> We had the sky up there, all speckled with stars, and we used to lay on our backs and look up at them, and discuss about whether they were made or only just happened...
>
> **- Mark Twain**

The **SAC** Story

Commemorating 50 Years

CSIR Satellite Applications Centre

1960 - 2010

CSIR

our future through science

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For more information about The SAC Story, visit the wiki page at www.sansa.org/spaceoperations thesacstory or contact **SANSA Space Operations.**

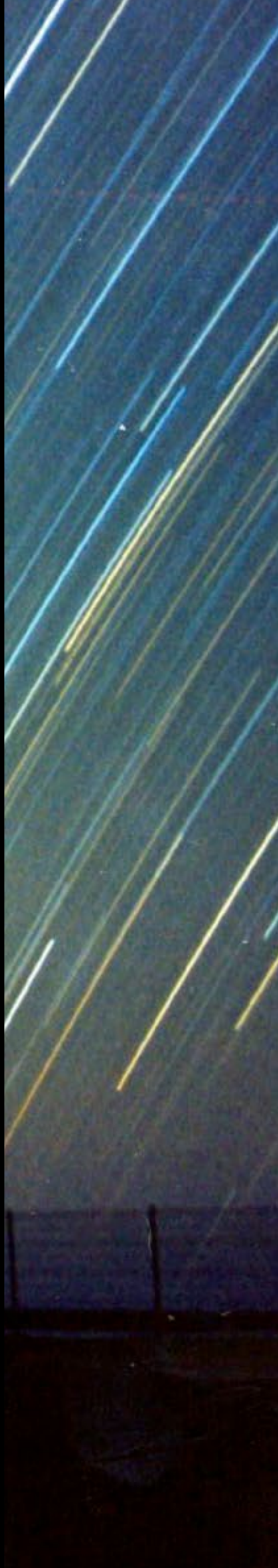

CSIR Satellite

Dedication

This commemorative book is dedicated to all the men and women who lived the story of the CSIR Satellite Applications Centre at Hartebeesthoek from 1960 to 2010, and to those who continue the journey.

This one's for you.

Contents



Acknowledgements

"In the vastness of space and immensity of time, it was my joy to momentarily share an epoch with the people of SAC."

- after Carl Sagan in Cosmos, with thanks

What started as a ten-month process in the minds of the writer and editorial committee for this book developed into a three-year marathon that wound along the highways of personal interviews and byways of documented information, a myriad of photographs and a solid stack of archived material.

The deeper we delved into the events that constitute the 50-year history of the CSIR Satellite Applications Centre, the greater the realisation of how much there is to know – far in excess of what could be captured in these pages. Yet, even in its immensity, the journey has been an enriching one, both in the time spent at Hartebeesthoek and with the people who lived the SAC story, as well as those who continue the journey.

The commemoration of their story in this book is not intended as a historic tome. Rather, it captures a timeline of remarkable events, challenges and achievements that started at the dawn of the world's space age. The storyline reflects the highlights of an unforgettable epoch, while the photographs illustrate the ways in which the men and women of SAC conquered an often unforgiving industry, as well as the lighter side of life at Hartebeesthoek.

The writing of this book was made possible by the contributions of many. Their memories, insights, anecdotes, knowledge and enthusiasm added authenticity to an inspiring tale. Without their participation, the story would have been far poorer in the telling.

I am deeply indebted to three SAC stalwarts: Willem Botha, Tasso Karantonis and Ike Marais. Your contributions gave life to the SAC story. I am most appreciative of your willingness to share your memories and experiences. The benefit I derived from your support cannot be expressed adequately in words. Thank you.

My heartfelt gratitude to Renier Balt, Piet van der Westhuizen† and Johan Helberg for time spent in personal interviews. Your assistance with the editing process and addition of many finer points added considerable value. And to Raoul Hodges, Tiaan Strydom and Eugene Avenant, thank you for taking the time to induct a novice into the complexity of space exploration. The value of your contributions and utmost patience in guiding this book to its conclusion cannot be overstated.

I am also immensely grateful to the SAC staff at Hartebeesthoek for willingly sharing the book journey and contributing content, photographs, statistics, logistics and moral support despite their own work commitments: Dr Corné Eloff, Johnny Rizos, Carole Liddy, Elsa de Beer, Chantelle Schoeman, Natascha Nieckau (for the editor's eye), Natalie Diemer, Betsie Snyman, Daphne Nsibande, Izak Ramela (dankie vir die blomme), Dennis Madavhu, Frikkie Meyer, Helmut Neumann, Yunus Bhayat, Dan Matsapola, Gladys Magagula, Paida Mangara, Rina Gremels, Farhad Hassim, Selaelo Mabeba, Piet Malan, Nokuthula Ntuli, Willem Voster

The more one delved into the 50-year history of the CSIR Satellite Applications Centre, the greater the impression of remarkable achievements ...

Bruno Meyer, Willem Voster and May Botha. Any and all others not mentioned here (not through wilful or careless omission) who supported the process in a myriad of different ways – *thank you.*

My thanks to Johan le Roux, Collette Vosloo, Alida Britz, Hilda van Rooyen and Biffy van Rooyen at the CSIR. I welcomed and appreciated your advice, guidance and support.

A special note of appreciation also to Maselo Rantho and the records team in the CSIR library for their assistance with access to the archived material. My appreciation for a well-catalogued archive knew no bounds.

Thanks too, to Vaneshree Maharaj at SANSA for supplying photographs and helping to edit the concluding remarks.

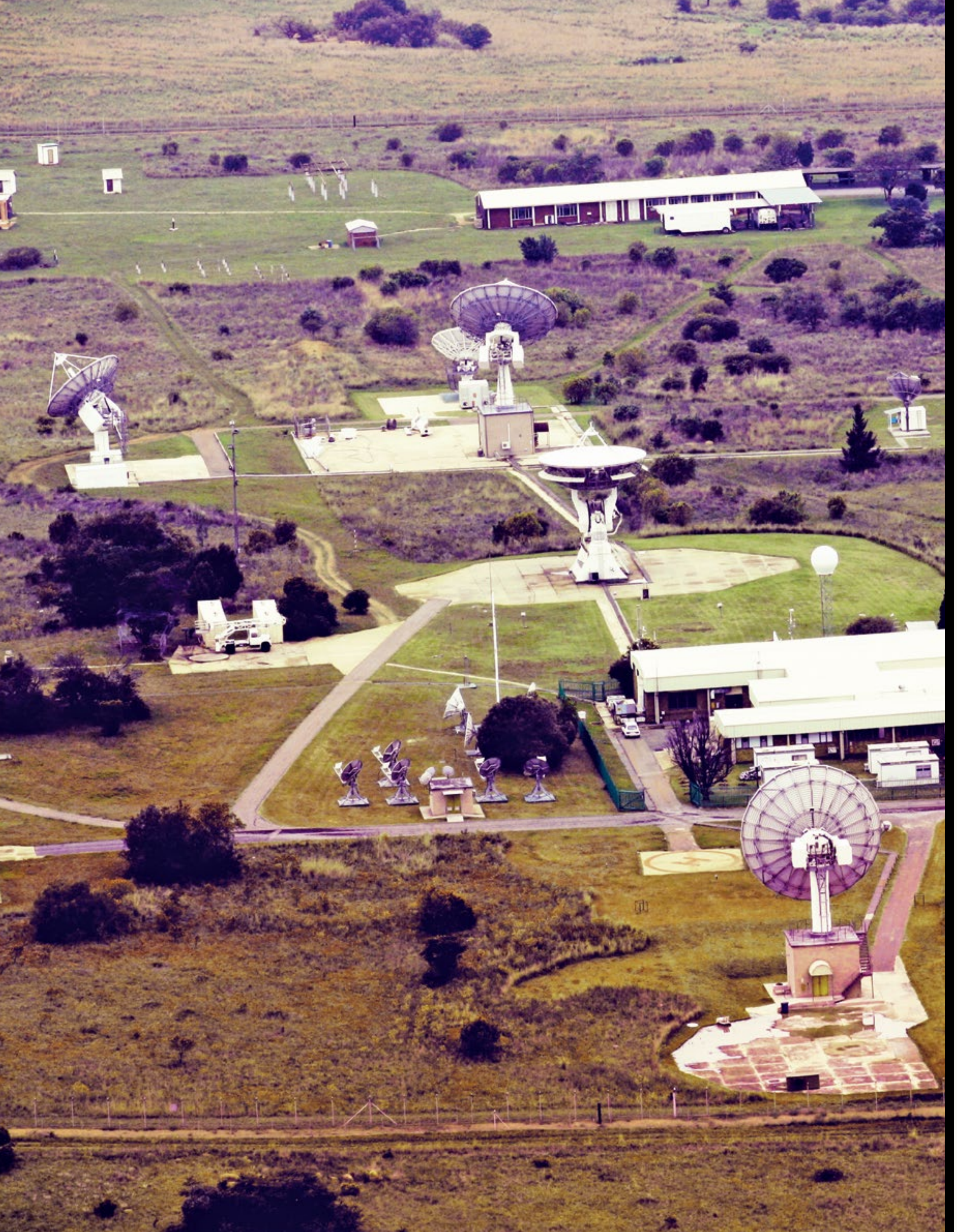
And to Leigh, my fellow conspirator in the creation of this book, your talent for design continues to amaze and your patience and skill throughout was a lifeline.

We hope that readers will be inspired to browse the wiki and add their own stories, so that the SAC story lives on in our memories.

Any inaccuracies, misinterpretations, inconsistencies or omissions from this book are the responsibility of the author.

It was a privilege, albeit briefly, to share the SAC journey.

Amie Hunter



Preface

"Books break the shackles of time, proof that humans can work magic."

- Sagan in Cosmos

When people talk about outer space as that 'final frontier' beyond the Earth's atmosphere, not many would associate South Africa with the early days of space exploration.

Few will know about the CSIR's role or the contributions made by the CSIR Satellite Applications Centre (SAC) to the development of satellite communications.

In fact, our footprint in space started more than five decades ago with the CSIR's involvement in two seminal events: the launch of the world's first artificial satellites, first by the Russians and shortly thereafter by the Americans.

CSIR engineers successfully tracked the Russian satellite and operated the locally-installed US tracking system to track the American satellites.

A story to tell

In the late 1950s, this laid the foundation for the country's early entry and continued active role in the global space community.

I feel privileged to have been part of the SAC team.

Over the years, our performance has been acknowledged repeatedly as world-class by major players in the international space arena – a performance made possible by the commitment of ordinary people achieving the extraordinary.

We look forward to continuing this work ethos under the South African National Space Agency (SANSA).

The idea of a commemorative book came about during a planning session for SAC's 50th anniversary celebration in 2010.

Our discussion was interspersed with stories and anecdotes as we remembered five eventful decades.

While the wry humour of hindsight tinged some memories, most elicited pride in what we had accomplished and we realised that the SAC story was one worth telling.

This commemorative book enables us to record and share the 'life and times' of SAC and the people at Hartebeesthoek with others.

Compiling material for the book made it clear that SAC's half-century of endeavour had generated far more information than we could include in a definitive number of pages.

The solution has been to extend the scope of the book with a wiki page on the SANSA website.

In this way The SAC Story - our story - can live on in our memories. Who knows, it may be the making of another book.

Tiaan Strydom
International Business Manager, 1997-2010

Foreword

This commemorative book is a tribute to the men and women of the CSIR Satellite Applications Centre and its predecessors at Hartebeesthoek between 1960 and 2010.

Their world-class performance has given South Africa a rich heritage in space exploration, a unique space infrastructure and a globally-recognised reputation for accuracy and reliability in an industry in which there is little margin for error.

Few things have fascinated man for such a long time, or generated such interest across borders, cultures and generations, as our exploration of space and its infinity.

In 1957, the unexpected launch of Sputnik-1 initiated the space age and resulted in five decades of human endeavour that has brought about astonishing scientific and technological achievements. At the time, a small group of young and singularly talented engineers at the CSIR's Telecommunications

In pursuit of a greater goal

Research Laboratory were already preparing to operate a satellite tracking station in Johannesburg.

The station was one in a global tracking system established to support America's intended launch of the world's first artificial satellite that would have given them prominence as the first nation in space. But it was the Russians who laid claim to that coveted title.

Within a week of the launch of the satellite, the CSIR team had devised a tracking system, solved the related orbital mechanics and calculated when Sputnik-1 would be visible over southern Africa.

Their predictions, which included the satellite's time of re-entry into the Earth's atmosphere, were the most accurate in the world and placed South Africa on the world map of space exploration.

Their ingenuity set the trajectory for the CSIR's, and in effect South Africa's, contributions to the space age during the next 50 years.

The CSIR Satellite Applications Centre gained global recognition for accuracy and reliability in space mission support and established exceptional capability in acquiring, processing and distributing Earth observation data. Hartebeesthoek currently houses a priceless archive with more than 150 terabytes of remote sensing data that date back to 1972.

Locally and throughout the African region, societies have benefited from the use of this data in a multitude of developmental and practical applications.

This includes the national 2.5 m natural colour seamless mosaic compiled from SPOT-5 imagery that is used for decisions in sectors such as food security, water and disaster management, agriculture, housing, utilities and infrastructure planning, mine rehabilitation, and national safety and security. Universities and research institutions can also access the data for academic and research purposes.

There is no doubt that, for the past half-century, the people at SAC have spearheaded the country's achievements in the peaceful investigation of outer space for the benefit of mankind.

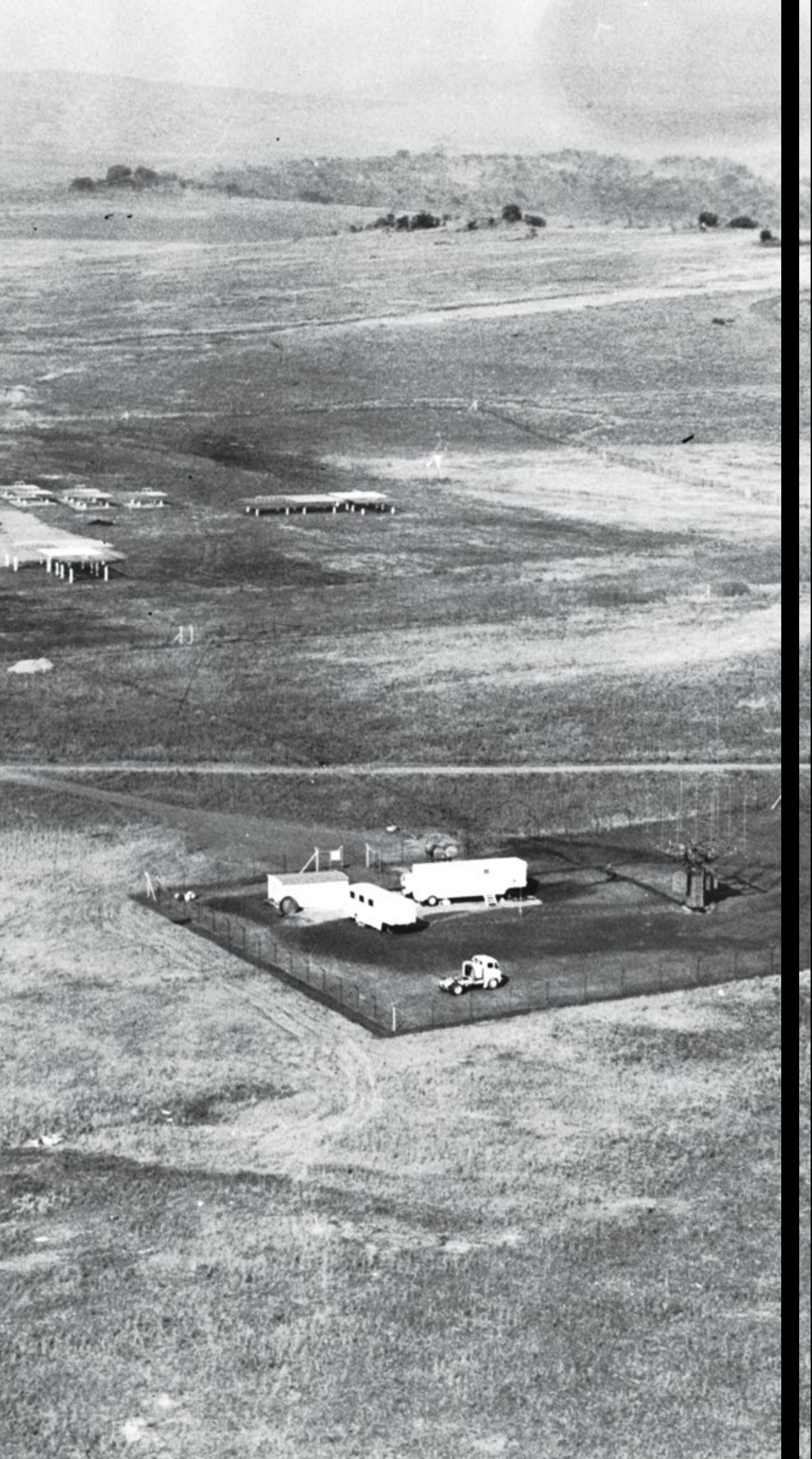
We salute them for a legacy that makes us proud and one that will serve South Africa for generations to come.

As the CSIR closed the chapter on the SAC era, a new future unfolded. Guided by the overarching principles of our National Space Policy, a National Space Strategy is in place to direct the country's participation in space exploration under the ambit of the South African National Space Agency (SANSA).

We wish the men and women of SAC well as they continue their endeavours under the SANSA banner. I have no doubt that a rewarding future beckons from the launch-pad of a commendable past.

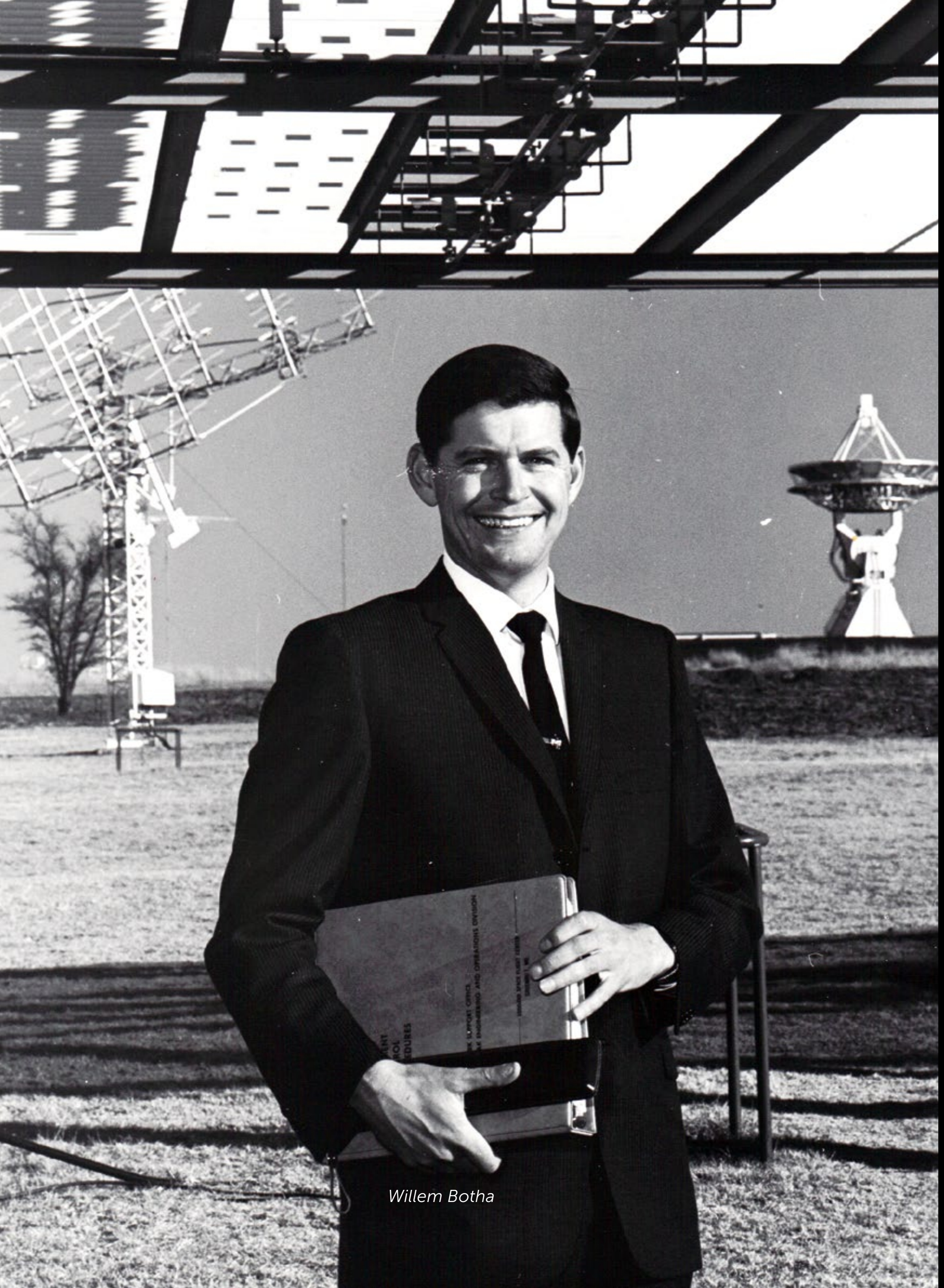
Dr Sibusiso Sibisi

CSIR President and CEO



Introduction

An enduring legacy



Willem Botha

During the first 50 years of South Africa's participation in the space age, it was not the cutting-edge, state-of-the-art equipment at Hartebeesthoek that made SAC such a reliable partner within the international space community – it was the people.

I welcomed the opportunity to write an introduction to the story about the CSIR's Satellite Application Centre (SAC). I had often thought that our role during the early years of space exploration could have been better recorded. The publication of this commemorative book has made it possible.

Remembering where it all began brought to mind a cascade of images, people and events that shaped, guided and directed an exceptional journey – one that I regard as integral to South Africa's role in exploring outer space to benefit the future existence of humanity.

SEPT/OCT 1963

EARLY NOVEMBER 1963

EARLY DEC 1963

Installing the 12 m hydraulically-driven X/Y parabolic antenna.

A REVOLUTION IN GLOBAL COMMUNICATIONS

Man's ingenuity has changed the way in which we live and perhaps never more so than during the first 50 years of the 'space age'[1]. It certainly played a key role during World War II, although mostly with devastating and destructive effect.

After the War, ideological differences between the United States and the Soviet Union resulted in a 'cold war'[2] that lasted for nearly 50 years. When Russia unexpectedly launched the world's first artificial satellite in October 1957 and scuppered America's plans to lead the field in space exploration, the rivalry escalated into a race for technological supremacy.

It is well-known that Sputnik-1 triggered the 'space race'[3]. Perhaps lesser known is that it hastened the creation of America's National Aeronautics and Space Administration (NASA) to "pioneer the future in space exploration, scientific discovery and aeronautics research"[4]. It also actuated an era of unprecedented technological progress worldwide. In fact, the rivalry was more about mastering complex technologies and manufacturing techniques than about winning a race.

Satellite technology has revolutionised global communications and location-based applications. Today, real-time audio, video and data communications are a reality for most of us. We use a global positioning system (GPS) to find any destination on the planet, while sensors on polar and geostationary meteorological satellites deliver data to ground-based meteorologists to forecast the weather and give early warnings of severe weather conditions.

This progress is truly astounding, given that the first transatlantic undersea telephone cable with 30 telephone circuits was commissioned only in September 1956. In a half-century, man has learnt more about Earth and the Universe from satellites than in all previously-known history. I regard myself as fortunate to have been part of that journey.

The SAC story is about the footprint of a relatively small group of people at Hartebeesthoek during the world's first 50 years of space exploration.

THE EARLY YEARS

The foresight of Dr Frank Hewitt[†5], then Director of the CSIR's Telecommunications Research Laboratory[6] (TRL), opened the door for South Africa's early participation in the space age. Keenly aware of the communications potential of satellites, he obtained funding to operate a Minitrack[7] system locally under the auspices of the US Naval Research Laboratory (NRL).

In the mid-1950s, preparations were underway for the International Geophysical Year (1957-58 IGY). America intended to use her Project Vanguard contribution to the IGY to launch the first artificial satellite into Earth's orbit, using a Vanguard rocket as the launch vehicle. Responsible for the project, the NRL had designed the Minitrack system to track the satellite.

We installed the system at the South African Railway College in Esselen Park near Johannesburg in 1957 and commissioned the station – dubbed the Joburg Minitrack by the NRL – in time to track the first US satellite early in 1958.

By then, America had been under significant pressure to demonstrate her technological ability to put a satellite into orbit. After a number of failures, Explorer 1 (1958 Alpha) finally took to space from

A trailer filled with promise

The large trailer that arrived at the Esselen Park Railway College with all the equipment to install a Minitrack system was an impressive sight.

Three engineers from the US Naval Research Laboratory (NRL) assisted with the installation: Ed Habib, an electronics expert, Al Bartholemeu, a specialist in radio systems and antennas, and Hal Hoff, a surveyor with expertise in positioning antenna systems.

We did not realise it at the time, but the CSIR's agreement with NRL, to operate a Minitrack Station in South Africa as part of the US global satellite tracking network, paved the way for our involvement in the space age – not on the sidelines, but on the field.

Without the foresight of Dr Frank Hewitt and support from others at the CSIR, such as Dr Chris van der Merwe Brink and Mr Raymond Vice, who recognised the potential benefits from satellite technology, the SAC story may have been very different and not nearly as rewarding.

Man's ingenuity has changed the way in which we live and perhaps never more so than during the first 50 years of the 'space age'

Cape Canaveral (now Cape Kennedy) in Florida on 31 January 1958. The battery-powered, spin-stabilised satellite's discovery of the Van Allen Radiation belts is considered as one of the major findings during the IGY. During the next year and a half we tracked over 7 000 satellite passes and recorded more than 2 000 magnetic tapes – a significant contribution to the US space programme at the time.

In 1959, NASA's Jet Propulsion Laboratory[8] (JPL) approached the CSIR to also establish a Deep Space Station[9] in the country as the third station in its Deep Space Instrumentation Network[10] (DSIN) to support the American lunar and solar systems research programme.

Doug Hogg and I were tasked to find an appropriate site within 200 km from Johannesburg. The site had to be in a valley with no radio interference but close to road, rail and air connections.

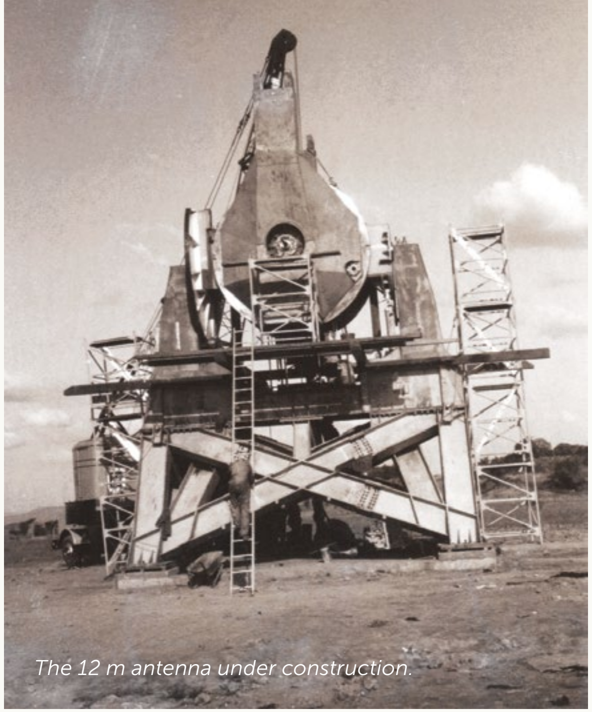
Hartebeesthoek met the requirements and the JPL engineers approved the site. At the same time, engineers from NASA's Goddard Space Flight Centre[11] (GSFC) – set to take over the Minitrack network from the NRL – approved Hartebeesthoek as the location for the new 136 MHz Minitrack system.

THE NASA YEARS

We will probably always remember our first 15 years at Hartebeesthoek, from 1960 and 1975, as the NASA years, when the Minitrack and Deep Space Stations respectively provided the GSFC in Maryland with tracking services for its Earth-orbiting satellites and the JPL in Pasadena, California with mission support for the US deep space research programme.

All the US-supplied electronic equipment and systems used to equip the two stations required 120 volts and 60 Hz power. We had to install four powerful Caterpillar Diesel generators in a communal power station to support the satellite and deep space tracking and telemetry activities.

The drone of those generators could be heard day and night down the valley. The eventual installation of a motor generator powered from the national grid provided NASA with a considerable cost saving in power supply for their systems and electronics at Hartebeesthoek.



The 12 m antenna under construction.

Signage at the entrance to the Minitrack Station at Hartebeesthoek

Deep Space Station at Hartebeesthoek

In 1961, the Minitrack network was renamed the Satellite Tracking and Data Acquisition Network (STADAN) and we became known as the Joburg STADAN. By the mid-1960s the entire STADAN network had been upgraded to 136-137 MHz band to receive telemetry data and deal with increasingly complex experiments aboard the spacecraft.

As part of the upgrade, NASA installed a 12 m hydraulically-driven X/Y parabolic antenna and upgraded the Yagi antennas, legacies from the IGY (1957-58) activities at Esselen Park. The 12 m antenna was one of three that NASA installed at tracking stations located approximately 120° apart in longitude, to receive data continuously from its Interplanetary Monitoring Platforms[12] (IMPs).

The Joburg STADAN at Hartebeesthoek (international code HBK) shared this distinction with the Woomera Station in Australia and the Santiago Station in Chile. Compared to most other tracking stations, which could interact with a single satellite at a time, the new and upgraded antennas enabled us receive data from three different satellites simultaneously, track a fourth, and send commands to any two of the satellites being tracked.

Hartebeesthoek's strategic downrange position on the African continent gave the Joburg STADAN 'first acquisition' status, as the first station to confirm that a satellite launched from Cape Canaveral was indeed in orbit. We could also initiate the deployment of experimental booms and solar panels aboard the satellites, or monitor and confirm their deployment.

Due to our location, there were times when we received a disproportionate percentage of NASA's satellite data. In fact, for about two months in the early 1970s, we received 40% of all data from more than a dozen satellites.

The workload was challenging and stretched our capacity, but it was at such times that the extraordinary team spirit at HBK kicked in and we made it work.

Memorable events

There were many exceptional and memorable events during the NASA years. One of them was the Syncom-1 launch in 1963, the world's first geosynchronous[14] communications satellite. We were not scheduled to record telemetry data but it was such an important milestone that, in the spirit of asking forgiveness rather than permission, we did it anyway.

When all transmissions from the satellite suddenly ceased abruptly, just before it could be placed into a geostationary orbit, none of the stations scheduled to record the data had managed to do so.

When NASA learnt about the recording, we were first berated before being asked to supply them with the tape.

Meteosat imagery used for fog research on the West Coast

The Hughes Aircraft Company used the data to correct the fault on Syncom-2 and launch it on schedule, which saved the company a significant amount of time and money.

The event contributed to the growing acknowledgement of our contribution to NASA's tracking network and, I suspect, contributed years later to Hughes (later Boeing) becoming a major SAC client.

Another memorable project was the installation of an optical station at Hartebeesthoek for the US Coast and Geodetic Survey in 1968. We seconded staff to man the station.

They had to photograph, simultaneously with other stations in Africa, Ascension Island, Tristan da Cunha and South America, mutually visible satellites against a star background to create a global geodetic reference system.

The satellites (or satelloons) were mostly the 30 m diameter Echo silver-coated mylar balloons. The US Coast and Geodetic Survey used the data to calculate intercontinental distances extremely accurately. These showed clearly that Africa and South America were drifting apart by some centimetres annually. The data provided the world with the first measurements of continental drift[15].

AN UNTIMELY END

Escalating political instability in South Africa in the early 1970s brought an untimely end to the NASA years. In 1973, NASA informed the CSIR of its intention to close both tracking stations at Hartebeesthoek. Ironically, it came at a time when the Joburg STADAN had become one of the busiest stations in NASA's network and achieved a reputation as one of the best globally.

In 1973 and 1974, we were placed first in the network for error-free operations and we were in second place when NASA closed the doors on 31 October 1975.

The Deep Space Station was closed down in 1974, also during one of the busiest periods in its 13-year history.

We had to decommission, crate and return NASA's equipment to the US. The last crate left South Africa in May 1976. All that remained at the Joburg STADAN was some discarded equipment in almost empty buildings and the 12 m antenna, which was too big, cumbersome and prohibitively expensive to dismantle and crate for shipping.

NASA's termination of the two contracts created considerable upheaval within the CSIR. Not all staff at the two stations could be redeployed and a large number of people, some with very specialised skills, had to be released. We had plummeted from peak performance into an uncertain future. Without doubt, 1975 was the worst time in SAC's history.

A NEW BEGINNING

The CSIR almost immediately re-established the facilities at Hartebeesthoek. The Deep Space Station became a radio astronomy observatory (HartRAO) in 1974 and is still in operation today. The Joburg STADAN was re-established as the Satellite Remote Sensing Centre (SRSC) in 1976.

A small group of ex-Joburg STADAN staff were retained at Hartebeesthoek to acquire and process data from meteorological and geostationary Earth observation satellites for local use. On a tight budget,

Our track record was always a source of pride, but it was the tenacity and team spirit of the exceptional group of people at Hartebeesthoek that gave it meaning.

but determined to make it work, we modified some of NASA's abandoned equipment, identified the technical specifications for additional equipment and facilities, and built a system to receive and process Earth observation data from planned and existing satellite systems.

These included the geosynchronous meteorological satellite, Meteosat-1, and the Landsat Earth resources satellite series. The South African Weather Bureau was the first recipient of Meteosat data, which we also made available for research projects in geology, oceanology, agriculture, forestry, land use and developmental studies in Africa.

An agreement with NASA in 1982 gave us direct access to Landsat data, previously bought from the Eros Data Centre in the US, which provided us with high-resolution, multispectral data. Projects in geology, agriculture, forestry, land use and developmental studies in Africa benefited from these data.

At the time, Hartebeesthoek was the first ground station globally to combine the receipt and processing of Meteosat and Landsat data.

This developed into a major programme at the SRSC, and Hartebeesthoek became a regional centre for receiving and distributing imagery that covered most of Africa south of the Equator.

By then the French space agency, CNES, had contracted the CSIR for TT&C[16] support for their Ariane launcher series. This was an exciting development with the opportunity to re-use well-honed skills from the NASA years. We were determined to give them the same level of service as we had given NASA, and Hartebeesthoek became a key role player in many CNES launch missions. To this day, CNES remains an important client.

In the late 1980s, we upgraded the equipment at the station to receive very high-resolution images from the Landsat and SPOT satellites. This data was suitable for cartography at a scale of 1:50 000 and added significant value to our Earth Observation (EO) products and services.

A DIFFERENT CHALLENGE

By 1988, the steady decrease in government funding resulted in a major restructuring at the CSIR to increase its external income. The SRSC was renamed the CSIR Satellite Applications Centre (SAC) with a directive to become 'market-driven'. This meant a strong focus on marketing and business development to increase our income from TT&C and Earth Observation products and services. We had to overcome a number of challenges. CNES was our only client and sanctions affected our ability to market our services overseas. Locally, EO data users expected free access to remote sensing data.

Daunting as the challenges were, I was confident that the SAC team would rally to meet them head on and they did. During the six years until my retirement in 1994, our external income grew from R250 000 in 1988 to more than R10 million.

Significant achievements included a range of new clients and, for the first time in almost 20 years, providing NASA with mission support for Project Clementine, the first lunar mission launched in 1994. In total, the TT&C team had supported more than 250 launches, recorded close to 300 000 tapes and tracked over 2 million passes successfully.

SAC's EO team had achieved significant milestones, using SPOT-5 data, to deliver a 2.5 m resolution

Enduring Legacy

natural colour seamless mosaic of South Africa, a first of its kind on the continent. A multi-government licence agreement with SPOT Image enabled us to distribute the data free of charge to users in government departments and education institutions.

AN ENDURING LEGACY

Those of us who shared the SAC journey will remember 2010 as the end of an indelible epoch. The 20-odd antennas at Hartebeesthoek today bear testimony to our consistent delivery of error-free operations, which made SAC a preferred partner of many in the space industry, globally.

SAC's track record was always a source of pride, but our achievements would not have been possible without the exceptional group of people at Hartebeesthoek. I am privileged to have led a team whose tenacity, spirit and will to succeed contributed significantly to the developments in satellite technology that shaped the world of instant communications as we know it today.

On behalf of SAC and its people, I thank the CSIR for making it all possible. The vision of Dr Frank Hewitt[†], Dr Chris van der Merwe Brink[†] and Mr Raymond Vice[†] and the continued support from the CSIR Board and Executive, as well as the encouragement from others in the organisation involved in SAC's challenges and achievements over the years, spurred us to 'boldly go' as South Africa claimed its place among the space nations of the world.

The publication of this book is opportune in commemorating the end of one era and celebrating the beginning of another: the continuation of SAC's activities under the banner of the South African National Space Agency (SANSA).

I believe that SAC's bequest is a firm foothold from which SANSA can move forward to create its own imprint on the country's endeavours in space exploration in the years ahead. As we close the book on the SAC story, I suspect that those of us no longer involved directly in forging South Africa's space landscape will retain a healthy interest in its well-being. I am also confident that those who continue the journey will continue to make us proud.

My wish is that through SANSA, SAC's legacy will endure to benefit this country, its people and all future generations.

Willem Botha
SAC Manager, 1960-1994

Global standing

A world-class performance

During its half-century of participation in the international space landscape, the CSIR received many accolades from clients and colleagues locally and abroad.

Many of these have been captured in the large, leather-bound visitors book that is on display in the reception area at Hartebeesthoek.

When some of SAC's overseas friends heard about the commemorative book, they sent the following contributions...

"The Deep Space Network (DSN) and Satellite Tracking and Data Acquisition Network (STADAN) Johannesburg Station – Joburg STADAN – supported a large number of different satellites during the 1960s through to the mid-70s. In addition to the 30 or more satellites that were supported in orbit, the Johannesburg station also provided optimal coverage of interplanetary probes launched on trajectories from Florida.

Johannesburg's location on the very southern tip of the African continent was an ideal location and the support that NASA received from the Johannesburg station was excellent.

The move of the Joburg STADAN to Hartebeesthoek (HBK) still provided NASA with an ideal location to provide launch and early orbit phase (LEOP) support for geostationary satellites.

The support from HBK during critical launches was exceptional, such as the support provided during the launch of NASA's Geostationary Operational Environmental (GOES-P) and Solar Dynamics Observer (SDO) satellites.

On a more routine basis, HBK also supports a constellation of earth-orbiting Themis satellites from its southern hemisphere location."

Harry Schenk

Programme Manager. Near Earth Networks Services at Honeywell, involved with the Joburg STADAN at Hartebeesthoek during the 1960s and 1970s

"My first visit to SAC at Hartebeesthoek was in October 1984, as a just-hired young engineer. I had to integrate the equipment and prepare the station to support the launch of the 11th Ariane rocket.

Before I left the CNES Center in Toulouse, some colleagues warned me: ***"Beware of the snakes under the false floor" .***

I didn't see any snakes beneath the floor at SAC. The real surprise for me was above the floor, when I met the engineers and technicians working at the station. All of them were skilled and experienced people from whom one could learn a lot. And I certainly did.

That first impression was confirmed on many occasions, during dozens of launch supports for Ariane and close to 100 launch supports for the other satellites operated by CNES. Not a single failure or mistake in 27 years!

The pioneers have been replaced, new staff joined SAC (or HBK as it is referred to in the global space community), but their dedication, professionalism and first-class service remained always at a level beyond expectation.

It is no surprise for me that the site expanded so quickly and a forest of antennas grew to respond to requirements from more and more users. I am convinced that in the new context of the South African National Space Agency, the site will continue to grow and maintain its services at the same high quality standard.

No snakes in the grass at SAC, just the right people to do the job. When young engineers of CNES go there now, I warn them before they leave: **Take advantage of your visit. You will learn a lot from the station staff ... and you will make friends there. I did."**

Jean-Marc Soula

DCT/OP/C-STA, Advisor, GN Operations, CNES in France, involved with Hartebeesthoek since 1984

“What began as a modest agreement in 1998 to co-operate in flying and testing Ku-band commercial satellites, developed into a strong partnership between SAC and Boeing’s Satellite Mission operations team. SAC supported well over two dozen Ku- and Ka-band satellites in the last 13 years, all successful and all delivering strong performance for their owners.

Along the way, SAC built its Ku 13.2 m antenna, and Boeing contributed the SAC Ka 13.2 m antenna. Both operations teams have grown together into leaders in their respective fields.

Detailed preparation, meticulous testing and rehearsal, and precise operations have become the signature of the SAC operations team. The Boeing operations team salute you as you take your place at the forefront of South Africa’s new Space Agency. We look forward to many more years of co-operation to team the world’s best satellites with the world’s most professional satellite operations team.

SAC’s favourable geographic location made it a sought-after site for launch and transfer orbit support (TOS) services and its track record for ground segment establishment is well-known, from the days when they completed the 13 m Ku/Ka antenna project in a record time of 12 months – from request for proposal to completion of acceptance testing.

This system has provided tracking support to virtually all types of satellites manufactured by the world’s major manufacturers of communications satellites.

Good luck in your new SANSA leadership role.”

Edwin Ramsey
Manager, Boeing SDC Mission Tracking Networks, involved with SAC since 1998

SAC's leather-bound visitor's book

is an eye-catching feature in the reception area of the building at Hartebeesthoek. Dignitaries and visitors, locally and from abroad, have left behind thoughts and impressions of their time at SAC. The book abounds with messages that all tell their own story.

A very rewarding experience
thankyou
Vincent Gore

Keep on continuing partnership
between SAC and GNTA as well as friendship.
Pierre-Yves Renaillon

Cheers to our friends at SAC/CSIR!
outstanding facilities, better people...
Conrad Bowers
Boeing Phantom Works. Seattle WA
18 March, 2002

What an incredible rich history and heritage.
Inspiring to see what has been achieved to
date and exciting to think about what
can still be done.
Jay-Marie Lawrence

OCT 30 2003
It is my Sincere hope and wish that
African States will aspire to achieve what you have
already achieved.
The CSIR facility is world Class in its achievements.
JOHN G. MUNGAI (KENYA MET. DEPT.)

Congratulations SAC.
Great history of outstanding
achievements! Best wishes
for the future.
Johan le Roux

Old SACcers never die.
Sometimes they go LOS
All the best for the
future
Joe Schilles

Ferdi Scheepers

TO INFINITY, AND BEYOND!

We appreciate very much South-African hospitality and are very impressed by the capabilities of SAC, scope of its activities.
With hopes to cooperate efficiently.
С надеждой на плодотворное сотрудничество

В. Боран

I appreciate a lot to be in such a fantastic centre where you can imagine the future. It is also a place where the associations between the French and the South African are effective. let consider it as an example for other cooperation

Jacques Blanché

4/6/2001

In our galaxy, the Milky Way, some stars shine brighter than others. May the SAC, shining as a super-luminous star in our country, grow from strength to strength.

To every SAC member...

always
LOOK up!

Never give up.

You are unique Σ!
irreplaceable.

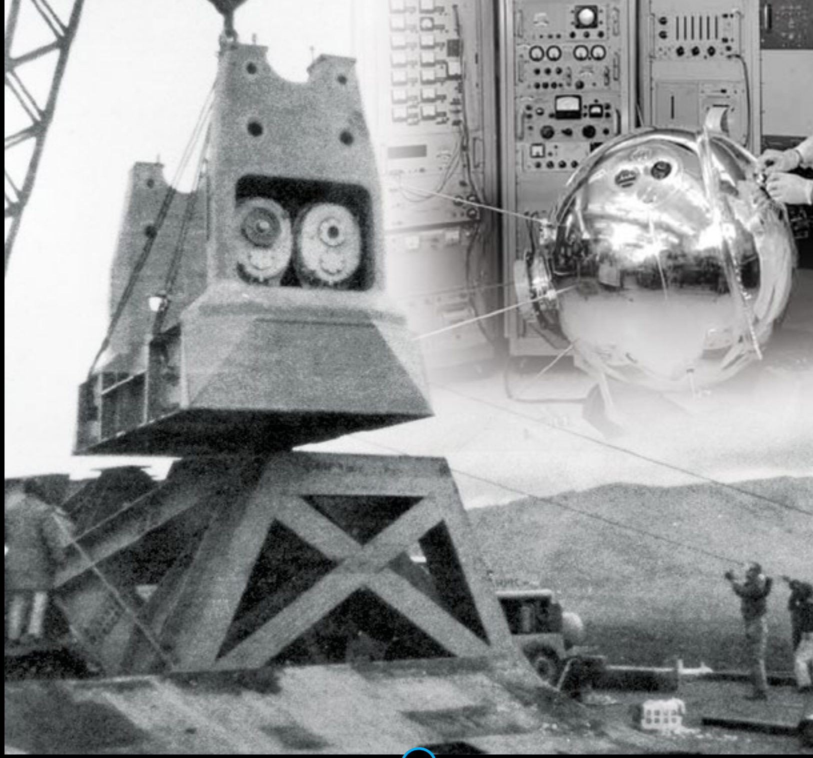
David A. Block
2002.

Robert

Snapshots in time

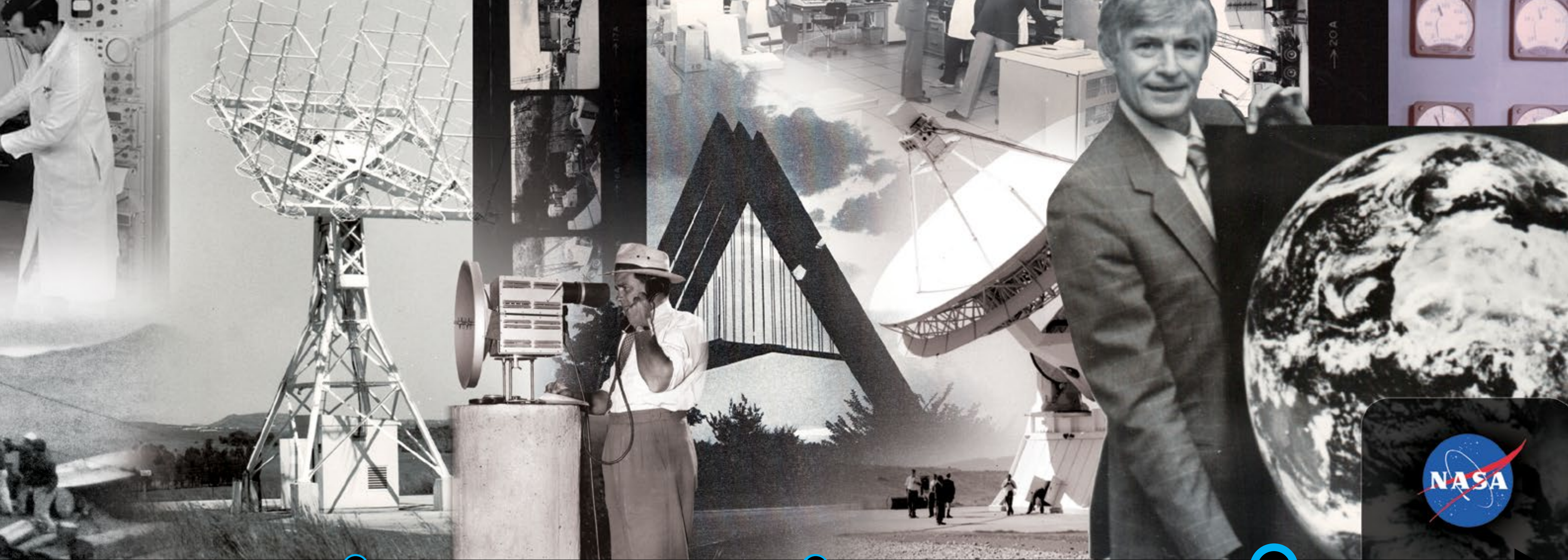
Some of the highlights

A timeline of events shaped the establishment and growth of the Satellite Applications Centre at Hartebeesthoek as a CSIR Centre of Excellence, globally recognised for accuracy and reliability and locally acknowledged as a national asset that has given substance to South Africa's role in international space exploration.



1957-1958

- CSIR-US Naval Research Laboratory (NRL) agreement signed to operate a Minitrack Station in South Africa[1] as part of a global network of satellite tracking stations to support the US participation in the world's first International Geophysical Year (IGY) 1957-58.
- CSIR engineers received international acclaim for being the first to track Sputnik-1, the world's first artificial satellite, a week after its launch by the Russians in 1957, and accurately predict its orbit visibility over southern Africa and date of re-entry into the Earth's atmosphere.
- CSIR National Institute for Telecommunications Research (NITR) installed and operated a Minitrack Station at Esselen Park Railway College near Kempton Park.
- Minitrack Station relocated from Esselen Park to Hartebeesthoek, where it shared certain facilities with the Deep Space Station.



- Minitrack tracked US Explorer-1 and Vanguard-1 satellites, launched six weeks apart in 1958.

1959-1960

- IGY events continued in 1959 as the Year of International Geophysical Co-operation.
- US Jet Propulsion Laboratory selected Hartebeesthoek as the location for a Deep Space Station and the South African government bought the land for the CSIR.
- South African-United States inter-governmental IGY co-operation agreement was extended, which facilitated CSIR-NASA contracts.
- Minitrack Station at Esselen Park tracked more than 7 000 satellite passes and recorded over 2 000 magnetic tapes for the US space research programme.

1961-1962

- CSIR inaugurated Hartebeesthoek as the South African Radio Space Research Station on 8 September 1961.
- Both the tracking stations played an important part in NASA's programme for the peaceful investigation of outer space.
- NASA carried the cost of operating the Radio Space Research Station through the CSIR-NASA contract, while both the Deep Space and Minitrack stations were manned by South African crews.
- Additional antenna pairs added to new 136 MHz tracking system to observe both polar and equatorial satellite orbits.
- Carried out telemetry assignments on the 1961 Upsilon or S-3, instrumented to study magnetic and radiation fields and energy particles, and recorded well over 700 hours of data.

1963-1964

- The Minitrack Station was relocated to Hartebeesthoek and renamed Joburg STADAN when NASA's Goddard Space Flight Centre (GSFC) took over the Minitrack network, renamed it the STADAN[2] and upgraded the stations to 136 MHz.
- Unscheduled telemetry recording of the failed Syncom-1 launch enabled the Hughes Aircraft Company to fix the problem and launch Syncom-2 as scheduled – probably the most important five minutes of data ever recorded by the Joburg STADAN, SRSC or SAC.
- Tracked the first commercial communications satellite, Early Bird, and verified its transfer into a synchronous orbit.

1965-1967

- Introduced 24/7 continuous operations at Hartebeesthoek to handle the telemetry, tracking and command (TT&C) workload.
- Performed 8 732 tracking operations.
- Tracked NASA's Orbiting Geophysical and Astronomical Observatories during their initial orbits.

1968-1969

- Established an Optical Geodetic Tracking Station at Hartebeesthoek as part of the US Coast and Geodetic Survey network to create a global geodetic reference system, with staff trained and seconded to the geodetic tracking experiment, which confirmed continental drift.
- Reported the real-time physical condition of the orbiting monkey[3] that was sent into space as part of the US BIOS-D mission.

1970-1971

- Joburg STADAN became one of the busiest stations in the GSFC network and was rated the top network station for May and June 1971, with an operational efficiency of 99.94% in the execution of 9 024 TT&C assignments.
- Assisted other STADAN stations to control the post-launch tumble of the OSO-7[4] satellite.

1972-1973

- **Commended for emergency support that extended the lifespan of the Nimbus[5] satellite.**
- **Tracked five Lunar Experiment Packages left on the Moon by the Apollo crews after reconfiguring the equipment to receive the different frequencies simultaneously.**
- **NASA advised the CSIR that the Joburg STADAN and Deep Space stations at Hartebeesthoek would be closed down by 1975.**

1974-1975

- Deep Space station closed on 30 June 1974 and its equipment was packed and shipped to the US by 28 February 1975, as scheduled.
- Joburg STADAN station closed on 31 October 1975 and its equipment returned to the US by 31 March 1976, as scheduled.

1976-1977

- After NASA's departure, CSIR re-established Hartebeesthoek as the Satellite Remote Sensing Centre (SRSC) to receive geo-information from Earth orbiting satellites and line scan data from remote sensing satellites for local use.
- Received first images from Meteosat in December 1977 with ex-NASA equipment modified locally and new processing equipment and software acquired overseas.

1977-1978

- Supplied the first visible and infrared cloud images from Meteosat to the South African Weather Bureau in 1978, while requests for the data almost immediately exceeded expectations.
- Updated Landsat database for southern Africa with several hundred Landsat scenes purchased from the EROS data centre in Sioux Falls, South Dakota, as Hartebeesthoek had no direct access to Landsat data at the time.

1979-1980

- Signed CSIR-CNES contract to provide launch and orbital support for CNES space missions, which included the Ariane rocket series launches from Kourou in French Guiana.
- CNES started the installation of S-band equipment at Hartebeesthoek to make it the 4th station in the CNES network (the others at Kourou, French Guiana in South America, Aussaguel in France and Kiruna in Sweden) and prepare to support the first French telecommunications satellite Telecom-1A, scheduled for launch in 1983.
- Signed CSIR-NASA contract for direct access to Landsat data.

1981-1982

- Received the first high-resolution, multi-spectral Landsat-3 data.
- Supplied some 4 500 Landsat data products to local users.
- First ground station globally to simultaneously receive both Meteosat and Landsat data.
- First regional centre to receive and distribute data over most of Africa south of the Equator.

1983-1984

- Provided quasi real-time declouded Meteosat infrared data to the research ship "Knorr".
- Used Meteosat-2 visible data to monitor the movement of cyclone Domoina, and Landsat-4 multi-spectral scanner data to evaluate the destruction caused by the cyclone.
- CNES completed the installation of the S-band equipment and interfaced it with the 12 m receive and 6.1 m transmit antennas.
- Supported the launch of the first French telecommunications satellite, Telecom-1A, and its month-long geostationary orbit transfer operations.

1985-1987

- Supported the launch, deployment and final positioning of the CNES Telecom-1B, the first French geostationary direct-broadcast satellite.
- Developed, built and operated a NOAA[6]-format synchroniser and computer interface unit to receive AVHRR[7] data from the US NOAA polar-orbiting meteorological satellites.
- Signed a CSIR-SPOT Image contract to distribute Earth data products obtained from SPOT Earth observation satellites.

1988-1989

- CSIR renamed the Satellite Remote Sensing Centre at Hartebeesthoek as the Satellite Applications Centre (SAC).
- Acquired LSX-band 10 m antenna and sent staff to the US for training to qualify, install and commission the LSX antenna – still called LSX today – at Hartebeesthoek.
- Upgraded equipment at SAC to receive, process and distribute high-resolution Thematic Mapper Earth observation data directly from the US Landsat and French SPOT satellites.

1990-1991

- Provided the European Space Agency with TT&C support for SAR[8] satellite launches.
- Supplied satellite data products from the NOAA-9 polar orbiting meteorological satellite for research in geophysics, hydrology and agriculture.
- Supplied digital terrain models from the French SPOT-2 satellite for cartographic and other applications.

1992-1993

- Received data from NOAA-11 and NOAA-12 over-flights and archived on average 80-90 images every month.
- Launched PICS, a Promotional Introductory Campaign for SPOT, and supplied participating investigators with almost R300 000 of SPOT data to assess its potential for addressing resource management challenges in southern Africa.
- Signed a distribution agreement with Cenacarta for the commercial distribution of SAC products in Mozambique.
- Signed a CSIR-European Space Agency Memorandum of Understanding to access the SAR data set from the European Radar Satellite (ERS-1).

1994-1995

- Supported NASA (for the first time again in 25 years) in the Clementine moon mission during the 10-minute lunar transfer orbit burn, which boosted the satellite out of its Earth orbit.
- Supplied SAR all-weather ocean data directly from the ERS-1 satellite for geological studies and to combat oil spills.
- SAC's TT&C and Earth Observations activities split into two groups for greater efficiency and more effective operations.

1996-1997

- Upgraded all civil, mechanical, electrical and electronic systems for the 13.2 m Ku/DBS band antenna, with on-the-job training, in a world-record time of nine months.
- Won the international bid, against strong competition, to provide Hughes Space and Communications with transfer orbit services (TOS) for all their and their clients' geostationary communications satellites.
- Produced SpaceMaps on 1:250 000 map sheets with Landsat Thematic Mapper, SPOT and ERS-1 satellite data for the National Land Cover Project.

1998-1999

- Completed the installation of the 13.2 m Ku/DBS-band antenna at Hartebeesthoek in a world-record time of nine months, an unprecedented achievement globally.
- Provided scientists with SeaWifs satellite imagery with information about marine resources.
- Supported Boeing's Bonum-1 launch with the newly installed Ku-band full-motion antenna.
- Provided the mining industry with SPOT imagery to help prevent slime dam disasters.

2000-2001

- Provided Statistics SA with the first satellite imagery used in a national population census.
- Constructed the world's first Ka-band satellite tracking facility at Hartebeesthoek.
- Became a primary Ku-band ground station in the CNES global network.
- Used Landsat imagery to produce a land cover map of Swaziland's forestry resources at a scale of 1:50 000 to support sustainable resource management.
- Acquired and added the first direct high-resolution data from the Eros satellite to the Earth Observation online database.
- Received and used the first data from Landsat-7 to evaluate Digital Terrain Models for MTN.

2002-2003

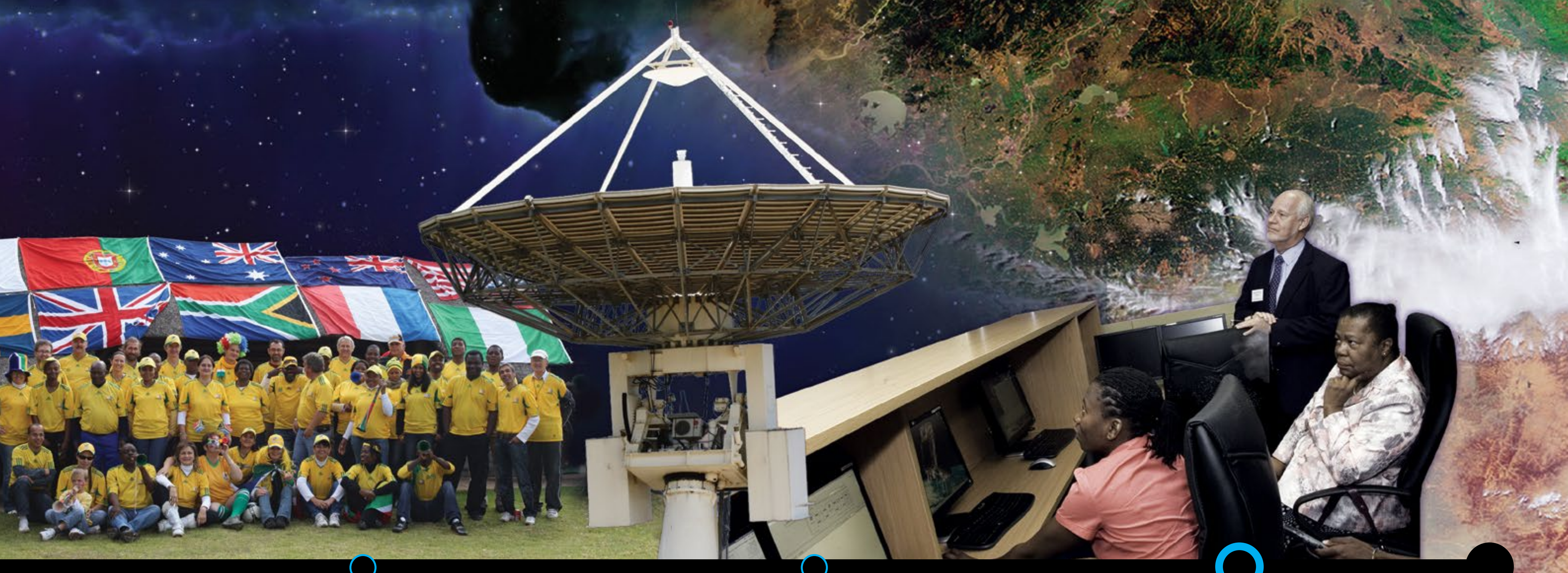
- Signed a CSIR-Boeing Space and Communications contract to support Delta-IV launches.
- Signed a CSIR-Lockheed Martin contract to support NASA's Solar Radiation and Climate Explorer mission and its Space Infrared Telescope Facility mission.
- Signed a multi-million Rand CSIR-Intelsat contact to provide TT&C support as a C-band ground station in the Intelsat global network.
- Established a European EGNOS[9] ground monitoring station at Hartebeesthoek.
- CSIR-Eskom Enterprises' Airborne Laser Solutions (ALS) agreement expanded SAC's Earth observation sensors portfolio.
- Provided Eskom with Landsat-7 imagery to identify growth areas for the roll-out of its electricity installation drive.
- Distributed imagery from Earth observation satellites about the extent of the oil spill along the St Lucia coast line and the occurrence of toxic red algal bloom off the Cape West Coast.

2004-2005

- Achieved CSIR Centre of Excellence status as a separate, strategic centre reporting directly to the CSIR Executive with an independent Advisory Board.
- Exceeded mission support expectations on all Tiros Operational Satellite LEOP[10] support.
- Won R30 million Boeing contract to support Spaceway-F1 as the first Ka-band TT&C satellite ever launched.
- Multi-million Rand grant-in-aid to SAC from the Department of Agriculture to procure, install and operate a MODIS (Moderate Resolution Imaging Spectro-Radiometer) sensor aboard the Aqua and Terra satellites, to provide the country with imaging data for agricultural land use monitoring.
- Used the MODIS receiving and processing system to launch a prototype satellite-based fire detection system for Eskom.
- Trained 15 Nigerian satellite engineers and scientists in TT&C in the practical application of satellite imagery, as part of a bilateral agreement between Nigeria and South Africa.

2006-2007

- Initiated the 'data democracy' concept as CEOS[11] Chair to make free data available for developmental purposes.
- Undertook a European Commission Framework Programme 6 Project with Thales Alenia Space to use Galileo[12] imagery locally and for the SADC region.
- First ground station to acquire and track the Honeywell THEMIS[13] constellation.
- Concluded a Telesat contract and extended the CSIR-CNES contract for three years.



- SAC Earth Observation produced the first 2.5 m satellite imagery mosaic over South Africa, using remote sensing data from SPOT-5.

2008-2009

- Supported the deployment of GeoEye-1, the world's highest-resolution Earth-imaging satellite.
- Doubled SAC's external income and provided TT&C support for an unprecedented 22 satellites in one year.
- Completed the national 2008 SPOT-5 high-resolution colour mosaic over South Africa in record time and with superb quality.
- Executed the first dual launch support for Boeing's AMC-21 and Superbird-7 satellites.
- Hartebeesthoek assigned as a ground station reference site for the Galileo satellites.
- Took over mission control for South Africa's SumbandilaSat Earth observation "pathfinder" micro-satellite.
- Launched FundisaDisk to provide free geo-information data to universities.
- Participated in the strategic planning process for South Africa's new space agency.

2010

- Continued tracking and operating Sumbandila-Sat through the use of a large-dish antenna.
- Provided first-ever satellite-derived baseline information on informal settlements for the North West Province.
- Implemented SAEOS[14] to create a world-class Earth Observation Data Centre and centralised remote sensing catalogue.
- Celebrated SAC's 50th anniversary on 16 July 2010.
- Participated in the launch of the South African National Space Agency (SANSA) on 9 December 2010.
- Launch support record improved for the 3rd consecutive year with 22 launches (2008:17; 2009:20), while maintaining service levels at 100%.
- Total number of spacecraft supported into low-Earth and high-altitude geostationary orbits since 1984 close to 300.
- Awarded a European Commission project to disseminate free data in SADC under the data democracy banner (initiated by SAC as CEOS Chair in 2008) to build skills within SADC.
- Completed the installation and handed the ORBCOMM South African Gateway Earth Station to its owners in September 2010.
- Top-line growth of 12% with a total income of R91.8 million against a target of R77 million, margin of R5.8 million and staff complement of 54 for the final financial year.

The Antenna Farm

at Hartebeesthoek

The Antennas

HBK-2: 12 m S- and ext C-band antenna with a 10°/sec slew rate, programme and auto-tracking. Installed in 1963 to undertake TOSS[3] and routine operations.

HBK-4: 6.1 m S-band uplink antenna with a 10°/sec slew rate, slaved to receive antenna systems, either HBK-2 or HBK-5. Installed in 1982. Known as S.A.T.A.N.

HBK-5: 10 m S- and X-band antenna with a 10°/sec slew rate, programme and auto-tracking. Installed in 1988 to provide TOSS, launch support and download Earth observation data. Known as LSX.

HBK-7: 13.2 m Ku/DBS-band antenna with a 2°/sec slew rate, programme and auto-tracking. Installed in 1998 for TOSS and IOT[4] support.

HBK-8: 13.2 m Ka-band antenna with a 2°/sec slew rate, programme and auto-tracking. Installed in 2001 to provide TOSS and IOT support.

HBK-9: 5.4 m X-band antenna with a 3°/sec slew rate, programme and auto-tracking. Installed in 2002 and used to download Earth observation data.

HBK-10: 11 m C-band antenna with a 5°/sec azimuth[5] slew rate, 1.4° elevation[6], programme and auto-tracking. Installed in 2003 and used for housekeeping (maintenance) and TOSS.

HBK-15: 9 m Ku-band antenna with a 5°/sec slew rate, programme and auto-tracking. Installed in 2006 and used for housekeeping of satellite constellations.

HBK-16: 7.3 m X-band antenna with a 3°/sec slew rate, programme and auto-tracking. Installed in 2008 to strengthen SAC's Earth observation capabilities.

MO-1: 5 m S-band mobile antenna, 20°/sec slew rate, programme and auto-tracking, to support off-site launches that took place away from the HBK ground station.

Egnos: ESA, EC and EUROCONTROL satellite-based augmentation system; supplements GPS, GLONASS and Galileo systems by reporting on signal reliability and accuracy. HBK is an EGNOS ground station (2003).

Intelsat: Intergovernmental consortium (1964-2001); owned and managed satellites constellation that provided international broadcast services; world's largest commercial satellites fleet. HBK hosts the monitoring station.

HMO: HBK hosts systems for SANSA Space Science, previously HMO, a national geomagnetic research facility and active participant in INTERMAGNET, which monitors the Earth's magnetic field

Modis: 3.2 m X-band antenna, 2º/sec slew rate; programme and step tracking. Provides Terra and Aqua satellite reception (2004).

NOAA: 2.1 m L-band antenna, 2º/sec slew rate, programme tracking. Provides NOAA satellite reception.

ORBCOMM: HBK hosts the ORBCOMM monitoring system that offers M2M global asset monitoring and messaging services from its constellation of 29 LEO communications satellites orbiting at 775 km (2010).

Eutelsat: French-based satellite provider, one of world leaders ito revenue, that covers Europe, Middle East, Africa, India and parts of Asia and the Americas. HBK hosts a Eutelsat monitoring station.

Key

EGNOS: European Geostationary Navigation Overlay Service

EC: European Commission

ESA: European Space Agency

HBK: Hartebeesthoek South Africa

HMO: Hermanus Magnetic Observatory

INTELSAT: International Telecommunications Satellite Organization

INTERMAGNET: International Real-time Magnetic Observatory Network

LEO: Low-Earth Orbit

M2M: Mobile-to-mobile

A unique signature

Space stations are globally identified by acronyms (signatures) given to them by the international space agencies. Hartebeesthoek is known as HBK. The acronym also identifies the antennas at each ground station, such as HBK-2.

In contrast, therefore, to the Bard's contention that "a rose by any name will smell as sweet", an antenna is not just (another) antenna. Each antenna is unique, with a 'signature' that clearly identifies the ground station where it is located.

During its lifetime, the CSIR Satellite Application Centre's antenna farm was integral to South Africa's broader space initiatives.

The expertise and facilities at the Hartebeesthoek ground station became indispensable in supporting national and international space initiatives.

LOCATION, LOCATION

Hartebeesthoek's location, some 70 km west of Pretoria and 40 km north-west of Johannesburg, in the Magaliesberg mountain range, places it on the outskirts of the Cradle of Humankind, one of South Africa's World Heritage sites.

The position of the site at the southern tip of the African continent gave SAC 'first acquisition' status as a ground station for satellites launched from Cape Canaveral in the US.

The Hartebeesthoek location was well-chosen and ideal for providing international clients with tracking, telemetry and command (TT&C) services for their geosynchronous and polar orbiting satellites. Most major satellite manufacturers, operators and space agencies worldwide benefited from SAC's TT&C services.

THE ANTENNA FARM

The idea of creating an antenna farm at Hartebeesthoek took root during a SAC strategic planning session in 2001. At the time, the site housed four antennas (12 m, 10 m, 5.4 m and 13.2 m).

Almost 10 years later, at the end of the SAC era in 2010, the number of antennas had increased to 19, with varying dish sizes and slew rates that accommodated a number of frequency bands and tracking modes.

THE GROUND STATIONS

SAC also installed, operated and maintained ground stations for clients. An example is the ORBCOMM ground station, which consists of two identical radomes[1] with high-frequency planar-arrays[2] on which the antennas were mounted. ORBCOMM is a specialist US satellite communications company with a fleet of micro-satellites in low-Earth orbit.

ORBCOMM clients can remotely track, manage and control assets from almost anywhere in the world.

1945 - 1959

The cornerstones


Field Marshall JC Smuts


Sir Basil Schonland

It is difficult to say what is impossible, for the dream of yesterday is the hope of today and reality of tomorrow.
- Robert H Goddard

Like all historical events, the story of the CSIR Satellite Applications Centre (SAC) – and South Africa's rich heritage in space exploration – must be placed in the context of its times. The SAC story started with the pioneers who laid the cornerstones well before 1960.

The establishment of the Council for Scientific and Industrial Research (CSIR) in 1945, as the country's first scientific research council and its Telecommunications Research Laboratory (TRL) a year later, provided the cornerstones for the foundation from which our story unfolds.

A CLEAR VISION

Shortly after the end of World War II in 1945, one man's vision of a better society for all shone brightly. Field Marshall Jan Smuts[1], serving his 2nd term (1939 - 1948) as the Prime Minister of the Union of South Africa, was a distinguished scientist held in universal esteem. Smuts saw clearly how scientific research and technological innovation would benefit the country.

He entrusted the realisation of this vision to his scientific advisor, Dr (later Sir) Basil Schonland. A brilliant scientist in his own right, Schonland drafted the Research Council Bill and directed the establishment of the CSIR. The science council was legally constituted at the Union Buildings in Pretoria on 5 October 1945, with Schonland as its first President.

Armed with the undeniable success of radar during the recent war, Schonland convinced the CSIR Council to establish a Telecommunications Research Laboratory (TRL) and seconded a few talented engineers and technicians from the Special Signals Service of the South African Defence Force to the laboratory. The group included some of South Africa's brightest young minds who brought with them invaluable expertise in radio physics[2].

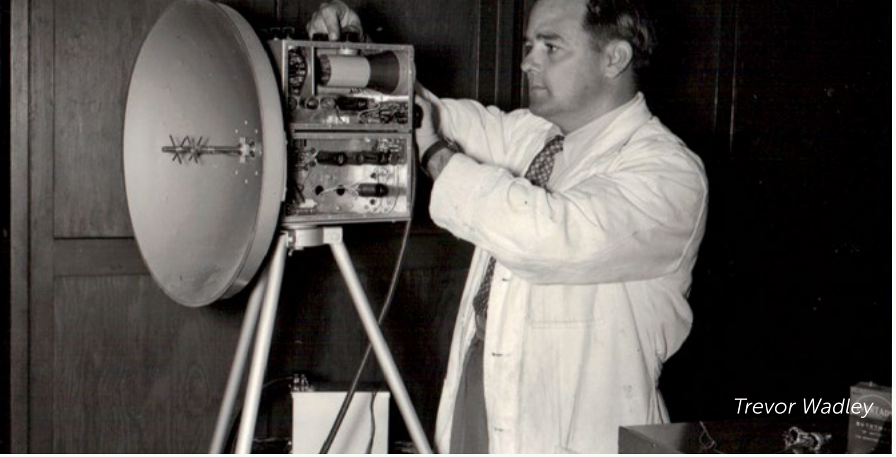
Worldwide, scientific endeavour during the 1950s set a dynamic pace for technological innovation. While many inventions at the CSIR's TRL at the time resulted from a natural progression of research into areas such as the effects of radio waves on natural phenomena in the ionosphere[3], others were specialised instruments developed for a multitude of industry applications, including radio communications and navigation systems. History tells us that the ingenuity of those researchers significantly influenced the events that followed.

FORERUNNERS TO SATELLITE COMMUNICATIONS

In 1954, the CSIR's innovation-infused environment saw the development of the Tellurometer[4] by Dr Trevor Wadley. This ground-breaking invention revolutionised land surveying throughout the world.

Reports from over 48 countries – as far afield as the Arctic, Australia and Malaysia – confirmed that the new microwave distance measurement system could achieve previously impossible feats of surveying and do so more cost-effectively than other systems.

The Tellurometer earned the CSIR and its inventor global recognition and was acknowledged by many as a forerunner to satellite communications.



Trevor Wadley

Sputnik-1

Another forerunner was the 1957-58 International Geophysical Year[5] (IGY), a historic event in which 67 countries collaborated to observe geophysical phenomena and learn more about the Earth – its weather, climate, earthquakes, ocean tides and atmospheric disturbances.

America's contribution to the IGY was Project Vanguard, developed and managed at the time by the US Naval Research Laboratory (NRL).

Their aim was to launch the world's first artificial Earth satellite during the IGY, measure its orbit accurately and obtain new information about the Earth's shape and field of gravity.

The NRL also developed a precision radio interferometer[6] system to track the satellite as part of Project Vanguard.

Code-named Minitrack[7], the system could determine the origin of a radio source in space to 1 000th of a degree and was not restricted by weather or dawn/dusk conditions. A network[8] of Minitrack Stations was installed around the globe to create an 'electronic fence' through which no satellite transmitting in the 108 MHz frequency band could pass undetected.

South Africa's position at the tip of Africa, relative to the US launch facility at Cape Canaveral in Florida, made it an attractive strategic addition to the network.

Such a station would be the first to detect a satellite launched from Cape Canaveral and confirm its orbit.

When Dr Frank Hewitt, TRL Director at the time, became aware that engineers from the NRL were battling to interest a government entity to take responsibility for the Minitrack system during the IGY, he acted swiftly.

Recognising the benefits of the CSIR's involvement in a new field of scientific research, he obtained permission and funding for the project.

The country's participation was confirmed when the South African National Committee for the IGY formally requested that the CSIR TRL accept responsibility for the installation and operation of a Minitrack system in South Africa.

Timeline

1945	CSIR established
1946	CSIR TRL established
1954	Tellurometer invented
1957	CSIR participated in global IGY events. CSIR team tracked Sputnik-1. Minitrack system arrived at Esselen Park.
1958	Minitrack commissioned to track US Explorer-1. First four US satellites tracked.
1959	CSIR-NASA agreement to establish a Deep Space Station. Hartebeesthoek selected as the site for the DeepSpace Station and relocation of the Minitrack Station.

African context

In the aftermath of World War II, South Africa experienced dramatic political, industrial and economic change. Industries expanded and diversified and foreign capital flowed into the country. Politically, the country became polarised as separate development became official government policy. It marked the start of nearly 50 years of racial conflict and many years of economic isolation.

A vision realised

Comments from Prime Minister Jan Smuts at the first CSIR Council meeting on 8 October 1945:

"I am confident that this body will become one of the most important organisations of advancement in this country. Science has come forward in gigantic strides and more and more everyone is beginning to feel that scientific research is a matter of vital importance."

His confidence was justified, when CSIR engineers were among the first to successfully track the world's first artificial satellite.

Minitrack Station at Esselen Park, 1958.

This opened the door to the CSIR's early participation in space exploration.

THE SPACE AGE DAWNS

1957 dawned with no indication that it would be a year indelibly carved in history as the advent of the space age, and an era of some of the most remarkable political, scientific and technological achievements known to mankind.

At the CSIR, the year started with final preparations for South Africa's participation[9] in the IGY, for which the Government had approved an expenditure of £275 000.

The funds were allocated mainly to the Weather Bureau and universities for programmes in ionospheric physics, oceanography and cosmic rays. The installation of the Minitrack equipment had also begun.

The station was set up with the aid of American equipment supplied by the US NRL, and completed with the assistance of a number of organisations, including the South African Army that supplied a portable generator in case of power failures.

Located at the South African Railways and Harbours Training College at Esselen Park near Johannesburg, the Minitrack would enable the TRL – later renamed the National Institute for Telecommunications Research (NITR) – to provide the US with "major support for [its] satellite tracking programme"[10].

On 4 October 1957, three months after the first IGY events rolled out and while delegations from the US and Russian IGY committees were at a reception at the Russian embassy in Washington, Sputnik-1[11] took to space from the Baikonur launch facility in Russia "without specific advanced warning"[12].

As a technical achievement, Sputnik caught the world's attention and came as a shock to US experts and citizens, who had expected America to be the first to accomplish this scientific feat.

When Sputnik-1 took to space, however, the Americans were still preparing to launch Vanguard-1, while in South Africa operational arrangements for the Minitrack system were being finalised.

Engineers at the CSIR's NITR reacted swiftly when the news broke. With a hastily assembled, "relatively inaccurate radio tracking system"[13] they 'roughly' determined the satellite's orbit within a few days after its launch and continued to track it until the spacecraft's transmitter failed.

By then, they had determined the satellite's orbit with considerable accuracy and gleaned certain facts about conditions in the upper atmosphere.

One of the engineers, Jules Fejer[14], used the data to correctly predict the spacecraft's lifetime and re-entry into the Earth's atmosphere.

His prediction was far more accurate than those made by the Russians, British and Americans.

The achievement earned the CSIR recognition for yet another world-class performance, this time in a new field of science.

The launch of Sputnik-1 changed the course of history. It spurred a revolution in telecommunications and fuelled fierce competition between Russia and America for technological supremacy – a 'space race' that peaked with the Appollo missions and ended only when the

The world's first artificial satellites

Sputnik-1 (Russian), launched 4 October 1957 in a 92.6-minute elliptical orbit around the Earth, weighed 83 kg, carried a thermometer and two radio transmitters that worked for 21 days, and was destroyed 57 days later upon re-entry into the Earth's atmosphere.
Sputnik-2 (Russian), launched 3 November 1957, 4-metre high cone-shaped capsule, carried a telemetry system, programming unit, radio transmitters and a regeneration and temperature control system for a sealed cabin that took the first living animal, a dog named Laika, into space.
Explorer-1 (US), launched 31 January 1958, weighed 13.9 kg, detected the Van Allen radiation belt, returned data for four months until the batteries ran out, and remained in orbit until 1970.
Vanguard-1 (US), launched 17 March 1958, weighed 1.47 kg, first solar-powered satellite, achieved the highest altitude of any man-made vehicle at the time, contains two transmitters, logged 50 years in space in 2008 and will orbit the Earth as the oldest man-made satellite well into the 22nd century.
Explorer-3 (US), launched 26 March 1958, weighed 14.1 kg (8.4 kg instrumentation), spin-stabilised with an on-board tape recorder to provide a complete radiation history for each orbit, decayed after 93 days of operation.

countries co-operated in the Apollo-Soyuz mission in 1975.

Despite an arguably inauspicious start to the year, 1957 stands tall in history as the year in which space exploration became a reality and mankind could finally pursue its fascination with space as 'the final frontier'.

MINITRACK COMMISSIONED

Early in January 1958, with pressure on America to launch its first satellite, engineers from the NRL arrived in South Africa to assist with the commissioning of the Minitrack system in time for the launch of Explorer-1 (1958 Alpha).

The satellite took to space aboard a Vanguard launch vehicle from Cape Canaveral[15] on 1 February 1958, almost four months after Sputnik-1. Six weeks later, on 17 March 1958, the Americans finally launched Vanguard-1C, followed by Explorer-3[16] (1958 Gamma) on 26 March 1958 aboard a Juno 1 launch vehicle.

Having rapidly gained experience in using the Minitrack system, the CSIR Minitrack team accomplished the feat of obtaining radio signals from the satellite before it had completed its first orbit.

During the rest of the IGY and its continuation as the Year of International Geophysical Cooperation in 1959 (IGC-1959), the Minitrack Station at Esselen Park tracked all US satellites and space vehicles launched from Cape Canaveral and transmitting in the 108 MHz band.

In late 1958, following the creation of NASA as the agency to operate the US civilian space programme, the Americans approached the CSIR to also establish a Deep Space Instrumentation Facility (DSIF) in South Africa, to track spacecraft launched to the Moon and distant regions of the solar system.

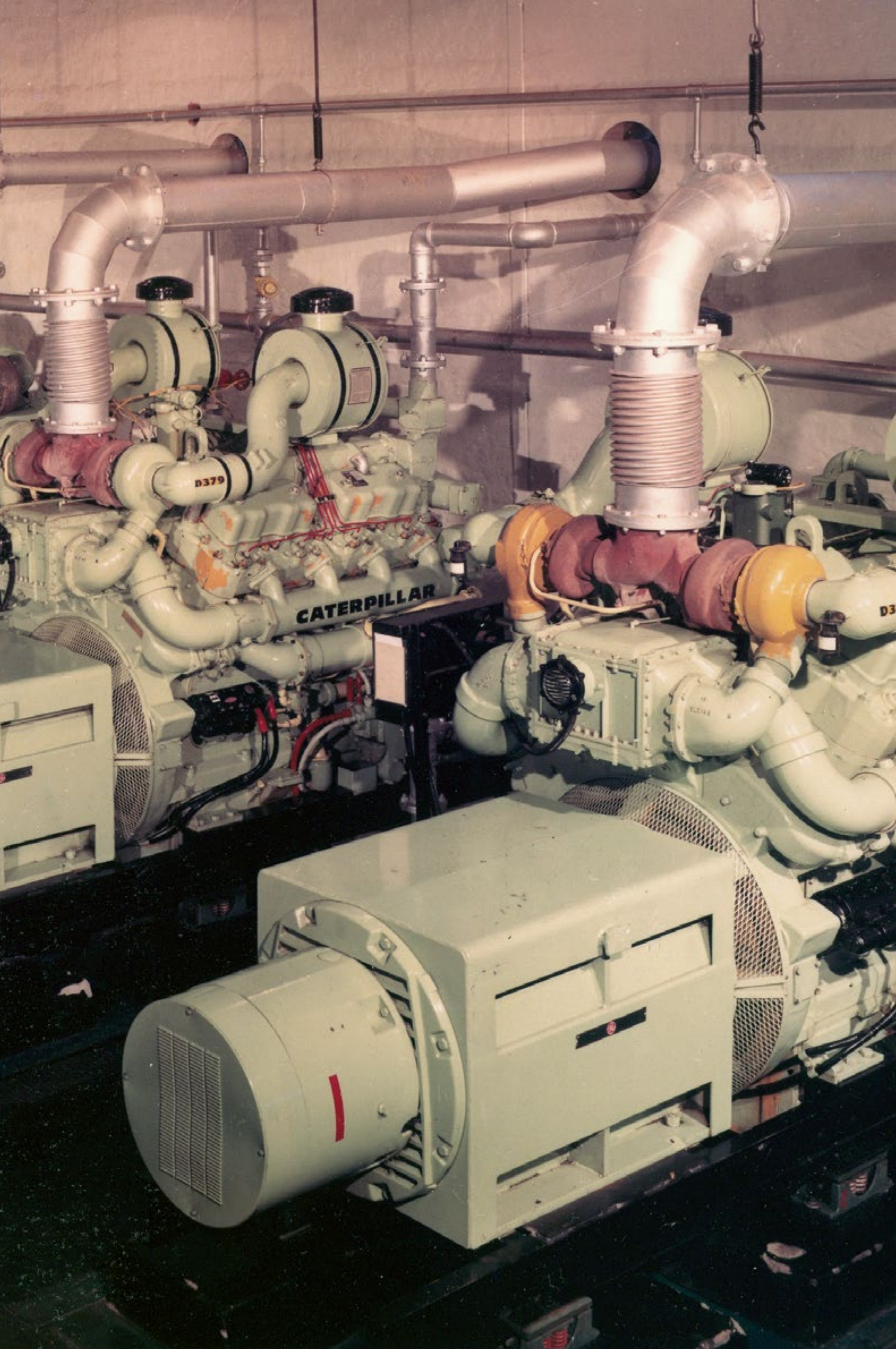
The CSIR-NASA agreement was in line with a decision by the South African and US governments to extend their inter-governmental co-operation after the global co-operation programme in geophysics came to an end in 1959.

The agreement included the establishment of the DSIF – one of only three in NASA's deep space network – and the relocation of the Minitrack Station to the same site. The stations would be managed by the CSIR's NITR, but operate as separate entities.

BEDROCK FOR THE FUTURE

The success with which the Minitrack pioneers at Esselen Park supported the American space programme and the performance of the CSIR engineers who tracked Sputnik-1, laid a firm foundation for the SAC story – a 50-year journey that started at Hartebeesthoek in 1960.

The first 15 years occurred during a golden age in space exploration – one that fostered a culture of innovation worldwide and, for the first time, showed mankind "the Earth as the collective ecosystem that it is"[17].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1960 - 1975

The NASA years

Exploration is in our nature. We began as wanderers and we are wanderers still. We have lingered long enough on the shores of the cosmic ocean. We are ready at last to set sail for the stars.

– Carl Sagan in Cosmos

The CSIR's early entry into space exploration during the late 1950s gained momentum during the first 15 years of the world's space age.

Between 1960 and 1975, a period referred to by SAC stalwarts as the NASA years, the CSIR's National Institute for Telecommunications Research (NITR) operated two satellite tracking stations at Hartebeesthoek under contract to the US National Aeronautics and Space Administration (NASA): the new Minitrack Station (later renamed the Joburg STADAF/STADAN[1]) and a Deep Space Instrumentation Facility[2] (DSIF) or Deep Space Station.

During that time, the so-called 'golden era'[3] of space exploration, both stations were integral to NASA's satellite and spacecraft tracking networks and the US space research programme.

Both stations also met an untimely demise when NASA ceased all its operations in South Africa in 1975 and moved out of the country.

INTERNATIONAL RELATIONS

Two events occurred at the beginning of 1960 that greatly increased South Africa's international relations in science[4], including in the new scientific field of space exploration.

South Africa's membership of the International Council for Scientific Unions (ICSU) automatically made it a member of the International Committee on Geophysics (CIG).

The committee was established early in 1960 to continue the activities of the Year of International Geophysical Cooperation (IGC - 1959). As the country's CIG representative, the CSIR was responsible for co-ordinating the country's oceanic, Antarctic and space research activities.

More or less at the same time, the South African and US governments agreed to extend their IGY and IGC (1957-1959) intergovernmental collaboration, specifically South Africa's participation in the US space research programme. This paved the way for the CSIR-NASA agreement to establish a "combined[5] Space Probe and Near Satellite Radio Tracking Station" in South Africa.

The NITR was tasked with the implementation. The 'combined station' would take shape as two major tracking installations located at the same site and managed by the NITR, but as separate entities.

A Deep Space Station would track space probes used for lunar and interplanetary exploration, while a new Minitrack system would be installed to replace the system at Esselen Park near Johannesburg. The Minitrack Station would track artificial Earth satellites used to study the Earth's environment.

AN IDEAL LOCATION

Plans for the installation of the Deep Space Station and new Minitrack system moved ahead rapidly during 1960. Willem Botha and Doug Hogg, both involved in the Minitrack Station at Esselen Park, were tasked to find a site 'without man-made interference' within driving distance from Johannesburg.

They scoured the countryside and identified a 500 ha tract of land on the Farm Hartebeesthoek in the Magaliesberg mountain range. Situated about 40 km north-west of Johannesburg in a pristine valley uninhabited since the days of the

Voortrekkers[6], the site had no direct line of sight of potential noise sources.

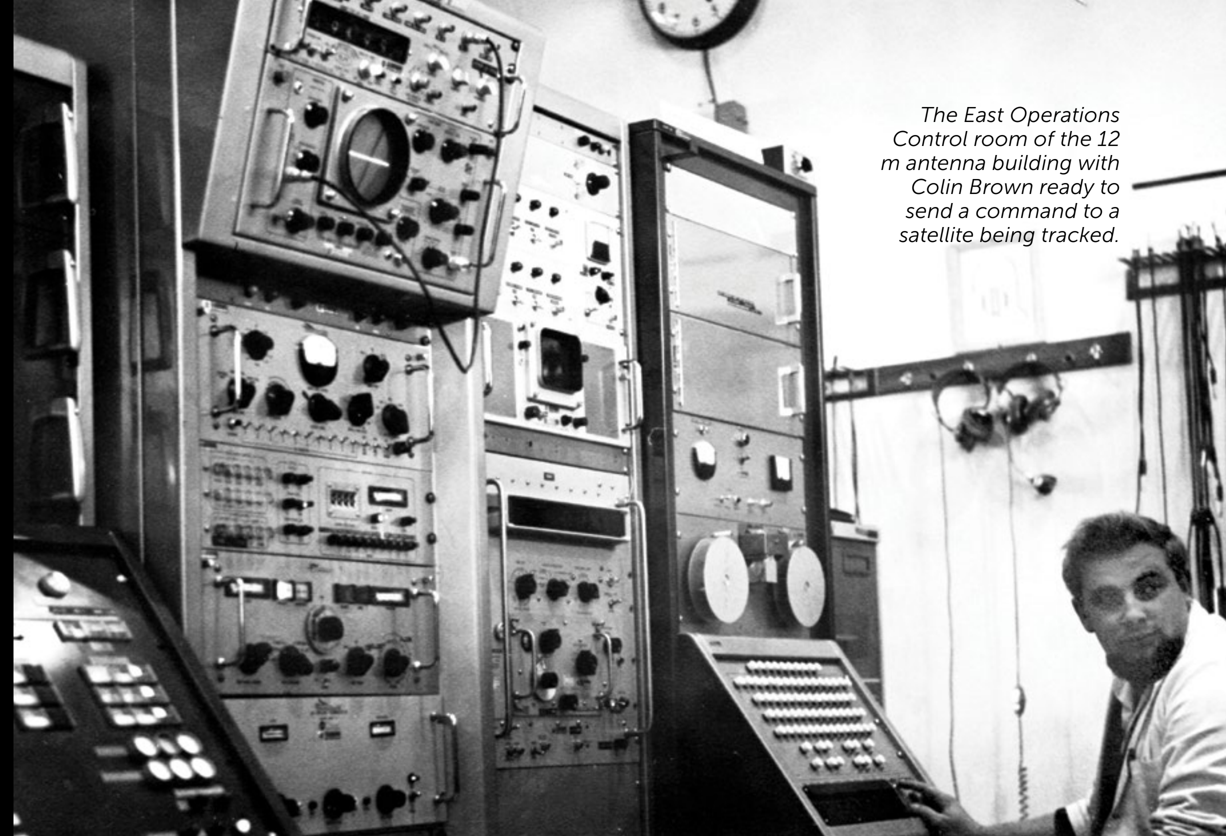
Representatives from NASA's Jet Propulsion Laboratory (JPL) responsible for the US deep space programme visited the country to approve the site and, in September 1960, the South African government bought the land.

Not long thereafter, the land was transferred to the CSIR and the Minitrack Station at Esselen Park moved to Hartebeesthoek on a plateau not far from the site identified for the Deep Space Station.

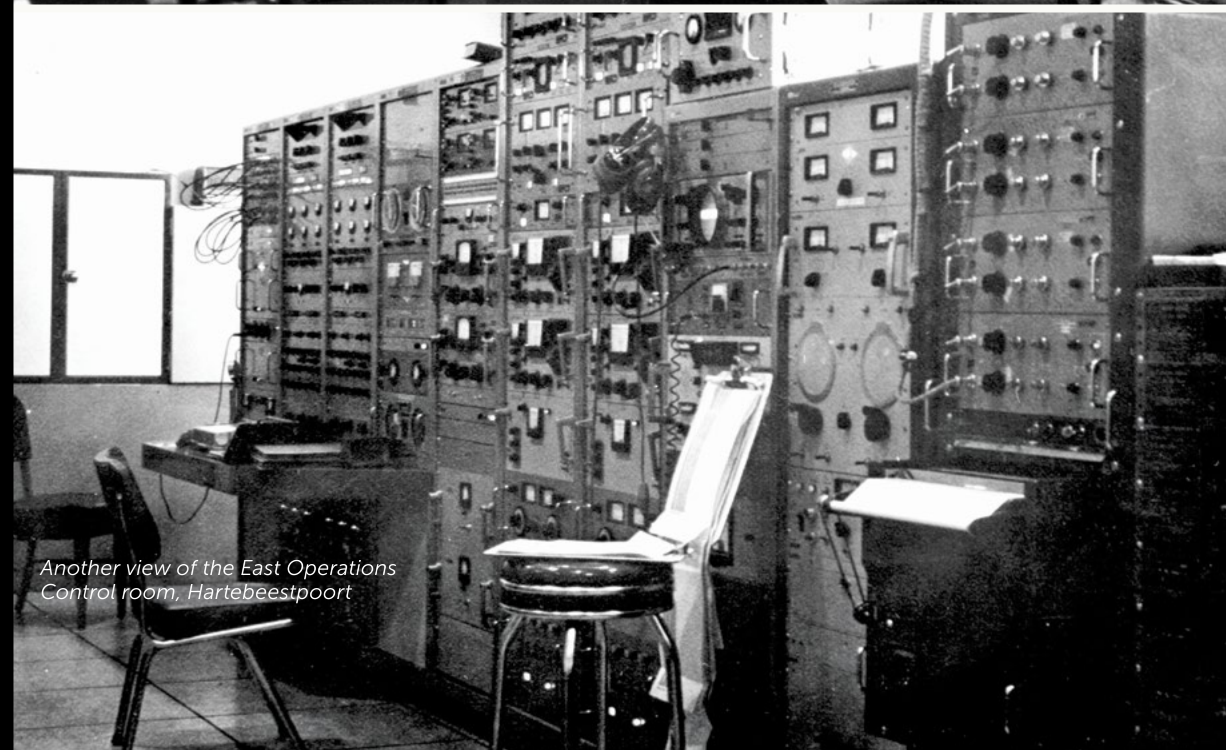
While at Esselen Park, the Minitrack Station had played a significant part in the US low-Earth observation research programme, having tracked over 7 000 satellite passes and recorded more than 2 000 magnetic tapes in less than two years.

PASSIVE COMMUNICATIONS SATELLITES

Shortly after its relocation at Hartebeesthoek in the late 1960s, the Minitrack provided technical, maintenance and logistical support for NASA's first two Echo balloon satellites.



The East Operations Control room of the 12 m antenna building with Colin Brown ready to send a command to a satellite being tracked.



Another view of the East Operations Control room, Hartebeestpoort

Timeline

1960 Hartebeesthoek selected for NASA's tracking stations. SA government bought the land and transferred it to the CSIR Minitrack moved from Esselen Park to Hartebeesthoek.

1961 Minitrack and Deep Space Stations commissioned. Hartebeesthoek inaugurated as the South African Radio Space Research Station (RSRS).

1963 Yagi legacy antennas upgraded. First geostationary satellite launched.

1964 12 m hydraulic X/Y mounted parabolic antenna installed. New building completed to house telemetry equipment and staff.

1970 CNES contract to manage Paardefontein operations.

1972 Joburg STADAN became one of the busiest stations in the GSFC network.

1973 NASA informed CSIR of plans to close the stations. Mariner-10 final mission.

1975 NASA ceased operations in South Africa. Both tracking stations at Hartebeesthoek closed down.

South African context

During the 1960s, following South Africa's independence as a republic in 1961, the country experienced an economic boom despite growing international criticism of the government's segregation policies. High rates of return on investments and a seemingly stable political climate attracted foreign investment, which almost doubled between 1963 and 1972. Towards the mid-1970s, however, South Africa's shaky political foundation was revealed when wildcat strikes escalated and spread throughout the country. Significant pressure was brought to bear on foreign companies to withdraw their activities from the country.

The 30 m Mylar spheres were launched into low-Earth orbits of up to 1 500 km and used as passive reflectors of high-frequency radio signals in space.

As the first space-based satellite communications system, the balloons produced good quality, two-way voice communications over a distance of nearly 80 000 km between America's East and West coasts.

Although an acknowledged feat of radio engineering, the passive telecommunications principle of the balloons was soon replaced by active satellite communications systems.

MINITRACK COMMISSIONED AND HARTEBEESTHOEK INAUGURATED

In August 1961, with the installation of the Deep Space Station and new 136 MHz Minitrack system at Hartebeesthoek completed, the two stations were commissioned and the original Minitrack installation at Esselen Park closed down.

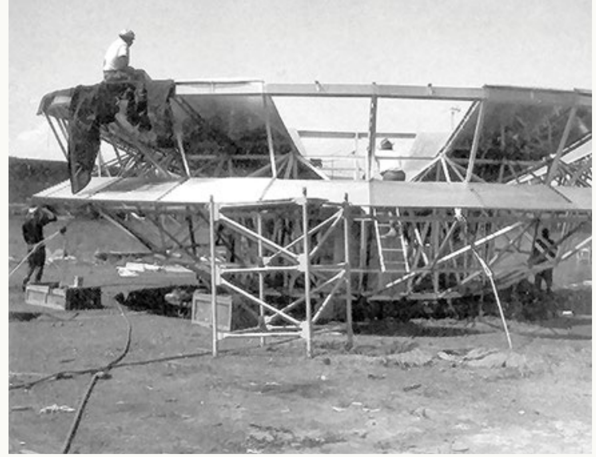
The stations were fully funded by NASA in fulfilment of its contract with the CSIR and manned entirely by South African crews. The US space agency regarded the stations as "important to its peaceful investigation of outer space" and, because of their geographical location, essential to its global deep space and low-Earth orbiting spacecraft tracking networks.

A month later, in September 1961, the CSIR inaugurated Hartebeesthoek as the South African Radio Space Research Station (RSRS). Some 300 guests attended the event, among them senior representatives from NASA and the JPL, as well as many "prominent men in science, industry and engineering in South Africa"[7].

NEW CAPABILITIES AND INTERESTING ASSIGNMENT

With its relocation at Hartebeesthoek and new 136 MHz radio interferometer tracking system, the character of the Minitrack Station changed completely.

NASA's upgrade of the Minitrack systems from 108 MHz to 136 Mhz at all its stations had transitioned the Minitrack focus from tracking satellites and determining their orbits, to receiving and recording telemetry[8] and collecting scientific data from NASA's 'second generation'[9] low-Earth



The installation of the 12 m steerable, parabolic data acquisition antenna at the Minitrack Station at Hartebeesthoek in 1963/64. The antenna was one of only three installed by NASA around the globe, the other two in Chile and Australia.

orbiting satellites. With the new system, using Yagi arrays and seven-channel recorders, the station could track and receive telemetry from orbiting satellites, as well as send up commands to the new, more sophisticated satellites that could be commanded from Earth.

Within the first six months of its commissioning at Hartebeesthoek, the Minitrack Station had tracked 300 passes, which had yielded about twice as many data messages.

One of the Minitrack's first interesting and demanding telemetry assignments at Hartebeesthoek was on the 1961 Explorer XII S-3[10] spacecraft, which was launched in a highly elliptical orbit of between 293 km and 77 249 km.

This placed the satellite above the local horizon for up to 17 hours at a time and significantly extended the data recording periods. About 120 tapes were used per satellite pass and some 1 400 reels of tape during the satellite's lifetime, which delivered well over 700 hours of data. The data provided scientists with a much clearer picture of trapped radiation regions. The Minitrack's successful mission support boded well for its involvement in NASA's pending communications satellite programme, set to involve active satellites in low and synchronous orbits.

The CSIR regarded the programme as being of great practical value in paving *"the way for the first commercial space communications systems"*[11].

During the CSIR's 1962-63 financial year, the South African government bought a further 2 335 ha of land in the Hartebeesthoek area to conserve the suitability of the site in terms of radio interference.

A number of new installations at Hartebeesthoek were also made possible by amendments to existing CSIR-NASA contracts.

The new Minitrack installations included a Range and Range Rate[12] system and 12 m steerable parabolic data acquisition antenna.

A new telemetry complex was erected near the Minitrack building and an advanced tracking system was installed to supplement the Minitrack's existing interferometer system. At the end of 1962, NASA requested the RSRS to make the Hartebeesthoek facilities available at short notice for the installation of a Syncom system, to obtain telemetry from and as a back-up for the planned Syncom programme[13]. NASA had contracted the Hughes Aircraft Company for the installation.

MINITRACK ACKNOWLEDGED

By 1963, the Minitrack's recorded amount of telemetry data had increased from almost nothing to between 10 000 and 30 000 minutes per month, while tracking data virtually trebled.

Due to its location, for a brief period during that time, the station also recorded a quarter of all telemetry data recorded by all the Minitrack Stations.

At that time the Minitrack had, since its inception in 1958, tracked some 8 917 satellite passes, dispatched 1 350 tracking-data messages and obtained 115 photographic plates of three satellites.

During a function at Hartebeesthoek on 31 January 1963 to celebrate NASA's 5th anniversary in space research, the US Embassy acknowledged the Minitrack Station's significant role in the American space programme.


12 m antenna


Yagi antenna


Generator control panel


Diesel generator

THE FIRST GEOSYNCHRONOUS SATELLITES

The end of January 1963 also saw the completion of the Syncom system at Hartebeesthoek. This enabled the station to obtain telemetry during the launching of the satellites and serve as a back-up command facility to the primary station in West Africa, which provided TT&C support for the Syncom programme, should it fail to control the satellites or be out of range.

Syncom-1 was intended to be the world's first geosynchronous[14], active-repeater communications satellite. During its launch on 14 February 1963, the Minitrack team was on standby[15] to use the interferometer system to determine when to fire the apogee[16] motor that would place the satellite in its 24-hour orbit. About 19 seconds after the motor was fired, the signal was lost and the satellite fell silent.

The failure was ascribed to an electronics fault and telescopic observations confirmed that the satellite had been in an orbit for almost 24 hours at a 33° inclination. The Minitrack's unscheduled, but critical recording of telemetry during the event is reflected in the Syncom story. Due to the availability of the data, Syncom-2 was launched successfully as planned on 26 July 1963, as the world's first geosynchronous satellite.

Placed in a geostationary orbit[17] of approximately 36 000 km above the Earth's equator, the satellite followed the direction of the Earth's rotation and would have appeared stationary in the sky to ground observers. The main advantage of satellites in a geostationary orbit is that their signals can be received continuously by ground-based facilities situated anywhere in an entire hemisphere.

A month later, President John F Kennedy in Washington DC telephoned Nigerian Prime Minister Abubakar Balewa on board the USNS Kingsport docked in Lagos Harbour. It was the first live two-way call between heads of government by satellite, with the Kingsport acting as a control and uplink station.

ATTEMPT AT RESUSCITATION

Another interesting and unusual role for the Minitrack Station that year was the attempt to resuscitate Telstar-1[18], a low-orbit, active-repeater satellite. The transmitter on the spacecraft had failed early in 1963 after having been in operation for several months. Engineers at NASA thought that high radiation levels at low altitude had led to the failure and wanted to bring it back into operation through transmitting certain commands.

Since the highest part of the Telstar-1 orbit was over South Africa, the Minitrack Station was chosen to assist with the resuscitation. Unfortunately, the station's efforts met with no success. Similar procedures attempted at a later stage from the US eventually restored the satellite to operation. The remarkable achievement illustrated "the advanced state of satellite technology"[19] at the time.

CAPABILITIES AND FACILITIES EXTENDED

During the rest of 1963, new equipment was added to the Minitrack Station, staff facilities were improved and the number of staff increased from 21 to 43. The continued addition of technical equipment at the station required an increase in capacity. The RSRS launched a recruitment campaign that continued for a number of years, until the equipment required had been installed.

Generator house (Genhouse) main control panel

Engineers and technicians were given opportunities to visit the Goddard Space Flight Centre in the US for training on new equipment. The reported results were gratifying[20] in significantly increasing the TT&C capabilities at the station. The construction of a new building to house all the telemetry equipment and Minitrack staff and the installation of a new 12 m parabolic antenna were well-advanced.

The 12 m X/Y-mounted antenna had both 136 MHz and 400 MHz reception and mono-pulse tracking capabilities. It was one of three that NASA was installing at stations, located some 120 degrees apart in longitude, to track their Interplanetary Monitoring Probes[21] (IMPs). The probes were launched in highly elliptical orbits, with an apogee (point furthest from the Earth) beyond the Moon's orbit. Continuous receipt of data from the IMPs required at least three large antennas that could detect and amplify very weak signals over great distances.

The Minitrack at Hartebeesthoek shared the distinction of being one of the three stations selected for the installation of a 12 m antenna. The other two were the Woomera Station in Australia and the Santiago Station in Chile.

In December 1963, the newly tarred road that connected Hartebeesthoek with the Krugersdorp-Hekpoort road was opened.

The road, built by a contractor to the former Transvaal Provincial Administration, greatly improved access to the RSRS and the tracking stations. Reportedly, the tarred road also "reduced the accident hazard" that was always a concern with the old gravel road.

MINITRACK RENAMED

The expansion of the Minitrack Station into a Minitrack 'complex', as part of the installation of the new 12 m hydraulically-driven parabolic antenna, was completed by mid-1964. S-band reception and tracking capabilities, as well as two 5 kW 148 MHz, each with its own antenna, were added to the antenna shortly after the installation.

The additions were intended for data acquisition on 'second generation' satellites in NASA's orbiting observatory[22] series. The observatories, such as the Orbiting Astronomical Observatory[23] (OAO), Orbiting Geophysical Observatory[24] (OGO) and Orbiting Solar Observatory[25] (OSO), consisted of large and

The Minitrack station

By the time the Minitrack Station – the only one of its kind on the African continent – had been relocated from Esselen Park in Johannesburg to the CSIR Hartebeesthoek site in 1960, it had already tracked over 7 000 satellite passes and recorded over 2 000 magnetic tapes. Early in the 1960s, the tracking system was upgraded from 108 MHz to 136 MHz with additional antenna pairs that enabled the observation of both polar and equatorial satellite orbits.

This enabled the station to receive and record satellite telemetry data on magnetic tape to deal with the rapidly increasing number of satellites that were being launched at the time.

Tracking the S-3

The complex 1961 Explorer XII S-3 satellite was instrumented to study solar wind, magnetic field, particles in space and trapped radiation regions. Launched in a highly elliptical orbit, the satellite was visible above the local horizon for up to 17 hours at a time.

The Minitrack had to run two 7-channel tape recorders alternatively at high tape speeds to record all the data – up to 120 tapes per single satellite pass.

The S-3 revealed much of the trapped radiation regions and was one of the most successful satellites launched at the time.

To reach for new heights and reveal the unknown so that what we do and learn **will benefit all humankind.**

- NASA vision

heavy satellites with science payloads, used for astronomical, geophysical and solar observation. In 1964 all the Minitrack Stations in the NASA network were renamed as Satellite Tracking and Data Acquisition Facilities (STADAFs).

The Minitrack Station at Hartebeesthoek became known as Joburg STADAF. The centre of its activity was the new building called the Data Acquisitions Facility (DAF), which became operational in August 1964.

Minitrack staff and all the telemetry equipment were relocated to the DAF, which had been built adjacent to the 12 m antenna and approximately 100 m from the original Minitrack Station.

It consisted of two large operations rooms, a communications centre, storage space and a radio workshop.

Since the DAF became operational, 170 000 minutes of data were recorded from 22 different satellites and 460 satellite passes were successfully tracked with the 12 m antenna. During the same period, the Minitrack system, which had remained in the old building not far from the newly constructed DAF building, tracked 2 400 passes.

MANNING THE STATION

By the end of 1966, the Joburg STADAF was operational 24 hours a day, seven days a week to manage an increasing workload.

The challenge was to ensure that operations ran smoothly, with a focus on effectiveness and efficiency.

Satellites were tracked with the Minitrack interferometer system in the old Minitrack building, while the 12 m and several directional antennas were used for TT&C activities carried out in the DAF building.

A Station Manager (Willem Botha during the NASA years and until 1994) was in charge and the station was manned continuously by four operational shifts, each with a Shift Supervisor and two deputies. Each shift consisted of 17 electronics technicians and operators, while a separate group was responsible for maintenance.

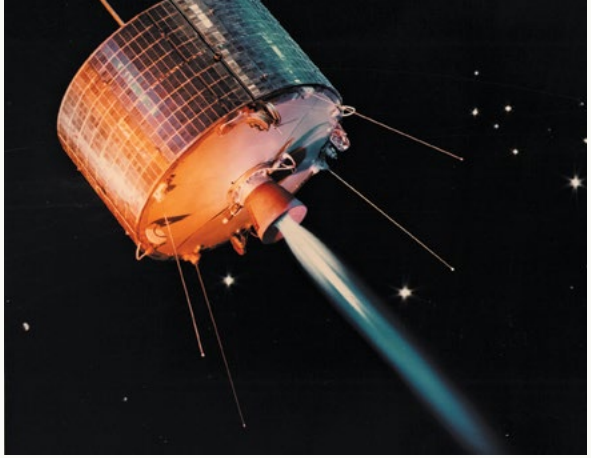
Day shifts were from 09:00 to 17:00 and nightshifts from 17:00 to 09:00 the next morning. Nightshift staff had a four-hour rest period each and could use the bunk house to catch some sleep. The system worked well and remained in place until NASA disinvested in 1975.

Three or four Telex operators were allocated to each shift to man the Communications Centre. These operators were supremely skilled typists and responsible for all incoming and outgoing traffic, as well as initiating voice contact with GSFC when required.

SECOND GENERATION SATELLITES

The launch of the first 'second generation' satellite, the Orbiting Geophysical Observatory (OGO), introduced the Joburg STADAF to a new type of mission.

The OGO was the first satellite to radiate information on 400 MHz and the station had to track, command, record telemetry data (TT&C)[26], and pass 'quick look'[27] information on certain experiments and engineering parameters to the control centre at the GSFC via voice circuit and telex post-pass.



Intelsat-1 (Early Bird) (left), designed and built at the Hughes Aircraft Company for COMSAT, was the first operational commercial satellite to provide 'live-via-satellite' regular telecommunications and broadcasting services between North America and Europe.

Syncom-1 (right), the first geosynchronous satellite, stopped sending signals a few seconds before it reached its final orbit. Syncom-2 was successfully orbited and transmitted coverage of the 1964 Olympic Games in Tokyo to stations in North America and Europe.

Based on the information, the GSFC could take real-time decisions and issue new instructions to the station. The station also participated successfully in tracking Intelsat-1, the first International Telecommunications Satellite[28] that was launched in April 1965.

Popularly known as Early Bird, the satellite was history's first commercial communications orbital satellite and made the first live television broadcast of the splashdown of a manned spacecraft possible, when Gemini-6 returned to Earth in December of 1965. The tracking was carried out by both the Minitrack system and the 12 m antenna, which made it possible to verify the effect of the successful firing of the apogee motor that placed the satellite into a synchronous orbit.

The Joburg STADAF TT&C team also used the station's optical tracking system to track GEOS-A[29]. Launched in November 1965, the gravity-gradient-stabilised solar-powered satellite was designed exclusively to study the Earth's magnetosphere from a geostationary orbit and determine the structure of the Earth's gravity field (which affected the orbits of satellites). The satellite was the first successful, active spacecraft of the American National Geodetic Satellite Programme.

TECHNICIAN TRAINING SCHEME

As the workload at the Joburg STADAF increased, it become evident that existing local resources could not supply the steady flow of suitably trained technicians needed at the station.

The RSRS at Hartebeesthoek collaborated with the Witwatersrand Technical College to develop a training scheme for technicians, to help the station meet the future need for additional staff.

Initially fully funded by NASA, the four-and-a-half year 'sandwich' course consisted of six months of formal instruction annually at the College, followed by six months practical training at Hartebeesthoek.

The course syllabus was based on existing training material at the College, but included subjects suited to the needs of the tracking station. The former Department of Education, Arts and Science approved the syllabus for the course and successful candidates received a National Diploma for Technicians in Space Communications.

The students from the first course that started in 1964 were all transferred to the Deep Space Station for their practical studies at the RSRS, but some of those from the second course in 1965 and all students from the third course in 1966 were transferred to the Joburg STADAF for their practical studies, and became useful members of tracking shifts at the station.

COMMENDABLE PERFORMANCE

By the mid-1960s, the Joburg STADAF team had tracked 31 different satellites, including 13 new satellites, such as the orbiting observatories. Data acquisition had increased significantly, as had the total amount of time spent tracking satellites and recording data.

The station staff was keenly aware of the complexity of satellites and the cost of each second of data transmitted to a tracking station. An incorrect command or one sent at the wrong time could adversely affect or even destroy the scientific payload aboard a satellite.

Control room operators were expected to do the right thing at the right time, all the time.

Spacecraft Tracking and Data Acquisition Network (STADAN)

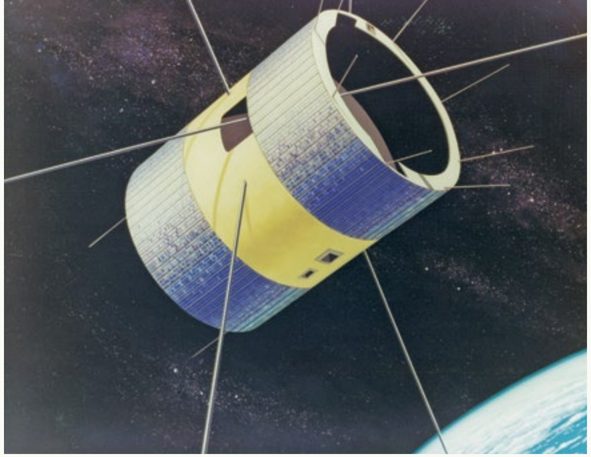
Moving beyond Minitrack, The Goddard Space Flight Centre (GSFC) was put in charge to develop an upgraded network to provide ~15% orbit coverage for Earth-orbiting robotic satellites.

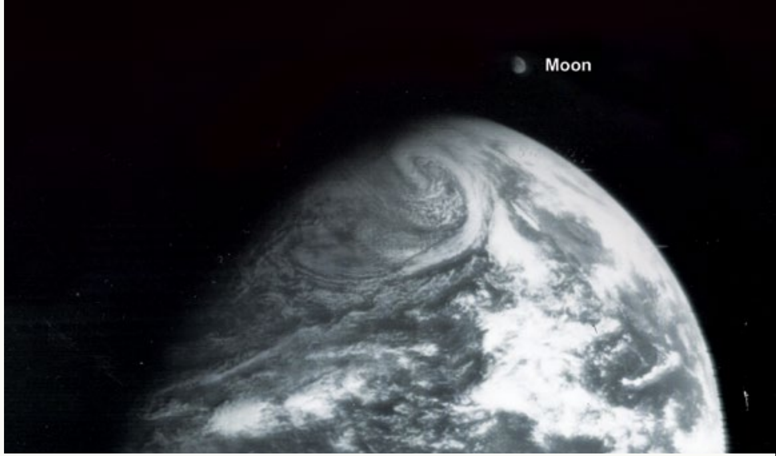
Antennas at the Minitrack sites in North and South America were upgraded and new, full TT&C sites added in North/South America, Africa, Australia, Europe and Asia. The initial network of 14 stations increased to more than 20 stations during the 1960s and became known as the Spacecraft Tracking and Data Acquisition Network (STADAN).

STADAN stations used arrays at 136 and 400 MHz and parabolic dish antennas up to 12 m in diameter to support higher data rates at VHF, UHF, L-Band & S-Band (2,100 MHz).

Similar to the Minitrack system, the STADAN stations could track and receive telemetry from orbiting satellites. Additionally, they could send commands as the new and more sophisticated satellites could be commanded from Earth.

Over time the network transitioned from a Minitrack focus on tracking satellites to determine their orbit, to a focus on collecting scientific data.





The expectation of a consistently faultless performance was non-negotiable, pertained to all staff and, over time, became ingrained as a work ethic at the station.

Appreciation for this approach became apparent when space programme and project managers at space control centres in the US acknowledged the quality, reliability and accuracy of the tracking information and telemetry data received from Hartebeesthoek. Increasingly, the station's performance in support of NASA's space research programme was noticed and acknowledged as commendable.

ADVANCED TELECOMMUNICATIONS SATELLITES

The design of NASA's ATS communications satellites provided sufficient space on board for an experimental imaging system. Data from the system provided meteorologists with the first cloud-cover images over an entire hemisphere.

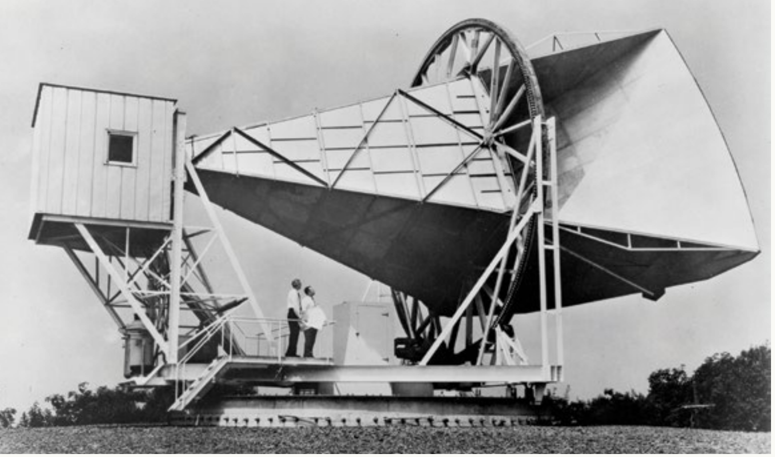
Today, images from dedicated meteorological satellites are used as primary meteorological data and with great success in early storm warnings.

The Joburg STADAN provided tracking, telemetry and command (TT&C) support for ATS-1, launched in December 1966 and stationed in orbit above the Pacific Ocean near Christmas Island.

Following the station's successful support of ATS-1, NASA scheduled the Joburg STADAF for early launch and orbit phase (LEOP) support for ATS-2 and ATS-3, respectively launched in April and November 1967.

The successful LEOP support for ATS-3 provided the world with the first colour photos of Earth taken from a synchronous altitude five days after its launch. The satellite was in service for 34 years as the oldest active communications satellite before it was finally decommissioned in 2001.

Benefits derived from the ATS-3 included regular communications services to sites in the Pacific basin and Antarctica, as well as emergency communications links during natural disasters, such as the Mt St Helens eruption in 1980 and the earthquake in Mexico City in 1985. The 'real-time' monitoring and data transmission of scientific observations and control systems on board satellites to space control centres in the US had become



The ATS-1 satellite (left) carried a black-and-white weather camera which, on 22 December 1966, captured the first image of Earth and the moon together (far right) from a geosynchronous orbit when it was 35 888 km from Earth and 434 529 km from the moon.

The 15 m Holmdel horn antenna (far left) was built in 1959 to detect radio waves that bounced off NASA's metalised Echo balloon satellites (satelloons) (right) that acted as passive reflectors for microwave signals, while communications signals were bounced off them from one point on Earth to another.

critically important for them to rectify malfunctions. Space station operators often praised the Joburg STADAN for its performance in this regard.

GEODETIC SURVEY EXPERIMENT

In the late 1960s, the Joburg STADAN participated in a geodetic experiment for the US Coast and Geodetic Survey (US CGS).

Ike Marais and Vidi la Grange spent three months in Beltsville, just outside Washington, to become familiar with the geodetic tracking system before it was shipped to South Africa.

The equipment was installed in an optical tracking station established at Hartebeesthoek for the duration of South Africa's participation in the experiment, from March 1968 to December 1969. The Joburg STADAF seconded a small number of staff to man the station. During the entire period the equipment worked flawlessly and only one operator error occurred.

The station was one of 45 distributed globally to photograph passive balloon satellites[30] (satelloons) against a star background. The stations were positioned so that at least three could observe and photograph each satellite pass simultaneously. Three balloons folded inside a canister, Echo-1 and Echo-2 (each with a diameter of 25 m) and Pageos (30 m diameter), were launched to an altitude of approximately 4 200 km and inflated in orbit.

The balloons were made of Mylar, a highly reflective, very thin and extremely strong plastic. Their high reflectivity and large size made them the brightest objects in the sky, apart from the Moon. Each station had a very sophisticated optical Wild camera that was mounted on a pedestal and positioned at an accurately surveyed position. The reflected light from the satellites as they moved through the camera's field of view were recorded on photographic glass plates, developed and shipped to the US CGS.

The photographic plates were archived in Rockville, Maryland, just outside Washington DC, and analysed by a group of experts. With accurate information about the orbital position and time of each satellite pass, they used triangulation to determine the position of the cameras photographing the pass and monitor even very small changes in their relative positions.

Data analyses indicated that Africa and South America were actually 10 cm further apart than generally accepted. The discrepancy was ascribed to continental drift, a theory that was first postulated during the 1950s.

History would record the Joburg STADAF as a participant in the world's first confirmed measurements of continental drift – the movement of the Earth's continents on tectonic plates by appearing to drift across the ocean bed.

MODIFICATIONS AND INCREASED CAPABILITY

The modifications to the Joburg STADAF were completed in the late 1960s when the STADAFs became STADANs (fully fledged stations rather than facilities). With the modifications, the Joburg STADAN was the only station in the NASA network that could receive telemetry and send commands to the malfunctioning ATS-5[31] satellite at the time.

Launched in August 1969, the ATS-5 was one of six satellites developed to test new technologies and techniques for communications, meteorological and navigation satellites. When the apogee kick motor

During April to June 1971, the Joburg STADAN was rated the top performing tracking station in the NASA network with an operational efficiency of 99.94%.

fired to place the ATS-5 into a geostationary orbit, the satellite went into an unplanned flat spin.

After a brief recovery and spinning about the correct axis, the satellite started spinning in the wrong direction and the gravity gradient booms could not be deployed.

The team at the Joburg STADAN transmitted critical wideband data from the satellite successfully, via an experimental communications satellite, to the GSFC Control Centre in Maryland. Despite continued rescue attempts, the ATS-5 could not be recovered and was retired in March 1984 after nine of the thirteen experiments on board had returned useful data.

CAPABILITIES INCREASED AND CAPACITY STABILISED

In 1969, the new undersea cable via Ascension Island greatly improved terrestrial communications at Hartebeesthoek. Reliable communications circuits increased efficiency at the Joburg STADAN and enabled high-speed data transfer to the GSFC Control Centre. This proved particularly valuable during the Bios-D32 mission when the station had to report on the physical condition of the orbiting pigtail monkey and could do so in real-time.

By the turn of the decade leading into the 1970s, the successful recruitment of staff at the RSRS ensured that, for the first time in many years, all posts were filled at the Joburg STADAN. A year earlier NASA had capped the number of staff at the station at 131. Despite increasingly heavy workloads, the station had sufficient capacity for its 24-hour operations.

Technical staff at the RSRS, including some from the Joburg STADAN when the workload allowed, continued their training visits to the US under the NASA/CSIR exchange programme agreement, while NASA technicians spent time at Hartebeesthoek.

The local technician training courses also continued, despite a concern that many students were reluctant to serve their two years at the station after graduating. Reasons given for this included higher pay in industry and a perceived under-utilisation of their newly gained knowledge and skills in the work at the station. The costs of the training programme, previously borne by NASA alone, became a shared expense between NASA and the CSIR.

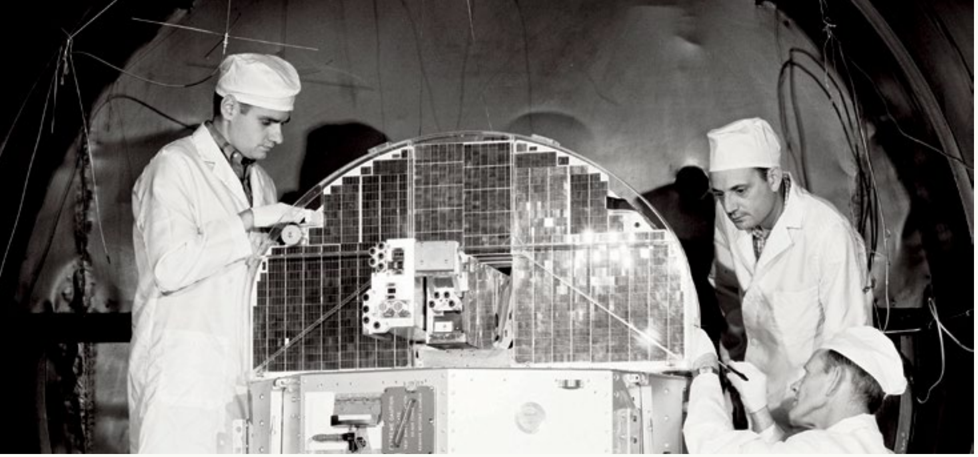
FOREIGN VISITORS, MODIFICATIONS AND A TOP RANKING

The start of the second decade of space exploration brought with it foreign visitors, major modifications to align the station with the latest STADAN standards, overseas training for staff and a French connection – all geared toward ensuring that, despite a 10% increase in its workload and an increasingly heavy tracking schedule, the Joburg STADAN would retain its reputation for efficiency and reliability.

The visitors included representatives from NASA and GSFC to discuss contracts, budgets and operations. Several members of staff went to the US for three-month training courses and the French space agency negotiated a contract with the CSIR to take over their satellite tracking operations at Paardefontein near Pretoria.

The French connection

The French Space Agency, CNES (Centre National d'Etudes Spaciales), had established a satellite tracking station at Paardefontein north of Pretoria in the 1960s and contracted a French company, Sodeteg (Société d'Etudes Techniques et d'Entreprises Générales) to manage the station.



NASA's Orbiting Solar Observatory (OSO-1) (left), built in the early 1960s, was the first satellite to undertake a scientific examination of the Sun from space. Eight OSO space probes were launched into Earth orbit between 1962 and 1975.

A Delta rocket launched OSO-8 (right) on 21 June 1975 from Cape Canaveral, Florida.

The Sodeteg management option eventually became too expensive and, during the 1970-71 financial year, the French space agency approached the CSIR to take over the operation of the station under contract.

Before taking a decision or assigning yet another task to the NITR, which already managed all the RSRS activities at Hartebeesthoek, the CSIR asked the Joburg STADAN to assess the operations at Paardefontein.

Willem Botha, Dough Hogg and Piet van der Westhuizen† visited Paardefontein and were impressed with the satellite tracking and weather balloon activities at the station.

Satisfied with their report, the CSIR concluded the contract with CNES, and the NITR became the operating agency at Paardefontein to provide CNES with satellite tracking support services.

Jack Goddard, at the time employed as the Deputy Station Manager at the Deep Space Station at Hartebeesthoek, became the station manager at Paardefontein.

Exceptional performance

The early 1970s was an exceptionally busy time for the Joburg STADAN. With the modifications completed (three separate tracking and two command systems), operations were easier and the station could track three different satellites and command two at the same time.

With the increased workload, the capacity of operators and technicians was stretched to the limit. At times, only six people could be scheduled for a nightshift and had to manage up to 46 passes.

The extended capabilities of the 12 m antenna to receive S-band transmissions at 2.2 to 2.3 Ghz enabled the station to track new generation satellites and, for the first time, launch vehicles and also transmit data in real-time to the US Control Centres.

The new capabilities meant voice contact with the various centres, continuous data transmission throughout satellite overflights and sending commands to satellites at short notice. The increased complexity of the station's mission support services did not affect the excellent operational results it consistently achieved.

During April, May and June 1971, the Joburg STADAN was rated the top performing station in the network, with an operational efficiency of 99.94% in the execution of over 9 000 tracking, telemetry and command assignments.

NOVEL ASSIGNMENTS AND EMERGENCY ASSISTANCE

With its enhanced receiving and data decommutating capabilities, the Joburg STADAN supported some of NASA's more novel launch operations. One such assignment was the OSO-7, one of NASA's Orbiting Solar Observatory (OSO) programme science satellites intended to study the Sun.

Launched in September 1971, it was nearly lost about seven seconds before the second engine cut-off, due to a loss of hydraulic pressure in the second-stage guidance control system. NASA controllers had 12 hours to recover the spacecraft before it lost power and commandability.

Finally, with only an hour or two left, NASA abandoned caution and "started slewing" the satellite. Through skill and luck they regained control

of the satellite. The Joburg STADAN, with some of the other stations in the network, continuously submitted real-time telemetry data to NASA's Control Centre, which assisted in the recovery of the satellite.

Another interesting assignment was the regular tracking and telemetry recordings of the ALSEPs[33], the five lunar experiment packages with scientific instruments that had been left at the landing sites on the Moon by the five Apollo missions after Apollo 11. No difficulties were experienced in configuring station equipment to receive the five different frequencies of the packages simultaneously.

The station also tracked and supported the launch of the RAE-B[34] satellite on 10 June 1973. As the largest spacecraft ever built, the RAE-B was used for long-wave radio astronomy research, which included astronomical measurements of the Sun, the planets and the galaxy.

The Joburg STADAN was commended for its prompt reaction in providing emergency support to reactivate a Nimbus satellite, which materially extended the life of the spacecraft after it had shut down due to a disruption to its power balance.

AN UNTIMELY END

A threat of closure had stalked the Joburg STADAN Station since the early 1970's, when South Africa's political turmoil escalated and pressure was brought to bear on NASA to pull out of the country. The existence of an American government facility in a country that practiced apartheid made NASA's budget a focal point of Congressional debate.

Each year a small but growing number of lawmakers proposed omitting funds for operating the Johannesburg station from the space agency's authorisation. Political protagonist US Senator Charles Diggs visited Hartebeesthoek to assess the situation, he also threatened NASA with budget cuts should the agency continue to operate in South Africa.

In July 1973, at the height of activity for both the Joburg STADAN and Deep Space Station, NASA advised the CSIR that for technical reasons it would phase out its South African facilities by the end of 1975. The Deep Space Network could utilise the Madrid station. The Deep Space Station, during one of the busiest periods in its 13-year history, was scheduled to close on 30 June 1974. The Joburg STADAN could not be shut down until 18 months later, on 31 October 1975, because it was vital to the Project Viking[36] near-earth operations. Carefully designed plans were prepared for the dismantling and packing of the NASA equipment and shipping it to the US after the closure of each station.

NASA had requested both stations to maintain their levels of activity until closure. Despite significant uncertainty about what the future held, the Joburg STADAN team rallied to the challenge – the knowledge that they did it better than most in their field, kept them focused on the job at hand.

During 1974 and until its closure in 1975, activity at the Joburg STADAN continued at a level much higher than that of most other stations in the network.

FINAL MISSION

The final mission undertaken by the mission support team at the Joburg STADAN was to provide launch vehicle support for the Viking-1 spacecraft. Launched from the Kennedy Space Centre on 20 August 1975, it was the first spacecraft designed to land on the Martian surface.

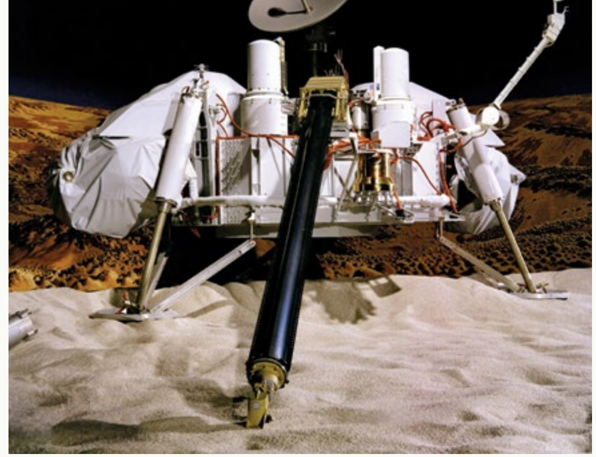


Image of Mars from the Mariner spacecraft (far left).

Astronaut Alan Bean, lunar module pilot (left), deployed Apollo Lunar Surface Experiment Packages (ALSEPs) on the Moon during the first Apollo-12 extravehicular activity.

NASA's Viking mission was the first US mission to land spacecraft, composed of orbiters and landers, successfully on Mars. The photo (right) shows a test version of the lander in the "Mars Yard" at NASA's Jet Propulsion Laboratory in 1975.

As the only station that could receive signals from the orbit required to send Viking-1 to Mars and confirm its separation from the launcher, the Joburg STADAN was scheduled to track the launch vehicle and satellite and communicate events as they occurred. The station was also briefed to send the command for separation should it not happen automatically.

"For the final time the station held the success of a mission in its hands. The engineers and technicians in the NASA Control Centre may have wondered whether the Joburg STADAN's performance that last time would be as impeccable as always, given the imminence of its closure. It would have been a senseless concern. Every member of the team in the control room was a professional and determined to perform the mission flawlessly. And they did." [37]

The dismantling, packing and dispatching of NASA's equipment at the Joburg STADAN was executed with the same reliability and precision as the team had applied to tracking NASA's satellites. The final tasks were completed on time and the equipment shipped to the United States by 31 May 1976. All that remained at the Joburg STADAN were empty buildings with dark windows and the 12 m antenna with its dish still tilted skywards but its sensors immobile, unable to detect the signals from the satellites as they continued in their orbits across the southern tip of Africa.

NASA's decision to close down the space stations at Hartebeesthoek resulted in a major reorientation at the CSIR. The NITR's management of the facilities and operations at Hartebeesthoek had been a major part of its activities. The termination of the contracts involved staff retrenchments and redeployment, as well as the loss of specialist skills, knowledge and experience.

A SIGNIFICANT RESOURCE LEFT LARGELY UNTAPPED

For 15 years the star of South Africa's space mission support at Hartebeesthoek had shone brightly. The Joburg STADAN team had established a reputation as one of the best stations in the global US STADAN network.

On an annual rating, based on the number of operational errors or equipment failures at each of the tracking stations in the network, expressed as a percentage of the total number of operations, the station was placed first in 1973 and 1974, and was in second place when it was closed down in 1975. NASA's untimely departure from South Africa left a significant resource largely untapped and brought the contributions from a highly competent team at the Joburg STADAN to an abrupt end.

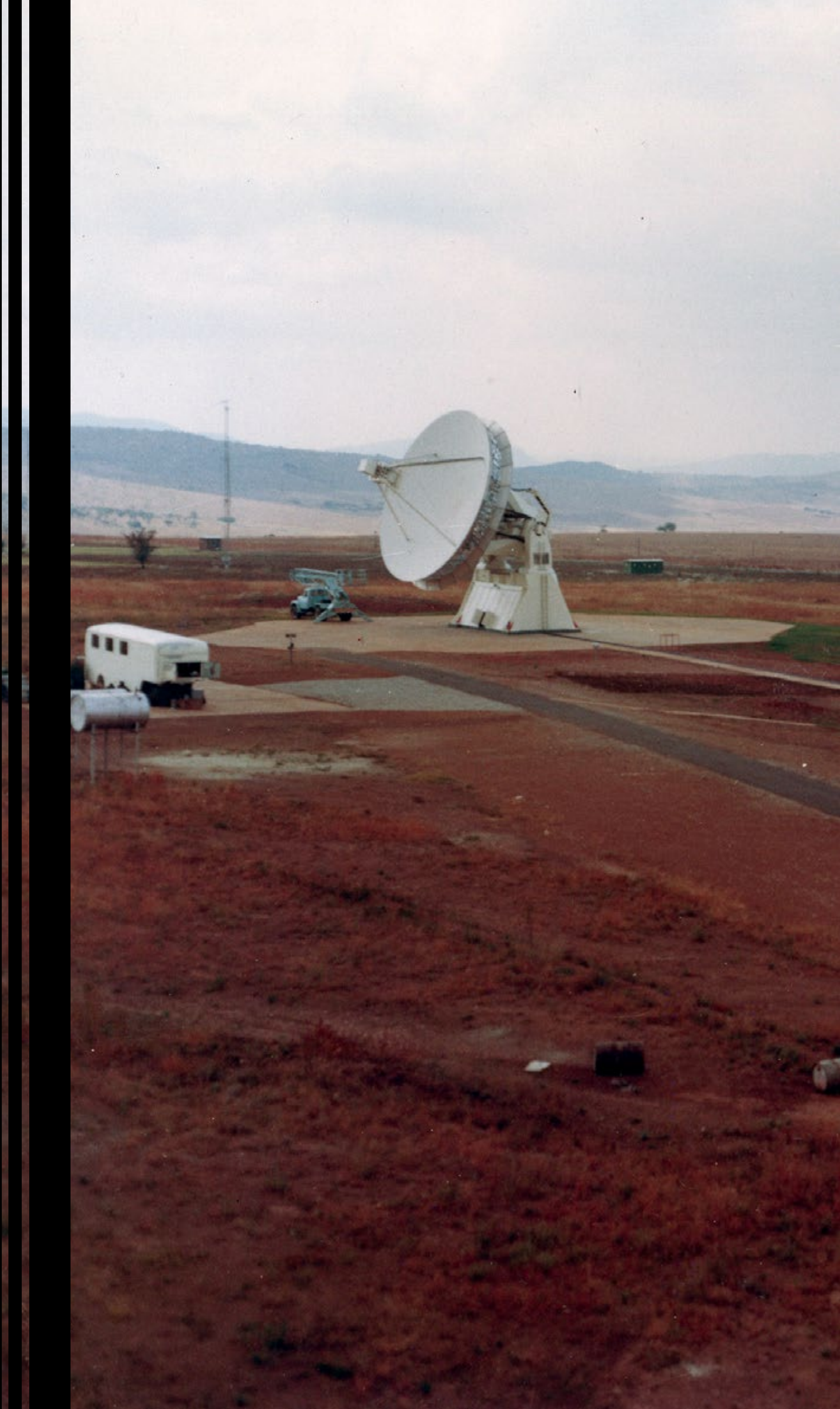
NOTEWORTHY STATISTICS

As part of the NASA STADAN network, the Joburg STADAN had received more than 8 million minutes of data, tracked 400 000 satellite passes and supported over 250 NASA launches. The statistics recorded for the Joburg STADAN during the NASA years show that the station had, remarkably:

- supported 253 satellites
- received telemetry on 154 600 satellite passes
- tracked 453 000 passes
- recorded 8 550 000 minutes worth of data
- used 132 000 magnetic tape reels
- sent 216 000 commands, and
- handled 314 000 teletype communications.

By any standard, it had been a commendable performance.

1976 - 1995
A new beginning




During the first 15 years of the space age, South Africa's active participation in NASA's satellite research programmes was given global stature by the people at the CSIR's Radio Space Research Station at Hartebeesthoek.

In the years leading to its closure, the Joburg STADAN was one of the busiest and most efficient stations in NASA's global tracking network for near-Earth satellites. In an error-averse industry, the station gained top performer-status for accuracy and reliability. NASA's departure from South Africa in 1975 had cast a pall over the future of the tracking station and its people. But even as the final containers were shipped back to the US in March 1976, a new beginning beckoned at Hartebeesthoek.

A NATIONAL FACILITY

In 1972, the launch of ERTS-1 (renamed Landsat-1[1]) as the first operational Earth resources technology satellite, gave the world its first commercially available remotely sensed multispectral data. The spacecraft carried an advanced scanning system with a near-global coverage capability every 18 days.

In a near-polar[2] orbit, the satellite obtained data on agricultural, forestry, geological, mineral, water and marine resources that could also be used in geography, cartography, oceanography, hydrology and meteorology.

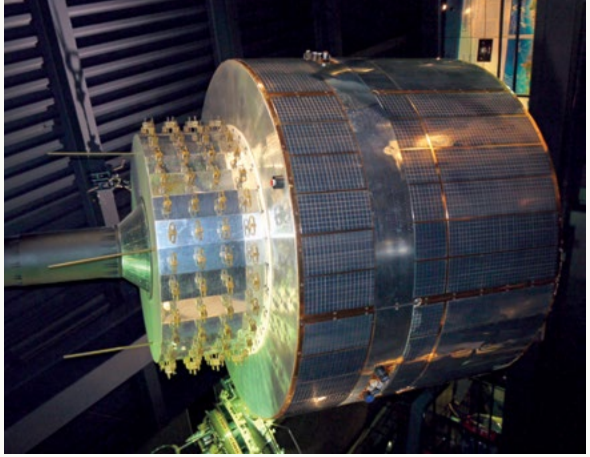
Direct access to the data would assist in managing South Africa's renewable and non-renewable resources. Establishing a facility to acquire and process such data was, therefore, of national importance.

Tasked to set up and operate the facility, the CSIR decided to use the infrastructure at the Joburg STADAN – notably the buildings and 12 m antenna that had been too large to dismantle and crate back to the US and had been handed over to the CSIR – and the skills and expertise of some of its staff to establish and man the new facility.

Shortly after the Joburg STADAN closed its doors, the CSIR re-opened the facility as the Satellite Remote

Timeline

1976	Joburg STADAN re-established as CSIR Satellite Remote Sensing Centre (SRSC)
1977	Received first Meteosat images
1979	Received first NOAA images
1980	CSIR-CNES contract to provide CNES with mission support
1981	Received first Landsat images. Hartebeesthoek designated as Landsat ground station
1982	First ground station to receive both Meteosat and Landsat data
1984	Mission support for Telecom-1A, first French telecommunications satellite
1985	Hartebeesthoek designated distributor of SPOT data
1988	SRSC renamed as SAC and given a R35 million upgrade
1989	Equipment upgraded for Landsat Thematic Mapper (TM) and SPOT XS and PAN data
1990	Mission support for SAR satellite
1991	Supplied SPOT-2 data for cartography
1993	Mission support for SEDS-1 satellite
1994	First use of satellite imagery in court case during Merriespruit disaster trial.End of an era - SAC stalwarts retire
1995	Supplied SAR satellite all-weather ocean data to combat oil spill. TT&C and Earth Observation split into two groups for greater efficiency



A mock-up of the meteorological satellite, Meteosat-1 (1977) (left) in the Museum of Air and Space in the Paris Le Bourget Airport Museum, France.

The initial image from Meteosat-1 (right) a few weeks after the launch marked the historic first in an uninterrupted flow of information that provided European weather services with more accurate forecasts.

Sensing Centre (SRSC). Operated as a national facility by the National Institute for Telecommunications Research (NITR), the SRSC was mandated to receive and process satellite data on the Earth's surface and atmosphere for local use.

A NEW VENTURE

The early autumn of 1976, arguably one of the darkest hours in South Africa's socio-political history, saw a core team of nine engineers, technicians and support staff, previously from the Joburg STADAN, start a new venture at Hartebeesthoek.

Their task was to 'get the station back into action'[3]. Armed with funding from the CSIR for running costs and some capital expenditure, they set about their activities with a determination to succeed.

The Hartebeesthoek site – where the CSIR had converted NASA's Deep Space Station into a radio astronomy observatory shortly after its closure in 1974 – hummed again with the sounds of human activity, while the 12 m antenna stood ready to once hone in on the signals from satellites as they orbited the Earth.

FIRST ORDER OF BUSINESS

The first order of business was to prepare the SRSC to receive Meteosat[4] data for submission to the South African Weather Bureau and provide a user-facility for the processing and analysis of line-scan data from remote sensing satellites.

Meteosat

The CSIR had secured the rights from the European Space Agency (ESA) to source images directly from Meteosat-1, Europe's first geostationary meteorological satellite.

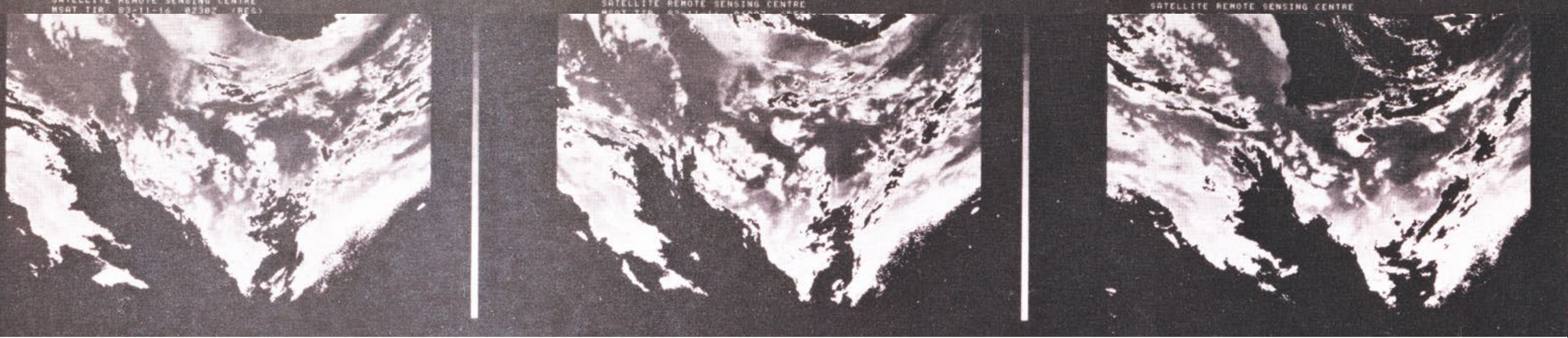
The intention was to supply the data to the South African Weather Bureau to improve their weather forecasts. Preparations entailed extensive equipment modifications and an upgrade to the 12 m parabolic antenna to add L-band feed and a new control circuitry and console. The latter was built in-house by the SRSC team.

The refurbishment of the antenna was so successful that, more than 50 years later, it is still in use, long after those who first commissioned it during the NASA years, and others who upgraded it thereafter, had retired.

A Canadian firm, McDonald Dettweiler and Associates (MDA), supplied the Centre with a Line-Scan Processing System[5] (LSPS) in 1976 to acquire and process data for delivery to the Weather Bureau. The data was also processed as black and white and colour film, computer compatible tapes and an interaction video system. Four members of staff were trained to use the LSPS at MDA in Canada and trained their colleagues to use the new system after their return. Two data lines were installed between Hartebeesthoek and the Weather Bureau to supply the latter with quasi real-time (resembling real-time) data.

Meteosat-1 was launched successfully aboard a Delta-II launcher on 23 November 1977 and early in December that year, 18 months after its establishment, the SRSC received the first raw Meteosat cloud cover data. Shortly thereafter, on 3 January 1978, the Weather Bureau received the first visible and infrared Meteosat cloud images from Hartebeesthoek via the high-speed 240 kHz data link.

Facsimile images were sent via a low-speed data line. The full Meteosat scene was divided into nine



segments. The Weather Bureau scheduled the segments from which images had to be sent via the low-speed data line.

The SRSC received the Meteosat images every half-hour. They were processed and relayed to the Weather Bureau within half-an-hour after receipt. The data assisted meteorologists to delineate the scale and development of weather systems and enabled weather forecasters to improve their shipping and aviation storm warnings considerably.

Landsat

CSIR researcher, Dr Okkert Malan, then at the National Physical Research Laboratory, had realised the value of Landsat data for South Africa and the CSIR and started purchasing scenes for the whole of the country from the Eros Data Centre in the US, soon after the satellite took to space in 1972.

Eros supplied the data on computer compatible tapes (CCTs) and photographic images of the data were produced locally.

With limited funding initially, the SRSC procured a Bulk Processing System (BPS) from MDA to ingest raw Landsat data and produce standard products. A stand-alone, interactive Image Analysis System (IAS) was also installed to process and analyse data from remote sensing satellites.

Although negotiations for direct access to Landsat data started late in 1976, the first images were received only in December 1980.

During its first year in operation, the SRSC purchased 90 historic Landsat scenes covering southern Africa – each with digital line-scan data of group scenes roughly 185 km[2].

DATA IMMEDIATELY POPULAR

Requests for Meteosat data exceeded expectations almost immediately. Within the first three months, facsimile transmissions to the Weather Bureau occupied 30% of available staff time every day. During the first year, the Centre supplied more than 1 500 high-resolution, visible and infrared images to local users, such as the CSIR's National Research Institute for Oceanology (NRIO) and National Physical Research Laboratory, as well as the Department of Sea Fisheries. A large number of private people also used the data.

The SRSC also provided high-resolution Landsat images to about 200 users, including the Johannesburg Consolidated Investment Company Ltd, Anglo American Corporation, Department of Geological Survey and the University of Cape Town.

A significant increase in the use of Meteosat and Landsat data put pressure on the SRSC to meet its operational commitments. Within 18 months after opening its doors, the Centre had produced some 7 000 high-resolution Meteosat and Landsat images and supplied the Weather Bureau with more than 35 000 facsimile sectors.

More than 1 000 CCTs were delivered to users and used for temporary archiving. The Image Analysis System was very popular in effectively correcting, enhancing and transforming images, as well as classifying the multispectral satellite data[6].

EFFICIENCY AND AWARENESS

Faced with the demand for data, the Centre installed more equipment to increase operational capacity and recruited new staff to respond to user requirements. In consultation with station manager, Willem Botha, the software, hardware

A sample of a declouded Meteosat infrared image sequence over the southern part of South Africa, acquired 16 November 1983 and supplied to the CSIR's National Research Institute for Oceanology (NRIO).

and operations managers at the time, respectively Alan Caithness[†], Frans Meintjies[†] and Ike Marais, decided to re-instate the four-shift system used at the Joburg STADAN during the NASA years. This led to greater efficiency and the ability to meet the Weather Bureau's requirement for a 24-hour, seven days-a-week supply of data for their weather forecasts. Many prospective users called or visited Hartebeesthoek to find out more about satellite imagery. Questions asked were mostly about data availability and application for specific needs, as well as data products and costs. The initial trickle of visitors turned into a flood at times and occupied a significant amount of staff time.

"Most first-time visitors were sceptics until they saw the station, what satellite imagery looked like and how they could use the data to address their needs cost-effectively. [38]

Most left the station impressed with what they had seen and learnt. Although time consuming, there was no doubt that the visits contributed to a growing awareness about the SRSC's activities and increased the sale of data products, which supplemented its income."[7]

METEOSAT DATA USED FOR RESEARCH

During 1978, the archiving and imaging of the successive half-hourly data from Meteosat-1 for research purposes was well established. The Centre also started using the data to support a number of research experiments.

Data for research

Declouded and processed Meteosat images were required for this project. The declouded images were constructed by extracting cloud-free portions from a number of consecutive Meteosat images and combining these in a new image. This image was then analysed and annotated as shown in the right-hand image at the top of this page. In one such instance, the NRIO used the data to determine the direction, extent and time of independently moving eddies in the Agulhas current. A NRIO staff member, stationed at Hartebeesthoek for the duration of the experiment, analysed the processed thermal Meteosat data and relayed it telephonically to NRIO in Stellenbosch.

From there it went via radio link to a research ship at sea. The data guided the vessel to the point in the current where it had to drop the drifting buoy.

Without the Internet and data lines of today, the transfer of data was elaborate but effective. The project provided the NRIO with valuable information about the flow of eddies in the Agulhas current. The SRSC also supported a study of the development and decay of the Von Kármán vortices[8] behind the Canary Islands and collaborated with the Heat Capacity Mapping Mission (HCMM) Control Centre at the Goddard Space Flight Centre to track, receive and record imagery from the HCMM satellites. A considerable amount of daytime visible and infrared imagery was recorded successfully and supplied to the GSFC *(refer to image on p66, top left)*.

Meteosat progression

When Meteosat-1 failed in November 1979, the SRSC used data from other polar-orbiting weather satellites to continue supplying the Weather Bureau with information for their daily weather forecasts.

Although the satellite had stopped providing cloud cover images, it still conveyed more than 1 000 meteorological messages from the South African National Antarctic Expedition (SANAE) base in Antartica, as well as Gough Island in the mid-South Atlantic Ocean and Marion Island in the

SRSC core group

The 1976 core team who established the CSIR Satellite Remote Sensing Centre at Hartebeesthoek consisted of:

- Willem Botha (Manager)
- Joyce Doyle (Secretary)
- Brian Broere† (computer hardware and antennas)
- Tasso Karantonis (radio-frequency, antennas and receivers)
- Roy Osborne† (tape recorders and electronics)
- Ike Marais (operations)
- Frans Meintjies† (technical)
- Selwyn Clark (mechanics and hydraulics)
- Johan Kruger (Electronics)

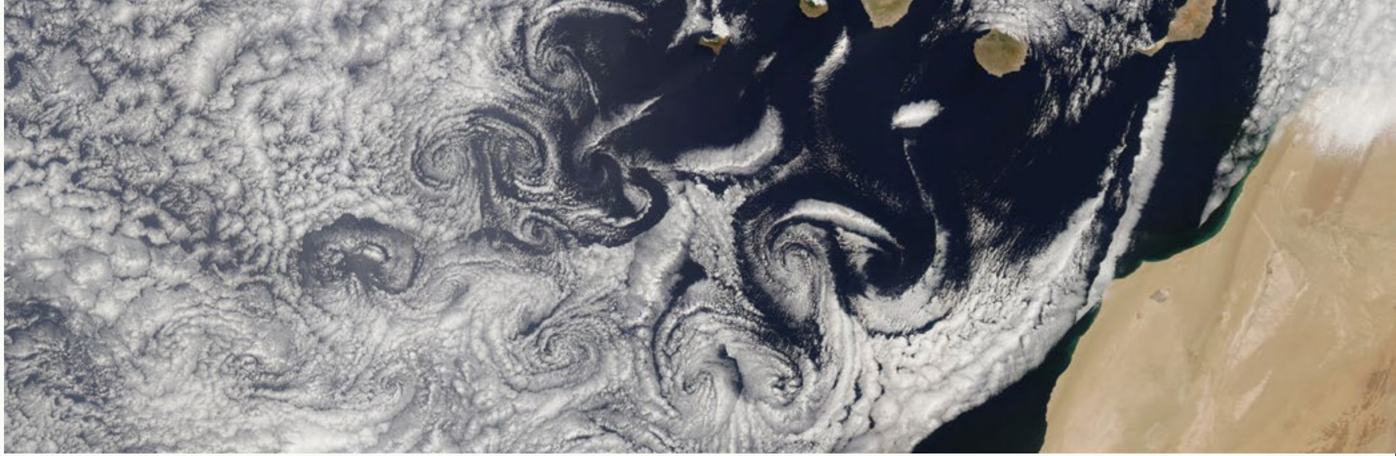
Alan Caithness† (computer software) joined the team in 1977 and Alan Watson (photographic workshop) joined in 1978.

Levels of activity exceeded expectations

Hardly back in operation at Hartebeesthoek and the team was at it again!

A mere 18 months after acquiring and processing the first geo-information data, the SRSC had produced more than 7 000 high-resolution images and over 1 000 computer compactable tapes, and sent more than 35 000 facsimile sectors to the Weather Bureau.

"The level of activity at the Satellite Remote Sensing Centre is much higher than anticipated and the personnel are hard pressed to meet operational commitments."
- 1977/78 CSIR NITR Annual Report



sub-Antarctic Indian Ocean, via Hartebeesthoek to the Weather Bureau in Pretoria. Meteosat-2 replaced the failed satellite in June 1981 and the SRSC received the first images a month later.

DEMAND FOR PROCESSED LANDSAT IMAGERY

Data from the Landsat satellites assisted countries with the management of renewable and non-renewable resources. Despite ongoing negotiation for direct access to Landsat data, by 1979 the SRSC was still purchasing the data from the Eros Data Centre in the US.

The high cost of the tapes and delay in availability of the data, as well as the infrequent coverage over southern Africa, made the data ineffective for renewable resource management in South Africa.

As a result, more than 90% of users of the 2 000 Landsat images produced by the SRSC from purchased Landsat data were mining companies, geologists and others involved in the minerals and precious stones industries. The remaining 10% were users in the forestry and agricultural sectors who used the data for experimental purposes.

In addition to the initial 90 magnetic tapes with Landsat data, the SRSC purchased a further 150 tapes, which included about 80 tapes of pre-June 1974 Landsat-1 scenes. At the time, the Eros Data Centre held the only archive of Landsat data prior to 1974. After selling the tapes to the SRSC, the US-based archive developed problems and permanently lost all pre-1974 Landsat data.

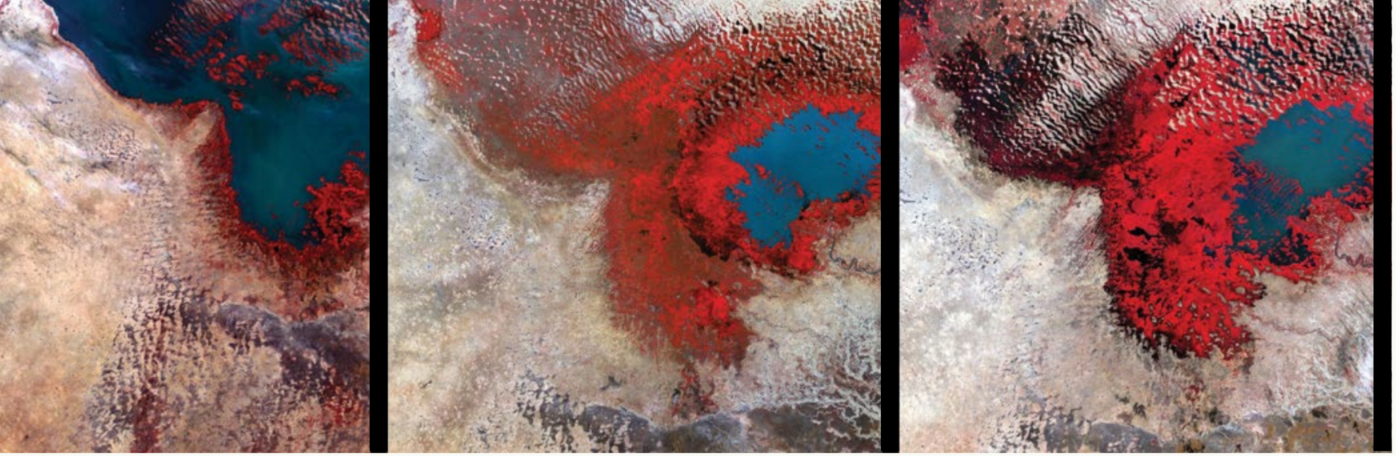
The only copies still available today are in the Landsat archive at Hartebeesthoek. Since historic data is primarily used for change detection, the value of those tapes has been proven many times over.

CONTRACTS WITH A LASTING IMPACT

In September 1980, the CSIR concluded two international contracts. Both contributed to the growth of the SRSC and, in retrospect, had a lasting impact on the development of SAC.

CSIR-NASA Landsat contract

Firstly, a CSIR-NASA contract finally provided the SRSC with direct access to the Landsat[9] Earth resources satellite series and its multispectral remotely sensed imagery over southern Africa. Under the contract, Hartebeesthoek became a



Spiralling eddies, known as Von Kármán vortices, form when air flows over and around objects in its path. The vortices in this Landsat-7 image on page 66 were created when winds swept across the northern Pacific Ocean and encountered Alaska's Aleutian Islands.

The change detection images on this page are of Lake Chad, which borders Nigeria, Niger, Chad, and Cameroon in West Africa and was the sixth largest lake in the world. The images were taken by the Landsat-1, Landsat-4 and Landsat-7 satellites on 8.12.1972, 14.12.1987 and 18.12.2002. Persistent drought since the 1960s has shrunk the lake to about a 20th of its former size. [11]

regional centre for the receipt, processing and distribution of Landsat data covering most of Africa south of the Equator.

MacDonald Dettweiler and Associates (MDA) in Canada supplied the SRSC with a Bulk Processing System to produce standardised products from Landsat data. The company sent an engineer to Hartebeesthoek to assist with the installation of the equipment in time to record the first data from the Landsat-2 satellite on 1 December 1980.

Direct access to the data was an important milestone for the SRSC and developed into a major Earth Observation (EO) programme at the Centre. Within just four months, the SRSC recorded, processed and distributed approximately 3 000 directly-accessed Landsat images to users.

Interest in Landsat data from other southern African countries opened up a new regional income stream and, to meet the demand, especially for Landsat processed colour imagery, the SRSC improved its computing, recording and photographic facilities. Four CSIR working groups investigated the application of Landsat data.

Co-operation with the then Department of Agriculture and Fisheries confirmed applications in mapping agricultural crops, classifying soil types, monitoring veld fires and determining the extent of flooding.

Projects undertaken with the Department of Environmental Affairs confirmed applications in mapping forestry and fynbos areas, while collaboration with organisations in Natal resulted in a publication on ground cover in the greater St Lucia area.

More than 30 years later, Hartebeesthoek is still an active ground station in the International Landsat Ground Station Network of the US Geological Survey (USGS) for the direct downlink and distribution of Landsat data.

CSIR-CNES TT&C contract

Secondly, the Centre National D'Etudes Spatiales (CNES) contracted the CSIR for tracking, telemetry and command (TT&C) support for all its geostationary satellites. Hartebeesthoek joined the CNES satellite tracking network alongside the other stations in Kourou in French Guiana, South America; Aussaguel in Toulouse, France; and Kiruna in Sweden. Kerguelen later became the fifth CNES network station, located on Kerguelen Island, south-east of the South African continent.

Whereas the Meteosat and Landsat activities were expense factors for the SRSC, the CNES contract provided the Centre with its first sizeable income. Over the years, that income contributed significantly to the growth and expansion of activities at Hartebeesthoek.

At the time of writing, the business relationship with CNES continues, now under the SANSA banner, as do the many friendships that evolved from it.

JOINING THE CNES NETWORK

The French had contracted Hartebeesthoek to join its tracking network for a number of reasons. By 1980, satellite transmissions had progressed to a 2 GHz high-frequency band. Not only was the SRSC's location at the southern tip of Africa[10] an important attribute but upgrading the 12 m antenna to interface with the sophisticated French equipment was more cost-effective than installing another similar antenna elsewhere in the world.

Ninety percent of all spacecraft ever launched do not explore space but play vital roles in our life, such as communications, surveillance, weather observation, and navigation. They are the unknown heroes of the Space Age.

- NASA

CNES was also satisfied with the infrastructure, communications, roads networks, power supply and security at Hartebeesthoek and the TT&C experience of the technical staff. And, interestingly for the times, the French believed that South Africa was more stable than other countries in the region.

Preparations for the SRSC to function fully as a CNES network station in time for the Telecom-1A[12] launch in 1984 took three years. Tasso Karantonis – fluent in French and with significant operations and maintenance experience – became the designated 'point of contact' between the SRSC and CNES and project managed the critical 1980-83 preparation phase.

The preparation entailed technical meetings and intertechnique training on the new equipment in Toulouse, France while French engineers and technical crews spent time at Hartebeesthoek to assist with the preparation.

The technical staff spent many training hours tracking an American solar mesosphere explorer (SME) satellite to exercise the newly installed tracking equipment and gain experience for the launch.

Some 2 500 minutes of data were relayed to the SME Control Centre in Colorado via CNES to monitor the station's progress and performance. They also practiced many launch simulations to ensure that the station was ready to join the CNES network.

SIMULTANEOUS DATA OPERATIONS

By 1982, Meteosat and Landsat operations were carried out simultaneously and approximately 38 000 different Meteosat-Landsat images were produced for users in southern Africa and overseas.

In contrast to the routine nature of the Meteosat operations, Landsat activities varied considerably. During SAC's 1982-83 financial years, those activities were severely affected by an increase in the cost of Landsat data when NASA trebled its annual direct access fee from $200 000 to $600 000.

The increase applied to all non-US Landsat stations and affected the station's income stream and efforts to become self-sufficient.

The SRSC had no option but to change its data pricing policy to a two-tier structure. Local users were quoted a Rand price, while foreign users received a rate in US$. As a result, Landsat product sales dropped by 50% the following year.

Problems with data acquisition from Landsat-3 and Landsat-4 also affected sales. Landsat-3 developed a multispectral scanner problem, which caused the loss of the western third of all images.

Since NASA could not resolve the problem and the data was useless, the SRSC stopped Landsat-3 operations. Syd Howe saved the day with software he had written to extract usable images from the data already received and paid for. Although initially, Landsat-4 provided the Centre with good imagery, the satellite developed technical problems that curtailed the TM-data transmissions to ground stations.

During that time, the number of visitors to Hartebeesthoek had increased to about 450 annually.

The Earth Observation (EO) team was called upon often to demonstrate the Landsat image processing facility, which occupied a significant amount of staff and computer time.

Landsat-2 images before (A) and after (B) the Laingsburg flood received respectively on 10 November 1980 and 8 February 1981.

An artist's concept of a Landsat satellite (below). These spacecraft use remote sensing technology to provide data on a variety of Earth resources and environmental conditions.

Those involved with the visits, however, regarded the time spent as an investment in potential sales and an opportunity to create awareness about the practical benefits of satellite imagery.

COST-SAVING LOCAL SOLUTION

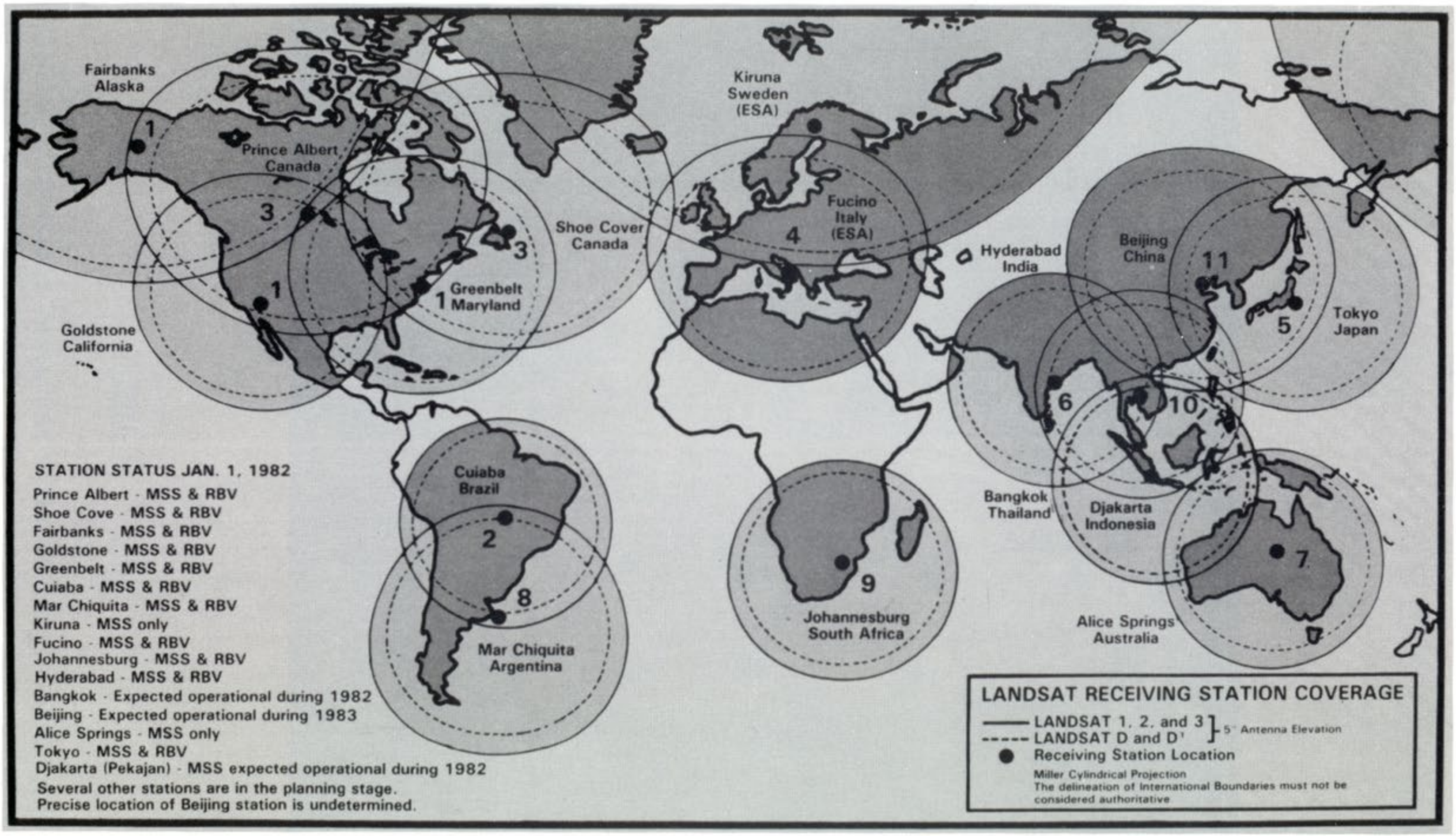
The 10 m parabolic antenna system was brought into operation in December 1983. During the summer of 1984, however, four low noise amplifiers (LNAs) in the feed of the antenna were severely damaged by lightning. The US manufacturer contacted for repairs quoted $3 236 for each LNA, equal to 66% of the price of a new unit.

The SRSC team decided to repair the LNAs in-house, despite advice to the contrary and no circuit diagram or list of parts for the LNAs. The fault was soon traced to a microwave transistor and replacements obtained at a cost of $46 each.

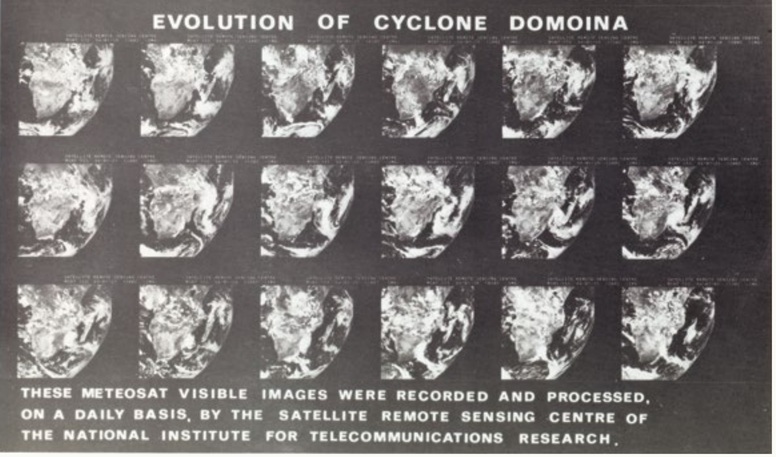
The new transistor was fitted to one of the LNAs, and gain and noise tested against specifications, before the other three LNAs were also repaired. The total cost for repairing all four LNAs came to $184. Local ingenuity and an in-house solution had saved the SRSC over R20 000 in repair costs.

FIGURE 3

The world-wide Landsat tracking network.



The map shows the locations of ground stations operated by the US and International Co-operator (IC) ground station network for the direct downlink and distribution of Landsat data. The circles show the approximate direct reception area of Landsat data for each station. The SRSC is indicated at JSA (Joburg, South Africa).



A series of Cyclone Domoina satellite images (left) over South Africa, recorded daily in late January/early February 1984 by the SRSC; the cyclone caused severe damage to the Mfolozi flats and surrounding areas south-west of the St Lucia Estuary.

Landsat-4 satellite (right), shown here as ¼ scale model in the US National Air and Space Museum in Washington DC.

APPLICATIONS OF SATELLITE DATA

In addition to processing and distributing remote sensing data, the EO team used the data to support research and disaster management projects on a number of occasions.

Castillo de Bellver oil spill

On 6 August 1983, the Castillo de Bellver, a Spanish oil tanker filled with 250 000 tons of light crude oil, exploded at sea, 80 km from Table Bay. The vessel broke in two and the stern sank 38 km off the popular bathing beaches of Cape Town with 200 000 tons of oil still in the tanks and 50 000 tons spilled into the sea.

The accident site is ecologically and economically sensitive with rich flora and fauna, an important fish reproduction area and a large seabird population.

The SRSC provided the disaster management team with data from the Meteosat-2 and Landsat-4 satellites. Meteosat imagery clearly showed the size and extent of the oil slick. The first Landsat-4 images came in three days after the disaster. The EO team delivered the reformatted data to the Department of Transport, via the Weather Bureau's facsimile link, within less than 40 minutes after the satellite passed over the disaster area.

Representatives from the Department voiced their appreciation for the quick response. The data helped to plan the anti-pollution operations. Still regarded as the largest oil spill in South African waters and one of the 10 largest in the world, the impact on fishing and the environment was largely contained, with relatively little damage to the South African coast.

Drought-affected Vaal Dam and Cyclone Demoina destruction

In 1983, Landsat imagery was used to illustrate the serious effect of drought on water levels in the Vaal Dam. The satellite data clearly showed the dramatic reduction in the volume of water in the dam, from 81% full in 1981 to only 24% full in 1983.

And in 1984, Meteosat and Landsat-2 multispectral scanner data were used to respectively record the development of tropical Cyclone Demoina and evaluate the destruction wrought by the cyclone. Heavy rainfall for five days over KwaZulu-Natal, Mpumalanga and Swaziland caused severe flooding along the North coast of the province.

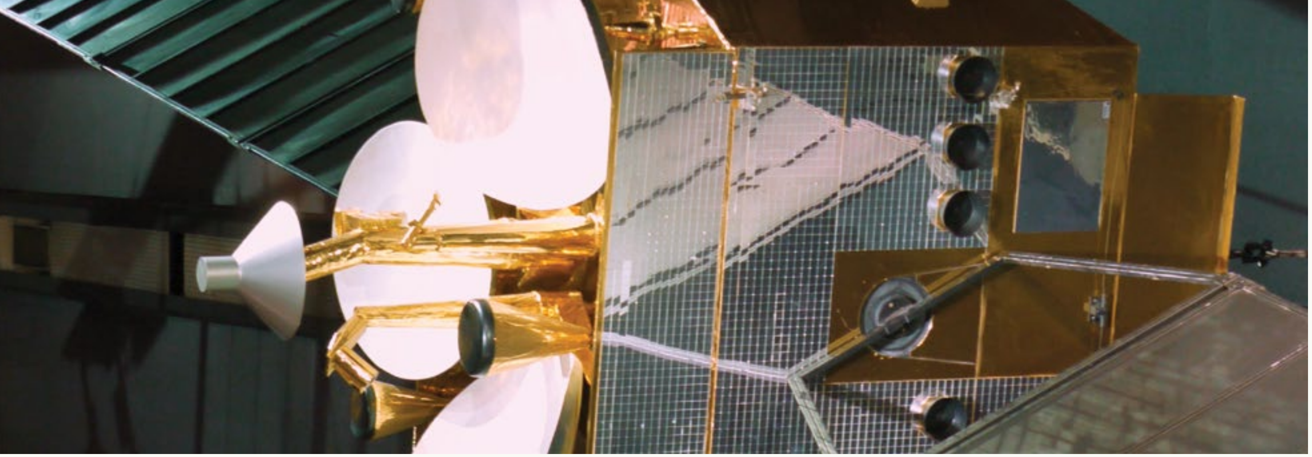
The cyclone claimed 214 human lives and countless numbers of livestock and wildlife. It destroyed bridges, ancient riverine forests and mangrove swamps and caused major geomorphological changes to the mouth of Lake St Lucia. Cloud-cover delayed the acquisition of the post-flood data. The images, however, clearly indicated the extent of damage to the landscape.

Meteosat archive

The Meteosat data were downloaded daily onto magnetic tapes. The SRSC archive consisted of sub-scenes over southern Africa (512 × 512 pixels) taken at midday and thermal infrared (TIR) sub-scenes taken at midnight.

Before long, the archived sub-scenes had increased to some 4 500 per year. Black and white film negatives of the 12:00 GMT visible and infrared cloud-cover images (some 700 images per year) were also archived and the full scene retained on tape for five weeks at a time.

The archive was freely available for general use by researchers in climatology and related fields, and supported projects undertaken by the NRIO.



FIRST MISSION SUPPORT FOR CNES

The installation of CNES equipment at the SRSC was completed by early 1983. The equipment was supported by voice and data lines between Hartebeesthoek (referred to as 'HBK' by CNES) and Toulouse in France and tested repeatedly through test runs with the American SME[13] satellite, as well as the Ariane-1V6 that was launched in June 1983.

Telecom-1A (TC-1A) was launched on 4 August 1984 as the first in a series of French telecommunications satellites. The launch was the SRSC's first mission support for CNES under its new contract with the CSIR. The spacecraft was lifted by an Ariane launcher[14] from the Guiana Space Centre near Kourou, French Guiana in South America and intended for a geosynchronous Earth-orbit.

Three years of preparation and extensive simulation training had given the technical staff confidence in their performance. But as they took up position at the CNES console, a measure of tension existed. The team had a number of new members and they were dealing with a new space agency under the watchful eye of a senior manager sent to observe every action during the launch.

The countdown and lift-off occurred on time and the first and second stages of the launcher separated as scheduled. As the third stage ignited and the spacecraft – launcher and satellite – rushed towards HBK at close to 28 000 km/h, the tension became palpable.

The critical moment when the spacecraft broke into view over the horizon would be the point of no return for the South African team. Only a flawless and accurate performance would be acceptable.

The first signals from Telecom-1A came through approximately 32 minutes after lift-off. The SRSC team established auto-track within 30 seconds and supported the separation between launcher and satellite seamlessly.

The telemetry, ranging, Doppler and angular measurement data that flowed from Hartebeesthoek to the Control Centre in Toulouse confirmed that the launch had proceeded as planned.

While in contact with HBK, the satellite deployed its solar panels, carried out a Sun/Earth acquisition and an attitude control procedure. The HBK team was on standby to send commands to the satellite in the event of a malfunction of any of its programmed actions.

"It was a proud moment. What gave us great pleasure was the knowledge that a team, whose performance during a launch simulation with a US training satellite a year earlier had been rated as inadequate by the American and French Control Centres alike, had performed flawlessly without a single operator error." [15]

Over the next few weeks, the Telecom-1A Control Centre, in conjunction with the HBK, Toulouse and Kiruna stations, placed the satellite into a geostationary orbit at its allocated orbital slot.

The satellite was thoroughly checked to ensure that all systems were working and handed over to its commercial owners. The network provided routine support thereafter.

Throughout the launch, early orbit, drift phase and final positioning, SAC's staff and equipment performed flawlessly. Satisfied with the South African team's performance, CNES scheduled

A mock-up of the Telecom-1A communications satellite (1984) (far left) on view in the Museum of Air and Space at the Pairs-Le Bourget Airport in France.

This 2.1 m L-band NOAA antenna (far right) at the Hartebeesthoek antenna farm, with a 2°/sec slew rate, provided SAC with imagery from NOAA satellites.

An artist's impression of the NOAA-M satellite (left).

Local space programme investigated

During the 1988/89 financial year, the CSIR reported on its investigation into South Africa's involvement in a space programme.

"Government accepted the findings of a CSIR investigation – commissioned by the Minister of Economic Affairs and Technology – which showed that a major South African space programme cannot be justified on economic ground alone.

"It also accepted recommendations to the effect that no country can isolate itself from space technology and that a brains trust must be maintained to advise on South Africa's optimum involvement."

– 1988/89 CSIR Annual Report, p 15

Hartebeesthoek to support all Ariane launches, apart from those launched into polar-orbits, which the SRSC tracked only when they were visible over southern Africa.

As the only tracking station in contact with spacecraft launched from Kourou in French Guiana during the critical satellite-launcher separation period, HBK became an important link in the CNES network.

In emergencies, commands sent from the Centre could, under certain circumstances, determine the success or failure of a mission. The SRSC provided similar support successfully for the launch of Telecom-1B in May 1985.

SIGNIFICANT INCREASE IN ACTIVITIES

By the mid-1980s, Hartebeesthoek had been the first station to simultaneously receive and process data from both the Meteosat and Landsat satellites.

The data reception activities at the SRSC had greatly increased with the addition of NOAA[16] polar orbiting satellite and CNES operations. The Centre was also tracking overpasses by the Russian Meteor[17] satellite.

The special NOAA format synchroniser and computer interface unit, developed and built by the SRSC staff, enabled the daily tracking day and night time passes of the NOAA-5, -6 and -7 satellites. Data products were supplied daily to oceanologists in South Africa and overseas.

A contract with the French company SPOT Image, to distribute processed imagery from the SPOT Earth observation satellite series, added to the continuous pressure on EO staff to supply clients with processed data products. Staff and equipment in the off-line processing and photographic facilities worked at full capacity most of the time, while the daily real-time feed of data to the Weather Bureau and NRIO continued.

Hundreds of high-resolution images were supplied to local users and private individuals, as well as infra-red images from the NOAA satellites to the Sea Fisheries Research Institute and the University of Cape Town for oceanographic research.

The CSIR's Scientific Liaison Office in Paris also provided the SRSC with feedback from overseas clients on the Centre's online Landsat catalogue.

"At the time, I was confident that the SAC team would surmount the new challenges, which they did. During the years until my retirement in 1994, our external income increased significantly."

- Willem Botha, personal communication 2010

The information was used to update the catalogue and extend the listings with data from the NOAA and SPOT satellites.

Sales of Landsat-4[18] and Landsat-5 data, which gave eight-day repeat coverage of the southern African region, had increased by almost 40%. Colour products (80% of sales) were the most popular, followed by computer-compatible tapes (31% of sales). About 66% of the data products were sold to countries outside South Africa. This was due in part to the acquisition of image processing capabilities by countries in the region, while foreign clients used the data mainly for providing development aid or undertaking mineral explorations in southern African countries.

Amidst the dynamic pace of activities at the Centre, staff remained focused on their mandate: to provide local, regional and international users with meteorological and remotely sensed data products satellites, while TT&C support to CNES for its Ariane launchers would continue.

During 1987, the modernisation of satellite reception at Hartebeesthoek continued to ensure that the country and its neighbours benefited from the latest satellites monitoring natural resources. Several user organisations in the private and public sectors were encouraged to acquire in-house image processing facilities. Training workshops and information sessions were held to assist where required in the full utilisation of the facilities and optimal application of satellite data products.

A CHANGE IN COURSE

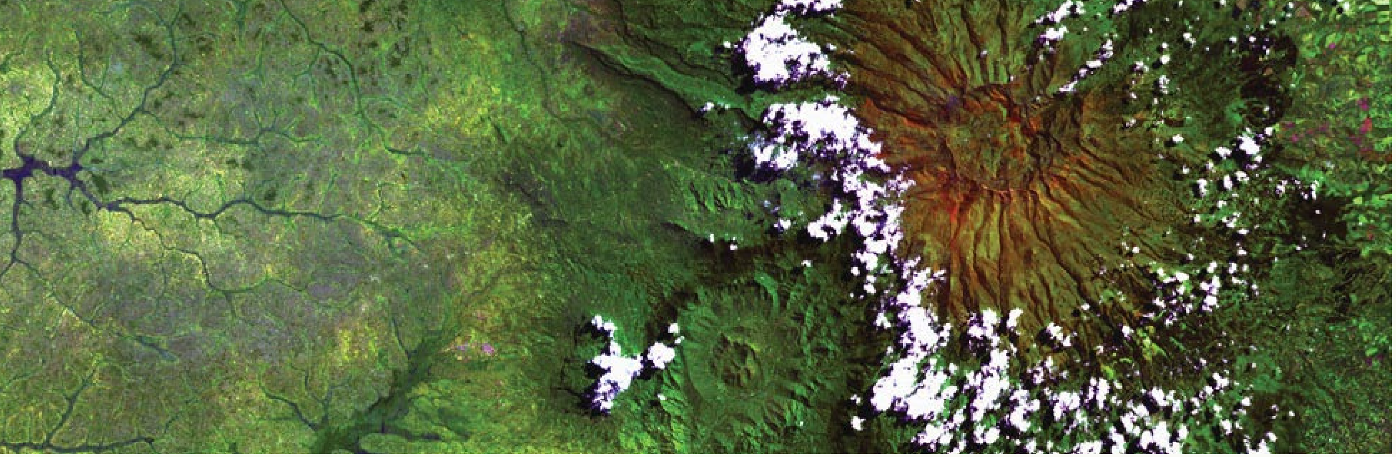
The announcement of a major change in course for South Africa's primary research organisation coincided with its 40th anniversary in 1985. Change had become an imperative for the CSIR to remain successful nationally and internationally. The objective was to position the organisation to better serve the scientific and technological needs of a country faced with socio-political complications, eroded investor confidence and the reality of sanctions.

The organisation-wide restructuring was implemented during the CSIR's 1987/88 financial year. Along with the CSIR business units, the SRSC tracking station at Hartebeesthoek did not escape the 'wind of change'[19]. For the third time since its location at Hartebeesthoek in 1960[20], the station was renamed and given a new mandate, this time aligned with the CSIR's new market-driven business philosophy[21].

SAC IS BORN

The SRSC became the CSIR Satellite Application Centre (SAC) early in 1988 as a programme of the new CSIR Microelectronics and Communications Technology (Mikomtek) business unit. Characteristic of CSIR 'speak's, the acronym was immediately adopted as the reference for the station. The Satellite Application Centre at Hartebeesthoek became known as SAC.

A new era had arrived for the CSIR and its reconfigured business units. Operating under the newly passed CSIR Act (Scientific Research Council Act, 46 of 1988), the organisation's research and development mandate had been widened to include the implementation of research findings. This required the entrenchment of an output-driven business culture throughout the organisation with on brief, on budget and on time (OB2OT) project delivery. The directive was to increase external sources of income.



Clouds encircle Africa's Mount Elgon, a long-extinct volcano on the border between Uganda and Kenya. The cauldron-like central depression (caldera) is about 6.5 km across. Landsat-5 image acquired 9 August 1984.

SAC's activities had to be aligned with the CSIR's new market-orientation. While its business goal was straightforward: increased income and less reliance on funding from the CSIR's annual government grant, the imperative of commercialising its services presented a number of challenges.

THE TRACKING, TELEMETRY AND COMMAND (TT&C) PERSPECTIVE

CNES, the French space agency, was SAC's only client for its mission support services and had been the station's only source of external income since 1983. The station had to look to the international space community for new clients, but was faced with the harsh reality that many countries had adopted trade and financial sanctions against South Africa and were hesitant to invest in the country.

Although SAC's business development team pursued opportunities to secure new business, it took a number of years before their initiatives came to fruition and new clients could be added to SAC's single client list.

In November 1988, SAC played a crucial role in the launching, deployment and final positioning of TDF-1, the first French geostationary direct-broadcast satellite ever launched. The satellite transmitted directly to TV viewers and received signals from a wide area on Earth. In the early 1990s CNES agreed to an increase in the cost of using the antennas at Hartebeesthoek, at the time a welcomed boost to SAC's external income from its mission support services.

THE EARTH OBSERVATION (EO) PARADIGM SHIFT

By 1988, the EO activities at Hartebeesthoek were well-established. The number of users of remote sensing products and services, locally and in the African region, had grown substantially and included some international clients.

The station had been upgraded and received, processed, archived and distributed data from the French SPOT, US Landsat Thematic Mapper (TM) and NOAA AVHRR and European Meteosat satellites. A comprehensive imagery archive for the entire southern African region, extending northwards to 5° South and including Madagascar, had been created and was being maintained. Applications ranged from geological survey and exploration to cartography.

The challenges under SAC's new mandate in the EO arena were two-fold: to retain its public sector funding for EO activities and increase the external income from its remote sensing products and services. Previously, EO activities had been funded by an allocation from the CSIR's annual parliamentary grant.

The funds were used to download and purchase expensive satellite data, maintain data continuity within the user community and rewrite archived imagery with mining potential.

During the late 1980s, the 'zero Rands and zero cents' concept for obtaining satellite imagery was still popular among the majority of data users, who expected the data to be freely available and eminently usable. SAC's new business imperative necessitated a change in paradigm within the user community.

The EO team used their daily interaction with users to create awareness about the costs and benefits of remotely sensed data. Initially a daunting task, their efforts met with remarkable success and, by early 1991, EO sales had almost doubled.

There is a single light of science and to brighten it anywhere is to brighten it everywhere.

- Isaac Asimov

The Centre attributed the increase to successful marketing efforts, supported by its direct access to satellite imagery and quick availability of the data. About 80% of the data sold were used for geo-exploration, cartography, land-use, hydrology, agriculture, forestry and vegetation purposes.

"Although these [EO prices] have risen, there are noteworthy exceptions, such as Landsat MSS digital data. And the SAC can genuinely claim that its clients continue to benefit from an unbeatable combination of product, price, quality and speed of delivery."[22]

FULL CIRCLE PERFORMANCE

Little more than a decade after the CSIR had re-established the Joburg STADAN as a remote sensing centre in 1976, a three-year R35 million upgrade at SAC had been completed to "handle higher data rates flowing from Earth satellites and the sensors which have brought better spectral coverage and ground resolution"[23].

SAC's mission support team had also come full circle. On par with the peak performance of the Joburg STADAN at its closure in October 1975, SAC was again a top performing TT&C tracking station, this time in the CNES network. And, critical to SAC's survival at the time, was the success of the EO marketing team and the resultant significant increase in its customer base, for a variety of products processed from remotely sensed satellite data.

Both achievements were commendable and aligned the station's activities with the CSIR's market-driven focus on meeting customer needs and increasing external income. The renewal of the SPOT contract in 1991, and continued reception and archiving of Landsat TM imagery, enabled SAC to provide users with greatly enhanced products and services. These included higher-resolution imagery, extended spectral coverage and greater revisit periods.

The Landsat and SPOT contracts had initially been negotiated when South Africa's political landscape did not support international collaboration. By the mid-1980s, P W Botha had delivered his Rubicon speech and sanctions isolated South Africa from much of the rest of the world.

"All SAC staff, past and present, owed a great deal to the team that concluded the negotiations. Without those contracts, SAC would not have had access to the new generation of remote sensing data and may not have survived for any length of time."[24]

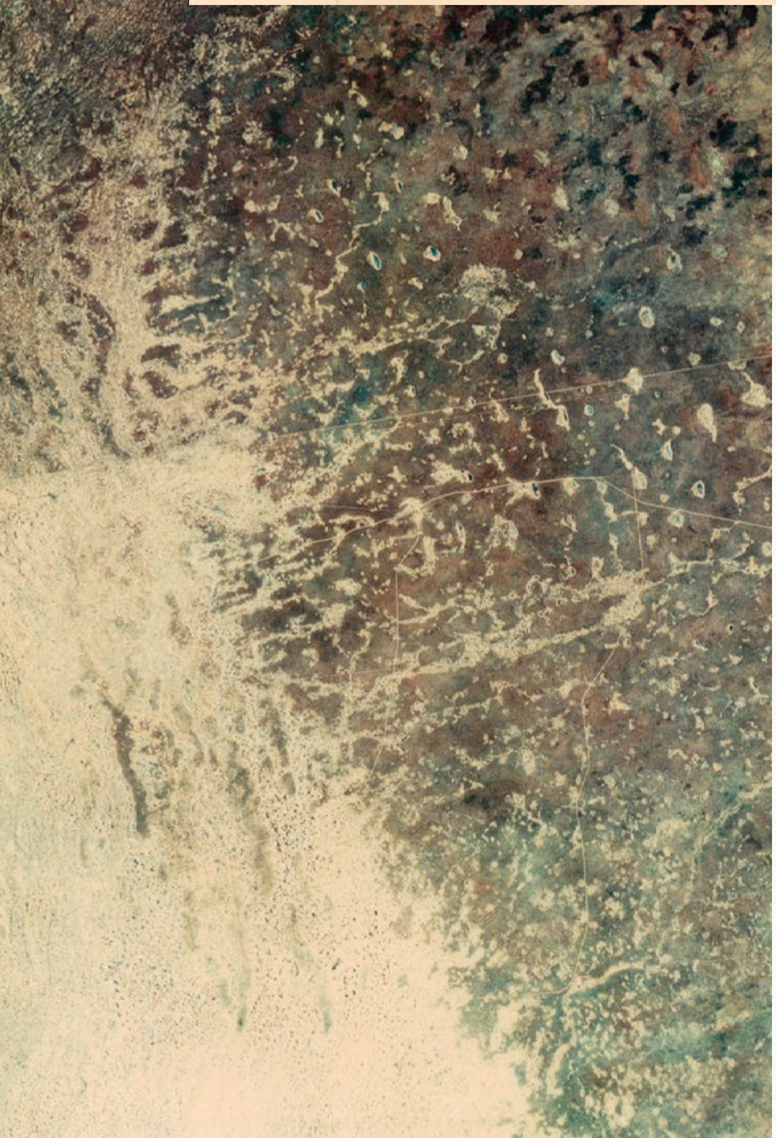
All SAC-acquired SPOT and Landsat data were archived, as well as Meteosat sub-scenes and NOAA data acquired during the two day-time and one night-time overflights of the NOAA satellite at the time.

PURSUIT OF BUSINESS OPPORTUNITIES

While sales of image data and value-add products almost doubled during the 1990-91 financial year, the EO team pursued new business opportunities relentlessly during the 1991-94 period, with the creation of a number of value-adding initiatives and systems upgrades.

PICS campaign

SAC and SPOT Image in France joined forces in 1991 to illustrate the benefits of using SPOT data. Project leader Tim Boyle launched the Promotional Introductory Campaign for SPOT (PICS), which attracted entrants from universities, government departments, research institutes and the private sector throughout southern Africa. Each participant received the required SPOT data, valued at about



A photographic print of a Landsat image received by the SRSC on 12 May 1984 and printed with a colour reference table along the right margin aligned with the image with the look-up table.

R300 000, free of charge for application in areas such as vegetation, geology, hydrology, land cover, urban use, pollution, soils and GIS.

SPOT Image and SAC shared the cost of the two-day event at which participants presented their results, while SPOT Image fully sponsored the first prize of a return air ticket and 10-day stay in France. SPOT Image welcomed the initiative, which stimulated significant interest among users in sharing data across disciplines.

By early 1992, SPOT Image reported an increase in world sales of 35%, with 8% of its market share in Africa. Initiatives such as PICS undoubtedly added to the increase in sales.

Upgrades and more

SAC's single-minded focus on client satisfaction was supported by ongoing system upgrades at Hartebeesthoek to add value to its data products and services.

Two CREO optical tape recorders were purchased to cope with the deluge, at the time, of 20 gigabytes of information daily.

The use of optical tapes increased the station's archival capacity dramatically, as well as its ability to process and deliver NOAA data to clients in quasi real-time.

The installation of one of the first large-format Rapid Access (RA) colour processors in the country, as well as the in-house adaptation of a B&W processor to process smaller sheets of Rapid Access paper, greatly increased the colour processing capacity of the SAC Photo-Lab, as colour prints were produced in less than five minutes.

The Lab also modified its enlarging system to create very large format photographic satellite images (12x enlargements of negatives) with outstanding resolution, greatly appreciated by the Lab's many satisfied clients.

SpaceMaps initiative

The SpaceMaps initiative started on a small scale due to a lack of equipment and resources. SAC purchased a stand-alone workstation to run commercial image processing software and Dr Geoff Longshaw, with extensive experience in Landsat data applications, managed the project.

The maps covered the same geographical areas as the 1:250 000 or 1:50 000 scale maps produced by the Surveyor General at the time.

Multiple images had to be precision-corrected to the relevant map projection, joined into one image and annotated with map scale graphics.

The project brought home the need for an equipment upgrade to add real value to remote sensing data products.

This vision became a reality some years later when a Geo-Information Products and Applications (GIPA) group was created at Hartebeesthoek.

SPACE INDUSTRY'S APOGEES AND PERIGEES

During the mid-1990s, the international space industry experienced a rollercoaster ride of apogees and perigees that took it from technological mastery to misery, sometimes in the blink of an eye.

Locally SAC was not short of noteworthy achievements, but also felt the effect of some of the industry lows.

The apogees ...

A space tether world record

By 1993, SAC had been a CNES network station for 10 years and supported more than 50 Ariane launches. Early in the year CNES requested SAC to provide NASA with mission support for its Small Expendable Deployer System (SEDS-1), scheduled to launch as a secondary payload aboard a Delta-II launcher on 29 March 1993. Unbeknown to the HBK team at the time, their participation would make them part of a world record-setting achievement.

Hartebeesthoek was ideally situated to observe some of the critical events aboard SEDS-1, a lightweight, "spinning reel" deployer[25] designed to investigate the use of tethers in space. The SEDS-I experiment involved deploying a 25 kg instrumented payload towards the Earth at the end of a 20 km non-conducting tether, to determine the dynamics of the deployer system.

SAC received the signals from SEDS-1 30 minutes after its launch and submitted the data to CNES in Toulouse, from where it went to NASA's Goddard Space Flight Centre and the Cape Canaveral Control Centre for analysis.

On its second orbit over South Africa, with SAC providing TT&C support, SEDS-1 deployed a tether to a distance of 19.8 km from the 2nd stage of the Delta launcher.

The successful deployment set a new world space tether record and was regarded as a singular achievement after earlier unsuccessful attempts had resulted in uncontrolled spinning and tether breakage.

A year later SAC assisted with the SEDS-2 experiment, identical to SEDS-1 except that the tether was left attached to the Delta's 2nd stage to burn up upon re-entry into the Earth's atmosphere. SAC's mission support lasted for two additional orbits and, once again, the Goddard Space Flight Centre expressed their satisfaction with the excellent quality of the data recorded by SAC. Yet another achievement added to a fast-growing list.

Impressive turnaround time

In anticipation of producing quality products from the Enhanced Thematic Mapper (ETM) aboard Landsat-6[26], MDA in Canada supplied SAC with a new data processing system in 1993. SAC's NOAA

An image of the Ngorongoro Crater (far left) in Tanzania acquired by the Landsat-7/ETM satellite in August 1995 at a resolution of 30 m over an area of 50 – 100 km.

A SPOT-5 true colour image of the Cape Agulhas coast line (left), acquired 4 April 2013.

processing software was also ported to a new workstation, which reduced the time to deliver a geometrically corrected sea surface temperature map dramatically from 16 hours to 40 minutes.

This impressive improvement had a positive effect on the station's EO income stream.

Final first generation SPOT satellite

SAC supported the launch of SPOT-3 from the Kourou launch site on 26 September 1993 aboard an Ariane-4 launch vehicle successfully and placed the satellite in orbit at an altitude of 822 km.

Launched as the last in the first generation of the SPOT optical observation satellites, SAC acquired the first data from SPOT-3 during its 4th orbit, after the solar panels had been deployed and adjusted to track the sun and the satellite's antennas had been orientated towards the Earth.

The second generation SPOT satellites, SPOT-4 and SPOT-5, were launched respectively in March 1998 and May 2002. While SPOT-4 suffered an early demise, SPOT-5 provided SAC's EO team with valuable two-metre-range imagery.

The perigees ...

A stillborn satellite

A month later, SAC looked on as technological sophistication hit rock bottom with the loss of Landsat-6. The satellite carried an Enhanced Thematic Mapper (ETM) that operated in standard TM-, panchromatic - and panchromatic-plus bands.

In anticipation of receiving data from the satellite, SAC had upgraded its equipment to provide clients with a full range of quality products, from the standard TM as well as the new panchromatic bands.

Two days after the launch from the Vandenberg Air Force Base in California aboard a Titan-II launcher, NOAA issued a press release that confirmed that the deployment of Landsat-6 had failed.

Controllers had received no signals from the satellite when it was expected to pass over Kiruna in Sweden and could not determine whether the spacecraft had achieved orbit.

Results of the investigation into the failure of the satellite indicated that the reaction control system had ruptured and fuel could not reach the engines. The spacecraft tumbled when it could not maintain altitude during the apogee kick motor burn and it re-entered the Earth's atmosphere south of the Equator 1 808 seconds after lift-off.

"In addition to the loss of a satellite, which in itself is significant, there must have been great disappointment among users in the remote sensing community who had been looking forward to the Landsat-6 ETM data set for many years."[27]

Ariane launch failure investigated

A significant loss to the space industry early in 1994 was the failure of Ariane-V63, which failed at 6 minutes and 43 seconds during the third stage burn. The launcher and its payload, the Turksat-1A and Eutelsat-2 satellites, crashed into the Atlantic off West Africa. A Commission of Enquiry concluded that the failure was due to accidental features and confirmed that all manufacturing, commissioning and operational procedures had been scrupulously applied. Insurers picked up the bill for €400 million.

Arianespace resolved the problem quickly and continued with its launcher programme until November 1994 when the Ariane-4 (V70), carrying

Placing a satellite into a geosynchronous orbit

A satellite is encased in a faring attached to the 3rd stage of an Ariane launcher and inclined 5° to the Equator. The CNES and NASA stations track the launch phase to confirm that the 1st, 2nd and 3rd stage separations of the launcher takes place. Just before Hartebeesthoek (HBK) acquires its signal, the satellite separates from the 3rd stage and starts transmitting telemetry data. HBK sends the data in real-time to the CNES Control Centre and checks that the satellite's solar panels are deployed, attitude is correct with antennae towards the Earth and solar panels to the Sun and all internal voltages and temperatures are within limits, before determining its orbit. CNES sends commands through HBK to correct any problems with the satellite. The launch trajectory places the satellite in an elliptical orbit - apogee of 37 000 km, perigee of 400 km. The final circular orbit at an altitude of 36 000 km requires several manoeuvres. The satellite's rocket motor is fired on its 4th orbit at apogee to circularise the orbit and the satellite moved North/South until directly over the Equator. It drifts to the allocated slot and the rocket motor is fired to stop the drift. When the satellite is on-station, it is checked again before handed over to its owners. Tracking stations then provide routine support or emergency operations.

the Panamasat-3 satellite, was lost, crashing 1 100 km off West Africa. Arianespace worked hard to get its launchers, credited as the most reliable in their class at the time, aloft again and succeeded to do so early in 1995.

CNES SCHEDULE OFFERS VARIETY

The increasing proficiency of SAC's technical staff at their TT&C consoles enabled CNES to schedule a variety of assignments for the station during the 1994-95 period. Some were interesting, others challenging ...

NASA, after 20 years

In January 1994, SAC provided mission support for the American DSPSE[28] spacecraft under the mission name Clementine.

For the first time in more than 20 years SAC had the opportunity to support a NASA space mission again – the last one had been in October 1975 when the Joburg STADAN had supported NASA's Mariner-10 (MVM) mission – when CNES scheduled HBK for the Clementine Deep Space Programme Scientific Experiment. A joint effort between the US Department of Defence, Naval Research Laboratory and NASA, the objectives were to map the lunar surface and return valuable data to the international civilian scientific sector.

Four American engineers arrived at Hartebeesthoek a week before the launch to interface the equipment between HBK and CNES and relay the data to the Operations Centre in California.

SAC's TT&C team and the American engineers jointly supported the mission.

The telemetry information from SAC during the lunar transfer orbit burn, which boosted Clementine out of Earth orbit and on its way to the Moon, probably covered the most important 10 minutes in the mission's lifetime.

The Operations Control Centre in California used the telemetry information received from Clementine to make mission-critical decisions and confirm the correct execution of commands to the spacecraft.

The whole operation was concluded successfully and performance all around exceeded expectations. The Californian Control Centre rated Hartebeesthoek's performance at 100%, the only station in the network to receive the accolade.

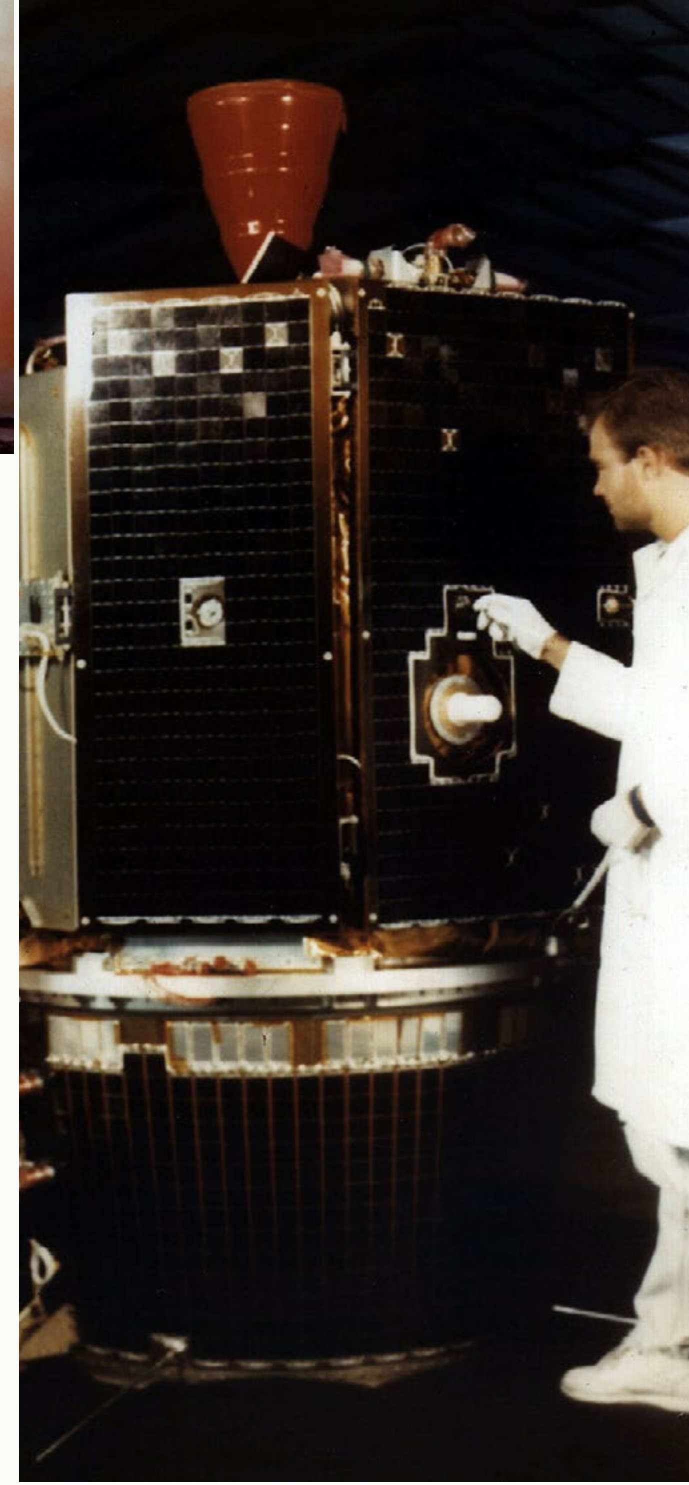
Tasso Karantonis, Pierre Picard and SAC were awarded a Certificate of Recognition by the Clementine Deep Space Programme Science Experiment for their technical leadership and contribution to the demonstration of advanced space flight technology.

"The performance impressed the American visitors and promises of future co-operation were mentioned. We hope that the future will open new doors for the Satellite Application Centre, the CSIR and the country as a whole."[29]

The GPS experiment

The Global Positioning System[30] (GPS) originated in the early 1970s when the US Department of Defence set up a space programme to provide users with a way to locate their position anywhere on Earth.

The intention was for the system to eventually run with 24 inclined orbit spacecraft. The system was by no means perfect and CNES spent six years working on a GPS overlay to offset the drawbacks.



Final checks to the Clementine satellite (far right) built by the US Naval Research Laboratory in 1993.

The launch of the Clementine Space Probe aboard a Titan 23G 14 launcher on 25 January 1994 (right).

The interpretation of data from the Clementine mission revealed that deposits of ice could exist in permanently dark regions near the South Pole of the Moon.

When CNES was ready to test the implementation of the system with a practical experiment in 1994, the agency requested SAC to install an experimental station as one of three experimental stations at Hartebeesthoek.

The other two were in Kourou, French Guiana and at the CNES facility in Toulouse, France. An Inmarsat-2 satellite in geostationary orbit was used to transmit a GPS signal over its area of coverage.

Data collection, regular time calibration and ionospheric calibration tests were performed between 20 April and 4 July 1994. Samples were continuously sent to CNES and, once a week, the bulk of recorded data was mailed to them on two 600 ft magnetic tapes. Once again, SAC delivered on time and according to the client's brief.

"At SAC the mission was carried out to the full satisfaction of CNES, which is presently processing the mass of data collected during the two-month duration of the experiment."[31]

Improved broadcasting services locally

Public broadcasting in South Africa improved significantly with the launch of Intelsat's Panamsat-4 (PAS-4) satellite on 3 August 1995. Placed in a geostationary orbit by an Ariane-4 launcher from Kourou in French Guiana, South Africans benefited from the satellite's powerful commercial television broadcasting.

As one of the global ground stations in the CNES network, SAC provided tracking support services successfully during the critical 3rd stage of the launch, also described as the Geostationary Transfer Orbit (GTO).

At the time, SAC had provided similar launch support services to more than 60 launches in the Ariane-4 programme under the CNES contract.

EARTH OBSERVATION: INCREASES AND INITIATIVES

SAC's income imperative required a further revision to its geo-information price lists in April 1994.

The SAC News monthly customer newsletter announced the 10% price increase and again endeavoured to put the issue of free access to satellite data into perspective.

By 1994 SAC had provided similar launch support services to more than 60 launches in the Ariane-4 programme under the CNES contract.

"We at the Satellite Application Centre prescribe to the [fact that] data should be eminently usable and fit for whatever purpose the user wants, but wish as we may, the data and its products will never be free. [There is a significant cost attached] to receive, process and maybe more importantly, archive the information, [for which] a well-equipped facility, staffed by highly trained and experienced people, is a necessity."[32]

By September 1994, numerous initiatives by the EO team had increased the sale of data products as well as SAC's external income stream. The team had also assisted in disaster management investigations such as...

First SAR data

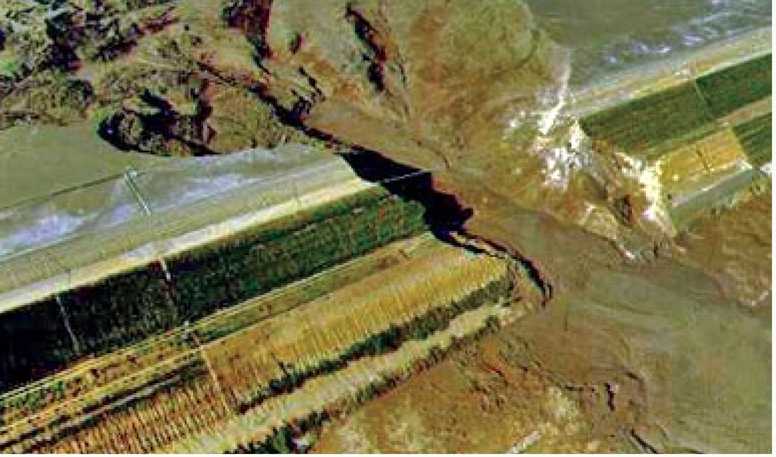
Late in 1993, following the conclusion of a Memorandum of Understanding between the CSIR and European Space Agency (ESA) for direct receipt of data from the European Radar Satellite (ERS-1) launched in 1991, ESA loaned SAC a Synthetic Aperture Radar (SAR) receiver to receive the data sets. The ERS-1 was ESA's first remote sensing satellite in the X-band frequency. The satellite used a microwave imaging system that penetrated cloud cover and rain during the day and at night and provided sea state parameters over vast areas of ocean. Applications included the assessment of soil moisture content, the detection and combating of oil spills and numerous applications in structural geology.

Less than a year later, SAC took delivery of its own demodulator and SAR processing system, with which to supply users with locally processed SAR data of southern Africa.

Satellite imagery approved for court case

On the night of 22 February 1994, following a late afternoon thunderstorm during which 50 mm of rain fell in 30 minutes, the 31 m high northern wall of the number four tailings dam of the Harmony Gold mine collapsed. The tailings dam is situated 320 m up-slope of Merriespruit, a suburb of Virginia in the Free State Goldfields of South Africa.

More than 2·5 million tonnes of liquefied tailings ripped through the sleeping mining village in waves of up to 2.5 m high. Eighty houses were swept away and 200 others severely damaged. Seventeen people were killed.



The Ariane-4 three-stage launcher (far left) was the work-horse of the commercial launch services industry from 1988 to 2003. The image shows an Ariane-4 launch vehicle in the mobile service tower rollback in the launch zone at the Arianespace Guiana Space Centre, French Guiana.

The collapse of a 31 m high tailings dam wall (left) of the Harmony Gold mine in Virginia in the Free State Goldfields of South Africa spilled more than 2.5 million tonnes of liquefied tailings into the Merriespruit mining village (right). Eighty houses were swept away, 200 were severely damaged and 17 people were killed.

SAC provided the investigators of the disaster with a sequence of satellite views that revealed a lack of maintenance over time.

For the first time in South African history, processed satellite images were allowed as scientific evidence in court. With the eyewitness reports, the evidence pointed to overtopping as the cause of the failure. The mine owner, operator and six employees were found guilty of negligence and fined heavily.

VECMAP added to package deal

In the interests of continuously improving its data products, SAC added sea current vector mapping (VECMAP) from NOAA images to its package deal of electronically delivered data. In addition to the VECMAP, the package contained METNET[33] and LBR33 data and used a Windows environment to display the information graphically.

Users received the data at their own premises within approximately four hours after the satellite overpasses and assisted, where necessary, with data application. The EO team used the SAC News newsletter to communicate the application of VECMAP data in more detail to its customers.

Value-added services

Towards the end of 1994, users could access SAC's online catalogue of archived Landsat TM and SPOT imagery. This enabled users to first select the data before placing orders with SAC. The database was updated daily with new acquisitions.

A record sales figure of R5.25 million for geo-information data products for the 1994-95 financial year was just reward for SAC's consistent focus on value addition. Examples included the catalogue database and SpaceMap products.

SAR data over southern Africa

By October 1995, SAC could supply users with Synthetic Aperture Radar (SAR) image data from the ERS-1 and ERS-2 satellites over the same southern African coverage area as SPOT and Landsat.

The advantage was that, unlike the optical SPOT and Landsat satellites, the ERS satellites could see through clouds. By merging SAR and optical images, far more could be brought out than when viewing the imagery separately. SAC's SAR processing system at the time produced image products that exceeded the specifications of the European Space Agency.

The system also contained a 'quick-look' database of images of southern Africa for inspection by users.

"ERS SAR provides a new look at the Earth, much as Landsat did in 1972. At the time nobody was aware that so much could be seen from space. Nowadays we accept as routine the amazing diversity of ground detail obtained from Landsat and SPOT, and we use the data operationally. In the same way, the use of SAR images will become routine." [34]

National land-cover database

Accurate and current land cover, land use and environmental data are critical in environmental planning and management.

Towards the end of 1995, the CSIR and the Agricultural Research Council launched a joint initiative to produce a single, standardised National Land Cover Database for the whole of South Africa, Swaziland and Lesotho.

Housed at Hartebeesthoek and managed by the GIPA team, the database contained 1992-1995 Landsat Thematic Mapper satellite imagery at the time.

The spirit of their legacy, the knowledge they had shared and the skills transferred, remained relevant to guide and support those who stayed behind.

With funding from the CSIR, ARC and external funding sources, the database was produced at a 1:250 000 scale and made commercially available for the first 24 months, after which it was released as public domain data.

Completed in 1996, the database conformed to national and international land cover classification standards and met the requirements of a wide variety of users.

CHANGING OF THE GUARD

A number of structural and other changes occurred at SAC between 1990 and 1995.

Tracker and Hackers evolve into TT&C and GIPA

The operations structure at SAC was split into two groups, the 'Trackers' and 'Hackers', to achieve greater operational efficiency. The first group was dedicated to the satellite tracking operations for CNES and acquiring the data from satellites for SAC's data archive.

The second group focused on the production and sales of data products and services to a wide range of customers, as well as interfacing with satellite operators and providing tracking schedules to the TT&C team for data downloads from the satellites SAC used for data processing.

Staff members were given an opportunity to select the group they wanted to work with, which interestingly resulted in an almost equal split. The 'Hackers' became known as the Geo-information Products and Applications (GIPA) group and later split into three groups: the GIPA, Data Acquisition and Distribution (DAAD) and Customer Services groups.

SAC purchased four Silicon Graphics workstations running ERDAS imagine processing and Helena Bosman, a systems engineer, managed the equipment upgrade for GIPA. Additional staff with the relevant qualifications and experience were hired and GIPA became the nucleus of SAC's EO business.

Retirement farewells

In September 1994, Hartebeesthoek bid a retirement farewell to seven of SAC's stalwarts: Willem Botha, Braam Broere†, Selwyn Clarke, Frans Meintjes†, Tasso Karantonis, Roy Osborne† and Louis Boshoff.

In their own inimitable ways, they had served the CSIR with distinction and contributed meaningfully to SAC's remarkable growth and many successful achievements.

Their presence at Hartebeesthoek had been such an integral part of 'life at SAC' for so long, that their sudden absence left a void felt by many. But the spirit of their legacy, the knowledge they had shared and the skills transferred, remained relevant to guide and support those who stayed behind.

Willem Botha was asked to stay on for some months in 1995 until Renier Balt took over as SAC manager. At the time, Willem took on new responsibilities as a Fellow of the CSIR.

GILDED HONOUR

After more than 30 years of active participation in the world's space age, it was a passion for excellence and the recognition that only people make things happen, that pervaded the work ethic at Hartebeesthoek.

Local and international clients alike expressed their appreciation regularly and certificates of merit on

International Peace Day (signified by the white balloons) celebrations at SAC in September 1994.

the walls of the buildings at Hartebeesthoek attested to a steadfast commitment to quality and value-addition prevalent among all staff at the station.

And in 1995, for the first time in the history of a CSIR business unit, SAC's entire staff complement and eight individuals were honoured for performance beyond expectation.

The CSIR Mikomtek Gold Coin Team Award went to every staff member, while Tim Boyle, Lynette Croft, Tasso Karantonis, Dr Geoff Longshaw, Ike Marais, William Matjebe and Alan Watson received individual Gold Coin Awards.

Willem Botha was honoured with a Mikomtek Director's Award. The Award citations[35] tell the stories of a team dedicated to a common purpose.

The SAC team *delivered a performance that surpassed expectation, acknowledged for "exceeding their [the SAC] budget and doing great work."*

AND, RIGHTLY, A TRIBUTE

If 1994 saw a "changing of the guard" at SAC, 1995 hailed the end of another era. This was the year when an icon of South Africa's involvement in space since the establishment of the first Minitrack at Esselen Park in 1957, announced 'LOS' ('loss of signal' as SAC's team leader), handed over the reins and bid farewell to Hartebeesthoek.

Whatever relationship individual employees had with Willem Botha, everyone acknowledged his strong, driven leadership and the high standards he set for staff and, more so, for himself.

As expected of a leader, he never shirked accountability – not to the CSIR, the staff or SAC's customers. His sense of responsibility resonated with those he led. On Willem's watch, everyone arrived on time, left on time, worked overtime when necessary and fully applied themselves while at work.

From the time that the Minitrack was established at Hartebeesthoek until 1995 when Willem left, members of staff who had travelled probably a few million kilometres to and from work in SAC's fleet of cars, did so without a single accident.

An unintended outcome, perhaps, but one never repeated.

The successes achieved by the CSIR's satellite applications facility at Hartebeesthoek during its first three decades, can be attributed to two factors: Willem Botha's leadership and the commitment of a dedicated and proficient team with the will to succeed. The relationship was symbiotic, but the golden thread was the strong leadership.

Many of those employed at Hartebeesthoek benefited from his benevolence. He took risks, when necessary, to employ them and supported them when they faltered.

Loathe to show his soft side, staff at SAC experienced it in abundance. Perhaps Roy Osborne[†] summed it up best when he said, "Willem Botha is a pussycat in a tiger suit!"

The people of Hartebeesthoek, the CSIR and the country owe Willem Botha a debt: there is no doubt that he led the SAC journey and guided the trajectory along which South Africa will continue to participate in the exploration of outer space to the benefit of the country and to humankind.

With thanks, from SAC colleagues, 2010.

1996 - 2010
Unprecedented growth


Timeline

1996 Produced SpaceMaps on 1:250 000 map sheets.

1997 Secured McDonnell Douglas and Hughes Space and Communications as first two new clients.

1998 Supported iridium constellation and Bonum-1 satellites, installed Ku/DBS band antenna and joined CEOS.

1999 Received SAEF Excellence Award and CSIR EHS and Outstanding Achiever Awards.

2000 Stats SA used satellite imagery for population census.

2001 Commissioned Ku-band ground station at Hartebeesthoek for CNES network.

2002 Secured Boeing and Honeywell contracts, supported inaugural Boeing Delta-IV launch and installed 5.4 m X-band antenna.

2003 Installed world's first Ka-band tracking facility and commissioned Eutelsat and EGNOS ground monitoring stations.

2004 Installed 11 m C-band antenna and secured Intelsat contract.

2005 Supported Spaceway-F1 launch and became a CSIR Centre for Excellence.

2006 Signed first-of-its-kind national coverage SPOT-5 data contract with Spot Image and delivered three faultless launch supports.

2007 Represented CSIR as CEOS Chair, installed 9 m Ku-band antenna and delivered first 2.5 mosaic from SPOT-5 data.

2008 Hosted international Landsat meeting locally and installed 7.3 m X-band antenna.

2009 Set new TT&C record of 20 launch supports and supported THOR-6 and NSS-12 launches.

2010 Improved TT&C record to 22 launch supports, achieved top line growth of 12% and took over operations of SumbandilaSat.

For the people at Hartebeesthoek, the common goal was to add value to local imperatives and enhance the station's global footprint.

The CSIR Satellite Applications Centre entered the final phase of its 50-year participation in the world's space age as a leading provider of satellite-based remote sensing data in southern Africa and a trusted partner in a global satellite tracking network.

Two years into the country's new democracy, 1996 dawned as the year in which South Africa's new Constitution, regarded by many as one of the most advanced in the world, was signed into law. At the CSIR Satellite Applications Centre, the venture started by a team of people at Hartebeesthoek in 1960 had come full circle.

Three-and-a-half decades later, SAC was again a valued link in a satellite tracking network, this time under contract to CNES, and was supplying users in Africa and beyond with sophisticated geo-information products and services.

With South Africa's re-entry into the global economy and a national focus on reconstruction and development priorities, the satellite tracking, data acquisition and geo-information facility at Hartebeesthoek entered a period of unprecedented growth that saw many of its business development initiatives come to fruition.

TOWARDS A COMMON GOAL

During the late 1990s, SAC's commercialisation initiatives substantially increased external income.

In Rand-terms, both the geo-information and satellite-tracking income streams were virtually on par, which boded well for future growth.

And two years into South Africa's new democracy, the enhanced data products that SAC produced were set to support many of the country's reconstruction and development initiatives.

With his hand new at the tiller, Renier Balt confirmed that the future direction at SAC would remain firmly entrenched in its established business domains and that it would also strive to play a constructive role in supporting national priorities.

A synthetic aperture radar (SAR) multi-temporal image of Botswana (left), received from the ERS-2 satellite on 28.07.1999 at 11:53 am.

The ERS-2 satellite (right), launched aboard an Ariane-4 on 21 April 1995, carried cloud-piercing radar instruments that monitored the Earth under all weather conditions as well as its ozone layer.

At the time, Hartebeesthoek (HBK) had supported many Ariane-4 launches under contract to CNES.

The station's satellite-tracking capabilities, well-experienced technical staff and unique geographic location favoured expanding its telemetry, tracking and command (TT&C) services, while remaining a trusted partner in the CNES tracking network.

Similarly, the growing demand for spatial information, as well as advances in satellite data-processing and new satellite sensors, such as the ERS-1, ERS-2 and RADARSAT satellites, were set to grow the market and boost SAC's geo-information business. SAC had already installed an enhanced processing system to provide users with the timely delivery of processed data.

"We will focus on market segments where we can add value and provide benefits with the eventual aim of providing customers with total solutions, rather than satellite imagery alone."[1]

For the people at Hartebeesthoek, the common goal was to add value, provide benefit and continually enhance the station's competitiveness.

In the build-up to the new millennium in 2000, SAC achieved considerable success in all its business domains.

SATELLITE TRACKING AND DATA ACQUISITION

Recognition within the international space community for SAC's satellite tracking and data acquisition (ST&DA) activities, confirmed the station's ability to contribute meaningfully to the business interests and research programmes of major players in the space industry.

First new contracts

In October 1996, McDonnell Douglas[2], then a prominent aerospace company, was the first to join CNES as a SAC client when the CSIR won the company's launch support contract for the Iridium constellation[3]. At the time, the constellation was identified as one of the most important satellite launch programmes of its kind.

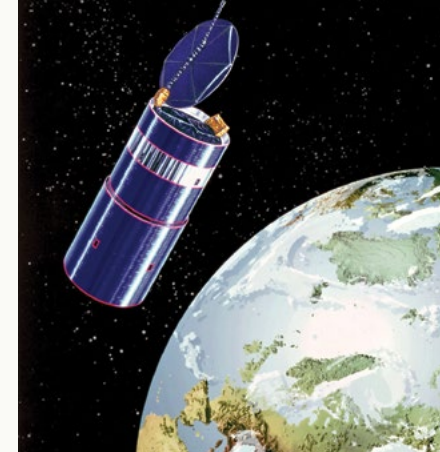
"CSIR SAC won the contract, not only because of its geographic position, but also as a result of its proven reliability and excellent track record in TT&C support. Iridium is one of the new generation satellite-based systems that will revolutionise the way we communicate. The 'information superhighway' is on its way and the CSIR is proud to play a part in this development."[4]

By early December 1996, a short three months after the contract was signed, the necessary equipment was installed and accepted at Hartebeesthoek. The 66 satellites (plus six spare satellites) of the constellation were scheduled to be launched over a period of 12 months and 12 days.

The McDonnell Douglas Delta-II was one of three launch vehicles contracted by Motorola and Iridium LLC (later Iridium Communciations Inc) to launch the satellites.

The first Delta-II payload consisted of five Iridium satellites and was launched over the South Pole from the Vandenberg Air Force Base in California on 5 May 1997.

The satellites deployed in Hartebeesthoek's visibility on the same day and the technical team successfully assisted in placing the satellites into their orbital slots.



McDonnell Douglas merged with Boeing on 1 August 1997 to form the Boeing Company. Boeing agreed to honour the CSIR-McDonnell Douglas contract for the remainder of the launch programme, which continued until May 1998.

SAC's performance contributed to 15 successful launches. In one 13-day period (late-March to early-April 1998) a record 14 satellites were placed into orbit. And 377 days after the first launch, on 17 May 1998, the full constellation had been deployed successfully.

In 1997, Hughes Space and Communications[5] became the second new international client when the CSIR won a competitive bid for a multi-year contract against a strong field of international competitors. Hughes required transfer orbit support[6] (TOS) and launch and early orbit phase[7] (LEOP) services in the Ku-band for all their geostationary communications satellites, for customers in Europe, the Middle East and Africa.

The project required a capital investment of R15 million and the installation of a Ku/DBS-band ground station at Hartebeesthoek by 31 July 1998. The deadline was unprecedented in the space industry. The target date was cast in stone: to calibrate and validate the new antenna system and baseband equipment with the Sirius launch in October 1998, to ensure that HBK was ready to provide reliable TOS support. The first prime TOS for Hughes was scheduled for the launch of the Russian Bonum-1[8] TV satellite early in November 1998.

With the prospective income from the Bonum-1 launch as the only collateral, Renier Balt and Michelle Le Saux convinced the CSIR Board of the long-term value of the investment.

The funding was approved and the first hurdle overcome, but others loomed. The SAC team had to install the new European antenna system in an unprecedented 10 months - an industry first - while its experience was based on US systems. The challenges seemed daunting.

SAC stalwarts, Willem Botha and Tasso Karantonis, were contracted to assist. Knowledge, skills and the determination to succeed won the day. The ground station, with its newly-installed 14 m Ku/DBS-band antenna and base-band equipment, was delivered as

A Boeing McDonnell Douglas Delta-II rocket (far left) lifted five of the 66 satellites for the Iridium communications system constellation.

A copy of the first Iridium satellite (far middle) in the US National Air and Space Museum.

SAC supported the launch of the Russian Bonum-1 satellite (far right), which delivered direct-to-home digital television services to the western part of Russia.

The Ku/DBS-band antenna (left) and and an Ariane-5 launcher (right) ready for lift-off.

planned, on budget, and in time for the launch on 22 November 1998.

The HBK systems worked faultlessly as SAC provided TOS for Bonum-1, lifted by a Delta-II launcher. The client was satisfied and the achievement created considerable respect within the space industry for the capability and proficiency of a small team at the southern-most tip of Africa in project managing the installation of ground infrastructure to meet client needs. Bonum-1 was the first of many projects for Hughes. The income from the Hughes contract doubled the station's revenue and confirmed the wisdom of the decision by the CSIR Board to approve the funding for the project. SAC's TOS and LEOP services eventually became the backbone of its commercial business.

CNES support

During the 1996–1999 period, as the world prepared for the new millennium, CNES scheduled SAC to provide launch support for a variety of spacecraft. These included the Indian Space Research Organisation's (ISRO) IRS-1C satellite and the first flight of the new generation Ariane-5 series of launchers.

Orbview-2 with SeaWIFS sensors

During the latter part of 1997, SAC's oceanology clients, who used NOAA data, indicated the need for data from the then recently launched Orbview-2 Seawifs* sensor. Following a stakeholder meeting in Windhoek, Namibia, SAC upgraded its facility to receive the Orbview-2 SeaWIFS data.

The upgrade improved the speed of processing the advanced, very high-resolution radiometer (AVHRR) data. This enabled SAC to provide clients who required data in quasi-real time with a better service.

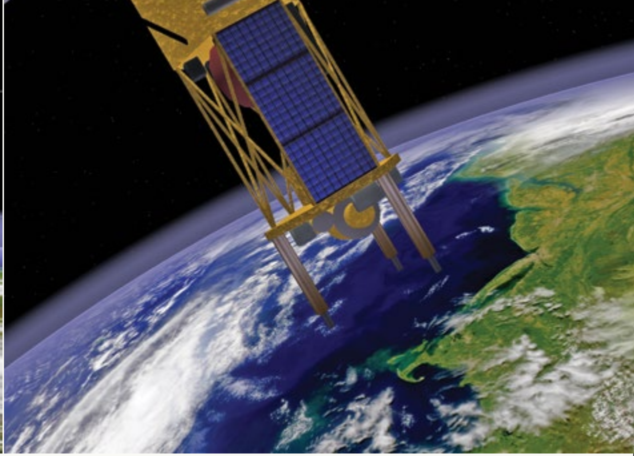
*Launched in 1997, Orbview-2 was the first commercial satellite to provide daily colour images of the Earth. The SeaWIFS sensor consists of an optical scanner and electronics module.

The online era

SAC's first website became available on 1 September 1996. Little more than a year after creating its online presence, the website had received over 11 000 hits. Initially, mostly international users visited the website, but as Internet access became more widely used in South Africa, more local users accessed the site for information about SAC's activities.

"Understandably, the initial traffic on the site has been slower locally than from international users, but we look forward to a steady increase as we continue to create awareness about the site."

- Ferdi Scheepers, SAC News 1997



The Indian organisation needed to transmit key commands to the IRS-1C satellite during its first and second orbits. These commands could be sent early from Hartebeesthoek because of its geographic location. The station upgraded its receive and transmit facilities in record time and ISRO engineers, Messrs N Lakshminarayana and V Subarao, spent two weeks at SAC to witness the launch and post-launch events.

The IRS-1C was launched on 28 December 1995 and during the 2nd orbit the Earth acquisition command was relayed successfully, which allowed the satellite to lock its sensors on the Earth and point its cameras on target. The ST&DA team supported the satellite with telemetry, tracking, ranging and commanding services faultlessly for two weeks, spending 500 man hours over the 1995-96 Christmas-New Year period and completing the mission early in January 1996.

On a visit to South Africa at the time, the Chairman of the Indian Space Research Organisation (ISRO), Dr K Kasturirangan, complimented the South African team for exceptional quality service, and another long-term international relationship was successfully established.

By 1996, the CNES was preparing for the first flight of its new generation Ariane-5 launcher, a larger version than its predecessors, designed to carry heavier payloads. At the time, SAC had been providing the French space agency with launch support for its first generation Ariane launchers since the first SAC support of Ariane-1 in July 1983.

Initially not scheduled to provide launch support for Ariane-5, a late decision by CNES six months before the launch to use HBK as a back-up station, triggered a frantic race against time to prepare for the event.

Michele Le Saux, Laure Boutemy, a French electronics engineer, and Tasso Karantonis teamed up to handle the preparations. In addition to installing custom-made Ariane-5 electronic, RF, telemetry and data processing equipment imported from France, new lower-loss RF cables had to be laid to connect the 12 m antenna feed and equipment to the operations room in time for the launch.

The team spent many hours during long days and longer nights communicating with CNES performing simulations to ensure that the HBK system was ready to support the launch.

A slow flyby of the SeaStar satellite orbiting the Earth (far left). The imagery of the Earth over North America was taken by the SeaWiFS instrument, on-board the SeaStar satellite, on 1 August and 24, 28 and 29 September 1998.

Artist's conception of the Mars Global Surveyor (MGS) (left) for which SAC provided launch support in 1996.

Wide angle cameras on the MGS recorded these Bluish-white water ice clouds above the Tharsis volcanoes on Mars (right) during one of its 12 planet orbits daily.

The special effort resulted in a truly outstanding achievement: completing in just six months what normally would have taken up to two years.

On the day of the launch, the SAC team was ready at the control console communicating with the CNES Control Centre. Seconds into the flight the launcher started tumbling and self-destructed. Faulty flight software activated the pre-programmed command to auto-destruct in the event of such a malfunction and destroyed the ill-fated Ariane-5.

"That was one of the lowest points in my career that I remember with great sadness, because of the effort and time we put into the project. We were proud of what we had achieved in such a short time. Although we knew that accidents happen in the space industry, the thought of one happening on our watch never crossed our minds." [9]

In 1999, CNES renewed its contract with the CSIR for SAC to provide tracking and telemetry support in S-band for the agency's space missions. A further agreement was signed for SAC to support CNES missions in Ku-band. According to SAC Business Development Manager at the time, Piet van der Westhuizen[†], the renewed contract and further agreement resulted from a long-term relationship between CNES and the CSIR and SAC's success in providing the French space agency with TT&C services.

Other new contracts

As the years rolled into the turn of the millennium, new clients and contracts increased the workload of SAC's Satellite Tracking and Data Acquisition (ST&DA) team significantly, adding to its experience and overall proficiency in an error-adverse industry. Budgeted targets were exceeded by more than 50%.

Late in 1996, US-based Core Software Technology (CST) contracted the CSIR for SAC to join the international Israeli EROS[10] network as the 6th station alongside those in Taiwan, Korea and Japan. SAC received, processed and distributed data from the high-resolution, Earth-imaging EROS satellites. The data went to SAC's GIPA group. EROS-A took to space only in 2000.

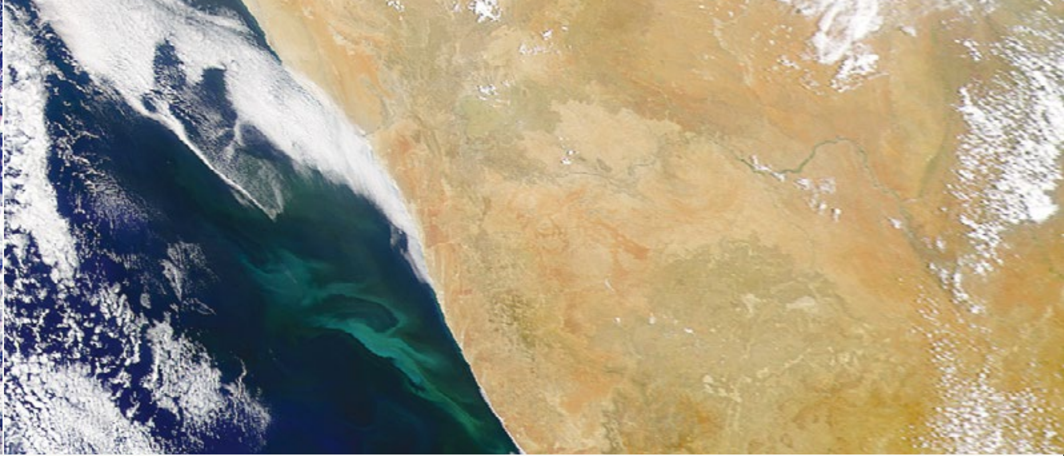
The facilities at Hartebeesthoek supported many deep-space missions in its early years and SAC remained involved. On 7 November 1996, SAC provided launch support for the US Mars Global Surveyor[11] (MGS), lifted by a Delta-II launch vehicle. HBK acquired the signal from the second stage of the launcher 32 minutes after lift-off. The technical team had to operate special equipment installed specifically for the launch and provided launch support faultlessly.

By 1997, the antennas at Hartebeesthoek were at times fully occupied for mission support, which jeopardised data acquisition activities.

To mitigate this, SAC reached an agreement with Denel to use its Overberg Test Range (OTB), tracking and reception facilities near Arniston in the Cape.

SAC equipped the facilities, which were established in 1980 to track satellites and receive data, specifically for the download of Landsat imagery to free up-time on the HBK antennas. This ensured that the data archive at SAC was not interrupted by downloads of geo-information.

And towards the end of that busy year, SAC supported the launch of OrbView-2[12] (SeaStar) aboard an Orbital Science Corporation (OSC)



Pegasus XL launcher on 1 August 1997. The OrbView-2 satellite carried the SeaWiFS[13] (Sea-Viewing Wide Field-of-View Sensor) imaging system, an 8-band multispectral imaging instrument with a 1 km spatial resolution.

The launcher was lifted below a Lockheed L1011 aircraft to an altitude of approximately 11 500 m, where the launch vehicle was released and fired to place the satellite into orbit. Following a month-long spacecraft checkout process that included 32 orbit-raising burns, the satellite was placed in its final orbit at an altitude of 705 km and declared operational in 18 September 1997.

On 12 December 1998, SAC supported a Delta-II launcher with NASA's Mars Climate (Polar) Orbiter[14] on board. The spacecraft was a robotic space probe launched by NASA on 11 December 1998 to study the Martian climate, atmosphere and surface changes and act as the communications relay for the Mars Polar Lander launched a month later.

Important events on SAC's ST&DA 1999 calendar included many successful launch supports, such as the Ariane Space Ariane-44L launcher on 26 February 1999 with the ArabSat-3A[15] and Skynet-4E[15] satellites on board. Then Communications Minister, Jay Naidoo, also announced that the CSIR would carry out a study into the feasibility of a geostationary communications satellite for South Africa. SAC was asked to spearhead the study.

"The supply of universal communications services to the country by means of a geostationary satellite could be an enabling factor for a large number of developmental initiatives: rural telephony, distance education, telemedicine and regional communications, to name but a few."[16]

Ground segment track record

SAC's geographic location and the proficiency of its ST&DA team made the Hartebeesthoek station a sought-after site for TOS services and station-keeping of geostationary satellites in Region 1 (Europe, Western Asia and Africa).

The proliferation of satellites already launched at the time, and those planned for the future, required expanded ground segments to deal with the increasing demands of the space segments.

SAC created a Ground Segment Establishment (GSE) unit in 1998 to respond to these demands after delivering the 13 m Ku-band antenna ground segment successfully and in record time for Hughes Space and Communications. Boeing (which bought Hughes Space and Communications Company in 2000) realised the potential of expanded facilities at SAC and confirmed their belief in the quality of the management and team at SAC.

They approved a large capital investment at SAC for a Ka-band antenna facility to complement the existing Ku-band facility. Boeing jumped to the number one overseas client of the CSIR during that period, which confirmed SAC's role in the organisation's international business development.

The Hartebeesthoek facilities enabled the GSE unit to cater for all ground segment systems, from small orbital determination and mobile antenna systems to single antennas and multi-antenna ground stations required for low-Earth orbiting satellite constellations. The unit also managed and maintained the ground segments on behalf of clients. SAC was leading the field amongst many of its peers in global tracking networks.

A fairly large fire in South Africa is visible in this SeaWiFS image (far left), possibly in the Tsitsikamma Forest and Coastal National Park. Sensor: OrbView-2/SeaWiFS, 12/13/99 (Source: SeaWiFS Project, NASA/Goddard Space Flight Center, and ORBIMAGE).

The increased number of antennas at Hartebeesthoek enabled SAC to receive and transmit signals in different frequencies, including the L-, S-, X- and Ku/DBS-bands (left).

All in all …

By 1999, SAC's TT&C client-base included CNES, Hughes Space and Communications, Boeing and, on occasion, NASA. Many other agencies and organisations also contracted its services through CNES, such as the Indian Space Research Organisation (ISRO) and the space agencies in Japan, Korea and Taiwan.

Due to a number of equipment upgrades since its first launch support for CNES in 1983, SAC could receive spacecraft signals in the L, S, X, Ka, Ku and DBS frequency bands and transmit in the S, Ka, Ku and DBS frequency bands. Initially, most clients required TT&C support in the lower frequency bands (L, S and X) but, by the turn of the millennium, higher frequency band support was gaining momentum.

Launch supports at the time tallied up to 130 for eight different international space agencies (although mostly for CNES) since 1983 and 600 since 1960, with TT&C support during the previous four years given on an estimated 10 000 passes and launches. Since SAC received the first image from Meteosat-1 in 1978, the number of Earth observation satellites from which SAC received imagery had increased to 24, with data received during an estimated 20 000 passes.

SPATIAL INFORMATION BUSINESS DOMAIN

During the 1990s, SAC gained recognition as a leading distributor of satellite-derived geo-information. Its footprint stretched across southern Africa and included the island of Madagascar to the East of the continent. Direct data reception from geostationary satellites and an extensive imagery archive enabled SAC's geo-information team to provide data users with a wide range of satellite data products and services.

SpaceMaps® and Quickmap versatility

In a joint venture with the Department of Agriculture, SAC used manual photo-interpretation techniques from a series of 1:250 000 scale geo-rectified SpaceMaps® to produce a standardised land-cover database for all of South Africa, Swaziland and Lesotho. Implemented in three phases over two years, the SpaceMaps® were mosaicked from seasonally standardised single-data Landsat TM satellite imagery for the period 1994-1995 to provide baseline land-cover information.

Completed map sheets were annotated, classified and digitised by a specialist team and the classification field-verified. Stringent quality checks ensured spatial data and scale accuracy.

The maps were produced in hard copy for the land-cover project, while other users could access it digitally. The land-cover project was completed at the end of 1997.

In 1998, SAC developed its UrbanEye 1:50 000 scale SpaceMaps® product. The maps produced detailed urban land-cover/land-use thematic mapping of South Africa's main metropolitan areas.

The maps provided Gauteng with full digital coverage of its main urban and peri-urban areas, promoted province-wide land-cover/land-use mapping and complemented the information in the national land-cover database.

With the UrbanEye products, the Gauteng administration could monitor its urban environments effectively. SAC also used data from sensors such as the SPOT and ERS SAR satellites as input into geographic and land information systems.

SAC contributed to land reform planning and decision-making with its Quickmap, a rapid mapping tool that used SPOT data to map remote land areas.

SAC had previously demonstrated its ability to quickly produce a map of a specific area in its reception footprint when it mapped the conflict area in Goma in the eastern Democratic Republic of the Congo during unrest in 1996. The map assisted the United Nations to supply thousands of refugees in the area with food and medical supplies.

When South African farmers were under pressure to optimise inputs and cut costs for financial survival in 1998, SAC used SPOT data to analyse sugar cane crops for biomass variations (waterlogged areas and irregular irrigation applications) and monitor the impact of corrective action. Imagery from SPOT multi-spectral sensors also provided farmers with information on crop conditions, such as irregular growth patterns in potatoes, maize and wheat.

SAC also contributed to the government's land reform programme. The Department of Land Affairs (DLA) required large volumes of information to manage more than 760 000 state-owned land parcels. The pooling of information between the DLA and SAC led to the creation of Quickmap to rapidly map remote areas from data received from the SPOT satellite.

The automated Quickmap method made specific satellite-derived geographic information available within a week of receiving a request from the DLA. Data users of the Department confirmed at the time that Quickmaps greatly assisted their land reform planning and decision-making processes.

International and regional collaboration

As the leading remote sensing organisation in southern Africa, SAC partnered with a number of international peers in co-operative projects. These included SpaceMaps® production and training at the National Remote Sensing Centre in the UK, joint data set in a GIS interface, and training with GAF, an applied remote sensing company in Germany, and the commercial exploitation of the SeaWiFS in the European/African region.

SAC also continued with its long-standing commitment to provide NOAA data for the Global 1-KM AVHRR data set, which the European Space Agency (ESA) and EROS Data Centre in the US collected and processed. Regional agreements included co-operation in Earth observation applications and data distribution with the Environmental and Remote Sensing Institute (ESRI) of Zimbabwe, and assisting the Land Use Planning Division of the Lesotho Ministry of Agriculture to monitor land-cover change in the country over a 20-year period.

Monitoring tailings dams

With the 1994 Merriespruit/Harmony Gold tailings dam disaster still stamped in memory, SAC, SPOT Image in France and the CSIR's Building Technology and Mining Technology Divisions collaborated in Project Pinotage. The purpose was to determine a way to monitor, predict and prevent the recurrence of such as catastrophe. Funded by the French Government, the investigation used SPOT data over South Africa to monitor water levels on the surface of tailings dams in the West Wits line area of Gauteng (from Roodepoort in the north-east to Carletonville in the south-west).

At the time, four mining houses – Anglo American, JCI, Gold Fields and Rand Gold – were operating in the area with numerous tailings dams of different types. The project team used field surveys to validate and refine their development of a preventative methodology. This initiative was taken further by SAC and Anglo Gold some years later.

Theodore Solomon (left) sits next to the metal ball that he saw fall from the sky on a farm near Worcester, outside Cape Town, South Africa in April 2000. This and two other space remnants found in the same area at the same time, were identified as a titanium pressure sphere, steel propellant tank and composite combustion chamber from a Delta-II rocket and are kept at the South African Astronomical Observatory (SAAO).

Space debris quo vadis?

"Space debris remains in orbit far longer than natural meteorites, which either disappear in space or burn up upon entering the Earth's atmosphere. Atmospheric drag, which increases as the altitude decreases, is the major cause of man-made orbital (space) debris that re-enters the Earth's atmosphere.

"The proliferation of space debris in the most useful orbital regions – especially the geo-synchronous region at 36 000 km from Earth where debris will last indefinitely – is of far greater concern than the threat of it falling to Earth.

"Many thousands of objects larger than 10 cm orbit the Earth, as well as 10 million particles smaller than 1 cm in diameter. Given the damage even a fleck of paint can cause in a hypervelocity impact, orbital debris poses a serious threat to man's future activities in space.

"In the future, the life span of a satellite will not be determined by the technicalities of the satellite itself, but by its ability to share orbital regions with existing, functioning satellites and space debris from past activities."

– Willem Botha

Data acquisition and database management

In September 1996, SAC's data catalogue became available on the Internet for the first time. Users could view and interact with the archive.

The catalogue initially provided SPOT data only, with 'quick looks' of all 1996 SPOT images. The catalogue was updated the following year to provide access to Landsat, ERS and NOAA data. Thereafter, all new data acquired by SAC were added on an ongoing basis.

By 1997, ground stations were increasingly required to tailor-make data products to meet specific market needs.

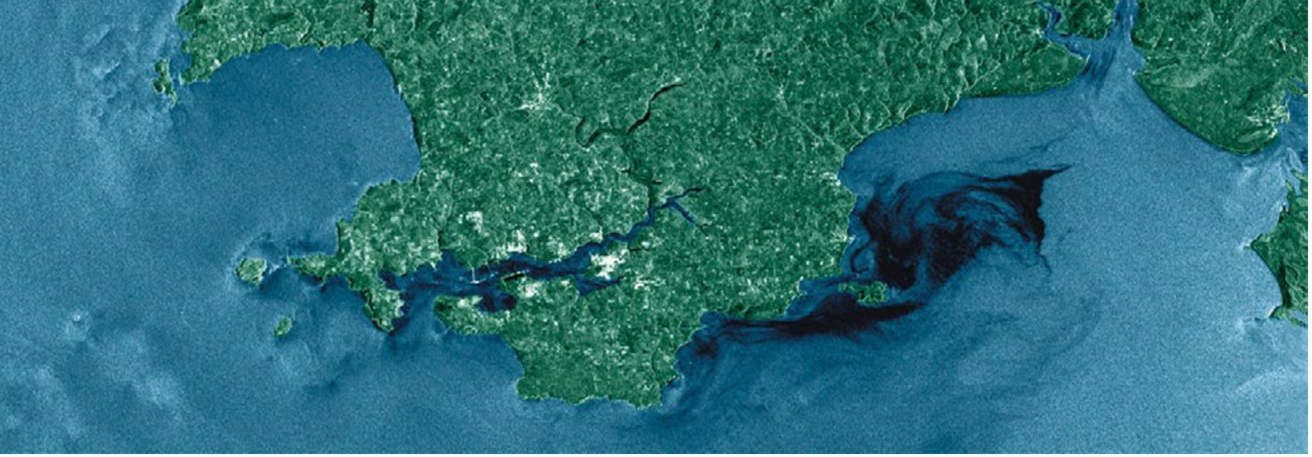
One such a niche market was the marine communities in Angola, Namibia and South Africa, who required information on sea surface temperatures from the NOAA AVHRR sensor and on ocean colour from the SeaWiFS sensor.

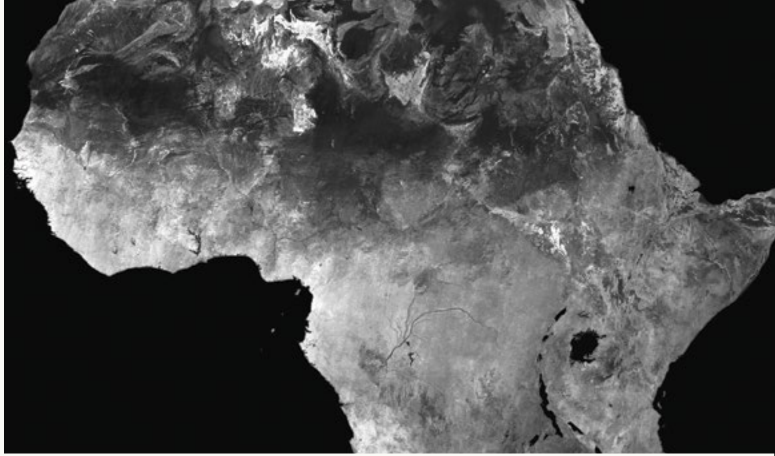
In addition, synthetic aperture radar (SAR) images had opened up new markets, either with their own applications or in interesting combinations with optical products. One of SAC's first initiatives in that regard was a license agreement with the Canadian-based RADARSAT[17] International in Richmond, British Columbia in 1997, to distribute RADARSAT products and services locally and in southern Africa.

"Our market intelligence clearly indicates the need for RADARSAT products and services in southern Africa. We intend to enhance our current position as a distributor of RADARSAT products, by including functions such as the direct reception of these data to offer clients a faster and wider range of services. SAC also believes that revenue sharing is a sound basis for business, which will help ensure that the benefits of Earth observation reach all the world markets, including those focused on development."[18]

Radar imagery was reliable, unaffected by weather conditions and available at regular intervals, and therefore especially cost-effective for wide-area monitoring, such as combating illegal fishing.

At the time, coastal areas were monitored by ships and aircraft only, and the illegal activities off the southern African coast near Prince Edward Island cost the South African and Namibian governments millions in lost revenue. The use of RADARSAT data assisted both countries greatly in curtailing





much of the illegal activity. As a RADARSAT network participant, SAC also offered customers subscription to an emergency response system to access radar imagery in emergency situations.

And, by 1999, SAC's unique Earth observation database consisted of almost 30 terabytes of imagery obtained from a variety of satellite sensors dating back to 1972.

The already invaluable resource contained data from the Landsat polar orbiting sun synchronous satellites (since 1980), SPOT polar orbiting sun synchronous satellites (since 1989), NOAA polar orbiting meteorological satellites (since 1984), ERS-1 and ERS-2 European polar orbiting Synthetic Aperture Radar (SAR) satellites (1994-1999) and OrbView-2 polar orbiting multi-spectral 'ocean colour' satellites (since 1998).

The multi-sensor, multi-spectral, multi-temporal database was used extensively in change detection over periods of time, and for vegetation index determination, land-cover mapping and cartography, as well as for renewable resources monitoring and management.

Geo-information equipment upgrades

As part of its ongoing upgrade programme, SAC procured a NOAA/Orbview-2 receiving, ingest, archiving, processing and data dissemination system from the SeaSpace Corporation in California. The stand-alone system consisted of a 1.2 m L-band antenna in a radome[19] with the related equipment and a decryption device for the Sea-viewing Wide Field-of-View Sensor (SeaWiFS) data.

Ike Marais and Helena Bosman visited SeaSpace for design input. During installation of the system at Hartebeesthoek, SeaSpace engineer Dan Waltman assisted with training and systems testing before the system became operational in July 1998.

The system automated many daily operational tasks and, once more, enabled SAC to add value to customer products and services. Midway through 1999, the facilities were also upgraded to receive, ingest, archive, catalogue and process SPOT-4[20] imagery.

The short-wave infrared band feature on the satellite greatly improved the ability to distinguish between different types of vegetation cover and land-use classes and was especially useful for precision farming[21].

The value of satellite imagery in precision farming was confirmed when Kynoch, a South African fertiliser manufacturer, started using satellite-derived information provided by SAC to add value to their services. A cost-saving of R350 per farming ha was achieved by managing fertiliser application in zones identified with satellite data.

"SPOT satellite imagery is proving to be an ideal, cost-effective data source and precision farming tool... [and] SPOT images support the provision of precision farming services to Kynoch clients."[22]

The main challenge for SAC's geo-information group at the time was that imagery from space was too expensive for most applications.

SAC responded by leading the way towards affordable datasets for many more users and developing cost-effective applications. With affordable application, users could experience the benefits and eventually use the wealth of information available in imagery from space.

Radarsat-1 image (far left) using synthetic aperture radar (SAR) to acquire imagery day or night, in all weather conditions, such as this oil spill from the Sea Empress oil tanker along the Wales coast line at Carmarthen Bay in 1996.

Africa mosaic (far right) compiled from about 1 600 Radar¬sat scenes acquired between 1997 and 2002.

True-colour scene (left) with a large dust plume blowing north-east from the Sahara Desert (acquired by SeaWiFS aboard the Orbview-2 satellite on 19 August 2004).

Ike Marais, SAC (right and right in photo) and a GSFC engineer (left in photo) during a SeaSpace system assessment visit to Washington.

In the various international forums where SAC was represented, such as the Landsat Ground Station Operators Working Group (LGSOWG), the call for affordable datasets to encourage wider use pioneered changes that led to data democracy in later years. Changes in legislation and international agreements often took years from idea to implementation.

The establishment of new value chains and the uptake of user communities of innovative new products were equally slow.

SAC took on this challenge by providing products and services in less lucrative applications, such as agriculture.

Data sets for academic study

The value of academic study to develop new and operational Earth observation applications is unassailable and cannot be underestimated.

In 1998, SAC responded to numerous requests for affordable data from academic institutions with a guideline policy that made data available at no cost to these institutions. The policy stipulated that should commercial gain result from such use of the data, it would accrue to CSIR SAC. The data were used, for instance, to show the effectiveness of GIS and remote sensing as tools for conservation management.

In a MSc thesis at the UK University of Greenwich, D S Hetherington used 'before' and 'after' Landsat TM imagery to show the extent of burns in South Africa's Kruger National Park when a dry electrical storm with no accompanying rain sparked a devastating fire that caused a loss of some 20% of vegetative surface area.

CSIR SAC a CEOS member

SAC joined the Committee on Earth Observation Satellites (CEOS) as a CSIR representative at a CEOS Plenary Session in India in November 1998. CEOS was created by a number of space-faring nations in 1984 to co-ordinate all civil space-borne missions that observed and studied our planet.

The involvement of South Africa in this body, despite the country's relatively small footprint in space, later led to South Africa's leadership role in many international bodies and was a significant breakthrough at the time. The table was set for bigger things to come.

The intent of CEOS, unchanged at the time of writing, is to understand how the Earth's systems of land, air and water interact to make life possible and how humans are impacting on these systems.

As a CEOS member, SAC promoted the practical application of Earth observation data in the context of Africa. Swaziland, for instance, was provided with an updated map in 1999 of indigenous woodland and exotic forest resources at a 1:50 000 scale, to assist the country in managing forestry degradation.

THE CAPACITY DEVELOPMENT DOMAIN

The need for additional capacity at SAC to deal with an increased workload, as well as an urgent need to increase the basic and specialised skills resource base in geo-information applications across the African region, gave impetus to the launch of SAC's training thrust in 1996.

During the ensuing years, the station's involvement in facilitating training programmes increased ten-fold.

Service Excellence

Specific needs at the time, in addition to training in geo-information systems (GIS), included the use of new technologies and sensors, such as synthetic aperture radar (SAR). Priority was given to training professionals in Earth Observation (EO) applications and geographic information systems (GIS).

In the years leading to 2000, some training courses were developed in partnership with international peer organisations and tertiary education institutions locally.

Training programmes included short courses, lectures and practical courses at universities, workshops and internships at Hartebeesthoek, and ad hoc, on-site training programmes in SADC countries to meet client needs.

In June 1997, SAC signed a Memorandum of Understanding (MoU) with the French Aerospace Remote Sensing Development Group (GDTA), recognised worldwide as one of the top remote sensing and GIS training groups. The agreement entailed the joint development and presentation of courses and workshops in satellite imagery and GIS applications for professionals from SADC.

"Given sufficient interest, ad hoc courses can be tailored to meet client requirements. If training facilities are available at client premises, training can be held at such premises."[23]

Training courses focused mainly on land use management and geo-information systems (GIS), synthetic apperture radar, Earth observation, remote sensing, satellite imagery, satellite data merging, radar processing and the use of the SpaceMaps® system. SAC assisted in lecturing and practical course work at the (then) Rand Afrikaans University in geo-informatics, remote sensing and image processing.

Client-specific training courses were presented, among others, at Cenacarta in Mozambique and locally at the Department of Communications' South African Institute for Space Applications (SAISA).

Three SAISA students – Mmule Pelo, Tumisang Sebitloane and Ziphokazi Mahlambi – received scholarships from the French Ministry of Foreign Affairs and the French Embassy in South Africa, to attend the 10-month CETEL remote sensing course at GDTA in Toulouse, France.

The course was preceded by a three-month internship at SAC and a further four months upon their return to complete their practical CETEL project. Fondly dubbed SAC's 'Space Girls', all three completed their training successfully and are contributing in their careers to the country's rare skills pool in remote sensing.

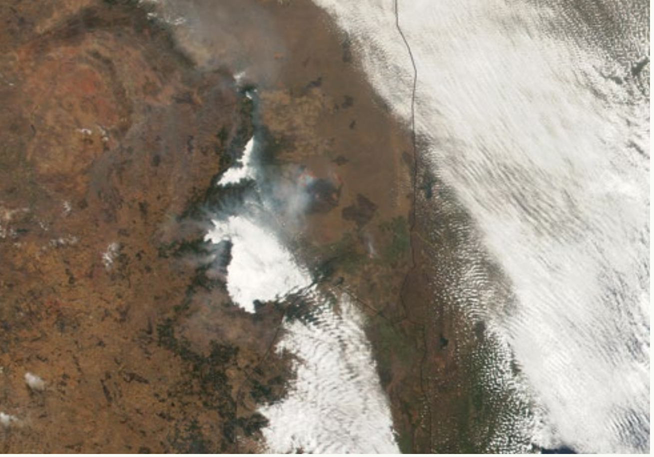
Two more students started a similar cycle in 2000. During the four years from 1996 and 1999, 176 students completed training at SAC successfully. The training team also investigated the integration of training activities under a CSIR-University of Pretoria partnership.

THE SAC TEAM TAKES HONOURS

As 1999 drew to a close and the world waited for the dawn of a new millennium, the culture of quality and excellence among the people at SAC was rewarded by a number of awards.

1999 SAEF Award

The South African Excellence Foundation (SAEF) granted its 1999 SAEF Award for Deployment in Excellence to SAC. The Foundation commended the Hartebeesthoek team for 40 years of leading



True-colour image of a fire in Kruger National Park (left) compiled from MODIS data acquired on 5 September 2001 shows the perimeter of the fire burning and emitting heavy smoke.

The first three-year training MoU signed between the SAC/GDTA/French Embassy tripartite (right) on 3 November 1997, with (ltr) Tim Boyle and Renier Balt (SAC), Pierre-Yves Revillion (GDTA) and Jacque de Mones, Cultural, Scientific and Co-operation Counsellor at the French Embassy at the time.

A new look for the TT&C nerve centre

By the early 2000s, SAC's fast growing customer base and the resulting increase in infrastructure, including the new Ka-band and X-band antennas, continually saw new client-specific equipment installed in the control room.

Older, larger pieces of equipment made way for small, computer-based systems that freed up space for expansion.

It was time to revamp the TT&C Operations Centre.

During the course of 2001 the entire area was given a new look. Separate control centres for the S-, X-, Ka- and Ku-band systems were created with an ergonomic design that allowed operators access to all the equipment from one sitting position.

The reconfigured functionality of the control room, which included a new electronic card security system, worked well from day one – in fact, so effective has it been that it has remained unchanged to the present day!

South Africa's involvement in space applications in the region – a time during which SAC provided launch support to more than 600 satellites and became the leading distributor of geo-information on the African continent.

In an error-averse industry, SAC had gained international recognition for its high levels of service and reliability, and given stature to the CSIR and South Africa in the international space industry.

1999 CSIR Technology Showcase Awards

The CSIR recognised SAC's service excellence when the station scooped the Environmental, Safety and Health (EHS) Award for the highest score (92%) in the organisation's annual National Occupational Safety Association (NOSA) EHS audit.

EHS team members Raoul Hodges, Piet Malan, Steven Tsefu and Amoure Patrick were commended for ensuring that SAC's EHS systems and processes exceeded expectations. And still there was more – SAC Manager Renier Balt was named an Outstanding CSIR Achiever for his commitment to delivering high-quality, value-added products and services to clients and stakeholders.

And (then) CSIR Fellow Willem Botha, one of the longest serving employees and station managers at SAC, received the MT Steyn Medal for a life-time achievement in Natural Sciences and Technology from the South African Academy for Science and Arts.

The award was made in recognition of his contribution to space matters, in which he had been involved since the first Sputnik launch.

A World Heritage Site

The pinnacle of reward, however, came with the announcement late in the year that the area around the Sterkfontein Valley in Western Gauteng (where SAC was located) and the North West Province, known as the Cradle of Humankind, had been declared a UNESCO World Heritage Site.

Elated employees ended an eventful year celebrating not only that their work environment was located in a World Heritage Site, but also that the motivation submitted to the World Heritage Bureau by the Gauteng Department of Agriculture, Conservation and Environment had benefited substantially from their contribution.

Two views of the 12 m antenna at the Hartebeesthoek antenna farm.

As a new (1997) signatory to the World Heritage Convention, South Africa's three nominations – Sterkfontein in the category 'culture'; Lake St Lucia in the category 'nature'; and Robben Island in the category 'history' – were all successful.

Passionate about conserving the area, the people at Hartebeesthoek committed to making satellite imagery available for any Environmental Impact Assessment of the area, to ensure that the Cradle of Humankind World Heritage Site remains protected as one of the 981[24] World Heritage sites (of which eight – at the time of writing – are in South Africa).

A WORD FROM THE CLIENT

By the end of 1999, staff members in both business areas and the capacity building domain at SAC could look ahead to a new millennium from a solid track record of accuracy, reliability and client satisfaction. In the words of some clients:

"Over two years ago, we set about building relationships between CSIR and Hughes Space and Communications. Today we can view with pride the industry leadership that this partnership has wrought. Both of our organisations have flourished as best-in-class in their respective communities. We enter into the new millennium with confidence that our joint efforts are making a difference for good, in the lives of people everywhere. Our partnership is definitely here to stay and grow."

- Edwin Ramsay, ***(then) Manager: Mission Operations at Hughes Space and Communications***

"Thank you very much for your prompt and very professional proposal. I only wish our specifications had been as comprehensive."

- Jonathan Barter, ***Marketing Development Manager, Europe*Star*** *(SAC was subsequently awarded a contract from Europe*Star to establish and operate a Ku-band antenna)*

"You and your organisation's team members were a major part of the CLEMENTINE (Deep Space Program Science Experiment) success. It is my sincere hope that we may again work together on another program like CLEMENTINE."

- Jack Chapman, ***Praxis Inc for the CLEMENTINE Project Team***

Rolls Royce in tracking excellence

Reliable and hard-working – SAC's gigantic 12 m high-performance parabolic antenna, which today still dwarfs the other antennas at Hartebeesthoek, celebrated a 40-year track record in 2004.

As the first resident at Hartebeesthoek, the antenna was comissioned to NASA in August 1964 to track and acquire data from the first Orbiting Geophysical Observatory (OGO) satellite. The OGO's highly eccentric orbit of 150 000 km into space was expected to be a challenge for the 12 m dish, but it performed perfectly.

Regarded as the Rolls Royce of low-orbit tracking antenna, the 12 m rescued a $400 million satellite, received data from scientific packages left on the Moon by the Apollo astronauts, tracked the BIOS capsule with a monkey on board, received more than four million minutes of data from dozens of NASA scientific satellites and supported hundreds of NASA launches between 1964 and 1975. The antenna's final launch support for NASA in 1975 was for the Project Viking exploration mission to Mars.

The 12 m antenna underwent a number of upgrades over the years and remains a stalwart at the Hartebeesthoek antenna farm.

External income for the 1999/2000 financial year was up by more than 45% compared to the previous year and, for a second successive year, had increased by more than 40%.

"Thank you for the excellent turnaround on the last order. With your assistance the gaps in our block have become few ..."

- Phil Bearden, ***EarthSat Corporation, USA***
(This comment followed the largest single order for Earth observation imagery in SAC's history: 375 Landsat TM data to deliver a project for NASA to provide once-off global high-resolution coverage using Landsat TM data).

A NEW MILLENNIUM

To be a world-class African organisation in the provision of services, products and information related to the space industry and its applications; doing competitive business in the global market with our internationally recognised staff.
- SAC mission, 2000.

SAC entered 2000 with an overall performance aligned with business plan forecasts for capital investments and a workforce that met its diversity targets. By 2000, 40% of the staff complement at SAC consisted of previously disadvantaged individuals. External income for the 1999/2000 financial year was up by more than 45% compared to the previous year and had increased by more than 40% for a second successive year. This reduced the station's dependence on government funding (CSIR Parliamentary Grant), which was used mainly to maintain datasets from Earth observation satellites. The ratio of its contracted external income to CSIR funding had also decreased to 28% (1995: 43%).

SAC's 2000/2001 business strategy was set to diversify its client base for orbital services and extend its geo-information product offering in line with market requirements.

Growth in its ground segment business was already positioning the tracking station for longer-term orbital and related services. Everyone at SAC welcomed and supported the suggestion of increasing the number of antennas at Hartebeesthoek to create a veritable antenna farm.

Strategic focus areas included developing SAC as a centre for advice on space and related matters, establishing constructive relationships with suppliers of image telemetry and adding further value to its Earth observation products and services (specifically agriculture, land affairs and water resources).

Internal priorities included new staff training and extending the competence base of existing staff, while all employees participated in a culture-shaping programme to reinforce a market-orientated and commercial approach to all business activities.

During the 2000 to 2004 period, solid progress was made in all SAC's business domains and, where challenges occurred, the inimitable SAC spirit of overcoming diversity ensured that they were dealt with head on.

TRACKING, TELEMETRY AND COMMAND (TT&C)

With three major clients (CNES, McDonnell Douglas and Hughes Space and Communications), SAC's proficiency in mission support services was firmly established within the global space industry.

SAC's client base for orbital services soon increased with contracts from space agencies in India and on the Asian continent, including the Indian Space Research Organisation (ISRO), Japanese Space Agency (NASDA), Korean Space Agency, Taiwanese Space Agency and others.

In October 2000, Boeing acquired Hughes Space and Communications following its earlier acquisition of McDonnell Douglas – all in the space of three years – and Boeing Satellite Systems became the CSIR's largest foreign client.

In addition to CNES and Boeing, long-term contracts included the Lockheed Martin-run Consolidated Space Operations Contract (CSOC) for end-to-end mission and data support in the S- and X-band.

SAC also became a validated station in the Space Systems Loral (SSL) global network after successfully completing TOS during the separation of Europe*Star[25] from the Ariane-4 launch vehicle in October 2000.

Launch and emergency support

The TT&C team successfully provided launch support for the Hispasat-1C, a communications satellite for Spain launched aboard a Lockheed Martin Atals-2A5 launch vehicle from Cape Canaveral in February 2000. Contracted by CNES, SAC provided TOS for approximately two weeks until the satellite was correctly positioned in its geostationary orbit. Hartebeesthoek acted as the primary station for data reception and transmission for about 90% of the time.

At the time, SAC was also contracted for emergency support when an anomalous 2nd stage burn left the Orion-3[26] satellite marooned in an orbit 30 000 km below its planned position.

The SAC team reacted swiftly. Within two hours, despite the satellite's instability and high angular velocities as a result of its low orbit, which was confirmed by other ground stations, they had implemented operational procedures and successfully tracked the satellite. SAC remained involved in a number of attempts to put the satellite to some practical use, but eventually CNES abandoned all attempts.

SAC also assisted CNES with TOS and LEOP support for the Asiastar, Nielsat 101 and Eutelsat-W1 satellites, respectively lifted by the Atlas-II, Ariane-5 and Ariane-4 launchers, as well as to Loral SS for Europe*Star and Boeing Satellite Systems for PAS-1R aboard an Ariane-4 and Ariane-5 launcher respectively. The tracking station also provided launch vehicle support to Boeing/NASA for the Delta-II and Delta-III launchers with the Image and Demosat satellites as the respective payloads, and to CNES for a Delta-II carrying the EO-1/SAC-C craft into space. In addition to the emergency support for Orion-3, CNES also contracted SAC to provide emergency support for the ETS-7, GRO and ERS-1 satellites.

Track record in turnkey delivery

Since its establishment in the late 1990s, effective marketing and the record-time installation of the 13.2 m Ku/DBS-band antenna ground segment established the reputation of SAC's Ground Segment unit to rapidly deliver turnkey projects.

By February 2000, SAC had completed the CNES-contracted installation of a 1.5 m Ku-band antenna to provide launch support for the Stentor[27] satellite. The Ku-band facilities were also integrated with the rest of the existing CNES equipment to provide the French space agency with TOS, including backup and emergency support, for future Ku-band missions.

An upgrade to the 12 m antenna in 2000 was done under contract to Boeing Satellite Systems to

A great adventure

The retention rate of staff in the space industry is arguably one of the highest in the world. People typically remain active in the industry for 30-45 years. At SAC the average staff retention rate was 15 years.

Why did people stay at SAC?

"Because space exploration is an adventure. You watch the Earth through the eyes of a satellite. You play on a global stage where the challenges take you into unchartered territory. Today's answers create tomorrow's questions and today's knowledge may still have been entirely unknown yesterday.

Because it offered a unique work environment. A few steps outside took you to within touching distance of a herd of wild antelope. Back inside was a high-tech world where the touch of a button took you out among the stars.

Because it was challenging. You had to be at the top of your game all the time. There was always a new satellite or a further frontier to discover.

And, because of SAC's exceptional team spirit, a real sense of family. When the pressure was on, there was always support. SAC's reputation for accuracy and reliability had a lot to do with the fact that we knew we could rely on one another.

And, of course, the SAC braai, popular among clients and staff alike. Visitor itineraries were often arranged around an invitation to a SAC braai. We tried not to disappoint anyone."
- Raoul Hodges

The Guiana Space Centre, Europe's space port in French Guiana, with an Ariane-5 launcher ready for lift off on the launch pad in 1998 (far left).

The 25° South marker given to Boeing as a memento of the inauguration of the Ka-band antenna at Hartebeesthoek (left).

support the launches of the XM-1'Rock' and XM-2 'Roll' radio satellites in 2001. And, under contract to prominent satellite operator, Intelsat, SAC installed a state-of-the-art RF fibre link over a distance of 4 km to the Telkom satellite groundstation to monitor the Intelsat geosynchronous Ku-band satellite orbiting at 66° east.

Following the successful installation of the Ku-band antenna, Boeing approved a large capital investment in December 2000 for a complementary 13.2 m Ka-band antenna facility at Hartebeesthoek. This investment confirmed Boeing's confidence in the proficiency of SAC's management and operational teams, as well as the station's role in international business development at the CSIR.

"Operating in the global business of satellite tracking, telemetry and command (TT&C) and satellite geo-information applications brings about a fair share of challenges, excitement and inevitable pressure. But the professionalism, dedication and innovation that characterise the way this industry operates and takes on daunting challenges, continue to motivate the individuals and teams at the Satellite Applications Centre."[28]

The antenna farm

The idea of establishing an 'antenna farm' at Hartebeesthoek was first discussed during a strategy planning session in 2001.

The CSIR's focus on commercialisation led to new thinking about market differentiation. More antennas at the tracking station, where there were only three at the time, would give SAC a competitive advantage of offering clients access to most of the frequency bands in which satellites operate.

SAC staff enthusiastically supported the vision of an 'antenna farm'. While the TT&C team could successfully install, operate and maintain antennas and ground stations, success depended on securing international funding for the antenna infrastructure.

The business development team set about their task of securing contracts with a strong selling point in their favour: SAC's already established track record for the efficient commissioning of antennas and ground segments.

It did not take long for the first clients to come on board.

20-year prospects

SAC orbital support services were boosted by a contract between the CSIR and the Launch Vehicle Systems Division of Boeing Space and Communications in 2001 for ground support for the company's Delta-IV launches. The first mission was scheduled for 2002.

The contract affirmed the long-standing relationship with Boeing and the level of trust placed in SAC's services. The South African tracking station had been providing Boeing with TT&C support for its Delta-II and Delta-III launch vehicles since the late 1990s.

'The Delta-IV is a 20-year programme and we are extremely pleased, not only at the prospect of supporting Boeing when the company undertakes its first Delta-IV launch, but also at the prospect of extending our working relationship into the next two decades and during the lifetime of the Delta-IV.'[29]

EARTH OBSERVATION PRODUCTS AND SERVICES

By 2000, the wealth of applications of high-resolution imagery and potential new markets started a scramble to get state-of-the-art sensors into space. The relevance and impact of a small selection of SAC's diverse range of Earth observation activities, products and services during the final 10 years under the CSIR banner are profiled here.

In greater detail

The launch of Space Imaging's (later GeoEye) Ikonos-2[30] in September 1999 provided the world with 1 m high-resolution data that showed more detail about the Earth's surface than any other remote sensing platform at the time.

Early in 2000, SAC obtained non-exclusive reseller rights for Ikonos imagery over southern Africa following an agreement with Space Imaging representatives, Earthgaze Holdings.

This enabled SAC to explore untapped market sectors with new value-added applications in areas such as real estate development, insurance and damage assessment, population density calculation in disaster-prone areas, as well as news reporting, crime prevention, crop estimation and search and rescue missions.

A view of some of the antennas at the Hartebeesthoek antenna farm (far left).

A Delta-IV Medium rocket launched from Cape Canaveral, Florida on 20 November 2002 with a Eutelsat telecommunications satellite on board (far right).

An artist's impression of the GeoEye satellite (left).

A GeoEye-1 image (right) of the Green Point stadium in Cape Town while under construction taken on 11 September 2009 at a 0.5 m resolution (GSD).

Satellite imagery to the rescue

Satellite imagery came to the rescue when the oil carrier, MV Treasure, sank off the western coast of South Africa on 23 June 2000. The resultant oil spill seriously affected large colonies of African Penguins (*Spheniscusdemersus*) on Robben and Dassen Islands.

SAC provided the rescue teams at the University of Cape Town with images acquired from RADARSAT in Canada to track the movement of the oil and plan rescue efforts. The quick action helped rescuers to catch and relocate 19 500 oil-free penguins, as well as collect more than 19 000 covered in oil, of which 17 000 survived the first month after being rescued.

As a regional distributor of RADARSAT products, SAC could use the RADARSAT Rapid Response Service to deliver an appropriate image within 15 hours of receiving the request.

Satellite imagery was also used during the first new millennium year to provide decision-makers with factual information about fires in the Cape Peninsula and the floods in Mozambique and in the Northern Province in South Africa.

The impact of the torrential rains in the north-eastern parts of the country and in Mozambique was evident only when the rains stopped. Photographic footage of the devastation gave an impression of the damage, but satellite imagery showed the extent of the human disaster. A combination of Landsat TM and ERS data were used to show the flooding along the banks of the Pongola River.

"In the aftermath of the flood, the potential role of satellite imagery prior to and during a disaster of this magnitude can be assessed again, and loss of lives and property can potentially be limited with the proper use of the available technology."[31]

First spin-off

During December 2000, SAC launched its first spin-off company, Agrimage, to provide the precision farming market with processed satellite imagery from the French SPOT satellite.

With the company's AGRi-I tool[32] farmers could cost-effectively identify and map areas of variation in their fields and, importantly, measure the biomass of crops since the variation in biomass is directly linked to variation in yield. Agrimage offered subscribers to the AGRi-I products training in the effective use of the tool and continued backup support, while subscribers received monthly time-series vegetation indices during growing seasons.

"The product will show stress on crops up to two weeks before it becomes visible to the human eye [which] enables the farmer to visit the specific management zone within the field, identify the factors contributing to the variation, and then manage it accordingly."[33]

Imagery for national census

Satellite imagery was used for the first time in a national population census when Statistics South Africa undertook the 2001 Census. SAC provided Stats SA with 128 satellites scenes – close to 25% of South Africa – over a four-month period, one of the biggest requests for data the station had received up to then. SAC requested programming for SPOT-2 and SPOT-4 satellites since November 1999 and selected cloud-free scenes over the required areas from the EO database.

While a combination of aerial photography and satellite imagery was used for the census, satellite

imagery was the predominant source used for change detection.

"The initiative paves the way for future image differencing that could render extremely valuable information in a timely fashion."[34]

First Landsat-7 imagery

In later February 2001, after weeks of upgrading the facilities at Hartebeesthoek in co-operation with ACS, an Italian satellite reception and processing software company, SAC received the first imagery from Landsat-7, with its additional panchromatic band and 15 m image resolution.

The upgrade was made possible by an investment from the Department of Agriculture, for whom Landsat-7 imagery was critical, and included functionality improvement to SAC's catalogue database with Landsat imagery.

Although the reception of Landsat-7 replaced that of Landsat-5, all data received from the latter since 1980 was available from the image database, while operationally Landsat-7 was far easier to maintain. At the time of the upgrade, SAC Systems Management and Support Manager, Helena Bosman, reported from a Landsat Technical Working Group meeting in Spain, that SAC's improved reception capability had been followed with interest by the representatives of all the other stations in the global network present at the meeting.

The upgraded facilities increased the compatibility with which SAC could exchange data with the other stations and ensured that clients world-wide received the same high-quality data products. Landsat-7 imagery over South Africa was central to a project for Eskom to provide information about fast-growing areas in the country in need of electricity.

The contract to compile change detection maps over all nine provinces was awarded to the SAC-Geospace International Demographic Change Consortium.

"The speed of [the influx of people into cities] translates into a lack of accurate land-cover and land-use data for planners and policy makers. Satellite imagery with its repetitive, large-area coverage is the ideal tool to address this information need."[35]

Boost for precision farmers

The significant uptake of the AGRi-I products by 2001 was a clear indication that South African farmers did not shy away from high-technology applications to deal with the climatic conditions, volatility of commodity markets and economic pressures of farming.

Convincing case studies that bore testimony to the value farmers derived from the use of satellite imagery emerged, including the ability to identify faulty irrigation, herbicide spills and the extent of hail damage.

A sugar cane farmer in KwaZulu-Natal detected stress from the AGRi-I data, replaced the nozzle in the irrigation system and ended the growing season with healthy crops.

In Mpumalanga, a farmer quantified the damage across parts of his bean field after a severe hail storm, while accurate mapping, area estimation and yield prediction enabled another farmer to determine compensation for eventual crop losses after an aircraft crop duster had inadvertently leaked herbicide onto his fields.

Before (far left) and after (far right) Landsat TM images of flooding in Mozambique, acquired on 22 August 1999 and 1 March 2000 respectively.

The MODIS (Moderate Resolution Imaging Spectro-radiometer) (left) reception system at Hartebeesthoek.

An image acquired by MODIS, aboard NASA's Aqua satellite, on 28 July 2007, of intense fires in the forests and grasslands of the Drakensberg mountains in South Africa's Mpumalanga Province.

Data distribution

A data distribution agreement in 2002 with the Russian Aviation and Space Agency, Rosaviakosmos, made SAC an official distributor of Russian satellite data captured over Angola, Botswana, Lesotho, Madagascar, Malawi, Mozambique, Namibia, South Africa, Swaziland, Tanzania, Zambia, Zimbabwe and the Democratic Republic of the Congo. The data increased SAC's ability to respond to diverse user needs.

SAC also secured reseller status from EarthSat for the two-panel mosaic of Africa. The mosaic consisted of thousands of Landsat images at a 30 m resolution, selected for quality and cloud cover. Features such as the Great Zimbabwe Dyke, Okavango Swamps, and even agricultural activities in the deserts of Libya were visible on the mosaic.

In the manner of MODIS

South Africa's Department of Agriculture provided SAC with a multi-million Rand grant-in-aid in 2003 for a MODIS[36] (Moderate Resolution Imaging Spectroradiometer) reception and processing system to supply users with important information about land, ocean and atmospheric processes.

Philip Frost and Alan Caithness[†] visited Kongsberg Spactec in Norway during July 2003 to review the design of the MODIS system before Kongsberg upgraded SAC's Earth Observation Data Centre (EODC) for MODIS and NOAA reception. The system was installed late in 2003.

With MODIS, SAC provided the SADC region with data that added substantial value to decisions about dealing with food security in southern Africa, as well as improving disaster management, such as fire identification and monitoring, throughout the region.

The CSIR's advanced fire information system, AFIS, was also introduced to the region. AFIS uses MODIS, SeaWIFS and NOAA data to detect hotspots or locate fires within minutes of one of the satellites passing over a specific area anywhere in southern Africa.

AFIS also identifies potential fires and indicates the probable spread and direction of the fires.

"The AFIS design fulfils a variety of user needs, such as pinpointing fires in near-real time over southern Africa and sending the location via SMS to Eskom and local and regional fire protection agencies."[37]

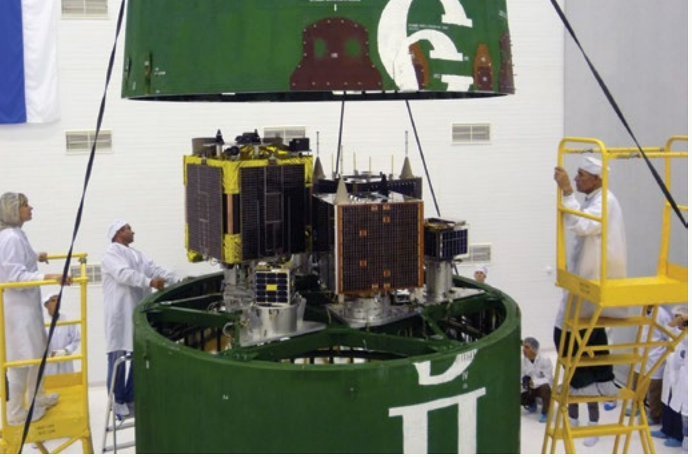
CAPACITY BUILDING INITIATIVES

SAC launched its new millennium capacity building initiatives with a number of remote sensing courses and workshops, and bade farewell to Veronica Rammala and Tsholofelo Mooketsi, who joined the SAC/GDTA training programme in remote sensing as the next two 'Space Girls' to qualify for the course in Toulouse and internships with SAC. Both equalled the performance of their predecessors in concluding their studies successfully.

SAC's first three 'Space Girls' received their remote sensing diplomas from French Prime Minister, Lionel Jospin, who visited SAC in June 2001.

During 2004, five of the 15 Nigerian engineers and scientists involved in the Nigerian satellite programme at the time participated in a training programme at SAC. The course focused on TT&C training (controlling a satellite) and skills development in applying satellite imagery to real-world challenges, such as effective environmental management and weather forecasts.

Nigeria's first wholly owned satellite was launched in 2003 on board a Russian Kosmos-3M launcher,



which made the country the 3rd African nation, after South Africa and Algeria, to launch a satellite into space.

"The training initiative served to expand SAC's offerings into the African market and promoted the bilateral agreement between Nigeria and South Africa within the NEPAD context."[38]

Excitement of space taken to rural classrooms

Jointly with the Department of Communications, SAC joined a global project to take the excitement of space exploration to rural schools. Initiated by the US-based Colorado Space Grant Consortium, Citizen Explorer-1[39] (CX-1) was designed to provide Grade 12's with space education. Scholars world-wide were equipped to be the ground observers.

The Department of Communications identified 10 schools and connected them to the Internet. SAC supplied each school with the equipment to build a 'ground station' to receive data transmissions from CX-1. Project leader Conrad Sebego and SAC colleagues trained the young science enthusiasts to operate their 'ground stations'.

"The project ensured that, for the first time, scholars had a real understanding of what space exploration is all about and how satellite data can be applied practically and shared with others."[40]

GLOBAL DOWNTURN MITIGATED

In the space industry, the year 2002 will be remembered as one with serious setbacks and loss in revenue. Satellite manufacturing declined by 18% (38% in the US), while revenues within the launch industry dipped by 41% (59% in the US). At SAC, the downturn resulted in fewer launch supports, increased competition and price pressures on products and services. The SAC team, as always, determined to overcome the challenges, diversified its business offerings and pursued market opportunities for off-site projects to mitigate the worst of the impact.

Antenna systems in Africa

The talents of SAC's technical personnel, experienced in the design and construction of antenna systems, were put to constructive use during slow periods. They serviced the satellite telecoms end-user market through the Full Motion Systems consortium.

In a joint venture between SAC and the locally-based systems integration house, Delphius Technologies, SAC staff were involved in designing, installing and commissioning off-site Earth stations in areas as remote as southern Rwanda. The initiative offered satellite ground segment establishment services throughout Southern Africa.

The systems were installed on-site at clients' premises and used for Internet backbone connectivity, gateways and Very Small Aperture Terminal (VSAT) hubs. The off-site work ensured that SAC's technical personnel remained challenged and stimulated and exposed to different applications of satellite technology.

"Not only does this provide additional revenue, but [it] has proved to be extremely valuable from a capacity development perspective, as staff members have been exposed to new applications, equipment and networks. This exposure is of great benefit to us as we expand our TT&C and monitoring services."[41]

BEYOND THE DOWNTURN

Despite a slow recovery within the satellite industry from the economic downturn, SAC secured a

Integration of the NigeriaSat-X and NigeriaSat-2 satellites (far left) into the spacehead module of the Russian Cosmos-3M launcher and (far right) the 22 m multi-spectral image of Auckland, New Zealand acquired by the NigeriaSat-X three days after its launch on 20 August 2011.

The 13 m Ka-band antenna under construction (right) and (left ltr) CSIR President, Dr Sibusiso Sibisi, then Science and Technology Minister Ben Ngubane and Boeing Africa President, Dr Walt Braithwaite, at the inauguration of the antenna.

number of new orbital support contracts and the antenna farm at Hartebeesthoek became home to new antennas.

New contracts

An agreement with Honeywell Technology Solutions in 2002 for TT&C support for the DataLynx™ programme – a worldwide satellite control network for remote sensing, Earth and space science and telecommunications – created a streamlined arrangement that allowed SAC and Honeywell to contract swiftly, as and when requirements arose.

New at the antenna farm

Paris-based satellite operator, Eutelsat, was among the first new 'antenna farm' clients for whom SAC installed a satellite monitoring station at Hartebeesthoek early in 2002.

The five-year operations and maintenance contract included the installation of six Ku-band antennas (three x 1 m and three x 2.4 m) to monitor the Eutelsat-W1, -W2 and -W4 satellites at RF and baseband levels. By then, clients in SAC's satellite monitoring portfolio included Intelsat, Europe*Star, CNES (Stentor) and Eutelsat SA.

In 2002, an X-band antenna arrived at Hartebeesthoek as the 'newest kid on the block'. Supplied by SMP, the 5.4 m diameter, 8 m high antenna was equipped with two high-data rate demodulators required for the new generation high-data rate satellites.

CSIR President, Dr Sibusiso Sibisi, inaugurated the X-band during his first visit to SAC in 2002 and the antenna was integrated into the South African Earth Observation Strategy (SAEOS) infrastructure as part of the satellite-to-customer data supply chain. When necessary, the TT&C group used the X-band antenna to support NASA/JPL launch and LEOP activities in the deep space reception band of 8.4-8.5 GHz.

And in February 2003, South Africa's then Minister of Arts, Culture, Science and Technology, Dr Ben Ngubane, inaugurated a new 13 m Ka-band antenna at Hartebeesthoek. The antenna was installed to provide the Boeing Company with ground support for a constellation of satellites for broadband communications.

With the new addition to the antenna farm, SAC became one of the first ground stations globally to offer clients TT&C support in all frequency bands, from L-band to Ka-band.

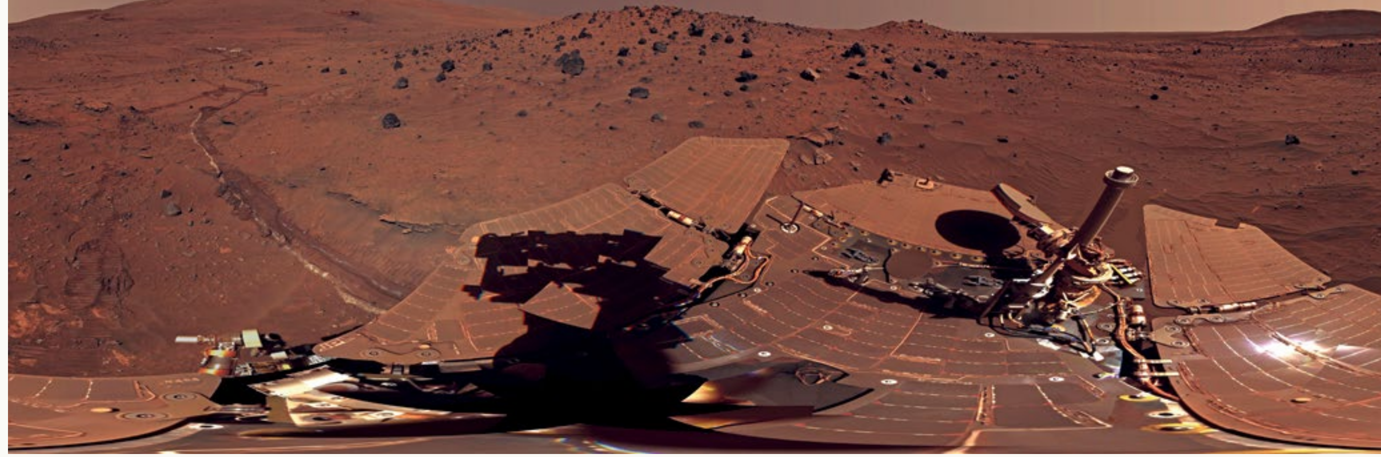
Significant growth in foreign income

By 2003, nearly 80% of SAC's income was derived from contracts with overseas clients, while the rest came from work done locally. The SAC-CNES history had been a critical contributor to SAC's revival in the international satellite launch and mission support arena. SAC's mission support services continued to generate a sizable income for the station.

In March 2003, Intelsat, already one of the CSIR's biggest clients for orbital support services, entered into a multi-year contract with SAC to establish, operate and maintain an 11 m C-band TT&C antenna system at Hartebeesthoek.

Installation started in December 2003 and the ST&DA group successfully supported the launch of the Intelsat-X satellite in 2004.

The antenna system is remotely controlled by the Intelsat Operations Centre, while SAC controlled it locally for LEOP support and other mission-critical activities.



"The contract was secured based on SAC's track record of providing several years of faultless Ku-band remote spectrum analyser operations to Intelsat. The long-term commitment to use SAC's TT&C services is indicative of the good relationship between Intelsat and CSIR SAC. We look forward to supporting Intelsat's satellites in the years ahead."[42]

Coverage beyond Hartebeesthoek

During April 2003, Boeing Expendable Launch Vehicles asked SAC to extend its mission coverage beyond the visibility of Hartebeesthoek to provide Boeing with continual telemetry coverage of the Delta-II launcher with the MER-A[43] on board (now known as the Mars Spirit Rover).

The challenge was to record telemetry while the Delta-II passed over Angola and northern Namibia before acquisition at Hartebeesthoek. Within only three months, SAC deployed a transportable S-band station at Oshakati in northern Namibia with permission from the Namibian government. The station was installed with voice communications, a real-time Ku-band satellite telemetry communications link and Denel's 4.5 m S-band tracking system.

"We have always been very happy with the support we receive from SAC. The NASA MER-A mission certainly showcased just how good the SAC team could be. Within a very short amount of time, a plan was made and executed that created a ground support capability where there had been none."[44]

And at the end of 2003, SAC installed and commissioned a new, fully automated 2.1 m L-band system procured from Kongberg Spacetec of Norway to improve the quality of NOAA data and receive METOP data. Customers included mainly those active in the oceanography and sea fisheries industries.

New EO business

A contract with the Department of Agriculture in 2002, for whom the availability and regular acquisition of Landsat imagery is critically important, facilitated the reception, ingestion, archival and processing of Landsat-7 imagery at SAC.

The team also put the full-motion 5.4. m X-band antenna to work after its installation. Its fully automated control system enabled unmanned system operation and helped to reduce the conflicts experienced at the time in the reception of imagery from a multitude of satellites.

Benefit for research and decision-making in Africa

In mid-2004, SAC became the first MODIS direct-broadcast receiving station in Africa when the then Deputy Minister of Agriculture and Land Affairs, Advocate Dirk du Toit, inaugurated the reception capability of the MODIS and Landsat satellites at Hartebeesthoek. The Ministry had, since 2000, invested more than R12 million in providing national, regional and international access to the two satellite systems.

As a MODIS receiving station, SAC monitored land, ocean and atmospheric processes to provide information on food security, crop yield monitoring, grazing capacity and land degradation assessments, as well as global change and disaster management.

SAC's EO team used the MODIS data to develop novel applications, such as the AFIS fire warning system mentioned before. The Deputy Minister also announced free access to all Landsat images (including archives that dated back 20 years) for use

SAC deployed a transportable S-band tracking station at Oshakati to provide Boeing with continual telemetry coverage of the Delta-II lifting MER-A43 (Mars Spirit Rover) (far left) while it passed over Angola and northern Namibia before its acquisition at Hartebeesthoek. After landing on Mars, the Spirit provided NASA with this 360° composite panoramic view (far right) of the Mars surroundings in approximately true colour.

The 5.4 m X-band antenna (right) at Hartebeesthoek and an Enhanced Thematic Mapper Plus (ETM+) Landsat-7 image of the Orange River mouth in South Africa's Northern Cape Province (left), acquired on 11 April 2001.

in managing agriculture, forestry, natural resources, environmental monitoring and land-use mapping, as well as in geological and hydrological applications.

At the time, free access to Landsat data represented an internationally unprecedented shift in data policy and accessibility.

Putting fossils on the map

South Africa's deposits of palaeontological fossils are of the richest in the world. Satellite imagery enables scientists to research the origins of vertebrates and solve riddles left behind by fossils.

Towards the end of 2004, the Bernard Price Institute for Palaeontological Research at the University of the Witwatersrand contracted SAC to create a spatial database of all vertebrate fossil sites in the Beaufort group in South Africa since the 1940's for research purposes.

The ground-breaking project saw the first introduction of GIS application to the field of palaeontology. It made a significant contribution to palaeontological research and opened up further avenues of spatially-based research in palaeontology.

FIVE YEARS AND COUNTING

2005 … restructured role

The restructuring of a number of CSIR business units into Centres of Competence in 2005 and its possible effect on SAC created uncertainty among staff at Hartebeesthoek about SAC 's role and responsibilities within the CSIR. This related to the future of its Earth Observation activities as well.

The CSIR Executive decided to move SAC out of the organisation's icomtek division and establish it as a Centre of Excellence for both mission support and EO activities.

The Centre's direct reporting line to the Executive gave focus to its strategy and spurred a renewed commitment to continued improvement on past performance - a work ethos well-entrenched at the tracking station.

World-first support for commercial Ka-band satellite

SAC made history when it provided launch support for Spaceway F-1[45], the first commercial Ka-band TT&C satellite ever launched. The satellite took to space from Long Beach, California in April 2005. Under contract to Boeing, SAC supported the launch of the first three Spaceway satellites with telemetry (receiving the satellite's health status and data), tracking (tracking the satellite and sending Boeing the antenna pointing and ranging data) and command (relaying commands from the Boeing Control Centre to the satellite) services.

Investments for the future

In 2005, a R5 million grant from the Department of Science and Technology (DST) and a R3 million subsidy from the Department of Land Affairs (DLA) enabled SAC to invest in R&D initiatives. These included undertaking science missions, as well as training and building capacity among scientists and engineers within South Africa's space community.

The DST funding was used mainly to maintain SAC's national remote sensing archive, while the DLA's contribution subsidised the acquisition of imagery from the Landsat-5 satellite.

The EO team also undertook a study of the EO market locally to assess the need for remotely sensed data.

World-first Support

Youth outreach

SAC submitted a series of satellite images and theoretical information for inclusion in the Grade 11 curriculum as part of its contribution to geography development at high schools. Consisting mainly of Landsat images, the submission comprised interesting landscapes in South Africa to help learners interpret, analyse and make sense of the physical attributes of the landscape.

And, under the able leadership of Johnny Rizos and several other enthusiastic staff, SAC participated in numerous exhibitions as part of its youth outreach programme to create awareness among scholars about space science, engineering and technology.

Scholars attending events such as Sasol SciFest and FutureX benefited from lectures and promotional materials about all aspects of space exploration.

2006 … PLANS AND A HAT-TRICK

By 2006, SAC's sensor portfolio could not fulfill the continuous demand for Earth observation data from a range of different stakeholders at the time. SAC negotiated a first-of-its-kind national coverage data agreement with Spot Image for SPOT-5 imagery for a period of three years. In return, government departments paid an annual subscription fee to receive a 493-scene mosaic fully processed at Hartebeesthoek and delivered at the end of each year (story below).

First 2.5 m natural colour dataset

After a partnership of almost 20 years with SPOT Image of France, a new chapter began when the company agreed to provide SAC with high-resolution SPOT data. This included SPOT-5 imagery, which was used to support South Africa's national imperatives.

Under the new 'open access' license, SAC's remote sensing specialists had direct access to SPOT-5 data to respond to the growing demand for high-resolution remote-sensing applications.

These data were especially useful for the observation of rural areas, land management, agriculture and urban planning, as well as monitoring South Africa's environmental conditions. The multi-government licence agreement provided government departments and research and academic institutions in South Africa with access to data from the SPOT-2, -3 and -5 sensors. The EO team used the data to compile a 2.5 m natural colour dataset or mosaic of southern Africa in the form of 30′ x 30′ tiles, divided into six° zones and Geographic WGS 84 datum as the ellipsoid measurement accepted internationally.

Benefits to the South African user community are significant as the mosaic facilitates informed decision-making in food security, housing development, infrastructure planning and mine rehabilitation, among others.

Some highlights

A number of notable highlights in SAC's training programme and business domains occurred in 2006. South African and French space science expertise received a boost through a skills development agreement between CSIR SAC and Alcatel Alenia Space.

The identified training areas included navigation, Earth observation, environmental research and meteorology, while co-operation in R&D activities focused on satellite programmes, space data information systems and customers' requests for information.

Roxi Lategan (right) at one of the exhibitions in which SAC participated to create awareness about space science and technology.

SPOT-5 optical 2.5 m resolution satellite image (left) of the Vanderkloof Dams in South Africa dated 19 December 2005.

The TT&C team again supported the launch of a communications satellite successfully, this time for the PanAmSat Galaxy-16[46] that was placed in a geosynchronous transfer orbit by sea launch.

SAC acquired the first signal after spacecraft separation on 18 June 2006 and confirmed the spacecraft's positioning and condition to the mission control centre. PanAmSat's global network of satellites reaches millions of people over vast geographic areas or targets specific groups in cities, countries or regions.

A hat-trick

A series of successful launch supports during December 2006 ensured that SAC ended the year on a high note. TT&C team members at the time - Yunus Bhayat, Nelson Canha. Carlos de Oliviera, Raoul Hodges, Frikkie Meyer, Tiaan Strydom, Pieter van der Merwe and Kowie Viljoen - delivered three faultless launch supports within less than two weeks.

These included launch support for a Boeing Delta-II launcher as it moved into the Hartebeesthoek visibility area, as well as support for the separation of the onboard NROL-21 satellite.

A few days later, the team supported the Russian Cosmos-3M booster launched from the Plesetsk Space Centre in northern Russia to lift Germany's SAR-Lupe satellite under contract to CNES.

The TT&C team assisted with critical orbit calculations to ensure the correct injection of the spacecraft into orbit.

And three days before the end of the year, a new Russian Soyuz 2-1B launcher with the French CoRoT (Convection, Rotation and Transit) satellite on board lifted off from Baikonur in Kazakhstan. SAC supported the launch and early orbit phase as well as the routine support of COROT. Commenting on this hat-trick, SAC's Operations Manager at the time, Raoul Hodges, noted that "it was a great way to end the year, with 100% mission success."

A national space agency

In 2006, the South African government approved the establishment of a national space agency. This important development was preceded by a study of similar agencies world-wide that had highlighted the diverse nature of such organisations, even in smaller countries.

As a result, the Department of Science and Technology contracted the CSIR to develop a strategic framework and operational directive for a South African space agency. Representatives from SAC participated in the process.

2007 ... STRATEGIC POSITIONING

The EO perspective

SAC's primary EO function was to acquire and archive remotely-sensed data from Earth observation satellites, and process and distribute the data to stakeholders as value-added products and services. By 2007, SAC's comprehensive and invaluable archive of remotely-sensed data over southern Africa, from 3° to 50° south, ensured that fundamental geographic data were available locally and to other communities in the African region. At the time, SAC supported and received data from the MODIS, NOAA, ERS-2, SPOT-4, SPOT-5, EROS-A1 and Landsat satellites. The Centre also had distribution contracts with Space Imaging (GeoEye), Digital Globe, SPOT Image, USGS and MDA (RSI).

Unique remote sensing capability

On 20 April 2007, SAC delivered South Africa's first 2.5 m natural colour seamless mosaic dataset for

SPOT-5 data. The direct receiving capability by the CSIR of SPOT-5 data since October 2006 has allowed its remote sensing scientists to reach significant milestones on the prime deliverable of the 2.5 m natural colour seamless mosaic.

SAC also employed marketing and sales personnel to take advantage of growth opportunities in its EO domain due to SPOT-5 data access and increase its ability to process and deliver information at what was then unprecedented scale.

SAEOS flagship

By 2007, the Earth Observation Service Centre (EOSC) at SAC had become integral to the CSIR's spatial information value chain and involvement in the South African Earth Observation System (SAEOS). As part of the Global Earth Observation Systems of Systems, SAEOS recognised the importance of remote sensing imagery and the strategic value of Earth Observation (EO) capabilities for the country.

At the Global Earth Observation (GEO) Summit in Cape Town in November 2007, then Minister of Science and Technology, Mr Mosibudi Mangena, announced that the DST had delegated SAEOS implementation to SAC. The system was set to contribute to areas such as monitoring and assessing natural disasters, climate change, biodiversity, ecosystems and weather patterns, as well as issues in the water, health, energy and agricultural sectors.

"SAEOS is a flagship project for South Africa. We are confident that its implementation will establish South Africa as one of the leading players in the African space arena, along with Algeria, Kenya and Nigeria." [47]

CEOS Chair

In November 2007, SAC's Raoul Hodges, Wabile Motswasele and Alex Fortescue attended an international CEOS meeting at which the CSIR was elected as CEOS Chair for 2008. SAC used the opportunity to launch a tenure project with "Data democracy for developing countries" as the theme. The project aimed to broaden end-user data access to advance the benefit of EO imagery within societies in developing and developed countries.

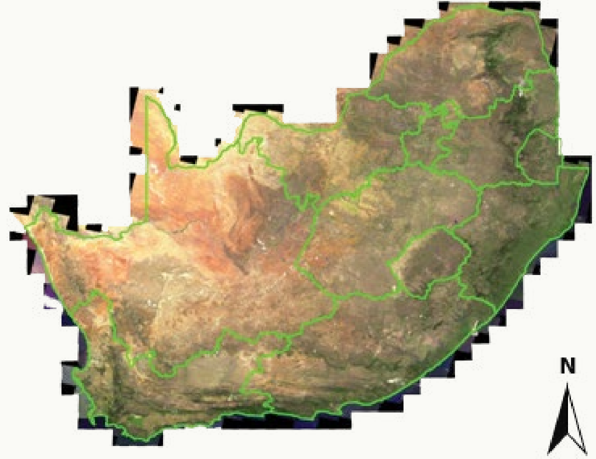
"It is an honour for the CSIR to chair CEOS. I believe it will allow us the opportunity to promote the goals of CEOS through proper international co-ordination of Earth observation programmes and the maximum utilisation of their data." [48]

The agreement gave government departments and research and academic institutions direct, open access to SPOT data. The access also enabled SAC to create the first national 2.5 m natural-colour seamless mosaic dataset of the entire country as a detailed picture of South Africa's land surface.

According to the agreement, SPOT-5 stakeholders paid for the data, while the private sector benefited from providing government departments with analysed and customised data to meet their specific needs for data applications that benefited all South Africans.

The TT&C perspective

Concurrently, by 2007 SAC's TT&C team had more than 47 years of experience in orbital support. The business domain was driven primarily by the needs of international customers mainly in Europe and the US. Over the years, SAC's track record for operational efficiency has positioned the tracking station as the most reputable on the African continent.



SAC's Earth Observation team used simulated true colour pan-sharpened SPOT-5 satellite imagery covering South Africa to compile the 2.5 m natural colour mosaic of the country (right, this page). Some of those images shown here depict (far ltr) the Northern Cape (22/10/2005), Lake Kariba (21/7/2006) and the Orange River (12/10/2005).

At the time, clients included CNES, Boeing Satellite Services and a number of national space agencies and commercial companies.

The antenna farm consisted of seven full-motion TT&C antennas in the L-, S-, C-, Ext C-, X-, Ku-, DBS- and Ka-bands and S-band mobile supports. The station maintained 24/7 operations and the Ground Segment Establishment (GSE) group had become well-experienced in the establishment and maintenance of ground stations for clients at Hartebeesthoek.

In April 2007, Intelsat commissioned SAC to install a full-motion 9 m Ku-band antenna as Hartebeesthoek's 10th resident at the antenna farm.

The company intended to use the antenna as back-up support for its fleet of satellites for a 10-year period. Antenna manufacturer, Vertex, assisted SAC with the civil works and installation.

Between February and November 2007, SAC was involved in supporting the deployment of the five probes of the THEMIS[49] constellation. NASA's Vassilis Angelopoulos from the THEMIS Operations Centre thanked all tracking stations involved, including SAC.

"Special thanks for continued THEMIS support [and] congratulations on a job well done … the Constellation in position with all instruments deployed - it is a dream come true for science!"

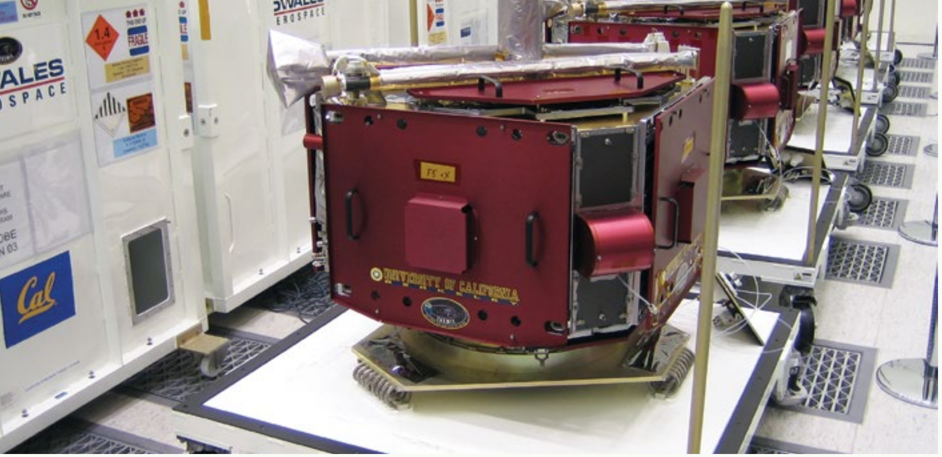
During June, SAC supported Boeing's first commercial Delta-II launch since the launch of five of the iridium satellites in February 2002. The launcher lifted the Italian COSMO-SkyMed-1[50], a dual-use satellite that records data in all visibility conditions for civil, scientific and military applications. In the early hours of 15 August 2007, the TT&Cteam provided tracking, telemetry and command support for the Spaceway-3[51] satellite aboard an Ariane-5 ECA launcher.

Hartebeesthoek received the first signals five hours and 46 minutes after the launch. All data indicated a healthy satellite that was placed into a geostationary orbit to form part of a new broadband network that could deliver bandwith on demand. In September, the SAC team supported the launch of Worldview-1, a sophisticated new Earth-imaging satellite regarded at the time as the most agile satellite ever flown commercially, with rapid targeting and efficient in-track stereo collection.

And from October to December that year, one of the busiest times of year for orbital support services at SAC, the TT&C team successfully supported a number of launchers and provided transfer orbit support (moving a satellite between circular orbits) and in-orbit tests for different satellites.

These included:
- Intelsat-11 and Optus-D2, two communications satellites lifted by the 'work horse' Ariane-5 launcher.
- Skynet-5B, the first privately-owned military communications satellite with a 8 700 kg payload, which was a new lift record for the Ariane-5.
- Sweden's Sirius-4, launched to provide direct-to-home TV services across Europe, African and the Baltic/Nordic region.

Between 2 and 23 December 2007, the TT&C team played a vital role in verifying the integrity of the communications payloads and satellite platforms to ensure that the satellites were fully operational.



And finally that year, between 20 to 25 December, SAC supported the evening launch of Horizons-2[52] as one of two communications satellites lifted by an Ariane-5 launcher to serve populations in Africa and North America. SAC provided the TOS services that placed the satellite into its geostationary orbit.

2008 … A VERY GOOD YEAR

The Hartebeesthoek tracking station ended its 2007-08 financial year as the most lucrative in its 48-year history.

With significant growth in both the geo-information and orbital services portfolios, the station delivered an exceptional financial performance. SAC also exceeded all its human capital development goals and participated in the planning of South Africa's national space agency.

Significant portfolio growth

After a number of slow years, the TT&C business saw a dramatic increase in requests for mission support and demands from the Ku-band sector exceeded expectations. The confidence with which a well-experienced launch support team repeatedly delivered faultless orbital support services entrenched client confidence and increased investments and contracts from the international sector.

By 2008, SAC's geo-information stakeholders benefited from complete data coverage over South Africa from the SPOT-5 system, while the development of a stable funding mechanism saw many clients signing three-year data contracts. The GIPA group started to also invest time in projects with the private sector. These included mapping changes in informal settlements for provincial growth planning and power distribution planning for Eskom.

Launch supports tip scales

During 2008, the TT&C team notched up a remarkable 17 launch supports, an unprecedented achievement for the tracking station at the time.

The team's competence was fully tested when Arianespace contracted SAC to perform its first dual launch support in August 2008. The AMC-21[53] and Superbird-7[54] telecommunications satellites were scheduled for launch on board an Ariane-5 launcher. Both satellites were intended primarily for television

The THEMIS probes (far left) ready for loading and seen inside the rocket fairing (far middle), which fit flush with the rocket's upper stage booster, and the Delta-II rocket with THEMIS aboard (far right) ready for launch from Cape Canaveral in 2007.

Artist's impression of the SPOT-5 satellite (left).

SAC's Dan Matsapola, Ilan Guest from urban planning consultancy SATPLAN and Kabelo Mpobole from the North West Department of Human Settlements (ltr in photo right) at an informal settlement in the North West. SAC and SATPLAN joined forces to develop a multi-year database to compare the year-on-year location and growth of informal settlements in the province.

broadcast services, Superbird-7 for the Japanese operator Space Communications Corporation and AMC-21 for the American operator SES AMERICOM. A period of intense preparation and testing in the control centre at Hartebeesthoek was rewarded when all manoeuvres were performed faultlessly.

"This is a great achievement and serves, once again, to prove our technical competence to the international space community."[55]

The SAC team also supported the deployment of the GeoEye-1[56] spacecraft successfully on board a Delta-II launcher from the Vandenberg Air Force Base in California in September 2008, to begin its mission as the world's highest-resolution commercial eye-in-the-sky.

Client feedback[57] after the launch referred to the *"Excellent quality data received from all tracking stations. Thanks to the AFSCN/MESA, HBK*[58] *and OTTR teams for an excellent support."*

Change detection with satellite imagery

Funded by the North West Housing Department, SAC and urban planning consultancy, SATPLAN, joined forces with the provincial Department of Human Settlements and Department of Public Safety and Liaison in 2008 to create the first-ever satellite-derived baseline data on informal settlements in the province.

The atlas consisted of archived data combined with fresh data from the SPOT-5 satellite at a 2.5 m ground resolution to create a multi-year database dating back to 1994. This enabled a comparison of the year-on-year data that showed the location and growth of informal settlements in the province.

The North West Housing Department used the baseline data to inform planning and funding decisions. Local municipalities could access the data to upgrade informal settlements in their areas to assist the Department in the delivery of housing in the province.

Planning the grid

Eskom's vision in the early 2000s of using satellite data to identify the need for electricity was realised in 2008. In partnership with Eskom, SAC used satellite imagery to pinpoint every house in South Africa, colour-coded by year.

The value of the project was illustrated after the first three years, when the movement of informal settlements could be tracked, providing Eskom with information about the movement and growth patterns in and of information settlements. These data continue to assist the national electricity supplier in its power distribution planning.

A mosaic gift

SAC interacted regularly with the SPOT-5 user community to identify user needs. The imagery, which the Centre had started receiving in 2006, was used to develop a 2.5 m natural colour seamless mosaic of Southern Africa.

SPOT-5 stakeholders (representatives from 15 government departments) met at SAC in October 2008 to map out a common vision for the future of the SPOT-5 programme. Attendees agreed that continued access to the mosaic was in the national interest and that the programme should be extended for a further term until 2011.

The benefits of the mosaic to the user community are significant. Applications include informed decision-making in areas such as food security,

“There are many agendas for space, but none more important to the South African cause than the task of looking after our own country and monitoring its progress. In this endeavour satellites are key and the CSIR’s highly successful Satellite Applications Centre is at the forefront of this critical effort.”

- Dr Mosibudi Mangena, Minister of Science and Technology (2009), Hartebeesthoek

water management, agriculture, housing development, mine rehabilitation, utilities and infrastructure planning and national safety and security. Under license to SPOT Image, the data are distributed free of charge to the public and the research and tertiary education sectors.

Combining satellite navigation and satellite communications

Initiated as a 12-month project in 2007 with European partner Thales Alenia Space, SAC’s participation in the African Satellite Communications and Galileo Applications (AFGASA) project continued in 2008 under the leadership of Eugene Avenant, TT&C Manager at SAC.

The project was funded and supported by the European Commission through the Sixth EU Framework Programme (FP6). Project aims entailed creating awareness about satellite navigation and communications applications in the Southern African Development Community (SADC).

The focus was also on identifying the applications most beneficial to the user communities. Identified applications included tracking and communicating with organ transplant patients, security for the 2010 FIFA Soccer World Cup, taxi assistance, automated census, monitoring fenceless livestock and the reducing of road accidents by analysing vehicle and pedestrian behaviour.

These application needs provided input to a regional action plan to remove the social, infrastructural and regulatory barriers to implementation. The results were disseminated to user communities and key stakeholders in SADC.

A four-step action plan for 2008-2016 was proposed for the development of a satellite-based augmentation system (SBAS).

The plan entailed, among others, obtaining political goodwill and support, as well as EC development funding for a safety of life (SoL) system and undertaking a study to determine how to successfully deploy such a system.

By 2013, the execution of the plan had reached the third and fourth steps of implementation in terms of SoL deployment and the incorporation of the Galileo[59] navigation system.

“Having this system will unlock a number of new systems across Africa, as well as contribute to the safety of air travel throughout Africa, which is a primary objective for the system.”[60]

2009 … CONTINUED GROWTH

By 2009, SAC was the undisputed supplier-of-choice of high-resolution satellite imagery locally and in the SADC region. SAC dealt directly with satellite owners for discounted rates on bulk data purchases and transferred those savings to its data user communities.

Bad weather and equipment failures during the 2008-09 financial year did not deter the SAC team from responding to increasing demands for orbital services (TT&C support) and geo-information (EO) products and services. The positive upswing in sales and three-year extension of the SPOT-5 contract, however, put significant strain on antenna capacity at Hartebeesthoek.

Improved antenna capacity

In response, and aligned with its proactive approach to developing the country’s space infrastructure, the CSIR invested R22 million in installing a

Inauguration of the second X-band antenna (left) and (right ltr) Dr Mosibudi Mangena, then Minister of Science and Technology, shakes hands with Dr Sibusiso Sibisi, CSIR President and CEO, against the plinth of the antenna at Hartebeesthoek during the event on 25 March 2009.

state-of-the-art X-band antenna. CSIR President and CEO, Dr Sibusiso Sibisi, inaugurated the 12 m high new resident at Hartebeesthoek on 25 March 2009. The keynote speaker at the event, Dr Mosibudi Mangena, then Minister of Science and Technology, highlighted South Africa's role in sharing the global custodianship of the Earth by using satellite data to do so effectively.

The added X-band capacity enabled SAC to track next generation satellites such as CBERS-2B and Landsat-8, and extend its archive of Earth observation data. It also boosted SAC's data democracy project, as well as a number of government-funded initiatives.

These included the annual delivery of the SPOT-5 mosaic to all government stakeholders and involvement in the Department of Science and Technology-funded South African Earth Observation Strategy (SAEOS) [61].

The strategy was developed to establish an overarching national EO framework for South Africa, linked to the Global Earth Observation System of Systems.

"We are now in a position to acquire additional valuable data to support national, regional and global priorities and can remain a relevant player in the international tracking, telemetry and command field to support space launches. However, our commitment extends beyond these priorities to those related to the formation of our new South African national space agency." [62]

The extension of SAC's sensor portfolio at Hartebeesthoek – aligned with its vision of establishing an antenna farm – not only increased the quality of its products and services, but also helped it with preparations for providing satellite data during the 2010 FIFA Soccer World Cup and taking over operational responsibility for SumbandilaSat [63]. After a number of delays, South Africa's second micro Earth observation satellite was finally set for launch in September 2009.

International projects

SAC's involvement in international projects during 2009 included the TIGER[64] and AMESD[65] initiatives. Both projects focused on supplying data and expertise within the SADC region to help manage Africa's water resources and natural environment more effectively. SAC's involvement enabled South Africa to host the Committee of Earth Observation Satellites (CEOS)[66] locally and showcase the country's capabilities and expertise to international Earth Observation committees.

"Well-managed stakeholder relationships and evidence of SAC's continued and increased involvement in the local and international TT&C and EO sectors created the stability for us to grow our business. At the time, our imminent incorporation into the planned new national space agency made it critically important to retain client confidence in our commitment to deliver on all signed contracts to ensure that long-standing and new relationships were maintained." [67]

Eutrophication monitoring

With the supply of fresh water under threat in South Africa, remote sensing offers a means to more effectively manage the country's inland water resources. In response to a request for assistance from the Hartbeespoort Dam water quality team in 2009, SAC proposed a trophic state monitoring programme of the most critical dams in the country, using satellite imagery it receives from suppliers.

The programme supports the National Eutrophication[68] Monitoring Programme funded by the Water Research Commission (WRC). The initiative is managed by the Resource Quality Services directorate responsible for water quality at the Department of Water and Environmental Affairs.

SAC contributed with the daily monitoring of satellite imagery of selected dams in the summer rainfall region and combining SPOT-5 imagery with that from current sensors to reveal the state of dam water enrichment. The data provided the WRC with a better understanding of South Africa's dam water status.

Data democracy initiative

In March 2009, SAC launched the FundisaDisc as part of its data democracy initiative. The 700 GB external hard disc was developed to provide students studying geospatial sciences with fundamental datasets free of charge. Previously, universities had to purchase such data at a high cost.

A joint initiative with the Department of Science and Technology, the FundisaDisc contains up-to-date geospatial raster and vector datasets of the entire country and several open source software tools for analysing the data. Students from the University of Venda were the first to receive copies of the disc. SAC staff Daniel Matsapola, Tammy Lotz and others distributed the discs to 19 universities to demonstrate its applications to students. The initiative was welcomed by tertiary educators and students alike.

"We decided to produce the FundisaDisc to enrich the tertiary geospatial research environment. We realise that our investment in science education will ultimately enhance our service offering, as we absorb some of these young students as researchers into the organisation in the long-term." [87]

Some tracking highlights

Following its 2008 record of 17 launch supports, the TT&C team again set a record when it supported over 20 satellites between February and December 2009. Eight of these took place during the last two months of the year. The launched satellites provide users with a range of applications such as telecommunications, satellite radio broadcasts, television broadcasting and Earth observation.

7.3 m X-band antenna

- Imported from French company In-SNEC.
- Operational since January 2009.
- Capacity to carry 87% of EO data downloads at SAC to allow maintenance on other antennas.
- 30-ton concrete base to counterbalance the 'sail' effect of the dish when the wind blows.
- Altitude at 1 500 m higher than northern sections of the Magaliesberg mountains.
- Installed by a French/SAC team; Pieter Kotzé, a specialist radio frequency engineer, led the SAC team.
- 3°/sec slew rate allows for the rapid orientation of the antenna to track a passing satellite.
- Fully automated with programmed instructions about the timing and spatial location of passing satellites.
- Receives satellites at 8.0-8.5 GHz.
- Most sensitive X-band antenna at Hartebeesthoek.
- Received signals are down-converted to a lower frequency and sent via underground cable to the EODC at SAC, where the information is demodulated and stored for further processing.

Image from the SPOT-5 satellite (far left) of mining activities at Phalaraborwa, South Africa.

Lift-off of Ariane-5 ECA flight V187 (left) on 12 February 2009 from Europe's Spaceport at Kourou in French Guiana, carrying Hot Bird™-10, NSS-9 and two Spirale microsatellites.

Artist's impression (right) of the separation of the fairing of an Ariane launcher to release the satellite.

Tracking highlights early in the year included a dual launch support when Arianespace lifted the Hot BirdTM-10[69] and NSS-9[70] communications satellites aboard an Ariane-5 launcher in February 2009 for Eutelsat and SES New Skies.

The Eutelsal satellite has a transmitting footprint in Europe, North Africa and the Middle East, while the NNS-9 beams across the Pacific Ocean region.

During March 2009, SAC helped to put the Kepler mission[71] into space. Named after the Renaissance astronomer Johannes Kepler, NASA launched the Kepler observatory to discover Earth-like planets orbiting other stars.

Two months later, the TT&C team was first in line to acquire signals from the IndoStar-2/ProtoStar-2[72] (later renamed SES-7) satellite nine hours and 57 minutes after its launch from the Baikonur Cosmodrome in Kazakhstan.

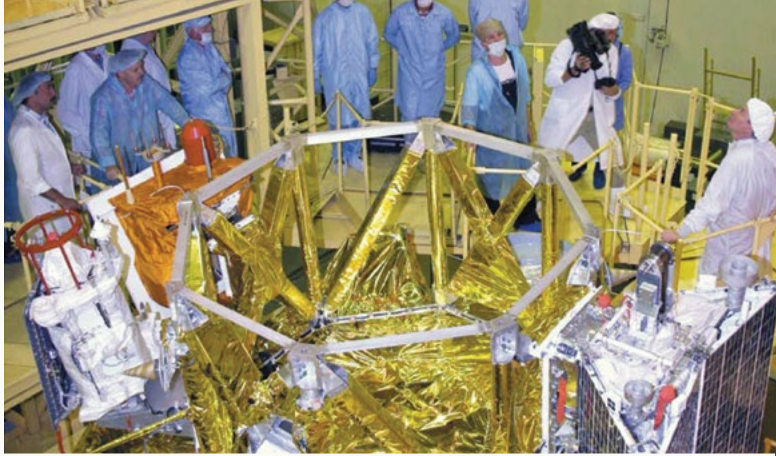
The team supported the satellite's separation from the launch vehicle and the transfer orbit phase and provided Boeing Satellite Systems with 12 days of post-launch support.

October and November were the busiest months of 2009 for the TT&C team with a number of launches. These included the tandem launch of the NSS-12[73] and THOR-6[74] communications satellites at the end of October aboard an Ariane-5 launcher. Both satellites were orbited to provide direct-to-home broadcasting services, the latter to the Nordic countries and Central and Eastern Europe.

In November, SAC provided launch support for the Soil Moisture and Ocean Salinity (SMOS)[75] communications satellite, one of eight in ESA's earth Explorer programme.

The aim is to obtain data that can assist decision-making about environmental concerns, such as the Earth's water cycle and climate.

Another November contract came from Intelsat for TOS services for Intelsat-14[76], the 112th satellite operated by the company. SAC used Intelsat's hosted antenna system at Hartebeesthoek to track the spacecraft. Although it became visible over Australia first, SAC pipped its peer station at the post as the first to locate the spacecraft and monitor the vitally important separation event.



The 'vitals' data of the spacecraft were relayed to the mission control centre. The satellite's 40 C-band and 22 Ku-band transponders cover the Americas, Europe and Africa. In all cases the satellites were acquired on time after injection and separation from the launch vehicle. The team also provided launch support for NASA's Wide-Field Infrared Survey Explorer[77] (WISE) early in December. The WISE infrared wavelength astronomical space telescope discovered the first Y Dwarf and Earth Trojan asteroid, as well as tens of thousands of new asteroids and numerous previously undiscovered star clusters.

"In all, these missions were successfully supported for launch plus a number of days of post-launch support." [78]

2010 … GRAND FINALE

Our exceptional growth since 1995 can be attributed to a management team with a singular focus and staff with exceptional commitment. This growth and SAC's local and international media exposure has placed us at the forefront of the country's participation in space exploration and entrenched our international space footprint." [79]

Early problem detection and corrective action in 2010 helped SAC to deal effectively with challenges during its final year as part of the CSIR. Despite the resignation of highly skilled staff and the continued impact of the global recession on external income, SAC reported a top-line growth of 12%, with a total income of R91.8 million against a target of R77 million and a margin of R5.8 million.

This remarkable performance in a tough economic climate was due mainly to new orbital service contracts and geo-information sales that far exceeded expectations as new projects within SADC came to fruition.

During its final 'CSIR' year at Hartebeesthoek, the TT&C team again, for the 3rd successive year, improved its launch support record with 22 launches (2008:17; 2009:20) while maintaining service levels at 100%. This brought the total number of spacecraft supported into low-Earth and high-altitude geostationary orbits since 1984 close to 300. In addition, the GSE team delivered a full turnkey project in collaboration with SPOT Image, from installing a ground station to implementing a data processing system in Tanzania.

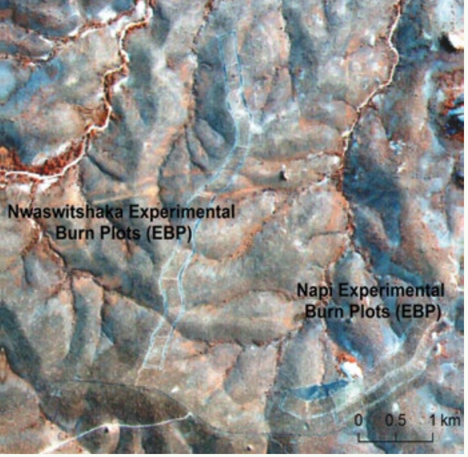
Decreased budget allocations in the public sector resulted in some government departments (SPOT-5 stakeholders) reneging on commitments to help fund the SPOT programme for the production of the annual SPOT mosaic of southern Africa.

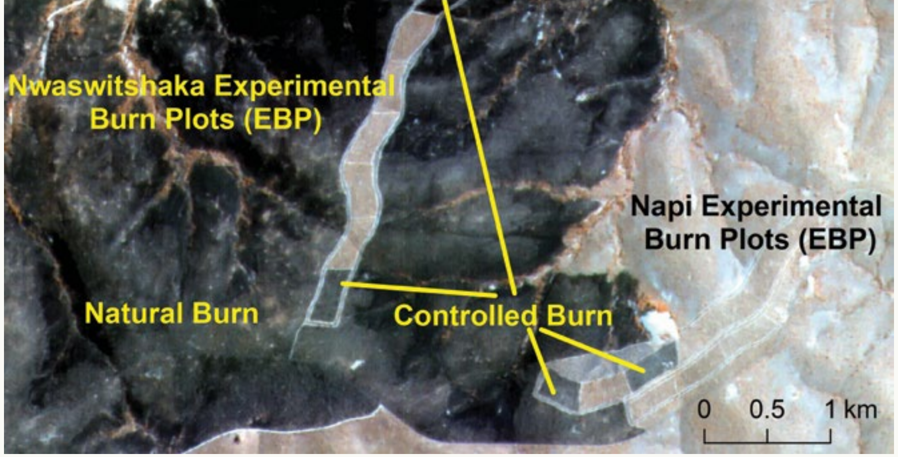
Neither SAC nor the country could afford to lose the momentum gained since 2006 with such an exceptional product. SAC's continued efforts to obtain funding for the programme were finally successful when it negotiated a revised price from Spot image for a further three years, with financial support from other government departments in South Africa.

SAC was also awarded a European Commission project to disseminate free data in SADC under the data democracy banner, which SAC initiated as CEOS Chair in 2008. The aim of the project was to build skills and relationships within SADC.

Successfully orbited

Early in March 2010, Intelsat contracted SAC to support the launch of EchoStar-14[80] aboard a Proton-M launch vehicle from the Baikonur Cosmodrome in Kazakhstan.





The Soyuz-2.1b/Fregat rocket (far left), being prepared for launch at the Baikonur Cosmodrome in Kazaksthan, clearly displays the South African flag and SumbandilaSat (far right) is seen lowered for integration into the launcher (left).

The false-colour composites of SumbandilaSat images, recorded on 1 August 2010 before (left) and 16 August 2010 after (right) fires in the Kruger National Park show the exclusion of fire from burn plots in an ongoing fire experiment. SANParks burnt plots inside the experiments as part of scheduled fire treatments. Green vegetation appears reddish/brown.

The satellite, one in a series of satellites used by the Echostar Broadcasting Corporation, reached orbit successfully and the TT&C team provided TOS for four days before losing visibility of the spacecraft as it moved to its final geostationary parking slot of 199° west.

EchoStar-14 has an expected lifespan of 15 years and is part of the DISH satellite network that serves more than 14 million satellite TV customers in the US.

The pathfinder

SAC's TT&C team took transfer of the operation and control of South Africa's second satellite, SumbandilaSat (Venda for "lead the way") late in March 2010.

Responsibilities included the download of telemetry (remote measurement and reporting of information) and imagery, as well as processing the data and scheduling all activities.

Commissioned by the Department of Science and Technology in 2005, the 81 kg micro spacecraft, about 1 m x 0,5 m in size, was developed by the Engineering Faculty at the University of Stellenbosch.

The satellite was integrated into the Russian Soyuz launch vehicle and lifted into space on 17 September 2009 from the Baikonur space base in Kazakhstan.

While operational, imagery from SumbandilaSat provided South Africa with 1 218 cloud-free images that can be applied in areas such as disaster management (floods and fires), food security (crop yield estimation) and health (prediction of disease outbreaks), among others. Some images clearly showed the severity of the flooding in Namibia, for instance. The international space community's assessment of SumbandilaSat as a successful technology demonstrator, put South Africa firmly on the map as a country with the capacity to develop, build and operate small- and medium-sized satellites. It also confirmed the country's ability to provide its own orbital support and data acquisition services.

New era for asset management

By 2010, SAC's ability and proficiency to respond to any ground segment requirements from international clients - from installing high-tech facilities to their operation and maintenance - was well-established and acknowledge globally.

In April of that year, ORBCOMM Inc, a global provider of satellite and cellular data communications solutions for asset tracking, management and remote control, contracted CSIR SAC to establish a ground station in South Africa.

A mere five months later, in September 2010, SAC had completed the installation and handed the ORBCOMM South African Gateway Earth Station to its owners.

The two identical radomes of the ground station are the largest at Hartebeesthoek and consist of ultra-high frequency planar arrays.

OROBCOMM's fleet of microsatellites in low-Earth orbit enable clients to remotely track, manage and control their assets from almost anywhere in the world.

The new facility is southern Africa's land-based link to ORBCOMM's global network of low-Earth orbiting satellites. Under contract to ORBCOMM, SAC also maintained the operation of the station on behalf of the client.

The ORBCOMM SA Gateway Earth Station at Hartebeesthoek with its two identical radomes (left), was handed to ORBCOMM Inc, a US satellite telecoms company, in September 2010.

A 1 800 x 900 km area of South Africa's Western Cape (right), recorded by the Multi-angle Imaging SpectroRadiometer (MISR) aboard NASA's Terra spacecraft on 3 August 2011.

"We believe that the local facility heralds a new era for asset management in the region. Companies in the commercial transportation, heavy equipment, industrial fixed assets and marine/homeland security sectors, specifically, will benefit greatly from tapping into the cost-effective and reliable two-way data communications services to track, monitor and manage their in-transit assets or remote equipment." [81]

Distribution of free satellite data

NASA announced late in 2010 that SAC would distribute 30 terabytes of data from an Earth-orbiting multi-angle imaging spectroradiometer (MISR), one of five instruments aboard NASA's Terra spacecraft, free of charge to the research community in Africa.

The purpose of this initiative was to provide data users in Africa with access to satellite imagery that would enable greater efficiency in managing Africa's natural resources.

The quality of SAC's remote sensing supply chain equipment positioned it to host, manage and distribute the MISR data after integrating it into the SAC data catalogue.

The MISR instrument is collecting important data on the causes and effects of global climate change. The instrument views the Earth from nine different angles to get a better picture of various atmospheric particles, cloud forms and land surface covers.

During the Terra mission's lifetime, the Multi-angle Imaging Spectro Radiometer has been instrumental in gathering unique views of weather events such as hurricanes and floods, as well as cataloging the effects of air pollution across the globe.

"Our expertise in image processing also allows us to prepare the data in a user-friendly format with subsets from which we can provide researchers with the exact data they require." [82]

"HBK… OVER AND OUT"

And so the 50 years of the SAC era under the CSIR banner ended on the last day of 2010. SAC concluded its final financial year as part of the CSIR on 31 March 2011.

The final five years of effective management that steered SAC through the effects of the 2008-2009 global financial crisis with 80% of its income derived

“Now this is not the end. **It is not even the beginning of the end. But it is, perhaps, the end of the beginning.”** [83]

from international clients, culminated in a total income for the 2010-2011 financial year of R91,8 million. Grant income had been reduced to R5 million only and SAC ended its final financial year with 54 employees on board.

This commendable performance by SAC’s management team and the people at Hartebeesthoek, capped five decades of remarkable endeavour that had irrevocably changed the space landscape in South Africa and the African region.

On 1 April 2011, SAC employees joined the South African National Space Agency (SANSA).

They did so in the knowledge that their experience, knowledge and expertise would equip SANSA with the competence and capacity to confidently continue South Africa’s space journey.

Over the years, the many achievements and global recognition for exceptional performance, as well as SAC’s solid reputation for accuracy and reliability, were made possible by the loyalty, commitment and will to succeed of an exceptional group of people.

The SAC story is their story, a story of ordinary men and women achieving the extraordinary by carving an indelible imprint for South Africa in the annals of space exploration.

Yet, even as the CSIR SAC era reported LOS[84], the people at Hartebeesthoek stepped into a new future with AOS[85] for the road ahead under the SANSA banner.

As part of South Africa’s new space landscape, their contributions are set to enhance the benefits of space applications to society and support the country’s responsible and innovative use of space science and technology.

With South Africa on the brink of developing a domestic space industry, the benefits for the well-being and quality of life of all South Africans might just be cosmic.[86]

This is the end only of the beginning of South Africa’s involvement in space exploration. The journey continues …

The people & the stories

"**Exploration is in our nature.** **We began as wanderers, and we are wanderers still. We have lingered long enough on the shores of the cosmic ocean. We are ready at last to set sail for the stars."**

– Carl Sagan

For fifty years, the ingenuity, commitment and creative energy of the people at Hartebeesthoek contributed to mankind's quest for a brighter future. Whatever the challenges, they tracked signals from satellites thousands of kilometres away in space, and looked through satellite aperture eyes at a distant Earth below to source, interpret and share new knowledge for the benefit of the country, the region and its people.

The people, stories and photographs profiled here reflect slivers only from the rich anthology of events[1] that created The SAC Story.

The vignettes evolved from personal interviews and articles from SAC News publications. Many are spiced with hindsight, some with humour and others more wistful or with a twist to the tale. All give a glimpse into the lives and times of the people at Hartebeesthoek.

The photographs are selected randomly from an astounding trove of images. Each tells its own story about an eventful and memorable journey during this country's participation in the world's first 50 years of space exploration.

CSIR STEPS INTO SPACE

In 1957 Dr Frank Hewitt recognised an opportunity for the CSIR to participate in space exploration during the world's 1957/58 International Geophysical Year (IGY). He agreed to a request from the US Naval Research Laboratory (NRL) for the CSIR's National Institute for Telecommunications Research (NITR) to operate a 108 MHz Minitrack (Minimum Weight Tracking System) station locally to support the US space programme during the IGY.

Engineers from the NRL assisted the NITR to commission the station in time to support the launch of the first US satellites early in 1958, including Explorer-1 and Vanguard-1.

The satellites were the second and fourth to be launched after the advent of the 'space age' and Vanguard-1 was the first satellite powered by solar panels.

"Communication with Vanguard-1 was lost in 1964 but it remains the oldest man-made satellite still in orbit today and it is likely to remain there for hundreds of years to come." ***– Willem Botha***

FORGIVENESS RATHER THAN PERMISSION

In 1963, NASA launched the Syncom-1 satellite as the world's first geosynchronous active-repeater communications satellite, built by the Hughes Aircraft Company. NASA had assigned the Joburg STADAN onlooker status only, but the Hartebeesthoek team decided that the historical importance of the event merited an unscheduled recording of telemetry data from the satellite.

About five hours after the satellite's launch into a highly eccentric transfer orbit with an apogee (highest point) of exactly 35 784 km (the geostationary altitude) the spacecraft suddenly fell silent.

Telescopic observations verified later that the satellite was in orbit for almost 24 hours at a 33 degree inclination, but none of the ground stations scheduled to record the telemetry data had managed to do so. None that is, except the Joburg STADAN. When told about the recording, NASA took the station to task for wasting an expensive tape on an unscheduled recording. Willem Botha realised the significance of the data on the tape and ignored the directive to wipe it. He locked it away for safe-keeping.

"NASA soon realised that our recording was the only data available with which to determine the cause of the failure. When they called us again to ask for the tape, I let them sweat for about 10 minutes before confirming that the data was still on the tape, much to their considerable relief. With the data, the Hughes Aircraft company identified and corrected the fault and launched Syncom-2 as scheduled at a significant cost-saving to the company. Syncom-2 was the first geosynchronous communications satellite to successfully relay a TV transmission."
– Willem Botha

A WAKE-UP CALL

During the early days of the NASA years, Willem Botha attended a station manager's meeting in the US. Although the NASA representatives gave the Joburg STADAN credit for dealing with equipment failures, the station was rated very poorly for operator errors.

Upon Willem's return the shortcomings were addressed by separating the maintenance and operations functions. Dennis Dicks became responsible for maintenance and Marius Fürst managed operations.

"The 'wake-up call' was a defining moment in the station's history. The focus on error-free operations improved our performance to the point where we repeatedly executed up to 100 scheduled tasks meticulously, without error. Other STADANs found it difficult to emulate the performance and it set the trajectory for SAC's reputation for accuracy and reliability." ***– Willem Botha***

NEEDLE IN A HAYSTACK

During the early days at Hartebeesthoek, Johan Helberg and Piet Myburgh† once had to locate a satellite that had veered completely out of orbit.

With little information about where to look for it, the task was daunting and not dissimilar to finding the proverbial needle in a haystack – looking through the eye of an antenna with a beam width of two degrees for a satellite that was only five to six meters high!

In true HBK spirit, however, they persevered long after others would have given up and eventually located the errant spacecraft.

"We were acknowledged for having achieved the seemingly impossible. We appreciated the recognition but did not expect it – we had only done our jobs." ***– Johan Helberg***

AN UNSUNG HERO

Alan Watson was one of the Joburg STADAN employees during the NASA years who returned to Hartebeesthoek in the late 1970s to help with re-establishing the station as the CSIR's Satellite Remote Sensing Centre (SRSC). With an active interest in photography and a keen eye for composition, Alan set up a darkroom to print Meteosat and later Landsat images from photographic film. On a tight budget, he built much of the equipment himself and managed the facility, mostly on his own, until its closure in the late 1990s.

"The quality of his work consistently reflected his remarkable skill. The international space community acknowledged some of the imagery from the SRSC darkroom as the best in the industry. Never one for the limelight, Alan accepted the well-earned praise with humility. He was one of SAC's greatly respected, but often unsung, heroes." ***– Ike Marais***

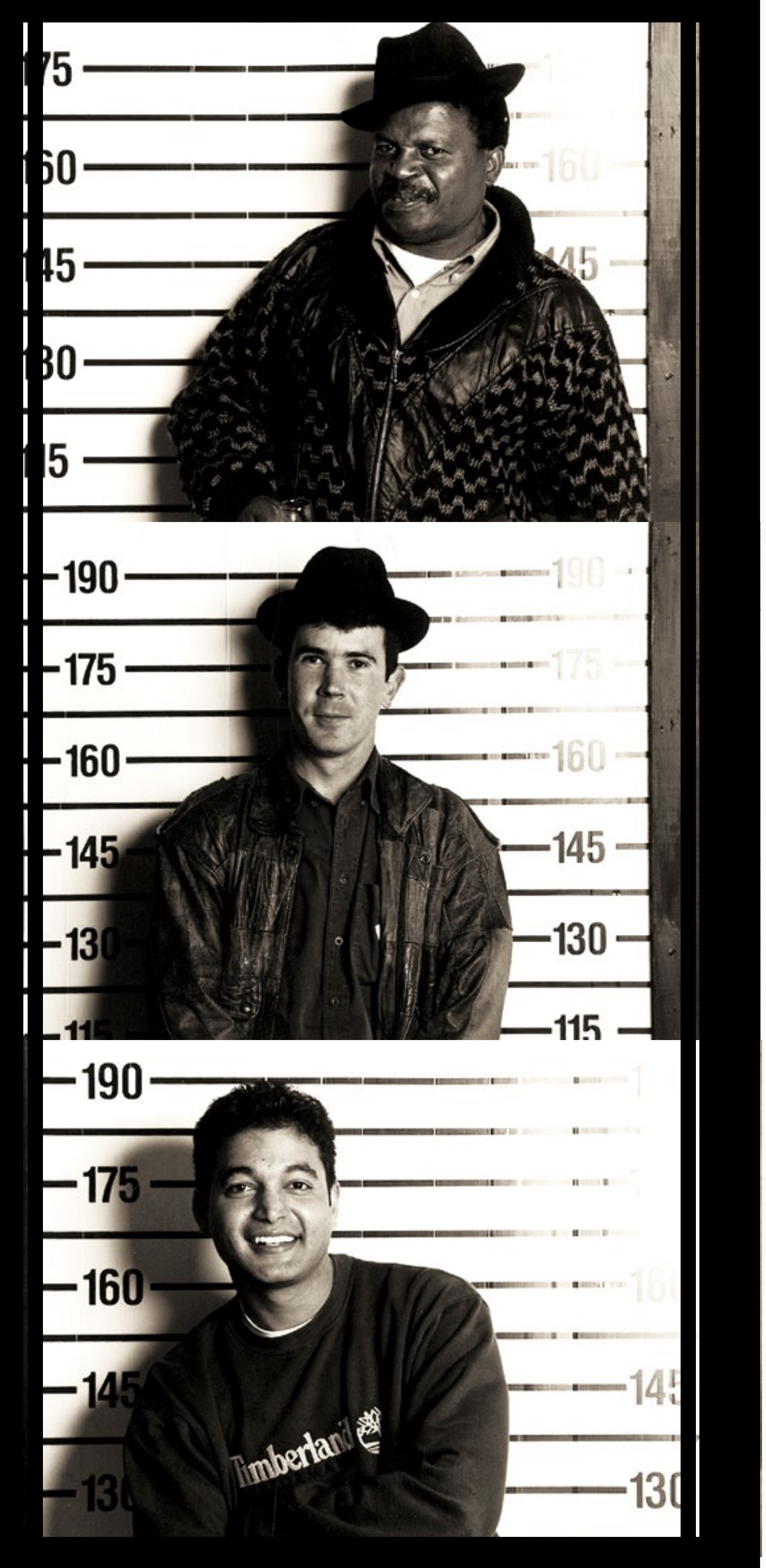
MANY FOND MEMORIES

There were always new experiences lying in wait for staff during the NASA days at Hartebeesthoek. First aid training was important for everyone and training in fire fighting started after Norman Hodges had converted an old Chev bakkie into a fire engine for the station.

Then there was the challenge of moving the entire intercom system with hundreds of wires successfully between buildings. When everything was sorted out and plugged in again, only one phone did not work: Willem Botha's, of course.

And playing darts at Christmas parties where beginners' luck once saw a delighted Flip van Staden and his wife win their first game.

The TT&C team also tracked NASA's Biosatellite-3 with a pigtail monkey[2] on board to monitor weightlessness. The team kept track of the animal's breathing, blood pressure, when he ate, even how he chewed – all from signals received from a relatively small capsule 400 to 500 km above the Earth. The operations room was tensely silent while locating



the satellite and the relief great when the monkey's heartbeat appeared on the scanner.

"There were always new experiences at Hartebeesthoek. I don't remember ever being bored, there was just so much to do." ***– Johan Helberg***

METTLE TESTED

The Joburg STADAN participated in a complex, global effort to recover the OSO-7 satellite that was nearly lost during its launch in September 1971. Seven seconds before the satellite separated from the launch vehicle, a sudden loss in hydraulic pressure in the launcher's guidance control system prevented its 'sail' from locking onto the Sun as intended. The satellite spun out of control.

The engineers at NASA had 12 hours to recover the satellite before the batteries ran down. A number of ground stations, including the team at Hartebeesthoek, tracked the launch vehicle and satellite simultaneously to supply NASA's Control Centre continuously with accurate, real-time telemetry data and assist the NASA engineers in their recovery efforts. Finally, with time running out, the engineers started slewing[3] the satellite and with great skill and some luck, regained control of the spacecraft.

"Regaining control of the satellite was an exciting and very rewarding moment. We felt good to know that Hartebeesthoek had played its part, with the other ground stations, in bringing the satellite under control." ***– Ike Marais***

GOOD TIMES, FUN THINGS

On a couple of occasions before the French team at Paardefontein[4] was relocated to Hartebeesthoek, Danny Searle[†] and Johan Helberg helped them with the early morning launch of weather balloons.

Their enthusiasm for doing this, by their own admission, was somewhat influenced by a standing invitation to join the Paardefontein team in an early morning glass of Chivas Regal – the French believed firmly that it was the only way to get going by 05:00 in the morning.

The balloons looked like giant worms as they slid out of enormous bags. The zips on the bags had special hooks for a tight grip.

The reason for this was not a lesson learnt twice. The force of the balloon pouring out of the bag pushed the zip down so fast that without a tight grip, bag, balloon and hanger-on were soon airborne, feet off the ground!

"We used helium to fill the balloons. Once, a cap broke off as Danny and I were down-loading a bottle and for some time afterwards we could happily have sung in the Drakensberg Boys Choir! Those were good times, doing fun things." ***– Johan Helberg***

LAINGSBURG, LEST WE FORGET

Early in 1981, the Buffels River in the Karoo came down in flood and the small town of Laingsburg suffered devastating damage. Many people were killed, swept away by the force of the flood into the Floriskraal Dam, 16 km south of the town.

Alan Caithness[†] used pre- and post-event Landsat-2 images and the SRSC's Image Analysis System[5] to identify the flood-damaged area, assess the damage to crops and determine the increase in the size of the dam. The analysis took a few days and when compared with the official assessment, published months later, it was found to be accurate to within a 3% margin.

"The speed and accuracy with which Alan prepared the analysis showed his remarkable skill and was the first practical demonstration of using remote sensing data to solve real-world problems."
– Ike Marais

HOME-GROWN INNOVATION

During the early 1980s, the innovative 'in-house' design and development of a format synchroniser led to a considerable cost-saving for the CSIR's Satellite Remote Sensing Centre at Hartebeesthoek.

Designed and built by Ike Marais, with system software written by Syd Howe and the computer data interface implemented by Ian Chisholm, the 'home-made' system could receive and process data from the US-designed National Oceanic and Atmospheric Administration (NOAA) satellites.

The satellites covered large areas of the Earth's surface to record data about ocean currents, land surfaces (night views) and vegetation, that added value to the station's Earth observation products and services.

"The system was used effectively for many years before new technology replaced it, initially by a workstation with software written by Tim Boyle and finally when SAC acquired a SeaSpace Orbview/ NOAA automated system." ***– Ike Marais***

TEAMWORK AT WORK

In 1983, Robert Guedj and Yves Moizant flew to France for training at CNES on a newly installed system to support the launches of the European Ariane family of launchers.

While the two were still in France, Hartebeesthoek was scheduled to support the launch of Ariane-6. With no-one trained on the new system and a manual available only in French, the challenges seemed daunting. Tasso Karantonis (fluent in French) and Ike Marais tackled the problem head on. Tasso translated the instructions and procedures in the manual while Ike took notes. With the translated notes and the benefit of years of experience, the TT&C team supported the Ariane mission successfully.

"We figured out what to do and wrote down the operational procedures. As the only English version available at the time, the translation became the training manual and was used for quite some time thereafter." ***– Ike Marais***

INGENUITY TO THE RESCUE

In 1984, the Hartebeesthoek station required a separate transmit facility to support the launch of the Telecom-1A satellite. Selwyn Clark's hydromechanics expertise and electronics engineer Bram Broere† came to the rescue.

Selwyn mounted a 6.1 m parabolic reflector onto an existing antenna and reconfigured ('skewed') the transmit feed to reach the satellite in its geostationary orbit 36 000 km above the Earth. Bram built the electronic interface to support the French Intertechnique command equipment. Their ingenuity provided SAC with the transmit facility it needed, ensuring that the TT&C team could complete their preparations for the launch and provide mission support for the satellite successfully.

"Selwyn and Bram's expertise and the co-operation from the French team ensured that the station could provide CNES with the required mission support. This was one of many similar examples of why SAC became known as a reliable launch support partner."
– Tasso Karantonis

A LANDMARK RULING

Early in 1994, disaster struck the Merriespruit mining community near Virginia in the Free State. Within less than 30 minutes, a late afternoon thunderstorm created a massive build-up of water that caused the collapse of a tailings dam wall. The 2.5 m high wave of sludge water flooded through the town, leaving a 4 km trail of devastation with 17 people killed, 80 houses destroyed and widespread damage to the environment.

SAC's extensive archive of SPOT data contained images of the dam and surrounding areas before the disaster. The images clearly showed the water build-up against the dam wall. The mine cited inoperative pumps as the cause of the build-up. During the trail, the mine's legal team objected to the use of satellite imagery as causal evidence. Dr Geoff Longshaw represented SAC as an expert witness and, based on his testimony, the judge ruled that the data was admissible as evidence.

"The ruling set a legal precedent and the mine was found guilty. The verdict enabled those affected by the disaster to file civil suits for compensation."
– Dr Geoff Longshaw

AN IMPRESSIVE WALKWAY

South Africa's post-1994 democracy drew an influx of foreign visitors. SAC received its fair share of dignitaries and traditionally rolled out a red carpet to welcome such VIPs – the red walkway always presented an impressive sight. On one such an occasion, the French Prime Minister, Lionel Jospin, flew in by helicopter. SAC's reception team at the helipad included the then Ministers of Science and Technology and Communications.

The red carpet was rolled out over the grass which, overgrown in patches, created unsightly lumps unsuitable for VIP feet.

With the sound of helicopter blades in the distance, Raoul Hodges was seen in low flight behind one of SAC's powerful lawnmowers, grabbed in haste without a bin to catch the cut grass. As the clumps disappeared, the grass fell where it was cut. The carpet rolled out smoothly. Murphy chuckled.

The helicopter arrived with blades spinning furiously and hovered for a moment before it set down on the helipad. The sudden gust of wind blew the freshly cut grass directly onto the carpet. As if orchestrated, numerous pairs of hands including those of VIP's, dignitaries and cabinet members grabbed and shook the carpet in snakelike undulations to rid it of the pestilence. When the helicopter door opened, Presidential feet stepped out onto an almost pristine, albeit not entirely straight, red carpet with no evidence of the frenetic activity moments before.

"We used the red carpet many times after that visit, but always made sure that no loose grass was lying around in the vicinity of the carpet before we unrolled it." ***– Renier Balt***

RECOGNITION FOR TECHNICAL LEADERSHIP

In 1995, Tasso Karantonis and Pierre Picard received a Certificate of Recognition from the "Clementine"[6] Deep Space Programme Science Experiment for their leadership and contributions in supporting the demonstration of advanced space flight technology.

During a hectic start to 1994, the pair configured the CNES communications equipment at SAC to interface with the equipment at the Van den Berg Base. After a pre-launch test, they supported 22 passes including the final solid rocket burn (SRM) to enter lunar orbit.

"The spacecraft was designed and launched in 22 months for less than $80 million and provided the first multi-spectral images of the entire lunar surface. The mission demonstrated the benefits of government/industry co-operation and SAC's ability to contribute meaningfully to space missions."
– Tom Kennedy

MISSED OPPORTUNITY

When CNES veered towards awarding the mission support contract for the new generation Ariane launchers to the Malindi ground station in Kenya in 1996, SAC negotiated to be the standby station for the first launch. The home team planned to somehow outperform the other ground stations and reclaim the contract.

Confident of their performance, the SAC TT&C team had invited the SABC to attend the launch event for publicity support. Journalist Kim Cloete and a cameraman joined them and a CNES oversight team in the control room, where all ears were on the audio-streamed countdown.

A mere 37 seconds after launch, the Ariane launcher self-destructed. A malfunction in the control software had caused the satellite to veer completely out of control, leaving the SAC team with no opportunity to demonstrate anything.

When Kim Cloete understood what had happened, she called Freek Robinson, head of SABC news at the time and shouted excitedly: "We have a story!" The story made the evening news as planned, but for all the wrong reasons.

"An hour later the French oversight team had packed up and left. Flawed manufacturing decisions that had caused the failure of a superior launch vehicle worth billions had also dashed our hopes of retaining that specific Ariane contract." ***– Renier Balt***

LIGHTNING BALT

In the late 1990s, lightning struck the control room at Hartebeesthoek, destroying much of the equipment. The damage was considerable. An investigation determined that unearthed equipment had exacerbated the damage, which required expensive repairs to bring the station back online and prevent a loss in revenue. Renier Balt, station manager at the time, contacted David Bath at the CSIR to explain the dire situation and request funding for the repairs. The funding was granted but Renier earned himself the nickname Lightning Balt.

"We learnt an important lesson: a maintenance job was never completed until everything had been well-earthed and checked. It was a lesson that had lasting consequences – we made sure that we didn't learn it twice and I was stuck with a nickname that I never quite lived down when David Bath was around." ***– Renier Balt***

LET SLEEPING DOGS LIE

In the late 1990s, SAC's three-man marketing team– Renier Balt, Roy Blatch and Piet van der Westhuizen[†] – negotiated contracts with aerospace companies in the US to increase its client base.

Negotiations with McDonnel Douglas had been ongoing for some time. The SAC team had done exhaustive preparation for a telephone conference to clinch the mission support deal for the launch of the Iridium satellites.

Their determination paid off when all parties agreed to finalise the contract. The trio said goodbye to their new client and, thinking that they were no longer connected, jumped up as one man with arms pumping the air and shouting with glee until one of them realised that the speaker phone was still on.

"We will never know if the client heard us and, if so, what they must have thought! For a couple of days we expected a phone call to cancel the contract. In our dealings with them afterwards we often wondered whether they had heard us, but they never let on and we never asked. It was a classic case of letting sleeping dogs lie."
– Piet van der Westhuizen[†]

ARCHIVED SATELLITE DATA AN INVALUABLE INVESTMENT

SAC's impressive archive of remote sensing[7] data that dates back to 1972 is an invaluable resource for analyses and change detection applications, such as finding out how land has been used over time.

The importance of access to this priceless archive was brought home when SAC received a call from the office of the then Director General of the

Department of Science and Technology, Dr Rob Adam. "Can you tell us what happened in the past?"

The Department had to deal with the dangerous situation of people erecting dwellings and structures under a power line. When efforts to convey the danger to those living in the dwellings did not succeed, the court had to make a decision to prevent harm, but the decision was dependent on knowing when these dwellings had been erected.

Dr Rob Adam contacted the station to find out if the archived satellite imagery at SAC could provide an answer. There were a number of obstacles. At the time, satellites covered the specific area only once every 25 days and cloud cover during the overpasses could have prevented coverage of the area. But the imagery from the SPOT satellite was clear and with the data SAC could determine the exact date when the dwellings were erected. Geoffrey Quick was SAC's expert in the court case.

"It was one of many instances where the immeasurable value of SAC's archive of satellite imagery gathered over many years was demonstrated. Over time it proved to be an invaluable investment for future comparative studies." ***– Renier Balt***

PREFERRED TRAINING PROVIDER

In the late 1990s, the old Minitrack station was refurbished as the SAC Training Centre. The success of training courses at SAC can be attributed to people such as training manager Tim Boyle and co-ordinator Betsie Snyman, as well as UK business consultant Geoff Quick, who sent training business SAC's way, and a variety of professionals who presented the training courses. The station became a preferred training provider in remote sensing, with course participants benefiting from the significant knowledge, skills and experience of SAC stalwarts, such as Tasso Karantonis and others who assisted with the training.

"Many course participants returned for further training or requested that additional courses be added to SAC's training schedule." ***–Tim Boyle***

THE SPACE GIRLS

In July 1998, four qualified young professionals – fondly referred to at the time as SAC's Space Girls – supplemented their South African qualifications with a 10-month remote sensing course at GDTA, the Aerospace Remote Sensing Development Group in France.

SAC had arranged for the graduates to train in France as part of a training partnership agreement with GDTA. The training included an internship at SAC and contributions from the Department of Communications, the French Embassy in South Africa, GDTA and the CSIR made it all possible.

"We were delighted when South Africa's 'Space Girls' obtained their diplomas in France. Credit was due to all four for their hard work, as well as to GDTA and the French Embassy for their support, while the assistance from SAC's Geo-information Products and Solutions team also contributed to their success."
– Renier Balt

THE BONUM-I STORY – CHALLENGES WELL MET

When SAC needed funding to upgrade the Hartebeesthoek station with Ku-band capacity, to secure the Hughes launch support contract for Bonum-1, former CSIR President Dr Geoff Garrett invited Renier Balt and Michelle Le Saux from SAC to present the R15 million funding proposal to the CSIR Board at a meeting in Cape Town. The duo knew that their thorough preparation had paid off when former Board Chairman, Dr Bill Venter, commended them on "one of the best presentations" he had ever heard. They returned to Hartebeesthoek with Board approval and the requested funding for the upgrade.

"We were nervous, but exceptionally well prepared. In line with the work ethos at HBK, our proposal covered every detail, was factually correct, well-practiced and concisely presented. It worked."
– Renier Balt

With the funding secured to install the Ku-band ground station, the SAC team encountered two further challenges: a very tight deadline and the assembly of a new European ground station system when SAC's expertise at the time was based on US systems.

Always galvanised into action by the seemingly impossible, SAC called in Willem Botha and Tasso Karantonis to assist them and the team set to work. With on-the-job training and the team's usual flair for ingenuity and will to succeed, SAC completed the installation of the 14 m antenna and baseband equipment on budget, on brief and in time for the launch on 22 November 1998.

"Our ability to meet and exceed client expectations always made me proud to be part of the SAC team."
– Renier Balt

MANKIND'S ASTOUNDING PROWESS

Willem Botha visited the Vandenberg Air Force Base in the US for the launch of Landsat-7 aboard a Delta-II launch vehicle in 1999.

The experience left him with a permanent impression of mankind's ability to achieve the seemingly impossible: from the countdown and billowing white smoke from six solid rockets that engulfed the nose fairing of the gigantic launcher as it lifted the satellite into space, to the deafening roar of the rocket motors as the launcher passed Mach 1 and climbed rapidly into the sky on a thick white smoke trail, until it became too small for the naked eye to see.

"The experience of seeing Landsat-7 on its way into orbit after a perfect launch impressed upon me the spectacular phenomenon of space flight and mankind's astounding technological achievements. While there have been failures, such as Landsat-6 that never achieved orbit, the many hundreds of successes far eclipse the failures. Landsat-5 is an example of a satellite that operated for an unbelievable 15 years when it had been designed for a lifetime of only three years." ***– Willem Botha***

GAMESMANSHIP FOR THE GREATER GOOD

In the early 2000's, SAC's management team decided to switch off the station's receipt of data from Landsat-7 as a cost-saving measure – a measure unheard of within the satellite tracking fraternity at the time, but one SAC felt compelled to make to reduce costs.

The consequence of the decision, which would have affected the continuous archival of full sets of imagery over South Africa and the sub-continent, was of great concern to the Department of Agriculture. Most of its applications were based on access to SAC's valuable source of Landsat imagery.

A week after the decision had been communicated to the affected stakeholders, a representative from the Department arrived at SAC with the news that an amount of R7.5 million would be made available for the station to continue with the acquisition of Landsat-7 data. The funds had been approved based on a strong motivation that spelled out the indispensible nature of the data to the activities of the Department.

"We received the funding just before the end of the financial year in 2003 and just in time to re-instate the Landsat-7 data contract without interruption to our archives. The funds also helped with critical improvements at the station, which in turn enabled SAC to continue providing stakeholders with the data products they required. It was an example, greatly appreciated, of where a client came to the rescue to the benefit of all parties concerned." ***– Renier Balt***

FIRST DUAL LAUNCH SUPPORT

The expertise and teamwork of SAC's mission controllers were thoroughly tested when the station was contracted to support the dual launch of the AMC-21 and Superbird-7 satellites aboard an Ariane-5 launcher from Europe's Kourou space port in French Guiana in 2007.

The TT&C team was well-practised, but the dual launch was a new experience and required intense concentration and supreme co-ordination to deliver error-free mission support services.

"Our faultless performance on the launch day again demonstrated our technical competence to the international space community." ***- Tiaan Strydom***

BEHIND THE SCENES

An invitation to a SAC event was welcomed by all within the space community, locally and abroad. Many itineraries were rescheduled to include attendance at a SAC event as a firm commitment.

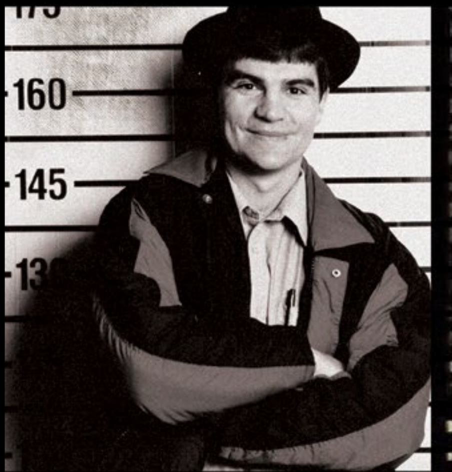
Credit for the popularity and success of those events must go to SAC's impressive events team, Magriet van Wyk, Elsa de Beer, Carole Liddy and Betsie Snyman "vir wie se hande niks verkeerd gestaan het nie", who all ensured that every event was a winner. Their 'behind the scenes' hard work always did SAC proud.

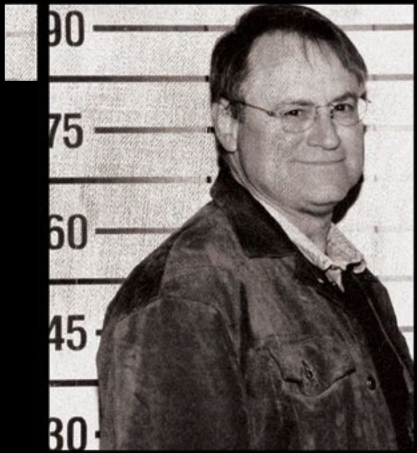
"SAC events had a special lustre.The faultless organisation by SAC's amazingly competent events team ensured that everyone always had an astounding amount of fun." ***– Karen Wentzel***

BARN OWL FAMILY AT SAC

During 2005, SAC's big Ka-band antenna at Hartebeesthoek became home to a family of barn owls. The female selected the structure of the antenna to build her nest and breed three chicks. Frikkie Meyer set up a web camera inside the nest for the staff to watch the chicks growing up.

"It was a unique experience, one that not many people are fortunate to see. Everyone became interested in the well-being of the baby owls and checked on them regularly. I think if we could, we would have adopted them into the SAC family." ***– Frikkie Meyer***





CAMARADERIE ACROSS CULTURES

The success of the unique working environment at SAC had a lot to do with a shared work ethic and amazing camaraderie among the members of staff, despite their diverse cultural backgrounds.

The larger group of people hailed from a number of different South African cultures, while other nationalities included Helmut Neumann (German), Yves Moizant and Bruno Meyer (French), Tasso Karantonis and Johnny Rizos (Greek), Jim Weeks (American), Geoff Quick (British) and many others. All were seamlessly incorporated into the SAC team.

"I have fond memories of Elijha Tshefu in the Genhouse, Isak Ramela, a whizz in the garden who brought the ladies flowers, and Piet van der Westhuizen[†] with his boule (steel balls), who taught us to play petanque (lawn bowling adopted from the French) – we even built a special area for the game." ***– Karen Wentzel***

TASSO'S LADY

Tasso Karantonis received training in the US on the electronics of SAC's 10 m LSX[8] antenna, which was installed and commissioned in 1988. After an illustrious 20-year career, the LSX, fondly dubbed Tasso's Lady, finally started showing signs of fatigue. A lightning strike in 2007 put the antenna out of action for several months. When all revival attempts failed, Tasso – who had retired in 1994 – was called in to rescue the Lady.

By March 2008, the antenna was back in action but in 2010 an electrical storm permanently crippled the control unit. As the SAC era came to an end, so it seemed, did two decades of service from Tasso's Lady.

In July 2011, a local company designed and installed a new control unit in the antenna, restoring it to full functionality. Once again, Tasso's Lady could look towards the stars and listen for the sound of satellites.

"The task to get her going again in 2007 was daunting. I had to repair the new control unit along with the S- and X-band feeds and auto-track systems. When it seemed that she had taken her final bow in 2010, it was a sad day for all who had known and worked with her. I am just happy to see her working again now." ***– Tasso Karantonis***

WE HAVE LIFT OFF!

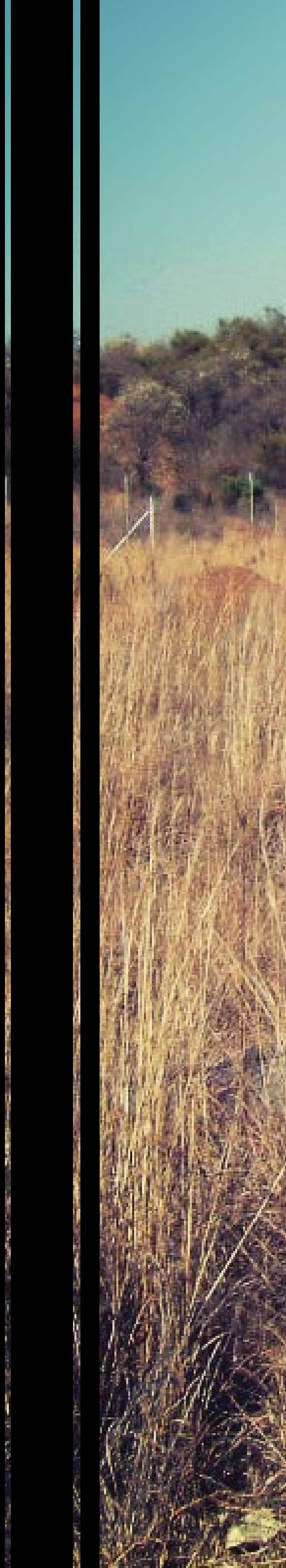
SAC staff celebrated the 1998 Year of Science and Technology with the launch of a variety of model rockets. The front runners among SAC's model builders were Frikkie Meyer, Pieter Sevenhuysen and Joe Schiller.

Onlookers showed a keen interest as the three-man team made critical adjustments to their rockets as they readied them on the launch pad before lift-off. The crowd waited in anticipation for the count-down and saw the rockets perform faultlessly during lift-off.

"Once again, attention to detail paid off. We proved our rocket building and launch procedure prowess with faultless precision. We had no choice but to get it right – there was SAC's reputation to think of." ***– Frikkie Meyer***

Our story in pictures

Memories through the years



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The way we (some of us) were in 1994

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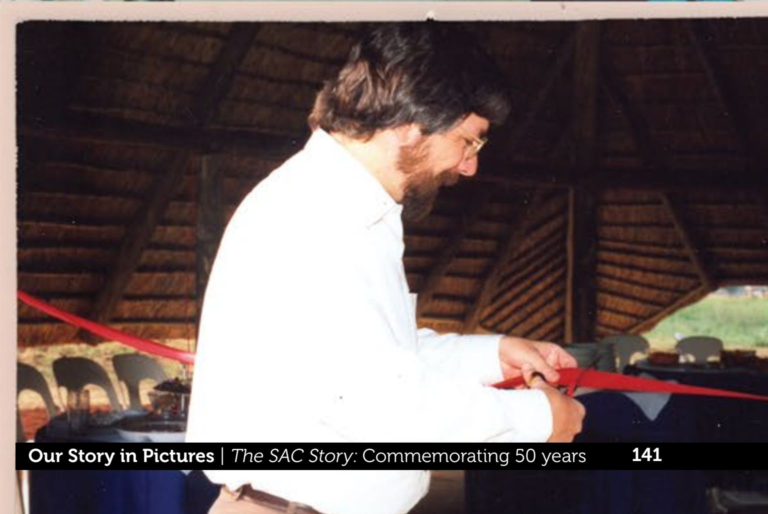

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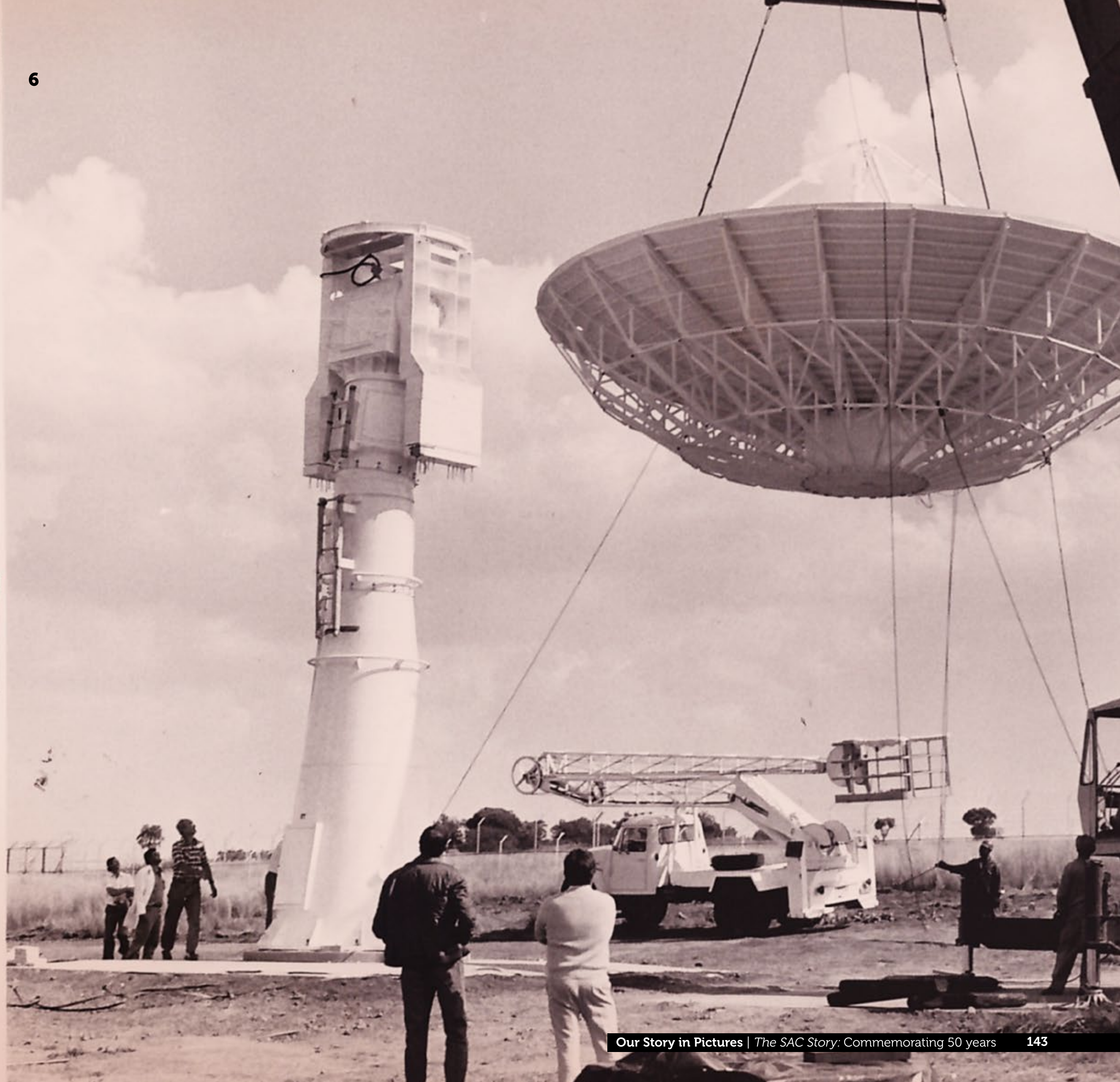

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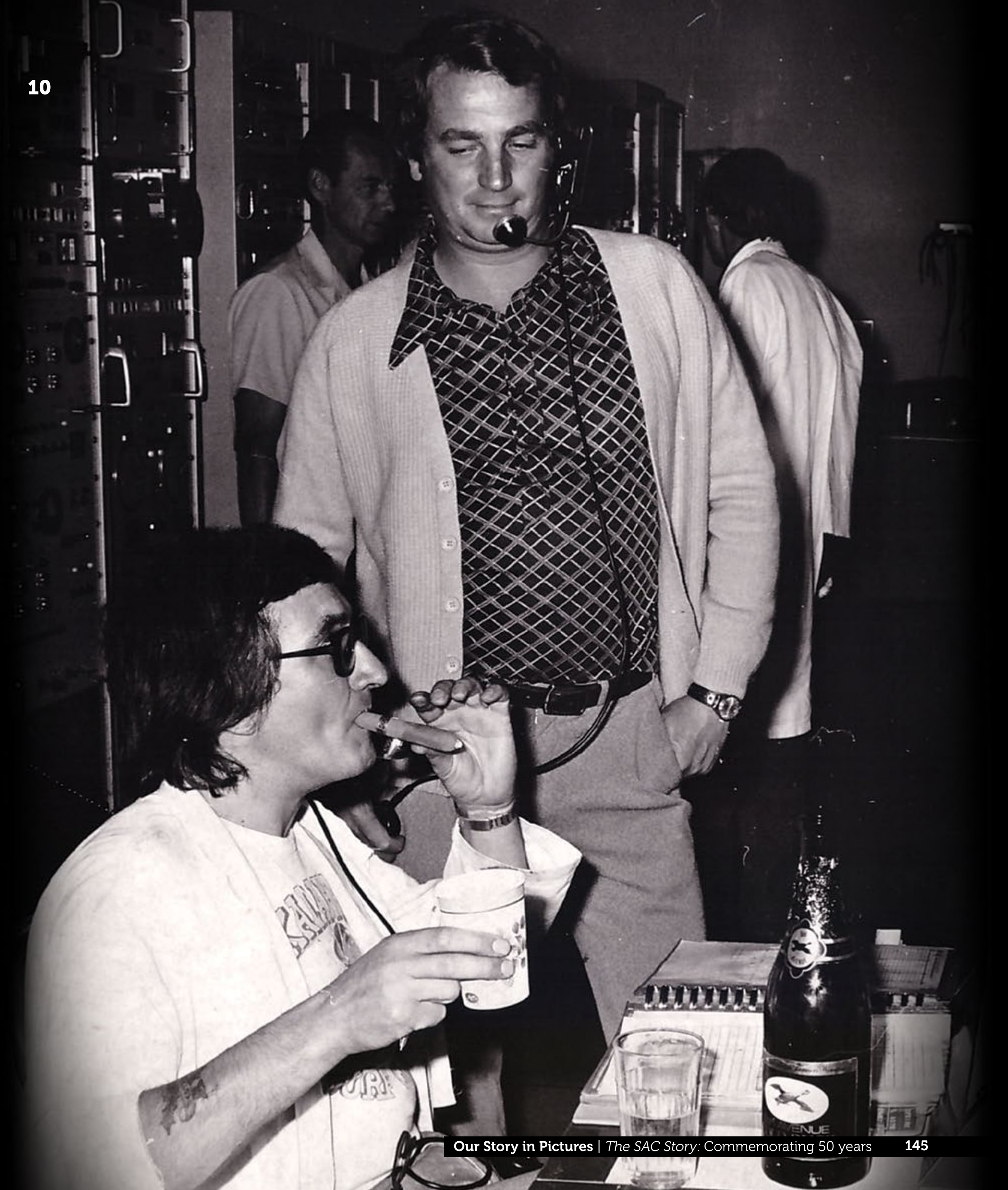

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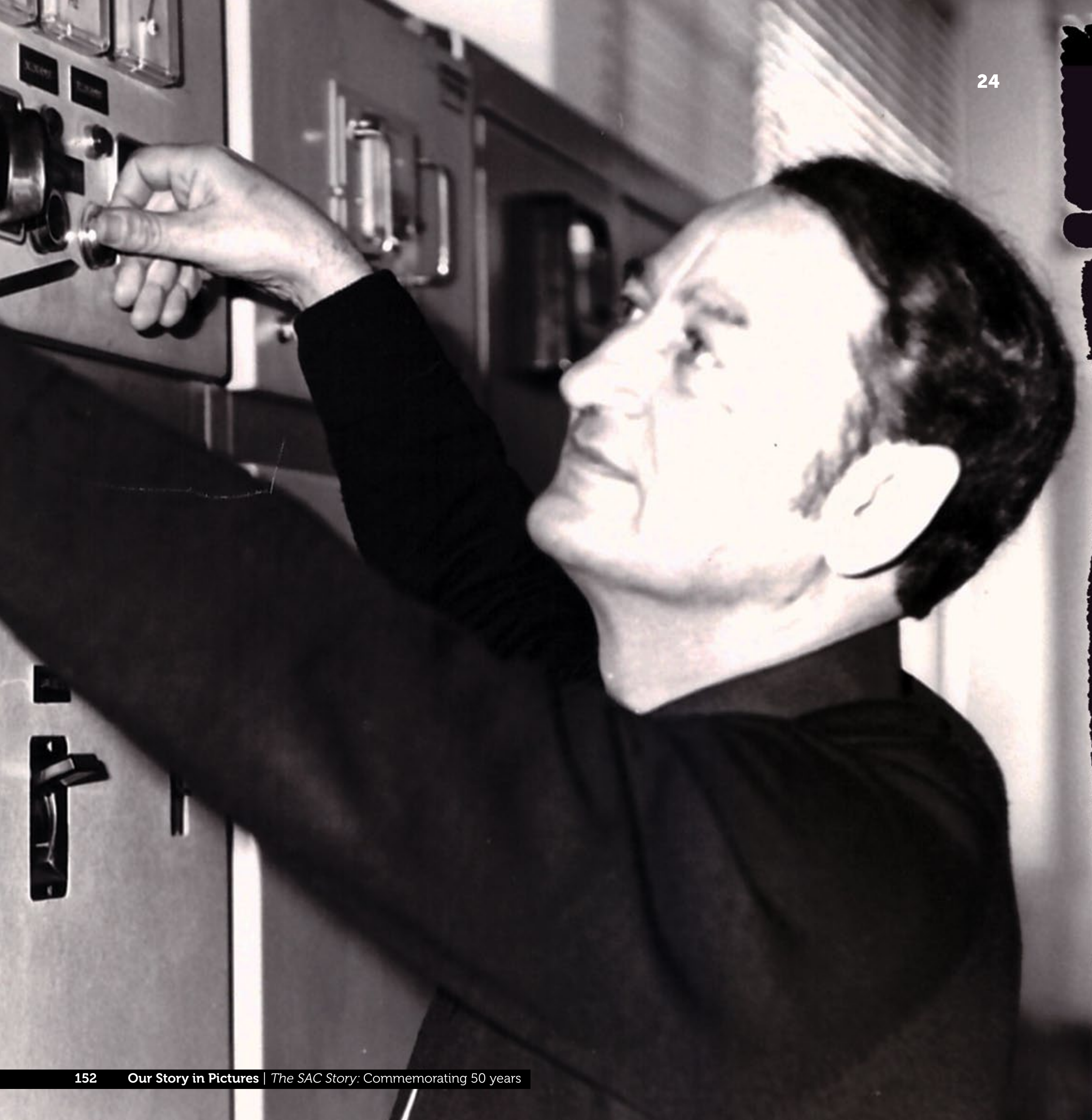

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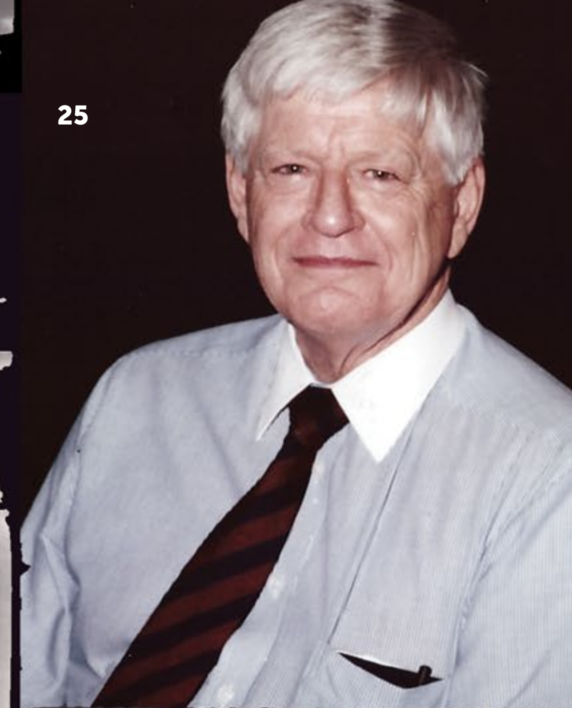

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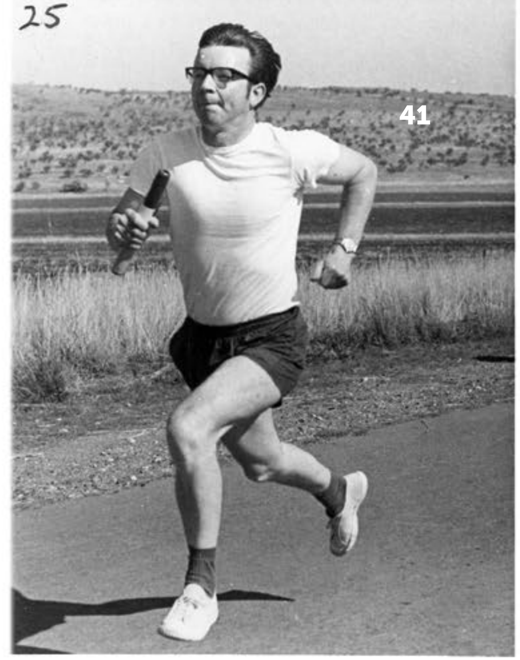

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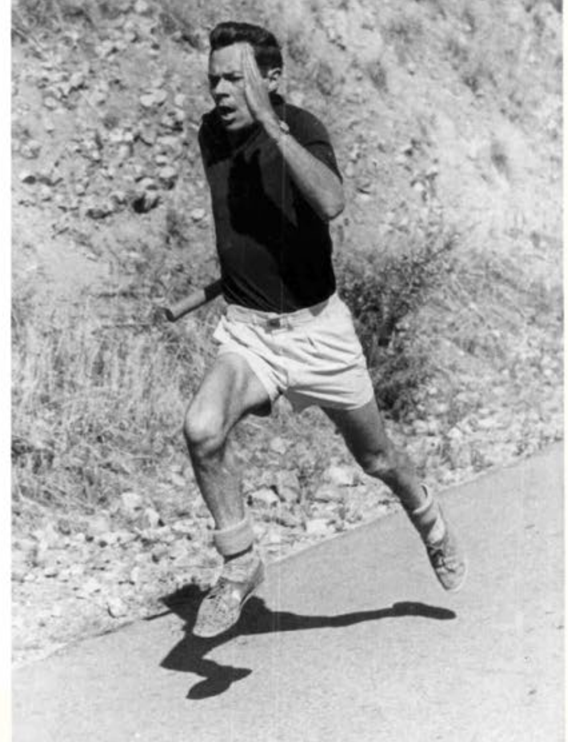

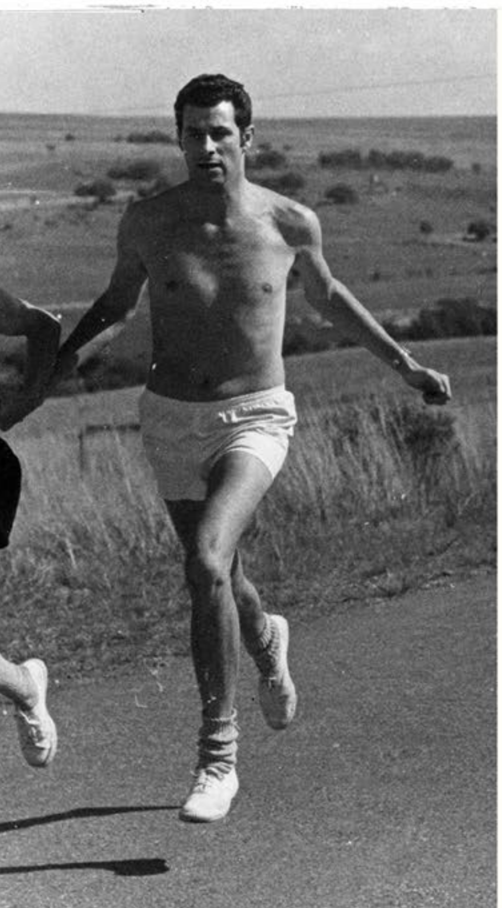

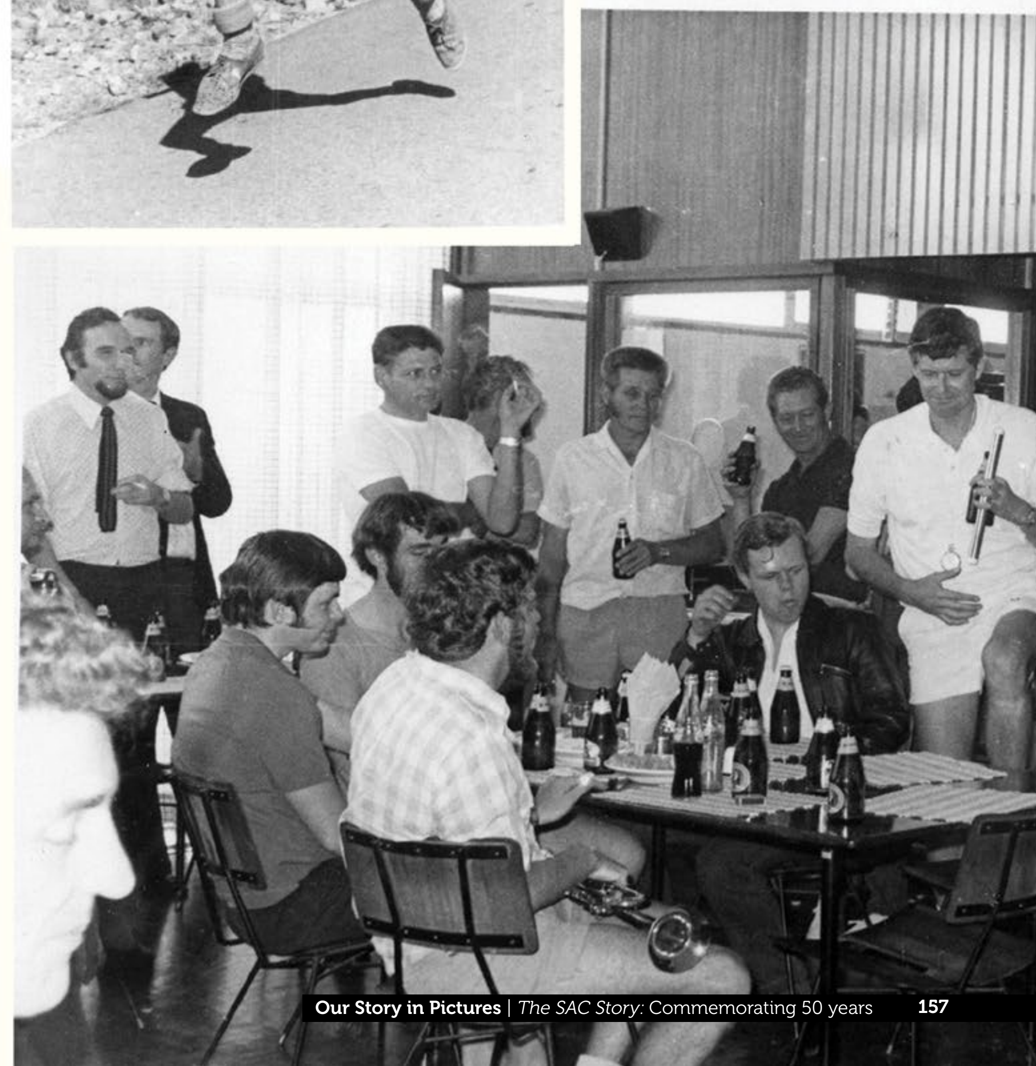

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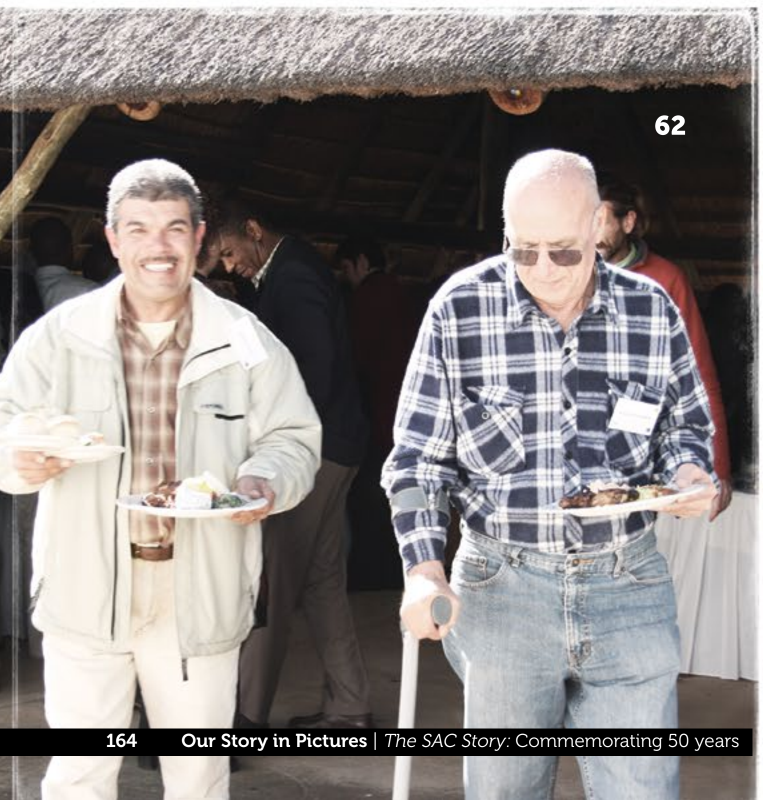

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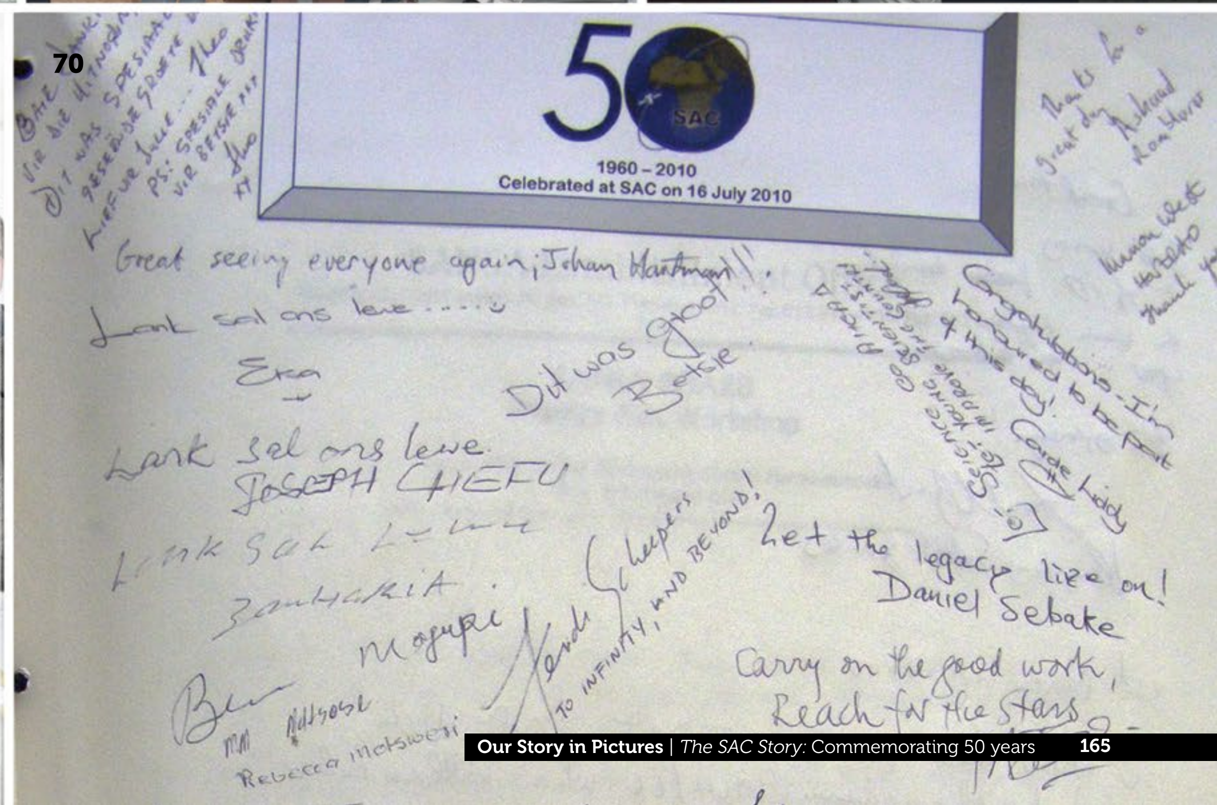

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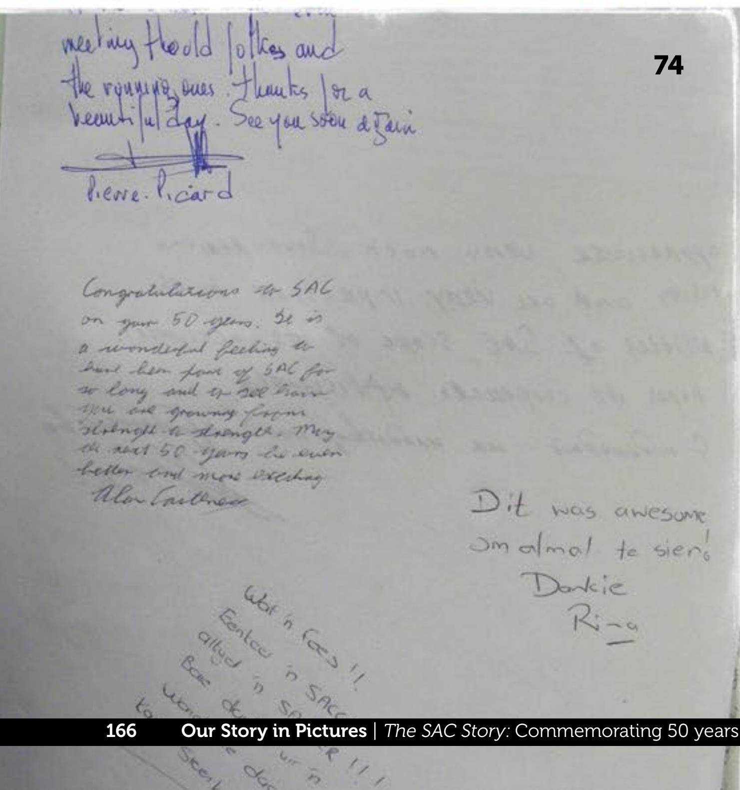

meeting the old folkes and the young ones. Thanks for a beautiful day. See you soon again

Pierre. Picard

Congratulations to SAC on your 50 years. It is a wonderful feeling to have been part of SAC for so long and to see how you are growing from strength to strength. May the next 50 years be even better and more exciting

Alan Carthew

Dit was awesome om almal te sien!

Dorkie

Rina

Wat 'n fees!!

Eenkeer 'n SAC

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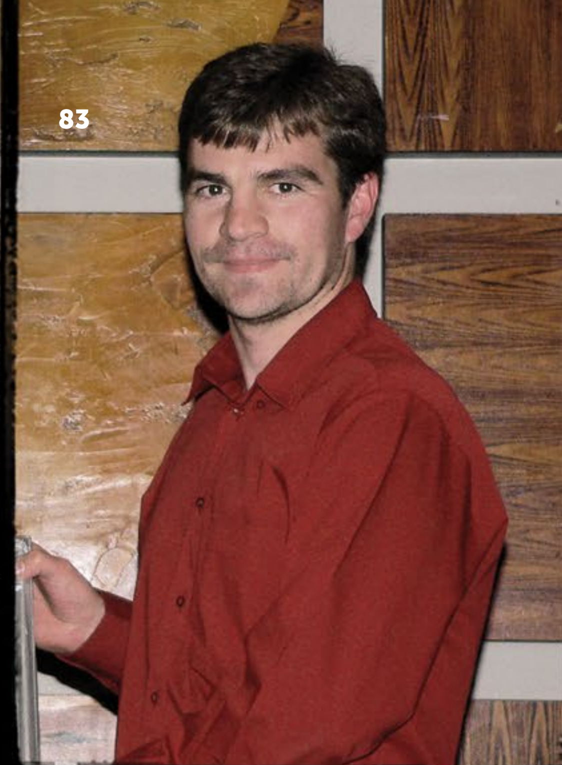

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Epilogue
The next era

History tells us that on its own, a nation can send a satellite or probe into space but that anything more substantial or sustainable requires international co-operation. Space exploration will only really be successful when nations pool their resources and work together.

I was privileged to have fulfilled a number of roles during a good part of the 50-year journey of the CSIR Satellite Applications Centre (SAC). Along with my SAC colleagues, I am proud of our contribution to the way in which the world today benefits from the exploration of outer space.

This commemorative book highlights SAC's role in major space programmes, from tracking the world's first artificial satellites during the pioneering NASA days and creating an invaluable remote sensing database with data products shared across the continent, to supporting NASA's first lunar mission and preparing to provide mission support to South Africa's own pathfinder Earth observation satellite, SumbandilaSat. Documenting the SAC story has in itself been a substantive journey – one with much reflection and many opportunities to relish the memories, recognise the excellence, savour the accomplishments and consider again the challenges and lessons learnt. I have no doubt that our story stands testimony to how local ingenuity gained South Africa stature as a global player in space science and technology.

I write this epilogue fully aware that the end of the SAC era concluded only the coming of age of South Africa's role in space exploration. We are already well into the next era, where nations world-wide are increasingly relying on space-based applications to address socio-economic challenges. Internationally, efforts are underway to increase co-ordination within the space industry and strengthen its technology base for global benefit.

Locally, the South African National Space Agency (SANSA) is spearheading the co-ordination of our space resources and technological capacity.

SANSA's merged resources have given it a competitive advantage for the road ahead. The CSIR's investment in SAC created a substantial space infrastructure and an invaluable database of satellite imagery with products that are shared throughout Africa. The people at SAC created a track record in space mission control on par and often rated better than those of international peers and competitors.

The Hartebeesthoek team took leave of its SAC identity and roots within the CSIR with a keen appreciation for the leadership from an organisation that, in its pursuit of excellence, supported an environment in which we could continuously challenge ourselves to achieve greater heights.

We look forward to helping SANSA fulfil its mandate of deriving value from space science and technology for the benefit of all in society. Our commitment to making a meaningful contribution remains steadfast. We were privileged to have lived the SAC story and will remember it as a prelude to the adventures that lie ahead.

Raoul Hodges
SAC Manager (2006 - 2010)

Visit the Wiki page on the SANSA website for more information on The SAC Story or to add your own story or photographs.

Way forward

In service of humanity

Some fifty years ago former US President John F Kennedy referred to space exploration as one of the greatest adventures of all time and an imperative that could not be ignored. He also said that America chose to go to the moon, not because it was easy, but because it was a goal that would measure the best of their abilities and a challenge they intended to win.

Those sentiments came to mind when I looked at the performance of the CSIR Satellite Applications Centre (SAC) during the first 50 years of the space age. I appreciate the opportunity to write the concluding remarks to a book that celebrates the significance of SAC's role, not only in the global space arena, but also in the economic and technological development of our country.

The husbandry of the CSIR and endeavours of the people at SAC have provided the South African National Space Agency (SANSA) with a unique space infrastructure and firm foothold from which to take forward South Africa's initiatives in space exploration. The country's National Space Strategy recognises space science and technology as one of the country's five great challenges.

Our task at SANSA is to co-ordinate the key strategic space institutions, activities and initiatives to create the societal, intellectual, human, economic and global capital with which to address the challenge.

SANSA is leading the implementation of the National Space Strategy. Our directorates for Earth Observation, Space Operations, Space Science and Space Engineering are driving the process, while SANSA's focus on science advancement, public engagement and human capacity building supports their activities.

Our purpose is to ignite a passion for space among our youth, ardently pursue South Africa's role in space research and create an awareness of its benefits among all in society.

On behalf of SANSA, I thank the CSIR for its stellar stewardship of a remarkable national asset. I am confident that the country will continue to benefit from that substantial legacy and that the skills and expertise of the SAC people who have joined SANSA will continue to add value to achieving our goals.

I look forward to a future of shared endeavour as we promote the peaceful use of space, foster international co-operation in space-related activities, increase our knowledge of the universe, develop space technologies and continue to contribute to the success of groundbreaking space missions for the benefit of humankind.

Dr Sandile Malinga
SANSA CEO

Captions for

Our story in pictures

Note from editorial panel

Despite concerted effort, we could not identify every person in the photo section. Should you know the name of someone we did not identify, kindly post the information on The SAC Story wiki page at www.sansa.org.za/spaceoperations/thesacstory

Pages 140 and 141

1. The way we were. Some of the SAC staff in 1994, (front row ltr) Alan Watson, Ian Whittaker, Willem Botha (then SAC Manager) and Raoul Hodges; (middle row ltr) Piet Myburgh†, Johan Hartman, Frans Meintjies†, Flo Coetzer†, Betsie Snyman, Lynette Croft, Syd Howe, Ronel Vermaak, Ike Marais and Pierre Pickard and (back row ltr) Johan Helberg, Tim Boyle, Joe Schiller, Johann Treurnich, Yves Moizant†, Steve van Niekerk and James Weeks†.

2. Heydays and highlights. The construction of the ever popular lapa at Hartebeesthoek (top and bottom left), with Lynette Croft (top right) planting a sapling near the skeletal outline of the lapa under the watchful eyes of (ltr) Helena Bosman, Alan Caithness†, Michelle le Saux and Raymond Vice†. Willem Botha (middle right) unveiling the name board of the aptly christened "Hartbeeshuis", with Raymond Vice† looking on and (bottom right) Dr Adi Patterson, then CSIR Executive Vice-President: Technology and Innovation, cutting the ribbon at the official opening of the lapa. The rest, as they say, is history ...

Pages 142 and 143

3. Song and dance. Karaoke and some Greek dancing from (top ltr) Tasso Karantonis and Renier Balt, with Solly Masinga, Philemon Moralo, Isak Ramela, Bennnet Thlale† and David Masiteng impressing as an impromptu choir and a duet from Theo Kasselman and Vanessa Rowe (right) and (bottom ltr) a jig by Piet van der Westhuizen† with Lynette van der Walt looking on, while Flo Coetzer† receives 'job-well-done' flowers from Willem Botha and Joe Schiller stands ready for action with microphone in hand.

4. Up for grabs. Alan Caithness† (left) listens smilingly as Willem Botha hands out rewards in the old Minitrack building at Hartebeesthoek.

5. Johan Helberg, Tasso Karantonis and Charles Chambers† (ltr) take a break during a lull in activities at the end of the NASA years while waiting for news of what the future holds.

6. A very good year. The dish of the 10 m L-, S- and X-band antenna lifted onto its pedestal at Hartebeesthoek in 1988 under the watchful eyes of Frans Meintjies† and Piet Myburgh (back ltr) and Hans Curver and Syd Howe (front ltr) looking on. The antenna added versatility to SAC's mission support and EO services, including TOSS, launch support and the downloading of Earth observation data, and eased the workload of the other antennas.

Pages 144 and 145

7. There's teamwork afoot! Working together, whether scaling precarious heights (top left, ltr) Raoul Hodges, Tim Boyle, Michelle le Saux, Tasso Karantonis (standing on the shoulders of giants?) and Adriaan van Zyl (pushing back against all odds), or (bottom left) trusting the blind to lead the blind, or (bottom right) taking a step in the right direction with (ltr) Renier Balt getting a helping hand from Adriaan van Zyl with Victor Matooane, Ike Marias and Michelle le Saux keeping close watch.

8 & 9. Impressive sight. Visitors to Hartebeesthoek (top) take a close-up view of the 12 m antenna and (bottom) visit the control room at the tracking station.

10. Celebrating success. Marius Fürst (standing) looking on indulgently as an American visitor celebrates with cigar and champagne yet another successful TT&C mission support by the SRSC team.

Pages 146 and 147

11. Ready for action. The control room at the Satellite Remote Sensing Centre (SRSC).

12. Up, up and away. Adding the final finishing touches to the SAC-made rocket just before its launch as part of the CSIR's participation in the 1998 Year of Science and Technology, (ltr) Pieter Sevenhuizen, Joe Schiller and Frikkie Meyer (with rocket in hand), prepare for lift-off.

13 & 14. "Feed the birds, tuppence a bag". Ike Marais (left) and Johann Treurnich (right) taking time off between business meetings in London to spend it with some feathery friends.

Page 148 and 149

15. Success! Thumbs up from Frikkie Meyer (left) and a contractor from US-based Hughes Satellite Systems, who worked with the Hartebeesthoek team to commission the Ku-band antenna.

16. Training the young guns. Tasso Kanrantonis (seated) in the control room, sharing his considerable expertise with (standing ltr) Tiaan Strydom, Pieter van der Merwe and Joel

Sekwakwa, while Angelos Stavrinos (behind Tiaan) continues with the mission support business at hand.

17. Braai time. Food aplenty during a braai event at Hartebeesthoek, with Piet Malan (right) and Raoul Hodges (left) dishing up and Nelson Canha in relaxed mood behind them.

18. Time with colleagues. Enjoying good company, (ltr) Asanda Sangoni, SANSA, Wabile Motswasele, Dan Matsapola and Kaizer Moroka, Deputy Director, Space Science & Technology, DST at a SAC event.

Pages 150 and 151

19. Welcome at Hartebeesthoek. Employees gathered on the platform of the Ku-band antenna with banner in hands to welcome Mark Shuttleworth as Africa's first Afronaut and the continent's first visitor to the International Space Station.

20. Well done. Handing over a framed photo of the antenna with which the SAC team tracked Mark's space flight, with (ltr) Patrick Buso, CSIR President, Dr Sibusiso Sibisi, Roy Blatch (behind Dr Sibisi), Mark Shuttleworth, former President Thabo Mbeki and Piet van der Westhuizen†.

21. Friendly encounter. Laure Boutemy (middle) and friends at one of the SAC events.

22. Taking time out. In jovial mood, (ltr) Goffrey Chalungumana, Andrew Roberts, Renier Balt, Gilbert Rankoe and Conrad Sebego at a SAC event.

23. Service excellence. Willem Botha (right), then Assistant Director of the CSIR's former National Institute for Telecommunications Research (NITR), handing a memento of appreciation to Raymond Vice† on his retirement after 39 years at the CSIR, 24 of those as Chief Director of the NITR.

Pages 152 and 153

24. Set-up routine. Skill and experience went hand-in-hand as Robert Guedj† set some of the controls on the early satellite tracking equipment at the French Tracking Station at Paardefontein.

25. Fond farewell. Willem and Adeline Botha at Willem's retirement function from the CSIR in 1994.

26. After hours. Catching up on conversation with colleagues during a SAC event, (ltr) Raymond Vice†, Jim Weeks and Tim Boyle.

27. Master braai chef. Isak Ramela doing duty at a staff function (left) and the 2010 FIFIA World Soccer Cup event (right) at SAC as an acknowledged master braai chef, a title well-earned.

28. Award time. A smiling Ashaad Rambharos receiving an award from Dr Bruce Foulis, then Acting Director of Mikomtek at the CSIR.

29. The brave. Fun on the mighty Tugela River, (ltr) Pieter van der Merwe, Piet van der Westhuizen† and Tiaan Strydom ready for any challenge.

Pages 154 and 155

30. Saying goodbye. Elijha Tshefu (front) sharing a laugh with colleagues (ltr) Willem Botha, Durje Laesic, Raoul Hodges and Dr Geoff Longshaw, during Elijha's farewell function at SAC.

31. Aspirant fire-fighter. Betsie Snyman blasts away at a would-be fire during a fire fighting practice session at SAC.

32. Foreign shores. Raoul Hodges (left) and Michelle le Saux (right) comparing notes after a business meeting in the USA in 1998.

33. Thank you. Joe Schiller (left) hands Marie Ootshuizen a gift of appreciation for dedicated service at her farewell function.

34. Happy times. Doing what friends do best, (ltr) Yves Moizant, Iris Himmel and Adeline Botha catching up during a SAC event.

35. Training for all. SAC training manager, Tim Boyle (left) with Renier Balt (middle) and a GDTA representative (right), signing a training agreement with the GDTA for a series of courses at SAC and in France.

36. Antenna commissioned. Former Boeing representative, Bill Brooks (left), with Raoul Hodges (middle) and Daniel van Niekerk (right), at the CSIR after the successful commissioning of the Ku-band antenna.

37. When a plan comes together. Members of the SAC team at the base of the then newly commissioned X-band antenna, which strengthened SAC's Earth Observation capabilities.

Pages 156 and 157

38. Relaxing. Nthabiseng Mojaki (left) and Chantelle Schoeman (right) enjoy the warm weather during a SAC event.

39. Another SAC braai. Time with colleagues as (ltr) Bennet Thlale†, Steven Tshefu, Sam Montwedi† and William Matjebe† enjoy some well-deserved time out.

40. Co-operation. CSIR President, Dr Geoff Garrett (left), hands a token of appreciation to Bill Brooks, formerly from Boeing, after the launch of the Ku-band antenna, with Edwin Ramsay (then Manager of Boeing SDC Mission Tracking Networks in the US) and Raoul Hodges looking on.

41. Competitive spirit. Captured here are images from one of the annual Mini-Olympics between DSIF and SRSC (SAC) during the NASA years, with the men's and ladies' teams in fiercely competitive spirit, giving their utmost to win the day. Seen here (top row ltr) in full sprint, Mike Ainsley, Hennie Roesch, Louis Boshoff and Hans Kurvert†, Frans Meintjies† and Norman Hodges† giving it their all, with the two ladies' teams battling it out and (bottom row ltr) Willem Botha, Tasso Karantonis, Bram Broere† and the Flying Manager in the home strait, and an after-work get-together between DSIF and SRSC staff at Hartebeesthoek.
Note: Kindly post the names of those in the collage we could not identify on the SAC Story wiki page at www.sansa.org.za/spaceoperations/thesacstory

Pages 158 and 159

42. Among friends. Relaxing after a day's work, (ltr) Ian Chisholm, Roy Osborne† ("Not missing anything, am I?") and Alan Watson enjoying a drink together.

43. Celebrating. Relaxed and smiling after the successful commissioning of the Ku-band antenna (ltr) Johan Ahlers, Victor Matoaane, William Matjebe† and Renier Balt.

44. Follow the money. A financial management meeting at SAC with (ltr) Nico Jansen, Philip, Johann Basson, Brenda Vermaak, Shane Miller, Raymond Vice† and Marysia.

45. Follow me? Amoure Patrick (left) listening intently to Darcel Winkler (right) during an event in the SAC lapa.

46. Shared wisdom. A SAC team meeting with overseas visitor, Norm Beer, (ltr) Frikkie Meyer, Norm, Tasso Karantonis, Raoul Hodges, Tiaan Strydom, Yunus Bhayat and Daniel van Niekerk.

47. Enjoying the sunshine. Renier Balt (left), Norm Beer (middle) and Tasso Karantonis (right), who accompanied Norm on some of his travels during his visit to South Africa.

48. Eye-catching. Betsie Snyman (left) and Willem Vorster (right) dressed the part for Casual Day in 2010.

49 & 50. Stork tea. Mothers-to-be (top ltr) Nthabiseng Mojaki, Gladys Magagula and Sarah Masiteng unwrap gifts for babies-to-be with (bottom ltr) Roxi Lategan, Natasha Nieckau and Natalie Diemer looking on approvingly.

51. Catching up. SAC colleagues (ltr) Dennis Madhavu, Dan Matsapelo, Kaizer Moroka (DST) and Joel Sekwakwa relaxing after a busy day.

Pages 160 and 161

52. "We all stand together". SAC stalwarts bid farewell to one of their own, Flo Coetzer† (middle), flanked here by friends and colleagues at her retirement farewell function, (front 'hand-holding' row ltr) Charles Chambers†, Jim Chaney, Flo†, Louis Boshofff and Tasso Karantonis and (back row ltr) Bruwer van Graan, Selwyn Clarke, Bram Broere† and Douglas Kalkwarf.

53. Soccer fever. Viva 2010 FIFA Soccer World Cup, viva! Fun and laughter at SAC with team members celebrating South Africa's hosting of the World Cup with a range of activities at Hartebeesthoek. (top row ltr) Tammy Wilde; Foster Mashele, Kedibone Mbuyisa, Farad Hassim, Nephiphidi Mutshutshu, Joseph Sebake and Frikkie Meyer; Farad Hassim and Pryaska Veramoothea; with (bottom row ltr) the entire SAC team pinning their colours to the mast (or rather, the lapa's roof); Betsie Snyman, Andre Breyntenbach and Izak Ramela.

Pages 162 and 163

54. Retiring again? In celebratory mood as Tasso Karantonis shared his 2005 retirement function with some of his colleagues and their partners. Seen here (standing left front to back) Raoul Hodges, Renier Balt, Willem Botha and Piet van der Westhuizen† and (sitting left front to back) Janet Blatch, Tasso and Noelene van Zyl and (sitting right front to back) Judy Karantonis, Adeline Botha and Adriaan van Zyl and (standing right back to front) Annette van der Westhuizen, Roy Blatch, René Hodges and Millene Balt.

55. Trees are forever. SAC staff planting young saplings to commemorate one of the many annual Arbor Days at Hartebeesthoek, (ltr) Dennis Madavhu, Nthabiseng Mojaki and Daphne Nsibande.

56. Youth outreach. Roxi Lategan and a scholar discussing the benefits of space science at SciFest.

57. Giving back to nature. Releasing fish into the Strydom Dam (standing ltr) Norton Mahada, Thapelo Ramela and Rudi Kamstra and emptying the plastic containers into the water (sitting ltr) George Baloyi, Alex Fortesque, André Breytenbach and Daniel Mthembu.

58. Sharing knowledge. Johnny Rizos and Tammy Wilde attended numerous youth outreach events to share SAC's activities with learners and talk to them about possible careers in space science and technology.

Pages 164 to 167: Commemorating 50 years (rather put a colon)

59. Flip Maimane (left), Carole Liddy (middle) and Japhta Padi (right).

60. Dr Hoffie Maree (left), CSIR Executive Vice-President and Johan le Roux (right).

61. Japhta Padi (left), Moses Dulang (middle) and Steven Tshefu (right).

62. Nelson Canha (left) and Angelos Stavrinos (right).

63. David Masiteng (left) and (ltr) Johannes Motshwane†, Daniel Sebake, Zagaria Molepolole, David Stombek and Flip Maimane.

64. Hans Brummert† (left) and Anne du Plessis (right).

65. Angelos Stavrinos (left) greets old colleague Alphuis Matsose (right) with obvious delight.

66. Joki Montswere (right) and Betsie Snyman (left).

67. Tasso Karantonis (left) with (ltr) Johannes Motshwane, Daniel Sebake and David Masiteng.

68. A fond welcome from Raoul Hodges (left) for Koos Matoang (right) with a smiling Simon Morake behind Koos and Monica Matsose in the foreground.

69. Gladys Magagulu (left) and (ltr) Pryaska Veramoothea, Hadley Remas, Casey Stephens and Paida Mangara, with Mike Ainsley standing in the background.

70 & 74. Messages and memories captured in SAC's message book from those who attended the 50th event.

71. Klaus Ludwig (left) and Anne du Plessis (right) with Monica Matsose in the foreground.

72. Joggie and Ronel Vermaak (left and middle) and Betsie Snyman (right).

73. Joe Schiller (left), Tiaan Strydom (middle) and Johan le Roux (right).

75. Sarah Masiteng (left) and Nale Madau (standing).

76. Flip Maimane (left) and Koos Matoang (right).

77. Joe Schiller (left), Tasso Karantonis (middle) and Frikkie Meyer (right).

78. Louis Boshoff (left), Hennie Roesch (middle) and Selwyn Clarke (right).

79. Willem en Adeline Botha.

80. Hennie Roesch (left) and Norman Hodges† (right).

Pages 168 to 171: Celebrating excellence

CSIR Mikomtek Awards early 1990s

81. All well-appointed. Excellence Award recipients (back row ltr) Piet Malan, Willem Botha, Ian Chisholm, Patrick Buso and Johan Hartman and (front row ltr) Dr Brian Armstrong, Nelson Canha, Raoul Hodges, Dr Namane Magau who handed out the awards as then CSIR Executive Vice-President: Human Resources, and Tasso Karantonis.

SAC Awards 2006

82 to 87. (ltr), Phil Hendricks (middle) handing awards to Bright Malatji and Cornelius Mokgadi; Dr Corné Eloff; Isak Ramela, Johann Treurnich, Bruno Meyer and Willem Vorster; Johnny Rizos; and Pieter van der Merwe.

SAC Awards 2010

88 to 90. Top row (ltr), Raoul Hodges handing awards to Carole Liddy and Eugene Avenant and Johan le Roux handing an award to Willem Vorster.

91 to 93. Johan le Roux with Mutshutshu Nephiphidi and Gladys Magagula, having received their awards and a smiling Betsie Snyman and Bruno Meyer after receiving their long-service awards for 21 and 27 years respectively.

94 to 98. Top row (ltr), Johnny Rizos, Fikile Mazibuko and André Breytenbach; Kowie Viljoen, Johan le Roux and Rudi Kamstra with LEOP team awards for excellence (other LEOP team members included Frikkie Meyer, Yunus Bhayat, Pieter van der Merwe, Norton Mohado and Carlos de Oliveira); and Alan Caithness† receiving an award from Raoul Hodges. Bottom row (ltr) Kobus and Elsa de Beer, Johan le Roux and Betsie Snyman; and Daphne Nsibande with her award for service excellence.

End notes references

Introduction – An enduring legacy (pp 12 – 19)

1. The so-called 'space age' started with the launch of Sputnik-1 in 1957 and reached a peak with the Apollo programme between 1968 and the early 1970s.

2. The 'cold war' began in 1945, directly after WWII, and ended with the fall of the Soviet Union in 1991.

3. The 'space race' was a mid-to-late 20th century competition between the USSR and USA for supremacy in attaining firsts in space exploration, regarded as necessary for national security and symbolic of technological and ideological superiority. It ended with the co-operative Apollo-Soyuz human spaceflight mission in 1975.

4. NASA was established on 1 October 1958 by the US National Aeronautics and Space Act of 1958.

5. Dr Frank Hewitt† (1919-2007) joined the CSIR Executive in the mid-late 1960s.

6. The CSIR's Telecommunications Research Laboratory (TRL) was renamed the CSIR National Institute for Telecommunications Research (NITR) in 1957.

7. The term 'Minitrack' referred to a Minimum Weight Tracking system, which was a battery-driven transmitter aboard a satellite. The term was also used to denote the NASA tracking stations established around the globe to track Earth-orbiting satellites during the late 1950s and early 1960s.

8. The US Army transferred the Jet Propulsion Laboratory (JPL) to NASA after its establishment in 1958.

9. While the Minitrack Station at Hartebeesthoek was the precursor to SAC, which is the focus of the SAC story, reference to the Deep Space Station is included to give a CSIR perspective and for historical completeness.

10. NASA's Deep Space Network (DSN) was established to support space missions that explore the solar system, the universe and some Earth-orbiting missions. In the 1960s and early 70s, the network consisted of stations at Goldstone in the US, Woomera in Australia and Hartebeesthoek in South Africa. Each station was equipped with a 26 m antenna positioned approx 120 degrees apart, for the constant observation of spacecraft as the Earth rotates. This made the network the largest and most sensitive scientific telecommunications system in the world. The Deep Space Station at Hartebeesthoek played an important role in the network for more than 13 years. It was replaced by a station in Spain in 1975.

11. The Goddard Space Flight Centre (GSFC), named after American rocketry pioneer Dr Robert H Goddard, was established in 1959 as NASA's first space flight complex.

12. At the time, satellites such as NASA's Interplanetary Monitoring Platforms (IMPs) were launched into increasingly eccentric orbits, with perigees (point in satellite orbit nearest to the centre of the Earth) and apogees (point in orbit most distant from the centre of the Earth) of between 100 km and 100 000 km or more above the Earth's surface.

13. Satellites in a geosynchronous orbit have the same orbital period as the Earth's rotation period and, therefore, when viewed from a particular location or ground station on Earth, are permanently in the same area of the sky and within view of a given ground station. The dishes of ground-based antennas do not have to move around to track them, but can remain fixed in one direction.

14. The US Coast and Geodetic Survey (now the National Geodetic Survey), is a US federal agency that defines and manages a national co-ordinated system that provides the foundation for transportation and communication; mapping and charting; and a large number of scientific and engineering applications.

15. Continental drift is the lateral movement of continents resulting from the motion of the Earth's crustal plates.

16. A tracking, telemetry and control (TT&C) system monitors the vital operating parameters of a satellite.

Snapshots in time (pp 26 – 33)

1. South Africa's strategic downrange position on the African continent relative to the US launch facilities at Cape Canaveral, positions it as an ideal partner to provide early confirmation of the launch and successful orbit of satellites.

2. STADAN: Satellite Tracking and Data Acquisition Network.

3. Several animals, including 32 monkeys, flew in the space research programme between 1948 and 1996 for scientists to investigate the biological effects of space travel.

4. OSO-7: the largest and most advanced spacecraft in NASA's Orbiting Solar Observatory (OSO) satellite series, launched in 1971 to study the solar corona.

5. Nimbus: meteorological research satellites designed to test atmospheric remote sensing systems.

6. NOAA: National Oceanic and Atmospheric Administration, an international leader in scientific and environmental matters. NOAA satellites monitor changes to our environment.

7. AVHRR: Advanced Very High Resolution Radiometer.

8. SAR: Synthetic Aperture Radar.

9. EGNOS: Global Satellite Navigation System.

10. LEOP: Launch and Early Orbit Phase support.

11. CEOS: Committee on Earth Observation Satellites.

12. Galileo: European global navigation satellite system for a civilian controlled, accurate, guaranteed global positioning service.

13. THEMIS: Time History of Events and Macro-scale Interactions during Sub-storms – constellation of five NASA satellites launched in 2007.

14. SAEOS: South African Earth Observation Strategy (2006 - 2009), funded by the Department of Science and Technology.

The Antenna Farm (pp 34 – 38)

1. Radome: a dome-shaped, weatherproof structure that protects a radar antenna and consists of a casing made from material that is transparent to radar and radio waves.

2. Planar array: an antenna with all the elements on one plane to create a large aperture (a circular opening that limits the quantity of light that enters an optical instrument) that controls a directional beam by varying the relative phase of each element of the antenna.

3. TOSS: Transfer Orbit Support Services.

4. IOT: In-Orbit Transfer.

5. Azimuth: The 'look' angle of a horizontally positioned antenna dish expressed as degrees from 0° to 360° (North = 0° with the antenna moving in a clockwise direction).

6. Elevation: the angle by which the antenna dish must be tilted up or down in relation to the theoretical horizon at 0° and 90° at zenith.

1945 – 1959: The cornerstones (pp 39 – 43)

1. South African soldier, statesman, philosopher and founder member of the Union of South Africa, Jan Christian Smuts (1870-1950), was the only person to have signed both peace treaties to end the 1st and 2nd World Wars.

2. Radio physics refers to radio wave communications and detection.

3. The ionosphere is the region 70-140 km above the Earth, where ionisation from solar radiation affects the transmission of radio waves.

4. The Tellurometer was designed primarily for geodetic surveying and measuring distance using microwaves, not light waves.

5. The International Geophysical Year (IGY) took place from 1 July 1957 to 31 December 1958 as a global scientific initiative that brought together 8 000 scientists in 67 countries to participate in projects across 11 Earth sciences: aurora and airglow, cosmic rays, geomagnetism, gravity, ionospheric physics, longitude and latitude determinations (precision mapping), meteorology, oceanography, seismology and solar activity.

6. Radio interferometry yielded accurate tracking angles from a target that emitted a radio signal. A radio interferometer consisted of two or more radio telescopes (antennas) separated by known distances, to pinpoint a signal in the radio range transmitted by a beacon on a satellite.

7. The name "Minitrack" came from the NRL's John Mengeland and referred to a "Minimum Weight Tracking System" that used radio interferometers and Yagi antennas to obtain orbital data from satellites whose orbits did not incline more than 45 degrees.

8. The initial nine stations in the Minitrack network increased to twelve in 1959, located at Antigua, Antofagasta, Blossom Point, Fort Stewart, Grand Turk, Havana, Johannesburg, Lima, Quito, San Diego, Santiago and Woomera.

9. South Africa's participation in the IGY included activities in meteorology, geomagnetism, aurora, ionosphere, solar activity, cosmic rays, longitudes and latitudes, oceanography, satellite observation, seismology, gravity and nuclear radiation.

10. "... major support for [its] satellite tracking programme". CSIR Annual Report, 1956-57, p6.

11. The word "Sputnik" means a 'travelling companion of the world'.

12. "... without specific advanced warning". CSIR Annual Report, 1957-58, p134.

13. The TRL engineers improvised a technique to measure the Doppler shift on the signal as it passed overhead to create a "relatively accurate radio tracking system". CSIR Annual Report, 1957-58, p135.

14. Jules Fejer predicted the lifetime of the satellite correctly as 57 days.

15. The Cape Canaveral Space Launch Centre in Brevard County, Florida in the US was renamed the Kennedy Space Centre in 1963 to commemorate President John Kennedy's contribution to space exploration.

16. The discovery of the Van Allen radiation belt by the Explorer satellites was considered to be one of the outstanding discoveries of the IGY.

17. Interview with Neil deGrasse Tyson, Director of the Hayden Planetarium, 2012 - blog posted by citybrights_ tmiller@sfgate.com (Todd Miller).

1960 – 1975: The NASA years (pp 44 – 59)

1. In the early 1960s, before NASA's Goddard Space Flight Centre (GSFC) took over the operation of the Minitrack Stations from the US Naval Research Laboratory, each station was referred to individually as a Space Tracking and Data Acquisition Facility (STADAF), such as the Santiago STADAF, Winkfield STADAF, Joburg STADAF and others. Under the GSFC they became part of NASA's Space Tracking and Data Acquisition Network (STADAN) and were renamed to distinguish them from the Manned Spaceflight Network (MSN). Hartebeesthoek became known as Joburg STADAN.

2. NASA established a global Deep Space Network (DSN) of three Deep Space instrumentation Facilities (DSIFs), also referred to as Deep Space Stations, in the US (Goldstone, California), Australia (Woomera) and South Africa (Johannesburg). Each had a 26 m diameter dish antenna with 960 MHz (L-band) 'receive and transmit' capabilities to process and record telemetry data at low data rates from US space probes. Telephone and teletype circuits, via undersea cable, land line or (for Johannesburg) a high-frequency radio link, linked the sites to a control and co-ordination centre at the Jet Propulsion Laboratory in the US.

3. The 1960s were in many ways the golden age of space exploration, with the first manned space missions, the American Mercury and Gemini programmes and the first Moon landing in 1969.

4. "... increased South Africa's international relations in science". CSIR Annual Report, 1959-60, p59.

5. CSIR Annual Report, 1959-60, p13 refers to the two stations at Hartebeesthoek as a 'combined station' managed by the National Institute of Telecommunications Research (NITR). Located in close proximity at the same site, the stations were, however, independent of each other and operated completely separately.

6. The Voortrekkers ("those who pull ahead") were pioneers who left the Cape Colony during the 1830s to 1840s and moved into the interior of what is now South Africa.

7. "... prominent men in science, industry and engineering in South Africa". CSIR NITR Annual Report, 1961-62, p18-19.

8. Telemetry is an automated process that collects data about a satellite's operations (temperature, batteries) or mission (scientific data) and transmits it to receiving equipment for monitoring, display and recording. Telemetry is also referred to as the 'housekeeping functions' that monitor the state of highly complex electrical equipment aboard a satellite.

9. The capabilities of the first satellites improved as technologies developed. The 'second generation' satellites could support bigger payloads and operate at higher frequencies. Ground facilities had to be upgraded to extend tracking to telemetry and control (TT&C) operations. The initial emphasis on tracking to determine a satellite's position shifted to recording data from sophisticated scientific instrumentation aboard the satellite and, when necessary, analysing the data to command the satellite.

10. The octagon-shaped Explorer XII (S-3) spacecraft was instrumented to study fields and energetic particles in space, including repeated observations of solar wind, interplanetary magnetic fields, distant regions of the Earth's magnetic field, the particle population of interplanetary space and the trapped radiation regions. This "windmill" satellite carried six experiments and it took several days to confirm its orbit.

11. "... the way for the first commercial space communications systems". CSIR NITR Annual Report, 1961-62, p22.

12. The Range and Range Rate system consisted of a ranging system, accurate to 15 m, and a system that determined the rate at which the range changed. The system, used with an interferometer system, could determine the orbit of a satellite in a single pass.

13. The three early Syncom (synchronous communications) satellites were experimental spacecraft built by Hughes Aircraft Company, to investigate communications systems based on satellites with an orbital period of 24 hours, which remain effectively stationary in relation to the surface of the Earth. The satellites were capable of relaying a single two-way telephone conversation.

14. Geosynchronous satellites travel in an orbit of 35 900 km above the Earth's equator with a 24-hour rotation that matches the Earth's rotation. When viewed from a particular location on Earth, the satellites seem to remain in the same area of the sky and therefore permanently within view of ground-based antennas that do not need to track them, but can remain fixed in one direction. Such satellites are often used for communications.

15. "... the Minitrack team was on standby". CSIR NITR Annual Report, 1962-63, p20.

16. The apogee is the point in the orbit of a satellite that is most distant from the centre of the Earth. The perigee is the point nearest to the centre of the Earth.

17. Communications and weather satellites were often placed in geostationary orbits, so that their signals can be received continuously by ground-based facilities situated anywhere in an entire hemisphere.

18. Telstar-1 was launched on 10 July 1962 and successfully relayed through space the first television pictures, telephone calls, fax images and live transatlantic television feed. Telstar-1 and -2, although no longer functional, were still in orbit in October 2013.

19. "... the advanced state of satellite technology". CSIR NITR Annual Report, 1962-63, p21.

20. "The reported results were gratifying." CSIR NITR Annual Report, 1963-64, p13.

21. The Interplanetary Monitoring Probe (IMP) was a proposal by the Goddard Space Flight Centre for a network of satellites launched in highly elliptical orbits, to provide continuous monitoring of space radiation in support of the Apollo programme.

22. An orbiting observatory was similar to a laboratory in space. It consisted of a series of satellites used for observation, either of distant planets, galaxies and other outer space objects or, when pointed toward Earth, for information gathering. The satellites were heavy, complex, accurately stabilised spacecraft that permitted more scientific payload and more sophisticated instrumentation. Observatories carried elaborate systems for maintaining a desired orientation in space, so that scientific instruments could be pointed in a chosen direction for optimum efficiency.

23. Orbiting Astronomical Observatory (OAO): a series of four satellites launched by NASA between 1966 and 1972 that increased awareness about the benefits of orbiting telescopes and set the stage for the development of the Hubble Space Telescope (HST) and other orbiting observatories.

24. Orbiting Geophysical Observatory (OGO): a large satellite observatory designed to take atmospheric measurements mainly over the Earth's polar areas.

25. Orbiting Solar Observatory (OSO): the first observatory-class satellite in a series of eight, built by NASA and launched in 1962 to study the Sun by measuring the solar electromagnetic radiation of the Sun's ultraviolet, X-ray and gamma-ray regions.

26. TT&C (tracking, telemetry and command) is the communication with and control of a satellite from the ground via a data channel, either with a single satellite or via one satellite to another.

27. 'Quicklook' refers to spacecraft parameters decoded from the satellite's telemetry data by the tracking station and transmitted via telex to the Control Centre post-pass. The parameters were specified by the Control Centre and were usually critical to the wellbeing of the satellite. With the advent of reliable data lines, telemetry data were sent to the Control Centre in real-time and Quicklooks became obsolete.

28. Early Bird: the first commercial communications satellite and the first to provide direct and quasi-instantaneous communication between the North American and European continents, including transmission of television, telephone and telefax signals.

29. GEOS-1 (Geodetic Earth Orbiting Satellite): a gravity-gradient-stabilised, solar-powered unit designed exclusively for geodetic studies. It was the first successful active spacecraft of the US National Geodetic Satellite Programme.

30. The passive balloon satellites did not transmit signals back to Earth.

31. ATS-5: an American communications technology satellite.

32. The Bios-D satellite was flown to conduct intensive experiments to evaluate the effects of weightlessness with a pigtail monkey on board. The spacecraft de-orbited after nine days because the monkey's metabolic condition deteriorated. The monkey expired eight hours after the spacecraft recovery from a heart attack brought on by dehydration.

33. The Apollo-15 lunar module, the fourth crewed vehicle to land on the Moon, carried an Apollo Lunar Surface Experiments Package (ALSEP) with scientific experiments that were deployed and left on the lunar surface. All Apollo missions left ALSEPs on the moon.

34. The Radio Astronomy Explorer B (RAE-B or Explorer 49) mission was the second of a pair of RAE satellites that provided radio astronomical measurements of the planets, the sun and the galaxy over the frequency range of 25 kHz to 13.1 MHz.

35. The Nimbus satellites were meteorological research satellites designed to test atmospheric remote sensing systems.

36. NASA's Viking Project was the first US mission to land a spacecraft safely on the surface of Mars and return images of the surface. Two identical spacecraft, each with a lander and orbiter, entered the Mars orbit. The landers descended to the planet's surface, took photographs, collected science data and conducted experiments to look for possible signs of life.

37. "For the final time, the station…", Ike Marais, personal communication, 2011.

38. "Most first-time visitors…", Ike Marais, personal communication, 2011.

1976 – 1995: A new beginning (pp 60 – 85)

1. Landsat-1 orbited the Earth every 103 minutes at a height of 917 km and recorded the entire surface of the Earth in 185 km wide-image sweeps, obtaining information about agricultural and forestry resources, geology and mineral resources, hydrology and water resources, geography, cartography, environmental pollution, oceanography and marine resources, and meteorological phenomena.

2. A satellite in polar orbit passes above both poles of the Earth on each revolution with an inclination of close to 90 degrees to the Equator and passes over the Equator at a different longitude on each orbit. Polar orbits are used for Earth-mapping, Earth observation, capturing the Earth as time passes from one point, reconnaissance and for some weather satellites. CSIR Annual Report, 1976, p21.

3. "… get the station back into action". Interview with Willem Botha (SAC Manager, 1961-1994).

4. Meteosat-1 was placed in a geostationary Earth orbit and provided a permanent field of view over most of Europe, the whole of Africa, the Middle East and the eastern half of South America - in total over 100 countries. The cloud cover images, received in the infrared and visible parts of the spectrum, were transmitted every half hour.

5. The LSPS was supplemented with a Digital Interactive Image Analysis System in 1978 for the precise geometric correction of images, scene-to-scene registration and classification of multi-spectral data, image enhancements and transformation functions. This enabled the SRSC to supply customers with information and solutions, as well as data.

6. A multispectral image captures data at specific frequencies across the electromagnetic spectrum by separating wavelengths with filters or sensitive instruments, including infrared. Originally developed for space-based imaging, spectral imaging extracts information invisible to the human eye with its receptors for red, green and blue only.

7. Interview with Ike Marais (joined the Joburg STADAN in 1965 and retired from SAC in 2000).

8. The double rows of vortices southwest off the Canary Islands in an archipelago off the western coast of Africa are called the Kármán Vortex Streets and are caused by the unsteady separation of water over bluff bodies, in this case the Canary Islands.

9. The Landsat satellites orbited the Earth every 103 minutes at a height of 917 km and recorded the surface of the Earth in 185 km^2 wide-image sweeps within 18 days.

10. The SRSC played an important role in the network as the only tracking station in contact with the spacecraft after its launch from Kourou in French Guiana during that critical period when the spacecraft separated from the final stage of the rocket launcher.

11. Images sourced from the Environmental Systems Research Institute (Esri) at http://www.esri.com/news/arcuser/0612/heres-looking-at-you.html.

12. Telecom-1A was the first French geostationary telecommunications satellite and was launched by an Ariane-1 booster on 4 August 1984. Operated by France Télécom under government sponsorship, it serviced both civilian and military users. The satellite was decommissioned in April 1992.

13. The US Solar Mesosphere Explorer (SME) was an unmanned spacecraft that investigated the processes that create and destroy ozone in Earth's upper atmosphere. The mesosphere is a layer of the atmosphere extending from the top of the stratosphere to an altitude of about 80 km. The spacecraft carried five instruments to measure ozone, water vapor and incoming solar radiation.

14. Ariane-1 was the first rocket in the Ariane launcher family developed by the European Space Agency (ESA) and designed primarily to put two telecommunications satellites at a time into orbit to reduce costs.

15. "It was a proud moment…", Ike Marais, personal communication, 2011.

16. The US National Oceanic and Atmospheric Administration (NOAA) is a scientific agency researching the oceans and atmosphere to warn of dangerous weather, and protect ocean and coastal resources with data from the NOAA series of polar orbiting meteorological satellites.

17. The Russian Meteor spacecraft are weather observation satellites developed during the 1960s to monitor atmospheric and sea-surface temperatures, humidity, radiation, sea ice conditions, snow-cover and clouds.

18. Landsat-4 was fitted with a high-resolution Thematic Mapper with a resolution of 30 m, compared to the 80 m of the multispectral scanner, which increased the quality of images significantly.

19. "Wind of change" speech by British Prime Minister to South African Parliament. In: Basson, N. 1996. Passage to Progress: The CSIR's Journey of Change 1945-1995.

20. The tracking station at Hartebeesthoek was named and renamed three times: Radio Space Research Station (RSRS) in 1961 (then also referred to as Joburg STADAN by NASA) and renamed twice as the Satellite Remote Sensing Centre (SRSC) in 1976 and the CSIR Satellite Applications Centre (SAC) in 1988.

21. The CSIR's restructuring transformed the organisation and its business entities from a semi-civil service type of environment into a market-orientated, output-driven contract research organisation with a focus on technology transfer and commercialisation.

22. "... product, price, quality and speed of delivery." SAC News, No 2, May 1991, p3.

23. "... better spectral coverage and ground resolution." CSIR Annual Report 1989, p3.

24. "All SAC staff, past and present ..."Ike Marais, personal communication, 2011.

25. "Deployer" defined as placing an object in a position ready for use.

26. The failed Landsat-6 satellite carried an Enhanced Thematic Mapper (ETM) that had a high-resolution panchromatic spectral band with a pixel size of 15 m, in addition to the normal thematic mapper spectral bands, with 30 m pixels for the bands 1 – 5 and 7 m and 120 m pixels for the infrared band 6.

27. "In addition to the loss of a satellite ...', SAC News, October 1993.

28. The Deep Space Programme Science Experiment (DSPSE), the first of a series of Clementine technology demonstrations jointly sponsored by the Ballistic Missile Defence Organisation and NASA, represented a new class of small, low-cost and highly capable spacecraft that used emerging lightweight technologies for a series of long duration, deep space missions.

29. "The performance impressed the American visitors ...", SAC News, No 7, September 1994, p5.

30. The Global Positioning System (GPS) is a space-based satellite navigation system that provides location and time information in all weather conditions, anywhere on or near the Earth where there is an unobstructed line of sight to four or more GPS satellites. The system provides critical capabilities to military, civil and commercial users around the world, is maintained by the US government and is freely accessible to anyone with a GPS receiver.

31. "At SAC the mission was carried out to the full satisfaction of CNES...", SAC News No 7, September 1994, p5.

32. "We at the Satellite Application Centre ..." SAC News, No 6, April 1994, p2.

33. METNET used Meteosat data and delivered one Meteosat mask image every half-hour, while LBR used ERS-1 data to deliver wind speed and wave height information.

34. "ERS SAR provides a new look at the Earth ...", SAC News No 9, October 1995, p1.

35. "The Award citations ...", ChipChat, CSIR Mikomtek Newsletter No 49, 1995, p11-14.

1996 – 2010: Unprecedented growth (pp 86 – 127)

1. "We will focus on market segments ...", Renier Balt, SAC Manager, 1995-2003 in: CSIR Mikomtek ChipChat Newsletter, No 49, 1995, p7.

2. McDonnell Douglas was a major American aerospace manufacturer and defence contractor before its amalgamation with Boeing.

3. The Iridium satellite constellation is a group of 66 satellites that provide voice and data coverage to satellite phones, pagers and integrated transceivers over the Earth's entire surface. Images are used in tracking climate change, crop disease, deforestation, wildfires and providing swift images of disaster zones to target emergency aid.

4. "CSIR SAC won the contract ...", Renier Balt, SAC Manager, 1995-2003 in: SAC News, 1996, p3.

5. Hughes Space and Communications built the world's first geosynchronous communications satellite, Syncom, in 1963 and the first geosynchronous weather satellite, ATS-1, in 1966. The Joburg STADAN was involved in the launch operations of both the satellites.

6. Transfer Orbit Support (TOS): consists of the telemetry, tracking and command of geosynchronous satellites at separation from the launch vehicle when the apogee motor is fired to circularise the orbit at geosynchronous altitude. It takes between one to four weeks before the satellite is finally turned over to its owners and TOS ceases.

7. Launch and Early Orbit Phase (LEOP): one of the most critical phases of a mission. Operations engineers take control of the satellite after it separates from the launch vehicle until the satellite is positioned in its final orbit and work 24/7 to activate, monitor and control the subsystems of the satellite, i.e. deploying satellite appendages (antennas, solar array, reflector) and undertaking critical orbit and attitude control manoeuvres.

8. Built by Hughes, Bonum-1 was designed to operate for 11 years and deliver direct-to-home television programming of up to 50 channels for the Russian TV network.

9. "That was one of the lowest points in my career ...', Tasso Karantonis, SAC Project Leader, Tracking, Telemetry and Command (TT&C), personal communication, 2011.

10. Earth Remote Observation System A (EROS-A): part of the EROS family of Israeli commercial Earth observation satellites. The satellite always crosses the equator at 9:45 am local time, which allows it to compensate for poor visibility due to clouds at different altitudes.

11. The MGS arrived at Mars in September 1997 where it surveyed and charted the entire Martian landscape in four months. The data gathered were used to plan future Mars missions.

12. OrbView-2: an imaging satellite, developed, owned and operated by US-based Orbital Imaging Corporation (ORBIMAGE). The OrbView-2/SeaWiFS mission provides quantitative global ocean bio-optical data to the Earth science community.

13. SeaWiFS (Sea-viewing Wide Field-of-View Sensor) has spatial resolution of 1.1 km for Local Area Coverage (LAC) and 4.5 km for Global Area Coverage (GAC), with 2 800 and 1 500 km swath widths respectively and an orbital repeat cycle of 16 days. A swath is the area of the Earth imaged during a satellite orbit and can range in width from ten to hundreds of kilometres.

14. On 23 September 1999, communication with the Mars Climate Orbiter was lost as the spacecraft went into orbital insertion because engineers failed to make a simple conversion from English units to metric, an embarrassing lapse that sent the $125 million craft fatally close to the Martian surface where it disintegrated.

15. ArabSat-3A, an Arab League satellite, was launched to provide direct TV broadcasting, telephony, fax and data transmission services to southern Europe and the traditional Arabsat coverage zone, while Skynet-4E belongs to the British Ministry of Defence and was launched to provide strategic and tactical communications to the British armed forces.

16. "The supply of universal communications services ...", Andrew Roberts in: SAC News, No 17, May 1999, p5.

17. RADARSAT: the world's first operationally-orientated radar satellite equipped with advanced SAR; its unique capabilities generated new applications around the world.

18. "Our market intelligence clearly indicates ...", Piet van der Westhuizen†, SAC Business Development Manager in: SAC News, July 1997, p4-5.

19. Radome or radar dome: a dome-shaped, weatherproof structure that protects an antenna with a casing made from a material that is transparent to radar and radio waves.

20. SPOT-4: a remote sensing satellite in the SPOT constellation with short-wave infrared band that provided low resolution, high quality imagery.

21. Precision farming adjusts farm practice to match variations of soils and terrain in relatively small areas rather than treating a field as a homogenous unit. It became possible through the use of PCs, satellite positioning systems, remote sensing data, telecommunications and GIS.

22. "SPOT satellite imagery is proving to be an ideal, ...", Dr Koos Bornman, then General Manager: Marketing at Kynoch in: SAC News, No 17, May 1999, p8.

23. "Given sufficient interest, ...", Timothy Boyle, SAC Training Manager, in: SAC News, July 1997, p2.

24. UNESCO World Heritage Centre at http://whc.unesco.org/en/list/ [accessed 5 April 2014].

25. Brought into service at the start of 2001, the innovative Europe*Star-1 satellite has five high-performance beams covering Europe, southern Africa, the Middle East, the Indian subcontinent and south-east Asia.

26. Orion-3 was an American spacecraft intended for use by Loral Space & Communications as a communications satellite positioned in geostationary orbit at a longitude of 139° east to provide communications services to Asia and Oceania. Due to a malfunction during launch, it was instead delivered to a low-Earth orbit.

27. The Stentor (Satellite de Télécommunications pour Expérimenter les Nouvelles Technologies en Orbite): an experimental communications satellite developed by CNES and French Telecom and designed to carry out propagation and transmission experiments, but was lost during the failure of its Ariane-5 launch vehicle on 11 December 2002.

28. "Operating in the global business of satellite tracking, ...", Renier Balt, SAC Manager, 1995-2003 in: CSIR Satellite Application Centre Portfolio 2000, p1.

29. 'The Delta-IV is a 20-year programme ...", Renier Balt, SAC Manager, 1995-2003 in: 25° South, No 2, January 2002.

30. Ikonos-2 is a GeoEye imaging satellite that provides high-resolution imagery on a commercial basis, which opened a new era of 1 m spatial resolution imagery.

31. "In the aftermath of the flood, ...", Dr Ferdi Shceepers, in: SAC News, No 19, March/April 2000, p2.

32. AGRi-I helps farmers determine the extent and location of the different areas in fields to manage the site and save input costs. AGRi-I data showed crop development over time for year-on-year comparisons.

33. "The product will show stress on crops ...", Joe Schiller, Managing Director, Agrimage in: SAC News, No 21, March 2001, pp4-5.

34. "The initiative paves the way ...", Karen Wentzel, SAC Project Manager in: SAC News, No 21, March 2001, p6.

35. "The speed of the influx of people ...", Alex Fortescue, CSIR Project Manager in: SAC News, No 24, July 2002, p3.

36. MODIS is a whisk broom radiometer on board the Terra and Aqua Earth-orbiting satellites, which respectively pass from north to south across the equator in the morning and south to north in the afternoon, viewing the entire Earth's surface every other day. The data help predict global change accurately to help protect the environment.

37. "The AFIS design fulfils a variety of user needs, ...", Philip Frost, SAC researcher in: SAC News, 2001.

38. "The training initiative served to expand SAC's offerings ...", in: SAC News, 2002.

39. The CX-1 satellite, launched on board a Boeing Delta-II launcher from the Vandenberg Air Force base in April 2000, was designed and built by university students and contained the SPECK spectrophometer that measures light reflected off the Earth's atmosphere to determine ozone levels.

40. "The project ensured that, for the first time, ...", Conrad Sebego, CX-1 Project Manager at SAC, 2000.

41. "Not only does this provide additional revenue, ...", Roy Blatch in: 25° South, No 3, March 2003.

42. "The contract was secured ...", Tiaan Strydom, SAC International Business Development Manager in: SAC News, 2001.

43. NASA's Mars Exploration Rover Mission (MER) is a robotic space mission that uses two rovers, MER-A Spirit and MER-B Opportunity, to explore the Martian surface.

44. "We have always been very happy ...", Comment from Mike Kennard of Boeing Delta Flight Operation about SAC's launch support for the Mars Spirit Rover in 2003.

45. The nine-satellite Spaceway constellation provides high-bandwidth and high-speed communications for Internet, data, voice, video and multimedia applications. The Spaceway F-1 and F-2 satellites were launched in 2005 and the F-3 in 2007, all aboard an Ariane-5 launch vehicle.

46. Sea Launch was selected to launch PanAmSat's Galaxy-16 communication satellite from its launch site on the Equator. The 1300-series hybrid satellite covers the continental United States, Alaska, Hawaii, Mexico and Canada as the fourth spacecraft Sea Launch will orbit for PanAmSat Corporation.

47. "SAEOS is a flagship project for South Africa.", Dr Corné Eloff, former Head: EODC at SAC in: CSIR eNews, December 2007.

48. "It is an honour for the CSIR to chair CEOS.", Raoul Hodges, SAC Manager, 2006-2011 in: CSIR eNews, December 2007.

49. The five probes of the THEMIS (Time History of Events and Macroscale Interactions during Substorms) constellation are in different orbits that line up once every four days over a dedicated array of ground observations in Canada and the northern United States.

50. The COSMO-SkyMed satellite is one of four medium-sized satellites in the COSMO system that uses an X-band synthetic aperture radar instrument that operates in all visibility conditions.

51. The Spaceway-3 design included 68 Ka-band transponders and on board dynamic multi-beam switching to deliver bandwith on demand and direct site-to-site mesh networking for corporations, small businesses, government agencies and individuals in North America, Alaska, Hawaii and parts of Latin America.

52. With its suite of 20 Ku-band transponders, Horizons-2, with a planned 15-year mission, augments communications services by increasing data quality and bandwith.

53. The AMC-21 all Ku-band satellite provides coverage to all 50 US states, Gulf of Mexico, Central America and the Caribbean. In addition to enabling broadcasting services, it also supports maritime communications.

54. Superbird-7 was designed and built for Japanese operator Space Communications Corporation, within the scope of a contract with Mitsubishi Electric Corporation and AMC-21 for American operator SES AMERICOM, a company of the SES group.

55. "This is a great achievement ...", Tiaan Strydom, SAC International Business Development Manager in: CSIR eNews, August 2007.

56. GeoEye is a polar-orbiting satellite that revisits any point on Earth once every three days. It stands two stories high, weighs more than two tons and is designed to train its camera on multiple targets during a single orbital pass.

57. "Excellent quality data received ...", Laura Maginnis of Boeing in: CSIR eNews, October 2008.

58. HBK is the acronym for Hartebeesthoek, which is used internationally to identify South Africa's ground tracking station and its antennas.

59. Galileo is a European global navigation satellite system that provides a highly accurate, guaranteed global positioning service, which is inter-operable with GPS and GLONASS, the two other global satellite navigation systems. Galileo delivers real-time positioning accuracy down to the metre range, which is unprecedented for a publicly available system.

60. "Having this system will unlock ...", Eugene Avenant, SAC Manager: TT&C in: CSIR Science Scope, Vol 3, No 2, October 2008, p37.

61. The SAEOS strategy is South Africa's response to the Global Earth Observation System of Systems (GEOSS) to co-ordinate the collection, assimilation and dissemination of Earth observation data and establish an overarching national framework for Earth observation in South Africa.

62. "We are now in a position ...", Dr Sibusiso Sibisi, CSIR President and CEO, CSIR eNews, May 2009.

63. SumbandilaSat was launched on board a Soyuz-2 launch vehicle from the Baikonur Cosmodrome on 17 September 2009. The first part of the name, Sumbandila, is from the Venda language and means "lead the way" or pathfinder.

64. In 2002-2004 the founding members of the TIGER initiative, including ESA, UNESCO (IHP), CSA and CSIR (South Africa), started a consultation process in collaboration with African water authorities, technical centres and other stakeholders in the water and EO sectors in Africa to define the institutional, technical, economic and social needs of the water sector in Africa to develop the TIGER strategy.

65. Launched in 2007, the AMESD ran to mid-2013 with funding of 21 million euro from the European Commission through the European Development Fund. The programme was managed by the African Union Commission in Addis Ababa, Ethiopia.

66. CEOS is a global umbrella body for civilian space agencies from developed and developing countries with an emphasis on remote sensing. SAC joined CEOS in 1998 and was one of only three African countries to participate in CEOS activities.

67. "Well-managed stakeholder relationships ...", Raoul Hodges, SAC Manager, 2006-2011 in: CSIR eNews, 2009.

68. Eutrophication is a process whereby water bodies such as lakes, estuaries or slow-moving streams receive excess nutrients that stimulate growth such as algae and weeds.

69. Hot Bird is a group of satellites operated by Eutelsat, located at 13° east over the Equator (orbital position) with a transmitting footprint over Europe, North Africa and the Middle East to both free-to-air and encrypted digital radio television channels.

70. NSS-9 is a communications satellite owned by SES WORLD SKIES. It is an all C-band satellite with wide coverage over the Pacific Ocean Region and an expected useful lifetime until 2024. It is ideal for inter-continental video, voice and internet services and also provides vital communication services to a number of Pacific Island communities.

71. Kepler is a space observatory launched by NASA to discover Earth-like planets orbiting other stars. The spacecraft, named after the Renaissance astronomer Johannes Kepler, was launched on 7 March 2009.

72. The Indostar-2/ProtoStar-2: sold in an auction to SES after the ProtoStar venture succumbed to multiple frequency co-ordination issues. The satellite was renamed SES 7 in May 2010.

73. NSS-12 is a broadcasting satellite used for providing high-power direct-to-home and digital broadcasting services to telecommunication providers, broadcasters, corporations and governments in Europe, the Middle East, Asia and Australia.

74. The THOR-6 satellite was launched on 29 October 2009 to provide direct-to-home (DTH) and telecommunication services for the Nordic, Baltic and Middle East regions. THOR-6 started services in 2009 with an operational lifetime of 15 years.

75. Soil Moisture and Ocean Salinity (SMOS) satellite: collects radio signals emitted by water cells on the Earth's surface to provide maps of soil humidity and measure ocean salinity with its 69 linked antennas.

76. Intelsat-14 is a communications satellite owned by Intelsat and located at 45° west longitude, serving the Americas, Europe and African markets. It was built by Space Systems Loral.

77. Wide-field Infrared Survey Explorer (WISE) is a NASA infrared-wavelength astronomical space telescope launched in December 2009 and placed in hibernation in February 2011 when its transmitter turned off. It discovered the first Y Dwarf and Earth Trojan asteroid, tens of thousands of new asteroids and numerous previously undiscovered star clusters.

78. "In all, these missions were successfully supported …", Yunus Bhayat, SAC TT&C Operations Manager in: CSIR eNews, February 2009.

79. "Our exceptional growth since 1995 …", Raoul Hodges, SAC Manager, 2006-2011, interview 2012.

80. EchoStar XIV is a US geostationary communications satellite positioned in geostationary orbit at a longitude of 119° west and used to provide high-definition television direct broadcasting services.

81. "We believe that the local facility … ", Tiaan Strydom, SAC International Business Manager, interview 2012.

82. "We believe that the local facility …"' Dr Corné Eloff, SAC Earth Observation Manager, interview, 2010.

83. Quote from Winston Churchill, after the final battle of El Alamein, 1942.

84. LOS – Loss of signal.

85. AOS – Acquisition of signal.

86. After Johan le Roux in: SAC Profile, 2000.

87. "We decided to produce the FundisaDisc …", Dan Matsepola at SAC, personal communication 2012.

The people and the stories (pp 129 – 137)

1. More stories and photographs are available at www.sansa.org.za/spaceoperations/thesacstory. You can upload photos and stories to add to the archive and share them with others interested in The SAC Story.

2. The monkey was trained how to eat and drink water aboard the satellite for about six months before the launch.

3. Adjusting the satellite's sail to lock onto the Sun.

4. The French managed a satellite tracking station at Paardefontein in South Africa before CNES contracted the CSIR Satellite Remote Sensing Centre (SRSC) to provide them with launch support. Some of the French staff joined the SRSC at Hartebeesthoek when the Paardefontein station closed down.

5. The Image Analysis System (IAS) was installed with a bulk processing system at the SRSC in 1980. The IAS ingested Landsat data from Computer Compatible Tapes (CCTs) and extracted information to meet specific client needs.

6. "Clementine" was the first application of light weight technologies and sensors to a spacecraft on a NASA space mission that returned to the Moon 25 years after the landing of Apollo 11.

7. Remote sensing uses electromagnetic radiation from satellites to collect data from objects/phenomena on Earth (surface, atmosphere, ocean) and from dangerous and inaccessible areas without making contact. Applications include disaster monitoring, as well as deforestation in the Amazon Basin and depth sounding of oceans, among others.

8. The antenna enabled the Hartebeesthoek station to receive signals in the L-, S- and X-bands from the new generation satellites. L-band (1 650–1 750 MHz) for data from the NOAA and Meteosat satellites; S-band (2 200 – 2 300 MHz) for telemetry from Delta and Ariane launch vehicles; and X-band (8.0 - 8.4 GHz) to track and receive wide-band signals from the new generation SPOT, Landsat, ERS and Terra and Aqua Earth-monitoring satellites.

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This book contains information and images compiled from a number of print and electronic sources, in addition to that derived from personal interviews (mentioned under Acknowledgements on pp 8-9). The print and electronic sources for the contents and the images are listed here.

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Page 118 THEMIS probes inside the rocket fairing http://en.wikipedia.org/wiki/THEMIS#mediaviewer/File:Delta_II_7925-10C_fairing_ready_for_ installation_around_THEMIS.jpg Credit: THEMIS/Artemis via Wikipedia

Page 118 Delta-II launcher with THEMIS aboard http://themis.ssl.berkeley.edu/pictures.shtml Credit: THEMIS/Artemis

Page 119 Spot-5 satellite http://www.astrium-geo.com/en/928-illustrations-images-of-satellites Credit: CNES/Airbus Defence & Space.

Page 123 Ariane-5 with Hot Bird™-10 and NSS-9 http://www.esa.int/spaceinimages/Images/2009/02/Ariane_5_ECA_V187_lifts_off3 Credit: ESA/CNES/Arianespace/Service Optique Video du CSG.

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Page 125 Kruger National Park before and after burn plots http://www.csir.co.za/enews/2011_mar/15.html Credit: CSIR.

Page 126 Terra satellite MISR image of False Bay, Cape Town http://earthobservatory.nasa.gov/blogs/earthmatters/2011/08/ Credit: Earth Observatory online.

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