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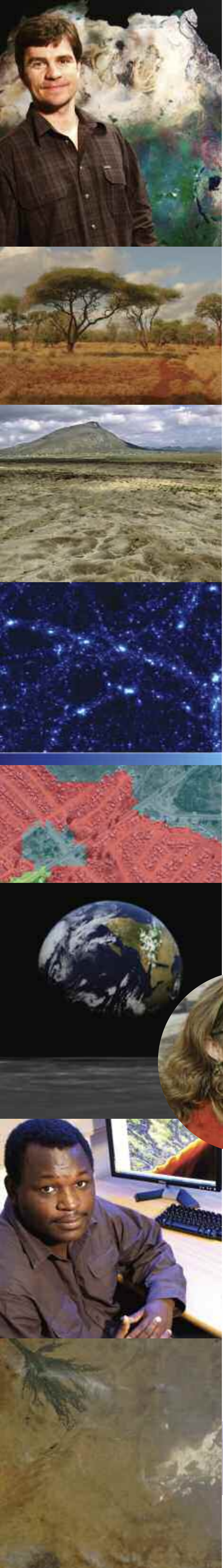
Space science & technology

CSIR

our future through science



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INTRODUCTION

Mankind's age-long interest in space is a recurring theme throughout this edition of the *ScienceScope*. Space exploration – whether referring to what we see in space from the earth or what we learn about the earth looking from space – has a following that extends beyond cultures, borders and generations.

At the CSIR, our research in this field encompasses far more than answering questions born out of curiosity.

The science behind space technology, which includes launchers, satellites, communication or optical payloads, is not isolated. It serves a cross-functional purpose. Scientists and engineers involved in space technology also contribute to other fields – aeronautics, natural sciences, safety and security. Sharing scientific and engineering knowledge enhances human capital development to build a stronger technological base within South Africa (see also the career section in this edition).

The CSIR's space heritage dates back to the National Institute of Telecommunications Research, established in 1957. The organisation gained experience in various space technologies over the past 50 years. These include telemetry, tracking and command, earth observation data acquisition and image processing, advanced remote sensing application development, ground segment establishment and optical engineering.

The articles in this *ScienceScope* communicate the benefits and applications derived from such research and support services. Monitoring our land use practices from space, for example, gives us a holistic picture enabling recommendations or interventions with which to maintain or enhance sustainable natural resources.

The importance of space technology is also highlighted by the Department of Science and Technology through its Ten-Year Innovation Plan. The National Space Science and Technology Strategy highlights the need for South Africa to develop a robust and effective space capability to increase knowledge, discovery and economic prosperity, and to enhance national security. The establishment of a National Space Agency in the near future, to coordinate and manage space activities in South Africa, creates a wealth of opportunities for the country's economy and human capacity building programmes.

As a leader in scientific and technological research, the CSIR will play a vital role in the development and utilisation of space technology to serve society and to stimulate economic growth within industry.

ON OUR **COVER**

'BULL'S EYE' – THE RICHAT STRUCTURE, MAURITANIA

This prominent circular feature in the Sahara Desert of Mauritania has attracted attention since the earliest space missions because it forms a conspicuous bull's-eye in the otherwise rather featureless expanse of the Gres de Chinguetti Plateau in central Mauritania, northwest Africa. Described by some as looking like an outsized ammonite in the desert, the structure (which has a diameter of almost 50 km) has become a landmark for space shuttle crews. Initially interpreted as a meteorite impact structure because of its high degree of circularity, it is now thought to be merely a symmetrical uplift (circular anticline) that has been laid bare by erosion. Paleozoic quartzites form the resistant beds outlining the structure. The reason for the high degree of circularity is not clear. This true-colour scene was acquired by the moderate-resolution imaging spectroradiometer (MODIS), flying aboard NASA's Terra satellite, on March 11, 2002.

Image: NASA/Visible Earth
http://visibleearth.nasa.gov

FROM THE DESK OF THE PRESIDENT AND CEO: DR SIBUSISO SIBISI

CONTEXTUAL

CONTEXTUAL OVERVIEW

Over centuries, scholars, poets and prophets

ON THE BRINK OF SPACE – A NEW ERA

BY JOHAN LE ROUX

FEW THINGS HAVE HELD mankind in such collective awe as space. Phrases such as "The eagle has landed", "It's time for the human race to enter the solar system", "Space – the final frontier", all ring familiar.

Over centuries, scholars, poets and prophets have pondered the great infinity called space. 'Space fiction' has long lost its derisive edge with Sputnik 1 hailing the advent of the 'Space Age' some 50 years ago – an age that, despite controversy, would bear testimony to astonishing political, scientific and technological achievements.

Space is defined as the area beyond the earth's measurable atmosphere, which has very few particles of any size and is flooded with electromagnetic energy. Despite its inherent fascination, the notion that space holds the key to solving current and future global challenges has increasingly been augmented with successes and demonstrations of space technology enriching the daily existence of society.

Internationally, space activities have had, and continue to have, significant and beneficial impact on everyday life and society. Although the cost of space activities is high, there are tremendous returns for the community relating to job creation, technological know-how, scientific knowledge, and space spin-offs.

From a social perspective, the value of space applications in addressing challenges to the state of the environment is undeniable. These are mainly relating to the management and use of natural resources, increasing mobility of people and products, growing security threats and the shift towards a knowledge economy.

Since space technology enables instant communication anywhere in the world, accurate observation of any spot on earth and the ability to locate a fixed or moving object anywhere on the surface of the globe, economic and human catastrophes can be timeously foreseen, predicted, averted or stemmed.

As a technologically-advancing country, South Africa is increasingly reliant on space-based services and applications. It has a rich tradition of involvement in space science and technology and has been an active participant in the exploration of space since the 1950s. Due to this heritage, South Africa also has some unique space infrastructure.

The Cabinet-approved Ten-Year Innovation Plan of the Department of Science and Technology (DST) also describes space science and technology as one of the five grand challenges and a national strategy supporting a viable space programme is being finalised for Cabinet presentation and approval.

The transformation of the space landscape in South Africa was ushered in when the government announced the intention to establish a space agency two years ago. The bill for establishing the agency is in the final stages of approval.

Space-related activities cut across all spheres of government and its agencies.

OVERVIEW

have pondered the great infinity called space

Johan le Roux, Group Manager: CSIR Strategic Initiatives

To optimise the utilisation of resources and to maximise the benefits of space applications to society, there is a need to coordinate activities. The Department of Trade and Industry has developed the space policy and with the support of the South African Council for Space Affairs, will regulate space activities. Being committed to responsible use of the space environment, the cornerstone of the space policy is the promotion of a domestic space industry, capacity building, space awareness and international cooperation.

The DST is responsible for the implementation of the national space programme. As such, DST has contracted the CSIR to host an interim office of the South African National Space Agency.

The National Space Science and Technology Strategy, developed by an intergovernmental committee, will aim to leverage the benefits of space science and technology for socio-economic growth and sustainable development. The strategy states that it is essential for South Africa to develop robust, effective and efficient space capabilities in order to increase knowledge, discovery and economic prosperity, and to enhance national security.

In this regard three key priority areas have been identified:

- The environment and resource management programme is a space programme helping South Africa to understand and protect the environment, and develop its resources in a sustainable manner
- The innovation and economic growth space programme stimulates innovation, while leading increased productivity and economic growth through commercialisation
- The safety and security space programme strengthens developmental efforts through ensuring the safety and security of South Africa's communities.

The National Space Science and Technology Strategy is an expression of national priorities and has three primary goals.

These are to capture a global market share for small to medium-sized space systems in support of the establishment of a knowledge economy through fostering and promoting innovation and industrial competitiveness; to empower better decision-making through the integration of space-based systems with ground-based systems for providing the correct information products at the right time, and to use space science and technology to develop applications for the provision of geospatial, telecommunication, timing and positioning products and services.

With South Africa on the brink of taking a giant leap into space, the benefits of such a step for the overall well-being and quality of life of all South Africans might just be cosmic.

Front from left: Wabile Motswasele (CSIR), Dr Darasri Dowreang (CEOS incoming Chair - GISTDA, Thailand), Raoul Hodges (CSIR), Dr Pakorn Apaphant (CEOS incoming Chair point of contact) Back: Asanda Ntisana (CSIR), Alex Fortescue (CSIR)

CEOS

CEOS: PRESENT AND FUTURE OPPORTUNITIES

BY WABILE MOTSWASELE AND ASANDA NTISANA

According to **www.ceos.org**, this body "was created in 1984 in response to a recommendation from the Economic Summit of Industrialized Nations Working Group on Growth, Technology, and Employment's Panel of Experts on Satellite Remote Sensing. This group recognised the multidisciplinary nature of satellite earth observation and the value of coordination across all proposed missions.

"Individual participating agencies make their best efforts to implement CEOS recommendations. The main goal of CEOS is to ensure that critical scientific questions relating to earth observation and global change are covered and that satellite missions do not unnecessarily overlap each other."

THE COMMITTEE on Earth Observation Satellites (CEOS) is a global umbrella body for civilian space agencies that have a common interest in collaborating on satellite-based remote sensing techniques.

Comprising 26 members (most of which are space agencies) and 20 associates, CEOS is seen as the major international forum for the coordination of earth observation satellite programmes and for interaction of these programmes with users of satellite data worldwide. The CSIR was presented with a number of exciting opportunities and worthwhile challenges in its role as CEOS Chair for 2008.

The organisation's strategic intent to assume the chairpersonship of CEOS was guided by the following set of criteria:

- Improving its global presence in the domain of earth observation
- Deriving benefit from the human capacity development
- Enhancing data democracy in developing countries.

PROMOTING ACCESS TO DATA

'Data democracy for developing countries' is a CSIR flagship project as CEOS Chair 2008 and comprises four pillars: access to datasets, software tools, capacity building and dissemination of satellite-based earth observational datasets.

The CSIR has structured the project into phases to derive targeted objectives. In the short term, the CSIR will collaborate closely with INPE (Brazil), CRESDA (China), USGS (USA) and EUMETSAT (Europe) on receiving, processing and distributing of satellite imagery received in South Africa for local and regional usage.

In the medium term, the CSIR will seek to strengthen the project by collaborating closely with other CEOS agencies such as CONAE (Argentina), CSA (Canada), ESA (Europe) and NASA (USA).

In the longer term, the CSIR will seek to sustain data democracy by working closer with agencies such as GISTDA (Thailand), CNES (France), ISRO (India) and others.

SUPPORTING CEOS ACTIVITIES

CEOS activities have direct relevance to our local earth observation community when taking into account the three important working groups within CEOS:

- Information Systems and Services facilitates data and information management and services. It undertakes the capture, description, processing, accessing, retrieval, utilisation, maintenance and exchange of earth observational data
- Calibration and Validation working group activities focus on enhancing coordination of spaceborne earth observational data
- Education and Capacity Building offers education and training on utilisation of tools and systems required to process earth observational data.

Currently, representatives from the CSIR, the Meraka Institute and the University of Fort Hare participate in these working groups. The CSIR stands to benefit from this active participation with international peers.

GLOBAL OUTLOOK

At a global level, South Africa, through the Department of Science and Technology (DST), presently co-chairs the Group on Earth Observations (GEO). GEO introduced and formalised the concept of societal benefit areas as a systematic method to represent the challenges planet Earth needs to address. The table illustrates a high level overview of the solution for each of these areas:

SOCIETAL BENEFIT AREA	BASIC SET OF CHALLENGES
Agriculture	Promote sustainable agriculture
Biodiversity	Establish a biodiversity observation network
Climate	Address climate variability and change
Disasters	Respond to natural man-made disasters
Ecosystems	Manage ecosystems for conservation and sustainable use
Energy	Provide energy that is clean and secure
Health	Protect human health and well-being
Water	Manage global water resources
Weather	Leverage the value of weather forecasts

As a participating member of GEO, CEOS contributes space-based observational data to assist GEO in fulfilling its 10-year Global Earth Observation System of Systems implementation plan.

On the local front, the DST is establishing the South African Earth Observation Forum in collaboration with the CSIR. The objectives of this forum are to involve a broader audience in the activities of GEO and CEOS.

TAKING THE BATON: HANDOVER TO THAILAND

The Geo-Informatics for Space and Technology Development Agency (GISTDA) is the CEOS 2009 incoming Chair designate. The CSIR will handover its CEOS 2008 chairpersonship to GISTDA during the 22nd CEOS plenary this year. Some effort and planning has already been expended in ensuring a smooth transition from the CSIR to GISTDA. During June 2008, a delegation from GISTDA visited the CSIR to seek alignment between the current and future Chairs of CEOS. The agency demonstrates a thorough understanding of the leadership requirements for this post as well as a high level of technical expertise.

With a staff complement of approximately 230 people, it has a ground receiving station in Bangkok and Lad Krabang, and a control centre for Thailand's first satellite, Thailand Earth Observation System (THEOS). THEOS will be launched in 2008 and will provide Thailand with worldwide geo-referenced image products and image processing capabilities.

During the 22nd CEOS plenary and official hand-over in Fancourt, George, on 11 and 12 November 2008, the current chairperson, Pontsho Maruping, will reflect on the resolutions adopted at the last plenary, provide an update on the developments and report on the achievements made throughout her tenure of twelve months.

The CSIR looks forward to its continued involvement and participation in CEOS and GEO in order to retain relevance in global earth observation developments.

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CONTEXTUAL OVERVIEW

EARTH OBSERVATIONS FOR EARTH SYSTEM SCIENCE

BY DR KONRAD WESSELS AND MARY-JANE KGATUKE

SINCE THE EARLY DAYS OF SPACE EXPLORATION IT WAS REALISED THAT SPACE PROVIDES A UNIQUE VANTAGE POINT FOR OBSERVING THE EARTH AS A SYSTEM. EARTH SYSTEM SCIENCE WAS FORMALLY INITIATED BY NASA BETWEEN 1983 AND 1986, WITH THE GOAL OF 'OBTAINING A SCIENTIFIC UNDERSTANDING OF THE ENTIRE EARTH SYSTEM ON A GLOBAL SCALE BY DESCRIBING HOW ITS COMPONENTS AND THEIR INTERACTIONS HAVE EVOLVED, HOW THEY FUNCTION, AND HOW THEY MAY BE EXPECTED TO CONTINUE TO EVOLVE ON ALL TIMESCALES.' AT THE HIGHEST LEVEL, THE FOUR BASIC ELEMENTS OF THE EARTH SYSTEM CAN BE REPRESENTED AS **AIR** (ATMOSPHERE), **WATER** (HYDROSPHERE), **LAND** (GEOSPHERE) AND **LIFE** (BIOSPHERE, INCLUDING HUMAN ACTIVITIES).

SATELLITES PROVIDING DATA ON EARTH OBSERVATION

An entire fleet of space craft (satellites) has been launched to observe different components of the earth as a system. These include satellites with interesting and unlikely names such as Terra, Aqua, Auro, Jason, Grace, ICESat, CloudSat, WindSat, TRMM, Envisat, SeaWifs, to name but a few. To highlight just three, ICESat (ice, cloud and land elevation satellite) measures ice sheet mass balance, cloud, aerosol heights and land topography using laser-ranging (lidar). TRMM (tropical rainfall measuring mission) measures rainfall rate in three dimensions with radar and microwave imagers. Jason-2 (ocean surface topography mission) measures global sea-level rise with a radar altimeter, global positioning system (GPS), laser retroreflector and microwave radiometer.

Currently, South Africa is using data from only a very small number of these available satellites.

Satellites are about more than supplying 'pictures' of people's neighbourhoods. Satellites are used to produce a constant stream of data measuring physical attributes of the land, oceans and atmosphere (even the cryosphere) at global scales.

These satellite data streams are fed into models that mimic the earth system to help scientists understand human impacts and predict global change, such as the climate impacts of tropical deforestation. Earth system science therefore not only relies on earth observation data, but embraces chemistry, physics, biology and mathematics by transcending disciplinary boundaries to treat the earth as an integrated system. The observation and computationally intensive coupled, biophysical models are brought together by high-performance computing.

UTILISING HIGH-PERFORMANCE COMPUTING FOR RESEARCH

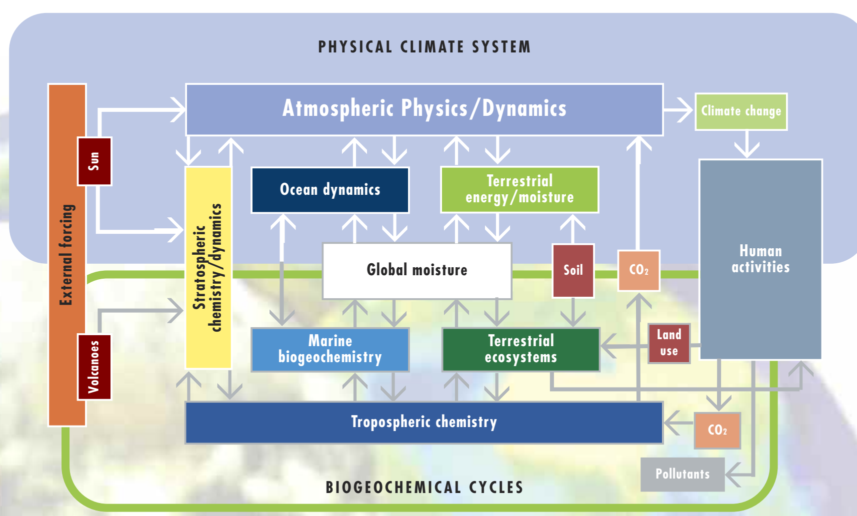
The Centre for High Performance Computing (CHPC), a Department of Science and Technology-funded initiative managed by the Meraka Institute, supports earth system science research through the provision of high performance computing facilities to carry out computationally expensive tasks. Currently, scientists from the universities of Pretoria and Cape Town, and the South African Weather Services are running ocean, atmosphere and coupled ocean-atmosphere models. The models currently being utilised were developed in Europe and the United States; however, the CHPC also supports model development taking place at the University of Pretoria.

Current activities in earth science at the CHPC are spearheaded by the computational climatology and oceanography special interest group (SIG). A new SIG called terrestrial, ecosystem and land surface modelling will be established soon. Earth observations form an important part of modelling activities for initial conditions, boundary conditions, verification of model simulations and for the study of the earth system itself, as mentioned earlier. For this reason, a remote sensing SIG is also being established by CHPC to provide computation resources to the CSIR's rapidly growing earth observation research.

Today, many space agencies operate satellites for the ultimate purposes of earth system science, driving international programmes such as the Intergovernmental Panel on Climate Change (IPCC) and International Geosphere Biosphere Program (IGBP). The Global Earth Observing System of Systems (GEOSS) is the embodiment of the dream to bring together all the space-borne and *in situ* sensors from around the world. The South African Earth Observation Strategy was developed by DST and implemented by the CSIR in response and close alignment to GEOSS.

The GEOSS societal benefit areas, such as climate change, ecosystems and natural disasters, represent complex issues that can hardly be solved with observations from a single satellite. These societal benefits will ultimately be achieved by unravelling complex systems through focused long-term earth system science research, which recognises humans as part of the system. This will be accomplished with the aid of constellations of earth observing satellites relaying data to coupled models applied using high performance computing.

BRETHERTON DIAGRAM



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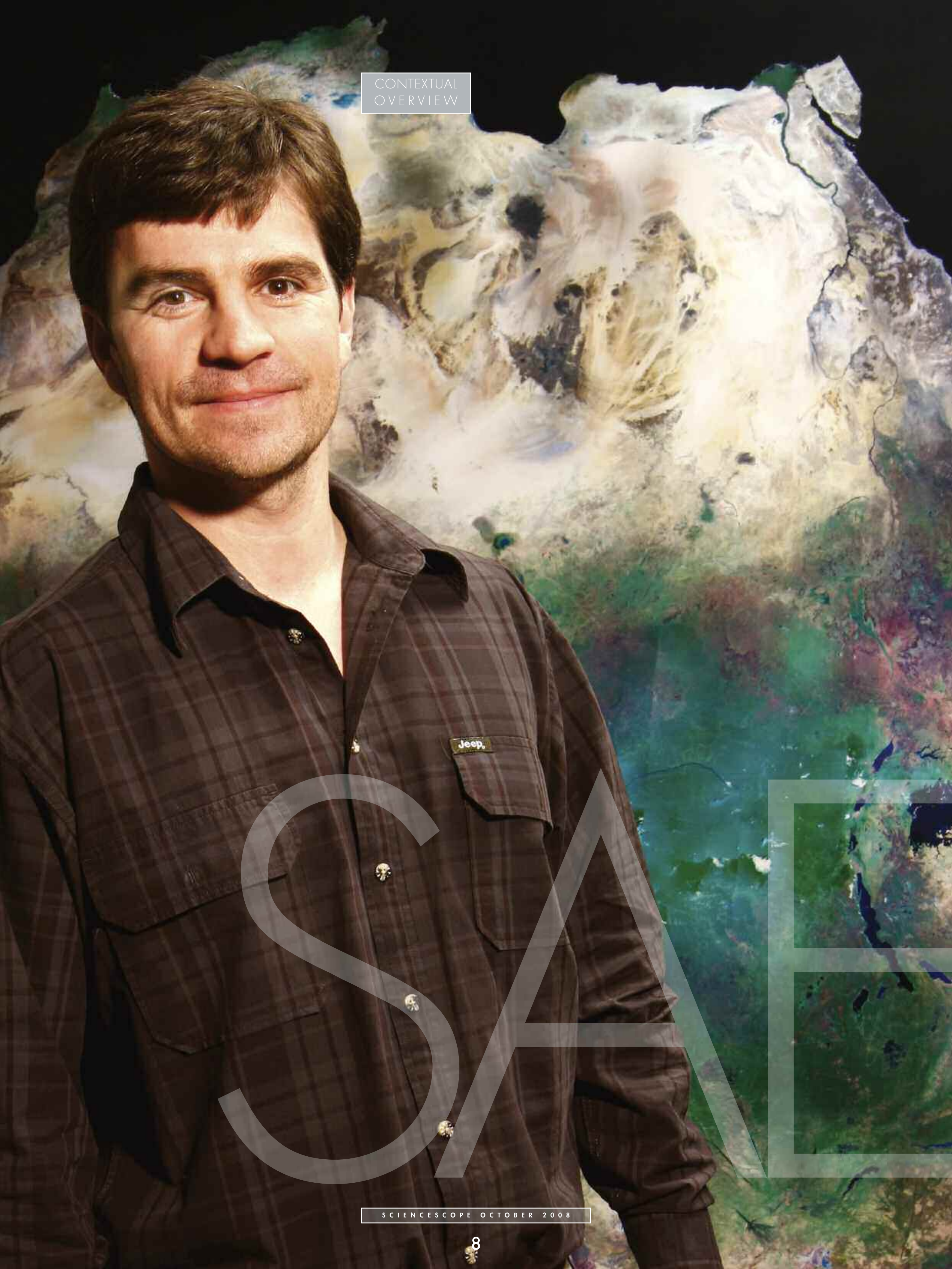


DERIVING VALUE FOR SOUTH AFRICA FROM EARTH OBSERVATIONS

BY DR CORNÉ ELOFF

THE OBJECTIVE of the South African Earth Observation Strategy (SAEOS) is to coordinate the collection, assimilation and dissemination of earth observations (EOs), to realise the full potential of these to support policy, decision-making, economic growth and sustainable development in South Africa. This is achieved by adding value to the existing expenditure on EO and related activities in South Africa, by making the information available to a broad spectrum of users in an integrated, timely and easily-accessible form.

SAEOS is implemented by the CSIR Satellite Applications Centre on behalf of the Department of Science and Technology (DST). Its ultimate goal is to contribute to the nine societal benefit areas identified by the Group on Earth Observations, directly or indirectly: monitoring and assessment of natural disasters, health, energy, climate change, water, weather, ecosystems, agriculture and biodiversity.

A WEALTH OF TELEMETRY

The CSIR has been receiving telemetry from EO satellites since 1980 and therefore has unique operational experience to manage the remote sensing supply chain to a geo-processed product for the end user. An archive hosting more than 100 Tb of remote sensing data dating back to 1972, creates a priceless temporal dataset for analysis and change detection applications.

The centralisation of an EO spatial portal as a final result of the SAEOS project presupposes an advanced EO data centre (EODC) to feed the EO portal with a remote sensing archive and new products and imagery. The collection and image processing of terabytes of imagery requires an advanced automated supply chain to control and manage the workflow of image processing. An advanced customer interface to order and search the required products from the EODC is essential.

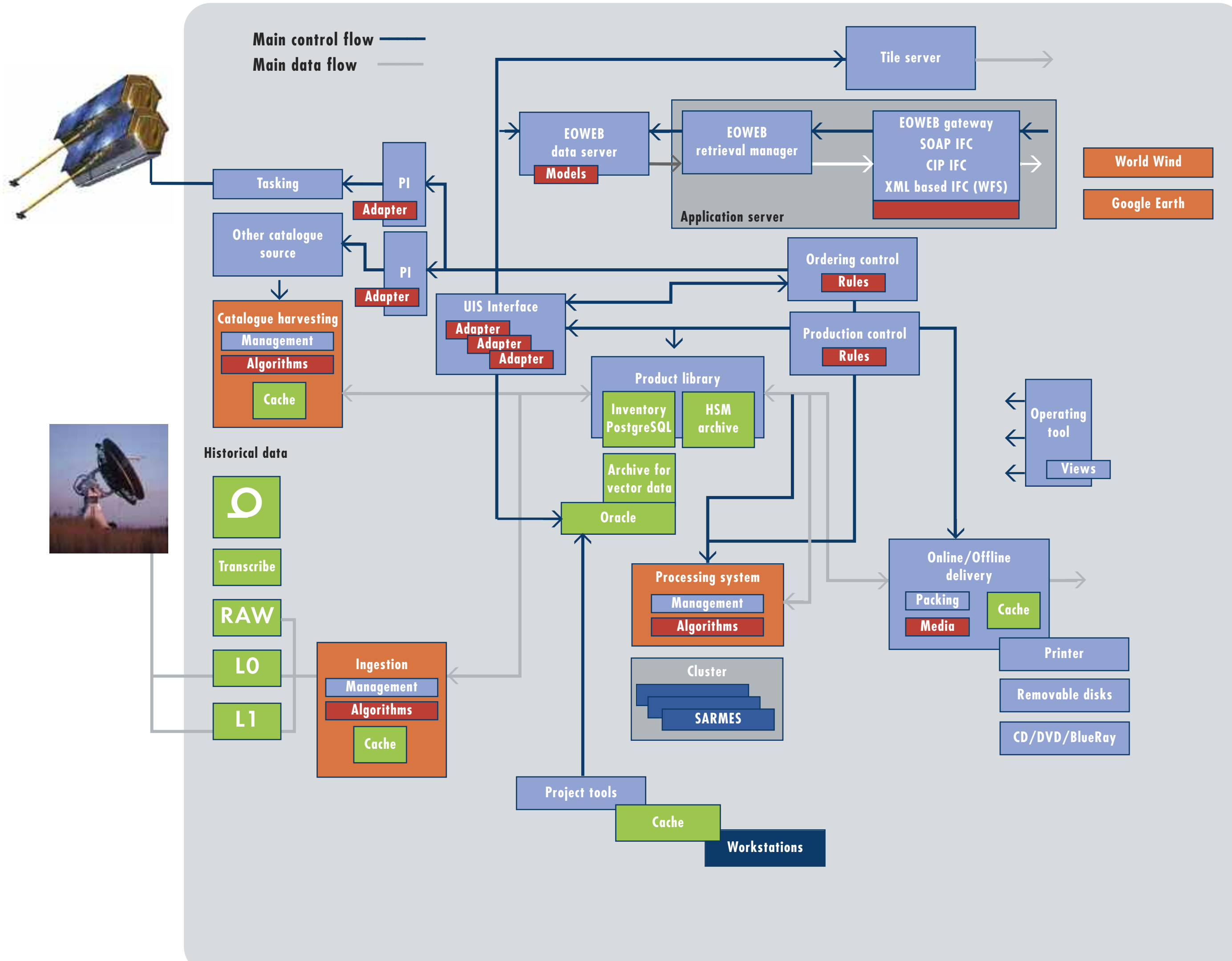
After intensive research, the Data Information and Management System (DIMS-EO) was selected. This product from WERUM, Germany, which has been implemented within DLR (the German Space Agency) and ESA (European Space Agency), will enhance operational control, quality and throughput within the CSIR's remote sensing supply chain.

MATCHING SERVICES TO REMOTE SENSING USER REQUIREMENTS

The CSIR hosted a user requirement workshop on 14 February 2008 to understand user requirements and align current and future earth observation satellite sensors. Over 50 delegates representing 23 government departments and representatives from parastatals participated.

The broad aims of the workshop were to inform stakeholders of the role of the South African Space Agency in coordinating EO data access. It was also an opportunity for these participants to gain better understanding of available imaging technologies for a potential follow-on reception agreement post March 2009 through presentations by various

Figure 1: The DIMS-EO system software elements



satellite and aerial imaging suppliers, notably Infoterra on TerraSAR-X; DigitalGlobe on Quickbird and the new Worldview satellite; Geoeye on Ikonos and the new Geoeye-1 satellite; RapidEye on its new high resolution constellation; Antrix on the Indian resourcesat and Cartosat 1 and 2 satellites; SpotImage on Spot 5 and Astroterra (Spot 6) and CDSM on the new digital airborne imager.

Through a questionnaire survey, user requirements for 2008-2011 per department were gleaned. This, together with information on available departmental budgets for 2008-2011, allowed for discussion on a suitable sensor portfolio for 2009-2011 and beyond.

Detailed user requirements are available on request and were used to formulate recommendations. These include renewing SPOT 5 and considering engagement into Astroterra (SPOT 6); direct telemetry access to CartoSAT (P5) and ResourceSAT (P6); procurement of sub-1 metre satellite imagery on an *ad hoc* basis where CDSM airborne camera is unavailable; and securing an 'emergency/rapid response' contract with TerraSAR-X.

THE WAY FORWARD

The SAEOS programme initiated by the DST has enabled the CSIR to re-engineer its EODC service and will conclude in March 2009. The DIMS-EO system will result in a world-class remote sensing supply chain centre. The EODC centre will contribute to various national, regional and international programmes and play a vital role in the South African Space Agency. Ultimately, its service will impact positively on every person in South Africa.

The DIMS-EO system elements depicted in Figure 1 consist of the following modules:

Product ingestion
This service accepts data from the various data producers and coordinates archiving and inventorying of the data. It implements a workflow that consists of data detection, metadata extraction, and data and metadata submission to the product library.

Catalogue harvesting
This module retrieves metadata from third-party catalogues to make the data available for ordering and implements a workflow performed at regular intervals, consisting of new entry detection and metadata retrieval, transformation and submission to the product library.

Product library with relational database management system and data archive
The earth observation data product is the central management unit of the EODC product library (PL). A product typically groups metadata describing the item and several logical components.

Production control
This controls and monitors complex production workflows in DIMS.

Processors and processing management
Processors like the South African Resource Management and Expert System (SARMES) or Definiens workflows are wrapped into operational processing systems. Processing systems consist of one or several processors and a framework layer – the processing system management.

Online/offline product delivery
This generates customised delivery packages of ordered product items, either for online transfer or on media.

UIS interface
The components user interface loader and user information services interface employ the PL insert and update event subscription to upload product data into the EOWEB User Services and external data management systems.

EOWEB
EOWEB is the user information service of the DIMS. It provides catalogue, ordering and data services to end users and external systems.

Order control
This component handles and processes user orders and covers aspects from validation and on-demand production to accounting.

Production interface
This component facilitates exchange requests and, optionally, data with external production or acquisition systems.

Definiens Intelligence Suite
This suite provides image analysis for earth observation data to generate higher-level thematic mapping from earth observation data, such as thematic maps and feature extraction information.

PCI Geomatics
The PCI Geomatics software suite is integrated into the system to support post-processing workflows during ordering, e.g. to extract subsets from mosaics to be supplied to the user.

SARMES
The SARMES system, based on PCI Geomatics software, is used to perform various processes. Level 1 satellite image data are converted to Level 3 (L3) and Level 4 (L4) data products. The L3 products are stored in the PL, the geographical query capabilities of which can then be used to select all relevant L3 products for the generation of the L4 product (Figure 2).

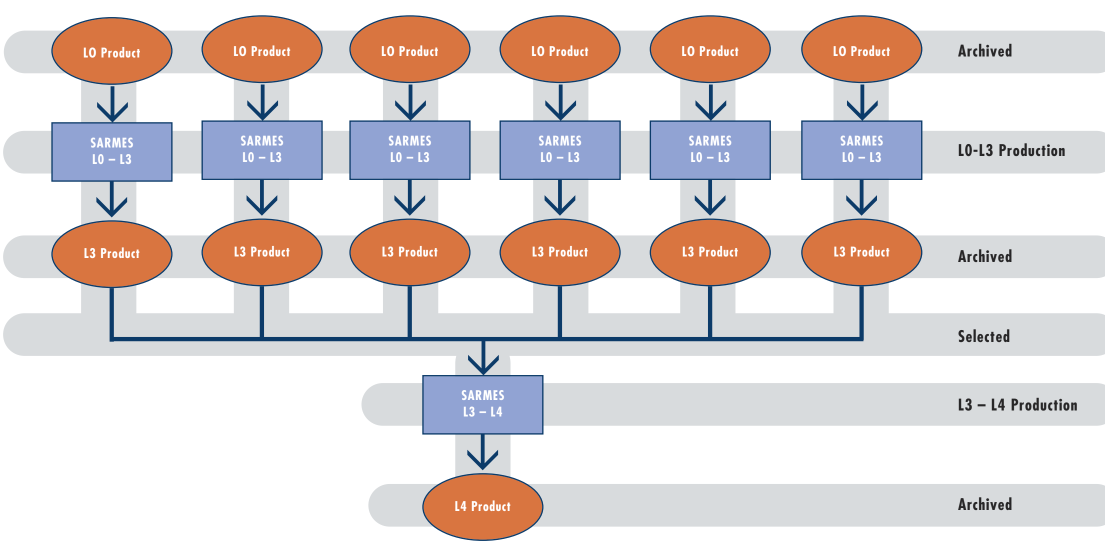


Figure 2: SARMES production chain L0 to L4

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MONITORING GOOD AND BAD LAND USE PRACTICE FROM SPACE

BY DR MELANIE VOGEL, DAVID LE MAITRE, DR KONRAD WESSELS

Image: Rudi van Aarde

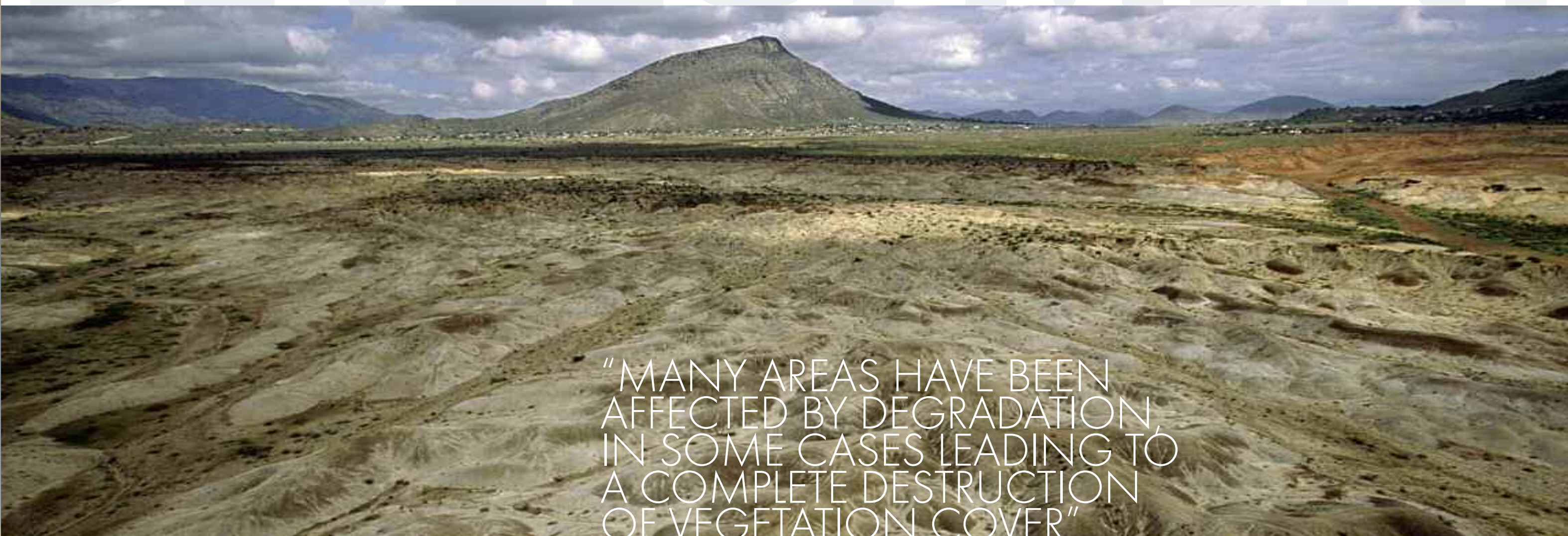
Intact savanna

SATELLITES GATHER DATA that allow us to assess whether South Africa's rangelands are ecologically in a good or bad condition. The state of our rangelands is of national concern and has a high priority because we can relate the 'good' and 'bad' condition to whether or not they are being used sustainably. Sustainably used, natural resources such as rangeland or cultivation lands will conserve the productivity of the land for a long time (picture above).

In contrast, unsustainable use leads to a decrease in the production of natural biomass and changes in ecosystem functioning and economic productivity as a result of mismanagement. The outcome of these processes is called 'degradation'. Degraded rangelands are usually less productive economically, as fewer livestock can be maintained on these lands. Protecting natural resources benefits the land user economically, especially in the long-term.

A drive through most parts of our country will show that many areas have been affected by degradation, in some cases leading to a complete destruction of vegetation cover (picture above right).

People who depend on land for their subsistence or commercial livelihoods will experience difficulties when the productivity of their land declines to



"MANY AREAS HAVE BEEN AFFECTED BY DEGRADATION, IN SOME CASES LEADING TO A COMPLETE DESTRUCTION OF VEGETATION COVER".

Image: Rudi van Aarde

Degraded savanna

such a degree that it cannot feed them anymore.

The CSIR is committed to research aimed at unravelling the interrelations between land use practices, ecosystem responses and the economic implications.

For example, scientists typically want to know:

- What are the economic benefits of an intact savanna for cattle farmers?
- Who benefits from these rangelands and cattle, both directly and indirectly?
- How does the value decrease if the savanna is degraded?
- Who carries the cost of the degradation?

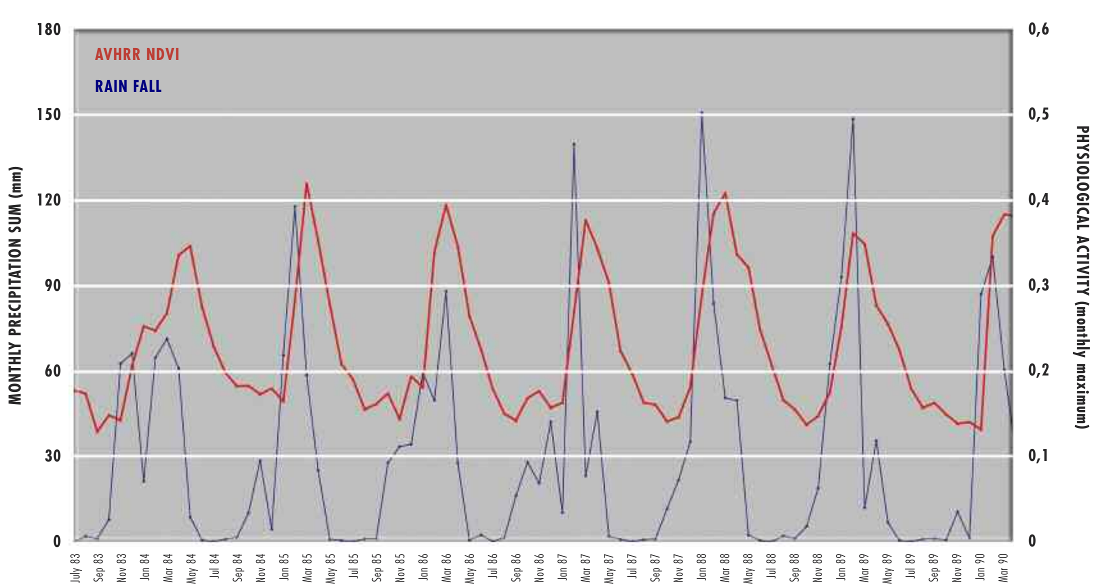
Before we can answer these questions, we need to understand those factors that determine when savanna is degraded. This is where satellite technology comes in. By enabling us to cover large areas, remote sensing imagery aids in the assessment of land cover and vegetation states for entire ecosystems, such as the catchment of the Inkomati River.

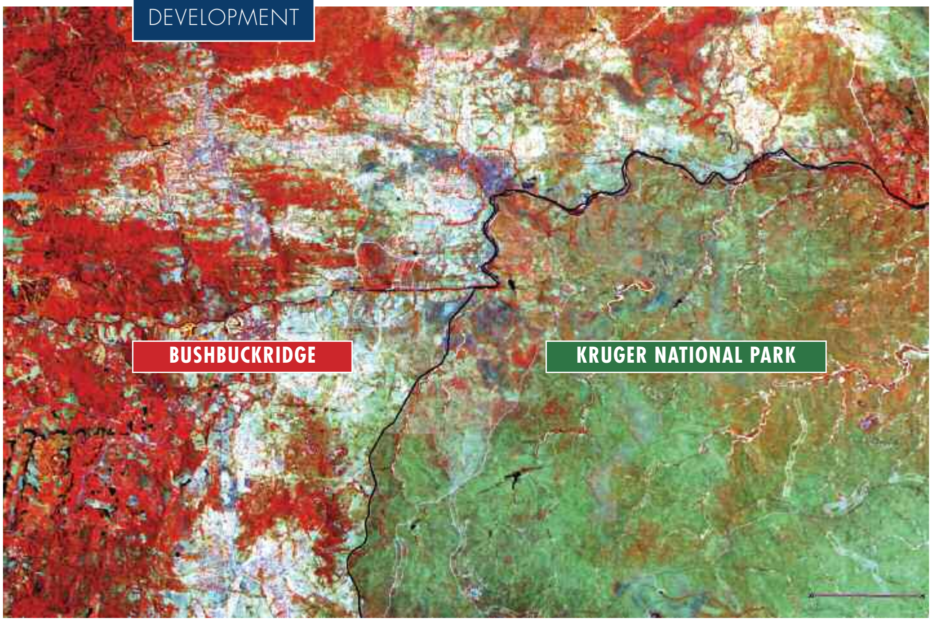
We use satellite imagery to assess the following:

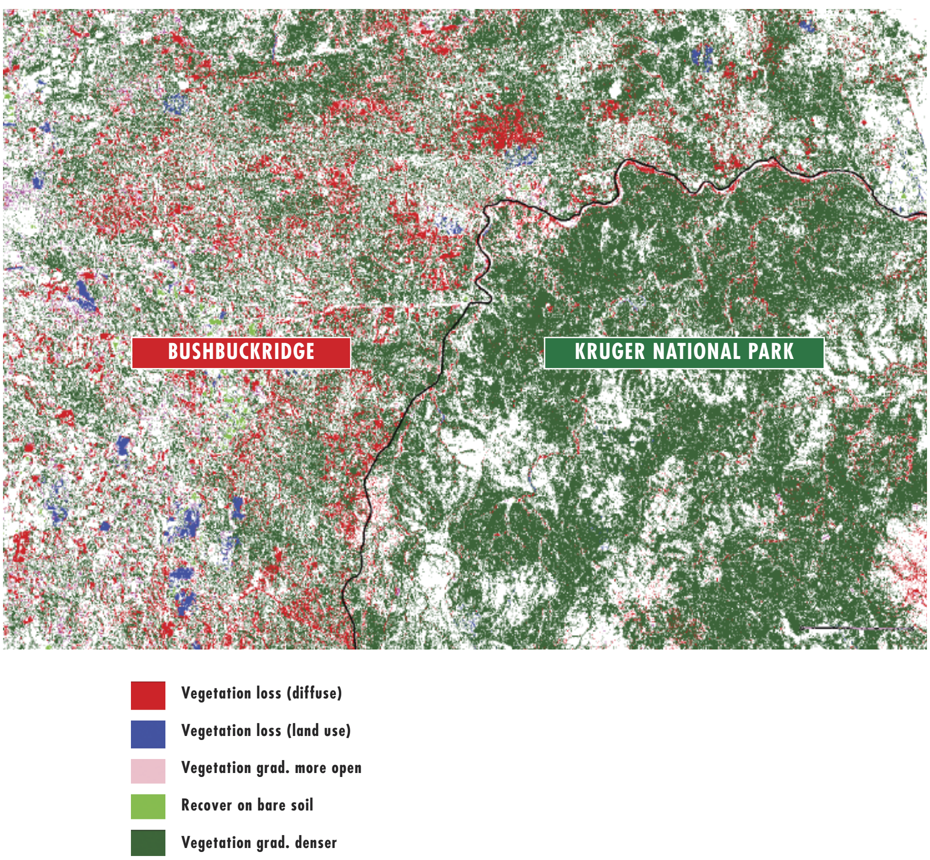
- Vegetation and land-cover type
- Infrastructure and settlement density
- Topological parameters
- Natural vegetation changes over time
- Degree of land degradation.

CSIR scientists found that inter-annual variability due to rainfall often masks the impacts of human-induced land degradation. Using a combination of satellite images in high temporal frequency (daily data, if necessary) and rainfall data, we can start to untangle these correlations by determining if the vegetation loss detected at a certain point in time is related to degradation processes – or simply the temporary effect of a drought.

The use of long-term time series of multispectral imagery from the Landsat satellite, dating back to the early 1980s, helps us to pinpoint when the degradation (or improvement) became visible.







Left:
Landsat satellite image: Kruger park area (intact savanna) on the right, and Bushbuckridge area (degraded) on the left

Below left:
Land cover changes for the same area as above, comparing Landsat imagery from 1990 and 2007. The fraction of detected vegetation loss is more pronounced in the Bushbuckridge area

By applying change detection techniques we can detect different spatial patterns of change inside the Kruger National Park and in the adjacent communal areas (compare images at the left). These changes are mainly related to rainfall distribution inside the park as opposed to land-use impact outside the park. Analyses like these also assist in distinguishing natural from man-made changes in a landscape.

Another aim of the CSIR's work is the definition of a degradation gradient. The ability to assess the degree of degradation is necessary for gauging the flow of economic benefits, because a landscape that is a little degraded delivers more services than a severely degraded ecosystem.

An interdisciplinary approach including CSIR experts from the fields of ecology, hydrology, resource economics, economic geography, town planning and geographic information systems ensures that the information derived from space technology delivers useful input for the assessment and modelling of ecosystem benefit flows. In this way, the CSIR contributes to the reduction and mitigation of poverty, especially in rural areas, and to the development of strategies for the sustainable use of natural resources.

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USING REMOTELY-SENSED DATA FOR OPTIMAL FIELD SAMPLING

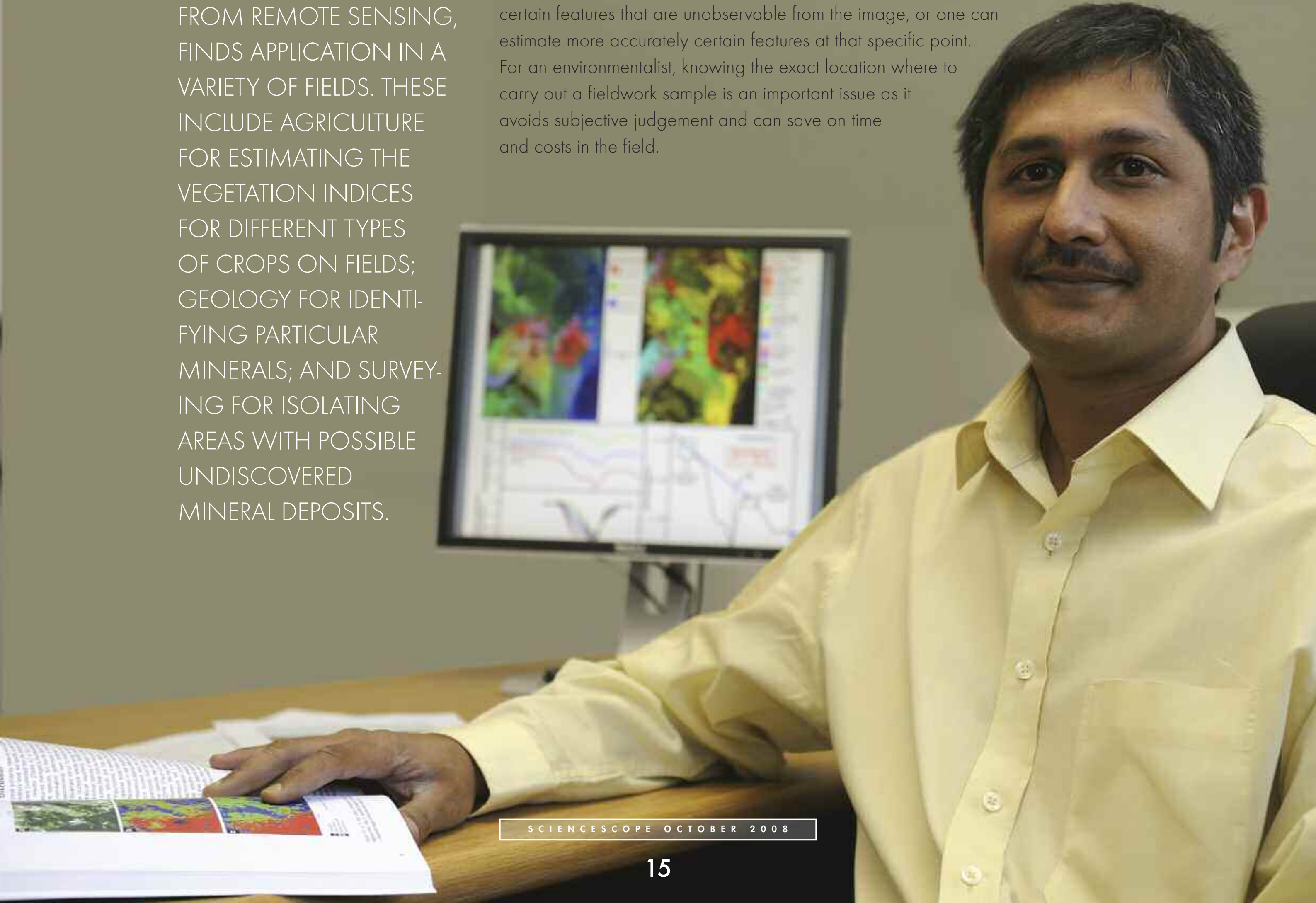
BY
DR PRAVESH DEBBA

STATISTICAL SAMPLING, USING DATA OBTAINED FROM REMOTE SENSING, FINDS APPLICATION IN A VARIETY OF FIELDS. THESE INCLUDE AGRICULTURE FOR ESTIMATING THE VEGETATION INDICES FOR DIFFERENT TYPES OF CROPS ON FIELDS; GEOLOGY FOR IDENTIFYING PARTICULAR MINERALS; AND SURVEYING FOR ISOLATING AREAS WITH POSSIBLE UNDISCOVERED MINERAL DEPOSITS.

STATISTICS IS THE SCIENCE pertaining to the collection, summary, analysis, interpretation and presentation of data. It is often impractical – or even impossible – to collect data from the total population of interest. Instead, one uses data from a subset of the population, called a sample. A sample, however, gives rise to uncertainty in terms of the process or population being studied. Subsequently, the design of sampling schemes plays an important role in statistics because a sample should represent the characteristics of the population, in terms of its distribution and associated parameters.

Some of the key questions in environmental studies are: where to sample, what to sample and how many samples to obtain. Conventional sampling techniques are not always suitable in environmental studies and scientists have explored the use of remotely-sensed data as ancillary information to aid in the design of sampling schemes. Remote sensing images provide a synoptic overview of a large area, thus giving a wealth of information over the entire area.

This can be far more informative than a few selected points on the ground for fieldwork. However, fieldwork is still an important exercise because one can measure certain features that are unobservable from the image, or one can estimate more accurately certain features at that specific point. For an environmentalist, knowing the exact location where to carry out a fieldwork sample is an important issue as it avoids subjective judgement and can save on time and costs in the field.



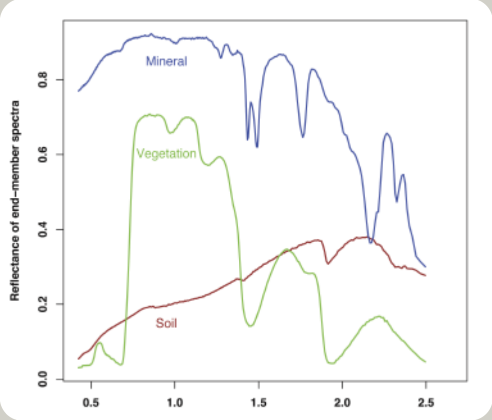
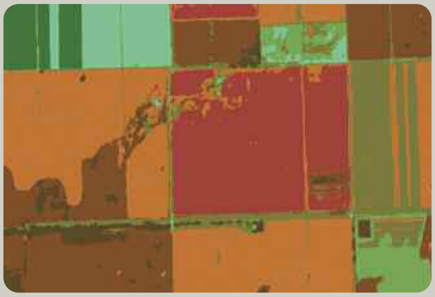


Figure 1: Examples of different spectral signatures

Figure 2: (a) Original image



(b) Classified image

Figure 3: Optimised sampling scheme

Remote sensing is the acquisition of data in the form of images obtained from a sensor mounted on an aircraft, spacecraft, satellite, ship or even hand-held over the earth's surface. Our study in designing optimal sampling schemes used hyperspectral images, obtained from sensors mounted on an aircraft. These sensors typically record the reflectance in many narrow contiguous bands at various parts of the electromagnetic spectrum, ranging from visible through near infrared to short-wave infrared. The recording at a specific part of the electromagnetic spectrum results in a grayscale image.

Observing a single pixel over the range of images, namely over the electromagnetic spectrum, results in a spectral signature (see Figure 1). Each object has a distinct spectral signature and it is this signature that can be used to classify an image into different classes, for example, barley, maize, sugar beet and sunflower.

Three examples follow to illustrate the way in which remotely-sensed data can be used to derive optimal sampling schemes for fieldwork.

ESTIMATES OF VEGETATION INDICES

CSIR researchers and their peers in the Netherlands designed an optimal sampling scheme for field visits, on an agricultural field in Hungary, which would be able to estimate more accurately the various vegetation indices for each of the different types of crops on the field. A vegetation index is a quantitative value used to measure biomass or vegetative vigour. First, the hyperspectral image (Figure 2a) was classified into eight classes (Figure 2b) using an automated process. Four classes were grouped to form a region of no interest (Figure 3) where there was no vegetation. Through a mathematical objective function and an optimisation procedure, 50 sample points were spread over the four classes (Figure 3).

The optimised sampling scheme resulted in more accurate estimates for various vegetation indices compared to simple random sampling, grid sampling or stratified random sampling. The optimised sampling scheme could potentially have an impact on providing improved estimates on the health status of the various types of crops in an agricultural field.

MINERAL DISTRIBUTION

In a geological study, applied to an area in Spain, we designed a sampling scheme that has the highest likelihood for identifying the occurrence of a particular mineral, namely alunite, while sampling from occurrences across the whole area. Geologists are often interested in creating a mineral alteration map. To achieve this, they need to identify hydrothermal alteration minerals (e.g. alunite), through field sampling.

First, each pixel in the hyperspectral image was matched to the alunite reflectance spectrum (Figure 1: mineral). We then created a soft classification of the image. Each pixel ranges between zero and one and the value was used as weights in a mathematical objective function. When this function was optimised, the sampling points were distributed over the alunite region and most of the points are found in the areas where

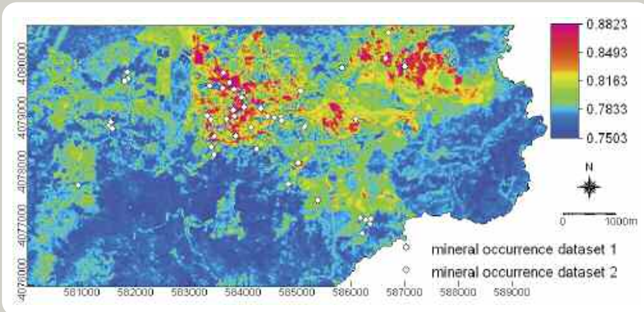


Figure 4(a): Band ratio 1

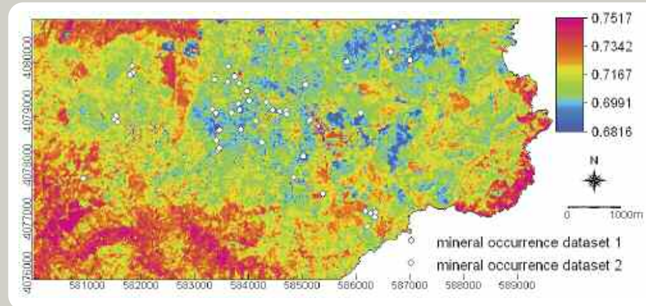


Figure 4(c): Band ratio 3

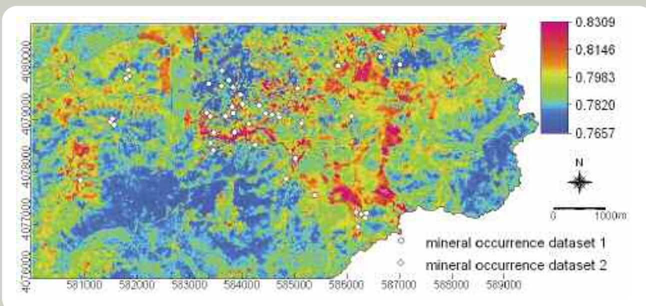


Figure 4(b): Band ratio 2

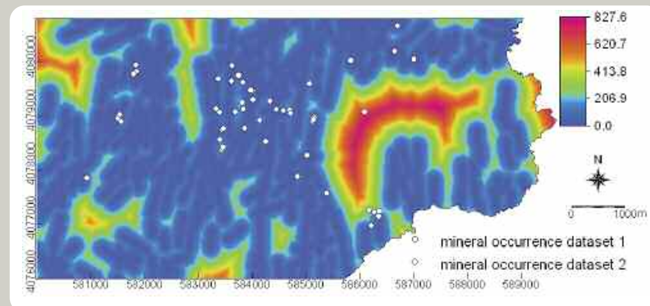


Figure 4(d): Distance to faults and fractures

there is a higher likelihood of alunite. This could potentially save time and costs because with this sampling scheme the geologist is almost certain to sample only alunite on the ground, while accurately reflecting the distribution of alunite in the region.

EXPLORATION TARGET ZONES

Another area in which sampling schemes play an important role is in deciding where to demark exploration target zones for further surveying as potential mining areas. Typically, these areas should have a high likelihood of undiscovered mineral deposit occurrences. This study was also conducted in Spain.

To test our methodology we obtained two independent datasets of discovered mineral deposits. One set was used to arrive at a mineral potential map and an optimised sampling scheme in terms of exploration target zones. The second dataset was used to determine if the predicted exploration target zones from our sampling scheme contains one of the 'now assumed' undiscovered mineral deposits.

To determine the mineral potential map, we created band ratio images from the hyperspectral images and a map of the distance to faults and fractures (Figures 4a-d). These were used as input layers in our modelling.

With the aid of an appropriately defined objective function and through mathematical optimisation, we arrived at the optimal target zones (black circles) on the derived mineral potential map (Figure 5). These target zones contain nine of the 14 assumed undiscovered mineral deposits. The remaining five that were undiscovered are not too far from a target zone. Furthermore, the optimised target zones suggest new potential areas of undiscovered mineral deposits for further surveying.

The advantage of this research is that it enables the geologist to concentrate on specific areas with a high likelihood of undiscovered mineral deposits for further surveying, thereby saving time and costs on surveying areas less likely to be commercially viable.

The research referred to in this article was conducted with collaborators and supervisors from the International Institute for GeoInformation Sciences and Earth Observations (ITC) in the Netherlands.

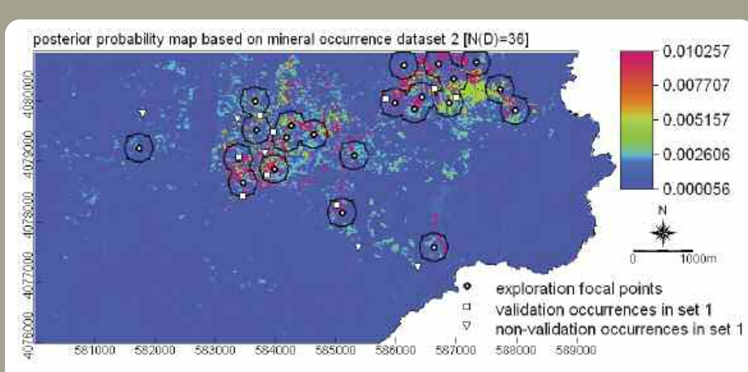


Figure 5: Optimal target zones on a mineral potential map

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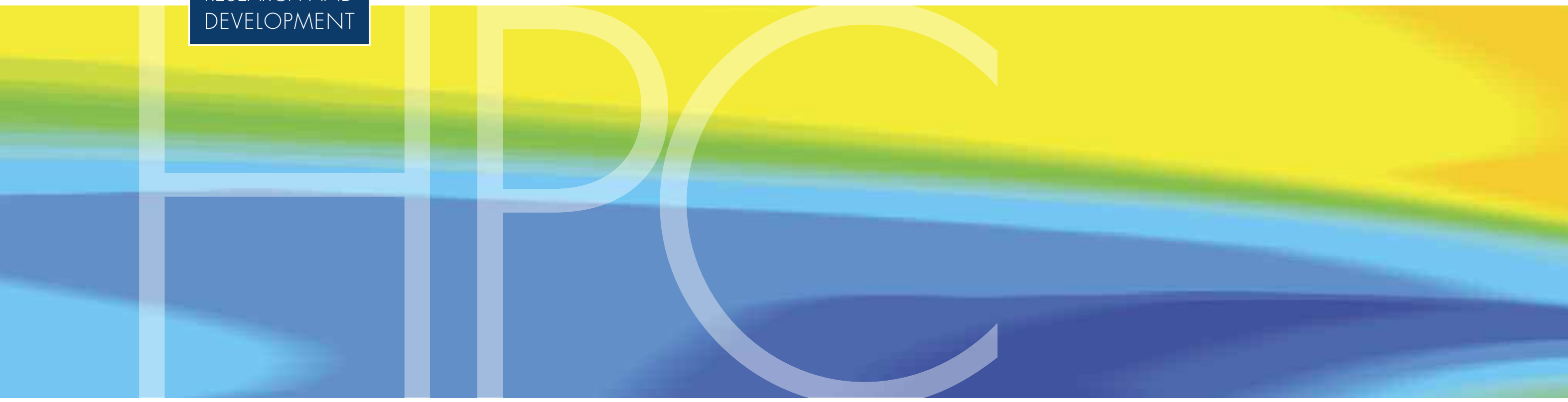

HIGH PERFORMANCE COMPUTING APPLICATIONS IN SPACE SCIENCE AND ASTRONOMY

BY DR DANIEL M MOEKETSI

THE CENTRE for High Performance Computing (CHPC) in Cape Town (under the auspices of the CSIR's Meraka Institute) was launched in May 2007 and is a national centre initiated by the Department of Science and Technology. The first phase of computational procurement consists of an IBM e1350 Linux cluster with 160 nodes. It has successfully passed its initial benchmark requirements of 2.5 Teraflops. The facility is the largest computational science laboratory in southern Africa and provides a unique platform for high performance computing research in various fields.

In particular, two cutting-edge research projects in space science and astronomy are currently utilising the CHPC computational infrastructure and are discussed in this article.

COMPUTATIONAL SPACE PHYSICS AND ASTROPHYSICS

The flagship project of Professor Marius Potgieter and his team at the North-West University focuses on computational space physics and astrophysics. Their project is titled *Cosmic rays and us: from 'birth' to 'death'*. Cosmic rays are charged particles of galactic origin with very high energies. Since these can be harmful to life on earth, they are studied in detail from their origin up to their detection on Earth, and by a large number of balloon experiments, satellites and spacecraft. Present challenges of astrophysics and space physics concern the origin of these cosmic rays, with their propagation through the galactic and interstellar medium up to where they encounter the heliosphere. Eventually these rays reach the earth where its magnetic field effectively shields us against these 'cosmic visitors' because they are charged particles. The heliosphere is the huge space surrounding the solar system, dominated by the activity cycle of the sun, which creates the solar wind that carries with it a turbulent magnetic field that also, fortunately, deflects cosmic rays.

The local interstellar conditions through which the heliosphere moves can change dramatically over thousands of years. These very long-term changes in our interstellar and heliospheric environment are called space climate. Since life on earth has taken millions of years to develop, space climate is an important issue that has probably played a significant role in previous and present climatic changes.

The research focuses on the computational modelling of heliospace physics, interstellar physics and astrophysics, using

THE CHPC STATE-OF-THE-ART HIGH PERFORMANCE COMPUTATIONAL FACILITY WILL ACCELERATE RESEARCH AND DEVELOPMENT IN THE FIELD OF SPACE SCIENCE AND ASTRONOMY.

state-of-the-art numerical models that are computationally very intensive. Figure 1 shows the hydro-dynamically-computed heliosphere using the CHPC cluster in the meridional plane, with the sun at 0 AU (astronomical units). The research aims to design, construct, link and expand numerical models to simulate the transport and acceleration of cosmic rays, from their creation in the galaxy up to their arrival on earth. These numerical simulations are used to test different leading theories, and to explain and understand recent observations and measurements from various spacecraft (e.g. from Voyager 1 and 2) and large telescopes such as those used by the High Energy Stereoscopic System (HESS) collaboration in Namibia. End results, to be obtained over the next decade, will be applicable to studies of the influence of cosmic rays, space weather and space climate on the environment of the earth; long-duration missions to Mars; and working environments on the Moon and Mars.

MODERN SOUTH AFRICAN ASTRONOMY AND COSMOLOGY: CONFRONTING THE SIMULATED AND THE OBSERVED UNIVERSE

The consortium project of Dr Kavian Moodley (University of KwaZulu-Natal), Professor Bruce Bassett (University of Cape Town and South African Astronomical Observatory (SAAO)) and Dr Catherine Cress (University of the Western Cape) focuses on computational astronomy and cosmology.

Cosmology is the study of the structure and evolution of the universe and its physical constituents and is a field that lies at the interface of astronomy and particle physics. Cosmology has undergone a major evolution over the past decade with the advent of a wealth of observational data from cutting-edge experiments and telescopes.

The standard cosmological model describes an expanding universe that is smooth on the largest scales, with inhomogeneous structures – such as galaxies, galaxy clusters and super clusters – present on smaller scales. These structures, which originated from small irregularities, were present at early times of the universe and grew *via* gravitational perturbations to form a variety of the observed structures. In addition to the visible matter, there is evidence that the universe contains significant fractions of dark matter and dark energy that dominate the cosmic energy budget today.

Besides the remarkable success that the cosmological model has enjoyed, the leading challenges in modern cosmology still exist: understanding the nature of dark energy and dark matter, the origin and evolution of galaxies and galaxy cluster,

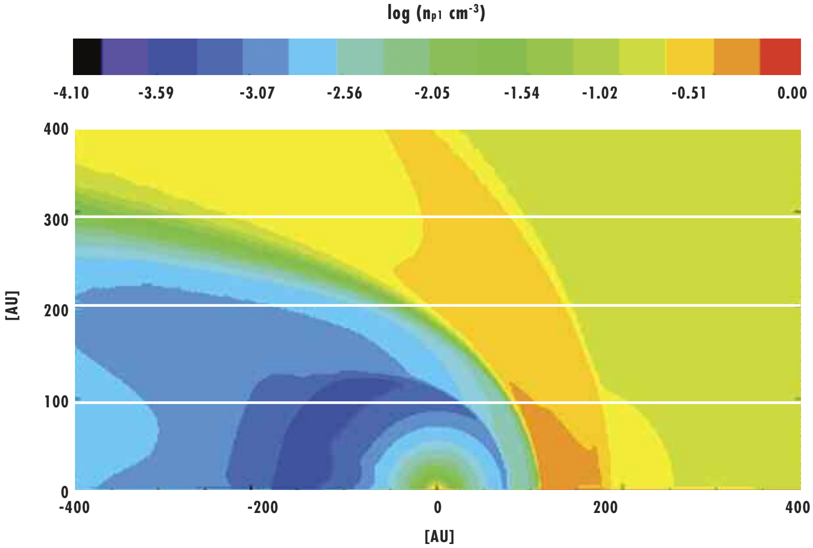

Figure 1: The hydro-dynamically computed heliosphere in the meridional plane, with the sun at 0 AU (Adopted from Ferreira *et al.*, (2007 a. Potgieter, 2008; private communication)

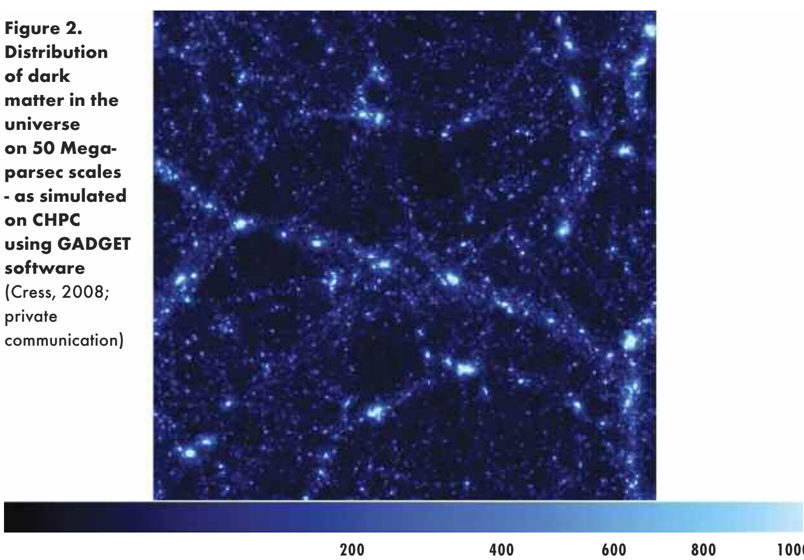

Figure 2. Distribution of dark matter in the universe on 50 Mega-parsec scales - as simulated on CHPC using GADGET software (Cress, 2008; private communication)

and describing the nature of the primordial fluctuations that seeded cosmic structure.

To address these challenges, the investigators are using high-precision data from new national and international astronomical facilities, such as SAAO, the Acatama Cosmology Telescope and the South African MeerKat radio telescope. However, to analyse and interpret these data and to use them to constrain theoretical models, require significant computational effort. The existing cosmological software and newly developed computational-intensive algorithms are applied for this purpose. Figure 2 is an example of distribution of dark matter in the universe as simulated on the CHPC cluster using GADGET software.

DISCUSSION AND FUTURE OUTLOOK

With the establishment of the CHPC facility, especially at a time when South Africa is making the transition from labour to a knowledge-based economy, it has indeed become possible to embark on such ambitious projects that require extensive numerical modelling of the nature described here. In particular, this occurs by enhancing human capital development; excellence in science and technology such as increasing the current research output; and technology innovation in the country. The latter will enable our local scientists to be highly competitive at international level, and strengthen collaboration with African and international institutions.

The CHPC is planning to achieve this by involving key stakeholders through the space science and astronomy special interest group. Considering that South Africa is heading towards establishing its own space agency, and given the current possibility to host the largest radio astronomy telescope in the world (the Square Kilometre Array, also known as SKA), the CHPC's important role in space science, astronomy and technology development and advancement is indisputable. It is envisaged that high-end computing to capture raw data from telescopes, process and disseminate these in a meaningful format, will play a critical role in determining the potential of a country to host facilities such as the SKA.

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MONITORING INFORMAL SETTLEMENTS IN SOUTH AFRICA USING REMOTE SENSING

BY KARISHMA BUSGEETH AND DR FRANS VAN DEN BERGH

INFORMAL SETTLEMENTS are common physical entities within the makeup of South African cities. These settlements have increased in number from 1,049 million dwellings (in 1994) to 1,376 million (in 2004), and are projected to continue increasing to some 2,4 million in 2008. The existence of informal settlements is fast becoming a serious problem since they accommodate a large proportion of the urban population who live in sub-standard living conditions.

Figure 1: Examples of delineated homogeneous settlements

In addition, the increasing trend in migration to urban areas inevitably leads to a shortage of basic engineering services such as water, sewerage and solid waste removal. Rapid urbanisation also places increased pressure on essential services such as health and education.

Informal settlements are known as shacks, squatter areas, shanty towns and irregular settlements. Regardless of the name, common features that distinguish these from formal settlements are that they do not adhere to local building codes, they have either low or no levels of infrastructure, they are either poorly serviced or not serviced at all, they have no security of tenure and they are characterised by a rather non-functional layout.

One of the fundamental difficulties that authorities face when planning a response to the formation and growth of informal settlements, is the lack of spatial and temporal data. Such data allow us to identify and quantify services and infrastructure, which are required to improve our understanding of settlement morphology, population distribution and emerging settlement patterns. Several reasons exist for the scarcity of data on informal settlements. Their dysfunctional structure and high building density make it hard to conduct surveys. The settlements are dynamic, with frequent population fluctuations – to the extent that the erection or removal of structures often happens overnight. Shifts in municipal boundaries and overlapping administrative responsibilities contribute to the confusion.

Additional challenges include deficits in human resources, funding and equipment. All these factors contribute to the difficulty of obtaining the data required for effective planning in and around informal settlements. To overcome some of these difficulties, the CSIR is investigating the use of satellite images to fill the gaps in the spatial data. The goal is to use QuickBird imagery (with a spatial resolution of 0,6 m) as a primary data source to map the extent of informal settlements, simultaneously determining the specific settlement type in each area.

The first step was to use the QuickBird imagery to delineate homogeneous areas manually (see Figure 1), from which urban settlement attributes were identified. These attributes relate to the settlement layout, housing structure, presence of engineering services and infrastructure existing within a particular settlement. The results of the manual extraction of the attributes showed that these could be identified from the QuickBird images, while establishing whether the settlements had access to different types of engineering services was inconclusive.

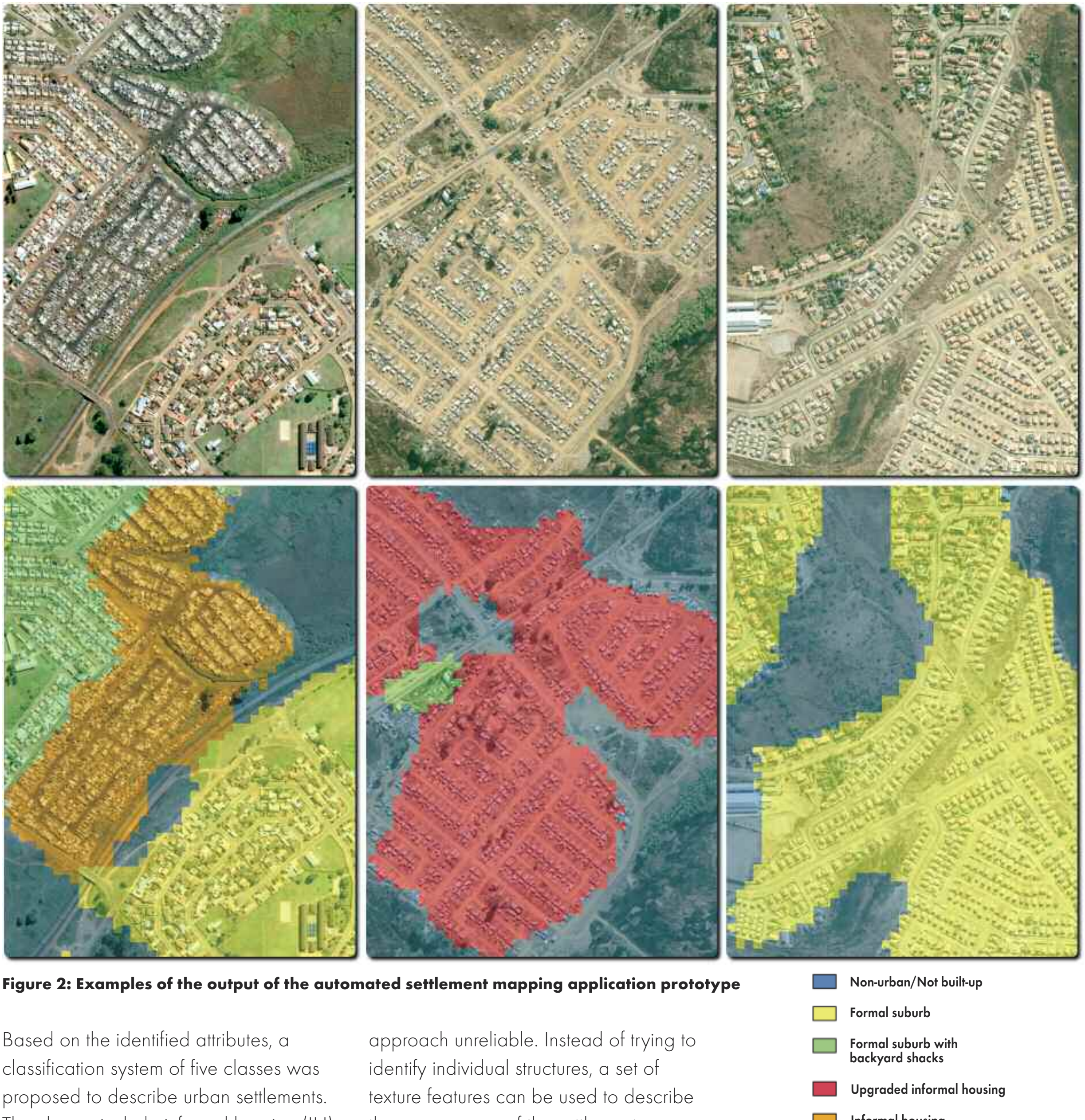

Figure 2: Examples of the output of the automated settlement mapping application prototype

Based on the identified attributes, a classification system of five classes was proposed to describe urban settlements. The classes include informal housing (IH), upgraded informal housing (UIH), formal suburb (FS), formal suburb with backyard shacks (FSB), and non-urban (NU).

The next step was to develop an automated settlement classification procedure, in collaboration with the Meraka Institute of the CSIR. An intuitive approach to identifying settlement type would be to look at the distribution of building shape and size over a small region, say, 100 m by 100 m. Building delineation methods could potentially be used to extract this information automatically from satellite imagery, but the small structure size and variability of construction materials used in the informal settlements make this approach unreliable. Instead of trying to identify individual structures, a set of texture features can be used to describe the appearance of the settlements.

Texture features describe the pattern of adjacent light and dark regions of an image – these features can be likened to the perceived 'roughness' of a surface. An informal settlement with many small, closely-spaced structures will appear to have a finer texture than a suburban area with larger buildings. These features can be extracted automatically from the satellite images, after which a classifier can be used to identify what settlement type we are looking at.

Researchers have developed a prototype of such an automated settlement mapping system – Figure 2 illustrates the output produced by the prototype. Current research is focused on the development of automated feature extraction algorithms that describe settlements more effectively.

The ultimate goal is to build a system that can identify changes in settlement patterns automatically over time using satellite images, thereby alerting officials of potentially significant changes on the ground.

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The Myrabo 'light-craft', being laser propelled with the bright plasma due to ablation clearly visible

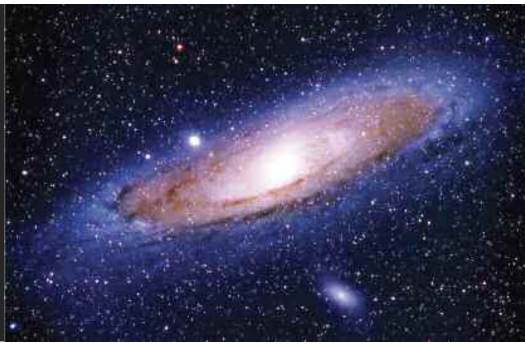
LASERS IN SPACE

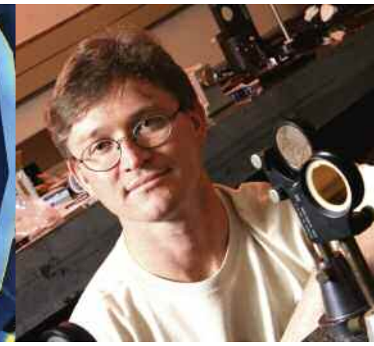
BY ANDREW FORBES AND MAX MICHAELIS

LASERS ARE UBIQUITOUS ON EARTH. HOWEVER, THEIR RANGE OF APPLICATIONS IS ONLY PARTLY PERCEIVED BY THE GENERAL PUBLIC, WHO ENCOUNTER THEM IN SUPERMARKET AND WAREHOUSE SCANNERS, IN CD PLAYERS, IN LECTURE ROOM POINTERS AND IN THE SURVEILLANCE AND MEDICAL ENVIRONMENTS. BUT THE GENERAL – AND MAYBE EVEN THE SCIENTIFIC – PUBLIC IS LIKELY UNAWARE OF THE FACT THAT LASERS ARE POISED TO INVADE OUTER SPACE, WHERE 'SCI-FI' HAS, OF COURSE, LONG PRECEDED THIS NOTION.

GETTING THERE: LASERS FOR SPACE?

Hybrid space propulsion has been a feature of most space missions. Only the very early rocket propulsion experiments like the V2, employed a single form of propulsion. By the late fifties, multi-staging was routine and the space shuttle employed three different kinds of fuel and rocket engines. During the development of chemical rockets, other forms of propulsion were being slowly tested, both theoretically and in practice. Yet the earliest type of non-chemical space propulsion to be thought of has never been attempted in space: laser and photon propulsion. The ideas of Eugen Saenger, Georgii Marx, Arthur Kantrowitz, Leik Myrabo, Claude Phipps and Robert Forward remain Earth-bound.





The very first proponent of photonic propulsion seems to have been Eugen Saenger, the great German rocket scientist, whose early designs were scaled up by several orders of magnitude. The idea is to shine a very powerful laser on a suitable target placed at the rear of a rocket. Photon-driven ablation then provides the thrust needed for propulsion. Saenger proposed photonic propulsion even before the invention of the laser. A small but growing number of scientists and engineers believe that laser propulsion offers an order-of-magnitude reduction in the cost of launching spacecraft and also provides the best method of solving the space debris problem. The USA, Germany and Japan are conducting laser propulsion proof-of-principle experiments. Myrabo's well-publicised 'lightcraft' programme has extended laser propulsion to the world outside the laboratory in the same way as recently developed laser micro-thrusters.

Even South Africa has embarked on some pioneering work on laser propulsion, with researchers from the University of KwaZulu-Natal and the CSIR having performed first-of-kind experiments in the laboratory.

LASERS IN SPACE

Lasers have a role to play not only in getting to space, but also for state-of-the-art experiments once there. After over half a century of research into gravity waves (GW), it seems that both ground-based and space-based interferometers are on the verge of detecting a variety of signals from near space to deep space. Solar oscillations, coalescing binary systems, massive black holes at the centre of our own Milky Way or of other galaxies and possibly the cosmological background may gradually come within GW range of the latest instruments, with neutron star binaries the most likely candidates.

> The Lagrangian points in space refer to the five points associated with a binary system (particularly Earth-Moon), where the combined gravitational forces are zero.

The reason that it has taken so long to detect anything is that the expected mirror displacements are fractions of an angstrom (a unit of length equal to one hundred-millionth (10^{-8}) of a centimetre). The sensitivity depends on the length of the arms of the interferometer and the number of passes down high vacuum tubes up to 4 km long. It is extremely difficult to effectively isolate ground-based interferometers from seismic events. This limits ground-based systems to signals above 1 Hz. It has since been realised that space-based interferometry would yield less ambiguous results and would extend the range of periods quite considerably. The resulting Laser Interferometer Space Array (LISA) project was born some 15 years ago and is expected to complement the earth-based results in the very near future.

Vertical projection of the 'lightcraft' using laser propulsion. The maximum height is similar in distance to the early flights of the Wright brothers

The full blown LISA will be one of the most costly and challenging laser space experiments ever, costing US$1 billion. It will consist of three spacecraft placed in an unusual circular configuration, such that the centre trails the Earth by 20° as seen from the sun and that the plane of the equilateral triangle that locates the spacecraft lies at 60° to the ecliptic.

The three arms are 5 000 000 km long! Each craft contains a Nd:YAG laser, detectors and telescopic equipment without which the laser beam divergence would destroy the signal. The heart of each satellite is a gold-platinum cube that acts as a reflector, but which floats freely in space (inside the spacecraft). The technology required to achieve zero coupling between the craft and the cube has taken a decade to develop and has never been fully implemented in space.

This is the purpose of LISA Pathfinder, due to be launched to the Lagrange L1 region before the end of 2008. LISA Pathfinder is a replica of the three LISA satellites intended to iron out any unexpected technical or physical problems that would be most difficult to solve at a great distance from earth. These 'lasers in space' are expected to make a telling contribution to our understanding of the early universe.

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RESEARCH AND DEVELOPMENT

MONITORING OF SOUTH AFRICA'S COASTLINES AND ESTUARIES

BY MELANIE VOGEL, ANDRE THERON, LAURIE BARWELL

THE USES OF SATELLITE IMAGERY IN ENVIRONMENTAL MONITORING ARE MANIFOLD. ONE APPLICATION THAT IS INCREASINGLY PREVALENT IN SOUTH AFRICA IS THE USE OF REMOTE SENSING TO MONITOR COASTAL ENVIRONMENTS. THIS FIELD OF RESEARCH HAS BEEN NEGLECTED IN THE PAST, SINCE ANALYSIS OF COASTAL PROCESSES REQUIRES COLLABORATION AND INTEGRATION OF BOTH OCEANOGRAPHIC AS WELL AS TERRESTRIAL SCIENTIFIC EXPERTISE TO ADDRESS PLANNING AND MANAGEMENT ISSUES IN THE COASTAL ZONE.

The National Committee on Coastal and Ocean Engineering of Australia (NCCOE, 2004) identified a number of potential major impacts on the coastal zone resulting from climate change, such as:

- Sea level rise and shoreline recession
- Inundation and displacement of wetlands and lowlands
- Increased coastal flooding by storms
- Salinity intrusion of estuaries and aquifers
- Altered tidal ranges, prisms and circulation in estuarine systems
- Changed sedimentation patterns
- Decreased light penetration
- Changed storm patterns, windiness, wave energy or direction impacting coastal stability and alignments.

THE TREND IS TO FOLLOW an interdisciplinary approach to finding solutions where complex coastal issues are addressed. The use of expertise from multiple scientific perspectives has become more common in recent years, mainly as a result of advancements in technology, coupled with the realisation that single discipline approaches are unlikely to assess the full complexity of the challenges to be addressed. The use of remote sensing has become a practical and feasible component in integrated coastal monitoring and management.

WHAT ARE THE CHALLENGES INHERENT TO COASTAL ZONES?

The coastal zone, where the influences of marine and terrestrial processes combine, is often in a highly dynamic state. High tides and storms hit the coasts, destroying beaches, coastal vegetation and often threatening human settlements and infrastructure placed within reach of natural processes.

In the Western Cape, heavy rainfalls frequently lead to inundations of river floodplains and low lands.

Negative impacts on natural landscapes and costly damage to infrastructure and agriculture can be overwhelming, while the impact on people is often equally devastating, ranging from fatalities and injuries to loss of livelihoods. Catastrophes like these are becoming more frequent as a consequence of climate change. In addition, global warming is expected to lead to a rise in sea level, coupled with a shore line recession of sandy coastal zones.

WHY IS COASTAL RESEARCH SO IMPORTANT?

Worldwide, coastlines are centres of high human population density. In South Africa, more than 30% of the population lives or works in coastal areas. The population density continues to increase, irrespective of future climatic forecasts. New developments, such as holiday resorts or harbours in exposed areas are expected to be more prone to damage through climate change impact.

Due to the anticipated impacts and the uncertainty of sea-level rise predictions, more comprehensive studies into the potential effects/impacts are required to protect coastal zones, prevent and manage disasters and develop plans for adapting to the changing environment and conditions.

HOW CAN SPACE TECHNOLOGY, SUCH AS SATELLITE IMAGERY, CONTRIBUTE TO ADDRESSING THESE ISSUES?

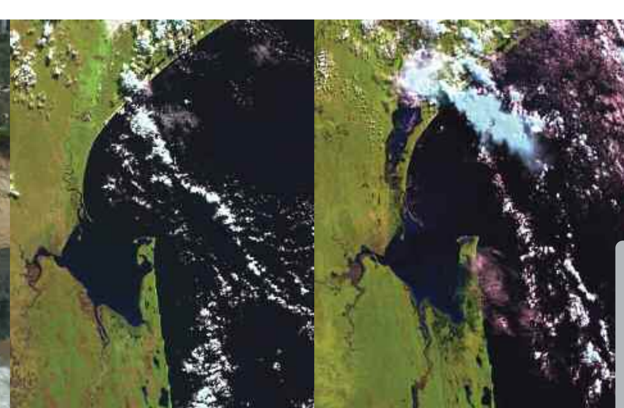
Satellite imagery is used to assess these issues on several levels. One of the most popular applications is the weather forecast, where information derived from satellite imagery on elements such as cloud coverage, humidity and wind speed and direction, and wave heights is used to model the weather for the next day or two (or even weeks and months). These calculations are the task of meteorological services and are not within the focus of CSIR work (except for wave climate forecasting).

The CSIR is involved in projects where remote sensing imagery is used to analyse the coast line by considering different perspectives. Firstly, analysis of topology and geology is important because more than 80% of the southern African coastline comprises sandy shores that are susceptible to large seasonal variability, high-energy wave regime and erosion. Elevation information is frequently derived from remote sensing imagery, such as stereoscopic multispectral data or radar imagery. Elevation data are used as information to model, for example, which coastal regions are potentially exposed to shoreline erosion or inundations. Infrastructure is detected and classified from satellite imagery to identify potential impacts. In combination with the environmental forecast scenarios, this information serves as a powerful tool for the development of land-use management plans and disaster response strategies.

The use of satellite imagery enables us to assess large regions homogenously within a short time, if necessary (as in the case of disaster management), on a daily basis. Moreover, the use of satellite imagery broadens the temporal dimension of any coastal monitoring approach. Even if coastal remote sensing is a more recent development in South Africa, suitable satellite imagery dating back to the early 1980s is available, while suitable aerial photos date back to the 1930s.

A 2005 CSIR project analysing time series of aerial photos revealed that the highly dynamic sedimentation and erosion equilibrium at First Beach, Port St Johns, was disturbed when the road along the Umzimvubu River mouth was protected against undercutting by flooding in the 1980s. As a result, First Beach was prone to irreversible erosion processes. This demonstrates that remote sensing data assist in proving (or disproving) statements such as "It used to be different…" and will help us learn lessons for the future by detecting and understanding processes from the past.

Damage to residential development inappropriately located in active littoral zone – a situation to be aggravated as a result of climate change



Maputo Bay (Mozambique) with the Limpopo River estuary. Left: Landsat 7 image from 5 July 1999. Right: The same area on 3 April 2000 with heavy inundations due to cyclone Eline that hit the coast in February

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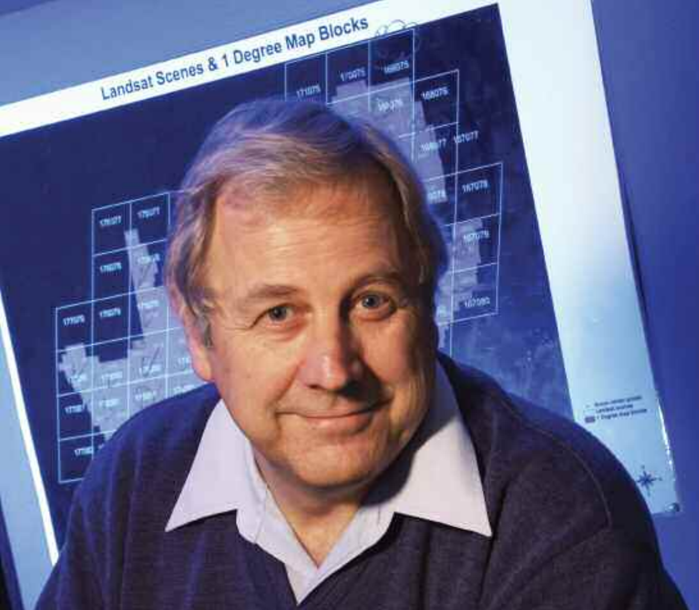

MAPPING THE SOUTHERN MOZAMBICAN COASTAL REGION

BY BRUNO MEYER

THE CSIR SATELLITE APPLICATIONS CENTRE HAS USED ITS EXPERTISE TO DELIVER A SEAMLESS MOSAIC IN NATURAL COLOUR FOR CENECARTA (NATIONAL REMOTE SENSING & CARTOGRAPHY CENTRE) OF MOZAMBIQUE. THE DESIGNATED AREA IS THE SOUTHERN PART OF THE COASTAL REGION IN MOZAMBIQUE.

This area of interest needed to be rendered as a seamless mosaic and in natural colour. The CSIR has previous experience in this type of product, based on the annual release of the SPOT 5 coverage over South Africa (now running in its third consecutive year).

SPOT 5 is the fifth satellite in the SPOT series, placed into orbit by an Ariane launcher. The SPOT system was designed by CNES in France and built in partnership with Astrium and Spot Image.

THE CHALLENGE

The major difference resided in the master sets used as reference. In South Africa, the Surveyor-General's production of geographical accurate maps is renowned and endeavours to improve the accuracy and extent of the master set is matched only by the demand for data from the ever-growing geographic community. South Africa has one third of its surface covered by maps at scales of 1:10 000 and better, particularly in urban areas.

In Mozambique, however, this luxury is limited to the main agglomerations while the rest of the country is in need of further improvement in both accuracy and extent. Satellite technology has the potential to enable improvement and delivery and SPOT 5 can address bigger areas at a more economical rate than the traditional aerial photographic approach.

The trade-off between the extent of coverage versus higher resolution translates mostly into different scales or accuracies. It requires a fine balance between affordability and the minimum requirements. This compromise is so much more delicate for cadastral applications where accuracy is paramount. (A cadastral map is a map showing the boundaries and ownership of land parcels.)

SPOT 5 offers coverage of 60 km² and a ground pixel size of 2,5 m. It has proven useful in mapping scales of up to 1:50 000. If prior accurate geographical reference exists, scales of 1:25 000 are possible, as is currently used in Europe.

THE SOLUTION

As sole reference, the Mozambican client offered the older version of 1:50 000 cadastral maps in digital form with better resolution maps over major cities. The request for more accurate global positioning system (GPS) points and the promise of an acquisition project to collect a minimum number of required ground points, was not feasible, as the extent of the area covered would have made this option too onerous.

The CSIR settled for a combination of Earthsat 15 m coverage of Landsat origin and a layer of Tracks for AFRICA, which, despite other limitations, offered better accuracies. For the orthorectification process, the SRTM 90 m digital elevation model (DEM) was used as the alternative to an inaccessible higher spatial and topographical accuracy elevation model.

The project was executed in four separate phases to enable four different deliverables:

Phase 1: Creation of panchromatic data set
As the major acquisitions could be stitched together, the referencing was eased by having an extended road

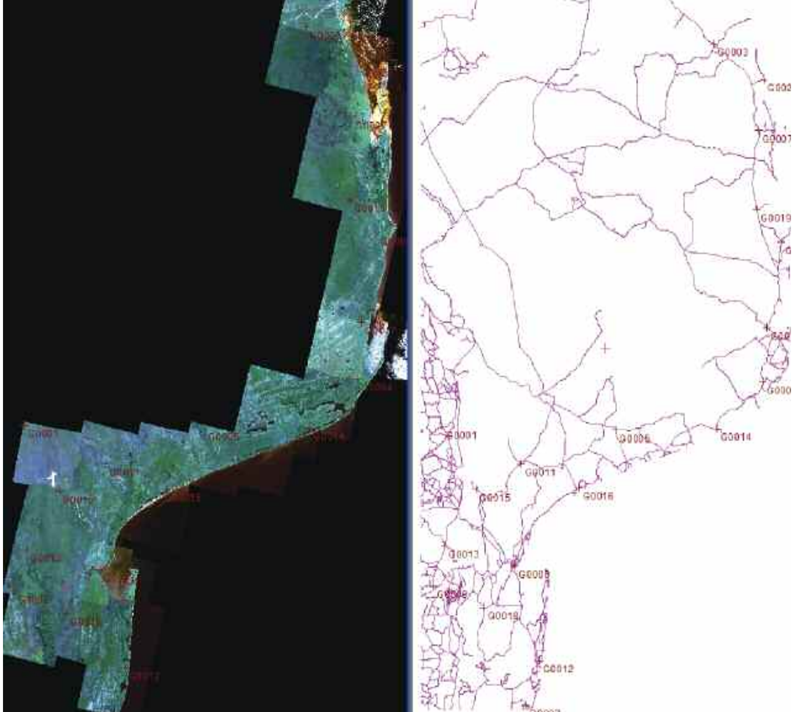

Figure1: Random points evenly spread

Orthorectification is a point-by-point correction of the scale and relief displacements normally resulting from variations in elevation between the image-gathering vehicle and the topography or documented information on the Earth's surface features.

network, and hence a better opportunity of point collection. The adjacent scenes had to be attached by keeping true to the roads as well as keeping the overlays to pixel match. This was the process adopted for most of the steps that followed, forcing a toggle of reference from raster to vector and *vice versa*.

The generation of a panchromatic (black-and-white) mosaic of all orthorectified scenes was generated to facilitate the processing of the multispectral data (which include light from frequencies beyond the visible light range).

Phase 2: Creation of colour multispectral set

A new project with 10 m resolution output was initiated. Wherever possible, stitched data were used again to improve the global RMS per image. RMS granularity measures the grain of an image and is interpreted as the square root (R) of the arithmetic mean (M) of the square (S), thus root mean square.

The panchromatic mosaic was used as a reference, facilitating automatisation of the orthorectification process. The advantage of automatic point generation was exploited whereby the PCI software generated points as input to the process. These points had to be manually verified, corrected and complemented to obtain an optimum result.

Phase 3: Creation of resolution merged set

The results from the panchromatic data were used in the resolution merge to create a 2,5 m multispectral imagery, maintaining the same band combination as the single 10 m data. After verification and minor adjustments, these data were then clipped back to the single scene to extend for packaging purposes and to conform to client requirements.

Phase 4: Creation of simulated natural colour set

The four spectral resolution-merged datasets were used as input to a pseudo natural dataset where additional pseudo blue and green bands were generated in order to simulate a natural colour rendering. This process required a colour-balancing calibre that was obtained from MODIS (moderate-resolution imaging spectroradiometer) data, which needed to be captured.

THE PRODUCTS

MODIS data covering Mozambique east was used to produce a natural reference set to which LUTs (lookup tables) of the SPOT 5 mosaic could be aligned. LUTs are used to calculate preview colours for the image before reproduction. An eight-day composite produced a natural image where red, green and blue bands further needed to be reprocessed and adjusted with predefined coefficients.

The colour rendering of the mosaic was mostly respected, matching the LUTs of the MODIS data after which the set of natural scenes was clipped out of the mosaic with the shape layer generated at the initial import.

The RMS errors were recorded per scene during triangulation as an indication of spatial accuracy during orthorectification and imbedded in the PCI .pix file. They were simultaneously exported and rendered in a .txt file, which was delivered along the remaining dataset. To get a better indication of the accuracy of the data, new ground control points, which have known ground coordinates, were collected over the final dataset (natural mosaic) and assessed against the input roads layer (see Figure 1).

These points were collected randomly and were statistically analysed to render the mean error, the standard deviation, sigma 1 and sigma 2 errors. The mean error is 12,95 m while the standard deviation is 9,12 m. The error at sigma 2 gives the certainty that, at a 95% confidence interval, all points within the image are closer than the given value to their true position.

The metadata directory contains the thumbnails of all SPOT 5 input data and is rendered as shape files to serve as reference in locating all the data. Shape files are popular geospatial vector data formats for geographic information systems software. The documentation directory contains the legal as well as the 'readme' file, which explains the numbering convention.

Despite hurdles, the resulting SPOT 5 dataset exceeded the client's requirements and will not only contribute towards updating the Mozambican cadastre, but will help in many additional applications, such as agriculture, land affairs and tourism. It was a valuable research exercise for the CSIR.

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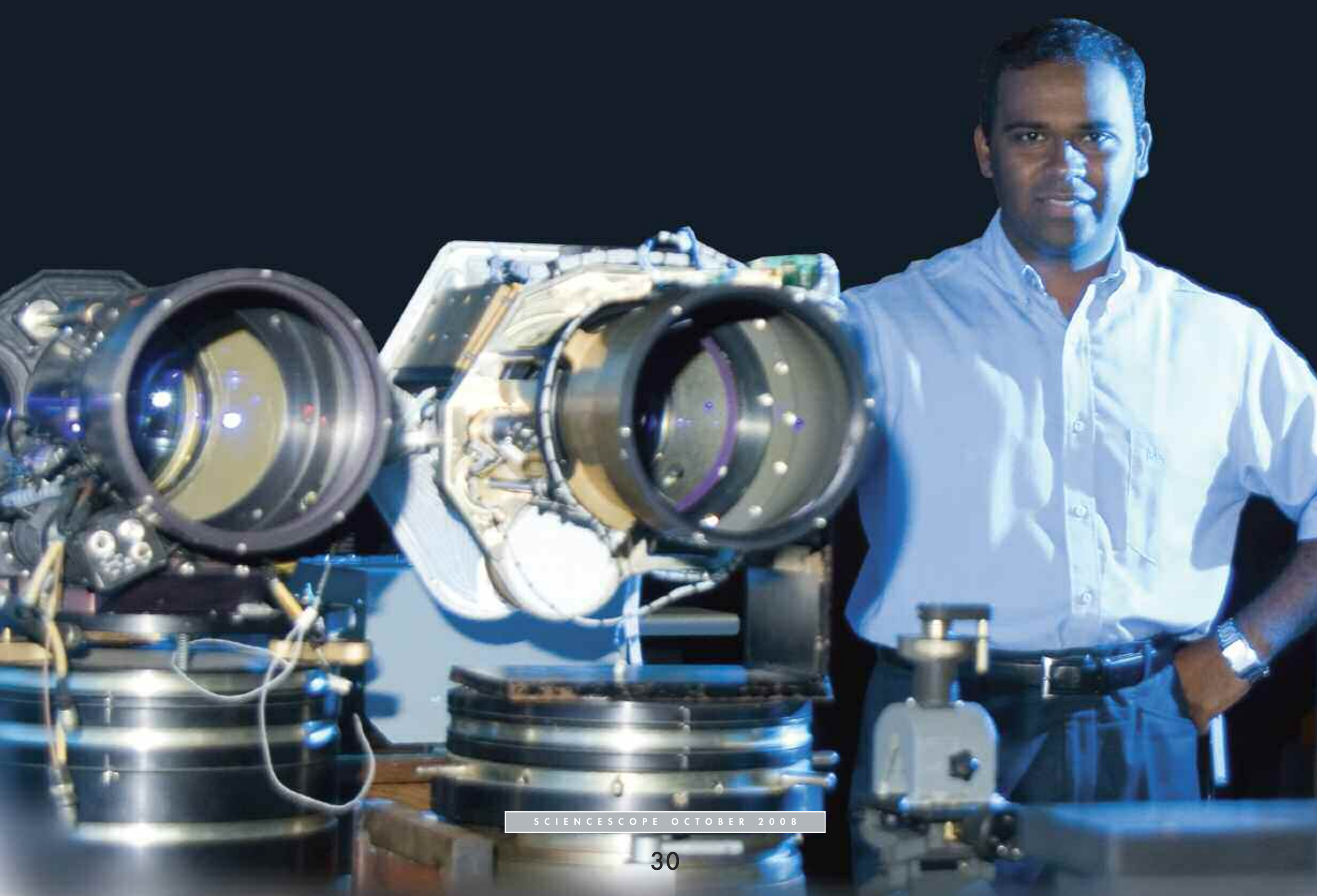
RESEARCH AND DEVELOPMENT

INSTRUMENT ENGINEERING

THE PURSUIT OF SPACE OPTICAL INSTRUMENT ENGINEERING IN SOUTH AFRICA

BY LEE ANNAMALAI

IN 2006, CABINET APPROVED THE MOTIVATION FOR THE ESTABLISHMENT OF A NATIONAL SPACE AGENCY FOR SOUTH AFRICA. IN ADDITION, CABINET ALSO APPROVED THE DEPARTMENT OF SCIENCE AND TECHNOLOGY TEN-YEAR INNOVATION PLAN OF WHICH 'SPACE SCIENCE AND TECHNOLOGY' IS LISTED AS ONE OF FIVE GRAND CHALLENGES.



THE SPACE STRATEGY clearly articulates the desire to obtain a slice of the small-to-medium satellite engineering global market. This objective is meant to be both a high technology knowledge-intensive economic stimulus and an ambitious challenge that would attract engineers and scientists into the field. The art of satellite and satellite instrument engineering is steeped in rigorous design, analysis and testing; it is pedantic about quality and focused attention on impeccable assembly and integration practices. These skills would provide an engineer with a solid foundation relevant to other engineering activities, which will result doubtlessly in future quality developments; though perhaps without the perceived prestige of space developments.

South Africa's reliance on space-related technology and services has been increasing steadily. Some of the major applications at present include communications, multi-media and television, weather forecasting, environmental monitoring, fire detection, mapping, navigation, security (vehicle and asset tracking and monitoring), and research and development on future service delivery applications using satellite data.

Currently, one of the most downloaded applications is Google Earth, a geographic information system-based application with a mixture of satellite images mosaicking the earth. This is used daily by thousands of South Africans for a host of applications ranging from planning of projects to observing where their homes are to orientating and route finding – or even more exotic applications such as embedded advertising and other web 2.0 content enhancements.

Unfortunately, the South African spend on these space-based applications results in a net outflow of funds from the country. Correcting this forms part of the complex value proposition that makes satellite engineering and the pursuit of space science and technology for South Africans one of the major grand challenges of the next decade.

The heart of space missions lies in the payload or instrument that is carried into space and to its final orbit by the satellite bus. Therefore, the most valuable intellectual property to achieve and offer competitively is a strategic independence in instrument engineering for space applications.

CSIR optronics sensor systems engineers are working hard to set up a South African centre of competence in space optical instruments, for small to medium satellites, in partnership with local industry, universities and institutes. They are leveraging the current strong military optical capabilities (design, integration, test and evaluation), and relationships with industry (optical, mechanical and detector manufacturing; satellite bus engineering, assembly and integration), to effect a compelling value proposition. The latter will look at the full technical spectrum of space optical instruments – design, engineering, assembly, integration and testing with associated human capital development.

Changing space technology trends are revealing an increased emphasis on small, quick and inexpensive missions that require small instrumentation payloads. Increased emphasis is placed on the infusion of new technology as well as the contribution of technology to national competitiveness. With this in mind, the objectives for the CSIR-DST proposed centre of competence in the field of space optical instruments are set to:

- Coordinate and lead local space optical instrument technology development using a technology cluster approach
- Focus on high priority remote earth observation and terrestrial *in situ* instrumentation for scientific and commercial applications
- Select development component technologies that clearly address the capabilities needed to enhance, enable or reduce the cost of scientific and commercial sensing missions and applications. Emphasis will be on enhancing the micro satellite niche market in which South Africa is already featuring
- Evaluate and utilise instrument technology capabilities of various role players – from industry, universities, institutional laboratories and selected international partnership arrangements.

The CSIR is geared to be a significant player in the knowledge economy of South Africa. Participation in prestigious and challenging technology programmes – by especially new talent – is crucial in increasing its impact. Space science and technology, with satellite engineering at its core, is one endeavour to realise these ambitions.

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ASSESSMENT OF VEGETATION STRUCTURE USING CUTTING-EDGE TECHNOLOGIES

BY WOLFGANG LÜCK

A CSIR STUDY aims to combine emerging remote sensing approaches to quantify surface roughness, biomass and surface types. These approaches consist of radar-interferometry and polarimetry as well as bidirectional reflectance distribution function (BRDF) characterisation. BRDF is a four-dimensional function that defines how light is reflected from an opaque surface.

Current passive land-based, remote-sensing applications focus on the classification of surface features based on their properties to absorb or reflect electromagnetic radiation (light) at different wavelengths with varying intensities over time (phenological analysis). These approaches give an indication of the feature cover type, such as urban areas, trees, forest, bush land, grassland, bare soil or crop type, found on a particular landmass. For many applications, this information is insufficient as a third-dimension – describing vegetation structure, vegetation height, ground roughness and building height – is required. Examples of such applications include the accurate description of tree-cover density over our savanna biome for grazing, bio-fuel and biomass assessment for agricultural and forestry crops to enable harvest forecasts.

Lidar (light detection and ranging) or airborne laser has been used for many years from airborne systems to extract this information in the third dimension. However, its high acquisition costs are a limiting factor.

An area in South Africa's Mpumalanga province – covering the southern Kruger National Park, Komatiepoort and the towns of Nelspruit, Sabie and Bushbuckridge – has been chosen for this study. The area contains natural savanna, commercial sugarcane fields, tropical fruit orchards, maize cultivation and commercial plantation forestry, as well as subsistence farming with all the above-mentioned commercial cultivation classes.

Figure 1: Cartosat 1 aft image over a wetland with varying reed height

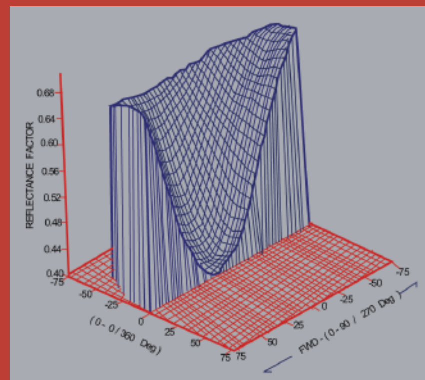

Figure 3: BRDF function reeds

Figure 2: Cartosat 1 BRDF image composite. Woody vegetation in dark blue, reeds at different heights in shades of lighter blue

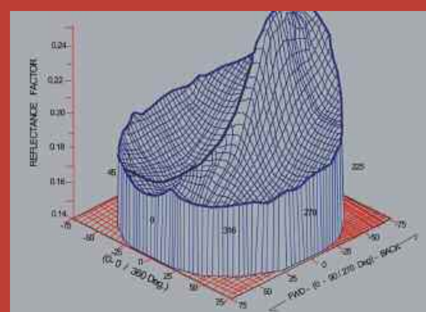

Figure 4: BRDF function of woody vegetation
Figures 3 and 4 illustrate the different BRDF functions from a range of viewing angles of reeds and woody vegetation at a constant solar incidence and azimuth angle for a wavelength of 0,826 mm

***Interferometry* is the science of combining complex radar imagery consisting of the phase and amplitude with minute differences in range at sub-wavelength scale for corresponding points in an image pair.**

UTILISING COMMERCIAL SAR DATA

Commercial space-borne synthetic aperture radar (SAR) systems providing data at a high resolution, such as ALOS-PalSAR, TerraSAR X and Radarsat 2, have recently been launched. They are an attractive image source to derive structural information through coherence layers generated from repeat pass interferometry and polarimetry.

PRINCIPLES OF SYNTHETIC APERTURE RADAR

A valuable parameter calculated during interferometric analysis is coherence. Coherence is the measure of correlation between image phases of an interferometric pair. It is high for surfaces with direct radar reflection and least for volume scatterers. Thus, the higher the biomass or biomass change, the lower the coherence values.

Coherence layers generated from permutations of analysing several interferometric pairs, together with the SAR intensity images, can thus provide a good description of vegetation structure and biomass with unique scattering characteristics.

A problematic aspect in the use of coherence as quantitative measure for vegetation structure and biomass is its susceptibility to varying ground conditions such as wind and rain. This requires a calibration of each coherence layer, making the automatic extraction of thematic information difficult.

This research focuses on ways to achieve an automatic calibration of coherence layers to infer the above-mentioned biophysical parameters. Polarimetry as an analytical technique may be applied to radar signals sent and received in various polarisation combinations. A signal may either be sent or received in vertical (V) or horizontal (H) polarisation, which leads to the following polarisation combinations of sent and received signals respectively: VV, VH, HV, HH.

Vertical signals provide a higher backscatter from vegetation, whereas horizontal signals are more susceptible to buildings and rugged ground features. Polarisation changes occur predominantly when signals bounce off a surface twice (double bounce) during its path from sensor to ground and back. In thick vegetation, a radar signal may be reflected from interfering obstacles, such as twigs, branches and leaves, several times before returning to the sensor. The resulting volume scattering, estimated from fully polarimetric datasets, is once again correlated to biomass and surface roughness. The challenge lies in the accurate characterisation and correlation of direct, double bounce and volume scattering to surface roughness, vegetation height and biomass for different wavelength and vegetation types.

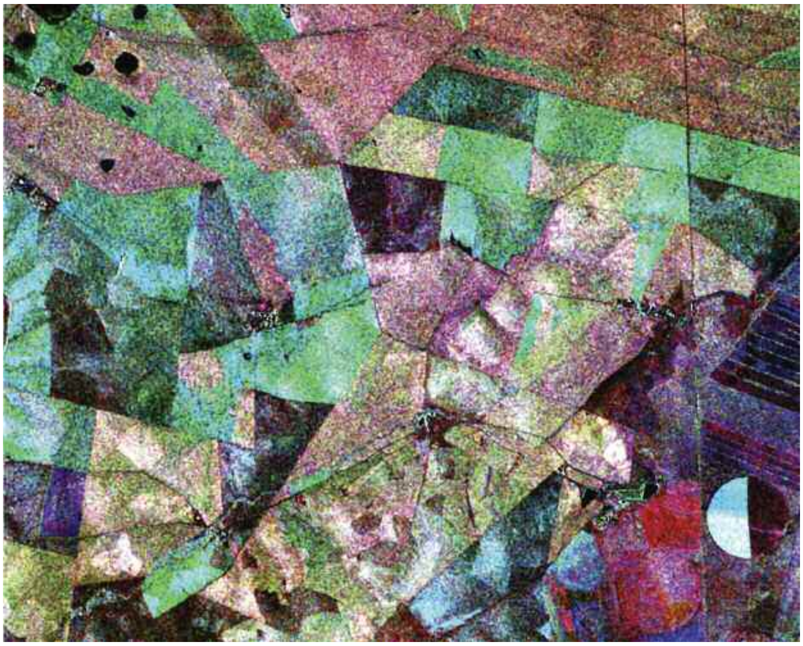

Figure 5: TerraSAR X stripmap image, multidate intensity composite over the Swartland (same area as below)

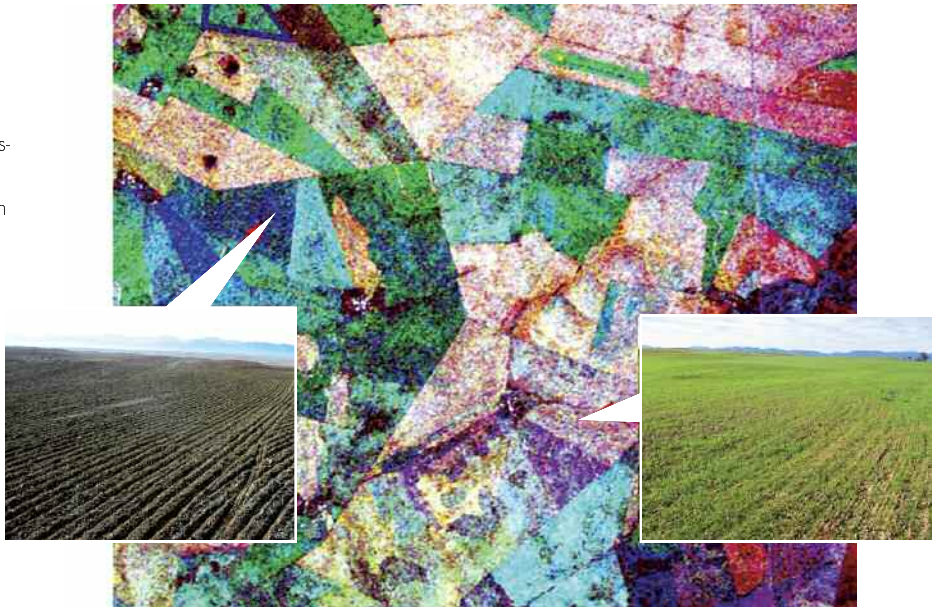

Figure 6: TerraSAR X stripmap image, multidate coherence composite illustrating structural differences between newly planted wheat (left) and recently germinated rye (right)

EVALUATING VARIATIONS IN LIGHT REFLECTION

Optical sensors imaging land masses at short intervals from different angles produce datasets that illustrate the BRDF phenomenon, where light reflects variably in different directions from an object. This variability is dependent on surface types, illumination angle, surface roughness and wavelength. The ability to describe this phenomenon sufficiently and converting BRDF values to physical parameters will enable the description of surface type, roughness and structure to an unprecedented level of detail from relatively cheap information sources.

Three approaches to illuminate inconsistencies and convert qualitative indices to quantitative estimations of vegetation structure and biomass have been combined. First experiments have shown promising results. Figures 1 and 2 on page 33 illustrate the BRDF phenomenon in a Cartosat 1 image with two sensors covering the same wavelength in the fore and aft mode. Structural differences of reed patches are difficult to differentiate within the gray image but are clearly differentiated in the BRDF composite of Figure 2.

During a preliminary study in the Swartland, Western Cape, TerraSAR X imagery was used to discriminate between wheat and barley cultivation. Although a multidate intensity composite, as illustrated in Figure 5, does not differentiate between the two crops, the multidate coherence composite (Figure 6), does so very well, with barley illustrated as yellow and wheat as greenish blue.

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COMBINING SATELLITE NAVIGATION AND SATELLITE COMMUNICATIONS

BY EUGENE AVENANT

DURING 2007 AND 2008 THE CSIR SATELLITE APPLICATIONS CENTRE UNDERTOOK A EUROPEAN COMMISSION FRAMEWORK PROGRAMME 6 PROJECT CALLED 'AFRICAN SATELLITE COMMUNICATIONS AND GALILEO APPLICATIONS' (AFSAGA), WITH EUROPEAN PARTNER THALES ALENIA SPACE. THE PURPOSE OF THIS PROJECT WAS TO ANALYSE THE POTENTIAL APPLICATIONS THAT COULD BE DERIVED THROUGH A COMBINATION OF GALILEO AND SATELLITE COMMUNICATIONS IN SOUTH AFRICA AND THE WHOLE SOUTHERN AFRICAN DEVELOPMENT COMMUNITY (SADC).

SOUTH AFRICA and its neighbouring countries combine urban centres, well equipped from a telecommunications perspective, with a large territory and a much lesser telecom infrastructure density. This makes satellite technology a definite contributor to national development. In addition, southern Africa is now undergoing an important transformation with rapid development. Galileo, combined with satellite applications, is clearly an enabler towards sustainable development in the SADC region.

APPLICATIONS

This project aimed first at raising awareness for such applications in SADC and ascertaining from user communities which applications have the most potential benefits.

Based on these application requirements, a regional project action plan for the removal of barriers to the implementation of such applications was devised. It looked at social, infrastructure and regulatory perspectives. Finally, the project disseminated these results to user communities and to key stakeholders in SADC.

RAISING AWARENESS

AFSAGA's goal was to raise awareness of satellite navigation and communications applications in southern Africa, while simultaneously providing a list of potential applications and the barriers to their development. A workshop in August 2007 at the Maropeng Centre, near Pretoria in South Africa, drew numerous interest groups, such as farming, water, forestry, timing systems, astronomy, space science, tracking, tourism, building, surveys and mapping, roads, civil aviation, earth observation, space systems, media, human capital development, safety and security, communications and health.

This workshop aimed to increase the awareness of the potential range of applications that can take advantage of EGNOS (European geostationary navigation overlay service) and Galileo, and in particular, those related to combined satellite telecommunications with satellite navigation throughout the SADC region. To establish the applications required by possible users and user communities, the technical capabilities of the EGNOS enhancement to current and future satellite positioning systems such as Galileo were disseminated to these groups.

STRUCTURING AND ACTION PLAN

The workshop and the discussion with regional key stakeholders highlighted many barriers to the development of the combined navigation and communications applications:

Regulation: different telecom regulations within and among the SADC countries curb the deployment of the applications (monopoly, duopoly, partially liberalised, fully liberalised).

Availability: some telecom infrastructures, such as the GSM network, have not yet been deployed everywhere in SADC because these are not economically viable.

Lack of knowledge and infrastructure: some early infrastructure is needed to trigger knowledge of what is feasible with this infrastructure.

Costs: the costs of end-user terminals required for wide implementation are still too high (both acquisition and operating costs).

Data sharing: the regulation for sharing information among the SADC countries can constrain the development of the applications.

The lack of infrastructure and *de facto* lack of knowledge are the main deterrents to the development of satellite navigation and satellite communications applications. By putting in place an early system allowing first navigation applications, awareness of this technology will increase and the market will develop itself. Consequently, regulation barriers to development will fall, as governments recognise real opportunities for their economy. Availability will automatically increase, as telecom providers see the business case for such a technological deployment. Thanks to economies of scale, the costs of navigation receivers – be it global positioning system (GPS)-Galileo receivers only or combined cellular-GPS-Galileo – will reach acceptable levels.

A number of applications were identified during the course of the project, starting at the workshop and continuing through the analysis part of the project. These opportunities are open to development by interested parties and range from local services to support for regional priorities:

- Tracking and informing organ transplant patients
- Improved experience of national parks
- 2010 FIFA World Cup security
- Taxi assistance
- Regulation of fisheries
- Automated census
- Road surface monitoring

A summary of the major challenges addressed by EGNOS/Galileo and combined communications, which was presented during that workshop, is detailed below:

ACCURACY OF POSITION
"WHERE AM I EXACTLY?"

RELIABILITY OF INFORMATION (INTEGRITY)
"AM I REALY THERE?"

TIME-TO-FIX THE LOCATION
"HOW LONG DOES IT TAKE TO GET MY LOCATION?"

INDOOR COVERAGE
"CAN I BE LOCATED IN THIS BUILDING?"

AVALAILABILITY OF INFORMATION
"DO I ALWAYS KNOW WHERE I AM?"

HYBRIDISATION OF LOCATION TECHNOLOGIES
"HOW TO COMPLEMENT SATNAV WITH COMMUNICATIONS TECHNOLOGIES?"

- Road accidents reduction by analysing vehicle and pedestrian behaviour
- Monitoring fenceless livestock
- Overloading control
- Ride matching/car sharing
- General tracking of animals or pets.

DISSEMINATION TO STAKEHOLDERS

The AFSAGA project concluded with a dissemination activity to deliver findings of the analysis to the regional key stakeholders. This was performed through one-to-one meetings during February 2008 in South Africa. These stakeholders were industry communities (road, safety and security, information and communications technology, asset tracking, map making, railway); civil aviation (Air Traffic Navigation Services), responsible for the efficient running of South Africa's air traffic control systems; and the South African government (departments of land affairs, trade and industry, and science and technology).

All these stakeholders recognised and acknowledged the benefits from the combined navigation and communications applications: market opportunity, business development, new regulations, job creation, economic growth and human capital development.

ROAD MAP TO THE DEVELOPMENT OF COMBINED APPLICATIONS

Once the South African Space Agency is operational, its navigation branch is set to supervise the deployment of any combined navigation and communications applications, ensuring the required infrastructure is deployed.

During the Africa-EU Summit held in December 2007 in Lisbon, Portugal, the summit adopted a Joint EU-Africa Strategy, which clearly explains that Africa and the EU should strengthen their cooperation in the fields of space-based technology, applications and sciences.

The AFSAGA project is entirely in line with this strategy and it appears that the proposed way forward is the development of integrated application projects (e.g. global monitoring for environment and security [GMES] + Galileo/EGNOS) in Africa.

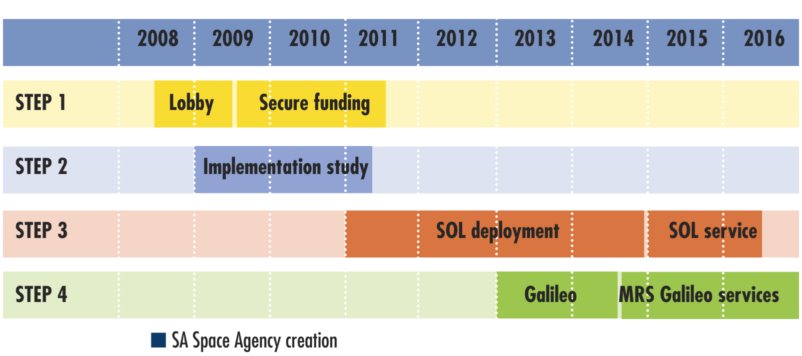
An action plan for the development of a satellite-based augmentation system (SBAS) for Africa is being proposed with South Africa and Nigeria as the primary contributors under the African Union banner. A roadmap is shown in the accompanying figure.

The steps for achieving this are seen as lobbying for the general acceptance of the project on a political level to all the stakeholders, primarily those in Africa, with Nigeria being a special case. (This country has already deployed satellite infrastructure and is actively working towards a regional solution.) Another step will be targeting the EC development funds set aside for African, Caribbean and Pacific countries as a major source of funding for a safety of life (SoL) SBAS system. Finally, a study of all the elements required for successful deployment of such a system is required, taking into account such issues as funding, project structuring and human capital development.

Having this system will unlock a number of new applications across Africa as well as contributing to the safety of air travel throughout Africa, a primary objective for this system.

Further information can be found on the project web page: **www.afsaga.org**.

(From left) Eugene Avenant, Dr Val Munsami (Department of Science and Technology), Phillip Roghi and Yannick Lefebvre (both from Thales Alenia Space) at the first AFSAGA workshop, held in August 2007



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DISASTER RISK MANAGEMENT THROUGH ICT

BY DR ANWAR VAHED AND PHILIP FROST

INTRODUCTION

Africa is generally regarded as the most vulnerable continent for natural disasters. In South Africa alone, approximately 40 000 people were affected by natural disasters over the past year, and more than 15 million over the past 10 years. It is generally accepted that climate change impacts significantly on the frequency and intensity of natural disasters. A number of global efforts have been initiated to manage and alleviate the consequences of disasters.

While a number of initiatives in South Africa have contributed to making historical information available to research and develop disaster response interventions, little attention has been given to providing access to space-based information for humanitarian and emergency response in a dynamic and near-real time context. Research scientists at the Meraka Institute of the CSIR are participating in two FP7 (European Union's seventh Framework Programme) programmes that address this very challenge.

USING INFORMATION FROM SATELLITE EARTH OBSERVATION TO MITIGATE DISASTERS

Coupled to the global campaign to address disaster risk, is the recognition that satellite earth observation can provide support for more effective responses to, and management of humanitarian and other crises. The United Nations Platform for Space-based Information for Disaster Management and Emergency Response (UN-SPIDER) is a UN programme created to "*ensure that all countries ... have access to and develop the capacity to use all types of space-based information to support the full disaster management cycle*". UN-SPIDER is a gateway to space information for disaster management support. It serves as a bridge to connect the disaster management and space communities and acts as facilitator of capacity-building and institutional strengthening for developing countries, in particular. These objectives would likewise be a sensible and appropriate outcome of a South African space programme.

Natural disasters are not constrained by national boundaries; clearly, an integrated and coordinated approach would constitute a more effective and complete solution. The significance of this aspect is evident in calls under FP7, for research and development of ICT, which integrate and leverage space-borne resources for environmental monitoring and disaster management. The FP7 ICT call for environmental management proposals specifically aims to integrate environmental monitoring and management systems through innovative ICT solutions. South Africa's strategic response is similarly to promote an integrated and coordinated system of disaster management.

FROM SPACE-BASED INFORMATION TO DISASTER INFORMATION: MANAGING NATURAL AND ENVIRONMENTAL RISKS IN AFRICA

The *Integrated Risk Management for Africa* (IRMA) project is aimed at developing and implementing an ICT platform to manage natural and environmental risks in Africa in a coordinated manner. The Meraka Institute's ICT for earth observation research group is contributing to the development of this platform through its experience in researching and developing sensor web technologies. The sensor web is an emerging technology concept that can leverage space-borne earth observation sensors to enhance the tempo of disaster response.

IRMA will deliver an open distributed platform that integrates resources, such as sensor networks, remotely sensed data and services, to provide information related to all phases of the disaster management cycle to end users. Specific operational scenarios, which range from vegetation fire and flooding to urban risks, will be implemented as reference for rapid risk management systems development. IRMA will facilitate the integration of local and global services such as the UN's *Relief Web* as well as future services such as Prevention Web.

AFFORDABLE ICT SOLUTIONS IN AFRICA TO REDUCE THE RISK OF NATURAL DISASTERS

Another research group at the Meraka Institute, the remote sensing research unit, forms part of FP7's Advancing ICT for DRM in Africa (AÏDA) project. The AÏDA project aims at acquiring and sharing knowledge about affordable ICT solutions in Africa to reduce the risk of natural disasters and improve the capacity to respond to disasters.

Many developing countries in Africa are exposed to serious natural disaster risks and their need for an adequate ICT infrastructure supporting disaster relief management (DRM) is high. Unfortunately, access to ICT knowledge and affordable ICT systems is often lacking.

The AÏDA project will assess the natural hazards, the vulnerability of the communities and the disaster risks in Africa, as well as the role of ICT-based systems in each hazard category. The project will explore affordable ICT trends and needs for the future in Africa. In this regard, the usefulness of GEONETCast (as an alerting system) will be tested.

GEONETCast, a Group on Earth Observation's initiative, is a near-real time, global network of satellite-based data dissemination systems designed to distribute space-based, airborne and *in situ* data, metadata and products to diverse communities. GEONETCast is a task in the GEO work plan and is led by EUMETSAT, the United States, China, and the World Meteorological Organization (WMO). Many GEO members and participating organisations contribute to this task.

To ensure the benefits of this research and development, it is planned that this information will be shared with all DRM stakeholders in Africa through workshops. Three showcases of operational African DRM systems will be prepared for demonstration at these workshops.

This will promote and support the take-up of this technology for use in other disasters and liaise with any new project in DRM with a significant involvement of African partners.

Another aim of the project is to prove that the GEONETCast concept works efficiently all over the globe and will pave the road for a widespread usage of GEONETCast in the future. AÏDA will test whether the existing GEONETCast infrastructure can be reused as a component of an alert or emergency system.

It is envisioned that the project will achieve a significant impact on a limited budget. This will be done by close co-operation with the African Association of Remote Sensing of the Environment, the EUMETSAT conferences, through the University Network for Disaster Risk Reduction in Africa (UNeDRA network), the UN Institute for Training and Research (UNITAR) Operational Satellite Applications Programme (UNOSAT) and the United Nations International Strategy for Disaster Reduction (UN/ISDR). This effort will support authorities in developing countries in setting up their national disaster action plans (as required by the Hyogo agreements) by offering knowledge about working ICT solutions and help them to manage their disaster risks better.

CSIR TEST CASE TO BENEFIT AFRICA DISASTER RISK MANAGEMENT SYSTEMS

AÏDA will set up a test case in South-Africa where the Forest Fire Association (FFA) in Nelspruit, South-Africa, will use the CSIR's wildfire-alarms within its operational activities to fight wildfires. If successful, many DRM systems can benefit from this technology.

The CSIR will develop a customised version of the Advanced Fire Information System (AFIS) for the FFA, located in Mpumalanga. The incident command centre at the Nelspruit air field is responsible for coordinating all vegetation fire fighting in Mpumalanga, Limpopo and Gauteng. Due to the high number of fires within these provinces during winter (in excess of 50 fires at any given time), preference needs to be given to fires with a higher probability of becoming disastrous.

The current system is based on phone calls from the public received by the command centre. With each report, a spotter plane is deployed to the scene to investigate the seriousness of the fire. Water-bomber planes and fire fighting helicopters will then be deployed to start fire suppression.

Currently, the internet connection to the Nelspruit FFA is very slow and unreliable, due to its remote location outside the city of Nelspruit. The AÏDA project will enable the distribution of fire-related products through GEONETCast to a dedicated fire information system for the Nelspruit FFA.

CONCLUSION

The use of space-based information resources and technologies has been proven useful in risk assessment, mitigation and preparedness phases of disaster management. As the global community learnt from the Asian Tsunami event of December 2004, space technologies have a central role to play in providing early warning to communities at risk. In order to incorporate the use of space technology-based solutions, there is a need to build national capacity and to develop solutions that can easily be customised and integrated into existing systems.

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DATA DEMOCRACY TO ENSURE MEANINGFUL PARTICIPATION IN EARTH OBSERVATION

BY DANIEL MATSAPOLA

THE COMMITTEE ON EARTH OBSERVATION SATELLITES (CEOS) IS A GLOBAL UMBRELLA BODY FOR CIVILIAN SPACE AGENCIES (BOTH FROM THE DEVELOPED AND DEVELOPING COUNTRIES) WITH A SPECIFIC EMPHASIS ON REMOTE SENSING. THE CSIR HAS BEEN AN ASSOCIATE MEMBER OF CEOS SINCE 1998 AND IT IS ONE OF THREE ORGANISATIONS ON THE AFRICAN CONTINENT PARTICIPATING IN CEOS ACTIVITIES.

The CSIR has adopted the theme of 'Data democracy for developing countries' as its special project during its one-year tenure as CEOS chair.

ACHIEVING SOCIAL BENEFITS THROUGH EARTH OBSERVATION

The CSIR holds the view that the sustainability of earth observation (EO) efforts will be determined by the end users. By broadening data access and capacity to these end users, CEOS will successfully advance the potential of earth observation in the relevant domains of societal benefit areas, as put forward by the Group on Earth Observation (GEO).

The data democracy theme relies on focused efforts along several fronts, with each front representing a pillar that constitutes the theme as presented in Figure 1. These pillars include unhindered access to EO information; open source software and open systems, such as freely-available image-processing software tools and image-processing systems; adequate dissemination models that reflect the realities of bandwidth in developing countries; and locally-initiated cross-border collaborative projects and intensive capacity building and training programmes.

EXPANDING EXISTING MODELS TO PROMOTE DATA DEMOCRACY

The CSIR recognises that specific models such as the one associated with CBERS-2B data, need to be expanded. The China-Brazil Earth Resources Satellite (CBERS) programme is a technological cooperation programme between Brazil and China, which develops and operates earth observation satellites. CBERS-2B is the second satellite launched by this programme in October 2003. Brazil, through its National Institute for Space Research (INPE), and China, through the Center for Resource Satellite Data and Applications (CRESDA), provide the necessary infrastructure for Africa-wide coverage. In this specific model, the local ground reception facilities commit, in return, to disseminate the data at no cost to countries within the region and beyond.

The data democracy theme is built on existing initiatives such as that of NASA and the National Imagery and Mapping Agency. That initiative led to free and unlimited access to specific global orthorectified Landsat archive data and has since had a massive impact in terms of broadening the user base of the EO data, particularly in developing countries.

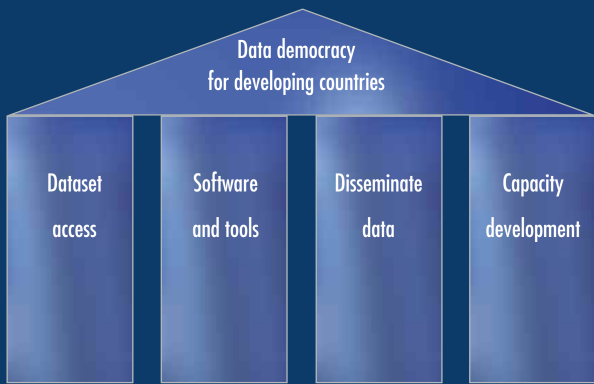
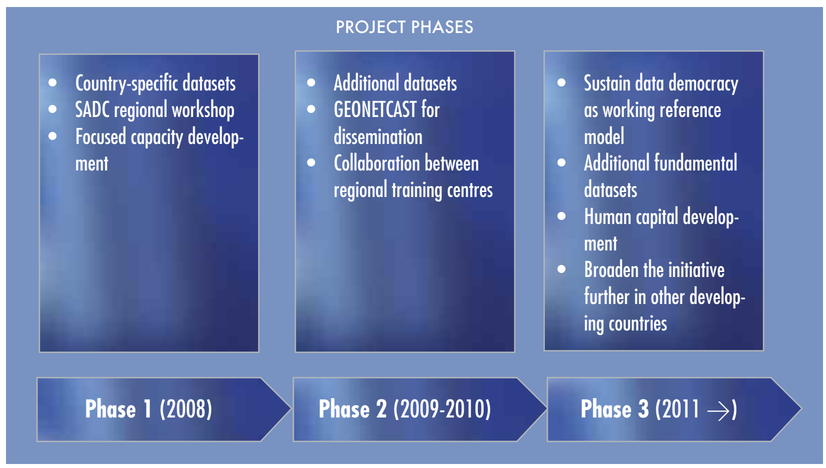


Figure 1: The four pillars of data democracy



The recent announcement by the United States Geological Survey that the entire Landsat archive will be freely available from February 2009, reflects another major contribution to a concept that is essentially complementary, if not synonymous, to data democracy, as espoused by the CSIR.

The CSIR has taken a short, medium and long-term view in its objective to realise the data democracy theme. Short term relates to the fundamental datasets and tools that will allow quick gains in EO-related activities of developing countries. It will include a country data package that will be delivered (generally on a courier basis) to regional country nodes. Connectivity still remains a constraint in many regional countries, and where available, is prohibitively expensive, even in South Africa. The data packages will include direct local access to:

- Africover (Food and Agriculture Organization of the United Nations's land cover) and Globcover (European Space Agency Medium Resolution Imaging Spectrometer's 300 m global land cover), to allow for monitoring of broad-scale land use change
- GeoCover (1980, 1990, 2000, 2006 Landsat Africa mosaics) for long-term multi-temporal change analysis
- Country coverage of vector infrastructure databases (digital atlas of the world)
- One regional workshop on the data democracy theme, as well as on the technical application of data democracy-related information.

The medium term relates to harnessing the data democracy theme by including additional datasets such as:

- CBERS-2B and the SAC-C satellite of the Comisión Nacional de Actividades Espaciales (CONAE), for the development of broad-scale fundamental base datasets for monitoring (e.g. urban change maps and land cover maps)
- The Shuttle Radar Topography Mission GTOPO 30, for the processing of CBERS-2B and other broad-scale EO information into ready-to-use image tiles
- RadarSAT Africa mosaic to complement broad-scale, optical EO data for monitoring, particularly in the equatorial regions where persistent cloud cover creates restrictions
- GEONETCast for data dissemination
- Effective collaboration between regional training centres.

Medium term also relates to access to tools such as LeoWorks, UN land cover classification system software and other similar software tools.

In the long term, it relates to sustaining the data democracy theme as a working and proven reference model in terms of enabling access to other fundamental EO data (e.g. Sentinel) and availing expertise and software such as accessing the Sentinel series. Human capital development will remain a strong feature of data democracy for many years to come.

Data democracy as a CEOS Chair 2008 special project is not only ambitious but also a very challenging initiative. The CSIR believes that in partnering with CEOS agency members, the ultimate objectives of CEOS and GEO can be realised to the benefit of both developing and developed countries.

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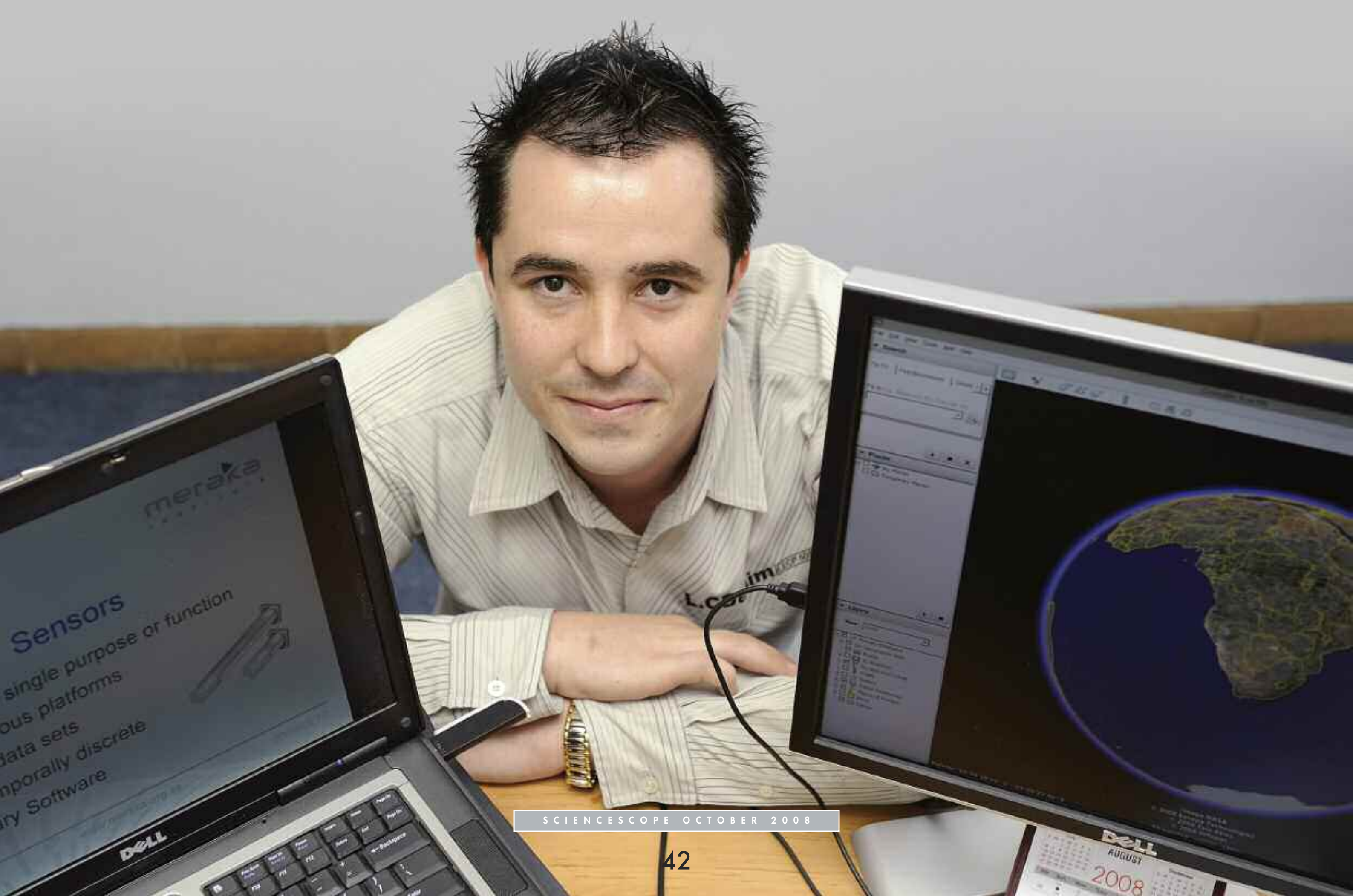
GEOSS

SENSOR WEB TECHNOLOGY UNDERPINS GEOSS OBJECTIVES

BY TERENCE VAN ZYL



THE GROUP ON EARTH OBSERVATION (GEO) CONSISTS OF 74 MEMBER COUNTRIES, 51 PARTICIPATING ORGANISATIONS AND FIVE OBSERVERS. CURRENTLY, SOUTH AFRICA IS A CO-CHAIR OF GEO (2008). THE MAIN FUNCTION OF GEO IS THE REALISATION OF A GLOBAL EARTH OBSERVATION SYSTEM OF SYSTEMS (GEOSS).

TO REALISE A GLOBAL earth observation system of systems, advances in informatics will need to be made to integrate a large number of heterogeneous earth observing systems and their disparate datasets, but also mechanisms to control these earth-observing systems. The Meraka Institute of the CSIR is involved in the sensor web, one area of informatics research that can benefit GEOSS.

Historically, organisations and countries have developed earth-observing systems in isolation. These systems have had very specific purposes, life times and clearly defined stakeholders. Current global events required a rethink in the policies and procedures surrounding how earth observation is done. Changes on a global scale in the form of urbanisation, climate change and disasters, to name but a few, do not confine themselves to the geo-political borders established by man.

Increasingly, it is becoming apparent that if these global or even local events are to be understood and mitigated, a more integrated view of our planet is required. The vision for GEOSS is to go beyond the current stove-pipe, short-sighted architectures of current earth-observing systems and facilitate an environment that enables the integration of all these systems and any future ones into a single macro earth-observing system of systems, namely GEOSS. The object of GEOSS is continual monitoring of the state and dynamics of the earth systems to increase knowledge and understanding. GEOSS will consist of a number of earth-observing components performing various tasks, including data exploration, processing, exchange and dissemination. It is envisioned that the components that make up GEOSS will be integrated, using standards and other interoperability arrangements.

A derived consensual view of the sensor web in the context of GEOSS is an 'open, coordinated observation infrastructure composed of a distributed collection of resources that can collectively behave as a single, autonomous, task-able, dynamically adaptive and reconfigurable observing system that provides raw and processed data, along with associated meta-data, *via* a set of standards-based interfaces'. Current thinking informing sensor web activities is to explore a service-oriented approach as a best practice, informed by a set of standard interface recommendations. The standards are currently being explored by the Open Geospatial Community.

The objectives of the sensor web are closely aligned with those of GEOSS. To achieve the goals of GEOSS, the sensor web community has begun to inform and participate actively in all facets of the GEOSS architecture. These include activities from the space arm of GEO, the Committee on Earth Observation Satellite (CEOS). In CEOS, an interest group has been set up to explore the sensor web and a GEO task has been centred around the same. All of these activities are led by South Africa.

One area in GEOSS that the sensor web concept is able to inform is that of the CEOS virtual constellations. A virtual constellation is 'a group of earth science satellites, each member of which is underwritten with its own unique experimental or operational purpose and agenda, but from which the collective set of platforms produces an integrated, first order environmental measurement'. By applying the lessons learnt through the sensor web, it is hoped that the virtual constellation can be achieved.

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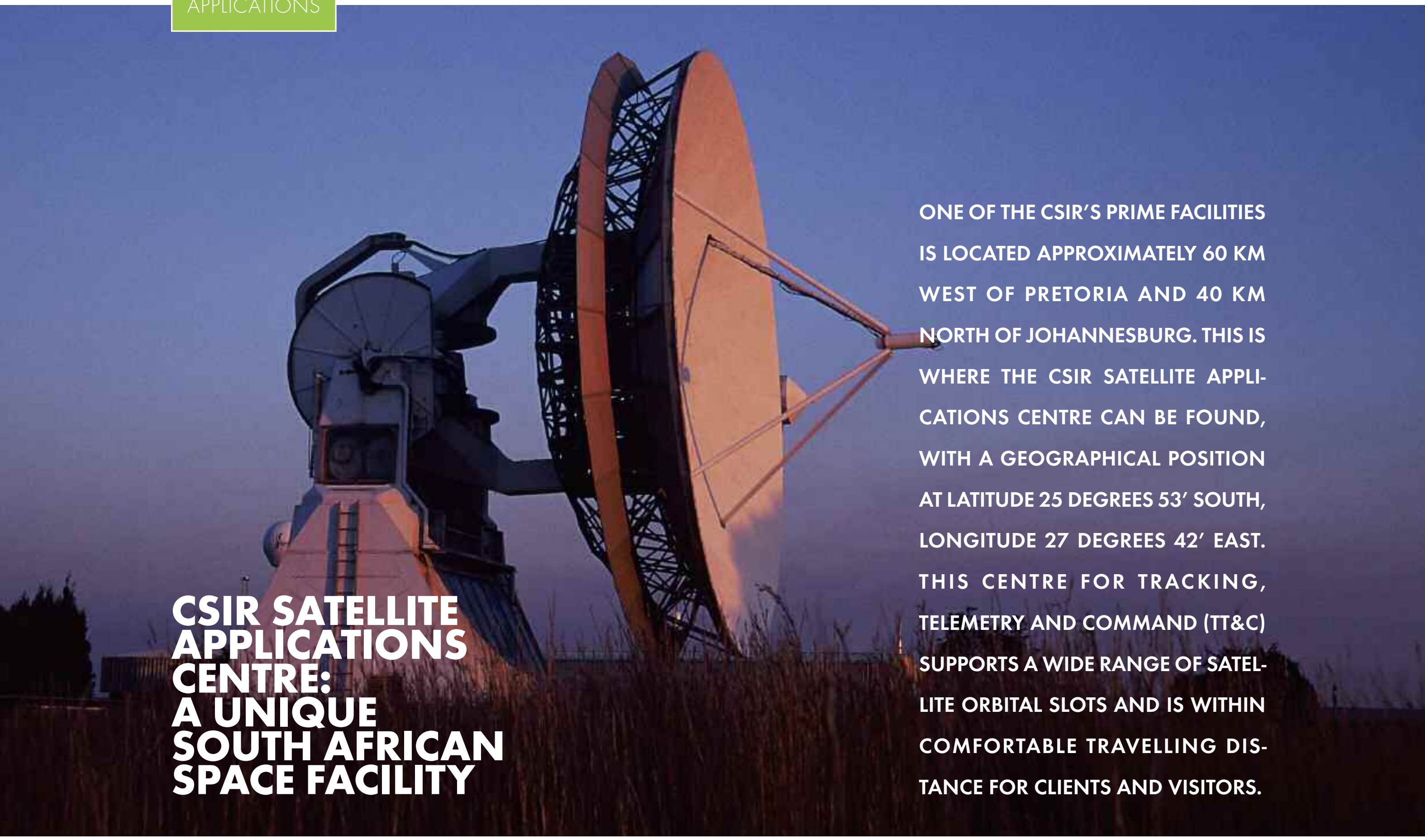

CSIR SATELLITE APPLICATIONS CENTRE: A UNIQUE SOUTH AFRICAN SPACE FACILITY

ONE OF THE CSIR'S PRIME FACILITIES IS LOCATED APPROXIMATELY 60 KM WEST OF PRETORIA AND 40 KM NORTH OF JOHANNESBURG. THIS IS WHERE THE CSIR SATELLITE APPLICATIONS CENTRE CAN BE FOUND, WITH A GEOGRAPHICAL POSITION AT LATITUDE 25 DEGREES 53' SOUTH, LONGITUDE 27 DEGREES 42' EAST. THIS CENTRE FOR TRACKING, TELEMETRY AND COMMAND (TT&C) SUPPORTS A WIDE RANGE OF SATELLITE ORBITAL SLOTS AND IS WITHIN COMFORTABLE TRAVELLING DISTANCE FOR CLIENTS AND VISITORS.

THREE DECADES OF TT&C

The CSIR has over 51 years of experience in the field of TT&C support, starting with NASA and its Jet Propulsion Laboratory (JPL) in 1957 and continuing with support for the French Space Agency (CNES), Boeing, Hughes, Intelsat, other national space agencies and aerospace companies.

It has offered satellite tracking and ground support since the late 1950s. From 1960 to 1975, it was operated by the CSIR as a station of NASA's Satellite Tracking and Data Acquisition Network (STADAN).

In 1980, the functions of the French CNES tracking station near Pretoria, which had been under CSIR management since 1974, were transferred to Hartebeesthoek and integrated with those of the (then) Satellite Remote Sensing Centre. Since then, the station has provided launch and orbital support for all CNES space missions within its coverage, including missions for other agencies supported by CNES.

Included in the latter category was the support for the NASA/DOD Clementine project, the IRS 1-C critical manoeuvres, the Lockheed Martin Launch Vehicle and the Ariane 5.

Since 1982 more than 230 successful launch support operations have been performed (mostly for Ariane 4), while TT&C support has been provided on a continuous basis for polar orbiting and geostationary satellites.

SOUND INFRASTRUCTURE RECEIVES NEW ADDITION

The Hartebeesthoek site operates around the clock throughout the year. Antenna systems located on 32 secured locations on 2 890 hectares are available in the L, S, C, X, Ku, DBS and Ka-bands. In several cases, antennas have been built and are being maintained for international clients, such as Boeing and Intelsat.

In October 1997, the CSIR won a competitive bid for a long-term contract with Hughes Space and Communications to provide transfer orbit devices in the Ku/DBS bands. The CSIR upgraded its facilities with a new 13,2 m Ku/DBS band antenna system and a 13,2 m Ka-band antenna system. This antenna was built in a record time of nine months from start to finish, as this was one of the prerequisites of the bid. This included the civil, mechanical, electrical and electronic systems. CSIR staff received on-the-job training for the first mission, namely Bonum. Many other antennas were installed to cover the full spectrum of TT&C frequencies.

The CSIR is currently installing new X-band capabilities dedicated to earth observation data reception. This new 7,3 m X-band antenna was delivered in September 2008 and will be operational by November 2008.

The specification on the new antenna is such that its performance will be greater

Tiaan Strydom is responsible for client liaison regarding TT&C services

than that of existing equipment on the site. It will be able to operate to lower elevation angles, extending the 'footprint' in which the CSIR can receive image telemetry data. The antenna also comes equipped with two new high data-rate demodulators required for the new generation high data-rate satellites.

This infrastructure upgrade will allow the CSIR to extend its offering to customers in terms of the sensors available for direct download. Given the increased sensor load, the number of antennas used for direct reception had to be increased to avoid data loss, due to satellite overpass conflicts.

The new antenna will be integrated into the existing South African Earth Observation Strategy infrastructure, forming part of the data supply chain from satellite to customer. The CSIR believes its investment will strengthen the earth observation capabilities in the country.

In addition to its existing and expanding infrastructure, the CSIR has access to other suitable sites and mobile support options in South Africa.

EXPERTS ON THE GROUND

CSIR staff at Hartebeesthoek provide technical support for all maintenance activities; operation support for all routine, launch and early orbit phases; and emergency and engineering support for all new projects, as well as system upgrade and modification projects.

INTERNATIONAL CONTEXT

The CSIR is an affiliate member of the Committee on Earth Observation Satellites and an observer agency of the Consultative Committee for Space Data Systems, participating in Panel 3. Involvement with these international organisations keeps it at the forefront of technology with issues related to protocols, cross-support and interoperability.

– Biffy van Rooyen

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UTILISING EXPERTISE AND PROMOTING EMPOWERMENT

The CSIR Satellite Applications Centre has partnered with five consultants with black economic empowerment status to assist in the execution of its services. This decision is in line with the CSIR's policy of contributing to the national objectives of broad-based black economic empowerment.

The five commercial suppliers assisted the CSIR in development of the dwelling inventory for its client, Eskom. The overall objective was to map the location of dwelling units off 2005/06 SPOT 2,5 m resolution satellite imagery. The purpose of the exercise was to quantify the existing electrification backlog, although it is anticipated that the point dataset will also be invaluable as a planning tool at the regional level.

The companies are Pulaworona, Imin Consulting, M&H Consulting, Umvoto and Create, the expertise and service offerings of which are in the broad earth sciences domain. Of the five companies, two are emerging businesses. Their participation in this specific project allowed them to establish themselves in the market.

Feedback from all consultants was overwhelmingly positive and all have indicated a desire to participate in phase 2 of the project.

– Biffy van Rooyen

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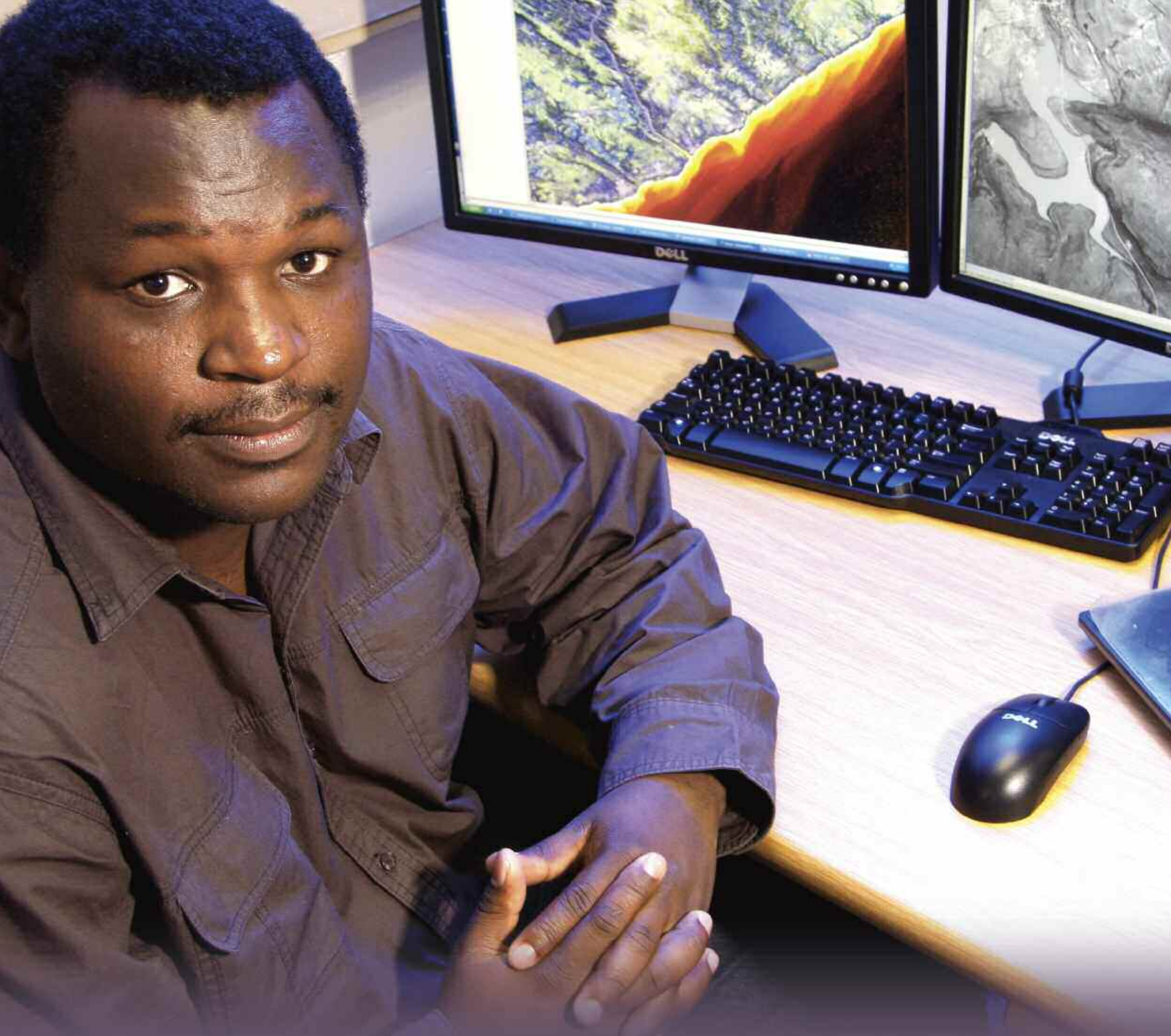

PROMOTING ENVIRONMENTAL SUSTAINABILITY THROUGH GIS AND REMOTE SENSING:

STUDYING THE KEISKAMMA CATCHMENT AREA

BY PAIDAMWOYO MHANGARA

THE ENVIRONMENTAL STATUS of the Keiskamma catchment area of South Africa's Eastern Cape province is of vital importance to the Keiskamma River and its associated estuary. Through the use of remote sensing and geographical information systems (GIS) studies, CSIR remote sensing specialists plan to model the land use and cover trends of this area as part of a PhD study. This, in turn, will inform land-use practices to ensure future sustainability.

The Keiskamma catchment area receives water from the Hogsback escarpment. Previous studies indicate high levels of environmental degradation in the Eastern Cape. Effective conservation measures are necessary to preserve indigenous flora and sustain the catchment area.

The study spans a 35-year period from 1972 to 2007, enabling the discerning of land cover trends over this time. Data in this study come from Landsat 1, 4, 5 and 7 for medium-resolution data, and pansharpened SPOT satellite images, which provide a higher spatial resolution of 2,5 m.

Classification of land use and land cover is done using an object-orientated classification algorithm, while changes in the different land use classes are quantified using post-classification comparison change detection. Land cover is defined as the materials that cover the surface of the earth, such as grass, forests and bare soil, while land use is determined by human activities taking place. The latter can be inferred from the former.

Scientists are interested not only in the rate of change over this period but also in a projection for the future. For this, a stochastic modelling technique is employed in remote sensing – entitled Markov cellular automata. Land use and land cover trajectories are crucial in providing us with a preview of what our tomorrow will look like. Catching an early glimpse of the future will certainly prepare us to put mitigation measures in place.

In addition, a robust and spatially explicit environmental model is used, applying the revised universal soil loss equation and a sedimentation model for a sediment budget analysis. According to scientists, this allows them to establish active zones where erosion by water is taking place, and other fundamental hot spots such as sedimentation environments.

While this advanced study will hone scientific skills and academic prowess, it also has valuable practical worth. As part of the research, baseline recommendations on the land use practices will be produced to ensure future sustainability. Research findings will have direct application to various government departments that are currently working towards reducing the impact of environmental degradation.

The findings will also provide further evidence of critical aspects of climate change and global warming. Through the integration of remote sensing and GIS, our understanding and assessment of the environment can be enhanced. Sustainability and improvement of many livelihoods depend on these critical inputs.

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USEFUL TERMINOLOGY

Medium versus high-resolution satellite data: Spatial resolution refers to the size of a pixel (the smallest piece of information in an image) in a raster image (a rectangular grid of pixels). Typically, pixels may correspond to square areas ranging in side length from 1 to 1 000 m. The resolution of Landsat imagery is 15 to 60 m; that of SPOT is 2,5 m.

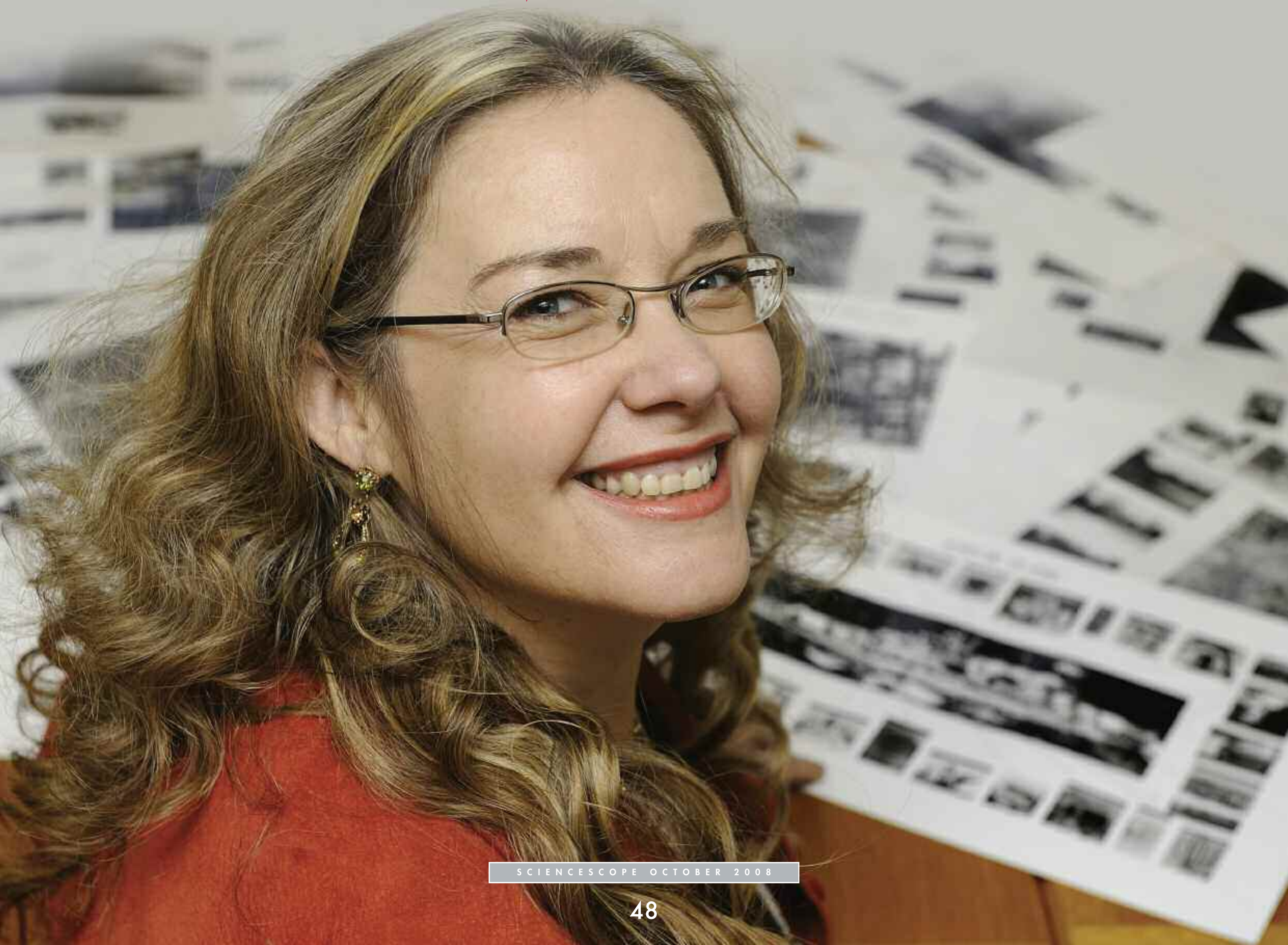
Pansharpened data: Pansharpening is a process of merging high-resolution panchromatic (single colour) and lower resolution multispectral imagery to create a single high-resolution colour image.

APPLICATIONS

REMOTE SENSING FOR GEOSPATIAL INTELLIGENCE PURPOSES

BY MINETTE LUBBE

THE QUEST FOR NATIONAL SECURITY IN A DYNAMIC WORLD DEMANDS THE ACCURATE PROCESSING OF INTELLIGENCE AND GEOGRAPHIC DATA INTO INFORMATION THAT CAN BE USED TO SUPPORT DECISIONS. WHILE IMAGERY INTELLIGENCE AND TEXT REPORTS ARE PRIMARY SOURCES OF DATA FOR MANY USERS, THIS INFORMATION IS INCOMPLETE UNLESS PRESENTED IN TERMS OF GEOSPATIAL RELATIONSHIPS. THE LOCATION, CONTEXT AND ACTIVITY OF A TARGET, AS WELL AS TERRAIN AND WEATHER CONSIDERATIONS, ARE KEY FACTORS THAT INFLUENCE THESE RELATIONSHIPS.



THE NEED FOR REMOTELY-SENSED data in military air, land and sea applications has grown exponentially. Weapon systems have become so advanced that they require information extracted from remotely-sensed data as input to be operational and/or effective. In the present era of precision munitions and weapon systems, virtual battlefields and unknown threats in denied terrain, remotely-sensed data are essential for the modern information soldier on the digitised battlefield.

Image analysts use imagery to find targets and assess collateral damage. Analysts derive map/grid coordinates from imagery for input into weapon systems, such as ground and naval artillery, and more recently for 'smart bombs' and precision munitions. Enemy fighting positions, ammunition depots and mobile targets are detected, tracked and reported to field commanders through the use of imagery. Terrain analysts/cartographers use imagery to create value-added products, such as cross-country mobility maps, situational maps, image maps of denied terrain and other products for inclusion in the intelligence preparation of the battlefield.

The CSIR's remote sensing specialists support the security services in exploiting the electromagnetic spectrum and sensor operating within these different wavelengths for geospatial intelligence purposes. Geospatial intelligence is a discipline that comprises the exploitation and analysis of imagery and geospatial information to describe, assess and visually depict physical features and geographically-referenced activities on Earth. Geospatial intelligence combines several disciplines such as mapping, charting, imagery analysis and imagery intelligence. Although normally associated with a military milieu, civilian and private sector organisations working in areas like telecommunications, transportation, public health and safety, and real estate are increasingly using geospatial intelligence to improve the quality of everyday life.

The military image (MI) analyst is able to detect, recognise and identify threat and friendly order of battle, as well as natural, man-made and cultural features recorded on land, aerial or space-based sensor imagery acquired from anywhere on the Earth's surface. The images of these objects, conditions and activities all have certain specific characteristics and signatures.

The process essentially consists of the identification of physical objects, such as military equipment, facilities and various activities, in the context of its surroundings. In essence, this equates to a series of information filtering decisions, progressing from the initial detection (perception) of the object's presence to the more difficult decisions implicit to recognition, identification and, in some cases, technical analysis. There is also the non-literal exploitation of metadata. This information can be derived in the form of technical, geospatial and intelligence information that is primarily derived by using advanced image-processing algorithms. Data fusion and other techniques are applied to discern the non-literal content in the imagery data.

Accurate and timely reporting of essential elements of information are ensured through the digital exploitation of multiple sources of imagery. Within the geospatial intelligence mission area, the computer becomes the photo-lab, exploitation light table and graphics shop, all in one system.

In addition to standard procedures, such as filter-sharpening, digitally adjusting the contrast and brightness and mensuration features, the geospatial intelligence mission area can accomplish other tasks unique to computer image processing. These functions include automatic change detection, feature extraction and the creation of geo-referenced intelligence databases capable of showing the spatial relationships between different intelligence targets.

At the tactical level, imagery-derived intelligence information is used to satisfy the immediate information needs, called essential elements of information. In developing this support, multiple sources of imagery are used to derive at the following general types of information:

- Location and types of enemy weapons and troop concentrations
- Location of enemy installations including missiles, artillery, stationary and mobile supply/POL (petroleum, oil and lubricants) and transhipment, communications and LOS (line of sight)
- Status/conditions of roads, bridges and other infrastructure
- Other information requirements from commanders.

At the strategic level, imagery-derived intelligence is used for:

- Command, control, communications, computers, intelligence, surveillance and reconnaissance
- Mission planning
- Situational awareness
- Precision engagement
- Military operations on urbanised terrain
- Defence mapping
- Training and simulation
- Terrain mobility
- Target reporting
- Operations other than war
- Environmental security and resource management.

Some of the frequently-used imagery-based products and geospatial intelligence products derived from imagery for military applications include target graphics, terrain mobility maps, battle damage assessment graphics, non-combatant evacuation operations graphics, obstacle overlays, combined obstacle overlays, gridded installation photomaps, gridded airfield photomaps, drop-zone overlays, helicopter landing-zone overlays, 3D data for simulation purposes, spacemaps, geospatial intelligence reports and military GIS products.

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APPLICATIONS

USING SPOT 5 DATA TO CLASSIFY LANDCOVER AND AGRICULTURAL BOUNDARIES

THE SOUTHWESTERN REGION OF THE WESTERN CAPE IS AN IMPORTANT AGRICULTURAL AND CONSERVATION AREA. KNOWN AS THE BREADBASKET OF SOUTH AFRICA, THIS WINTER RAINFALL AREA PRODUCES MUCH OF THE COUNTRY'S WHEAT REQUIREMENTS AND RATES AS A PRIME AGRICULTURAL REGION. AGRICULTURE EMPLOYS A SIZEABLE PERCENTAGE OF THE PROVINCE'S WORKFORCE. NOW THE SWARTLAND IS THE SUBJECT OF CSIR EARTH OBSERVATION STUDIES.

One of the CSIR Satellite Applications Centre's young and upcoming remote sensing specialists, Tammy Lotz, is part of a research team that has undertaken research to determine the sustainability of the Swartland grain production. The study area covers most of the winter grain production area under the jurisdiction of the Velddrif and part of the Wellington municipalities.

DEFINING THE LIMITS: SWARTLAND DEMARCATION OF AGRICULTURAL BOUNDARIES

The aim of the project has been to demonstrate that precision agricultural requirements can be met with remote sensing technologies. This demonstration is continuing throughout the winter growing season of May to October 2008.

Lotz's contribution to the project has been the classification of natural areas, agricultural land and transport features (such as roads and railway lines). For this, she has relied on SPOT 5 imagery.

SPOT 5 imagery is funded by a broad funding consortium comprising government departments and government agencies and utilities, and is made available free of charge by the CSIR to South African government departments or local researchers.

She explains the process of automatic classification, "Ecognition software is used, on which we set up rules or protocols. A protocol determines the values and sequence by which characteristics of objects or collections of pixels or dots on an image are classified. In this case, the protocol contains spectral, textural and shape values, which refer to visible light, surface cover and topography or surface shape.

"This protocol is run through every SPOT 5 image received since 2006 and objects are classified accordingly."

A 100% hit rate is unlikely, says Lotz. "Once I've looked at the classification and determined its accuracy, I can then go back and adjust the protocol to give better results."

The end result is well-illustrated by giving a different value for each classification, and by adding colour coding for ease of reference.

MORE TO THE PICTURE THAN MEETS THE EYE

The project will also deliver a range of other products: classification of ploughed fields before planting; crop type classification of barley and wheat, possibly also canola and sweet lupine, mapped at the beginning of the growing season; detection of growth response variations within fields, and biomass estimated towards the end of the growing season.

To make this possible, the CSIR is utilising two new technologies, TerraSAR X, a radar-imaging system that is weather-independent, and Rapid Eye, an optical high-resolution imaging system on a constellation of five satellites, designed specifically for the agricultural sector. SPOT 5 data help to analyse the spectral properties of an agricultural area and are thus useful for extracting information.

Lotz confirms, "We believe that these can be valuable for a range of parties, which includes local farmers; provincial and national agricultural departments; the fertiliser, seed, herbicide and pesticide industries; and the agricultural marketing arm (agricultural cooperatives). Other parties who can benefit are the insurance industry, soil scientists and land-use consultants."

– Biffy van Rooyen

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FRUIT OF THE VINE TO BENEFIT FROM TERROIR STUDIES

Planning of vineyard locations and layout in the Robertson wine district will receive a boost through the findings from postgraduate studies by Hadley Remas, a remote sensing specialist at the CSIR Satellite Applications Centre.

The topic of Remas's MSc thesis in remote sensing is 'The identification of natural terroir units in the Robertson wine district, using GIS and remote sensing'.

The term, terroir, is bandied about among wine lovers and is regarded as one of the factors that determines the quality of wines produced in a particular winegrowing region or on an estate.

Remas sheds light on this concept, "Natural terroir units or NTUs are land surfaces with homogeneous patterns of environmental parameters, such as topography, climate, geology and soil. These natural terroir units are then combined with viticultural practices, in the case of my study, and the expertise of wine farmers to produce a unique product over a specific time period."

The terroir concept has been identified by the South African Wine of Origin Scheme (SAWOS) to ensure the quality of wine products of South Africa's viticultural production areas. In the past, marketing strategies abused the names of outstanding agricultural regions to promote products, such as wine, meat, cheese and fruit. With the laws and legislation of SAWOS in place, it will become more and more difficult to register products under these names. Products of outstanding agricultural areas will no longer be open to abuse as is currently the case.

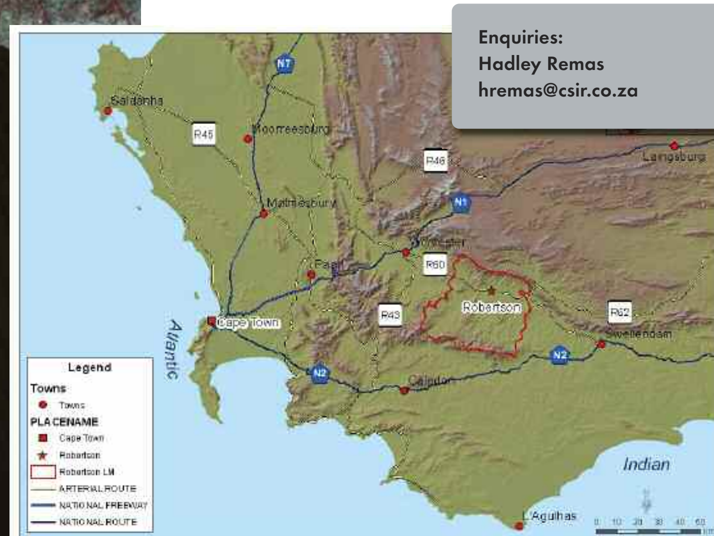
Remas's study area is the Robertson wine district in the southwestern Cape. It falls between the Langeberg and Riviersonderend mountain ranges (see map) on Route 62 and is approximately 160 km from Cape Town. Besides its white wine varieties, the area is also renowned for its lime-rich soils, roses, cannas and breeding of race horses.

Geographical information systems (GIS) and remote sensing are multidisciplinary tools to aid in the delimitation of natural terroir units. Remas explains, "Existing GIS data layers such as climate, soil, geology and digital elevation models will be used together with satellite imagery to identify terroirs. I will use satellite images to classify existing agricultural landscapes and identify other areas for future agriculture."

Satellite imagery to be used in this study will be SPOT 5 (2,5 m panchromatic and 5 m multispectral) and imagery from the ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer) on the Terra satellite platform, which has a spatial resolution of 15 m in the visible and near-infrared spectrum, 30 m in the shortwave infrared spectrum and 90 m in the thermal infrared spectrum.

Remas explains the practical value of his project, "The results can be of great value for planning purposes in the area. For example, Shiraz (a red grape) and Chardonnay (a white grape) will be cultivated on different land surfaces depending on the environmental parameters as defined by the results of this study."

– Biffy van Rooyen



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CAREERS

INSPIRING FUTURE SPACE SCIENTISTS AND ENGINEERS

SPACE SCIENCE AND TECHNOLOGY ARE AMONG THE MOST EXCITING AND INSPIRING DISCIPLINES, AND ARE GUARANTEED TO GRIP THE INTEREST AND THE IMAGINATION OF YOUNG AND OLD. FOR JOHNNY RIZOS AND TAMMY LOTZ OF THE CSIR SATELLITE APPLICATIONS CENTRE, WHOSE OFFICIAL DUTIES INCLUDE A ROUND OF PUBLIC SCIENCE EXHIBITIONS AND SHOWS, RECEIVING A POSITIVE RESPONSE FROM THEIR AUDIENCE EACH TIME IS ALL THEY NEED TO KEEP GOING.

Rizos, who works in the processing and production group at Hartebeesthoek, has participated in science exhibitions throughout South Africa over the past 11 years and has developed a good 'recipe' for engaging with his target audience. "I use a combination of a presentation with tangible objects to enliven my talks." This has been particularly useful in strengthening the understanding of how data reach the antennas and are then 'turned' into images. He confirms the strong interest by his audience in this topic, as he is bombarded with searching questions.

He estimates that he reaches about 2 000 to 3 000 learners at each exhibition; he attends about three each year. The highlight of 2008 was Scifest and National Science Week. "I find learners are keen to absorb new information and I take this opportunity to tell them about the work the CSIR does at its Hartebeesthoek ground station." He is in demand for public lectures and has been invited to speak at the University of Pretoria's Sci-Enza Centre and in Durban at the MTN Science

"Doing a BSc is not as hard as people think."

Centre during World Space Week. In addition, he receives young visitors (learners in Grade 10, 11 and 12) for site visits.

The nascent space industry in Africa does not yet compete with that of the US or Europe, and he is keen that learners should realise its potential. "Once the South African Space Agency is up and running, I predict that our public awareness programme will grow," he comments. He hopes to target the Western Cape, Mpumalanga, the Free State and Limpopo, where he has not yet had the opportunity to share his enthusiasm for space science and technology.

Lotz, a remote sensing specialist, assists Rizos and confirms the satisfaction of sharing with learners the excitement of space, "I enjoy speaking to people about what we do and telling them about career options related to geography. Doing a BSc is not as hard as people think!" *– Biffy van Rooyen*

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THE FOLLOWING PAGES FEATURE A SMALL SELECTION OF CAREERS RELATED TO SPACE SCIENCE AND TECHNOLOGY. THE CSIR WILL ALSO SOON HAVE A DVD AVAILABLE ABOUT SCIENCE AND TECHNOLOGY CAREERS IN FIELDS WHERE SKILLS ARE SCARCE. SOME OF THESE WILL FEATURE ON WWW.CSIR.CO.ZA.

DEVELOPMENT PLANNING SPECIALIST

Eric Makoni, a development planning specialist, conducts research on urban and regional planning. He holds an MSc in development planning from the School of Architecture and Planning, University of the Witwatersrand.

His interest in every day socio-spatial, economic and political processes shaping our cities, regions and politics, compelled him to take up a career in planning. He believes that being a development planner in South Africa provides one with the opportunity to influence the development trajectory of post-apartheid cities and regions.

Makoni is currently involved in the mapping and analysis of city and regional planning processes in South Africa. His research interests also span a range of disciplines, from city-regional planning, regional economic competitiveness, social inclusion and exclusion in planning as well as post-colonial readings and interpretations of cities in the global South.

Creating liveable, inclusive and sustainable cities and regions calls for a multidisciplinary approach to development planning. Development planners and those working within the built environment must take cognisance of the impact their decisions have on cities, regions and most importantly, the people who define the character of those places and spaces. Sustainable development planning is about enriching the lives of all people.

Makoni finds development planning one of the most dynamic and exciting careers of the 21st century. Having been identified at government level as one of the scarce skills, development planning is critical, particularly in a South African context where public and private institutions are challenged to create sustainable and inclusive cities and regions.

People with whom a development planner would work include architects, urban designers, environmental planning specialists, public policy-makers, project managers, regional scientists and economic geographers.

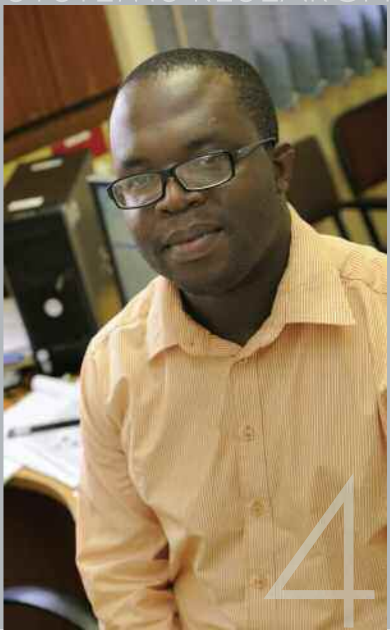
Related career fields that one could pursue with the same degree include strategic spatial planning, urban and regional planning research, regional and local development planning, public and planning policy formulation and analysis, environmental planning, and development planning consulting.

RESEARCH STATISTICIAN

Khuluse is interested in statistically modelling the relationship between climate and energy, specifically the effect of extreme weather on peak electricity demand.

GEO-SPATIAL ANALYST

OPTRONICS SENSOR SYSTEMS RESEARCHER



SIBUSISIWE (SIBU) KHULUSE is a research statistician working in the area of statistical modelling and research. She completed her BSc and BSc Honours degrees in applied mathematics and statistics, and mathematical statistics, respectively, at the University of KwaZulu-Natal. She is currently reading for an MSc at the University of the Witwatersrand.

Her choice in studying statistics was sparked by her enthusiasm and appreciation for mathematics. She regards statistics as being central to all disciplines as it involves measuring real-world phenomena objectively and subjecting these to mathematical analysis. Khuluse therefore saw an opportunity in statistics to apply her knowledge in projects across various disciplines and in the process, increasing her general knowledge. Her current research interests involve statistical modelling and analysis using methods from the theory of stochastic processes, time series, spatial statistics and extreme values. She is part of a team that uses these methods for assessing the risks of global climate change in regions of South Africa. Khuluse is interested in statistically modelling the relationship between climate and energy, specifically the effect of extreme weather on peak electricity demand.

To be a good statistician one has to keep abreast of methodological developments in the subject area as well as be aware of how these methods have been used in practice. One has to be careful about the methods, assumptions and the subsequent conclusions one makes, as the consequences of drawing inappropriate conclusions could be devastating.

With a degree in mathematical and applied statistics one can become an academic statistician; a quantitative analyst in financial institutions; a biostatistician or epidemiologist in biological and medical science; an applied statistician in consulting services; and an industrial statistician.

Typical areas of application may include agriculture, official statistics, engineering, chemistry, telecommunications, manufacturing, genetics, remote sensing, geographic information systems, life sciences, mining, geology, weather forecasting, image processing and data compression, and forensic statistics.

MINETTE LUBBE is a GIS and remote sensing specialist/ military geospatial analyst from the optronics sensor systems research group at the CSIR. Her expertise and unique contribution are in the field of natural resource and military applications of remote sensing data and the integration of remotely-sensed data into a GIS system. Her research interests lie in the fields of digital image processing, image exploitation, data mining, modelling and simulation, satellite systems and geomatics. Lubbe is registered with the South African Council for Professional and Technical Surveyors as a professional geo-information science practitioner. She serves on specialist work groups within the international bodies of GEOSS and CEOS, and is also a member of GISSA.

Related career types include geo-information science researcher, technician and specialists; remote sensing scientists, technicians and researchers; GIS technicians/specialists; geospatial image analyst; geospatial software developer; surveyor.

LUFUNO VHENGANI is an optronics sensor systems researcher. He joined the CSIR in September 2007. He is part of the remote sensing research group. Vhengani obtained a Diplôme d'Etudes Supérieures Spécialisées (DESS) in satellite remote sensing from the University of Pierre et Marie Curie (UPMC) in Paris and has a background in physics, statistics and mathematics.

METEOROLOGIST

5

"Any scientist or engineer can work in an HPC environment."

His research interests lie in the fields of remote sensing and geographic information systems. At the beginning of 2008 he was appointed to the Committee on Earth Observation Satellites (CEOS), an international body charged with coordinating civil space-borne missions for earth observation. He also obtained the following qualifications: BSc in physics, mathematics and statistics (University of Venda); BSc Honours in physics (University of Venda); and a postgraduate degree in electrical engineering (Stellenbosch University).

Related careers include image processing, programming and database management.

5

MARY-JANE KGATUKE is a meteorologist who works as a project leader at the Centre for High Performance Computing. She completed her MSc in meteorology through the University of Pretoria on internal rainfall variability using two different models. She is currently studying towards a PhD in meteorology and will make use of high performance computing (HPC) for modelling.

Related careers include computer engineering or electronic engineering.

COMPUTER SCIENTIST

6

TERENCE VAN ZYL is a computer scientist from the ICT4EO (information and communications technology for earth observation) research group. His expertise and unique contribution are scientific workflows in the sensor web. The sensor web is an advanced spatial data infrastructure that combines data from multiple sensors and sensor networks to provide feedback to users and sensors. The PhD that he is currently doing through the University of Johannesburg focuses on using a component-based self-adaptive software architecture to realise agent ontogeny. He serves on specialist work groups within the international bodies, GEOSS and CEOS.

Related careers include computer engineering, electronic engineering and mathematics.

PHYSICIST

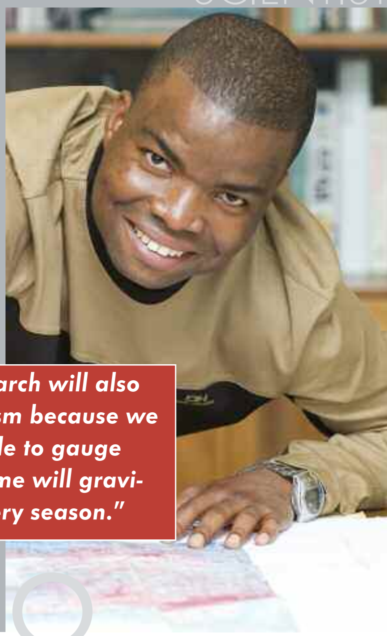
7

"Physics gives you the ability to probe nature's inner workings, and the thrill of discovering something new that no-one else in the world knows is a wonderful feeling."

DR ANDREW FORBES is a physicist specialising in mathematical optics. This research is unique in that it involves computing, mathematics, experiments and physics, but deals with lasers. Increasingly, a multidisciplinary background is becoming a sought-after skill in innovative research. Lasers dominate our modern world in a variety of forms ranging from tiny diode lasers in all CD and DVD players to large industrial lasers to cut and weld.

Forbes's love for astronomy and ever-enquiring mind attracted him to physics. He also excelled at mathematics during his schooling. He obtained his doctorate at the University of KwaZulu-Natal in 1998 and has authored or co-authored over 100 research papers and articles. He says, "Physics gives you the ability to probe nature's inner workings, and the thrill of discovering something new that no-one else in the world knows is a wonderful feeling."

GIS/RS SCIENTIST



"This research will also help tourism because we will be able to gauge where game will gravitate to every season."

8

ABEL SELAELO RAMOELO is a geographic information systems (GIS) and remote sensing (RS) scientist who admits that he fell in love with environmental sciences from an early age. His expertise includes advanced environmental spatial modelling and analysis, advanced satellite image analysis, interpretation of the images as well as detection of change and the classification thereof.

Ramoelo says his team's research projects include ecosystem modelling and monitoring, land degradation, water resources, coastal bio-dynamics, integrated land use planning and decision support systems.

"To do this we use image spectroscopy, hyper-structural approaches and medium to coarse scale multispectral information.

"My recent PhD research projects involve studying how change in natural elements like nitrogen and phosphorus in grass affects the distribution of animals – whether in communal grassland, game farms and agricultural areas. Animals naturally gravitate to these mineral-rich grazing areas."

Ramoelo is optimistic that in the future researchers will be able to advise farmers which part of their land is more conducive for grazing. "This research will also help tourism because we will be able to gauge where game will gravitate to every season," he says.

Ramoelo obtained his BSc and Honours degrees in environmental sciences at the University of Venda, graduating top of his class. He started his career at the CSIR in 2004, and spent the following 18 months at different European universities upon which he obtained his Master's degree.

"I was privileged to have studied at the University of Southampton in the UK, Lund University in Sweden, the Warsaw University in Poland, and the Dutch-based International Institute of Geographic Information Systems (GIS) and earth observation," he says.

Related careers include:
Geo-information science researcher, technician and specialists; remote sensing scientists, technicians and researchers; GIS technicians/specialists; natural resource ecologist/ecologists; natural resource managers.

REMOTE SENSING SPECIALIST

9

DR MELANIE VOGEL is a remote sensing specialist in the assessment of vegetation characteristics and dynamics. A senior scientist in the CSIR earth observation group, Vogel's research focuses on the use of satellite remote sensing techniques to monitor and assess vegetation and any other land cover.

"This enables us to understand and aid managing ecosystems and to ultimately conserve the susceptible biodiversity of our country," she explains. "We also make recommendations on sustainable management of natural resources such as water and soil."

By monitoring vegetation such as natural forests *via* satellite, Vogel and her team can predict how fauna and flora will change over time. "Conservation through careful land use is essential and an important step towards this goal is the scientific understanding of the ecosystems.

"While it is not necessary to study remote sensing (RS), independent sciences like botany, geography or informatics offer a wider scope in our field of research," she says. "I have a sound biological and ecological knowledge that allows me to understand the things and processes that I see on satellite imagery."

Vogel obtained her Master's degree in biology – with distinction – at the University of Bonn in Germany. Her focus areas were geobotany, soil sciences and ecology. After obtaining her PhD at the University of Würzburg in 2006, Vogel started her career at the CSIR.

Related subjects that give students a solid base in remote sensing include botany, geobotany, geography, geology, informatics and computer science.

OCEANOGRAPHER

10

REMOTE SENSING SPECIALIST

RADIO FREQUENCY ENGINEER

ELECTRONIC ENGINEERING TECHNICIAN

10

DR STEWART BERNARD, oceanographer at the CSIR marine remote sensing group in Stellenbosch, is one of only a small group in the country in the satellite oceanography field.

Bernard's primary study area is the colour of the ocean, which can be used to determine the growth of phytoplankton – tiny single celled plants that are the building blocks of most marine life. The group Bernard works with is also working to develop a South African capability to use other forms of marine remote sensing that include measurements of the temperature of the ocean with infrared sensors, and sea level height, winds, waves and currents using microwave sensors.

Bernard's particular interests include multi-scale and sensor marine observation, ocean colour, bio-optics and harmful algal bloom research.

"Water occupies 70% of the earth's surface and therefore exerts a considerable influence on climate: marine remote sensing is an important and cost-effective way of observing the ocean over decadal time scales to assist in monitoring climate change," Bernard notes. "The ocean is a difficult and expensive place to make measurements in – with satellites we can see how both the physical forces that control the system, such as wind, are changing, and how these changes affect ocean biology and carbon fluxes."

Bernard says his interest in water emanates from all the time he spent in the water as a boy, growing up near Lake Malawi.

He obtained his BSc in oceanography and physics at the University of Southampton in the United Kingdom, and both his Master's and PhD at the University of Cape Town.

Related subjects include: Marine research, operational oceanography, commercial oceanography, geo-spatial programming and analysis, marine environmental management and marine resource management.

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HADLEY REMAS is a remote sensing specialist. He is registered for an MSc at Stellenbosch University on the topic of 'The identification of natural terroir units in the Robertson wine district, using GIS and remote sensing'. He has always been interested in maps, computers and geography, and is part of the CSIR team working on South Africa's third natural colour, seamless mosaic dataset of South Africa, with a 2,5 m resolution. Remote sensing is regarded as a scarce skill and Hadley hopes to become a highly-respected researcher in this domain.

Related careers include: Ecologist, ecosystem researcher and geomatics specialist.

12

PIETER KOTZÉ is a radio frequency engineer. He has a Master's in electronic engineering from Stellenbosch University, which was based on the SunSAT micro-satellite project at Stellenbosch. He has always been fascinated by space and computers, and is currently overseeing a project to build a new X-band antenna at the CSIR's Hartebeesthoek site.

Related careers: Electronic engineering, electrical engineering and computer engineering.

13

YUNUS BHAYAT is an electronic engineering technician. He has a national diploma in electronic engineering and oversees operations in the tracking, telemetry and command environment at the CSIR's Hartebeesthoek site to provide services for international clients in the space industry. This involves tracking satellites and providing housekeeping operations to ensure the continuous operation of these satellites in orbit. He fell in love with space science when he started working at the CSIR at the age of 21 and enjoys working with international peers at ground stations throughout the world.

Related fields: Remote sensing, electronic engineering and industrial engineering.

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