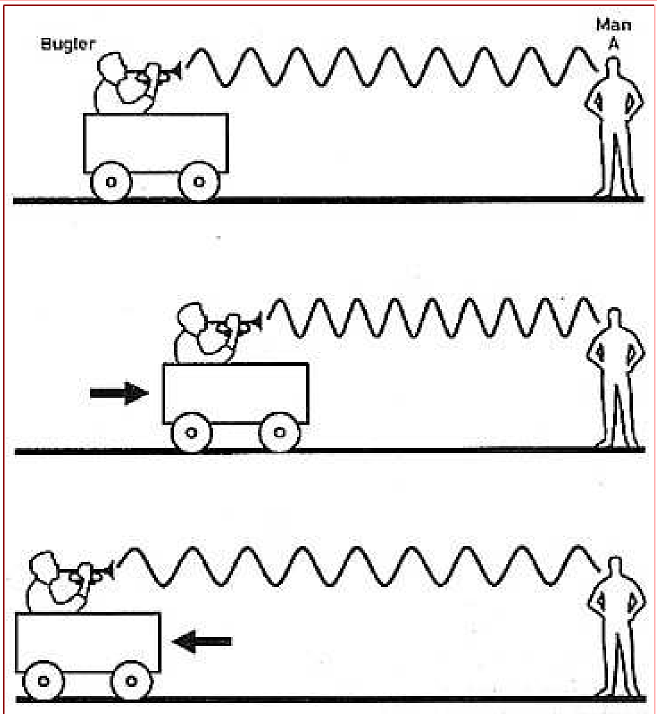
There are frequency allocations for satellite operation on 145.800 to 146.000 Mhz, 435.000 to 438.000, and 1260 to 1270 MHz. Precise allocated frequencies of amateur satellites can be found at https://www.amsat.org/fm-satellite-frequency-summary/ and the WIA Call Book. Division of bands for Up and Down links is set by defined modes as in the table.

OSCAR Operating Modes

Mode	Uplink Band	Downlink Band
A	2 m (145 MHz)	10 m (29 MHz)
B	70 cm (435 MHz)	2 m (145 MHz)
J	2 m (145 MHz)	70 cm (435 MHz)
L	24 cm (1269 MHz)	70 cm (436 MHz)
S	70 cm (436 MHz)	13 cm (2401 MHz)
JL	2 m/23 cm	70 cm
K	15 m	10 m
T	15 m	2m

OSCAR Operating Modes
(From 'Space Communications' 1989 ARRL Handbook}

One interesting effect on communicating with a satellite is the shift of carrier frequency with the movement of the satellite through space. (Doppler Effect).



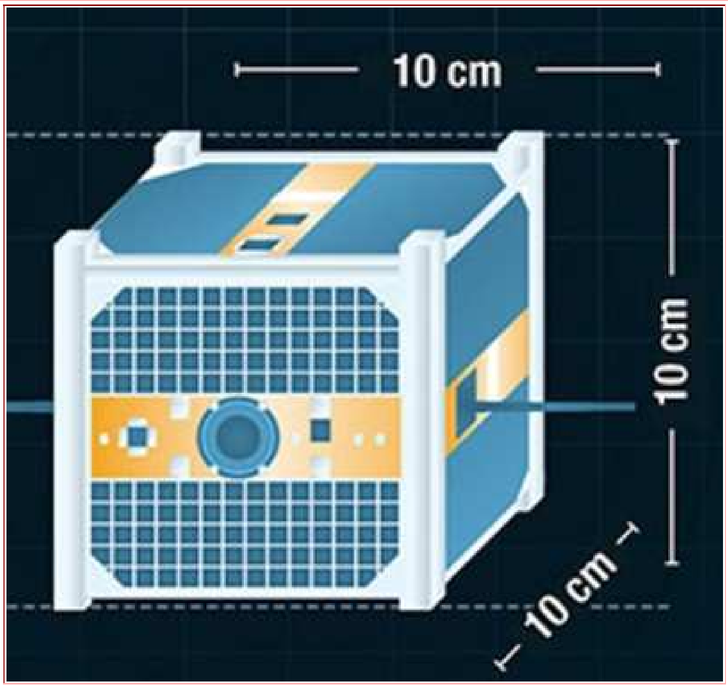
Doppler Shift illustrated at Sound Frequencies
(From Radio Communication Handbook
RSGB 1995)

Miniature Satellites (Cube Satellites)

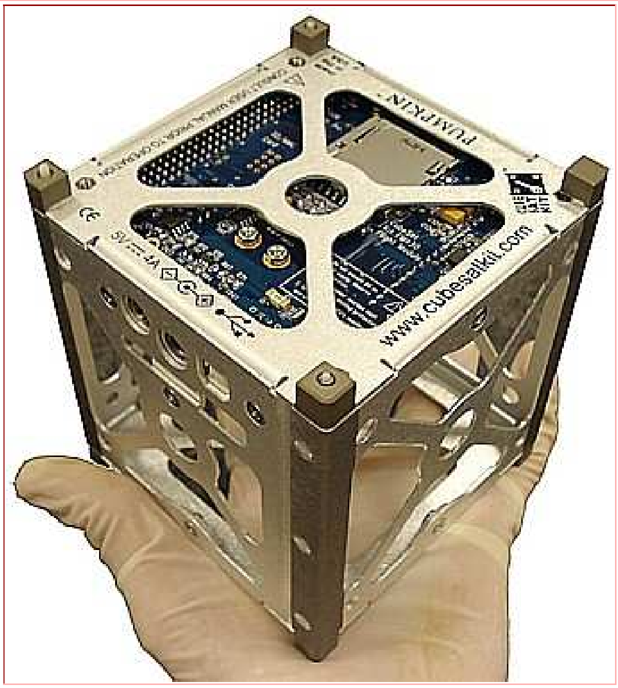
A CubeSat is a 10cm square-shaped miniature satellite weighing about 1 kgm. It can be used alone (1 unit) or in groups of multiple units. It can carry small science instruments to conduct an experiment or take measurements from space. It can provide students with a unique hands-on experience in developing space missions from design, to launch and operations. It can also be used for commercial applications, such as providing telecommunications services or capturing Earth observation images.

As at November 2018, more than 510 CubeSats had been launched into space by 50 countries.

CubeSats tend to hitch a ride into space using extra space available on rockets. They are packed in a container which, with the push of a button, activates a spring that ejects the CubeSats into space. CubeSats can also be deployed from the International Space Station by using a technique from its airlock. Like other satellites, the CubeSats can be flown alone or in a constellation network.



CubeSat Dimensions



Typical CubeSat Structure

These small satellites are attractive as they can be built within two years and are less expensive than large satellites. They are simple to design and use standard parts available off-the-shelf. For a short mission, there is no need to use thermal blankets and there is no problem of space debris as they burn up in the atmosphere upon re-entry. More detail can be found in Reference 11.

Without external vanes fitted to theCubeSat, there are limitations in powering and the provision of antennas for radio communication. The area available for solar panels and antennas is then limited to the areas on the cube (or cubes). And because of the limited antenna space, radio communication is somewhat restricted to the UHF and microwave S bands.

Typical CubeSat operation has been the building and tracking of four of the satellites by Fleet Space Technologies in South Australia. The satellites were launched via Rocket Lab at Launch Complex-1 on New Zealand's Mahia Peninsula.

Space Debris and Human Spacecraft

According to one report, more than 500,000 pieces of debris, or space junk, are tracked as they orbit the Earth. They travel at speeds up to 28,000 kmh, fast enough for a relatively small piece of orbital debris to damage a satellite or a spacecraft.

The rising population of space debris increases the potential danger to all space vehicles, but especially to the International Space Station, space shuttles and other spacecraft with humans aboard.

NASA takes the threat of collisions with space debris seriously and has a long-standing set of guidelines on how to deal with each potential collision threat. These guidelines are part of a larger body of decision-making aids known as flight rules. These specify: evasive action, or other precautions, that are needed to ensure the safety of the crew, when the expected proximity of a piece of debris increases the probability of a collision,

A number of inactive satellites either have de-orbited and came back to Earth, or have burnt up in the atmosphere. The Union of Concerned Scientists (UCS) keeps a record of the operational satellites. According to UCS, an average of about one satellite a week returns to Earth in one form or another. They say that of the 453 objects launched in 2017, only 390 of them were still in space at the end of the April 2018. (Apparently, 14% had already returned to Earth}. Of course some may have been brought back due to malfunctions. But a lot of the small satellites only have short lifespans and these could have already completed their missions.

Satellite Beacons

Satellite beacons have been used for a variety of purposes, ranging from tracking and telemetry to ground navigation and tropospheric and ionospheric research. Many amateur satellites have beacons which can be used to monitor various operational parameters of the satellite.

Most beacons carried by satellites have transmitted radio signal. However, an unusual satellite was built by Japanese engineering students in Japan. This carried a high intensity LED modulated by Morse Code to make visual patterns across the sky and be seen by a ground observer.

Space Stations

Mir was a space station that operated in low Earth orbit from 1986 to 2001, operated by the Soviet Union and later by Russia. Mir was the first modular space station and was assembled during orbit between 1986 and 1996. It had a greater mass than any previous spacecraft. At the time it was the largest artificial satellite in orbit, and was succeeded by the International Space Station (ISS) after Mir's orbit decayed. The station served as a micro-gravity research laboratory in which crews conducted experiments in biology, human biology, physics, astronomy, meteorology, and spacecraft systems with a goal of developing technologies required for permanent occupation of space. After more than 86,000 total orbits, Mir re-entered Earth's atmosphere on Friday, March

23, 2001. The 134-ton space structure broke up over the southern Pacific Ocean.

The International Space Station (ISS) is a space station, or a habitable artificial satellite, in low Earth orbit. Its first component launched into orbit in 1998, with the first long-term residents arriving in November 2000. It has been inhabited continuously since that date. The last pressurised module was fitted in 2011. The station is expected to operate until at least 2028. Development and assembly of the station continues, with components scheduled for launch in 2018 and 2019. The ISS is the largest human-made body in low Earth orbit and can often be seen with the naked eye from Earth. ISS components have been launched by Russian Proton and Soyuz rockets, and by American Space Shuttles.

The International Space Station

In May 1996, astronaut Dr Andy Thomas, born in South Australia, took his first flight into space as the payload commander and mission specialist aboard the Space Shuttle Endeavour. The functions of the space shuttles are to launch and service various satellites, service various interplanetary probes and scientific experiments in orbit and participate in construction and servicing of the International Space Station.

Communication by Earth-Moon-Earth (EME) or Moon Bounce

The moon is a satellite of the world which orbits Earth, one revolution in about 29 days, and at an average distance from the Earth centre of around 385,000 km. From about 1960, radio amateurs have been bouncing signals off the moon in the VHF, UHF and microwave amateur bands. Because of the large distance, signal attenuation on the up and down paths is very high and further attenuated by the reflection loss at the Moon, returning about 6% of the level it received..

To achieve workable signal return, radio amateurs have used high power combined with high gain directive antennas. There are a number of other factors which also intercept the signal transmission such as when the signal passes through the Ionosphere. One effect through the ionosphere is that of changing polarisation of the signal waveform (known as Faraday Rotation). This can be a problem if the changed polarisation received signal is to be received on the polarised transmitting antenna.

Summary

The science and engineering concerned with operating satellite systems in space is certainly a large subject. I have attempted to give but a broad overview of the subject.

Advancing into the satellite era in the late 1950's, was probably an initial step into introducing broadband and high speed data connection between overseas locations. The first live international satellite television production called "Our World" was circulated to the world via satellite on 25th June 1967. Connecting up satellites (and their orbits) in the form which led up to the Internet as we use it today, seemed to come together in the early 1990's.

We now have this international web of systems such as: communications, media distribution, GPS, weather forecasting and many other scientific and operational functions. But it might not be there had the space experts not learnt how to fire rockets and put the satellites in space.

On the other hand, they might still have established the data transporting systems, perhaps a bit further down the track. This is because fibre optic transmission systems have been under development and in particular, tthe launching of those undersea fibre optic cables. The first inter-continent fibre optic cable was laid across the Atlantic Ocean in 1988. Since then, many undersea fibre optic cables have been laid across oceans all over the world and now carry much of the communications data previously confined to satellite links.

Clearly we need satellites for functions such as weather forecasting and navigation (GPS). But perhaps we don't need so many for communications as are now in orbit. Much like the plastic junk which pollutes the seas, we could well do without much of the dead metal junk which now pollutes our earth's outer space.

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