REPUBLIC OF
SOUTH AFRICA

National Working Group on Space Science and Technology

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Space Science and Technology for Sustainable Development

Space Science and Space Technology

Space science is the study of everything above and beyond the surface of the Earth, from Earth's atmosphere to the very edges of the universe. Space technology refers to the technology in the satellites and ground systems used by space scientists to study the universe (looking up) and the Earth (looking down), or to deliver services to users on the ground. The vast majority of satellites are launched into space to provide services to people on Earth.

Space systems have become an indispensable component of the modern information society, touching every aspect of our daily lives. Every time you make a cellphone call, surf the internet, use an ATM, or watch a satellite TV broadcast, you are using space technology.

Space technology contributes to sustainable development by supporting better management of our natural resources, by helping us to improve agricultural output, and by providing valuable information for disaster relief and peace-keeping operations.

This booklet has been created by the National Working Group on Space Science and Technology to showcase the contribution of space science and technology to sustainable development in South Africa

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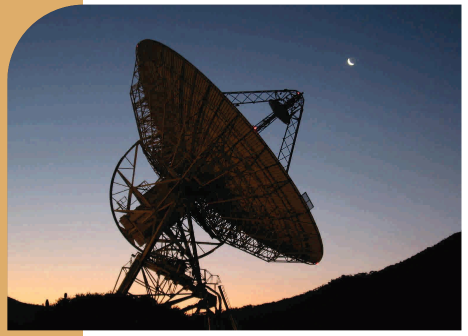


"Man must rise above the Earth - to the top of the atmosphere and beyond - for only then will he fully understand the world in which he lives."

Socrates
ca. 450 B.C.

satellites serving people

The word *satellite* is derived from the ancient Latin word *satelles*, meaning a servant or attendant. This is a particularly appropriate term, since most satellites have been placed in Earth orbit to serve humankind. Satellites support sustainable development by providing up-to-date and comprehensive geospatial information to support planning and decision-making. Geospatial information acquired from space complements measurements obtained on the ground in a powerful way. Satellites further support sustainable development by facilitating communications and sharing of information.

Communications Satellites are used to communicate from one point on the Earth to another and to provide broadcast services to large areas on the ground. When you make an international telephone call, surf the Internet, watch a television news or sports programme or view a weather forecast, chances are you are making use of a communications satellite. Communications satellites can also be used to deliver tele-medicine and tele-education services to remote regions.

Earth Observation Satellites are used to study the Earth for a very wide variety of applications in areas as diverse as environmental monitoring, urban planning, mapping, disaster management and weather prediction. Every time you see a television or Internet weather forecast you are using data from an Earth observation satellite.

Navigation Satellites are used for precise determination of position in space *and* in time. The spatial information is used for navigation on land, sea and air and for tracking of hazardous shipments. The temporal information is used wherever precision time-keeping is required. Every time you make a cellphone call, use a bank ATM, or use a GPS receiver, you are using a navigation satellite. Navigation satellites can also be used to study the properties of the atmosphere.

Scientific Satellites are used to study near-Earth space and to explore the solar system and the distant universe. Satellites monitoring the Sun provide advance warning of approaching space weather events, called geomagnetic storms or sub-storms, which can damage other commercially important satellites and interfere with communications on Earth. These warnings allow the diversion of airline flights on polar routes for communications or navigational reasons and also to reduce passenger and crew exposure to increased radiation levels. Spacecraft built by humans have flown past seven other planets in our solar system, given us glimpses of over 60 moons and other solar system bodies, and landed on the Moon, Mars and Venus. These remarkable voyages of discovery are providing deep insights into the origin and evolution of our own Earth. Orbiting astronomical satellites have given us breathtaking views of distant regions of the universe not visible from the ground. When you marvel at a photograph of the surface of another planet, or view an image of the oldest and most distant galaxies in the universe, you are using the results of a scientific satellite.

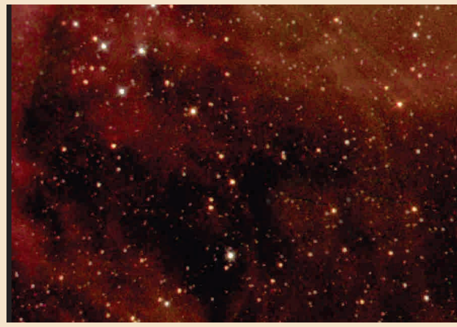


Photo: NASA

navigation by satellite

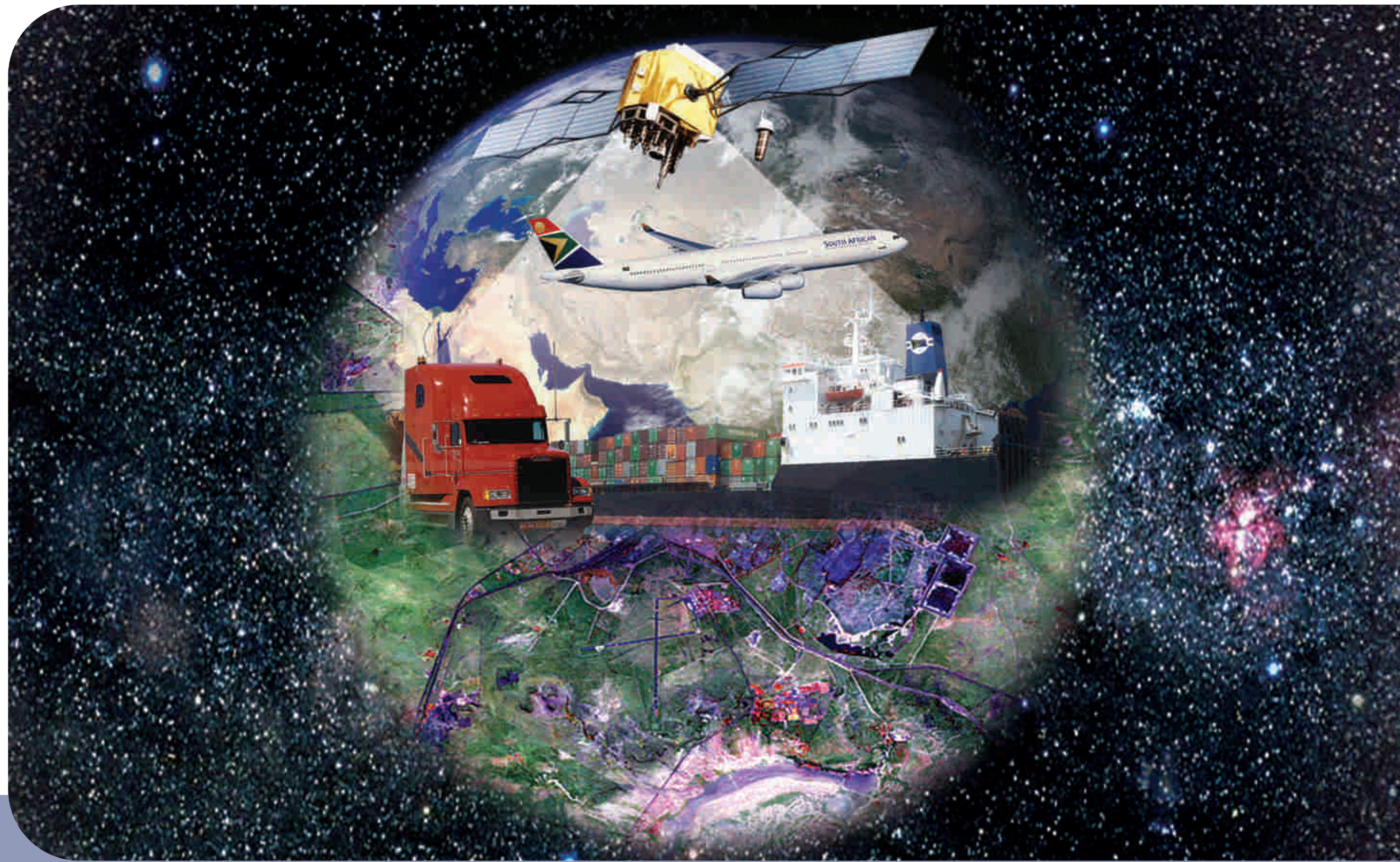
Satellite-based navigation has become a global utility with enormous daily benefits to people on the ground in a wide variety of areas such as aviation, maritime and land transportation, mapping and surveying, precision agriculture, power distribution and communications networks, as well as disaster warning and emergency response.

Navigation satellite systems comprise a constellation of satellites in orbit, where several satellites are simultaneously visible from any given point on the Earth at any given time. Each satellite emits signals on different frequencies that can be detected by a receiver on the ground, and the combination of these signals yields time and position information.

There are a number of navigation satellite systems either already in operation or in planning stages and which are collectively known as Global Navigation Satellite Systems (GNSS). The major systems in operation at the moment include the U.S. Global Positioning System (GPS), with more than 30 operational satellites and a similar Russian system known as Global'naya Navigatsionnaya Sputnikovaya Sistema (GLONASS). These systems are soon to be joined by the European Galileo system, the Chinese Beidou / Compass system, the Indian Regional Navigation Satellite System (IRNSS) and the Japanese QZSS further extending the benefits of GNSS to people on the ground.

The atomic clocks in GNSS satellites provide timing for the Internet, cellular phone networks, ATM networks, power distribution and other networks where a reliable, precise time standard is necessary. By combining GNSS data with satellite images and computer mapping techniques, we are better able to identify and manage our natural resources. Navigation satellites together with communication satellites are used to track fishing vessels and vehicles transporting hazardous materials.

Businesses with large amounts of mobile assets can manage their resources more efficiently thus reducing consumer costs. In future, intelligent vehicle location and navigation systems will allow us to avoid congested freeways and find more efficient routes to our destinations, saving fuel and reducing air pollution.



Navigation satellites can be used for applications in atmospheric and space weather research in support of environmental monitoring and protection, which is important for our understanding of global climate and weather and for the mitigation of the effects of abnormal occurrences in the ionosphere. An understanding of the latter events is essential for communications and the management of power grids. These systems in conjunction with communication satellites also support nature conservation by allowing the tracking of wild animals over rough or inaccessible terrain. Scientists also use satellite positioning measurements in conjunction with other techniques to study the crustal dynamics of the

Earth. Navigation satellites are even used to support navigation in space by other satellites.

Satellites pass over the same areas many times over, making it possible to monitor environmental change caused by human activity and natural processes. Because the data are collected in a consistent manner, satellites can reveal subtle changes that might otherwise remain undetected. Satellites are also important for monitoring remote or dangerous areas that would otherwise remain unobserved. The well known “ozone hole” over Antarctica and the phenomenon of atmospheric ozone depletion was discovered using satellites.

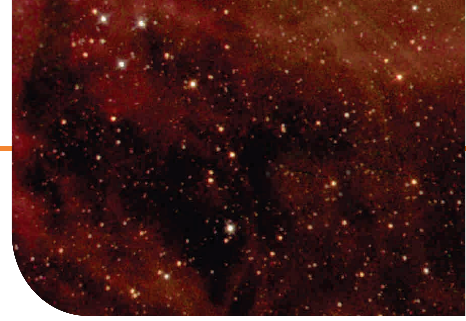
Satellites are often used to provide data rapidly for the monitoring and management of natural disasters such as earthquakes, volcanoes, floods or forest fires, where there may not be enough time to assess damage levels through conventional ground or aerial surveys. Satellites are also used to monitor humanitarian disasters, such as refugee flows from war zones, or for monitoring the spread of water-borne diseases, such as cholera and malaria. Satellite data allow relief organisations to deliver supplies and humanitarian aid rapidly and effectively where they are most needed.

Most satellites are capable of being used for a variety of applications during their life times. All satellite data are archived, providing a valuable data bank for future, unanticipated applications, long after the satellite has ceased to operate. This provides a valuable return on the cost of building and launching the satellite. In South Africa, the CSIR Satellite Applications Centre maintains an archive of images taken by a variety of satellites dating back to 1972. This archive is a national resource.

earth observation by satellite

Earth observation satellites are used to monitor the land surface, oceans and atmosphere of our planet, and how all of these change over time. Images of Earth from space are a routine and essential tool in our efforts to manage and protect the Earth’s resources and environment. Depending on their mission, Earth observation satellites have different orbits. Weather satellites are placed in high orbits (altitude about 36,000km) above the equator called *geostationary* orbits, from which they have a constant gaze on the same hemisphere of the Earth. These satellites complete one orbit around the Earth every 24 hours. Other Earth observing satellites are placed in low Earth polar orbits (altitude about 800km) that pass over the poles. These satellites complete one orbit around the Earth every 100 minutes. Because the Earth rotates in the plane of the orbit, such a satellite eventually covers the whole Earth.

Because remote sensing satellites cover the whole globe, they are important for the study of large-scale phenomena like ocean circulation, climate change, desertification and deforestation. They can also be used for a variety of applications such as mapping, urban planning and land use, agriculture, pollution monitoring, coastal monitoring and natural resource management.



communications by satellite

Communications satellites are used to transmit information from one point on the Earth to another. These points may be separated by thousands of kilometres, and they do not have to be connected to communications infrastructure on the ground. Satellite communications can thus reach people in remote villages, on ships or aircraft, and in areas where the existing infrastructure on the ground has been damaged by a disaster. Satellites have great potential to deliver tele-medicine and tele-education services to remote areas, providing access to expertise otherwise only available in major urban centres.

Communications satellites also provide a wide variety of broadcasting services, by relaying signals down to established ground networks for local distribution, or by direct-to-home services to individual subscribers. Aside from the obvious example of satellite television, if you make an international telephone call, watch the news or sports on television, or use the Internet, chances are some of the information has reached you via a communications satellite.

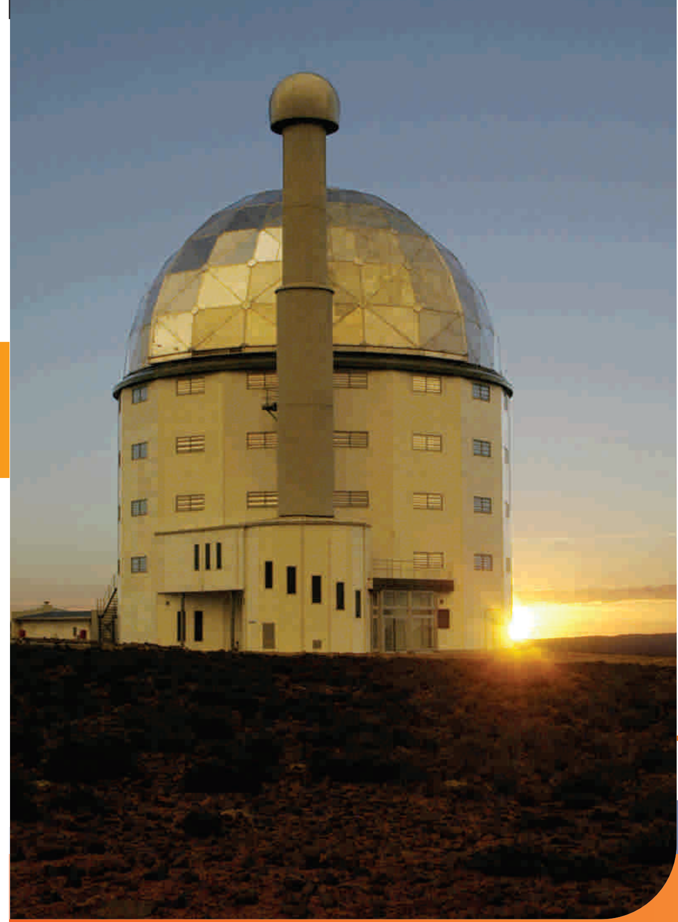
Satellites have played an important role in accelerating the development of the modern information society. By providing access to communications in areas not served by extensive ground-based networks, satellite communications has the potential to help developing countries quite literally to bridge the digital divide.

Satellite communications can contribute to sustainable development by giving people access to information and allowing them to participate in decision-making, by improving education and health services and by promoting a culture favourable for environmental protection. In recent times South African citizens in remote areas have been linked to their elected representatives in Parliament via satellite, providing a practical example of space technology being used for improved governance.

Communications satellites are usually placed in *geostationary* orbits, so-called because a satellite in such an orbit appears to be stationary above the ground, allowing pointing of ground antennas to a fixed point in the sky. Because geostationary orbit is a finite resource, and to avoid interference among different satellite systems, international regulations govern the allocation of orbital slots and frequencies to different countries.

Communications satellites can also be used to relay data from one spacecraft to another, or from a spacecraft to the ground. Such communications relay satellites are used to maintain contact with the Hubble Space Telescope and the International Space Station, for example.

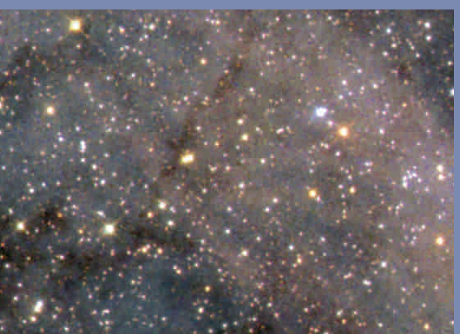
exploring the universe



Southern African Large Telescope (SALT)
SALT is located at Sutherland in the Northern Cape Province. This large optical telescope was built by South Africa and partners in Germany, Poland, New Zealand, the United Kingdom and the United States. SALT has an effective mirror diameter of 10 metres, making it the current largest single optical telescope in the southern hemisphere. This telescope gives South Africa and its international partners an extremely powerful tool to study the southern sky. SALT is able to record light from distant stars, galaxies and quasars a billion times too faint to be seen with the unaided eye - as faint as a candle flame at the distance of the Moon.

Astronomy
Astronomers explore the universe by detecting the electromagnetic radiation and cosmic rays emitted by celestial objects. Different objects emit their radiation at different wavelengths spanning from very short wavelength gamma rays, to X-rays, ultraviolet, visible light, infrared and long wavelength radio waves. The Earth's atmosphere shields us from much of this radiation, so modern astronomy is done from large optical and infrared telescopes on high mountains. Radio telescopes must be situated in remote, “radio quiet” areas, far from man-made radio interference. Certain wavelengths are totally blocked by the Earth's atmosphere and can only be studied from space using orbiting satellite observatories.

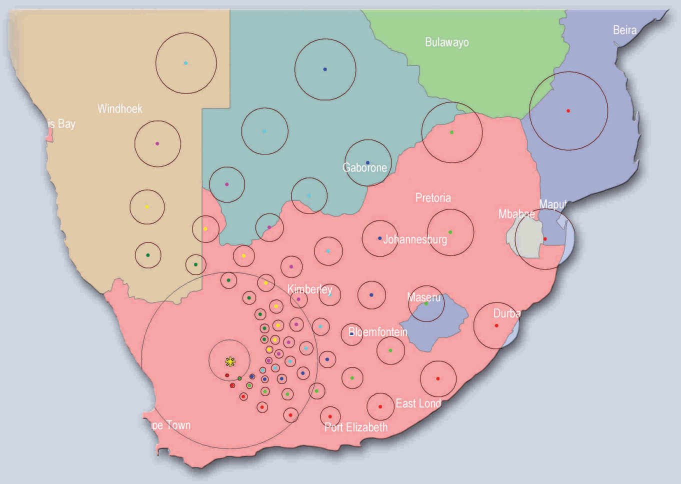
South African astronomers are fortunate to have access to some of the largest facilities for astronomy in the world. The Southern African Large Telescope (SALT) at Sutherland in the Northern Cape is the largest single optical telescope in the southern hemisphere, while in neighbouring Namibia the High Energy Stereoscopic System (HESS), an array of four gamma-ray telescopes is the largest such facility in the world. South Africa is building the Karoo Array Telescope (KAT), a radio telescope that will form the core or a much larger radio telescope facility called MeerKAT. The latter project is in support of South Africa’s bid to host the Square Kilometre Array (SKA), an international project to create a receiving surface of a million square metres, one hundred times larger than the biggest receiving surface now in existence. South Africa would be an ideal location for the SKA owing to its geographical location, large expanses of radio-quiet land and its record of accomplishment to build, host and support such large-scale facilities.



meerkat
karoo array telescope

Karoo Array Telescope (KAT) and MeerKAT
South Africa has started construction of a radio telescope called the Karoo Array Telescope (KAT). The prototype 15-m diameter dish for this array was completed in late 2007 at the Hartebeesthoek Radio Astronomy Observatory. The KAT array comprises seven 12-m diameter dishes located near Carnarvon in the Northern Cape. The site of KAT has been declared an Astronomy Advantage Area in terms of the Astronomy Geographic Advantage Bill. KAT is just the first phase of a much more ambitious project to build an extended radio telescope array of some 50 or more dishes, called MeerKAT. When it is commissioned in 2012, MeerKAT will be one of the world's premier mid-frequency radio astronomy facilities and will put South Africa at the cutting edge of radio astronomy.

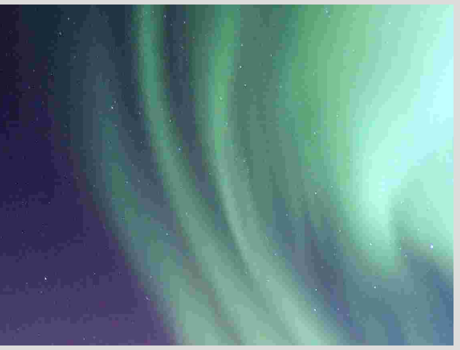
Square Kilometre Array (SKA)
South Africa has been short-listed to host the SKA, a 1.6 billion Euro international project to create an array of antennas for detecting radio waves that will cover an area of one square kilometre (about the size of 150 soccer fields). This area is 100 times larger than the biggest receiving surface that now exists. The result will be an instrument capable of probing the secrets of the very early universe. If South Africa wins this bid, the main part of the SKA will be built in the Northern Cape, with other parts distributed across Africa. The MeerKAT will comprise the central core of the SKA telescope, if South Africa wins the SKA bid.

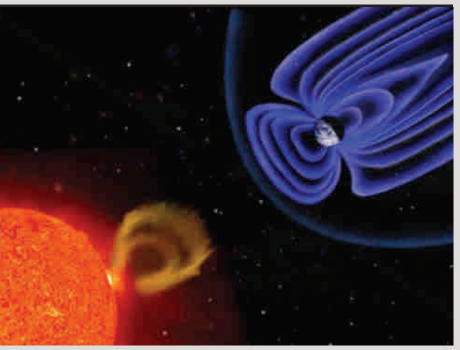


understanding our space environment

Space physics

Space physics is the study of the space environment and its interaction with the Earth. The gases that we know in our everyday lives consist of neutral atoms. The gases in space exist in a hot, fully ionised state called plasma in which the constituent particles are charged electrons and ions. Because of this, plasma interacts with electric and magnetic fields very differently than gas made of neutral atoms or molecules. Plasma physics has long been studied in laboratories. However, space provides a natural and large-scale laboratory for the study of plasma processes. Space physicists seek to understand the complex plasma environment of the Earth, shaped by the interaction of the solar wind with the atmosphere and magnetic field of the Earth. They do this by studying aurorae, geomagnetic storms, cosmic ray acceleration and propagation, solar flares, *etc*. These phenomena are studied using *in situ* measurements by satellites or rockets and complementary measurements done from the ground using radars and photometers. South African space scientists work at the Hermanus Magnetic Observatory, the South African base in Antarctica and at various universities.

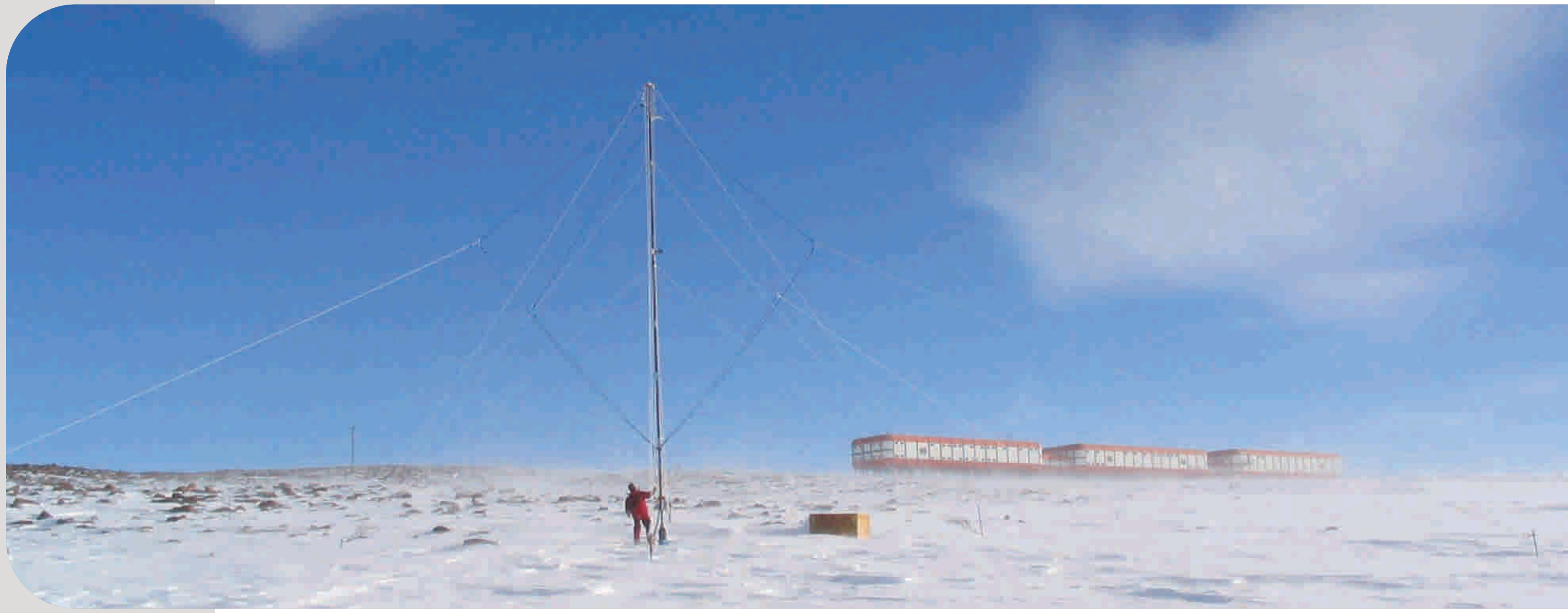




"Space weather" is the term applied when the phenomena of space physics assume practical or economic significance. From a space physics perspective it could be said that the Earth is inside the extended atmosphere of the Sun. The effects of storms on the Sun are felt on the Earth. Geomagnetic storms are therefore a natural hazard, like hurricanes and tsunamis. Particularly severe storms interfere with the operation of, or cause serious damage to, spacecraft systems, radio signals, aircraft navigation, power grids and oil pipelines. The same satellites that observe the Sun and study space physics can be used to provide early warning of the onset of severe space weather events, allowing operators of sensitive systems to take evasive action. The Hermanus Magnetic Observatory is a Regional Warning Centre in the International Space Environment Service. It is the only such Centre in Africa and, as such, it contributes to rapid exchange of space weather information and space weather forecasts.

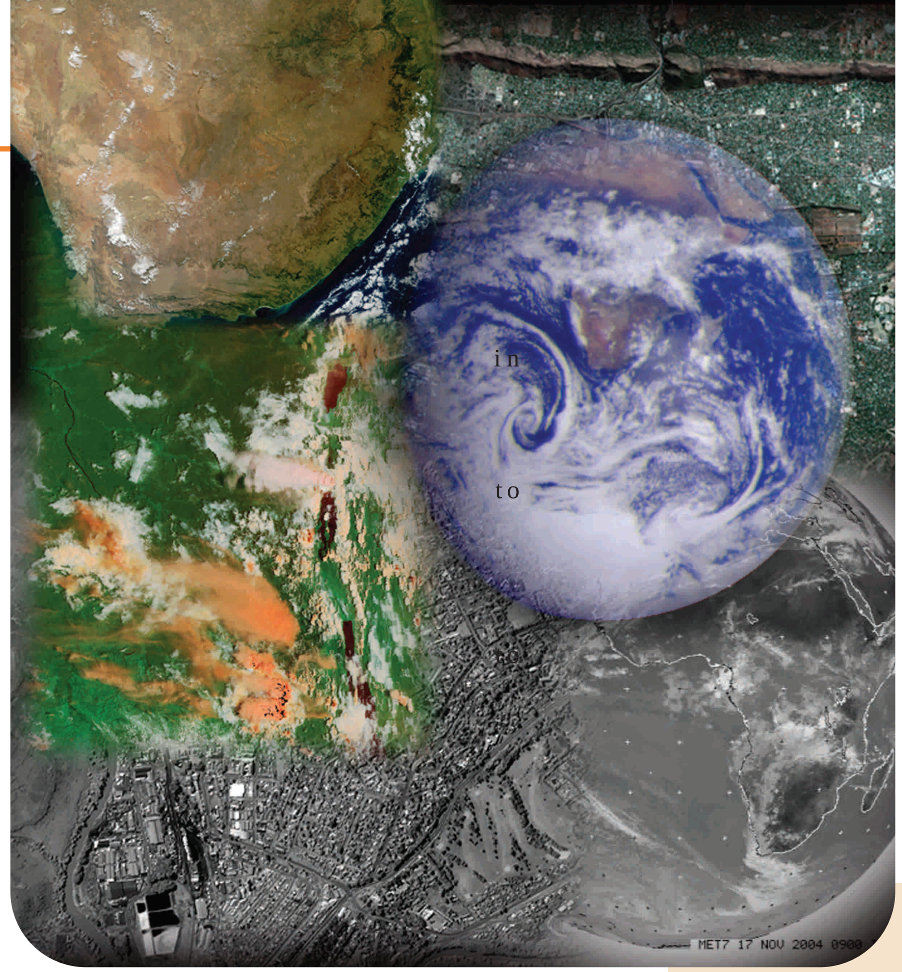
The space contribution to understanding the magnetic field of the Earth

The Earth's magnetic field has numerous important benefits for life on Earth and for human society. The magnetic field provides shielding against the damaging radiation from space. The orientation of the field is used for navigation by humans and other species. Circulating motions of molten, ionized metals in the Earth's core generate a global magnetic field. This magnetic field is roughly a "dipole", as though a giant bar magnet runs through our planet. The so-called "north magnetic pole", residing about 10 degrees away from the geographical north pole, is really like the south pole of a magnet, inasmuch as it attracts north poles of compasses. The orientation of the Earth's magnetic field is of great importance in many civilian and military applications. Because the orientation of the magnetic field varies with location and time, magnetic surveys are an important activity. During the Earth's history, the magnetic poles have reversed several times. It seems that such a reversal is presently taking place. The Earth's magnetic field is decreasing at a phenomenal rate. At this rate, the dipole field will vanish within one thousand years. The greatest decrease in magnetic intensity has been recorded at the Hermanus Magnetic Observatory. The southern African region is thus an ideal location for the study of regional and global changes in the geomagnetic field.



Satellites are important tools to study geomagnetic phenomena. Scientific satellites in low-Earth orbit provide an ideal platform for obtaining global magnetic field measurements required to produce accurate models of the Earth's magnetic field. The phase delay in Global Positioning System (GPS) satellite radio signals can be used to determine certain parameters of the ionosphere, a region in the upper atmosphere of importance to radio communications and radio direction finding.

The icy continent of Antarctica does not belong to any single country, but several countries have bases there. South Africa has had an Antarctic research base since 1962. Data gathered at this base are used to study the upper layers of the atmosphere in detail, especially the ionosphere and the magnetosphere. Information is also gathered about the ozone hole. Due to the configuration of the Earth's magnetic field, solar-induced space weather phenomena are best studied in the polar regions. These ground-based measurements complement the data obtained from space by satellites.



space and sustainable development

The space contribution to Earth stewardship and sustainable development

Earth observation satellites provide a global view of the dynamic processes on the land, in the oceans and in the atmosphere of our planet. The collection of satellite imagery compiled over many years is a national resource which allows environmental changes to be detected and monitored. Satellites also provide the “hard evidence” to enforce environmental legislation and provide a powerful tool to communicate environmental issues in a manner that is understandable non-specialists.

Endangered species

Many endangered species are closely associated with a particular habitat. Space technology can be used to map and monitor particular vegetation types to estimate the ranges of species that depend on them. Space technology is also used to study the movements of animals in the wild.

Agricultural applications

Farmers rely on weather forecasts derived from weather monitoring satellites for their normal farming operations. Rainfall and evaporation measurements from satellites allow farmers to regulate crop irrigation. Satellite images also allow farmers to assess areas at risk of, or already affected by, crop threats due to pests or disease. Mapping crops from space can help predict an area’s agricultural yield and provide early warning of disease or poor soil conditions. This information may help authorities to anticipate food shortages, allowing time to procure food from alternative sources thus avoiding food shortages or famines.

Law enforcement

Earth observation satellites are used to detect and map areas where illicit drugs are cultivated, thus helping to attack trafficking of drugs at the source. These satellites can also be used to obtain evidence of marine pollution by vessels, illicit fishing activities or violations of water consumption regulations. Navigation satellites are used to track sensitive shipments or stolen vehicles. In South Africa, the Department of Environmental Affairs and Tourism is making it obligatory for more fishing vessels to have satellite technology on board so it can monitor their movements. The Department of Water Affairs and Tourism uses satellite imagery to detect illicit consumption or damming of water.

Water management

Water is vital for life and for much economic activity. The provision of clean, safe drinking water is therefore a key component of poverty alleviation. South Africa is an arid country. Satellites can be used to manage precious water resources by mapping surface water distribution, measuring water quality and measuring ground water content. Waterborne diseases, such as cholera and malaria, may also be studied from space – an emerging discipline known as “space epidemiology”. The international Committee on Earth Observation Satellites has launched the international TIGER Initiative as part of its follow-up programme from the Johannesburg World Summit on Sustainable Development, focusing on Earth observation for integrated water resources management in Africa as part of the NEPAD process.

Weather prediction

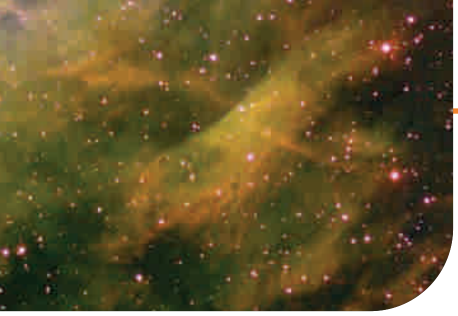
The daily weather forecasts that so many of us take for granted are derived from satellites. These satellites constantly monitor weather around the globe, allowing us to predict cyclones, tornados and other storm activity. Communications satellites are then used to disseminate weather information widely to the public as a global utility. The predictive power of weather forecasts has saved countless lives since the beginning of the space age. The long-term, global coverage provided by weather satellites makes them ideal tools for monitoring the drivers of global climate, such as the recurrent El Niño phenomenon or secular, long-term global climate change.

Management of natural and humanitarian disasters

Satellites can provide warning of disasters and assist in the management of disasters or emergency situations arising from floods, fires, oil spills, earthquakes, volcanic eruptions and landslides. When disasters strike the different types of satellites are pressed into service to alleviate the suffering of people on the ground. Remote sensing satellites allow the extent of the disaster and its impact to be mapped. Such maps are used to prioritise relief needs and also to ensure that relief workers can locate and reach the victims. Communications satellites are essential for distributing information and for coordinating relief efforts. Often in a disaster situation the communications infrastructure on the ground is destroyed or severely degraded. Communications satellites allow information to be distributed rapidly to local authorities and relief workers. Navigation satellites allow relief workers to establish their location, especially when the disaster has rendered existing maps useless, or where the disaster strikes in remote, poorly mapped areas. Even after the crisis subsides, satellites may be used in the post-disaster reconstruction effort.

Spin-offs of space science and technology in everyday use

In addition to the direct benefits of space services to people on the ground, there are also indirect, long-term benefits arising out of the spin-offs of space technology to commercial, non-space applications. There are literally hundreds of products and processes in daily use that had their origin in space exploration. Many of these spin-offs contribute directly to increased productivity and to improved human health and safety.



space in south africa

South Africa has a rich heritage of involvement in space science and technology. The country's involvement in modern astronomy dates to 1685. In 1820, a permanent observatory was established outside Cape Town. Astronomy has been practised continuously since then, an uninterrupted history spanning more than 180 years and culminating with the construction of the Southern African Large Telescope in Sutherland. The country has been an active participant in the exploration of space since the dawn of the Space Age. From the 1950s to the 1970s satellites were tracked to determine the effects of the upper atmosphere on their orbits. Lunar and interplanetary missions were supported from a tracking station at Hartebeesthoek (near Krugersdorp). This station received images of the planet Mars taken by the Mariner IV spacecraft - the first images of Mars and of another planet to be received on Earth.

In the late 1980s South Africa commenced a military programme to develop a launcher and a reconnaissance satellite but this was discontinued in 1994. In 1999, the first South African satellite, *Sunsat*, was lofted into space as a NASA-sponsored secondary payload on the rocket that delivered much larger *Argos* satellite into orbit. The 64-kg *Sunsat* micro-satellite was built by staff and students at the University of Stellenbosch. The team that built *Sunsat* is presently planning a second, more capable, South African satellite.

In 2005, the Department of Science and Technology commenced the *Sumbandila* satellite programme. The main objective of this programme is to build capacity in all aspects of a national space programme: satellite engineering, satellite operations, definition of user needs, applications development, regulatory issues, policy issues, etc. Sumbandila is equipped with an optical imager that can deliver images with a 6.25-metre resolution in six colour bands in the visible and near infrared. The satellite also has a store-and-forward communications payload and some other experimental payloads.

South Africa has a variety of institutions that play a significant role in the scientific study, exploration and utilisation of space. These institutions, situated in academia, the science councils and industry, have broad competencies in satellite applications, satellite engineering and space science, and all their supporting technologies. The existing infrastructure and skilled workforce, both inside these facilities and in wider industry supporting them, allows South Africa to position itself as a regional hub of space science and technology. This can be used as a basis for strengthening ties with industry in established spacefaring nations, and for developing links with other emerging national space initiatives, particularly in Africa.

South Africa is an active participant in the international space arena. South African space professionals participate in numerous forums, such as the United Nations Committee on the Peaceful Uses of Outer Space. South Africa has ratified and/or signed several international space treaties governing the space activities of independent States. The primary South African legislative instrument governing the regulation of both governmental and non-governmental space-related activities is the Space Affairs Act, No. 84 of 2 July 1993, as amended by the Space Affairs Amendment Act, No. 64 of 6 October 1995. Section 4 of the Space Affairs Act establishes the South African Council for Space Affairs under the authority of the Minister of Trade and Industry to implement the regulatory, monitoring and registration functions of the Act. South African national space legislation has been adopted in accordance with international space treaties.

The contribution of space to sustainable development received much attention in the Johannesburg World Summit on Sustainable Development in 2002. This led to South Africa playing a prominent role in the international space arena in the use of space for sustainable development in Africa, particularly in regard to water. South Africa was selected to play leading role in the Group on Earth Observations (GEO), an international partnership created at the Earth Observation Summit, held and initiated by the United States in July 2003. The objective of the GEO is to coordinate a dedicated global initiative to work towards the creation of a new comprehensive, sustainable and globally coordinated Earth observation system, called GEOSS. The GEO is a direct response to the outcomes of the World Summit on Sustainable Development and is one of several international partnerships to implement the Summit's Johannesburg Plan of Implementation. South Africa's contribution to GEOSS is the South African Earth Observation Strategy (SAEOS), which provides a framework to integrate all forms of Earth observation in South Africa.

Given the accelerated pace of space science and technology developments in South Africa since 2000, in 2003 a number of government departments established the National Working Group on Space Science and Technology to improve coordination of space-related activities among government departments and agencies in the South Africa. The emphasis is on linking space to national priorities, particularly with regard to issues of poverty reduction, disaster management, economic development, technological empowerment, and improved quality of life.

In 2006, the Minister of Trade and Industry appointed new members of the South African Council for Space Affairs. The Council overseas space activities and advises the Minister on all matters pertaining to space activities in the Republic. The Department of Trade and Industry (DTI) established a Space Secretariat to support the work of the Space Council and other space activities falling within the mandate of the DTI. In early 2008, the Space Council started the development of a South African space policy to provide a high-level framework for all public and private sector space activities in the Republic. The draft policy was released for public comment in mid-2008. This policy places a strong emphasis on the peaceful uses of outer space for sustainable development and socio-economic benefit.

In early 2007 the Department of Science and Technology (DST) was mandated by Cabinet to develop plans for the establishment of a South African space agency. The DST commenced work on the drafting of the necessary legislation to establish the space agency and also started developing a national space science and technology strategy to guide implementation of the future space programme.