NEW FRONTIERS OF SPACE GEODESY FOR AFRICA

HI-TECH AT HartRAO

NEW HI-TECH DEVELOPMENTS AT THE HARTEBEESTHOEK RADIO ASTRONOMY OBSERVATORY (HartRAO) GIVE SOUTH AFRICA A VITAL NEW GLOBAL ROLE. WE NOW JOIN SCIENTISTS AROUND THE WORLD IN MEASURING TO THE HIGHEST DEGREE OF ACCURACY THE ORBITS OF SATELLITES AND THE MOVEMENT OF CONTINENTS. THE HIGH-PRECISION DATA HAVE MANY APPLICATIONS, INCLUDING UNDERSTANDING CLIMATE CONDITIONS SUCH AS THE EL NIÑO EFFECT.

For the first time in Africa and in the southern hemisphere a single site will house the world's three most important techniques for determining the changing shape and the physical dimensions of our dynamic Earth: very long baseline interferometry (VLBI), global positioning system (GPS), and satellite laser ranging (SLR).

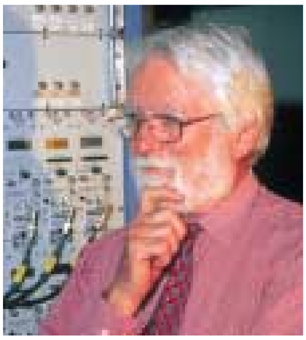
In the world of every day, the position of a state-of-the-art cell phone fitted with a GPS receiver, for example, can be pinpointed to the nearest ten metres or so. If you get lost, help can come fast "when you have HartRAO in your pocket"!

In 2000, the National Aeronautics and Space Administration (NASA) sent its SLR instrument, MOBLAS-6, for operation at HartRAO. Says the Director of the Observatory, Dr George Nicolson, "This installation makes us one of only half a dozen similar stations worldwide. Satellite laser ranging at HartRAO rids us of the 'African gap' in the coverage of SLR stations. We have repositioned ourselves in the field of space geodesy - regionally and globally as well."

GROWING HARTRAO'S SPACE GEODESY PROGRAMME

The term 'geodesy' combines the ancient Greek prefix, *geo* (meaning 'the Earth') with the verb *daiein* (meaning 'to divide'). 'Space geodesy' uses space techniques and related instruments - like radio astronomy and satellites - to take precise measurements of great distances. HartRAO's special space geodesy programme has developed over just two decades into a showpiece for Africa and beyond.

There is an international network of measuring stations situated in different parts of the globe. They take measurements from their unique positions on land and combine results to provide crucial information about dynamic phenomena on Earth - such as the rotation of our planet, and motion of the Earth's crust that causes volcanoes and earthquakes.



Nicolson

When different geodetic techniques act in concert, they provide checks, and they increase the accuracy of the measurements. Nicolson explains, "It's like three different people doing three independent surveys of a particular area, each using a different technique. We may not know if any one of them is correct - but if all three come up with the same answer, we have a lot more confidence in the results."

"THE CONTRIBUTION OF YOUR STATION IS PARTICULARLY IMPORTANT, BECAUSE IT IS THE FIRST IN THIS AREA (AND THEREFORE MUCH MORE IMPORTANT THAN HAVING ANOTHER STATION IN SAY WESTERN EUROPE)."

Dr Ron Noomen,
Delft Institute for Earth Orientated Space Research at Delft University of Technology, The Netherlands

The first measuring instrument in the programme was the Mark III recording terminal for VLBI, which became operational at HartRAO in January 1986. The 26-m radio telescope (at the site since 1961) was ideal for collaboration with 20 or so other VLBI stations - in Europe, North and South America, Australia, and elsewhere. Its location provides north–south as well as east–west baselines that can be used for measuring long distances on the Earth’s surface with great accuracy.

VLBI measurements monitor the motions of the tectonic plates that make up the Earth’s crust and hence the movement of the continents. HartRAO’s data show, for instance - with an error of less than 1 mm per annum - that Africa is drifting in a north-easterly direction at a rate of 25 mm a year.

Such precision is possible because the VLBI uses quasars as reference points. These are sources of radio emission at the edge of the known universe that behave with great stability because of their enormous distance; they can therefore tell us in an absolute sense about the orientation of the Earth in space.

On 5 September 1996 the first GPS station was installed at the site. It added a further method for taking measurements at the Observatory, using not quasars but 28 satellites orbiting the Earth as reference points for measurements from land-based stations all over the world. This technique helps us to monitor possible deformations in the Earth’s crust.

"THE CO-LOCATION OF MULTIPLE TECHNIQUES AT THE NEW SITE WILL USHER HARTRAO INTO THE ELITE GROUP OF FUNDAMENTAL GEODETIC AND GEOPHYSICAL OBSERVATORIES."

Dr Erricos C Pavlis,
Goddard Space Flight Center,
NASA

Four years later, HartRAO reached another milestone when it added to its space geodesy programme the third component - NASA’s SLR system - formally inaugurated on 20 November 2000 by Dr Ben Ngubane, South Africa’s Minister of Arts, Culture, Science and Technology.

"THERE ARE ONLY TWO OTHER TOP-QUALITY STATIONS SOUTH OF –17 DEGREES LATITUDE, BOTH IN AUSTRALIA. ADDING MOBLAS-6 TO THE SMALL NETWORK OF SOUTHERN HEMISPHERE STATIONS WILL IMPROVE THE TEMPORAL COVERAGE OF OBSERVATIONS."

Dr John Luck,
Australian Land Information Group

"THE NEW STATION AT HARTRAO WILL PROVIDE IMPORTANT TRACKING COVERAGE FOR ALTIMETER SATELLITES ... TO HELP IMPROVE THE ORBITS AS WELL AS PROVIDE THE VERIFICATION OF THE ORBIT ACCURACY (A TASK ONLY SLR CAN DO IN AN ABSOLUTE SENSE)."

Dr John C Ries,
Center for Space Research,
University of Texas at Austin

HOW THE SLR MOBLAS-6 CAME TO HARTRAO

1992-97	Discussions and test observations (involving HartRAO, NASA, and the German Institute for Applied Geodesy [IfAG]) set the scene for filling the void in satellite coverage over and around Africa, and highlight the benefits of the Hartebeesthoek location
1997	NASA proposes to the Department of Arts, Culture, Science and Technology (DACST) that South Africa fund the operation of MOBLAS-6 in the country
1997-98	DACST Review Panel on National Facilities recommends the SLR's location at HartRAO
1999	February: At a meeting of the US-South African Bi-National Commission, DACST agrees to NASA's request to fund the operation of MOBLAS-6 at HartRAO
	September: Memorandum of Understanding signed between NASA and the National Research Foundation (NRF), which manages the HartRAO National Facility
	November: Senior HartRAO staff train on the MOBLAS-6 for four months at the NASA Goddard Geophysical Observatory outside Washington, DC (USA)
2000	June-August: Arrival, installation and testing of MOBLAS-6, and the training of staff
	September: MOBLAS-6 starts regular observations
	20 November: Opening and Dedication of MOBLAS-6 by Dr Ben Ngubane, Minister of Arts, Culture, Science and Technology.

SOUTH AFRICA'S MOBLAS-6

SLR uses a global network of about 40 stations with laser beams that measure the distance of satellites fitted with special reflectors. South Africa's MOBLAS-6 is built into a 12-m mobile trailer.

Says Ludwig Combrinck, the Space Geodesy Programme Leader at HartRAO, "By measuring accurately the orbits of satellites with radar altimeters that determine height above the Earth's surface, for instance, SLR can help to measure variations of sea level. We can monitor the El Niño effect when ocean warming can raise sea level by up to 30 cm."

HOW DOES MOBLAS-6 WORK?

The SLR instrument shoots out a flight of very short-duration pulses of green light, which bounce off the satellite's reflectors, return to Earth and are then detected by its receiving telescope. "We measure the time when the pulses shoot out and the time they return; then we use the time difference plus the speed of light to calculate the exact distance of the satellite from the SLR - this gives us information about the precise orbit of the satellite and the position of the SLR," explains Combrinck.

"As a satellite moves, its orbit is not accurately known. There are variations due to the changes in the gravity field as the spacecraft passes over mountains or oceans, for instance - and we need to measure these small variations in the satellite orbit (of the order of 5 to 10 cm) very precisely. We can measure the movement of continents by VLBI and also, independently, by SLR: the combination gives us better readings."

BENEFITS FOR AFRICA

The SLR instrument at HartRAO in combination with GPS adds significant value to geodesy throughout the region and the whole of Africa. There are plans to expand the number of permanent GPS stations on the continent. One station is to be added at Simon's Town and three more outside South Africa (in Nigeria, Zambia, and Madagascar) to those already operating (at HartRAO, Sutherland, Windhoek, and Richards Bay). The new facility will offer great opportunities for meaningful scientific exchange within and outside Africa, and for developing expertise in the region.

Everyday use of GPS measures a global position to between about 1 and 100 m of accuracy - telephone companies use it to situate telephone lines, for instance, and electricity supply utilities for power-lines. Yachtsmen and hikers use GPS receivers to plot their changing positions; luxury motorcars carry them, and soon they will become the standard thing in cell phones.

Where greater levels of accuracy are needed - to the millimetre level - for monitoring the Earth's movements and for precise positioning, a stable and accurate reference point is essential.

"HartRAO's SLR now provides such a fixed point," explains Nicolson. "We monitor its stability continuously, then we transfer that position to our fixed GPS receiver, which in turn gives a stable reference point for other GPS users in southern and central Africa. A GPS receiver in Zambia, for example, will be able to link that country's survey network to a global network through access to the SLR at HartRAO; precise cross-border surveys in the SADC (Southern African Development Community) region will become possible." South Africa wants to collaborate with colleagues across Africa, to study the continent's stability and to see whether or not the continent really will start to split apart in geological ages to come, as some scientists are suggesting.

"THE DATA FROM MOBLAS-6 WILL GIVE INFORMATION ABOUT THE TECTONIC MOTION OF THE AFRICAN PLATE, AND THE SCIENTIFIC COMMUNITY WILL GET ALL THE BENEFITS OF A NEW STATION WITH CO-LOCATED VLBI, GPS, AND SLR TECHNIQUES."

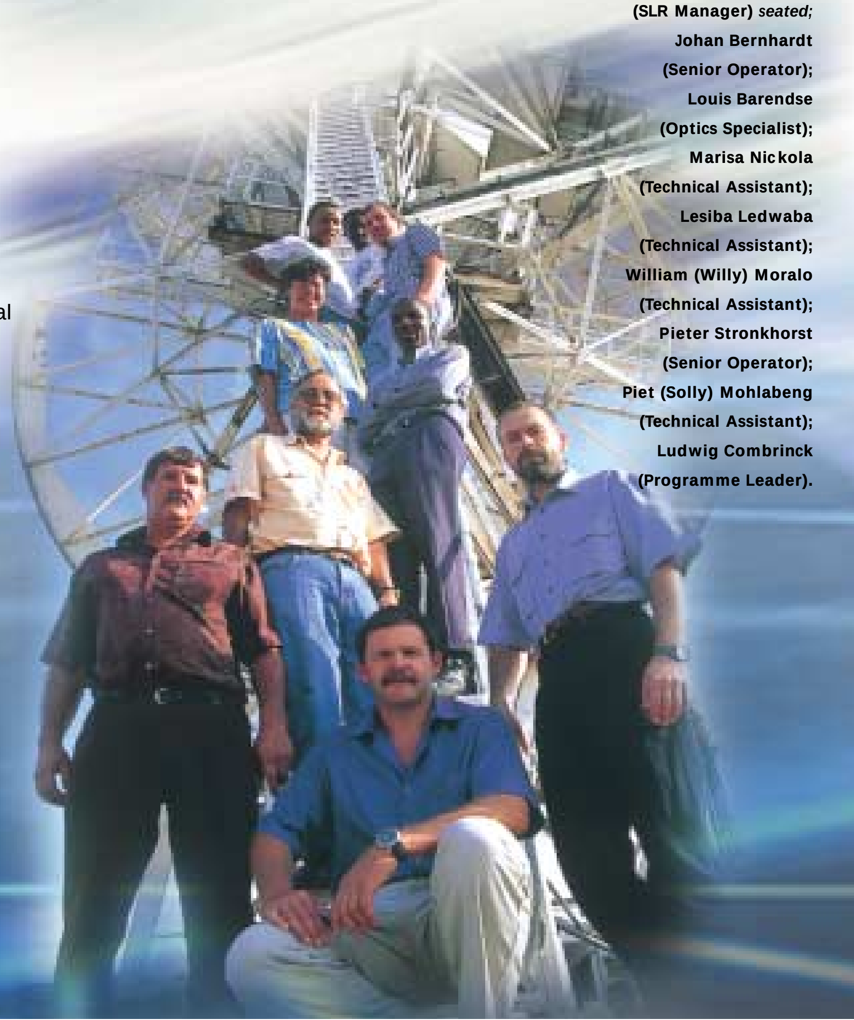
Dr Vincenza Luceri,
Centro di Geodesia Spaziale "G Colombo", Matera, Italy

THE PERFECT LOCATION

"It is wonderful to see South Africa return to the international community of SLR," says Dr John Bosworth of NASA's Goddard Space Flight Center. "A satellite laser ranging station was active from 1971-75 at Olifantsfontein in a co-operative agreement with the NASA-supported Smithsonian Astrophysical Observatory. The station's closure and the loss of its data were quite noticeable to the space geodesy community. This was because of its unique location [in a continent where measurements were sparse and scattered] and the quantity and quality of data that had been produced."

HartRAO has a proud track record for accurate and reliable data, and for the calibre of its scientists. The addition of the SLR in 2000 to the Observatory's facilities "immediately promotes the site to an elite scientific level," concludes Bosworth. "It is now considered by the international community as a full 'fundamental station', one of only a handful."

The world's six 'fundamental' stations (with VLBI and SLR and at least two other microwave measuring techniques on one site) are situated at Greenbelt (USA), Hartebeesthoek (South Africa), Kashima (Japan), Matera (Italy), Shanghai (China), and Wettzell (Germany).



THE SLR team:
clockwise from bottom
Wilhelm Haupt (SLR Manager) *seated;*
Johan Bernhardt (Senior Operator);
Louis Barendse (Optics Specialist);
Marisa Nickola (Technical Assistant);
Lesiba Ledwaba (Technical Assistant);
William (Willy) Moralo (Technical Assistant);
Pieter Stronkhorst (Senior Operator);
Piet (Solly) Mohlabeng (Technical Assistant);
Ludwig Combrinck (Programme Leader).

SOME TECHNICAL SPECIFICATIONS OF MOBLAS-6

Receiving telescope type	Cassegrain
Aperture	0.762 metre
Mount	AZ-EL
Transmitting telescope type	Refractor
Aperture	0.163 metre
Transmit efficiency	0.94
Receive efficiency	0.76
Laser type	ND:YAG
Primary wavelength	1 064 nanometres
Primary maximum energy	220 millijoules
Secondary wavelength	532 nanometres
Secondary maximum energy	100 millijoules
Pulse width (FWHM)	200 picoseconds
Laser repetition rate	5 hertz
Fullwidth beam divergence	30 seconds of arc
Final beam diameter	0.093 metre

"We applaud the vision of the South African science community in supporting the expansion of HartRAO so that it can also justifiably be called a 'Geophysical Observatory'."

Dr John M Bosworth,

Associate Chief: Laboratory for Terrestrial Physics and Head: Space Geodesy Networks and Sensor Calibration Office, Goddard Space Flight Center, NASA

"It has been a long road since we first visited South Africa to discuss the installation over six years ago. The HartRAO site will be a very important asset to the global SLR network. The HartRAO staff are to be congratulated on the successful installation of MOBLAS-6."

Dr John L LaBrecque,

Manager: Solid Earth and Natural Hazards Program, NASA

"In accepting NASA's request to support the operation of their MOBLAS-6 satellite laser ranging system, we recognised South Africa's regional responsibility to support those international projects where our unique geographical location and local expertise can enhance research into global problems. We are committed to extending the benefits accruing from this collaboration to the scientific community throughout Africa and particularly to the SADC countries."

Dr Ben Ngubane,
South Africa's Minister of Arts, Culture, Science and Technology

HartRAO

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