

South Africa's space programme - Past, present, future

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ABSTRACT

This article introduces and analyses South Africa's space programme. This divides into three phases. First was the age of amateurs 1947-1962.

Second, between 1963-1993, South Africa's apartheid ancien regime started various missile projects. A secret military space launcher programme aimed at orbiting reconnaissance satellites. Under US Government pressure, this was cancelled before the first democratically-elected government came to power, and the facilities for manufacturing and testing solid propellant missiles destroyed.

But South Africa still maintains a nucleus of space heritage infrastructure, including a coastal space launch range with telemetry capabilities, satellite testing and integration facilities, and modest aerospace and software industrial sectors.

Third, South Africa became a democracy in 1994, and rolled out the legal and institutional infrastructure for a space programme. It is increasingly active in COPUOS and other international forums.

South Africa has started to shape a new space policy, this time with public transparency. Since developing countries have severe resource constraints (aggravated by global recessions) the reviving future of South Africa's space programme clearly needs to involve bilateral and multilateral partnerships. First fruits are that South Africa has negotiated with Algeria, Kenya, and Nigeria, the African Resource Management constellation, to pool imagery and other remote sensing data from all their microsats.

Introduction

This article conceptualises South Africa's space programme in the broad sense. Astronautics, Astronomy, and other space sciences, usually develop in parallel, with increasing technology convergence in our digital age, and today have more synergies than is usually realised. Especially in developing countries, the political drivers for astronautics and astronomy hugely overlap. This paper on South Africa's space programme focuses on astronautics, but is inclusive of astronomy where they mesh. The methodology is an analysis of print and digital publications, plus briefings by some participants. It also draws on the author's experience while serving on the policy and advocacy committees of the Space Affairs Council of South Africa (SACSA), a statutory entity within the Department of Trade and Industry. (All views are the author's alone.) The history of South Africa's space programme can be divided into three chronological epochs.

The Age of the Amateurs: Rocketry 1947-1962

Astronautics enthusiasts formed in 1953 a South African Interplanetary Society in Johannesburg. Desmond Prout-Jones, who had been launching home-made rockets since 1947, formed in 1959 the South African Rocket Research Group (SARRG). Another amateur group, near Port Elizabeth, also staged successful launches until 1963.

The SARRG:

- launched 528 rockets, and 102 static firing tests, without any injuries or fatalities.

These included South Africa's first

- two-stage rocket;
- five-stage rocket;
- many two-stage supersonic rockets; one reached over 28 kms. altitude;
- first liquid-propellant rocket on 6 October 1959, coincidentally the date a Soviet rocket first reached the Moon.

Their final rocket reached 40 kms altitude, and they were readying one for a 100 kms altitude flight, when the Government Explosives Inspector banned all further rocket flights.¹ It is interesting that the apartheid authorities refused permission for all further civilian amateur launches in the year that we now know the South African military started developing tactical surface-to-air missiles. This chronology is reminiscent of what happened to the *Verein für Raumschiffahrt*, the German amateur rocket society, in 1933.

Prout-Jones obtained five industrial sponsors, who donated all propellant, and donated, fabricated, and machined his rockets. He did not have the political skill to perceive that if he had persuaded them to sponsor a paper corporate R&D consortium, they would certainly have not been vetoed by the Explosives Inspectors.

This is also the chronological place to mention that the amateurs of the Astronomical Society of Southern Africa enthusiastically participated in NASA's Project Moonwatch, which ran from 1957-1967.² Using the Baker-Nunn telescopes with an unusually wide field of view, they tracked and timed the transit of satellites, when the changing structure of the upper atmosphere was not as well understood as today. Alongside better understanding of solar-terrestrial physics, new satellite data, and advances in communication, radar, and lidar replaced them by the 1970s.

In addition to the unpaid amateurs, we need to mention at this point in the timeline that NASA also established its Deep Space Network Station 51 at Hartebeeshoek with a 26-metre dish in 1961. This was a vital link in both uploading and downloading telemetry to and from space probes orbiting the Moon, Venus, and Mars, throughout the next decades. In 1974 NASA decommissioned its first generation of dish antennas, and donated it to the Council for Scientific and Industrial Research (CSIR).³ This was also the decade when anti-apartheid campaigns pressed for sanctions and ending links with South Africa.

The Military Epoch: Missiles 1963-1993

From 1963, the apartheid regime started in earnest to build up a military-industrial complex. From that year, Armscor, with French cooperation, started local manufacture of tactical missiles, such as the French *Crotale*, manufactured locally under the name *Cactus*. In 1979 the South African Air Force introduced air-to-air missiles slaved to look-and-shoot helmet sights. By the 1980s Armscor also manufactured a rocket-boosted artillery shell for its G-6 cannon.

After accumulating two decades of experience in such developments, in 1980 the Israeli Government briefed their then South African ally about their cabinet decision to develop a reconnaissance satellite. President P.W. Botha decided they too needed a space launcher to insert into LEO a reconnaissance satellite, reportedly to keep an eye on Angolan air force bases.⁴

Israel, with French cooperation, had during the 1960s-1970s refined the French Dassault MD-620 into the Jericho-2 IRBM. In March 1975, one South African Defence Force (SADF) strategic planner had in fact urged swift acquisition of the Jericho-2. During the 1980s, the Israeli aerospace industry adapted their largest missile, the Jericho-2, to become the *Shavit* space launcher. In the institutional dimension, Israel founded its space agency in April 1983. Its first prototype reconnaissance satellites were *Ofeq-1* launched on 19 September 1988, and *Ofeq-2* on 3 April 1990.

The South African Government paid licence fees to the Israelis for all the *Shavit* technology, down to translating its instruction manual from Hebrew into English. The Israeli provenance of the space launcher was camouflaged by locally re-naming it the *RSA-3* (as in **R**epublic of **S**outh **A**frica). The *RSA-3/ Shavit* had a mass of 23 tonnes, with capability to launch a 330 kg satellite into a 212x 460 km orbit at a 41° inclination.

What is interesting is the chronology. The Israeli and South African Governments began preparations for their space launcher from 1980, with South African fabrication and test range infrastructure being laid out from the early 1980s, more than five years before Israel itself launched its own first satellite. But South African test firing of the first stage only finally occurred on 1 June 1989, nine months after Israel had successfully launched its first satellite. Two further sub-orbital test launches, apparently of both the first and second stages, succeeded on 6 July 1989, and on 19 November 1990.

Much research awaits future historians. Our fragmentary knowledge of this R&D partnership is contradictory. On the one hand, consider the evidence of cash flow and chronology. The payment of royalty fees to Israel, and that South Africa had not launched its first satellite using the RSA-3 even two years after Israel had, intimates that South Africa was the junior partner. But on the other hand, both a South African and an Israeli source confirmed to the author that South Africa had in fact made a “substantial contribution” to the *Shavit* ballistic development. Bearing in mind Israel’s world-class electronics and IT industry, and South Africa’s century of industrial experience with

commercial explosives, is it most likely that South Africa's contribution centred on detonics, refining the solid propellant, and on materials science?

Good news for the long-term is that Israeli authorities have commissioned their first full-length history of Israel's space programme. While this will remain classified, it is probable that a summary might be placed in the public domain. At worst, the history will be declassified after five decades.

Spaceflight historians will also ask at least one further question. Did Israel - the only space player who had to incur the payload penalties for launching westwards into orbit - also hope to launch its future *Ofeqs* eastwards from OTB? When the end of the apartheid regime prevented that, Israel's space diplomacy later got the ESA from 16 May 1996, Russia from 7 July 1998, and then India from 21 January 2008, to launch their further reconnaissance, SAR, and civil-military communications satellites. Both the ESA and Indian spaceports are closer to the equator than South Africa's OTB, and so allow heavier payloads to be orbited than a launch from either Israel or South Africa.

By 1991 the apartheid regime had started the negotiations that would culminate in transition to democracy under a predominantly black government. This abruptly ended the US Government's benign tolerance of the space launcher programme. The US Government demanded that Somchem destroy the rocket casings, Denel destroy the three-metre diameter solid motor casting pits; let a U.S. contractor demolish the Rooi Els static firing test stand; and that Houwteq should retrieve and destroy data from its contractors during 1992-93. The intention to build an 80-tonne *RSA-4* had to be aborted at the design stage.

The De Klerk Administration also signed a diplomatic letter agreeing not to resume developing a space launcher until the country joined the Missile Technology Control Regime. South Africa became a member of the MTCR in September 1995. At its height, this space launcher programme employed between 1 300 – 1 500 persons working for some 30 - 50 contractors. Due to the US diplomatic pressures summarized above, all but 28 had to be retrenched by 1997. A few emigrated, some retired, most found jobs in industry or research, or at university engineering faculties. Over ZAR five billion was spent,⁵ equivalent in 2010 purchasing power to perhaps fifty billion rand.

Nevertheless, this space launcher programme did leave a heritage of a considerable physical space infrastructure. Below is a brief overview of facilities available for future South African or African space programmes, along with cognate facilities that could be used for a HOTOL RLV R&D programme.

Heritage Space Physical Infrastructure

CSIR

At least six units within the Council for Scientific and Industrial Research are actually or potentially space-related. The Defence, Peace, Safety and Security Unit leads R&D on turbines, with wind tunnel series that go up to mach 4.5.⁶ The Materials Science &

Manufacturing Unit, its Meraka Institute for ICT, the National Laser Centre, and the High Speed Computing Network are all relevant. The Satellite Applications Centre (SAC) has command and control facilities, used since 1960s for uplinks and downlinks to spacecraft in orbit, including orbit around Venus or Mars.

*ISSA*⁷

The Institute of Satellite and Software Applications (before 1998 named *Houwteq*), between Cape Town and the OTB, has all the facilities for satellite integration: a clean room, the biggest anechoic chamber in the southern hemisphere, and a vacuum and thermal stress test chamber. Its vibration table can test satellites up to one tonne. Its gantry cranes have the capacity to handle up to a 23-tonne satellite, space station component, or spacecraft. It has the work stations for downloading and all imaging and other data processing.

OTB

The Overberg Test Range (acronym in Afrikaans *Overberg Toetsbaan*) was built from the start as an eastwards and polar space launch facility, with control centre, three launch pads, 4.5m tracking antenna, cinetheodolites and radar tracking facilities, and an air transportable tracking station. In total, it covers 43 000 ha, including 70 kms of coastline, with 25 000 cubic miles of airspace. It has been sub-contracted for coverage of stage separation for many vehicles in orbit, plus uplinks to Mars and Venus space probes. Currently, about 35% of its income is from international clients. Its hostel can accommodate up to 120 engineers.⁸

*SAAF - TFDC*⁹

The South African Air Force's Test Flight and Development Centre has a primary runway 3115m long, and good telemetry and optical tracking facilities. Their runway and control tower have the capability to accept a Boeing 747, and is situated on the coast, suitable for HOTOL RLV and other UAV test flights - the TFDC is embedded on its north, east, and south perimeters by the Overberg Test Range (OTB). The hangar currently holds three prefab bays, any one of which could service a 5-tonne flying test-bed. The entire hangar could accommodate a 100-tonne technology demonstrator.¹⁰

SAAF – Waterkloof AFB

The South African Air Force Waterkloof Base includes engine test cells and other very under-used R&D facilities.

Pierre van Ryneveld Airport, Upington

This airport has a 4.9 km runway, the longest in Africa, used for only three scheduled flights per day, surrounded by the sparsely-inhabited Kalahari desert. The runway could accommodate an emergency landing of the STS. With spacious aircraft parking facilities, it is also suitable to become a test flight area for a HOTOL RLV.¹¹

The Civilian Era: Space & Democracy 1994 -

The African National Congress is justly proud that it is the only liberation movement in the world that formulated a science and technology policy before it came to power. During the transition, it in 1993 appointed Roger Jardine its science and technology policy coordinator. After winning the first democratic election in 1994, it established a Department of Science and Technology under a Minister and Deputy Minister, with Jardine becoming the youngest-ever Director-General.

Legal Infrastructure

Democratic South Africa ratified what might be conceptualized as the founding statutes of the space constitution: the Outer Space Treaty (1967), Rescue Convention (1968), International Telecommunication Satellite Agreement (1971), Liability Convention (1972), Registration Convention (1975), International Mobile Satellite Organization (1976), and the International Telecommunication Convention (1992). The country has not yet ratified the Moon Agreement (1979).

The major national statutes relevant to this article are the Space Affairs Act 84 of 1993 and Space Affairs Amendment Act 64 of 1995, which address the regulatory obligations accepted by the Government under international treaties.

Next, the Astronomy Geographic Advantage Act 21 of 2007 empowered the Government to cap or ban radio and light pollution that would impair the sites of radio- and optical telescopes. This was both to protect the state's unprecedented investment in the new Southern African Large Telescope (SALT), and to enable the banning of mobile phones over much of the Northern Cape Province, to strengthen South Africa's credibility to bid for the world's largest radio-telescope, the Square Kilometre Array (SKA).

The South African National Space Agency Act, 36 of 2008, paves the way for the Department of Science and Technology to establish the overdue NSA, already a decade behind Algeria's ASAL (founded 2002) and Nigeria's NASRDA (founded 1998).

Institutional Infrastructure

From 1995 the Department of Trade and Industry (DTI), established a Space Affairs Council of South Africa (SACSA), in close cooperation with the DST. Its thirteen councillors' functions fulfil regulatory functions. It also has policy and advocacy sub-committees. These drafted South Africa's first space policy, and first space strategy. The Minister of Trade and Industry endorsed the first, and the Ministry is working through the second.

In 2003, an astronomer, Dr. Peter Martinez, who uniquely amongst his South African colleagues couples his doctorate in astrophysics with a B.Sc Honours degree in Materials Engineering,¹² headed up a new National Working Group on Space Science & Technology, (NWGSS&T) housed in the SA Astronomical Observatory head offices in Cape Town. In 2004 he worked with the Department of Trade & Industry to convene a meeting of senior civil servants to discuss government uses of space technology. This

forum decided to establish the Government Lead Users' Group, a group of consumers of space products and services, ranging from Agriculture to Trade & Industry. The Secretariat for this National Working Group was housed within the National Research Foundation, under contract to the Department of Science & Technology.

These working groups were designed to navigate their way around turf defence issues, and enable government departments to talk to each other. The NWGSS&T provided a platform within government to discuss the need for a national space policy and strategy, and the establishment of a national space agency to implement a national space programme. The Working Group also provided a forum which developed plans for South Africa's second microsat, Sumbandila. Regrettably, budget fears and turf issues meant that initial hopes that South Africa's nascent space agency could house both Astronomy and Astronautics, failed to win majority consent from the astronomers.

In 2007 cabinet decided that South Africa would establish a space agency and tasked the Minister of Science & Technology to develop plans for this. Meanwhile, the Department of Trade & Industry, which has statutory responsibility for space issues, started to develop a national space policy, which the Minister of Trade & Industry launched on 3 March 2009. In April 2009 the Department of Science & Technology wound up the NWGSS&T, which it will replace by other forums pending the establishment of the space agency.¹³ The national space agency will be launched before the 62nd International Astronautics Congress opens in Cape Town in October 2011.

Space Policy: Astronomy and Space Science

Another common thread weaving together astronautics and astronomy are that both are perceived by the political decision-makers and allocators of public resources as projecting an image of cutting-edge modernity that debunks racial stereotypes of Africa and blacks as backward. South Africa has over a score of tenured astronomers and space scientists. The national research facilities are the South African Astronomical Observatory (SAAO), the Hartebeeshoek Radio Telescope (HartRao), and the Hermanus Magnetic Observatory (HMO). The University of Cape Town (UCT) has the only Astronomy Department in the country, with its Applied Mathematics Department also hosting a Cosmology Working Group. The University of the Western Cape (UWC) is the first historically-black university to be awarded an endowed Chair in Astronomy. There, and in other universities, the astronomers are housed in Physics, or Maths, or Statistics Departments. An inter-university partnership launched the B.Sc (Honours) and M.Sc-level National Astrophysics and Space Science Programme (NASSP) to fast-track graduates, especially those from historically-disadvantaged communities, for eligibility to enrol for doctorates. UWC supervises astronomy M.Sc students from Mozambique and Madagascar, to build the scientific personnel base essential should South Africa win its bid to host the SKA. The bid proposes outlying dish antennae in neighbouring countries in Southern Africa.

The democratic black state has committed more funds to Astronomy during its first fifteen years than all the earlier colonial and apartheid regimes spent over the previous

150 years. The eleven-metre SALT saw first light in 2005 as the largest optical telescope in Africa, and in the southern hemisphere. NASA's Deep Space Network station became HartRao, combining its radio-telescope with laser rangefinders for space geodesy work, and working as a station of the VLBI. The Government has now committed to SKA over \$100 million, twentyfold the budget it paid towards SALT. Auroral and magnetosphere research in the Antarctic and elsewhere adds to the portfolio of space sciences currently researched. The Institute of Satellite and Software Applications has trained over 400 students from previously-disadvantaged communities in IT by 2004.¹⁴ Stellenbosch University started a satellite engineering programme in 2005.

Space Policy: Industrial Capabilities

Stellenbosch University (SU) electronic engineering masters students built the 64kg microsat *Sunsat*, which waited for almost a decade for a launch donor, finally reaching LEO, courtesy of NASA, on 23 February 1999. In 2000 this spun-off the company Sunspace, which built the larger *Sumbandila*, ("Lead the way" in the Venda language) completed in 2006, whose launch also suffered repeated delays, this time in Russia, before orbital insertion on 17 September 2009. The political spin-off these enjoyed requires understanding that multi-lingualism policy is highly politicized in South Africa. The then chancellor of Stellenbosch University, Dr. Elize Botha, a heavyweight in the cultural establishment, was enthralled that *Sunsat* transmitted the first words in the Afrikaans language broadcast from orbit. *Sunsat* and *Sumbandila* are also Africa's first two microsats that were entirely constructed on the continent, demonstrating hi-tech industrial capabilities.

Today's democratic environment sees civil space involving many more participants. While the corporate sector was involved in the military launch programme as contractors, we currently see the emergence of both independent companies such as SunSpace, with foreign clients, and also individual consultants. Current direct South African expenditure in space-related activities, depending on how broadly you conceptualize the category, is between ZAR 48-80m (\$6-10m) per year, employing some 180-200 personnel.¹⁵ The national space agency will not attempt to manufacture in-house, but will outsource building satellites and software development to the private sector. Over half the value of the engineering contracts for SALT were won by South African companies. Should the SKA bid be won, it would boost South Africa's IT and electronics industries.

The National Aerospace Centre of Excellence (NACoE), is in reality a nascent network of centres, seeking synergies in bringing together every aeronautical course and researcher at the country's different university engineering and other relevant departments.¹⁶ Founded in 2007, this is supported by the DTI, whose space affairs directorate also put in place programmes such as the South African Aerospace Industry Strategic Initiative (AISI) and the Advanced Materials Technology Strategy (AMTS).¹⁷

The national space policy launched in 2009 commits South Africa to utilising outer space for peaceful purposes and the benefit of all humankind. It focuses on helping South

Africa enter global aerospace supply chains, participate in the knowledge economy, and develop space-related products and services. Its long-term vision is to develop and maintain a robust and appropriate set of space capabilities, services and products. Last but not least, a developing country has to commit energy and resources into raising popular space awareness and science and technology outreach.

Space Tourism and Outreach

Mark Shuttleworth, a software developer, is South Africa's first IT billionaire. At the high end of space tourism, he became in 2002 the first African and second space tourist to orbit and visit the space station. On his return, he sponsored a major science outreach programme aimed at rural black schoolchildren. SAAO has funded a post for the first full-time astronomy public educator, Kevin Govender, starting our move towards the long-established, better-funded programmes run by NASA and other countries. SAAO also set aside some of its funds to upgrade remuneration for a maths teacher in the Sutherland high school, and the SKA bid team donated a school computer lab and several teaching posts to rural high schools.

At the low end of space tourism, the hilltop SAAO observatory and the nearby, formerly declining desert town of Sutherland now enjoy an astro-tourism boom. Two guest farm ranch-owners make telescopes available; twenty-five B&Bs have sprung up; property prices now more than double those of comparable neighbouring rural villages. During 2006, the Cape Centre of the Astronomical Society of Southern Africa staged the first Yuri's Night party in South Africa; in 2009 the SAAO Observatory ushered in the International Year of Astronomy (IYA) with South Africa's first new year star party. Unprecedented numbers now attend the daily public tours of SAAO observatories and South Africa's two planetariums. All this is auspicious progress for a developing country.

Future prospects include more than multiplying star parties and the gentrification of Sutherland. The OTB-TFDC complex is ideally suited for the sub-orbital hops of current space tourism entrepreneurs, as it offers an unending panorama of bays and beaches stretching over the horizon, as viewed from 100 kms altitude. Some South Africans have initiated business negotiations to such adventure tourism operators.

Public participation and enthusiasm requires civil society organizations. The Astronomical Society of Southern Africa (ASSA) of amateur astronomers will soon celebrate its centenary. Model rocket clubs, and radio hams using satellite communications, both have their own umbrella associations. IYA witnessed the launch of the newest organisations, the South African Space Association, and the Foundation for Space Development. These are now starting to attract a rainbow of diversity with their newest members.

International Partnerships

Under democracy, South Africa became active in COPUOS, since 2003 in GEOS, and similar international space forums. South Africa hosted the second African Leadership Conference on space science and technology in 2007.

Space policy finds synergy with foreign policy in more than one arena, including Pan-African and South-South alliances. Communication and imaging satellites will help South Africa fulfil its continental peace-keeping obligations towards the African Union and UNO.

With UNESCO and African Union support, the first African Leadership Conference on Space Science and Technology for Sustainable Development (ALC) convened in Abuja, Nigeria, in November 2005. The second ALC was held in Pretoria, South Africa in October 2007. In Algiers, Algeria, in December 2009, during the third ALC, after years of patient negotiations, the African Resources Management constellation MoU was signed. This ensures that Algeria, Kenya, Nigeria, and South Africa share their satellite imagery archives. The ARM clearly needs to give priority to coaxing Egypt to join. When South Africa's space agency is launched, this will provide a South African cognate agency to work with Algeria's ASAL and Nigeria's NASRDA on the ARM constellation. The national agency will also facilitate future agency-to-agency cooperation with ISRO, NASA, ESA, JAXA, AEB, RSA, KARI, and other potential partners.

The African Union's (AU) African Ministerial Council on Science and Technology, AMCOST, founded in 2003, has identified space science and technology as one of four priority clusters for cooperation. The regional African satellite communications organization, RASCOM, has struggled to gather momentum over the past decade, but will sooner or later play an increasing role. RASCOM, and the ARM Constellation MoU are the incremental developments that need to grow organically, to avoid duplication, and optimize cost-effectiveness in space policy for resource-constrained developing countries.

If African national space agencies can in future coordinate launching several satellites and micro-satellites in the same space launch, this will enhance their bargaining leverage to negotiate both contract prices, plus the optimal orbital inclinations and altitudes. A solitary micro-satellite is a secondary payload that has no choice on the primary customer's selection of orbit.

In the long term, AMCOST, RASCOM, and ARM, will surely need to culminate in an African Space Agency. Even the incomparably more wealthy European states had to complement their national space agencies with ESA, in order to become a major space-faring player. After several African states make substantial commitments of budgetary and human resources to their own national space agencies or remote sensing agencies, this imperative will repeatedly table itself on the future continental space agenda.

South Africa and visiting business delegations have noted many possibilities for partnerships in space technologies.¹⁸ Here, South Africa's DST has a directorate for International Cooperation, while the Department of International Relations & Cooperation has a science and technology directorate. India's then President, Abdul Kalam, on his 2004 visit to South Africa singled out space technology as one area for future cooperation.¹⁹ India has offered the African Union for its NEPAD programme satellite services for tele-education and telemedicine. The trilateral India-Brazil-South Africa alliance, IBSA, offers a framework for joint R&D projects and programmes which forms an obvious node to which space S&T should be added.²⁰

Above all, international partnerships will help South Africa attain assured access to space. For example, *Sumbandila's* Russian launch was held up for two years due to South Africa's Defence Ministry withdrawing from a provisional agreement to use a Russian military satellite.²¹

Future Possibilities

South Africa's industrial strategy aims at becoming part of global aerospace supply chains. Already, several South African companies and research institutes are contractors to the Airbus consortium. Stand-alone national space programmes using ELVs have reached their financial ceilings. ISRO can afford to build and launch only one GSLV-3 per year. When AEB succeeds in launching its first satellite, it too will face the same one launch per year budgetary limits. Should South Africa in future seek to revive manufacture of the legacy technology *RSA-3*, its smaller budget will hit the same low ceiling for one launch and micro-satellite per year. Further, the *RSA-3 / Shavit* suffered from the inevitable drawbacks of adapting military missiles into space launchers. The military priority for robustness, and need to launch within minutes, necessitates solid propellants, which give lower performance than cryogenic propellants. An SRM is not throttleable for optimal thrust through max Q, nor *g* forces, nor vibration on the payload. The use of heritage fins, and vanes in the exhaust, instead of gimballed engines, also gave the *RSA-3 / Shavit* sub-optimal performance as a space launcher.

In the immediate future, South Africa's most-effective strategy for assured access to space will be to invite Antrix, SpaceX, and other foreign commercial space launchers to tender for launch services. In the long-term, ISRO's decadal budgetary commitment to R&D a TSTO RLV could lower the cost of access to orbit. The IBSA treaty could make it possible to broaden the partners in this. One Indian project of outstanding long-term potential,²² is for an air-breathing SSTO HOTOL RLV, termed, in its various incarnations, the Hyper-Plane, Avatar, Hypersonic Technology Vehicle (HTV), and Trans-Atmospheric Vehicle (TAV). This would cause a supply-side two orders of magnitude reduction in the costs of access to space.

South Africa would gain most of all from an RLV revolution, for it is on the tightest budget of any space player. The cryogenic propulsion capabilities of India, the manufacturing and marketing capacity of Brazil's Embraer, and the hugely under-used space infrastructure of South Africa, will make a perfect match.

This project of India's DRDO was mothballed after sixteen years of design work, 1987-2002. This was due to the twin intractable problems of intra-office politics, and inter-agency turf defence. These circumstances make the case to propose reviving the project under IBSA auspices. South Africa, and its allies Brazil and India, stand to gain more than others from the introduction of scheduled hypersonic and RLV flights, as they are budget-constrained, geographically far from other major industrial economies, and far from each other.

Conclusions

South African space policy is slowly but steadily taking institutional shape. Its drivers and constraints are the same that are familiar to other countries.

The most serious constraints are limited human and budgetary resources, bureaucratic politics, and institutional turf defence.

The drivers are:

First, it aims at industrial innovation for hi-tech materials and sub-systems, to increase capabilities to win contracts for manufacturing and software.

Second, South Africa seeks to boost its R&D. The DST is mandated to issue contracts for a further seven microsats over a decade.

Third, national prestige, and continental African pride, benefit from the halo effect of cutting-edge astronomy mega-projects such as SALT and the SKA. This, seen as puncturing stereotypes of Africa and Africans as "backward", provides much of the political will.

Fourth, space policy has exciting synergy with foreign policy, with the AU and IBSA prominently in mind.

Fifth, is increasing civil society support. This is currently small but enthusiastic, and growing. The necessity for a developing country to encourage more youth into S&T careers requires a major commitment of resources to popularize Astronautics and Astronomy, so as to build up future high-level human capital.

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