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SUPARCO

BEGINNER'S GUIDE TO SPACE

A PUBLICATION OF
PAKISTAN SPACE & UPPER ATMOSPHERE RESEARCH COMMISSION

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PUBLICATION

Pakistan Space & Upper Atmosphere
Research Commission

REVIEW AND EDITING TEAM

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OUR UNIVERSE

1.1 OUR SOLAR SYSTEM

The Solar System

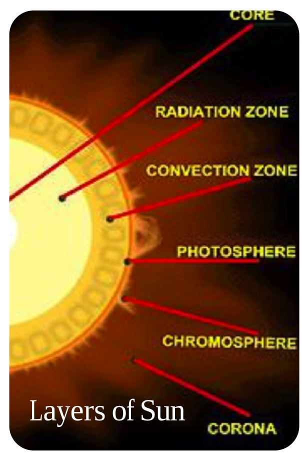
Our solar system is the one we know the most about. The Sun is at its centre. Our solar system includes everything that orbits or goes around the Sun. Planets, moons, asteroids; comets and dust are all part of the solar system. Our solar system lies near the edge of the Milky Way galaxy. The Milky Way is shaped like a whirlpool. All the stars in the galaxy, including our Sun, orbit around the centre of the Milky Way. With the discovery of Pluto in 1930, astronomers considered the Solar System to have nine planets. Pluto was classified as the ninth planet and it remained so for 75 years but in 2006, International Astronomical Union classified Pluto as a 'dwarf planet' due to its smaller mass. In view of this, our solar system now consists of eight planets. Mercury, Venus, Earth and Mars are known as the inner planets, as they are nearest to the sun. They form a group of rocky planets. The outer planets are Jupiter, Saturn, Uranus and Neptune.

1.1.1 The Sun


The Sun

The sun is a bright star, and it is the largest object in our solar system. At sunset or sunrise when it is safe to look at the sun, we can see the sun's photosphere, the level in the sun from which visible photons escape most easily. Dark sunspots come and go on the sun but only rarely are they large enough to be visible to the unaided eye.

The solar atmosphere consists of three layers of hot, low-density gas: the photosphere, chromosphere, and corona. The granulation of the photosphere is produced by convection currents of hot gas rising from below. Larger super-granules appear to be caused by larger convection currents deeper in the sun. The chromosphere is most easily visible during total solar eclipses, when it flashes into view for a few seconds. It is a thin, hot layer of gas just above the photosphere, and its pink color is caused by the Balmer emission lines in its spectrum. Filtergrams of the chromosphere reveal spicules, flame like structures extending upward into the lower corona. The corona is the sun's outermost atmospheric layer and can be imaged using a coronagraph. It is composed of a very-low-density; very hot gas extending many solar radii from the visible sun. It's high temperature — over 2 million K — is believed to be maintained by the magnetic field extending up through the photosphere — the magnetic carpet— and by magnetic waves coming from below the photosphere. Parts of the corona give rise to the solar wind, a breeze of low density ionized gas streaming away from the sun.



Layers of Sun

Astronomers can study the motion, density, and temperature of gases inside the sun by analyzing the way the solar surface oscillates. Known as helioseismology, this field of study requires large amounts of data and extensive computer analysis.

Nuclear reactors on Earth generate energy through nuclear fission, during which large nuclei such as uranium break into smaller fragments called fission. The sun generates its energy through nuclear fusion, during which hydrogen nuclei fuse to produce helium nuclei. In nuclear fission or nuclear fusion, the energy comes from the strong force.

1.1.2 Mercury

Mercury is the closest planet to the sun. It is very hot. It is only 57,900,000 Km away from the sun. Each day lasts 59 earth days and a year lasts 88 earth days. Mercury is a world of extremes. Because it is so close to the Sun, a visitor could easily cook to death. However because Mercury spins so slowly it gets very cold in the night time, which means a visitor could also freeze to death. The average temperature on the lit side of the planet is 350°C (660°F). Mercury is so close to the Sun, and so small, that it has only a very small atmosphere. Its atmosphere has been blown away by the Sun’s solar winds. It means that there is almost no air on Mercury. Mercury has no moons. Due to its smaller size Mercury has lesser gravity. Therefore, if someone weighs 70 pounds on Earth, he would weigh only about 27 pounds on Mercury.

1.1.3 Venus

Venus is the second planet from the sun. It is the planet closest to the earth. It is almost the same size as the Earth. Apart from the moon, Venus is by far the brightest object in the night sky. The temperature of the surface is 480°C. Its thick cloud cover makes it impossible to see the surface, and traps much of the Sun's heat. This extra heat gives Venus the hottest average temperature of all the planets. There were once oceans on Venus but these have long since boiled away due to the great heat on the surface. In its early days, Venus was just like the Earth. It had oceans and may even have held life, but as it has so much carbon dioxide now, that life is not possible any more. In many ways Venus is similar to the Earth. It has active volcanoes, Venus quakes, mountains and valleys. The major difference is that Venus's atmosphere makes the planet far too hot for life. Aside from the fact that Venus rotates very slowly so that a day on Venus actually lasts longer than a year, Venus also rotates in the opposite direction as almost all the other planets. Due to this reason, the Sun instead of rising in the east and setting in the west, would appear to rise in the West, and set in the East on Venus.

Venus

1.1.4 Earth

Our planet ‘Earth’ is an oasis of life in an otherwise desolate universe. The Earth's temperature, weather, atmosphere and many other factors are just right to keep us alive. Earth is the 5th largest planet in our solar system. It is located at third position from the sun. Earth’s mass is 6.0 x 1024 Kg. Its atmosphere mainly contains 78.084% Nitrogen and 20.946% Oxygen. It takes 24 hours to rotate on its axis and 365 days to complete its one orbit around the sun. LUNA, the earth’s moon is our closest neighbour. Its average distance from earth is 384,000 km (239,000 miles). The moon takes 27 days to travel around the earth. This is the only planet we know which has life.

Earth

1.1.4.1 The Earth's Moon

The Earth's Moon

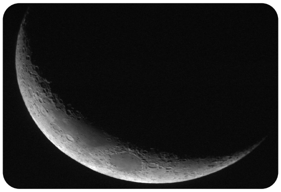
The Moon is Earth's only natural satellite. It is 2,160 miles (3,476 kilo meters) across, which is a little more than one quarter of Earth's diameter. The Moon orbits Earth once every 27.3 days.

The Moon has no atmosphere and no liquid water at its surface, so it has no wind or weather at all. On the lunar surface, there is no protection from the Sun's rays, and no ability to retain heat like the greenhouse effect on Earth. Temperature on the moon range from about 253°F (123°C) to –387°F (–233°C). The Moon's surface is covered with rocks, mountains, craters, and vast low plains called Maria ("seas").

On an average, the Moon is about 238,000 miles (384,000 kilo meters) away from Earth. This value was measured quite accurately by the ancient Greek astronomer Hipparchus, who lived in the second century B.C.E. Today, laser rangefinders have been used to measure a very precise value.

Galileo Galilei, the first astronomer to study the universe with a telescope, observed that the Moon's surface was not smooth, but rather covered with mountains and craters. The broad, dark patches on the Moon looked to him like seas on Earth, so he named them Maria, or "seas" in Latin.

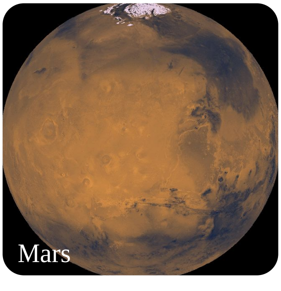
Moonlight is reflected sunlight. This was discovered long ago by the ancient Greek astronomer Parmenides, who lived and worked around 500 B.C.E. Depending on the location of the Moon in its orbit around Earth, different parts of the Moon will reflect sunlight onto Earth. Since Earth and the Moon are so close together, and since the Moon has such a shiny surface, large amounts of sunlight come to Earth after bouncing off the Moon.



A snapshot of the moon taken from CCD camera at Sonmiani

Although the Moon is very massive having a mass of 73.5 billion billion metric tons—it is so far away from Earth (238,000 miles or 384,000 kilo meters) that it has very little gravitational pull on objects at or near Earth's surface. It produces about 1/300,000th the gravitational acceleration that Earth produces at its own surface which is far too weak to be felt by any person.

1.1.5 Mars



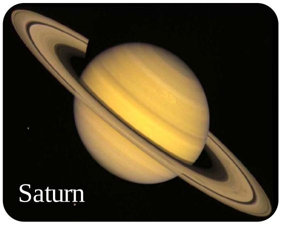
Mars

Mars excites scientists because its mild temperament is more like the Earth's than that of any of the other planets. Evidence suggests that Mars once had rivers, streams, lakes, and even an ocean. But later on, Mars' atmosphere slowly depleted into outer space, the surface water began to permanently evaporate. Today the only water on Mars is either frozen in the polar caps, or is underground. Mars is 249 million km away from the sun. Mars' day is calculated at 24 hours and 37.5 minutes. It tilts at an axis of 23.98 degrees. Summer and spring last for 381 days and autumn and winter last for 306 days, which makes it cold most of the time. It takes 687 Earth days for Mars to orbit the sun. Mars has two moons. Their names are Deimos and Phobos. Its atmosphere is made up of mainly Carbon Dioxide.

1.1.6 Jupiter

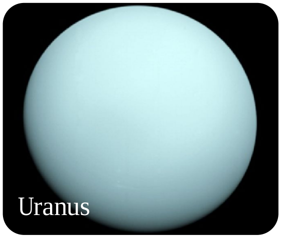
Jupiter is the fifth planet from the sun and is about 770 million km from it. It takes almost twelve years for Jupiter to orbit the sun. It spins in less than 10 hours. For that reason its middle has been stretched out. Rather than round it is short and fat. This rapid spinning causes powerful winds that push the clouds into colourful bands, streaks and swirls that circle the planet. The temperature on the surface is very cold about 150°C below freezing and that's in the daytime! The centre of Jupiter is very hot. Jupiter has sixty three moons, and more are discovered with every space probe sent there. It is likely that there are more not yet identified. As of 2009, Jupiter has 67 satellites known and classified as moons. This giant planet has no solid surface. Under its atmosphere is a large liquid ocean of hydrogen and water. There is nothing in between the ocean and atmosphere. The atmosphere slowly gets thicker and thicker until it becomes part of the ocean. In other words Jupiter's ocean has no surface on which you could float a boat. The sky slowly becomes the ocean.

1.1.7 Saturn



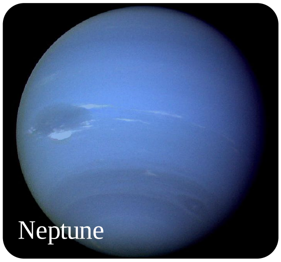
Saturn is a favourite object for many observers. It is the sixth planet from the Sun. Saturn is 95 times heavier than earth. The main system has a total diameter of over 270,000 km. In many ways Saturn is similar to Jupiter, but it is much smaller. Under the clouds of methane and helium, the sky gradually turns into liquid until it becomes a giant ocean of liquid chemicals. It takes a whole 29 years and 167 days for Saturn to orbit the sun. The length of one-day is just 10 hours and 14 minutes. Saturn has 61 confirmed moons by now.

1.1.8 Uranus



Uranus is almost identical to the planet Neptune. Unlike all the other planets and most of the moons in our Solar System, Uranus spins on its side. It is believed that long ago a very large object smashed into this planet. The crash was so powerful that it completely changed the direction of Uranus' spin. Uranus may have an ocean of water beneath its clouds. It has a large rocky core, and because of the tremendous pressure it could possibly contain trillions of large diamonds. The atmosphere is thought to be 10,000 km deep (6,200 miles). It has 27 moons.

1.1.9 Neptune



It is the last planet in our solar system. Neptune has a giant storm much like the storm on Jupiter. This storm is often called The Great Dark Spot. We do not know how long this storm has been active because it is so far away that we could not get a good view of Neptune. Neptune has six rings which circle the planet. The distance from the sun to the blue planet is 4,500,000,000 km (2,800,000,000 miles). One day (24 hrs) lasts for 16 hours 3 minutes and one year lasts 164 earth years. Neptune has 13 moons that we know of. Because Neptune is so far away, it is difficult to see any of these worlds. There are probably many more moons orbiting this blue planet which we have not yet discovered.

1.1.10 The Kuiper Belt and Beyond

The Kuiper Belt (also called the Kuiper-Edgeworth Belt) is a doughnut-shaped region that extends between about three to eight billion miles (5 to 12 billion km) out from the Sun (its inner edge is about at the orbit of Neptune, while its outer edge is about twice that diameter).

Kuiper Belt Objects (KBOs) are, as their name implies, objects that originate from or orbit in the Kuiper Belt. Pluto is the only one KBO which was known for more than 60 years. Many KBOs have been discovered since 1992, however, the current estimate is that there are millions, if not billions, of KBOs.

KBOs are basically comets without tails: icy dirt-balls that have collected together over billions of years. If they get large enough, such as Pluto did, they evolve as other massive planet like bodies do, forming dense cores that have a different physical composition than the mantle or crust above it. Most short-period comets, those with relatively short orbital times of a few years to a few centuries are thought to originate from the Kuiper Belt.

Plutinos are Kuiper Belt Objects that are smaller than Pluto, have many physical characteristics similar to Pluto, and orbit around the Sun in much the same way that Pluto does. The discovery of Plutinos led to the recognition that the Kuiper Belt is heavily populated, and that Pluto itself is a Kuiper Belt Object.

Pluto is about 1,400 miles (2,300 kilometres) across, less than one-fifth the diameter of Earth and smaller than the seven largest moons in the solar system. Pluto is composed mostly of ice and rock, with a surface temperature between –350 and –380 degrees Fahrenheit (–210 to –230 degrees Celsius); the bright areas observed on Pluto are most likely solid nitrogen, methane, and carbon dioxide. The dark spots may hold hydrocarbon compounds made by the chemical splitting and freezing of methane.

Pluto’s day is about six Earth days long, and its year is 248 Earth years long. Pluto travels in a highly elliptical orbit around the Sun compared to the terrestrial planets and gas giants. For 20 years out of its 248-Earth-year orbital period, it is actually closer to the Sun than Neptune. When Pluto is closer to the Sun, its thin atmosphere exists in a gaseous state, and is comprised primarily of nitrogen, carbon monoxide, and methane. For most of its very distant orbit, though, there is no standing atmosphere because it all freezes out and drops to the surface.

Pluto has no rings and three known moons. The largest one, Charon, is large enough to be considered a dwarf planet in its own right.

Rabinowitz (1960) discovered a new solar system body beyond the orbit of Pluto and larger than Pluto. The discovery of 2003UB 313, proved that Pluto was not the largest Kuiper Belt Object in the solar system. Further observations showed that 2003UB 313 even had its own moon.

The discovery of 2003UB 313 hastened the need for planetary astronomers to define the term “planet” in a scientific way. Since it was larger and more distant than Pluto, it would have to be called the tenth planet, unless Pluto was not to be considered a planet any longer. After substantial debate, the objects were officially reclassified in August 2006 by the International Astronomical Union (IAU). That is why there are only eight planets in our solar system today, and why Pluto is not one of them.

1.2 ASTERIODS

Asteriods

An asteroid is a large rock in outer space. Due to their smaller size, asteroids do not have enough gravity to pull themselves into the shape of a ball. It is believed that asteroids are left over materials from the formation of the Solar System. 26 very large asteroids have been discovered. There are still millions of smaller ones that we have yet to see because they are too tiny, only a mile or so across. If all the materials of all the asteroids were squashed up into one planet, it would be smaller than our moon.

Astronomers group asteroids into different categories based on the way they reflect sunlight. The asteroid belt is divided into an inner belt and an outer belt. The inner belt which is made up of asteroids that are within 250 million miles of the Sun contains asteroids that are made of metals. The outer belt, which includes asteroids 250 million miles beyond the Sun, consists of rocky asteroids. These asteroids appear darker than the asteroids of the inner belt, and are rich in carbon.

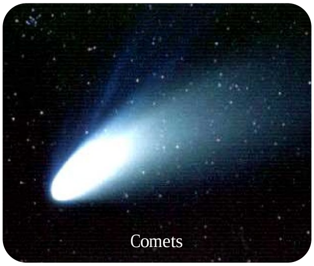
1.3 METEOROIDS AND METEORITES

The term meteor comes from the Greek meteoron, meaning phenomenon in the sky. It is used to describe the streak of light produced as matter in the solar system falls into Earth's atmosphere creating temporary incandescence resulting from atmospheric friction. This typically occurs at heights of 80 to 110 kilometres above the Earth's surface. The term is also used loosely with the word meteoroid referring to the particle itself without relation to the phenomena it produces when entering the Earth's atmosphere. Even smaller particles are called micrometeoroids or cosmic dust grains, which include any interstellar material that should happen to enter our solar system. A meteorite is a meteoroid that reaches the surface of the Earth without being completely vaporized.

1.4 COMETS

A comet is a small body which scientists sometimes call a planetesimal. Comets orbit the Sun just as the planets do. That is why astronomers see the same comet return over and over again. But comets have huge oval-shaped orbits. They swing far out to the edge of the solar system. It takes Earth 365 days to go around the Sun whereas; the orbits of some comets are so big that it takes them hundreds of years to go around the Sun once. For example Halley's Comet appears about every 76 years. When a comet nears the Sun, some of the ice in the comet turns into gas. The gas and loose dust freed from the ice create a long, luminous tail that streams behind the comet.

Comets come from places in the outer solar system called the Kuiper Belt and the Oort Cloud. The Kuiper Belt and the Oort Cloud are made up of chunks of ice and rock. Comets that orbit the Sun in less than 200 years come from the Kuiper Belt. The Kuiper Belt is just beyond the planet Neptune. Comets that take longer than 200 years to go around the Sun come from the Oort cloud. The Oort Cloud is far out at the edge of the solar system, beyond Pluto.



Comets

1.5 STARS

The most fascinating body in the sky at night is a star. A star is a big ball of hot, glowing gases. The gases are mostly hydrogen and helium. Stars give off heat, light, and other kinds of energy. At night stars look tiny because they are millions of miles away from our earth. The closest star to our Earth is the Sun. The Sun is a star at the center of our solar system. A star can get birth and can encounter death as well. The life of a star depends on its mass. The higher the mass the lower its life time because high mass stars burn their fuel more quickly as compared to low mass stars. Our Sun is believed to be about 4.6 billion years old and scientists believe that half of its life is passed away.

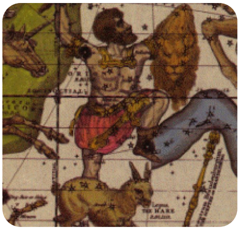
There are stars older or younger as well as bigger than our Sun. Stars are born from swirling clouds of gas and dust. Gravity pulls the gas and dust together. The gas and dust form a spinning ball. As it spins, it gets hotter. The gas and dust get tightly packed and birth of new star takes place. Likewise when a star burns up its fuel it comes to death. Now question arises what makes a star glow and give off energy? As stated, mostly stars are made up of gases i.e., hydrogen and helium. A star has several layers. The center of a star is called its core. A star shines because of its core. The core is so hot and tightly packed that atoms crunch together. Hydrogen atoms crunch together and become helium atoms. This is called nuclear fusion. Nuclear fusion gives off enough energy to make stars shine.

Planets differ from stars in a variety of ways. A star is a collection of hot glowing gases that are held together by gravity which give off enormous quantity of energy as light and heat caused by the thermonuclear fusion taking place in its core. A planet on the other hand is a body that orbits around a star and it can be rocky, gaseous or a combination of the two having its own gravitational field holding it together. The sun is a star and Earth is a planet.

Stars

1.5.1 Constellations

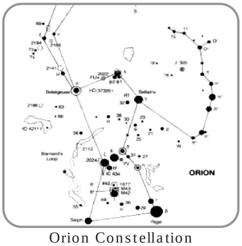
From ancient times, people living in different parts of the world defined their own ways of categorizing groups of stars termed as constellations. Their old scriptures also reflect their cultural influence on their depiction. Constellations are, thus, the ideas and picture that human mind have imposed in the sky in an effort to connect our lives on earth with the working of the heavens.



Orion Constellation depiction in an old Scripture

An asterism is a group of stars in the sky that, when viewed from Earth, create an outline of some recognizable shape or pattern. Two well-known asterisms are the Big Dipper, which many astronomers use to point out the location of the North Star, and the Summer Triangle, which is marked by three of the most prominent stars in the Northern Hemisphere's summer night sky.

A constellation is similar to an asterism, but it is usually much more complicated, containing more stars or larger areas of the sky. A few asterisms are constellations: the asterism called the Southern Cross, for example, is the constellation Crux (the Cross). Modern constellations are mostly named after mythological themes, such as gods, legendary heroes, creatures, or structures. Although most constellations resemble the figures after which they are named, others are not as recognizable. The constellations encompass the entire celestial sphere and provide a visual reference frame. Astronomers can plot the stars and other objects in the universe using constellations, charting the apparent movement that is caused by Earth's own rotation and orbit.



Orion Constellation shown in star charts

The current, internationally agreed upon map of the sky contains 88 constellations. Some well-known constellations include Aquila (the Eagle), Cygnus (the Swan), Lyra (the Harp), Hercules and Perseus (two mythological heroes), Orion the Hunter and Ophiucus the Knowledge-seeker (two other mythological characters), Ursa Major and Ursa Minor (the Big Bear and Little Bear), and the constellations of the zodiac.

1.5.2 Colors of Stars

Stars come in different colours. They can be deep red, orange, yellow, white, or even blue. The colour of a star depends on how hot the star is. The coolest stars are reddish and the hottest stars are bluish. It is hard to imagine how hot a star can be. The temperature at the surface of red stars is about 3000° Celsius. Yellow stars have surface temperatures about 6000° Celsius. Our Sun is a yellow star. White stars are about 10,000° Celsius. Astronomers study the light of stars. Patterns in the light can tell astronomers what the stars are made of and how hot they are.

1.5.3 Distance between Stars

There are many different methods used to find distance between stars, but historically the most accurate has been parallax. This is the same effect that makes distant trees appear to move more slowly than nearby ones when you drive past them in a car. Basically, as the Earth orbits the Sun, nearby stars appear to move a teeny bit as a reflection of our motion, while stars farther away move less. Since we know how big the orbit of the Earth is, we can use trigonometry to calculate the stars' distances.

1.6 BLACK HOLE

A Black Hole is an extremely dense celestial body that has been theorized to exist in the universe. The gravitational field of a black hole is so strong, that nothing including electromagnetic radiation can escape from its vicinity. It is surrounded by a spherical boundary called the horizon, through which light can enter but not escape, it therefore appears totally black.

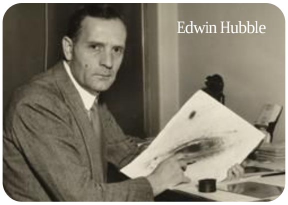

Black Holes in the Galaxies

The black hole concept was developed by a German astronomer in 1961 on the basis of Einstein's General Theory of Relativity. According to General Relativity, Gravitation severely modifies space and time near a black hole. In 1994, astronomers used the Hubble Telescope to uncover the first convincing evidence that black holes exist.

1.7 ORIGIN OF THE UNIVERSE

Cosmology is the study of the origin, structure and the history of the universe as a whole. Astronomers and physicists who do research in cosmology are called cosmologists. The darkness of the night sky leads to the conclusion that the universe is not infinitely old. If the universe were infinite in extent, infinite in age, and static, then every spot on the sky would glow as brightly as the surface of a star. This problem, commonly labelled Olbers's paradox, implies that the universe had a beginning.

1.7.1 Hubble's Law

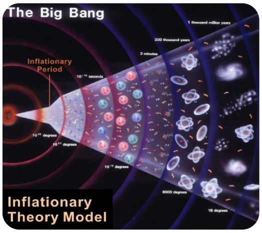


In 1929, Edwin Hubble discovered that the galaxies are moving away from each other. He presented his finding in the form of a law which is known as Hubble's law. Tracing the expansion of the universe backward in time bring us to imagine an initial high-density, high-temperature state commonly called the big bang. A rough estimate of the age of the universe based on the presently observed expansion rate is called the Hubble time. The cosmic microwave background radiation is blackbody radiation with a temperature of about 2.73 Kelvin, spread nearly uniformly over the entire sky. This radiation is the light from the big bang. The background radiation is clear evidence that the universe began with a big bang.

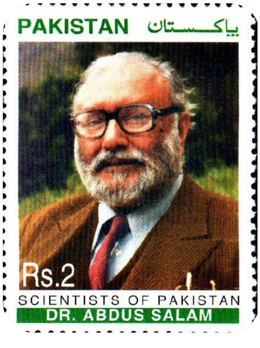
1.7.2 The Big Bang Theory

During the earliest moments of the universe, matter and antimatter particles continually flashed in and out of existence. A slight excess of ordinary matter remained after most of the matter and antimatter particles annihilated each other. During the first three minutes of the big bang, nuclear fusion converted some of the hydrogen into helium but was unable to make many other heavy atoms because no stable nuclei exist with weights of 5 or 8. Now, hydrogen and helium are common in the universe, but heavier atoms are rare. For a period of hundreds of millions of years called the Dark Age, the universe expanded in darkness until the first stars came into existence. Astronomers have observed signs of re-ionization of the universe caused by that first generation of stars. The chemical composition of the oldest stars is about 75 percent hydrogen and 25 percent helium, which is what models of the big bang nuclear processes would predict. This is a further evidence supporting the big bang theory.

1.7.3 The Inflation Theory



The inflationary theory, a modification to the big bang theory, proposes that the universe briefly expanded dramatically, just a tiny fraction of a second after the big bang. The energy to drive inflation would have been released when the four forces of nature changed their respective properties as the universe cooled in its earliest moments. This "separation" of forces is predicted by grand unified theories (GUTs) that explain the forces of nature as being aspects of a single force, unified in particle interactions with very high energies.



A major role in the development of GUT is played by Dr. Abdus Salam, the founder of Pakistan's space program and the founding director of Pakistan Space and Upper Atmosphere Research Commission (SUPARCO). He was convinced that weak nuclear forces are not really different from electromagnetic forces, and that the two could inter-convert. Salam presented a theory that shows the unification of two fundamental forces of nature, strong and weak nuclear forces and electromagnetic forces. In 1961, Glashow extended electroweak unification models due to Schwinger by including a short range neutral current, the Z0. The resulting symmetry structure that Glashow proposed, SU (2) x U (1), forms the basis of the accepted theory of the electroweak interactions. For this discovery, Glashow along with Steven Weinberg and Abdus Salam was awarded the 1979 Nobel Prize in Physics.

1.7.4 Properties of Universe

The universe is isotropic and homogeneous. In other words, in its major features, the universe looks the same in all directions and in all locations. Isotropy and homogeneity lead to the cosmological principle, the idea that there are no special places in the universe. Except for minor local differences, every place is the same, and the view from every place is the same.

There are three models about the fate of the Universe.

- Closed universe models are finite in size, but their space-time is curved back on itself so they have no edge or center.
- Open universe models have curved space-time, but it is not curved back on itself. Such universes are infinite.
- Flat universe models have uncurved space-time and are infinite. Modern observations show that the universe is probably flat.

1.7.5 Dark Matter

Matter component that does not radiate in the electromagnetic spectrum and, therefore, is not detected by means of telescopes is known as dark matter. In the 1930s, astronomer Fritz Zwicky (1898–1974) noticed that, in the Coma cluster of galaxies, many of the individual galaxies were moving around so fast that there had to be a tremendous amount of gravitational pull toward the centre of the cluster; otherwise, the galaxies would literally hurl themselves out of the cluster.


Dark Matter

The amount of matter that needed to exist in the cluster to produce that much gravity far exceeded the amount of matter observed in all the galaxies in the cluster put together. This extra matter became known as “dark matter.”

After decades of further study, dark matter has now been confirmed as an important constituent of matter around galaxies, in clusters of galaxies, and throughout the universe as a whole. According to the latest measurements, about 80 percent of the matter in the universe is dark matter.

1.7.6 Dark Energy

When Albert Einstein and others were working on the nature of the universe in the early twentieth century, Einstein introduced a mathematical term into his equations to keep a balance between cosmic expansion and gravitational attraction. This term became known as the “cosmological constant,” and seemed to represent an unseen energy that emanated from space itself.

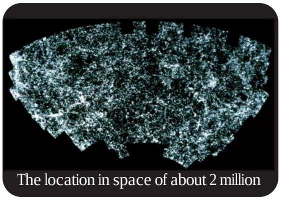
After Edwin Hubble and other astronomers showed that the universe was indeed expanding, the cosmological constant no longer appeared to be necessary, and so it was not seriously considered again for decades. Then, starting in the 1990s, a series of discoveries suggested that the “dark energy” represented by the cosmological constant does indeed exist.

Current measurements indicate that the density of this dark energy throughout the universe is much greater than the density of matter—both luminous matter and dark matter combined.

Statistical observations of the large-scale structure of the universe confirm that it is flat and contains 4 percent baryonic matter, 23 percent dark matter, and 73 percent dark energy. The mass equivalent of dark energy added to dark matter and baryonic matter makes the observed density of the universe equal to the critical density, thereby confirming the prediction made by inflation theory that the universe is flat.

1.8 GALAXIES

A galaxy is made up of millions or billions of stars. Big clouds of gas and dust swirl in space between the stars. Galaxies give off different kinds of rays e.g. radio waves, heat or infrared rays, X-rays and gamma rays. All these rays are types of light. Though some of them can be seen with our naked eye but the others like X-rays and gamma rays could only be seen through electronic instruments. Astronomers and scientists study the light to learn about the galaxies. They have instruments that can detect each of these types. The different types of light provide clues about what galaxies are made of and how do they form. Powerful telescopes like Hubble Space Telescope have been launched in the space to take pictures of galaxies.


The location in space of about 2 million


Spiral Galaxy


Lenticular Galaxy


Elliptical Galaxy

All the stars visible to the unaided eye from earth belong to Earth's galaxy, the Milky Way. Galaxies come in different shapes. Some galaxies look like giant whirlpools or pinwheels. They have long arms made of gas and dust clouds and stars. These are called spiral galaxies because the arms spiral into the center. The Milky Way is a spiral galaxy.

The stars and clouds of gas and dust in a spiral galaxy move slowly in a circle. They go around the center of the galaxy. New stars form in the clouds of a spiral galaxy. Another shape of galaxy is called Lenticular. These galaxies are spiral galaxies but without spiral structure. Mostly old stars are found in these galaxies. Some galaxies are oval or round in shape. These are called elliptical galaxies. Elliptical galaxies tend to have older stars. Few new stars form in elliptical galaxies. Some galaxies do not have any particular shape. These are called irregular galaxies. When galaxies come close to each other, their shapes can change. Sometimes galaxies collide with one another. Irregular galaxies may be galaxies whose original shapes were distorted by collisions.

Section 2

SPACE EXPLORATION

2.1 OVERVIEW OF SPACE EXPLORATION

For as long as there have been people on Earth, they have looked up at the sky and wondered about the Sun, Moon, stars, and occasional dramatic events they saw there, like a comet sighting bringing a bad omen. But it is only in the past 40 years that humans have developed the technical ability to leave their planet and actually visit other bodies in the universe.

Space travel is only possible if we can escape Earth's gravitational field. However, for a spacecraft to do so it must reach a velocity of 11 km/sec (7 miles/sec), or 39,600 km/hr (nearly 25,000 mph). It was only by the middle of the twentieth century that mankind finally understood enough about rocketry to make such high speeds attainable. Today, spacecrafts can also be carried into space by a shuttle, which releases them while in orbit. After leaving Earth's gravitational field, spacecrafts then use small on-board thrusters to navigate through space and explore the universe.

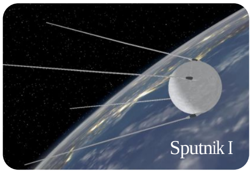
During the last four decades, hundreds of satellites, probes and space shuttles have been launched which have explored near-Earth space, travelled to the Moon, the Sun, and to all the planets. And, with permanent space stations already in orbit around Earth and telescopes exploring more and more of our universe, space research is still continuing. Talk of future developments include building a colony on Mars, searching for life in other galaxies, and other exciting programs.

2.2 EARLY ARTIFICIAL SATELLITES

On 4th October, 1957, Soviet Union launched the first satellite named Sputnik I into space. On 3 November, 1957, Soviets launched Sputnik II, which contained the first space traveller, a dog named Laika.

News of the first Sputniks intensified efforts to launch a satellite in the United States. The initial US satellite launch attempt on 6 December 1957 failed disastrously when the Vanguard launch rocket exploded moments after lift-off. Success came on 31 January, 1958, with the launch of the satellite Explorer 1.

The satellites that followed Sputnik and Explorer provided scientists and engineers with a variety of new knowledge. For example, the scientist who tracked radio signals from these satellites determined that Earth is slightly flattened at the poles. In August 1959, Explorer 6 sent back the first photo of Earth from the space.



Sputnik I

2.3 PLANETARY STUDIES

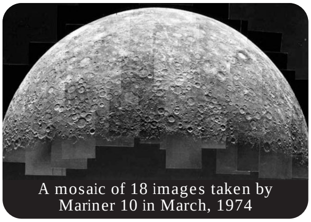
Earth’s closest neighbours, Venus and Mars, became the first planets to be visited by a spacecraft in the mid 1960s. By the end of 20th century, spacecrafts had visited every planet except the dwarf planet “Pluto”. Brief details about missions to planets of our solar system are mentioned next.

2.3.1 Missions to Mercury

Mercury has been the least explored of the inner planets due to its proximity to the sun and resulting difficulties in sending spacecrafts to orbit the planet in order to investigate it. Nevertheless, it has been of utmost interest to many scientists and astronomers. As of 2014, Mariner 10 and MESSENGER Missions have been able to visit Mercury. A future mission by the name of BepiColombo has been planned by the European Space Agency (ESA) and the Japanese Aerospace Exploration Agency (JAXA) to complement MESENGER in further investigating this interesting world.

2.3.1.1 Mariner 10 Mission

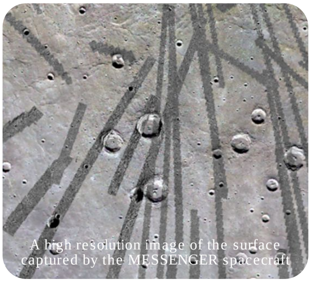
Mariner 10 space probe was sent to Mercury to photograph and collect data about its atmosphere, surface and physical characteristics. It was launched on November 2, 1973 from Cape Kennedy, NASA's Kennedy Space Centre in Florida. In order to get a close flyby of Mercury, the probe was first made to orbit the Sun then the gravity of Venus accelerated the space probe towards Mercury to get the first set of observations on March 29, 1974. The probe then orbited the Sun such that it was able to photograph only 45% of the same side of the planet two times in its orbit on September 21, 1974 and March 16, 1975. The mission came to an end on March 25, 1975 as the probe ran out of fuel but it was able to collect significant data of the planet's magnetic field and photographs of its surface littered with craters (dents on the surface made by impact of meteoroids and asteroids). This allowed scientists to estimate the age of Mercury and investigate its crustal composition.



A mosaic of 18 images taken by Mariner 10 in March, 1974

2.3.1.2 Messenger Mission

NASA's first ever robotic probe Mercury Surface, Space Environment, Geochemistry, and Ranging (MESSENGER) was launched on Aug 3, 2005 aboard a Delta II Rocket which took 6.5 years to actually reach Mercury. During its interplanetary journey, the probe took several gravitational slingshot flybys of Earth in February 2005 and Venus in October 2006 and October 2007. It made 3 passes of Mercury, twice in 2008 in January and October, and in September 2009 before successfully entering into orbit on March 18, 2011. 95% of Mercury's surface was photographed during its flybys. The Mission's objective was to study Mercury's chemical composition, its geology and its magnetic field. This primary mission was duly achieved on March 17, 2012 with a collection of about 100,000 images of the planet and 100% mapping of the planet was achieved on March 6, 2013. The mission was expected to end by March 2012 but the availability of fuel allowed the mission's extension by another year. The mission officially concluded on March 17, 2013 although the probe is still in orbit around Mercury.



A high resolution image of the surface captured by the MESSENGER spacecraft

2.3.1.3 BepiColombo Mission

This mission is a joint venture of ESA and JAXA and is planned for launch in August 2017. This ambitious mission has a lot of scientific feats to achieve and questions to answer like Mercury's roleplay in the formation of the planetary system, its unusually high density of the innermost core, the existence of its magnetic field, composition of the craters at its poles and testing Einstein's general relativity theory by taking advantage of Mercury's proximity to the sun, etc. This mission will be comprised of two satellites: the Mercury Planetary Orbiter (MPO), provided by ESA which will take images of the planet and the Mercury Magnetospheric Orbiter (MMO), provided by JAXA, which will study Mercury's Magnetosphere (the comet-tail like area of influence on charged particles emitted by the sun-the solar wind, governed by the planet's magnetic field).

2.3.2 Missions to Venus

Venus has been the centre of attraction for humans and revered as a deity for centuries in ancient civilizations and cultures of Mesopotamia, Asia, Egypt, Greeks and Romans and the Mayans. But the first astronomer to observe Venus through a telescope and make sketches of its phases like those of the moon was Galileo Galilei in December of 1610. Other observations like those of transits (when an inner planet crosses directly between the Earth and the Sun's disk), as early as the 17th century, gave a reason to further explore this interesting and mysterious planet which was visible on Earth at dawn for six months of the year and at dusk for the other half.

During the 20th century, radio observations of Venus' atmosphere and estimates about its surface structure were made enabling scientists discern about its retrograde motion (it rotates in opposite direction of east to west on its axis), rotation speed, its thick atmosphere and its unexplored, interesting and unusually hot surface. These results prompted scientists and engineers of Russia, USA and Europe to send flyby missions, orbiters and landing spacecrafts on the planet as early as the 1960s.

2.3.2.1 Early Flybys, Landers and Orbiters-Soviet and NASA Missions

The first ever space probe launched to another planet, Venus in this case, was a Soviet Spacecraft Venera 1 on February 12, 1961 but the mission proved to be a failure. The American probe Mariner 2 successfully flew past Venus in 1962 found that Venus had no magnetic field of its own and its temperature ranged between 217° C(217 degrees celsius) to 317° C(317 degrees celsius). Mariner 5, however, measured the strength of Venus' magnetic field in 1967 and Mariner 10 revealed high wind speeds in the Venusian atmosphere from ultraviolet pictures in 1974.

The Soviet space probe, Venera 3 became the first spacecraft to land on another planet on March 1, 1966. Venera 4 was the first probe to return direct measurements from a planet's atmosphere, entering Venus' atmosphere on October 18, 1967. The data and observations showed that the composition of the atmosphere consisted of 95% carbon and high surface pressure of 75 to 100 atmospheres persisted. These results were confirmed by Venera 5 and Venera 6 in May 1969. Venera 7 became the first probe to successfully land on the Venusian surface on December 15, 1970 and remained in contact with Earth for a whole of 23 minutes to send back surface temperature data ranging between 455°C to 475°C (855°F to 885°F). Venera 8 landed on July 22, 1972 which provided temperature and pressure profiles, and chemical composition of the crust. Its photometer revealed that the Venusian clouds, after forming a layer, ended over 35 km (22 miles) above the surface.

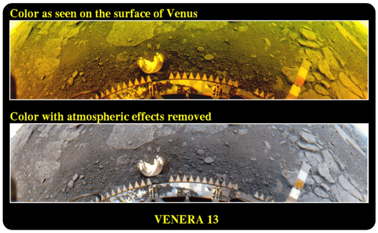
The Soviet probe, Venera 9 became the first artificial satellite of Venus when it entered into orbit on October 22, 1975. It made definite measurements of the clouds, its ionosphere and magnetosphere. A decent vehicle separated from the orbiter, landed on the surface and took its first pictures. Venera 10 followed in the footsteps of Venera 9 and carried out similar observations.

First image of the Venusian surface taken by Venera 9

An important NASA Mission, Pioneer Venus, comprising of two probes was sent in 1978. Pioneer Venus Multiprobe carried a large and three smaller probes which entered the Venusian Atmosphere on December 9, 1978. A delivery vehicle detached itself from the probe to land on the surface and remained operational for 45 minutes. The objective was to study the composition and structure of the Venusian Atmosphere, from the cloud structure to the temperature and pressure at the surface. The Pioneer Venus Orbiter was sent to orbit Venus elliptically on December 4, 1978. It carried out 17 experiments to understand the composition of the Venusian atmosphere and its interaction with charged particles from the sun. It remained operational until its fuel was exhausted and it was burned up in the atmosphere upon re-entry in August 1992.

2.3.2.2 Other Soviet missions

Venera 11 & Venera 12 dropped descent vehicles on December 21 and 25 respectively which were able to detect strong lightening activity and an unexpected large proportion of chlorine along with sulphur in the clouds. Venera 13 sent the first colour pictures of the surface of Venus in 1981 and the probe stayed on the hostile surface for a record 127 minutes. In the same year, Venera 14 detected possible signs of seismic activity in the planet's surface which was further investigated by later missions. The Vega probes, Vega 1 & 2, launched in December 1984, further investigated the cloud aerosol composition and structure, and made findings of phosphoric acid and high turbulence in the atmosphere.



Venera 15 & Venera 16 were made to enter a polar orbit in October 1983 to map the upper atmosphere and northern third of the planet's geological structure with a Synthetic Aperture Radar (SAR) from November 11, 1983 to July 10, 1984. The probes detected volcanoes on its surface and no seismic activity in the northern part was being monitored.

2.3.2.3 Magellan probe

The US mission of detailed radar mapping of 98% planet's surface with a resolution of 100 m at a frequency of 2.38 GHz was inserted into orbit on August 10, 1990. The mission was named after the famous Portuguese explorer, Ferdinand Magellan. During its four years, the mission successfully found no evidence of seismic activity although it found thousands of km long lava channels and very less impact craters. After the completion of the mission, it was made to enter the atmosphere on October 11, 1994, partly vaporising the probe with some parts supposedly impacting the surface.

2.3.2.4 Venus Express

This mission was sent by the European Space Agency for long-term observation and study of the atmosphere and its surface in detail, while in orbit, to contribute to understanding of Earth's climate and atmosphere. It has also made global maps of the surface temperature of Venus. Since it was inserted into polar orbit on April 11, 2006, it has been continuously sending back data till date. The expected mission life was only two Venusian years (500 Earth Days). Venus Express has found evidence of oceans in the past, a huge atmospheric vortex at its south pole and has detected hydroxyl in the atmosphere.

2.3.3 Missions to Mars

Mars, like the planet Venus, has intrigued humans for hundreds of years. This interest was fuelled by the invention of the telescope. Finding possibilities of life on the red planet and exploring its geology for future habitation is what inspired space probes and rovers to be sent to orbit or roam the surface by Russia and the US. But before missions could successfully complete their targeted mission, nearly two-thirds of them failed. However, missions like the twin Mars Exploration Rovers have not only carried out their mission successfully but have also managed to operate for years beyond their original time period. Since August 6, 2012, two of the scientific rovers, Opportunity and Curiosity are beaming back signals, and three orbiters: Mars Odyssey, Mars Express and Mars Reconnaissance Orbiter are currently surveying the planet. Mars Orbiter Mission and MAVEN, launched in November 2013 are making the journey through interplanetary space to reach Mars.

2.3.3.1 Mariner program

In July 1965, NASA's Mariner 4 flew past Mars for a 7.5 month voyage and took pictures of a small portion of its surface giving scientists their first close-up look at the red planet. Mariner's pictures showed cratered terrain resembling Moon's surface. On November 14, 1971 Mariner 9 became the first space probe to orbit another planet when it entered into orbit around Mars. This mission proved to be most successful; it took its first glimpse at a planet-wide dust storm and sent back pictures of gorges and canyons indicating that liquid water once flowed on Mars in the past. It also found the largest volcano in the solar system, Olympus Mons, on the red planet.

2.3.3.2 The Soviet Mars Program

USSR launched its Mars exploration program by successfully sending orbiter and lander combination spacecrafts, Mars 2 and Mars 3 of which Mars 2 crashed upon landing on November 27, 1971, becoming the first man-made object to touchdown on the Martian surface. Mars 3 successfully landed on the surface on December 2, 1971 but stopped transmitting data after 14.5 seconds. Mars 2 & 3 orbiters successfully sent back data and first 60 pictures of the Martian terrain till August 1972 which were useful in creating relief maps of the Martian gravitational and magnetic fields. The Soviets launched four more probes: the Mars 4 & 5 orbiters and Mars 6 & 7 fly-by/lander combinations. Mars 5 was the most successful of these missions and except Mars 7, all missions sent back data to earth.

2.3.3.3 Viking Program

The 1975 NASA launches of the Viking program consisted of two orbiters, each with a lander that successfully touched down in 1976. Viking 1 remained operational for six years and Viking 2 for three. The Viking landers relayed the first colour panoramic images of Mars and the Viking orbiters mapped the surface so well that the images remain in use till today.

2.3.3.4 Mars Global Surveyor and Mars Pathfinder

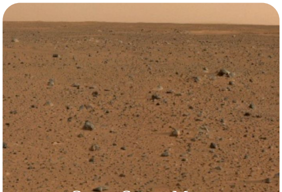
The NASA Mars Global Surveyor achieved Mars orbit in 1997. This mission was a complete success, having finished its primary mapping mission in early 2001. Contact was lost with the probe in November 2006 during its third extended program, spending exactly 10 operational years in space. The NASA Mars Pathfinder, carrying a robotic exploration vehicle Sojourner, landed in the Ares Vallis on Mars in the summer of 1997, returning many images.

2.3.3.5 Mars Odyssey and Mars Express

NASA's mission, Mars Odyssey Orbiter, which arrived in 2001 was an important mission which discovered traces of past water, volcanic activity and large deposits of water ice in the upper 3 meters of Mars' soil within 60° latitude of the south pole. ESA's mission, Mars Express, launched on June 02, 2003 consisted of a lander named Beagle 2 and an orbiter which entered orbit on December 25, 2003. It confirmed previous findings of water ice and carbon dioxide ice at Mars' south pole. Unfortunately, soon after landing, attempts to contact Beagle 2 failed and it was declared lost in mid-February of 2003. Beagle carried a digging device and a robotic arm to accurately analyse the soil samples with the smallest mass spectrometer device installed on the lander.

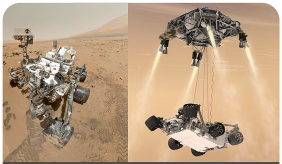
2.3.3.6 Mars Exploration Rover Mission

The twin rover mission was sent to land on Mars in 2003. The MER-A (Spirit) rover landed on Jan 3, 2004 in the Gusev Crater (shown in image). It examined rock and soil for evidence of the area's history of presence of water. The second rover, MER-B (Opportunity) landed on 24 January, 2004 in Meridiani Planum (where there are large deposits of hematite, indicating the presence of past water) to carry out similar geological work. Having only been designed for three-month missions, they both lasted much longer than planned, but Spirit lost contact with Earth in March 2010. Opportunity, however, continues to carry out surveys of the red planet to date, and has surprisingly exceeded its planned duration of 90 Martian days to a mark record of 10 years as of 2014. These rovers have made significant discoveries including past evidence of water, Basalt rocks, magnetic dust and Heat Shield Rock, the first meteorite to be discovered on another planet.



Gusev Crater, Mars

2.3.3.7 Mars Science Laboratory-Curiosity Rover



Left: self portrait of the Curiosity Rover, Right: An artist's concept of the skycrane descent technique of the rover

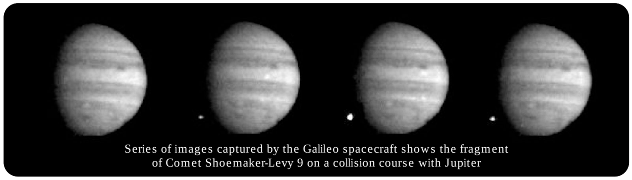
NASA's robotic space probe mission called Mars Science Laboratory (MSL) landed the Curiosity Rover on Mars on August 6, 2012 to explore a different geological Martian terrain and its climate. Its objective was to collect data for future manned missions to Mars. The rover houses a variety of instruments designed in collaboration with the international scientific community.

The mission consisted of a spacecraft capsulating the rover and carried an instrument to acquire Martian atmospheric data. The rover was landed in the Gale Crater in a very unique way instead of an airbag system which was used in the MER Mission. After atmospheric entry, the heavy rover was slowly lowered by a sky crane which was rocket-powered to freely roam the surface.

2.3.4 Missions to Jupiter

Jupiter has been the most explored planet of the solar system. Ever since telescopic observations and sketches of Jupiter and the Galilean moons (4 large and prominent moons of Jupiter, Io, Europa, Ganymede and Callisto) by Galileo Galilae had been made in the 17th century, Jupiter has captivated the minds of the astronomers and scientists and motivated them to send spacecrafts to explore this giant gaseous planet.


Image captured by Pioneer 10

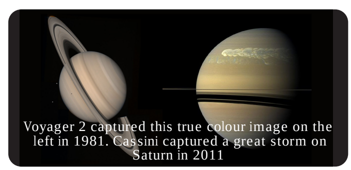

Series of images captured by the Galileo spacecraft shows the fragment of Comet Shoemaker-Levy 9 on a collision course with Jupiter

Pioneer 10 was the first spacecraft to make a flyby of Jupiter in 1973 followed by Pioneer 11 a few months later. The probes not only captured stunning images of the planet but also discovered its strong magnetic field and its fluid interior. The Voyager 1 & 2 spacecrafts visited the planet in 1979. The mission studied the Jovian moons and a ring system, discovered the volcanic activity of its moon, Io which was caused by the tug-of-war of its strong gravitational pull and also discovered the presence of water ice on its moon, Europa. The Cassini-Huygens spacecraft, sent to study Saturn, also flew past Jupiter in 2000 and took detailed images of its atmosphere. New Horizons spacecraft made a flyby of Jupiter during 2006-07 taking detailed infrared images of its moon, Callisto along with several black and white photos of the planet itself.

The Galileo Spacecraft was the only one sent exclusively to enter into orbit in 1995 and studied the planet until 2003. An atmospheric probe was also made to enter the Jovian atmosphere, so far the only spacecraft to do so. Galileo studied the Jovian system extensively and made close approaches of the Galilean Moons, discovering a magnetic field around Ganymede. It found evidence of a thin layer of atmosphere on the three of them along with the possibility of the presence of liquid water underneath their surface. Galileo also observed the collision of a comet with Jupiter. In July, 1994, Comet Shoemaker-Levy 9 broke apart under pressure from its intense gravitational field and collided with Jupiter. This event was the first direct observation of an extraterrestrial collision of the solar system objects. The event was greatly publicized by the media and closely observed by astronomers world wide.

2.3.5 Missions to Saturn

Three flyby missions to the majestic ringed planet formed an extended foundation of knowledge about the planet. After tremendous effort, the most successful mission of the Cassini-Huygens spacecraft, is still currently in orbit and is expected to last till 2017.

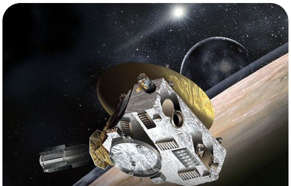

Voyager 2 captured this true colour image on the left in 1981. Cassini captured a great storm on Saturn in 2011

Pioneer 11 was the first spacecraft to have visited Saturn in 1979 and flew within 20,000 km of the planet's top cloud layer. The spacecraft studied its rings and its moons and measured its moon, Titan's temperature at 250 Kelvin. Voyager 1 flew past Saturn in November 1980, sending back high resolution images to discern certain surface features of its many moons. When the Voyager approached Titan, its thick atmosphere prevented the spacecraft to see any surface details at visible wavelength. Voyager 2 approached Saturn in August, 1981, taking more detailed pictures of the planet and changes in its ring system. The spacecraft took temperature and density profiles of the upper atmosphere with its radar.

The Cassini-Huygens mission studied the planet and its moons in more detail like no other mission before it. Before entering into orbit around the planet, Cassini orbiter had already studied the planet and its moon, Phoebe, sending back high resolution images and data. The orbiters also made two flybys of its largest moon, Titan before sending the Huygens probe on December 25, 2004. It landed on Titan's surface on January 14, 2005. It sent back a flood of data during atmospheric entry and descent while its orbiter continued to make flybys of Titan and the other icy moons. It discovered hydrocarbon seas on Titan's north-pole nearly the size of the Caspian sea in July, 2006. Cassini probe found that liquid geysers on Saturn's moon, Enceladus, erupt in the form of geysers, like fountains as reported by NASA in 2006. Cassini also discovered a new planetary ring outside the brightest rings in 2006. The probe also discovered four new satellites of Saturn. The primary Cassini mission ended in 2008 and the probe began its first extended mission, the Cassini Equinox Mission in 2010. It is currently in its second mission extension, the Cas sini Solstice Mission which is expected to last till September 2017.

2.3.6 Mission to Pluto-New Horizons

Part of NASA's New Frontiers Program to further explore Jupiter, Venus and Pluto, New Horizons space Probe has been sent to study Pluto, its moons and a couple of Kuiper Belt Objects. It was launched into an interplanetary space journey on January 19, 2006. It is travelling with the highest velocity attainable by human-made object released from earth, i.e. 16.26 km/s. The probe took the first pictures of Pluto in September, 2006 and later pictures helped distinguish its moon Charon, from it as two different objects in July 2013. It is expected to visit Pluto on July 14, 2015.


An artists's depiction of the New Horizons mission spacecraft

During its journey, it passed closed to the planet Jupiter (2.3 million km) to test its system and collect data about planet's atmosphere, moons and the magnetosphere. This flyby also increased the probes' speed by 14,000 km/hr due to assistance from the planet's gravitational field, lessening the travel time by three years. The probe is continuing the journey in hibernation mode to preserve power consumption of onboard systems.

2.4 SUN OBSERVING SATELLITES AND OTHER SOLAR SYSTEM MISSIONS

Apart from the planets and their moons, space missions have focused on the sun and a variety of other solar system objects. Between and beyond the orbits of the planets, innumerable smaller bodies - asteroids and comets also orbit the sun. The Soviet satellite Sputnik 2, launched in 1957, first carried instruments to detect ultraviolet and X-ray radiation from the Sun. A series of Earth orbiting US satellites known as Orbiting Solar Observatories studied the solar activities from 1962-1978. In addition, a number of other solar missions were undertaken in the turn of the 1990s to study the solar radiation while others revealed Sun's internal structure and its outer atmosphere. Some details of the missions to the sun and to the solar ystem objects like asteroids, comets and interplanetary space are mentioned in the sections below.

2.4.1 Solar & Heliospheric Observatory (SOHO)

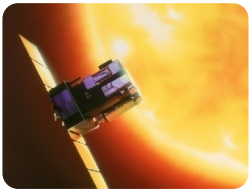
While other telescopes are busy looking at distant stars, SOHO is focused on our own. Jointly launched by NASA and ESA in 1995, SOHO was designed to study the structure and dynamics of the interior of the sun, as well as the solar wind and the stream of charged particles ejected from the sun's upper atmosphere. Understanding these solar phenomena is the key to making better predictions of space weather, such as solar flares and coronal mass ejections which can affect electrical grids and communication networks here on Earth. SOHO is located at a distance of 1.5 million kms from earth at the Lagrangian point L1. To date, SOHO has taken the first images of the sun's convection zone, shown the structure of sunspots below the sun's surface, and discovered new phenomena, such as solar tornadoes. SOHO has also spotted 1,500 new comets. It collects and transmits near real-time data available for the general public to use on its website.

2.4.2 Solar Terrestrial Relations Observatory (STEREO)

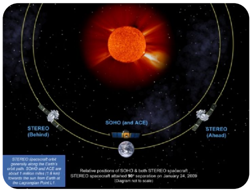
Another solar observer, NASA's STEREO (Solar Terrestrial Relations Observatory) mission is actually two separate spacecrafts (STEREO A & B) that after launch in 2006, moved apart so that one trails Earth and the other leads it. These positions allow for stereoscopic imaging of the Sun and solar phenomena. STEREO has taken 3-D images of solar storms known as Coronal Mass Ejections (CMEs). These powerful solar eruptions are a major source of the magnetic disruptions on Earth, interrupting satellite operations, communications and power systems. STEREO relays near real-time on its website and makes it available for public use. Since July 2014, STEREO-B has been put into a reduced operations mode due the danger of meltdown of its high gain antennas as both spacecrafts are near the sun (backside). It is expected to resume operation from January 2016.

2.4.3 Solar Dynamics Observatory (SDO)

This NASA mission was launched on February 11, 2010 as part of the Living with a Star (LWS) Program. The purpose of the program was to understand the Sun-earth connection, its influence on the near-Earth environment and its impact on life and society in general. SDO has been continuously monitoring the sun and its activity, how the Sun's magnetic field is generated and projected in the



2.4.1 SOHO



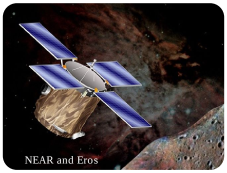
2.4.2 STEREO A& B

2.4.3 Solar Dynamics Observatory

interstellar space (basically the heliosphere, where the influence of the sun's magnetic field can be felt), and how the magnetic energy is stored, converted and released a stream of energetic charged particles under the magnetic field's influence (the Solar Wind). SDO is placed in a geosynchronous orbit of 36,000 km at 102°W longitude and inclined at 28.5°. It has 3 instruments on board which 'see' the sun in many wavelengths to cover many regions of the solar atmosphere, i.e. the photosphere, the chromosphere and the corona. All the data is made available as soon as it received from the satellite. The mission's lifetime is 5 years but it may last for another 10 years.

2.4.4 NEAR Mission

NASA launched a mission in 1996 to study the NEAR-Earth asteroid, Eros for a whole year. NEAR Earth Asteroid Rendezvous-Shoemaker (NEAR-Shoemaker) was named in honour of the planetary scientist, Eugene Shoemaker. NEAR mission's objectives were to collect data about the bulk properties, composition, mineralogy, morphology, internal mass distribution and the magnetic field of Eros. The mission was successful in closely orbiting the asteroid several times before impacting the surface on February 12, 2001.



NEAR and Eros

2.4.5 Deep Impact Mission

DEEP IMAPCT mission's impactor hitting comet 9P/Tempel

This NASA mission was sent on January 12, 2005 to investigate the interior composition of the comet Tempel 1. The mission consisted of a flyby, an impactor and 3 main science instruments. The impactor hit the comet's surface on July 4, 2005 releasing debris in the vicinity and formed an impact crater. This mission was one of a kind in which debris was excavated to study the comet's interior and it was found to contain more dust and less ice than expected. The Deep Impact mission continued to make flybys of Comet Hartley 2 , Comet Gerrard in 2012 and 2013 and observed Comet ISON until contact was lost with the spacecraft and the mission was abandoned in September 2013.

2.4.6 Rosetta Mission

Rosetta spacecraft was the first ever to be built and launched by ESA as a part of the ESA Horizon 2000 cornerstone missions to orbit and land on a comet, 67P/Churyumov-Gerasimenko. The spacecraft consists of two main components: the Rosetta space probe orbiter featuring 12 instruments and the Philae robotic lander featuring nine additional instruments. The purpose of this mission is to understand the formation and evolution of comets in the early solar system. Rosetta was launched on March 2, 2007 and has flew past Mars in 2007 and two asteroids, one in September 2008 and the other in 2010 during its journey. Since June 2011, it had been in hibernation mode for 31 months to save unnecessary power consumption and was restored on January 20, 2014. It reached the comet on August 6, 2014. Its orbiter will keep orbiting for 17 months but the Philae lander touched down on its surface on November 12, 2014.

2.4.7 Dawn Mission

An artist's depiction of the Rosetta Space Probe

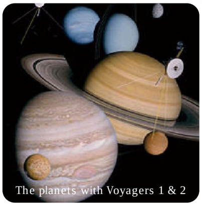
On September 27, 2007, NASA sent the Dawn spacecraft to study two very massive protoplanets in the asteroid belt i.e. the asteroids Vesta and Ceres. It was the first mission sent to any asteroid/extra-terrestrial body to visit and orbit around it.

The purpose of this mission was to investigate the processes involved in the formation of the solar system, mainly the formation of the inner terrestrial planets. Ceres is made of ice and rock and is quite primitive while Vesta is purely rocky and is much evolved. This contrast will help scientists understand the conditions necessary to form rocky and icy bodies and how these conditions were met in the early solar system formation to sustain and evolve both kinds of structures together. Dawn first visited Vesta and entered into orbit around it on July 16, 2011 to successfully complete the fourteen month survey mission in September, 2012. Dawn entered Ceres orbit on March 06, 2015.

2.4.8 The Voyager Program & the Voyager Interplanetary Mission

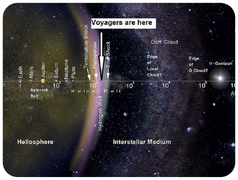
The American mission- the Voyager program was sent to study the gaseous giants of the solar system taking advantage of a rare yet, favourable planetary alignment during the 1970s (occurs every 175 years). The two NASA space probes, Voyager 1 & 2 were launched in 1977, with Voyager 2 sent out first to explore all four gas giants and their planetary systems together for the first time, visiting the Jovian system in 1979; Saturnian system in 1981; Uranian system in 1986 & Neptunian system in 1989. On its flyby of Jupiter at the closest approach of 570,000 km, Voyager 2 discovered a faint ring system, new moons orbiting it, the giant, raging storm system known as the Great Red spot and volcanic activity at its moon, Io. After its flyby of Saturn and studying its moons and


Dawn spacecraft together with Vesta and Ceres

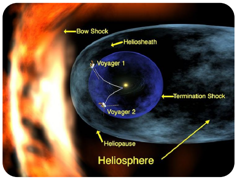

The planets with Voyagers 1 & 2

rings, Voyager 2 moved on to explore Uranus. On its closest approach on January 24, 1986, Voyager 2 came to within 81,500 kms where it discovered several of its moons, its unique atmosphere and ring system, its magnetic field and its axial tilt of 97.8° (meaning its north and south poles are tilted to face eastwards and westwards as a consequence of a collision with a heavier body in the early days of the solar system formation). One of its moons, Miranda was found to be the strangest body in the solar system. It had bizarre canyons made from geological faults as deep as 20 kms and a mixture of young and old structures.

Next in line was the blue, gas giant, Neptune. Voyager's closest approach to Neptune occurred on August 25, 1989 where it discovered the giant storm system like Jupiter's known as the 'Great Dark Spot'. The blue colour of Neptune comes from the Methane gas in its atmosphere which absorbs red light from the sun but reflects blue light back in to space. Voyager 2's primary mission ended on December 31, 1989 and since then it has been drifting in interplanetary space with most of its instruments gone out of order but it is still relaying signals back to earth. Voyager 2 became the third object to reach a distance of 100 Astronomical Units (AU) from the Sun on November 7, 2012 after Pioneer and Voyager1 spacecrafts.



Voyagers as of March 2013



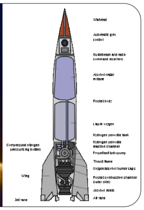
Voyagers near the edge of the solar system as of early 2013

Although Voyager 1 was launched after Voyager 2 but it eventually surpassed it with its faster velocity, making it the farthest object from the sun. Voyager 1 set out to explore the planets Jupiter and Saturn. During January to April, 1979, Voyager 1 made observations of the moons of Jupiter, its rings, its magnetic field and its radiation belt environment, not to mention the unexpected volcanic activity at its moon, Io. Voyager 1 then set out to explore Saturn, its atmosphere, its rings, its moons especially Titan, and discovered high speed winds in its atmosphere. It also discovered beautiful polar and equatorial auroras (streaks of lights created when charged particles from the sun strike with the atmospheric particles).

After studying Titan, its primary mission was completed in November, 1980 but it continued drifting in space with the fastest speed of 17 km/s on record, surpassing Pioneer 10 and reached a distance of 69 AU on February 10, 1998. In 2010, Voyager 1 was in the Heliosheath (region between 80 to 100 AU from the Sun). As of June 27, 2014, it is at the farthest distance of 127.63 AU outside the Sun's magnetic field influence i.e. right in the interstellar medium. Both the spacecrafts are expected to keep communicating with Earth until 2025 and if Voyager 1 continues drifting, it will reach the Oort cloud in 300 years and will take about 30,000 years to pass through it.

2.5 ROCKETS


Launch of Jupiter C with Explorer 1


German's V-2 Missiles

Rockets are self-propelled devices that carry their fuel, as well as oxygen, or other chemical agents, needed to burn fuel. Most rockets move by burning their fuel and expelling the hot gases shooting out in one direction causing the rocket to move in the opposite direction. The most common use of rockets is for missiles-weapons that deliver explosive warheads through the air to specified targets. Rockets also have numerous peaceful purposes. Upper atmosphere research rockets or sounding rockets carry scientific instruments to high altitudes, helping scientists carry out astronomical research and learn more about the nature of the atmosphere.

American Physicist Robert H. Goddard evolved his theory about use of rocket for space flight and on 16 March, 1926, Goddard launched the world's first liquid-fuelled rocket.

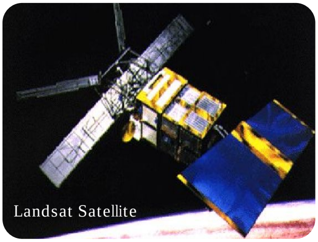
During World War II, the Germans developed a variety of solid and liquid-fuelled missiles. The most important of these were the V-2, the world's first large-scale liquid-fuelled rocket.

Around 1954, USSR developed their first intercontinental ballistic missile R-7 inspired by V-2. On October 4, 1957, USSR used a modified version of R-7 to put Sputnik 1 into orbit around Earth. In 1957, US launched a satellite with Vanguard rocket but unfortunately Vanguard fell back to its launch pad and exploded after a few seconds after flight. Later in 1958, Jupiter-C rocket placed America's first satellite Explorer 1 into orbit.

2.6 SCIENTIFIC SATELLITES

Years before the launch of the first artificial satellites, scientists anticipated the value of putting telescopes and other scientific instruments in orbit around earth.

2.6.1 Earth Observing Satellites


Landsat Satellite

One main advantage of putting scientific instruments into space is the ability to look down at Earth. Viewing large areas of the planet allows meteorologists, scientists who research Earth's weather and climate to study large scale weather patterns. More detailed views aid cartographers and map makers in mapping regions that would otherwise be inaccessible to people.

Beginning in 1960 with the launch of US Tiros I, weather satellites have sent back television images of parts of Earth. The first satellite that could observe most of the Earth, NASA's Earth Resources Technology Satellites 1 (ERTS 1, later renamed Landsat 1) was launched in 1972.

Landsat 1 was equipped with the cameras that recorded images not just of visible light but also of the infra red light which provide a wealth of information about the earth's resources. Seven additional Landsats were launched between 1975 and 1999.

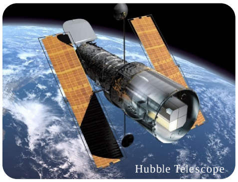
The success of Landsat satellites encouraged other nations to place Earth observing satellites in orbit. France launched a series of satellites called SPOT beginning in 1986 and Japan launched the MOS-1 (Marine Observation System) in 1987. The Indian Remote Sensing satellite IRS-IA began operating in 1988.

2.6.2 Astronomical Satellites

Astronomical objects such as stars emit radiation energy, in the form of visible light and many other types of electromagnetic radiation. Different wavelengths of radiation provide astronomers with different kinds of information about the universe. In the early 1960s, rockets equipped with scientific instruments (called sounding rockets) provided brief observation of space beyond our atmosphere, but orbiting satellites have offered far more extensive coverage.

Britain launched the first astronomical satellite, Ariel 1 in 1962, to study cosmic rays and ultraviolet and X-ray radiation from the sun. In 1962, NASA launched first Orbiting Astronomical Observatory, OAO 1, equipped with an ultraviolet telescope. More details to some of the important Deep space missions are given below.

2.6.2.1 Hubble Space telescope


Hubble Telescope

The Hubble Space telescope was the largest and most versatile telescope to be launched in space in its time. It was launched in a low earth Orbit (560 km above the earth) with a 2.4 meter (7.9 ft) mirror on April 24, 1990 by a joint collaboration between the US space agency, NASA and the European Space Agency, ESA. There are four main instruments on board which observe the surrounding universe in near ultraviolet, visible and near infrared electromagnetic spectra and take high resolution images free from distortions and reflections from the Earth's atmosphere. It is named after the famous astronomer, Edwin Hubble. It is operated by the Space Telescope Science Institute in Baltimore, Maryland, USA. Since its launch, it has been maintained by 5 servicing missions of NASA space shuttles in which astronauts repaired, replaced and installed some of the degraded or failed components and instruments. The first servicing mission in 1993 was conducted to rectify faults in the telescope optics which would have otherwise compromised the telescope's abilities. The last servicing mission was carried out in 2009 and the telescope is expected to last until 2020. The telescope has been available for scientists as well as amateur astronomers to fuel their interest. Between 1990 & 1997, 13 amateur astronomers were awarded time on the telescope. Hubble has carried out research projects in coordination with the Chandra X-ray Observatory and the Very Large Telescope (VLT). The Frontier Fields Program was initiated in 2012 by the name of "Hubble Deep Fields Initiative" to observe the faintest galaxies in the distant universe.

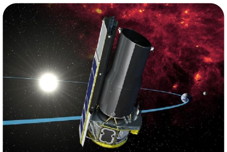
The Hubble telescope has served the purpose of accelerating astronomical research and public outreach, and its observations have led to testifying of one of the greatest discoveries in astrophysics i.e. accurate determination of the rate of expansion of the universe, the scale of the universe, the life cycle of stars, black holes, and the formation of the first galaxies.

2.6.2.2 Chandra X-ray Observatory


Chandra X-ray Observatory

NASA launched Chandra X-ray observatory in 1999. It has eight times the resolution of any previous X-ray telescope. It examines the X-rays emitted by some of the universe's strangest objects, including quasars, immense clouds of gas and dust and particles sucked into black holes. X-rays are produced when matter is heated to millions of degrees. Chandra has teamed up several times with other telescopes, including Hubble, to take composite images of galaxies.

2.6.2.3 Spitzer Space Telescope


Spitzer Space Telescope

The Spitzer Space Telescope was the fourth of the NASA Great Observatories program to be launched in 2003. It has been named after the great scientist of the 20th century, Lyman Spitzer. The telescope gathers the infrared radiation emanating from cosmic objects, including faraway galaxies, black holes and even comets in our own solar system (Infrared radiation is hard to observe from the ground because it is largely absorbed by the Earth's atmosphere).

Spitzer was the first telescope to see light from an exoplanet, which it was not originally designed to see. It has been running continuously for the last nine years but only one out of the 3 instruments on board is working properly.

2.6.2.4 Herschel Space Observatory


Herschel Space Observatory

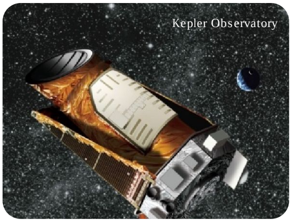
Herschel, a joint venture by NASA and ESA was launched into space on May 14, 2009 along with the Planck telescope. It was named after the discoverer of the infrared spectrum and the planet Uranus, Sir William Herschel alongside his sister Caroline Herschel. Herschel was operational from 2009 till 2013 because it ran out of the coolant available for functioning the three science instruments but was the largest, most powerful infrared telescope looking at the far-infrared to sub-millimeter wavelengths of light generated by some of the coldest and dustiest objects in space. Herschel successfully fulfilled the purpose it was designed i.e. to look for water, both in nearby comets and faraway dust clouds, and also to peek into stellar nurseries-the birthplaces of stars.

2.6.2.5 Planck Observatory


Planck Observatory

The Planck Space Observatory, launched by ESA in May 2009, was designed to observe the microwave light of the universe and NASA specialists analysed its scientific data. Planck recorded the remnants of the first light to shine freely in the universe right after the Big Bang i.e. the Cosmic Microwave Background Radiation (CMBR). It was named after the German Nobel Laureate Physicist, Max Planck. In February, 2010, Planck started an all-sky survey to gather evidence of CMBR and an all-sky map of the CMBR was officially released on March 21, 2013. The mission followed in the footsteps of NASA's Cosmic Background Explorer (COBE) and the Wilkinson Microwave Anisotropy Probe (WMAP), mapping the CMB and providing the most detailed measurements of the temperature variations of the remnant light from the Big Bang Explosion. Planck also probed the mysteries of dark matter and dark energy and mapped the magnetic field of the Milky Way in 3-D.

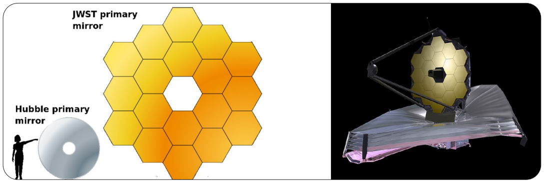
2.6.2.6 Kepler Observatory


Kepler Observatory

NASA's planet-hunting telescope, Kepler was launched on March 7, 2009 with an objective to search for other Earth-like planets in or near habitable zone that support life like the Earth in other solar systems of our Milky Way Galaxy. The spacecraft was named after the famous 17th century mathematician and astronomer, Johannes Kepler. The spacecraft has a light detecting instrument called a photometer of 0.95 m diameter. Kepler works on the principle to look for characteristic variations in the light from a pre-selected target group of 145,000 stars. Dips or dimming in the light from the stars can indicate a planet passing in front of the star (from Earth's perspective). First light from the telescope came on April 16, 2009. Since then, Kepler has found 977 confirmed Exoplanets in more than 400 stellar systems.

2.6.2.7 James Webb Telescope

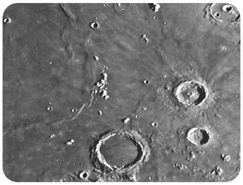
This telescope, a successor for the Hubble Space Telescope and the Spitzer Space Telescope, is planned to be launched in 2018 by NASA. It was previously named as the Next Generation Telescope (NGST) but was renamed after James E. Webb, the second administrator of NASA who played an integral role in the Apollo Program. It features a unique 6.5 m (21 feet) diameter mirror which is segmented into 18 parts joined to work together as one unit, and four science instruments and a guide camera for observing the universe in near and mid-infrared wavelengths. The purpose of this telescope is to achieve four important scientific quests: to hunt for first light from the stars that were formed immediately after the birth of the universe- the Big Bang; to study how galaxies evolve and form; to understand how stars and their planetary systems are formed; and to study how life originates in planetary systems. It is expected to remain in operation for 5 years but may extend another 10 years. It will be placed at a linear distance (sun-earth line of sight) of 1.5 million km further from the earth instead of a LEO orbit in which the Hubble is currently situated.

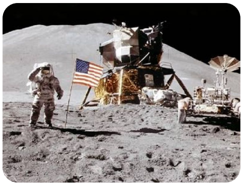


The James Webb Telescope's (right) mirror in comparision with Hubble Telescope's primary mirror (left)

2.7 LUNAR MISSIONS

Apollo program was initiated by the U.S to send manned spaceflights on the surface of moon. On 20 July, 1969, a dream was made to come true, when Apollo 11 spaceflight launched through Saturn V rocket landed on the surface of moon. Neil Armstrong was the first human who set his footstep on the lunar surface. His famous first words, as he landed on the moon were "that's one small step for man, one giant leap for mankind". Six Apollo missions were made to explore the moon between 1969 and 1972.


Kepler Observatory


Kepler Observatory

2.8 SPACE STATIONS

A space station is an artificial structure designed for humans to live in outer space. So far only low earth orbit (LEO) stations are implemented, also known as orbital stations. A space station is distinguished from other manned spacecrafts by its lack of major propulsion or landing facilities; instead, other vehicles are used as transport to and from the station. Space stations are designed for medium term living in orbits for periods of weeks, months, or even years.

2.8.1 Salyut Space Station

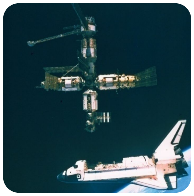
Even before the first human spaceflights, planners in the United States and USSR envisioned space stations in orbit around Earth. In April 1971, USSR succeeded in launching the first space station, Salyut1. Six more Salyut stations reached orbit between 1974 and 1982.

2.8.2 Skylab Space Station

Skylab, the first US space station mission was launched in May 1973. The Skylab mission gave US researchers valuable information on human response to long duration space-flights.

2.8.3 Mir Space Station

In 1986, USSR launched the core of the distinct units to be composed of modules. This modular space station was named Mir (Peace). Over the next ten years additional modules were launched and attached to the station. Cosmonauts lived abroad Mir for more than a year. Such long duration missions helped researchers understand problems posed by lengthy stays in space. By 1997, the 11 year old Mir was experiencing a series of calamities and subsequent repair missions returned the station to a relatively normal level of functioning. In March 2001,


Mir Space Station

Mir was abandoned and de-orbited. It returned to earth and was plunged in the South Pacific Ocean on March 23, 2001.

2.8.4 International Space Station


International Space Station as seen from Endeavour space shuttle on May 30, 2011

One of the NASA's goals was to build a permanent, Earth-orbiting space station. After several redesign efforts by NASA, the station was reshaped into an International venture and renamed the International Space Station (ISS). The ISS Programme is a joint project among five participating space agencies: NASA, the Russian Federal Space Agency, JAXA, ESA and Canadian Space Agency (CSA). The ownership and use of the space station is established by intergovernmental treaties and agreements. The station is divided into two sections, the Russian orbital segment (ROS) and the United States orbital segment (USOS), which is shared by many nations. Launch of the first ISS element, occurred in 1998. The ISS is maintained in a nearly circular orbit with a minimum mean altitude of 330 km (205 mi) and a maximum of 410 km (255 mi), in the centre of the Thermosphere, at an inclination of 51.6 degrees to Earth's equator. It travels at an average speed of 27,724 kilometers (17,227 mi) per hour, and completes 15.7 orbits per day. Due to the size of the ISS, which is the size of an American football field and particularly due to the large reflective area offered by its solar panels , ground based observations of the station are possible with naked eyes. In many cases, the station is one of the brightest objects in the sky, though it is only visible for brief period of time. This is because the station is in Low Earth Orbit and the sun angles and observer locations need to coincide. (Complete information about the location of ISS over a region at specific day and time can be acquired from the website (www.spaceflight.nasa.gov).

Since the arrival of Expedition 1 on November 2, 2000, the station has been continuously occupied for nearly 12 years, currently the longest continuous human presence in space. (In 2010, the station surpassed the previous record of almost 10 years held by Mir). The ISS serves as a mircrogravity and space environment research laboratory in which crew members conduct experiments in biology, human biology, physics, astronomy, meteorology and other fields. The station is suited for the testing of spacecraft systems and equipment required for missions to the Moon and Mars. In addition, the ISS provides a platform to conduct scientific research that cannot be performed in any other way.

While small unmanned spacecraft can provide platforms for zero gravity and exposure to space, space stations offer a long term environment where studies can be performed potentially for decades, combined with ready access by human researchers over periods that exceed the capabilities of manned spacecraft. Scientists on Earth have access to the crew's data and can modify experiments or launch new ones, benefits generally unavailable on unmanned spacecraft. Crews fly expeditions of several months duration, providing approximately 160 man-hours a week of labour with a crew of 6.

After more than a decade of construction, it is nearing completion and finally has a full crew of six astronauts. The last components were installed by September 2, 2012. The station has been visited by astronauts from 15 countries. The ISS was also the destination of the first five space tourists. It is envisioned as a world class research facility which will continue to be funded till 2020 and will hopefully operate till 2028.

2.8.5 Chinese Tiangong Space Station

Tiangong (derived from Chinese, means Heavenly Palace) is a space exploration and space station program of the People's Republic of China to create a third generation space station that can be comparable to Mir and the ISS. This program is China's indigenous and autonomous program, unconnected to any other international space-faring countries. The main objective of the


An artist's concept of Tiangong

program is to conduct scientific experiments in microgravity conditions (very little or no gravity at all, free fall). The program began in 1992 as Project 921-2 consisting of three stations; Tiangong 1 being the "Target Vehicle", Tiangong 2 being the "Space Laboratory" and Tiangong 3 being the "Space Station". Tiangong-1 was launched on 29 September 2011 at 13:16UT from Jiuquan Satellite Launch Centre. It is placed into Low Earth Orbit and remains in orbit as of 2014. Tiangong-1 is an 8.5-metric-ton (19,000 lb) "space-laboratory module". It is capable of supporting the docking of manned and autonomous spacecrafts.

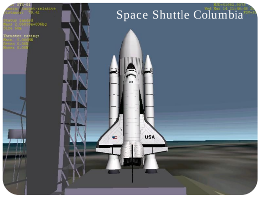
Structurally, Tiangong-1 is divided into two primary sections: a resource module, which mounts its solar panels and propulsion systems, and a larger, habitable experimental module. It is intended for short stays for a crew of 3 astronauts. Tiangong-1's experimental module is equipped with exercise gear and two sleep stations. The interior walls of the spacecraft have a two-colour paint scheme – one colour representative of the ground, and the other representative of the sky. This is intended to help the astronauts maintain their orientation in zero gravity. High-resolution interior cameras allow manned missions to be closely monitored from the ground, and the two sleep stations have individual lighting controls.

Tiangong 1 was visited by a series Shenzhou spacecrafts with the first being the unmanned Shenzhou 8 which successfully docked with the module in November 2011. Two manned Shenzhou missions, Shenzhou 9 and 10 carried China's first female astronauts, Liu Yang and Wang Yaping and docked with Tiangong 1 in June 2012 and June 2013 respectively.

Tiangong 2 is expected to be launched in 2016 and replace Tiangong 1 which will be deorbited eventually. It will support a crew of 3 with 20 days of provisions.

Tiangong 3 is expected to be a complete space station and will replace the ISS when it will be launched during the time frame of 2020-2022. It will be a larger, multi module station docked with previous modules of Tiangong with a total mass of 60,000 kg (130,000 lb) and will be housing 3 astronauts for long term habitation. It will have a design life time of up to 10 years.

2.9 SPACE SHUTTLES


Space Shuttle Columbia

In April 1981, the launch of the space shuttle Columbia was carried out by world's first reusable rocket engines. The solid rocket boosters that launch the shuttle into orbit can be retrieved and refurbished. Twenty-four successful shuttle launches fulfilled many scientific and military requirements until January 1986, when the shuttle Challenger exploded after launch, killing its crew of seven.

The Challenger tragedy led to a reevaluation America's space program. The new goal was to make certain a suitable launch system was available when satellites were scheduled to fly. Today this is accomplished by having more than one launch method and launch facility available and by designing satellite systems to be compatible with more than one launch system.

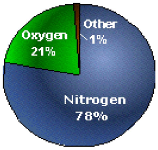
THE EARTH

3.1 EARTH’S ATMOSPHERE

The Earth is surrounded by a blanket of air, which we call the atmosphere. It reaches over 560 kilo-meters (348 miles) from the surface of the Earth, so we are only able to see what occurs fairly close to the ground. Early attempts at studying the nature of the atmosphere used clues from the weather, the beautiful multicoloured sunsets and sunrises, and the twinkling of stars. With the use of sensitive instruments from space, we are now able to get a better view of the functioning of our atmosphere. Life on Earth is supported by the atmosphere, solar energy, and our planet's magnetic fields. The atmosphere absorbs the energy from the Sun, recycles water and other chemicals, and works with the electrical and magnetic forces to provide a moderate climate. The atmosphere also protects us from high-energy radiation and the frigid vacuum of space.

3.2 COMPOSITION OF ATMOSPHERE

The atmosphere is primarily composed of Nitrogen gas (N_2, 78%), Oxygen (O_2, 21%) and Argon (Ar, 1%). A myriad of other very influential gases are also present which include water (H_2O, 0-7%), “greenhouse gases” or Ozone (O_3, 0-0.01%) and Carbon Dioxide (CO_2, 0.01-0.1%)



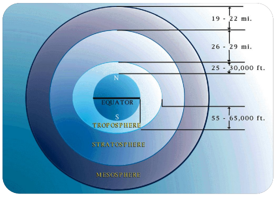
Composition of the Atmosphere

3.3 LAYERS OF ATMOSPHERE

The envelope of gas surrounding the Earth changes from the ground up. Four distinct layers have been identified using thermal characteristics (temperature changes), chemical composition, movement and density.

3.3.1 Troposphere

The Troposphere starts at the Earth's surface and extends 8 to 14.5 kilo-meters high (5 to 9 miles). This part of the atmosphere is the densest. As you climb higher in this layer, the temperature drops from about 17 to - 52 degrees Celsius. Almost all weather is in this region. The Tropopause separates the Troposphere from the next layer. The Tropopause and the Troposphere are known as the lower atmosphere.



Layers of Atmosphere

3.3.2 Stratosphere

The stratosphere starts just above the troposphere and extends to 50 kilo-meters (31 miles) high. Compared to the troposphere, this part of the atmosphere is dry and less dense. The temperature in this region increases gradually to -3 degrees Celsius, due to the absorption of ultraviolet radiation. The ozone layer, which absorbs and scatters the solar ultraviolet radiation, is in this layer. Ninety-nine percent of "air" is located in the Troposphere and Stratosphere. The Stratopause separates the Stratosphere from the next layer.

3.3.3 Mesosphere

The Mesosphere starts just above the Stratosphere and extends to 85-90 kilo-meters (53 miles) high. In this region, the temperatures again fall as low as -93 degrees Celsius as you increase in altitude. The chemicals are in an excited state, as they absorb energy from the Sun. The Mesopause separates the Mesosphere from the Thermosphere.

The regions of the Stratosphere and the Mesosphere, along with the Stratopause and Mesopause, are called the middle atmosphere by scientists. This area has been closely studied on the ATLAS Spacelab mission series.

3.3.4 Thermosphere

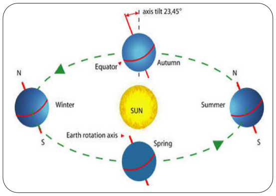
The thermosphere starts just above the mesosphere and extends to 600 kilo-meters (372 miles) high. The temperatures go up as you increase in altitude due to the Sun's energy. Temperatures in this region can go as high as 1,727 degrees Celsius. Chemical reactions occur much faster here than on the surface of the Earth. This layer is known as the upper atmosphere.

3.4 BEYOND THE ATMOSPHERE

The exosphere starts at the top to the thermosphere and continues until it merges with interplanetary gases, or space. In this region of the atmosphere, Hydrogen and Helium are the prime components and are only present at extremely low densities.

3.5 ROTATING EARTH

Technological developments in general and space technology in particular, have proven the theories related to our solar system. In ancient times, it was considered that earth was the center of solar system and it was the sun which rotates around our earth. This idea was theoretically rejected long ago by scientists. Space technology has proven that sun is the center of our solar system and the planets move around the sun.



Different Orientations of Earth Rotation

Our earth is not a perfect sphere but is slightly flattened at the poles. The earth encounters two motions while orbiting around the sun i.e., rotation around its own axis and revolution around the sun. Scientists have divided the spherical earth into two hemispheres North and South for different geographical purposes. An imaginary line divides these spheres and is called Equator. Day and night are outcome of rotation of earth around its axis. The period of one complete rotation is defined as a day and takes 23 hours 56 minutes 4.1 seconds. The period of one revolution around the sun is defined as a year or 365.2422 solar days, or 365 days 5 hours 48 minutes 46 seconds.

Earth’s axis of rotation is inclined (tilted) to 23.45° relative to its plane of revolution around the Sun. This inclination of the axis creates the seasons and causes the height of the Sun in the sky at noon to increase and decrease as the seasons change. The Northern Hemisphere receives the most energy from the Sun when it is tilted toward the Sun. This orientation corresponds to summer in the Northern Hemisphere and winter in the Southern Hemisphere. The Southern Hemisphere receives maximum energy when it is tilted toward the Sun, corresponding to summer in the Southern Hemisphere and winter in the Northern Hemisphere. Fall and spring occur in between these orientations.

Section 4

SATELLITE SYSTEMS

4.1 INTRODUCTION TO SATELLITES

A satellite is something that goes around and around the earth or another planet. Some satellites are natural, like the moon, which is a natural satellite of the earth. Other satellites are made by scientists and technologists to go around the earth.

Some satellites send and receive television signals. The signal is sent from a station on the earth's surface. The satellite receives the signal and rebroadcasts it to other places on the earth. With the right number of satellites in space, one television program can be seen all over the world. Some satellites send and receive telephone, fax, and computer communications. Satellites make it possible to communicate by telephone, fax, Internet, or computer with anyone in the world.

Other satellites observe the world's weather, feeding weather information into giant computer programs that help scientists know what the weather will be. The weather reporters on your TV news program get their information from those scientists.

Some satellites take very accurate pictures of the earth's surface, sending back images that tell scientists about changes that are going on around the world and about crops, water, and other resources.

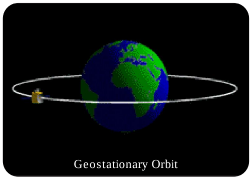
4.2 ORBIT TYPES

When a satellite is launched, it is placed in orbit around the Earth. The Earth's gravity holds the satellite in a certain path as it goes around the Earth, and that path is called an "orbit."

There is only one main force acting on a satellite when it is in orbit, and that is the gravitational force exerted on the satellite by the Earth. This force is constantly pulling the satellite towards the centre of the Earth. A satellite doesn't fall straight down to the Earth because of its velocity. Throughout a satellites orbit there is a perfect balance between the gravitational force due to the Earth, and the centripetal force necessary to maintain the orbit of the satellite. There are several kinds of orbits.

There are essentially three types of Earth Orbits: High Earth Orbit or Geosynchronous orbit, Medium Earth Orbit and Low Earth Orbit. Many weather and some communication satellites tend to have a high Earth orbit, farthest away from the surface. Satellites that orbit in a medium (mid) Earth Orbit include navigation and special satellites designed to monitor a particular region. Most scientific satellites including NASA's Earth Observing System fleet have a low Earth Orbit. During the launch of a satellite or other space probe a temporary orbit known as Parking orbit is used prior to positioning it in it's desired orbit. A launch vehicle boosts into the parking orbit, and then coasts for a while, then fires again to enter the final desired trajectory.

4.2.1 Geostationary Orbit


Geostationary Orbit

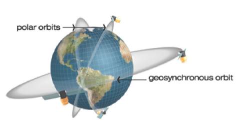
A geosynchronous orbit may be defined as the one with an orbital period (the time needed to orbit once around the Earth) that matches the rotation rate of the Earth. This is a sidereal day which is 23hrs, 56 minutes and 4 secs in length, and represents the time taken for the Earth to rotate once about its polar axis relative to a distant fixed point. This is about four minutes shorter than the common length of 24 hours which is relative to the sun.

A geostationary orbit is a special case of a geosynchronous orbit. A satellite is in a geostationary orbit when it appears stationary from a point of view of an observer on the Earth's surface. This can only occur when:

- The orbit is geosynchronous
- The orbit is a circle
- The orbit lies in the plane of the Earth's equator

This orbit is commonly used for satellite communication as the satellite launched in this orbit remains stationary with respect to a point on the surface of the earth. Advantage of such an orbit is that the satellite provides continuous operation in the area of visibility of satellite and the second advantage is that no tracking is required from the ground station. Most of the communication satellites are in this orbit. Also some of the weather/environmental satellites as METEOSAT and GOES series are in this orbit.

4.2.2 Medium Earth Orbit (MEO)



Different Orbits of Satellites

A medium earth orbit, sometimes called Intermediate Circular Orbit (ICO), is the region of space around the Earth above the Low Earth Orbit (altitude of 2,000 km (1,240 mi)) and below the Geostationary orbit (altitude of 35,786 km (22,236 mi)).

The most common use for satellites in this region is for navigation, such as the GPS (with an altitude of 20,200 km (12,522 mi), GLONASS (with an altitude of 19,100 km (11,868 mi))and GALILEO (with an altitude of 23,222 km (14,429 mi)) constellations. Communication satellites that cover the North and the South Pole are also put in MEO. The orbital periods of MEO satellites range from about 2 to 24 hours. Telstar, one of the first and most famous experimental satellites, orbits in MEO.

4.2.3 Low Earth Orbit (LEO)

A low earth orbit is generally defined as an orbit extending from the Earth's surface up to an altitude of 2,000 km. Given the rapid orbital decay of objects below approximately 200 km, the commonly accepted definition of LEO is the orbit existing between 160 km and 2,000 km (100-1,240 mi) above the Earth's surface. Objects in LEO encounter atmospheric drag in the form of gases in the Thermosphere (approx 80-500 km up) or the Exosphere (approx. 500 km and up), depending on orbit height.

Majority of artificial satellites for remote sensing purposes are placed in LEO because of the added detail that can be gained, where they travel at about 27,400 km/hr (8km/s), making one complete revolution around the Earth in about 90-100 minutes. The remote sensing satellites are launched by different nations including Landsat, SPOT, IRS, RADARSAT, IKONOS etc. Weather satellites

are also launched in the LEO orbit as NOAA series. The International Space Station is in a LEO that varies from 319.6 km (199 mi) to 346.9 km (216 mi) above the Earth's surface.

4.2.4 Elliptical Orbits

An elliptical orbit, also called an eccentric orbit is in the shape of an ellipse. In an elliptical orbit, the satellite's velocity changes depending on where it is in its orbital path. When the satellite is in the part of its orbit closest to the earth, it moves faster because the Earth's gravitational pull is stronger. The satellite is moving the fastest at the low point of the elliptical orbit. The low point of the orbit is called the perigee. The high point of the orbit, when the satellite is moving the slowest, is called the apogee.

4.2.5 Highly Elliptical Orbit (HEO)

A highly elliptical orbit (HEO) is an elliptic orbit with a low-altitude perigee and a high altitude apogee (over 35,786 km (19,323 mi)). It is a type of high Earth orbit. Such extremely elongated orbits have the advantage of long dwell times. HEO orbits offer visibility over Earth's Polar Regions, which most geosynchronous satellites don't. Much of Russia is at higher latitudes, so geostationary satellites do not provide full coverage of the region. Russia uses HEO called Molniya orbits for communication satellites.

4.3 SATELLITE LAUNCH VEHICLE

A satellite is launched on a launch vehicle, which is like a taxicab for satellites. The satellite is packed carefully into the vehicle and carried into space, powered by a rocket engine. The best places to launch satellites are near the ocean, so that when the launch vehicle falls away, it lands in the water and not on land. In Geosynchronous Satellite Launch Vehicle (GSLV) there is three-stage launch vehicle with the first stage being solid-propelled, the second liquid-propelled (with hypergolic fuels) and the final stage being liquid propelled as well (with cryogenic fuels). The solid first and liquid second stages are carried over from the Polar Satellite Launch Vehicle (PSLV). Early GSLV launches used cryogenic upper stages supplied by Russia. At launch, the launch vehicle's rockets lift the satellite off the launch pad and carry it into space, where it circles the earth in a temporary orbit. Then the spent rockets and the launch vehicle drop away, and one or more motors attached to the satellite move it into its designated orbit. A motor is started up for a certain time, sometimes just one or two minutes, to push the satellite into place. When one of these motors is started, it's called a "burn." It may take many burns, over a period of several days, to move the satellite into its assigned orbital position.

When the satellite reaches its orbit, a motor points it in the right direction and its antennas and solar panels deploy that is, they unfold from their travelling position and spread out so the satellite can start sending and receiving signals.

4.3.1 Types of SLV with respect to Propellants

There are two groups of rocket propellants, liquid and solid. Many spacecraft launches involve the use of both types of rockets, for example the solid rocket boosters attached to liquid-propelled rockets. Hybrid rockets, which use a combination of solid and liquid, are also being developed. Solid rockets are generally simpler than liquid, but they cannot be shut down once ignited. Liquid and hybrid engines may be shut down after ignition and conceivably could be re-ignited. To date, the only way to achieve the propulsive energy to successfully launch spacecraft from Earth has been by combustion of chemical propellants, although mass drivers may be useful in the future for launching material from the Moon or other small bodies.

4.4 OPERATION OF SATELLITES IN SPACE

Space is a difficult place to be in. Satellite systems need to adopt unique and reliable technologies for their launch, survival and operations in the hostile and harsh environment of the outer space. We can't plug in a cord in outer space, so satellites need to take a power source with them. It's hard to get satellites pointed in the right direction because there's nothing to turn them with. Satellites need to work in the freezing cold of Earth's shadow as well as in the blazing heat of the Sun's rays. They also need to be tough enough to survive collisions with tiny asteroids. Some of the important operations of satellite in space are as follows:

4.4.1 Power

A satellite provides its own power for the duration of its mission. Most satellites use both power from the Sun and batteries to work. They catch the Sun's energy using large flat solar panels. Satellites keep these panels pointed at the Sun. They use batteries when the Sun doesn't shine on them.

4.4.2 Direction or Orientation

Satellite orientation is the direction each of its sides faces. Satellites keep the solar panels pointed towards the sun. Whereas, the satellite's antennas and sensors point toward Earth or toward the object the satellite is observing. For example, communication and weather satellites have antennas and cameras pointed earthwards while space telescope are pointed towards the astronomical objects that scientists wish to study. Satellites can stay pointed in the right direction using small rockets called attitude thrusters. They can also use instruments called gyroscopes. Sometimes magnets on board the satellite can push against the magnetic field of Earth to aim the satellite correctly .

4.4.3 Heat Dissipation

A satellite comes across intense heat and intense cold as it faces or hides from the sun. The equipment on the satellite also creates heat. With no air blowing in space, the satellite releases its heat through the panels which open and close. In this way heat escapes the satellite. In order to protect from the Sun's direct rays, satellites spin so that the heat is distributed evenly.

4.4.4 Radiation Protection

Satellites need to be made from material strong enough to bear the effects of strong cosmic radiations which may cause it to become brittle or damage the equipment and computers on board. Moreover, it must endure damaging hits of objects present in space. Therefore, they need material that should not become brittle in intense heat or cold and under strong radiations of outer space.

4.5 RE-ENTRY AND SATELLITE DISPOSAL

When satellites stop working they are often left in orbit as space junk. Others drift too low to keep orbiting and burn up as they fall. Still others are brought back to Earth for repairs. Nonworking satellites are sometimes sent down from orbit into the atmosphere to burn up on purpose. Space is very large, but still scientists need to be careful that satellites don't crash into each other. They try to get rid of the broken ones.

Space debris, also known as orbital debris, space junk, and space waste, is the collection of defunct objects in orbit around Earth. This includes everything from spent rocket stages, old satellites and fragments from disintegration, erosion and collisions. Since orbits overlap with new spacecraft, debris may collide with operational spacecraft. Currently about 19,000 pieces of debris larger than 5 cm are tracked, with another 300,000 pieces smaller than 1 cm below 2000 km altitude.

4.6 TYPES OF SATELLITES

Many kinds of satellites have been developed to serve specific purposes and missions. Some of them are listed below:

4.6.1 Communication Satellites

Telecommunications and broadcasting industries use communications satellite to carry radio, television and telephone signals over long distances without the need for cables or microwave relays. Communications satellites can reach people in remote villages, ships on the high seas and areas where infrastructure on the ground has been damaged by a natural disaster such as an earthquake. They can also help to improve education, health care and the standard of living, and have special potential for the poorest and most devastated areas. Together with ground-based networks, they provide access to the World Wide Web. Today satellites in geostationary orbit provide voice, data, and television communication, including the direct broadcast of television to homes around the world. Over 400 communication satellites have been launched since 1957.

4.6.2 Earth Observation Satellites

4.6.2.1 Earth observation satellite with respect to sensors

Several earth observation satellites are currently available, providing imagery suitable for various types of applications. Each of these satellite-sensor platform is characterised by the wavelength bands employed in image acquisition, spatial resolution of the sensor, the coverage area and the temporal coverage, i.e. how frequent a given location on the earth surface can be imaged by the imaging system.

In terms of spatial resolution, the satellite imaging systems can be classified into:

- Low resolution systems (approx 1 km or more)
- Medium resolution systems (approx 100 m to 1 km)
- High resolution systems (approx 5 m to 100 m)
- Very high resolution systems (approx 5 m or less)

In terms of spectral regions used in data acquisition, satellite imaging systems can be classified into:

- Optical imaging systems (include visible, near infrared, and shortwave infrared systems)
- Thermal imaging systems
- Synthetic aperture radar (SAR) imaging systems

Optical/thermal imaging systems can be classified according to the number of spectral bands used:

- Monospectral or panchromatic (single wavelength band, "black-and-white", grey-scale image) systems
- Multispectral (several spectral bands) systems
- Superspectral (tens of spectral bands) systems
- Hyperspectral (hundreds of spectral bands) systems

Synthetic aperture radar imaging systems can be classified according to the combination of frequency bands and polarization modes used in data acquisition, e.g.:

- Single frequency (L-band, or C-band, or X-band)
- Multiple frequency (Combination of two or more frequency bands)
- Single polarization (VV, or HH, or HV)
- Multiple polarization (Combination of two or more polarization modes)

4.6.3 Navigation Satellites

Navigation satellites can help locate the position of ships, aircraft and even automobiles that are equipped with special radio receivers. Signals from satellites contain data that a special radio receiver on Earth translates into information about satellites' position. The receiver further analyses the signal to find out how fast and in what direction the satellite is moving and how long the signal took to reach the receiver. From this data, the receiver can locate its own location.

With extremely high accuracy, global coverage and all-weather operation, global navigation satellite systems (GNSS), including the United States' Global Positioning System (GPS), the Russian Global Navigation Satellite System (GLONASS) and the European GALILEO, are a new global utility with increasing benefits in people's daily lives.

Benefits of GNSS are growing in areas such as aviation, maritime and land transportation, mapping and surveying, precision agriculture, power and telecommunications networks and disaster warning and emergency response.

4.6.4 Weather Satellites

Weather satellites carry cameras and other instruments, pointed towards Earth's atmosphere. They can provide advanced warning of severe weather and are a great aid to weather forecasting.

4.6.5 Military Satellites

Many military satellites are similar to commercial ones, but they send encrypted data which only a special receiver can decipher. Military surveillance satellites takes pictures just as other earth imaging satellites do, but cameras on military satellites usually have a higher resolution.

4.6.6 Scientific Satellites

Scientific satellites serve as space-based platforms for observation of Earth, the planets, the sun, comets and galaxies and are useful in a wide variety of other applications.

There are two types of scientific satellites:

1. Earth Observing Satellites
2. Astronomical Satellites

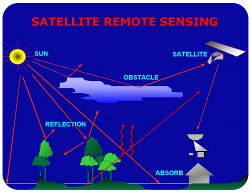
SPACE TECHNOLOGY APPLICATIONS

A famous quote by Einstein states that “Not everything that counts, can be counted”. The same is also true for the diversity of applications and spin off benefits derived from space technology. The countless benefits of space have encompassed almost every sphere of life. It is quite easy now to communicate worldwide through the use of internet, telephone, mobile phones etc. In case of natural disasters like earthquakes, floods, fires and cyclones, space technology comes to play its role in saving life and property of people. Artificial satellites, space telescopes, space probes, space shuttles, space stations and launch vehicles constitute space technology.

Space technology applications can act as a catalyst in socio-economic development. Applications of space technology offer a great deal in the areas of weather forecasting; tele-medicine; environmental monitoring; agriculture yield analysis and forecast; and satellite positioning, navigation and timing applications. Data collected through satellites can also help policymakers to develop better strategies for sustainable development in the areas of agriculture, natural resources, hydrology and land used urban planning.

This section briefly describes some of the applications, which these satellites offer and how these applications are serving people around the world.

5.1 SATELLITE REMOTE SENSING



Remote sensing satellites offer pictures of the earth. They work on the same principle as our eyes work. Light strikes the objects around us and is reflected back to our eyes. An image of the object is formed on retina of our eyes (retina is a layer inside our eye which translates light into human brain reading format). Our brain processes that information and we recognize the object. In a similar way, an artificial eye called sensor is placed on satellites that receives the reflected light from different objects. This electronic sensor translates reflected light energy into electrical energy. Electrical energy signals are sent back to earth at satellite data ground receiving stations where they are further processed to show pictures/images of the earth. This process, in which the sensor collects reflected light and does not physically touch the objects, is called remote sensing. Remote sensing systems are commonly used to survey, map and monitor the resources and environment of the earth.

5.1.1 Types of Remote Sensors

Two types of sensors are used: passive and active.

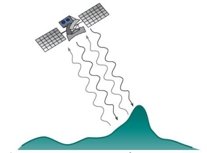
5.1.1.1 Passive Remote Sensors

Passive sensors are much like our eyes. In the night time when we switch off the lights, it is hard to see anything in the darkness. But when candle light or torch illuminates the room, light strikes the objects and the reflected light forms images of objects. Similarly, passive remote sensors depend on energy. Light is a form of energy obtained usually from the Sun. When sunlight strikes the surface of earth, two major phenomena take place: reflection and absorption. Depending upon the type and nature of object, light energy reflected by different objects is different. For example, water absorbs most of the light whereas snow or sand reflects a large amount of it.

The light, reflected by different objects is recorded by sensors onboard remote sensing satellites. Satellite sensors send this information to ground station where they are processed to form images of objects. Some examples of Passive sensors are Thematic Mapper (TM) and Enhanced Thematic Mapper (ETM), onboard Landsat series of satellites and High Resolution Visible (HRV) sensor onboard SPOT series of satellites.

5.1.1.2 Active Remote Sensors

Active sensors emit energy in the form of radio signals – it is a kind of energy like light but we cannot see it with our eyes. These signals strike objects and are bounced back towards satellite where they are received. Satellite sensors record the received signals and return them to ground receiving stations where they are further processed and converted to pictures/images. Active sensors can image the earth during nights as well as in cloudy weather. The most common type of active sensing method is RADAR (RAdio Detection and Ranging) and SAR (Synthetic Aperture Radar). Some active remote sensing satellites include RADARSAT, JERS, TerraSAR-X.



Active sensors generate their own energy in the form of radio signals. After striking objects the same bounce back to satellites, where they are recorded.

5.1.2 Information Extraction using Remote Sensing

Objects are made of different materials like concrete bricks, wood, leaves, soil and rocks. All these materials have different chemical and physical characteristics and colours. Images/pictures captured by remote sensing satellites give us different objects in different colours. Scientists have studied the characteristics and the behaviour of all materials in laboratories, and know how objects composed of different materials, appear on satellite images. For example, the colour of barren land on satellite image will be different from that of cropland. On the basis of different characteristics of materials as well as using other knowledge of the area remote sensing application scientists extract valuable information from the satellite images without physically visiting the area.

5.1.3 Applications of Remote Sensing

Satellite Remote Sensing can be used for many applications. This technology is being used for better management of earth's resources and its environment (more information can be found at www.suparco.gov.pk). The main areas of application of remote sensing technology are mentioned below.

5.1.3.1 Agriculture

Remote sensing can help us determining which crops are sown and on how much area, and whether or not some diseases are damaging the crops. We can also find out where the damage is taking place and how much area is damaged. Similarly, we can estimate the crop yield.

5.1.3.2 Forestry

Forests are an important natural resource of a country. It is believed that about 25% of the total land area should be under forest cover in order to maintain good environmental and weather conditions in a country. Natural forests are threatened by illegal logging, fires and diseases. In order to better manage forest resources, remote sensing can be used for finding out where these activities are taking place. Remote Sensing can also be used for planning how to arrest fires, stop spread of diseases, control illegal logging and assess deforestation efforts.

5.1.3.3 Geology

Geology is the study of the earth, its formation and materials that compose the earth. If we look around, different kinds of features like mountains, rivers, seas, deserts and fertile land constitute our earth. All these mentioned features are present on the surface of the earth. But there is a lot which is underneath the surface of earth. Geologists not only explore the surface features but they also explore sub-surface materials such as oil, gas and other precious minerals. Though remote sensing satellites cannot look under the surface of earth, they give us information about the composition of mountains, landforms which help in the exploration of oil, gas and other minerals. All the changes taking place on the surface of earth can be easily identified and demarcated with the help of remote sensing images.

5.1.3.4 Natural Disasters

Disasters such as flood, earthquake, cyclone and heavy rain are common natural calamities. Disasters, in any form, cause loss of lives as well as property. Though it is not possible to predict the occurrence of some disasters, such as earthquakes using current technologies, but rescue operations and damage assessment can be carried out using remote sensing images. For example, for management of rescue operations, images clearly tell us the most affected areas, the availability of roads, bridges and other communication infrastructure. A variety of remote sensing systems are being used to detect, monitor and respond to natural disasters.

5.1.3.5 Cartography

Maps and other information about any area play a vital role in our daily lives. If we are visiting an unknown city but we have guide maps of that city, we can easily explore the whole city without any other help. Guide maps give us information about residential areas, markets, parks, historical places, hotels and roads. Similarly, land-use maps tell us which land is being used and for what purpose. For example, on a land-use map, land being used for cultivation of crops may be highlighted in agriculture use category. The making and study of maps is called Cartography. Cartography makes extensive use of satellite images in the preparation of different categories of maps like guide maps, town planning maps and land-use maps because alternative information sources for map making are either too expensive or unavailable.

5.1.3.6 Geographic Information System

As discussed in Cartography section, maps play a vital role in urban planning and management. One disadvantage associated with paper maps is that we cannot add as much information as needed. For example, in a city guide map we can only highlight the location of parks in a city but paper size does not allow us to add more details about parks. Similarly, a residential area map does not tell us about the number of housing units or the number of people living there. All this supporting information is called attribute information. When we associate the attribute information with the map features, in computer based soft copy maps, the maps become intelligent. We can interact with these maps by asking question and in response maps give us the answers. This intelligent map making is called Geographic Information System (GIS). Use of both GIS and remote sensing is a valuable source of information.

5.1.3.7 Environmental Assessment

Many human activities result in or cause potentially harmful environmental effects on natural resources. For example, fertile lands turn unproductive and saline due to continuous over watering of crops. On the other hand, non-availability of water may turn the productive lands into deserts. Natural water resources such as lakes are being polluted by the humans and industry. Similarly, cutting of forests for domestic and commercial purposes causes environmental harm. The environmental assessment of all natural resources is important for the sustainability of our environment. Remote sensing images give us the status of natural resources and identify locations where damage is taking place.

5.2 SATELLITE COMMUNICATION TECHNOLOGY

We use telephones and cellular phones. Phone companies use terrestrial telephone lines or radio communication towers to connect the telephone network. But in remote areas where such networks are not available, at sea, in air and in space, often satellite communications are used. Special satellites, called communication satellites, receive a signal from a transmitter and send the signal back to a receiver somewhere else. Satellite communications are also used by TV stations for beaming their programmes over vast areas of the globe.

5.2.1 Telemedicine

Tele means at a distance and medicine is treatment for the patient. The term Telemedicine implies that the patient in remote area who may not physically visit the physician, his health and medical condition can be assessed by a physician who is located at a distant location. The development of communication satellites and computer technology has helped to improve the quality of health care for those who live in remote and isolated areas where access to quality health care is a problem. Communication satellites provide connectivity to areas where terrestrial or ground based communications network are either unavailable or have failed due to any disaster such as earthquakes. A communication network is established between hospitals through high speed internet or satellites. Patient’s medical data including photographs, x-ray, ultrasound and reports are communicated to connected hospitals to seek advice of specialist doctors.

5.2.2 Tele-Education

In addition to medical facilities, satellite communication technology also offers educational facilities at the computer desktop through internet. Educational institutions all over the world can communicate across countries, regions and cultures, share libraries and databases of research information or offer distance-learning services.

5.3 SATELLITE POSITIONING AND NAVIGATION

In our daily lives we use references while travelling. If we travel through a road we can see milestones in which distances of cities are written. If we have to go to some unknown city we try to find out the maps of city or ask someone who has already visited that city. When technology was not available, people travelled using stars as references in order to reach the desired destination. But with the advent of Global Navigation Satellite Systems (GNSS), travelling in unknown areas, even in deserts and seas, has become quite easy. These GNSS satellites orbit around the earth. A person having a GNSS receiver can locate his position on the earth.

Satellite Positioning and Navigation applications use GNSS system for its functionality. GNSS applications use GNSS Receivers to collect position, velocity and time information to be used by the application. The initial objective of the first GNSS systems was military applications. But with the free availability of GNSS signal and the availability of cheap GNSS receivers' use of GNSS technology has become pervasive in civil, industrial and scientific areas. Some of the major GNSS applications are classical geodesy & surveying, geodynamics (monitoring of the Earth's movements and deformations), seismic monitoring for earthquake hazards, volcano monitoring, atmospheric monitoring (troposphere) to improve weather predictions, space weather monitoring (ionosphere) for space situation awareness, precise orbit determination of low earth orbiting satellite etc.

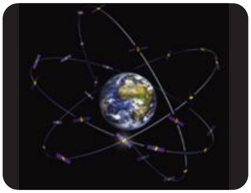
5.3.1 Global Positioning System (GPS)

The only complete known satellite navigation system is the United States' Global Positioning System. GPS consists of 24 to 27 satellites. Satellites are continuously monitored by ground stations located worldwide. The satellites transmit signals that can be detected by anyone with a GPS receiver. Some of the common uses of GPS are tracking of vehicles and equipment. Dispatchers for police, fire, and emergency medical service units use GPS vehicle tracking systems to determine which police car, fire truck or ambulance is nearest to the emergency. GPS is also used by the military for navigation and targeting.

Automatic Vehicle Location

5.3.2 Galileo Positioning System

The Galileo positioning system is a planned Global Navigation Satellite System, built by the European Union (EU) and European Space Agency (ESA). This project is an alternative and complementary to the U.S. Global Positioning System (GPS) and the Russian GLONASS. It is mainly intended for a set of practical services such as guiding cars, supporting safe aircraft landings or helping blind people to find their way. When in operation, it will have two ground operation centres, one near Munich, Germany, and another in Fucino, near Rome, Italy. Galileo will include 30 spacecraft and satellite lifetime of more than 12 years. When 30 satellites are in space on all its three orbital planes, Galileo will be fully operational, providing its services to a wide variety of users throughout the world.


Galileo Positioning System-Constellation

5.3.3 Glonass

The formerly Soviet, and now Russian, GLObal'naya NAvigatsionnaya Sputnikovaya Sistema (Global Navigation Satellite System), or GLONASS, was a fully functional navigation constellation but after the collapse of the Soviet Union, it fell into disrepair, leading to gaps in coverage and only partial availability. Restoration was underway in 2010. GLONASS is a system of 24 satellites in MEO at an altitude of 19,100 km.

5.3.4 Compass

China intends to expand their regional navigation system, called Beidou or Big Dipper into a global navigation system by 2020, a program that has been called Compass. The compass system is proposed to utilize 30 medium earth orbit satellites at an altitude of 21,150 km and five geostationary satellites. The regional Beidou 1 system was decomissioned at the end of 2012.

5.4 SATELLITE METEOROLOGY

Meteorology is the study of the earth's atmosphere and especially the study of weather. Several meteorological or weather satellites have been launched since 1960 to monitor the earth's atmosphere and forecast weather. The most basic form of satellite imagery provides pictures of the current cloud conditions. This is a familiar sight on TV weather forecasts. In case of any cyclone, it is the meteorological satellite which provides us the information about the formation of a cyclone, its speed and direction. Using this information, measures are taken to evacuate the probable area where a cyclone could hit.

5.4.1 Advantages of Satellite Meteorology

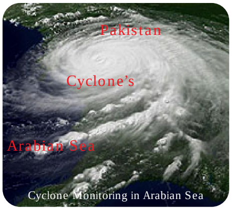
Every single image from a meteorological satellite contains a wealth of detail. Typically, the meteorologist will be able to see at a glance the location of major weather systems, the regions of settled weather and the areas of showers and local storms. All this is very different from the days before meteorological satellites became fully operational in the late 1970s. At that time the meteorologists used to deduce weather patterns with the help of half-a-dozen weather ships widely scattered across the world's oceans, a limited number of weather reports from merchant ships on a few ocean routes.

5.4.2 Applications of Satellite Meteorology

There are a number of applications of satellite meteorology. Some of them are described below:

5.4.2.1 Weather Forecasting

One of the most important justifications of meteorological satellites is their ability to detect, forecast and monitor the weather patterns at a regional scale. Weather satellites play a vital role in providing information about hurricanes and storms enabling forecasters to track them for days before they occur and provide essential warnings to save human lives and properties.



Cyclone Monitoring in Arabian Sea

5.4.2.2 Drought Monitoring

Drought is the state in which shortage of water reaches below the minimum level and it becomes difficult for vegetation to survive. Meteorological satellites offer a great deal of information on drought monitoring of the affected as well as drought prone areas.

5.4.2.3 Forest Fire Monitoring

Forest fires are a major environmental problem in Mediterranean countries with large areas affected every summer. Meteorological satellites provide images, several times a day, containing information about the energy reflected and emitted by the earth. They provide information on the extent of damage and the area affected by fire.

5.4.2.4 Sea Surface Temperature Monitoring

Sea Surface Temperature (SST) plays an important role in determining formation of sea fog and sea breezes and identifying potential fishing areas. Special sensors are mounted on board meteorological satellites to identify differences in temperature over the sea surface. This application of meteorological satellites has also a great impact on the economy of a country.

5.4.2.5 Fog and Haze Monitoring

One of the most important applications of meteorological satellites is their ability to detect, forecast and monitor bad weather (fog/haze) at a regional scale.

NATIONAL SPACE AGENCY OF PAKISTAN-SUPARCO

6.1 INTRODUCTION

SUPARCO Headquarters, Karachi

Pakistan Space and Upper Atmosphere Research Commission (SUPARCO), Pakistan's national space agency, was established in 1961 as a Committee. It was granted the status of a Commission in 1981. The Commission comprises of a Chairman, five Technical Members,Member Finance and Secretary.

6.2 FUNCTIONS

Mobile Lab for carrying out Environmental Surveys

SUPARCO's main functionalities include design, development, fabrication and launching of sounding rockets, communication and earth observation satellites for various scientific and research purposes. In addition, it carries out research and pilot studies based on the applications of satellite remote sensing data and GIS, space and atmospheric sciences, radio wave propagation and geomagnetism.

SUPARCO operates ground receiving stations in Islamabad and Karachi for earth observation and atmospheric data. SUPARCO also develops software and instrumentation for various scientific and technological purposes.

6.3 MAJOR ACHIEVEMENTS

SUPARCO launched a two-stage sounding rocket: Rehbar-I from Sonmiani Rocket Range on 07 June 1962. It carried a payload of 80 pounds of sodium and soared to about 130 km into the atmosphere. With the launching of Rehbar-I, Pakistan became the third country in Asia and the tenth in the world to conduct such a launching. Rehbar-II was also successfully launched from Sonmiani Rocket Range on 09 June 1962.

The data received from Rehbar-I and Rehbar-II gave information to scientists about wind shear and structure in the layers of the upper atmosphere extending beyond the stratosphere. The data collected also helped in the study of cloud formation, cyclones and weather over the Arabian Sea.

Space science and atmospheric research was one of the first activities initiated in early 1960's. This program covers diverse fields related to satellite meteorology, tropospheric and stratospheric studies, ozone monitoring, atmospheric pollution, satellite geodesy, astronomy, optical tracking of satellites, ionosphere and its effect on radio wave propagation.
In 1972, as a part of space research and applications activities, SUPARCO initiated and organized the remote sensing applications program for resource and environmental surveying.

In 1989, SUPARCO established a Satellite Ground Receiving Station at Rawat, near Islamabad, to receive real time satellite remote sensing data. The acquisition zone of the station covers 25 countries besides Pakistan.

BADAR-1, Pakistan's first experimental satellite, developed by SUPARCO was successfully launched in July 1990 from a Chinese Long-March 2E rocket. It provided necessary experience to SUPARCO scientists and engineers to develop satellites within the country.

Pakistan's second Experimental Satellite BADAR-II, an upgraded version of BADAR-I, was designed and developed as part of SUPARCO's Satellite Development Programme. It was launched from Russian Zenit-II vehicle on 10th December 2001. BADAR-II was an intermediate step between BADAR-I and an operational service oriented satellites. The main objectives of BADAR-II were indigenous development of low cost satellites and the creation of necessary infrastructure for future development in this field.

In order to meet the communications needs of the country SUPARCO hired the services of the communication satellite named Palapa C1 from Hughes Space and communication company for Indonesia, and renamed it to PAKSAT-1. It provided satellite communication services for variety of applications.

Paksat-1 was replaced by Paksat-1R which was launched from China on 11th August 2011.

6.4 SPACE APPLICATIONS

Under its space applications program, SUPARCO has undertaken a number of projects targeted towards the socioeconomic development of the country. It has been rendering its services to a large number of organizations including national, multinational, Federal and Provincial Ministries, departments and NGOs. Some of the recent activities/projects which have been conducted by SUPARCO for different user agencies are as follows:

Acquisition Zone of Satellite Ground Receiving Station, Islamabad

- SUPARCO has upgraded its satellite ground station at Islamabad to receive data from more advanced and the latest satellite systems.

- SUPARCO, in collaboration with erstwhile Ministry of Food, Agriculture and Livestock (MINFAL), initiated the program for monitoring of crops such as cotton, sugarcane, rice, maize, wheat using satellite remote sensing technology in different areas of Pakistan. The ultimate aim of this project is to bring improvements in this field by providing information about crop health, area, yield, etc, using satellite technology.

- SUPARCO has conducted a project for Ministry of Environment for the development of digital maps and Web GIS using satellite remote sensing data and GIS technology. These maps contain updated information about the important land-use categories all over the country such as agricultural land, deserts, water bodies, forest, Urban sprawl, etc.

- SUPARCO has also conducted a number of studies related to Urban / Rural planning, Agriculture, Forestry, Water Resources, Desertification, Environmental Monitoring and Impact Assessment, Oceanography, Geology / Geomorphology and Natural Hazards. Some of the major projects carried out by SUPARCO on user request in the field of Remote Sensing and GIS are:

a) National Environmental Information Management System (NEIMS)
b) Land Cover Classificaion System (LCCS) UNFAO
c) National Land-use Plan: for erstwhile Ministry of Environment
d) Development of GIS for Emergency Response/Control Centre: PSO
e) Security GIS for Karachi and Vehicle Tracking for Pakistan Rangers, Sindh

f) Wireless Local Loop (WLL) Project: PTCL
g) Environmental Impact Assessment of LBOD: WAPDA
h) Selection of route for Oil pipeline from Macheke To Gujranwala: Attock Refinery
i) Feasibility study of Bunji Hydro Power Project: SSGC
j) Baseline survey of Kacho areas In Sindh: Forest Dept
k) Study of Mangrove Forest along the coast of Pakistan: IUCN
l) Upland Rehabilitation and Development Project: IUCN
m) Baseline Study of the Environment Azad Jammu and Kashmir
n) Selection of Route for Chamman to Kandhar Railway Line: Pakistan Railways
o) Fog Aerosol Characterization, Source Apportionment and Impact Study which include Black Carbon (Soot) measurements, Aerosol Impact Assessment on Health and Air pollution impact assessment on crops yield.

A project has been conducted by SUPARCO for Sindh Government for monitoring the improvement of water courses in Sindh province using Satellite Remote Sensing data. SUPARCO has developed hardware, software and tracking system for real time monitoring and data sharing. Similar projects have been initiated in the provinces of Punjab and Khyber Pakhtunkhwa in consultation with respective provincial governments.

In order to understand fully the temporal as well as spatial variations taking place in the ionosphere over Pakistan, it is necessary to probe the ionosphere using ionospheric sounding equipment. SUPARCO presently operates three Vertical Ionospheric Sounding Stations, one each at Islamabad, Multan and Sonmiani, for monitoring local ionosphere round the clock at 15-minute intervals.

SUPARCO, being the national space agency of Pakistan, uses various kinds of earth observation satellites and GIS techniques for identifying, examining and assessing natural / anthropogenic disasters such as extreme weather(snowfall), floods, cyclone/low depression, Dust storm, Oil Spill, Earthquake, depletion of glaciers, and glacial lake outburst floods (GLOF), fog.

Under its Paksat Project, SUPARCO in collaboration with Jinnah Post Graduate Medical Centre (JPMC) has established a satellite communication based telemedicine network as pilot project which has been successfully established using VSAT antenna. Two sites have been connected through Paksat-1R satellite transponder, one at JPMC, Karachi as hub and other at Shikarpur civil hospital (interior Sindh) as remote site. Live Video conferencing has linked specialists in JPMC to patients in rural areas thus providing specialist health care services to the rural areas.

SUPARCO has successfully completed Commissioning Test of Pakistan Mission Control Centre at SUPARCO HQs Karachi under COSPAS-SARSAT International Program for support of Search and Rescue using satellite aided tracking technology. COSPAS-SARSAT is an international satellite-based search and rescue system, established by Canada, France, the United States and the Soviet Union in 1979. The Commissioning Test was carried out from 10 Nov 2009 at 0500 - 1300 UTC to 12 Nov 2009. Successful completion of Commissioning test recognized Pakistan as a member of the International COSPAS-SARSAT Program. COSPAS-SARSAT is providing services to different Airlines and Civil Aviation Authority and Maritime Security Agency of Pakistan.

Atmospheric Data Receiving and Processing Centre (ADRPC) have been established in Jan 2009 for real time satellite data acquisition and processing at SUPARCO HQs, Karachi. The facility is now operational and is receiving data from AQUA, Terra, NOAA series, FY-1D and MTSAT satellites. Data received and processed at ADRPC is used for monitoring of atmospheric temperature profile and sea/land surface temperatures, glacier melt, tracking of cyclones, flood mapping, agriculture, etc.

SUPARCO regularly organizes training courses in Remote Sensing and GIS, Environmental Applications as well as Atmospheric Sciences to promote their use in national and international user agencies. SUPARCO also interacts with several international space agencies, foreign, national R&D organizations and academic institutions.

SUPARCO has an active participation in the activities of Inter Islamic Network on Space Science and Technology (ISNET). ISNET provides a platform to promote the use of science and technology in Islamic countries. It has presently 16 Islamic member countries. SUPARCO acts as the main hub of ISNET activities.

SUPARCO has been organizing the World Space Week since 2005 which includes many activities especially for students. World Space Week is an international event celebrated in more than 66 countries since 2000. Objective of organizing WSW is to encourage the general public in space exploration, educating children and promoting international co-ordination in space-related endeavours.

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