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Networks and contacts

- Use the NCPs both in South Africa and the EU to obtain additional information and links to individuals and institutions in your area of research interest.
- Partners must understand and clarify their respective roles before submitting a proposal. The contract should be understood by and acceptable to all the partners.
- Informal contacts already established with EU researchers through other programmes or mechanisms are often a useful place to start, but not all EU researchers are familiar with the FP.

Research areas

- Apply for research areas and within networks where South African experience and/or resources will be useful for EU partners. Keep to areas where South African expertise is strongest. Certain existing projects in South Africa are of interest to the EU and may be quite easy to link to EU projects.
- Social scientists and humanities researchers should not feel limited to the social science and humanities priority area 7. Natural scientists and engineers are urgently looking for social scientists to help with the social and multidisciplinary dimensions of their projects in all other priority areas.

Special opportunities

- Consider the mobility opportunities where funds are available for researchers from third countries to work in the EU and vice versa. There are funds for early stage researchers from South Africa (that is, those with less than four years' research experience and no doctorate) to work and gain research experience (and probably a doctorate) in the EU. For experienced researchers (those with a doctorate or more than four years' research experience) there are funding opportunities to undertake research in the EU for one or two years. The EU also wants South Africa and other non-member countries to support outgoing fellowships where EU researchers are funded by the EU to work in South Africa for one or two years. About €1.5 billion will be used to fund human resources development and mobility.

Notes

1. One euro (€) is currently equivalent to about R8.77 or US$1.1.
2. At the FP6 launch, Philippe Busquin, Commissioner for Research of the European Commission (EC), lamented the widening gap between R&D spending in Europe and the U.S. Ten years ago, he reported, Europe spent about €12 billion less than the U.S. on R&D: the gap is now more than €60 billion. The EC aims, by 2010, to reach an R&D expenditure level equivalent to 3% of GDP, up from around €164 billion in 2000 (i.e. 1.93% of GDP for the 15 EU member states). In contrast, according to its 1997–98 R&D survey, South Africa devoted only about 0.72% of GDP to R&D spending.
3. In a reciprocal move, South Africa has opened the Innovation Fund to applicants from the EU, provided that the lead organization of the consortium is South African.
4. Republic of South Africa (2002). *South Africa's National Research and Development Strategy*. Pretoria. (See *S. Afr. J. Sci.* **98**, 314; 2002.)

Lizard telemetry: an exercise in passive monitoring, skulduggery and embargoes

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An attempt twenty years ago to measure the internal temperature of a sand-diving lizard, *Meroles anchietae*, an inhabitant of the Namib Desert, by a novel microwave technique first used as an espionage device, and its subsequent thwarting by an international arms embargo, is described.

Introduction

A problem that had long confronted zoologists (and physiologists too) was how a quite remarkable lizard (*Meroles anchietae*, previously in the genus *Aporosaura*) survived when its usual habitat underwent daily variations in temperature in excess of 40°C. Its propensity for burrowing into the Namibian desert sands, where it stayed submerged for lengthy periods, seemingly held the key but quite how one measured its body temperature to verify this conjecture posed its own problems.

Strange as it may seem, it was the Cold War — an apt though inverted name in the circumstances — that provided a possible solution. It was to be found amongst the myriad electronic devices devoted to subterfuge and subversion that were used by the 'superpowers' as they held each other at bay by the threat of mutual annihilation. Such technology, however, was often classified Top Secret and beyond. To make life just that little bit more difficult, South Africa at that time was itself severely restricted in its machinations by an arms embargo imposed by the United Nations in 1977. That such things should also constrain honest scientific endeavour whose objectives were, at least to us innocents at the University of the Witwatersrand (Wits), so benign, was certainly not foreseen when the problem was first posed to the author in 1981. But constrain it they certainly did and *Aporosaura anchietae*, as we knew it then, was seen in some quarters as just another of those crafty code words for what was clearly South African subterfuge aimed at disguising military matters of much greater moment.

This brief account recalls a fascinating interlude in the early 1980s when a device code-named *SATYR* by British Intelligence formed the basis for a temperature telemetry system intended for implanting into a lizard that lives and thrives in the Namib Desert.

On lizards, Great Seals and bugs

The lizard in question (Fig. 1) weighs little more than a gram and is a mere 7 cm long with fringed toes and a duckbilled snout. These features make it the most agile of sand divers — a manoeuvre it executes both to escape its predators and also the searing desert heat in its native environment. The physiological mechanisms involved in maintaining some degree of thermal equilibrium were naturally of great interest to colleagues within the medical and science faculties at the university and reliable methods of measuring the processes at work had long been sought. However, size was the key since minimal physical encumbrance to the host creature was vital and only an electronic solution seemed viable. Even

Fig. 1. The Namibian sand-diving lizard *Meroles anchietae*.

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Fig. 2. A replica of the passive bugging device superimposed on the Great Seal of the U.S.A.

so, electronic packages, for all their micro-miniaturization, still required some form of battery to power them and it was this power source that usually provided most of their bulk. A device that could be powered remotely was clearly the long sought-after ideal. It came, at least as an idea, as a result of a long-running episode of espionage and counter-espionage carried on as a matter of routine between the embassies of the East and West.

In 1946, Soviet schoolchildren presented to the U.S. Ambassador in Moscow a 60-cm-diameter wooden plaque representing the Great Seal of the United States with the golden eagle resplendent at its centre. This fine piece of craftsmanship was duly hung in the ambassador's residence. However, there was more to it than a mere token of friendship. In 1952, during an exhaustive check for bugging devices in all the American embassies and residences abroad, the eagle was found to be an attentive listener as well as an effective communicator of information to its handlers nearby. In 1960, the U.S. Ambassador to the United Nations, Henry Cabot Lodge, in a carefully choreographed performance before the General Assembly, separated the two halves of the plaque to reveal the most ingenious of devices — a passive transponder powered by a radio signal transmitted from elsewhere (Fig. 2). In the case of the Great Seal in Moscow that signal had come from a vehicle conveniently parked beyond the boundary wall of the American embassy.

The technology of the bugging device was remarkable both in its simplicity and in its effectiveness. It was totally passive, containing no in-built power source of any kind, yet it functioned as a remotely powered transponder when stimulated by a carefully tuned transmitter some distance away. The key elements of the device were its cylindrical resonant cavity about 20 mm in diameter, and roughly the same length, with a diaphragm forming one of its faces. Protruding from the cavity was an antenna some 230 mm long. A radio signal, at the appropriate frequency, on striking the antenna would excite one of the resonant modes of the cavity that are determined simply by its size. Under this state of stimulation the cavity would be very sharply tuned and would exhibit, in the parlance of the communications engineer, 'a very high Q', thus rendering it most sensitive to any changes in its dimensions. These would occur as the diaphragm responded to any nearby sound and this movement would disturb, or modulate, the natural frequency of the resonator. This modulated signal would then be re-radiated by the antenna to be picked up by a sensitive receiver some distance away.[1]

Thus, by courtesy of those engaged in the nefarious activity of bugging, was born an idea as to how one might telemeter temperature information while, one hoped, causing minimal inconvenience to a small host creature. It now remained to turn such a fanciful idea into practice.

Before leaving the saga of this clandestine world, at least for the moment, it is appropriate to mention that the agents of British Intelligence as personified by James Bond and his comrade-in-arms, conveniently also known as 'Q' , were themselves skilled practitioners in this particular art of skulduggery. When it was published everywhere except in England in 1987, *Spycatcher*, Peter Wright's notorious account[2] of the machinations of MI5, revealed how he had unravelled the mystery of this Russian device to the amazement and admiration of his American counterparts. Wright it was who called it *SATYR*.

The problem of size

Our first attempt to produce a device capable of responding with an appropriate echo to a remote radio signal was severely hampered by its size. It was the principle that mattered, however, and if this could be shown to be sound then consideration could be given to ways and means of reducing the dimensions to suit the lizard. The prototype made use of standard X band (10 GHz) microwave equipment as found in most undergraduate teaching laboratories twenty years ago. The attempt to prove its feasibility formed the major part of a project undertaken by two students[3] in the final year of their electrical engineering degree at Wits in 1982. Since the size of a resonant cavity is directly related to the wavelength at which it operates, this 10-GHz frequency was far too low. The resulting 3-cm wavelength meant that a cylindrical metal tube approaching such dimensions would clearly hinder the movements of the lizard in question a little more than somewhat. However, the results obtained when testing this oversize system in the laboratory were most encouraging.

A cylindrical cavity, 47 mm in diameter and tuneable by means of a movable piston driven by a micrometer, was coupled to a horn antenna. It was then illuminated by a 10-GHz signal from a microwave source and parabolic antenna located nearby. A return signal, scattered by the cavity and its antenna, was received over a range of some metres using the same dish suitably connected to a microwave detector and monitoring oscilloscope. By adjusting the micrometer, the resonant frequency of the cavity was shifted by a few megahertz and this showed up as a distinct dip in the response displayed on the oscilloscope.

If, in a suitably designed system, a change in temperature could bring about a change in the dimensions of a cavity, then this experiment indicated that it was possible to detect that change. Suitable calibration would quantify the effect in terms of temperature, pressure or whatever.[4]

What now had to be done was to achieve miniaturization by a factor of at least ten. One way of doing that was by increasing the frequency to 100 GHz. In 1982 that was a demanding requirement; it remains no less daunting today. So another technique was sought. If the resonator were filled with a material of high dielectric constant K, then the wavelength of the fields within the cavity would be reduced by an amount inversely proportional to the square root of K. Various ceramic composites such as barium tetratitanate with a dielectric constant of about 40 and a very low loss tangent (to ensure high Q) had been developed so it was certainly feasible to reduce the cavity size by suitable dielectric loading. It turned out, on further investigation, that an emerging technology offered even more scope for miniaturization. Devices known as dielectric resonators, the size of a small medicinal tablet and which required no metallic housing, were at the forefront of such technology. With the assistance of two of the research institutes of the CSIR we were able to make considerable headway in exploring the possibilities. A cylindrical slice of barium tetratitanate, 3.5 mm in diameter and 1.4 mm thick, would exhibit all the characteristics we required at our X band frequency except for one — it was too insensitive to temperature. In most other applications of dielectric resonators every effort is made to ensure temperature stability, in ours it was a decided drawback since we wished to measure temperature by noting some change in the characteristics of the device. However, we discovered that compounds of strontium and titanium would be ideal for our purpose because they would exhibit a change in resonance at 10 GHz of some 4 MHz per degree Celsius, an amount well within the capability of our equipment to detect[5]. Such specially processed material, though, did not exist in South Africa and so our quest to obtain it began.

The United Nations intervenes

In 1983, dielectric resonator technology had not yet entered the mainstream of electronics: its applications tended to be confined to those tributaries serving the military. This, as it soon transpired, did not bode at all well for us in our ivory tower. Few will need reminding that South Africa at that time was viewed in many parts of the world as a pariah state — its policy of *apartheid* having condemned it to international odium. In 1977, the United Nations imposed a mandatory arms embargo on the country and though this had the effect of stimulating some sectors of its industry to feats of great resourcefulness, it immediately barred the country at large from gaining access to any equipment or technology likely to have military applications. It never occurred to us that an attempt to measure the temperature of a lizard in the Namib Desert would put our hardware into that category but, as others saw it, it did indeed.

Our initial approaches in May 1983 to a British manufacturer of advanced electronics materials met with an immediate and favourable response. They could certainly supply dielectric resonators to our specification and promised to explore other sources for more exotic materials not within their normal product range. By August, following further investigations in the laboratory, we had refined the specification and the order we placed that month spelt out in detail the characteristics and dimensions of the resonators required. But nothing happened.

We blamed the lack of an acknowledgement on the summer holidays in the northern hemisphere but the real reason was more sinister than that. When it came a month later, the response, previously so positive, was now decidedly terse: 'Please accept apologies for delay in replying. We did not receive your earlier telex[†]. I regret that we can not now quote for supply of the parts requested'.[6] Someone, clearly, had smelt not a lizard but a rat: South Africa was known to be interested in cutting-edge technology and had demonstrated considerable guile in acquiring it but this latest attempt was surely nonsense. *Meroles* (*Aporosaura*) *anchietae* was obviously much more than some sand-diving lacertid possessed of remarkable heat-dissipating qualities. It was, so they deduced in England, just a cunning ploy wrapped in the guise of a zoological curiosity to circumvent the arms embargo. And so the door slammed shut and we never received the material with its high dielectric constant and poor temperature coefficient, and the lizard escaped its fate of being the bearer of a transducer that, we thought, was rather clever.

All was not lost, however, at least in the interests of science. We published what we had achieved and in due course others elsewhere, who laboured under no such restrictions, were soon to exploit the idea, and the technique was certainly shown to be viable.[7]

Though we never quite got there, a Russian bug may yet find itself roaming in the Namib Desert.

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[†] The e-mail of the day.