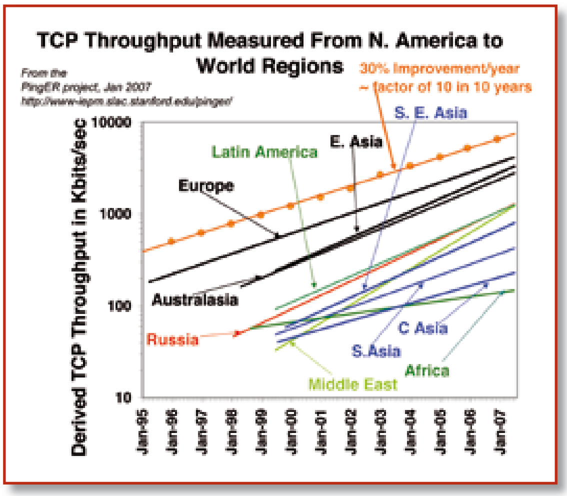
Bridging the digital divide

South Africa needs cheap, fast, and reliable bandwidth to fulfil its aspirations – not just in big science, but to reach its development goals as well. **Phil Charles** demonstrates the relationship between astronomy and the Internet and argues that the time has come for bold action.

More and more people are gaining access to the Internet at work and at home, and broadband services are increasing in speed while simultaneously decreasing in cost. So a 'digital divide' between Africa and the rest of the world (especially Europe and the USA) is not immediately apparent to many people. But a glance below the surface tells a very different story. Something needs to be done urgently.

Africa and the 'digital divide'

The data connection speed (TCP, or Transmission Control Protocol, or throughput, or simply the speed at which data can be moved around on the Internet) between the USA and other world regions has evolved exponentially over the past decade or so (*see graph*). Yes, everybody has improved. The average growth rate has seen the speed increasing by an amazing 30% per year, or a factor 10 in a decade, but Africa has seen by far the *poorest* level of improvement. Remarkably, at the turn of the millennium, our continent was ahead of Asia and the Middle East. But they have progressed much more rapidly than Africa (indeed, the Middle East at a rate faster than anybody!), leaving us now well and truly at the bottom of the league.



Above: International internet throughput, as monitored worldwide from Stanford University in California (USA), demonstrates the logarithmic growth in bandwidth over the past 12 years. All areas are growing, but the different slopes of the lines in this graph show that the rate of growth in Internet speed is different. Africa's rate of growth is the lowest, which means that it is further behind the rest of the world now than it was in 2000. Figure courtesy of Les Cottrell of SLAC and the worldwide PingER team

Internet performance can be measured in other ways too – the Digital Access Index, the cost of Internet access, the % of data losses, the unreachability of sites, congestion, and the quality of VOIP (Voice-Over-Internet protocol) connections. All have one thing in common: *Africa is at the bottom*[1].

The rates of growth in Internet speed are different too. Not only is Africa slowest, but it is falling *further behind* as we move into the future! You only have to visit Europe or the USA to experience and appreciate the magnitude of this digital divide. Given South Africa's current political emphasis on evolving from a resource-based towards a knowledge-based economy, keeping up with international developments is absolutely critical.

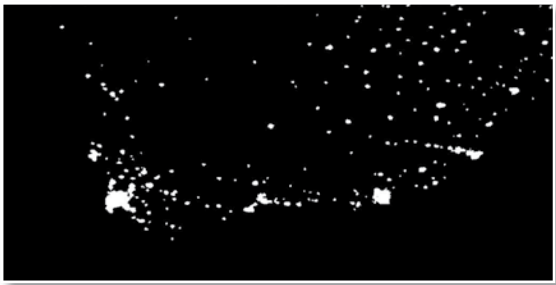
Astronomy Geographic Advantage Programme (AGAP)

Fast, cheap, and reliable Internet bandwidth is crucial for developing South Africa's economy as a whole as well as its science. Astronomy is significant to Africa and to the world, and this field of research serves as a clear case study for the country's – and the continent's – need to bridge the digital divide if it's to become a meaningful global player.

A look at the map of the world shows the importance of our astronomical observation sites for exploring the southern skies. World-class research requires access to dark, clear skies with good seeing conditions – that is, we need places where there is little atmospheric turbulence, or 'twinkling'. This means moving away from sea level to areas above 1 500 m, and, for southern-hemisphere astronomy, only Chile and South Africa qualify, as Australia's optical observatories are located at lower altitudes and have poorer seeing conditions.

South Africa's 'astronomy geographic advantage' (AGA) makes it an attractive partner for international astronomical collaborations, in which the country provides the observing sites, and participants elsewhere provide technical and financial resources. In this way, South Africa benefits scientifically in global projects that it would otherwise be unable to afford, and that

1. For details about measures of Internet performance see **www-iepm.slac.stanford.edu/pinger**.



Top left: The red dots mark the locations of the best astronomical observing sites for optical and infrared astronomy around the globe. The horizontal line shows the position of the equator, demonstrating how only Chile, Australia, and South Africa have access to the southern skies. Image: David Buckley

Top and above: Blow-up of the southern African region as seen from space at night. The Cape Peninsula is clearly delineated, as are the Garden Route cities. What is remarkable is how dark the area is in the Karoo around Sutherland, where the Southern African Large Telescope is located. Images courtesy of NASA/GSFC

bring new skills and opportunities to our rapidly developing nation.

The Southern African Large Telescope (SALT) is a splendid example. Constructed and commissioned over the last seven years, it cost about R200 million, but South Africa contributed only R50 million, part of which is the assessed value of the site and local infrastructure at Sutherland in the Northern Cape. The country did even better than these figures suggest, as two-thirds of the capital cost of the telescope was expended with South African companies.

To protect this advantage, the Department of Science and Technology (DST) sponsored an Astronomy Geographic Advantage Programme (AGAP) bill, recently passed by Parliament. It seeks to limit the human activities that can be undertaken (from the light and radio interference arising out of housing developments and mining, for instance) in areas close to South Africa's best astronomical sites. The extraordinary quality of our African skies is demonstrated by the familiar night-time compilation image of the Earth, showing southern Africa. The darkness of the Karoo on a clear, moonless night is truly awe-inspiring.

Modern astronomy, SALT, and the Internet

Not so long ago (only 25 years), ground-based observational astronomy was conducted with telescopes using photographic plates, and the main means of communication with the outside world was by telephone, fax, or telex machine. Conditions have changed dramatically. Telescopes evolved during the 1980s to being fully computer controlled; and highly efficient, digital detectors (charge-coupled devices, or CCDs, similar to those now common in digital cameras) have replaced the photographic plates. But the real transformation came in the 1990s with the World Wide Web. It revolutionized research communication for all branches of science, and for astronomy it opened up a host of possibilities. These included the ability to access astronomical databases compiled and maintained anywhere in the world, as well as the ability to receive and respond rapidly to time-critical results[2].

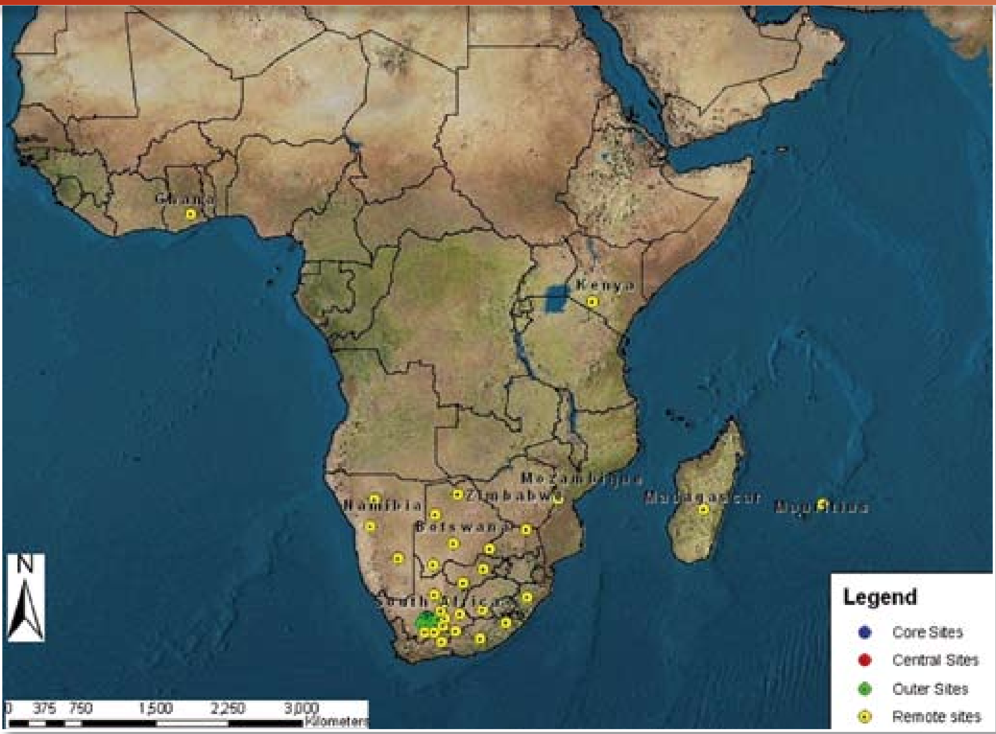
Increasing Internet bandwidth brought the possibility of shipping data immediately from the telescope to the home base (often overseas) for reduction and analysis. For many research projects, this needs to be done during the observing run so that particular observations can quickly be followed up with observations at other wavebands. This process is being applied to SALT data, but for different reasons.

SALT[3] is completing its commissioning phase and has already produced valuable results. But how does SALT data get to the scientists who want to work with them? There are five large-format (8-million-pixel) CCDs in the cameras used by SALT, and a typical night can produce 1–10 gigabytes of data. Sending such large quantities of data over our existing international links with Europe and America, for instance, is impossible, so we use a different approach. We have a dedicated (1.5-million-bits per second) line between Sutherland and Cape Town, which can transfer a night's data in a few hours (data are sent throughout the night while observing is taking place). However, these are all raw, uncalibrated data in the form of large files, which are then processed automatically (using a 'pipeline' processing system) into reduced data occupying far less computer space. These data can then be accessed over the Internet by the SALT partnership's scientists, both internationally and within South Africa.

Astrophysical virtual observatory

The 1990s saw massive growth in the volume of astronomical data generated around the world, as a result of the new generation of large telescopes combined with larger-format detectors and more powerful computing facilities. ▹▹

2. An example of how rapidly scientists can respond to observations concerns what is happening in the world of gamma-ray-burster (GRB) research (see Martin Still's article, "The birth of a black hole", in *Quest*, vol. 3, no. 1, pp. 12–15).
3. For details about SALT, see *Quest*, vol. 2, no. 2.



Left: Map of southern Africa, showing the proposed location for the Square Kilometre Array core in the Northern Cape, with the rest of the array distributed among Namibia, Botswana, Mozambique, Madagascar, Mauritius, Kenya, and Ghana. Image: KAT Project Team

Above: Two views of the KAT test dish.

This was true for all wavelengths, from radio to infrared to optical to ultraviolet to X-ray, both in space and on the ground. For deeper understanding of the physical processes occurring in many astronomical objects, scientists combine observations made at different wavelengths in what is known as 'multi-wavelength astronomy'. Beginning with space missions, and now expanding to include most major ground-based observatories, such data have been and continue to be archived into large, central computer databases which (at least in the case of nationally funded observatories and missions) are made publicly available to astronomers over the Internet.

Working with such huge databases, however, and combining the data effectively can be difficult and time-consuming. It is now feasible to consider accessing an atlas of the entire sky taken at a resolution of 0.1 seconds of arc[4] – but such an atlas would correspond to 100 terabytes (TB)[4] – that's 100 000 gigabytes (GB)! Distributing such a giant database is obviously impossible (just think, your home or school PC most likely contains everything on a ~100-GB hard disk, so you'd need 1 000 of them to store this atlas). Enter the International Virtual Observatory Alliance (IVOA), which aimed to simplify the process through the power of the World Wide Web.

The IVOA has created standards for formatting such data and provided suitable software by which to access these huge datasets remotely. So there is only *one* copy of the atlas (it could be located anywhere in the world) and you simply query it, work with it, and get results, which are then sent over the Internet to your own computer. Such is the power of the IVOA. But to work effectively it needs high-speed Internet links.

The digital divide and South Africa's SKA bid

The dark Karoo skies are 'dark' (or 'quiet') at radio frequencies too, giving South Africa a further geographic advantage, this time for radio astronomy. As a result, with the support of other countries in the region, South Africa is on the short-list (together with Australia) as one of the two potential sites to host the Square Kilometre Array (SKA).

With an effective collecting area of a million square metres, the SKA will be the most powerful radio telescope on Earth, achieving a sensitivity a hundred times greater than current instruments, and costing ~US$2 billion. If the SKA is located in southern Africa, an array of antennas will be distributed over the entire southern African region (*see map above*), with its central core area concentrated near Carnarvon in the Northern Cape. This remote, radio-quiet area is ideal because of the very small number of people living and working there – no people means no cell-phones, television, or radio transmission, all of which cause the high levels of radio 'interference' over so much of our world.

In preparation for the SKA, South Africa and Australia are both constructing 'SKA pathfinder' radio telescope arrays. In South Africa, the KAT (Karoo Array Telescope) Project Team has commenced design and construction of the MeerKAT[5], a world-class radio telescope, composed initially of 80 12-m dishes and extending over a distance of up to 10 km in the Karoo.

4. A second of arc (arcsec) is a very small unit of angular measure, equivalent to one-sixtieth of an arc minute or 1/3600 of a degree. (For example, the Sun and Moon are each 30 arc minutes across.) The prefix 'tera-' (T) is used in the metric system to denote one million million times, so 1 terabyte (TB) = 1 000 gigabytes (GB).

The current limitation in data transmission from the Northern Cape is a very large factor in the MeerKAT construction. To complete it at this stage would be impossible, because the bandwidth, computer processing power, and data storage required simply do not yet exist anywhere. The problem will partly be solved through Moore's Law, the remarkably well-established relation by which raw cpu (central processing unit) power and hard disk storage capacity essentially double every two years. Extrapolating this into the future indicates that the necessary technology should be available by about 2014 (even if we don't yet know what form that technology might take).

For South Africa, the main problem lies in the data transmission. We are way behind in terms of affordable bandwidth on both local and international scales – that is, the digital divide is holding us back. *A large investment is required to improve this situation!* Progress has been frustratingly slow, but encouraging signs are beginning to emerge, and the government is aware that intervention is needed. A high-speed academic internet backbone is an urgent priority.

Put simply: without high-speed links, MeerKAT and the SKA bid are non-starters.

In the short term, SALT (as will probably also be the case for KAT) is using the Virtual Observatory method described above. Users and other interested astronomers (locally and overseas) access only final data-products (for example, the processed images) and not the (much more voluminous) raw data. This approach can be extended to other astronomical observatories, both ground and space-based, if the data archives are copied and moved to a central South African site (a 'mirror'), from which the data can be accessed. The broad support that exists for the recently passed AGA Bill and KAT (as well as other developments) is being used as a lever to change the face of research networks. Furthermore, our international partners (in SALT and MeerKAT) are providing external support, since South Africa has so clearly shown that it wants to participate in science on the global stage – as a 'real' partner, and not just as a third-world provider of first-class research locations.

In time, the cost and speed of commercial bandwidth in South Africa will both improve – driven (it is to be hoped) by increased telecomms competition. But when ...? □

Acknowledgements: I am grateful to Bruce Bassett, Roy Emmerich, Jasper Horrell, and Duncan Martin for providing material for my April 2007 presentation to the meeting in Florida, USA, where representatives from around the globe met under the auspices of the American Physical Society to discuss how to 'bridge the digital divide'. This article is a summary and an update of that presentation.

Professor Phil Charles is Director of the South African Astronomical Observatory, which has its headquarters in Cape Town and is contracted to operate SALT at its observing station in Sutherland, Northern Cape, on behalf of the international SALT partnership. He has worked with computers in astronomy throughout his entire 35-year career, and was an early convert to the concept of the Virtual Observatory as a result of ESA (European Space Agency) and NASA data archives for space astronomy missions. ▷▷

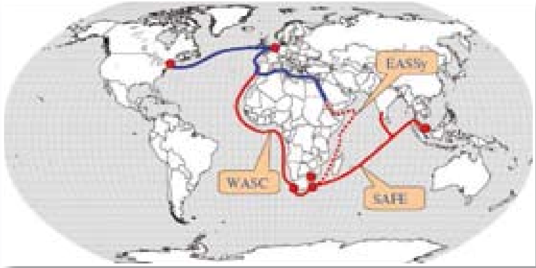
5. The KAT (Karoo Array Telescope) is a 1% version of the projected Square Kilometre Array (SKA), and is intended as a technology demonstrator radio telescope array. A single prototype dish has been constructed at the Hartebeesthoek Radio Astronomy Observatory (HartRAO) in Gauteng to test the dish manufacturing technology. MeerKAT (or 'more KAT') is the logical next step in this process, and will comprise an array of approximately 500 dishes, equivalent to 10% of the SKA. It will be constructed based on technologies developed from what is learnt in building and operating KAT, and will be an extremely powerful radio telescope and research tool in its own right. The full SKA (if South Africa is chosen to host it), will expand the array over its full extent. The decision as to which country will host the SKA is unlikely to be taken until 2009 or later.

Developments in eastern and southern Africa

Optical fibre (for data transmission) is being deployed throughout Africa at an accelerating rate, as a result of developments by national and cellphone operators, electrical power expansion, and various international consortia.

As is the case in Europe, national research and education networks (NRENs) are emerging in African countries to provide the academic backbone to link their major institutions by procuring Internet bandwidth. In South Africa, to begin this process, SANREN is being funded by the Department of Science and Technology through the Meraka Institute, as well as TENET (Tertiary Education Network), the broadband system that serves South Africa's higher education and research institutions. Together with six other African NRENs, they have formed UbuntuNet, aiming eventually to become the 'Geant' of Africa – inspired by the European Geant2 network, which currently provides a staggering 10-gigabits per second academic backbone throughout Europe and is at least 1 000 times faster than that currently available within South African academia!

Providing the linkage between southern Africa and the rest of the world means developing intercontinental connectivity (*as proposed in the map above*). Many groups of professional people in all walks of life recognize the urgency of providing affordable, international bandwidth. But achieving it requires political intervention on a heroic scale.



Map showing how southern Africa might be connected to the rest of the world. The WASC and SAFE cables exist, but have limited affordable bandwidth available. EASSy (and the recently proposed Seacom) cables could transform the situation for South Africa if political and financial hurdles can be overcome. Image: Duncan Martin, TENET

Side view (top) and close-up (above) of the former NASA deep space tracking station, converted and upgraded as the HartRAO 26-m dish for radio astronomy.

KAT, MeerKAT, and the SKA

The first KAT test dish, manufactured at HartRAO (the Hartebeesthoek Radio Astronomy Observatory), is currently undergoing engineering tests. Telescope arrays work as interferometers, where the radio waves detected by each dish in the array 'interfere' with each other, producing a pattern that is related to structure in the image (see **http://en.wikipedia.org/wiki/Interferometer**); the sensitivity is achieved by having many dishes, geographically widely separated, all observing the same part of the sky at the same time.

MeerKAT is intended to start operations around 2012, with the first phase as a 7-dish system operational from 2010. The telescope array will generate data at different rates, depending on its level of performance. When operating optimally, its data-rates will be truly phenomenal. For example, an 80-dish MeerKAT will generate data in excess of 8 gigabits per second (that's eight thousand times faster than current South African broadband rates!) after the first stage of correlation processing in the standard imaging mode*. This will produce a full spectral image cube of 11 terabytes (TB) after typically 8 hours of observation (which would take about 30 hours to download over a dedicated 1-gigabit link). For a 10% SKA comprising 900 dishes, the numbers are much larger: the data rate at the correlator output would be of the order of 6 terabits per second, and spectral image cube sizes of the order of 265 TB would be produced. This is a very large amount of data to try to move around!

* The correlator is the piece of electronics that combines the signals from each of the dishes and produces the interference patterns that tell us about the detail in the radio image.

Above left: Photograph of the HartRAO 26-m radio dish at Hartebeesthoek, with the MeerKAT test dish in the background.

Left: The MeerKAT test dish.

For more information, visit the following websites: The International Virtual Observatory Alliance is at **http://ivoa.net**; **wiki.astrogrid.org** and **www.euro-vo.org**. You'll find SALT at **www.salt.ac.za**; KAT and SKA at **www.kat.ac.za** and **www.ska.ac.za**; TENET at **www.tenet.ac.za**; and telecommunications reform in South Africa at **www.busrep.co.za/index.php?fSectionId=&fArticleId=4004971**

News

Communication for Africa

Telephone access

There's no getting away from it – the cost of expensive telecommunication has pricey ripple effects.

The Human Sciences Research Council (HSRC) report, *Mapping Communications Access in South Africa* (2007), highlighted the fact that the Accelerated and Shared Growth Initiative of South Africa (ASGI-SA) had identified the high cost of telecommunications – which includes computers, the Internet, and other electronic developments – as a key factor that could affect the goal of achieving 6% economic growth and alleviation of poverty in South Africa by 2014.

To assess the reality in South Africa, the HSRC investigated the extent of access to landlines and cellular phones. Gauteng had the highest proportion of households with cellphones (48.7%), closely followed by the Western Cape (46.7%); the Northern Cape had the lowest (20.1%); and the national average was 33.1%. The Western Cape had the highest proportion of households with landlines (55.3%), followed by KwaZulu-Natal (31.7%); Limpopo had the lowest (7.1%); and the national average was 23.6%.

Access, in other words, was much higher in cities with good infrastructure and higher household income levels than in poorer rural communities. Cellphones remain the great liberator, enabling services to reach less populated parts of the country. For more visit **www.hsrc.ac.za/HSRC_Review_Article-62.phtml**.

EASSy does it

The Eastern Africa Submarine Cable System (EASSy) is an initiative to connect countries of eastern Africa by means of a high-bandwidth fibre optic cable system to the rest of the world. It is considered a milestone in the development of information infrastructure in the region

The plan is to run it from Mtunzini in South Africa to Port Sudan in Sudan, with landing points in six countries, and connected to at least five landlocked countries – which would no longer need to rely on expensive satellite systems to carry voice and data services.

The project, funded by the World Bank and the Development Bank of Southern Africa, was initiated in January 2003. Telkom, a major EASSy stakeholder, has indicated that it may withdraw, as it could be forced to reduce the fees it charges rival operators to use its bandwidth on SAT-3, the cable connecting Portugal and Spain to Melkbosstrand, South Africa, which is co-owned by Telkom.

EASSy is 27% owned by three South African companies, but policy guidelines are being drafted that would forbid any cable system that is not majority owned by South African companies from landing in the country.

The World Bank Group says it will fund the construction of the cable, whether or not South Africa grants landing rights to it. Its director of information and communications technology hopes that South Africa will in fact allow EASSy the rights it needs to provide international bandwidth to South African consumers, but the project will continue regardless. It is scheduled to come on stream in early 2009.

Sources: Wikipedia and *Financial Mail*, 21 September 2007.

A wireless option

The way to bridge the digital divide, said Intel chairman Craig Barrett during a tour of Africa in October 2007, is to communicate "wirelessly".

Less than 1% of Africans has access to broadband, and only 4% uses the net. The continent's geography and political barriers have made it difficult to roll out wired broadband – quite apart from the shortage of fibre cable links between African countries, and the fact that few states have the extensive copper wire networks for ADST broadband.

Cellphones outnumber fixed-line connections in most African countries, and the advice from Intel is to "forget about wires and twisted copper and go directly to broadband wireless technologies like WiMax." This is a long-range, low-power wireless broadband system that can be used to connect PCs and laptops to a broadband network, and, in future, cellphones too.

Source: BBC News, 31 October 2007.