Critical success factors in high-technology infrastructure projects: PBMR, SKA and RCP.

Rob Adam for the PAUL collaboration

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What is this presentation about?

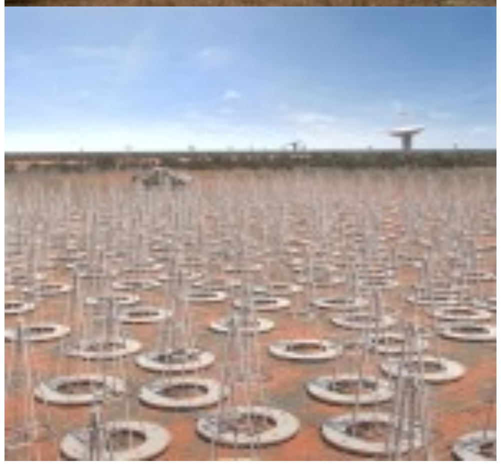
In this presentation to NACI I will examine critical success factors in high technology projects by comparing the Square Kilometre Array, the Pebble Bed Modular Reactor and the Reactor Conversion Project.

These three complex projects illustrate rather well what mistakes can be made both in the conceptualising and in the execution phases. The confluence of a range of diverse factors such as

- Simply getting something done
- Sufficient prototyping
- Understanding and balancing political stakeholders
- Understanding your market
- Getting the organisational culture right
- Managing company ambitions and aspirations

is necessary for success to be achieved.

What is the SKA?



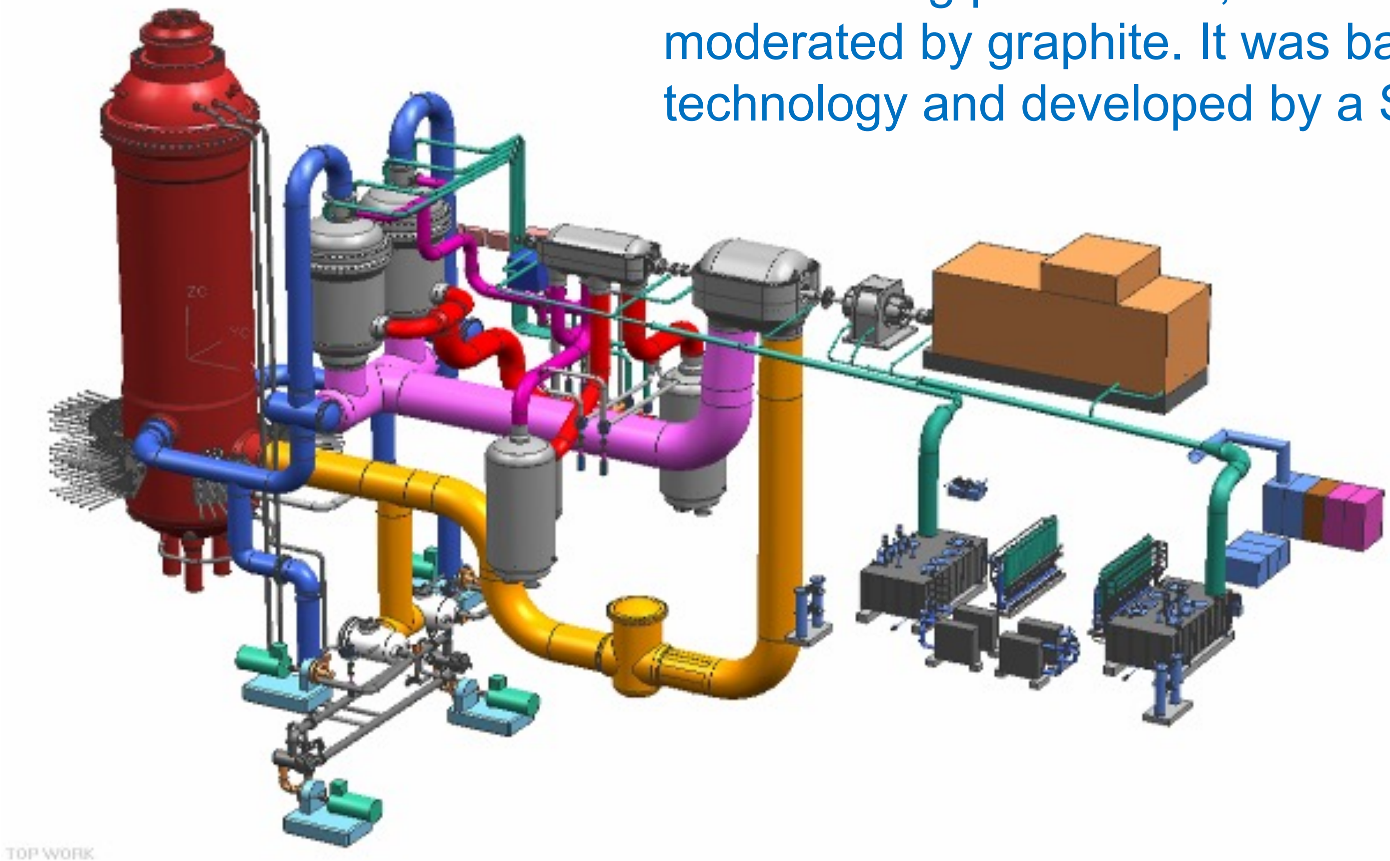
The Square Kilometre Array (SKA) project is an international effort to build the world's largest radio telescope, up to 50 times more powerful than any existing facility.

Hundreds and eventually thousands of mid to high frequency 15m dishes will be located in South Africa and Africa

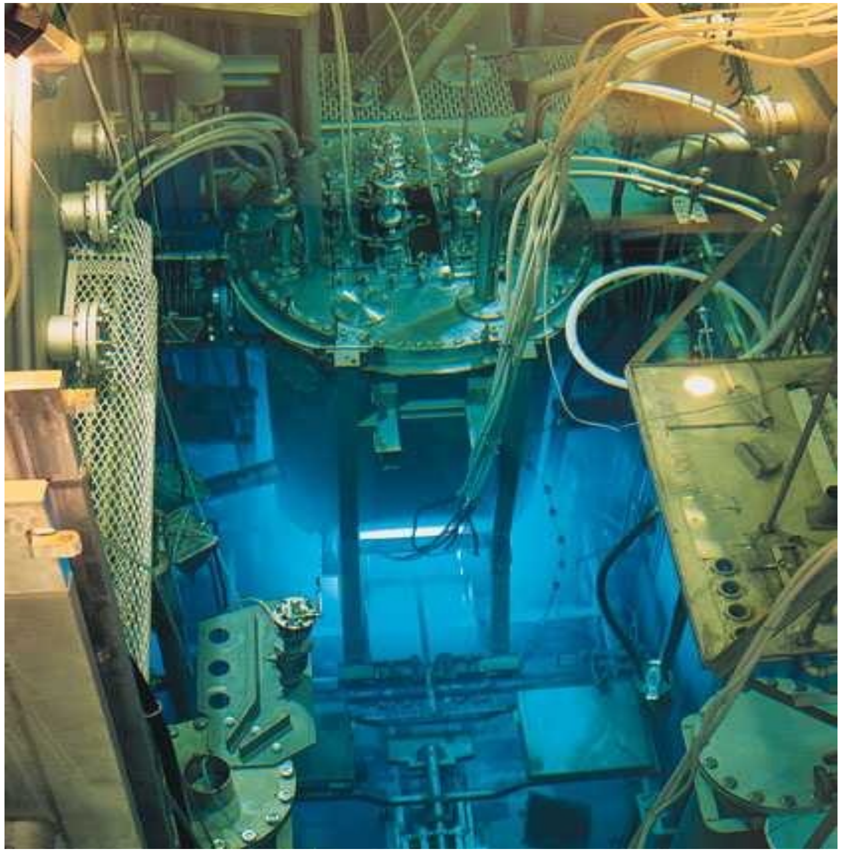
Hundreds of thousands and eventually up to a million low-frequency antennas will be located in Western Australia.

What was the PBMR?

The PBMR was a smallish high temperature nuclear reactor using pebble fuel, cooled with helium, and moderated by graphite. It was based on German technology and developed by a South African company.



What was the RCP?



The Reactor Conversion Project (RCP) was a project to convert the SAFARI research reactor from using weapons grade uranium as fuel and for making medical radioisotopes to using low enriched uranium. Through the RCP South Africa became the first country in the world to industrialise a low enriched uranium route for this technology.

Three iconic high technology projects with a South African footprint

- All with excellent global value propositions
- All with excellent local value propositions
- What went wrong and what went right?

PBMR: Global value proposition: technology

- **To generate electricity:** The higher temperature output (> 900C) would lead to more efficient electrical plants
- **To provide "process heat":** A carbon-free heat source for industries that require heat as part of their process
- **To provide high temperature steam:** For specialist applications such as "Enhanced Oil Extraction" (EOE)
- **To generate hydrogen:** By catalytic cracking of water, thereby transferring nuclear-origin energy to transport systems, steel production etc
- **To desalinate seawater:** Fresh water without generation of CO_2

PBMR: Global value proposition: safety

- **Thermal stability:** Core cannot melt or overheat beyond fuel failure temperature
- **Nuclear stability:** Nuclear transients will not lead to unacceptable power outputs
- **Chemical stability:** Fuel elements will not corrode excessively
- **Mechanical stability:** Core will not deform or change composition
- **All leading to:** Reactor cannot melt, practically no release of fission products, catastrophe-free nuclear power

SKA: Global value proposition

- **Transformational Science:** Capable of addressing key questions in physics and astronomy
- **Excellent observing conditions:** Low radio frequency interference and dry conditions
- **Affordable infrastructure:** Power, telecommunications and transport costs reasonable
- **Available local skills:** Sophisticated engineering and maintenance sector to ensure competent operations
- **Cooperative Host:** SA Government sees SKA as the jewel in its research system
- **Good location:** Astronomical richness of the Southern skies

RCP: Global value proposition

- **Health:** to provide affordable nuclear medicine worldwide

- **Combating nuclear terrorism :** to contribute positively to a global nuclear safeguards system, particularly in a post 911 world

- **A great moral example:** to epitomise swords to ploughshares technologies in the only country in history to have voluntarily decommissioned its entire nuclear weapons inventory

PBMR: Local value proposition

- **Local manufacturing:** Using PBMR design capability to stimulate a local high tech manufacturing capability
- **Addressing South Africa's "technology balance of payments":** Using SA competence in PBMR technology to capture an increasing part of the global supply chain for other nuclear power systems
- **Energy solution:** PBMR promised flexible, load following nuclear power in small modules.
- **Raising our game:** Participation in a massive international engineering project, with deliverables and deadlines Promoting high quality human resource development
- **Geopolitics :** A powerful footprint of modernity on the African continent

SKA: Local value proposition

- **Big data:** Development of South African capability in Big Data technologies.

- **Economic diversification:** Diversifying the Northern Cape economy towards technology and engineering support

- **Human resources:** Linking human resource development in South Africa with the best universities in the world.
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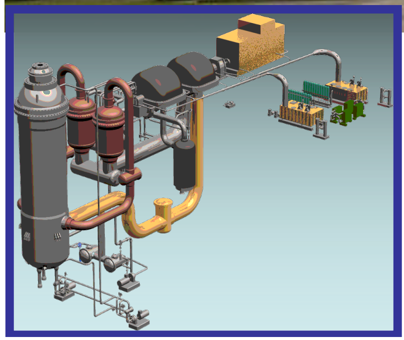
- **Raising our game:** Participation in a massive international engineering project, with deliverables and deadlines Promoting high quality human resource development

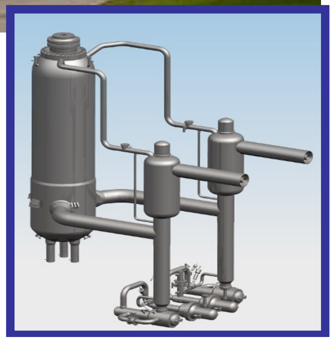
- **Geopolitics :** A powerful footprint of modernity on the African continent

RCP: Local value proposition

- **Local high tech production:** to create an industrial platform for radioisotopes production using Necsa's legacy capacity in strategic nuclear technology
- **Addressing South Africa's "technology balance of payments"** to capture an increasing part of the global radioisotopes supply chain by using SA competence in radioisotopes technology
- **Medical promotion of nuclear:** to deliver a social dividend for nuclear technology in the health sector via production of medical radioisotopes
- **Raising our game:** to compete with major industrial nations, deliver a high-value niche product and promote high-quality human resource development
- **Geopolitics :** A powerful footprint of modernity on the African continent

PBMR prototyping





The Arbeitsgemeinschaft Versuchsreaktor (AVR) was a prototype pebble bed reactor located outside the Julich Research Centre in Germany. It was an **indirect** cycle machine, commissioned in 1967 and ceasing operations in 1988.

No South African prototype was planned or built. Instead, the decision was made to go immediately for a **direct** cycle commercial reactor. Various technology problems identified in the AVR reactor were assigned to the in tray of the PBMR Chief Technology Officer, assuming they would be solved.

PBMR went straight from the Julich reactor to detailed commercial designs, which changed continually, causing regulatory delays and market uncertainty.

SKA prototyping

KAT-7

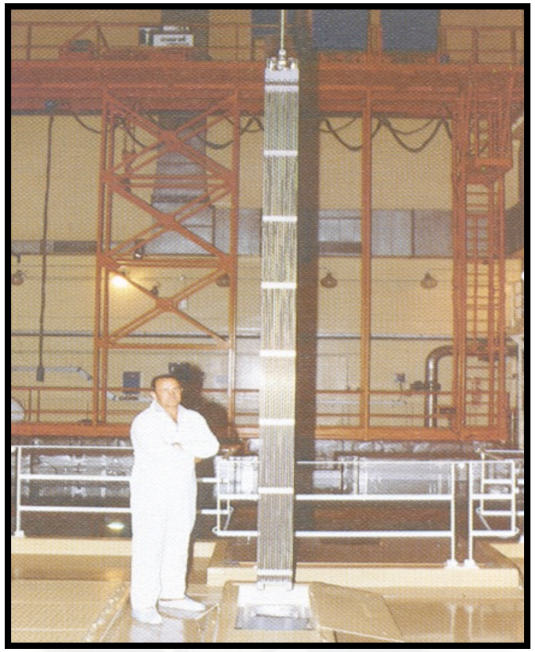
MeerKAT

A strong prototyping culture and practice is embedded. In South Africa we are already on the third generation of precursor instruments. XDM → KAT-7 → MeerKAT. Australia has ASKAP at Mid frequency in parallel with MeerKAT, and South Africa has HERA at low frequency.

HERA

ASKAP

RCP prototyping



Necsa/NTP staff leading the RCP had a background of success in strategic nuclear projects in uranium enrichment, weapons production and fuel manufacture during a period of limited international contact and assistance. They had developed, on their own, the nuclear and chemical processes to produce the key medical radioisotope molybdenum-99 using high-enriched uranium and understood very well the stepwise progression necessary for full industrialisation.

This broad range of highly developed nuclear skills, where prototyping and stepwise industrialisation were embedded in the engineering culture, stood them in good stead.

PBMR relationship with SA government

A **Eskom**

Eskom bought rights to exploit the PBMR intellectual property. It was seen as a commercially viable project initially, with potential for international sales. Later this view changed and in 2003 the Eskom Board voted to terminate PBMR work.

B **Strategic project**

The Presidency intervened to ensure continuation of the project for strategic reasons. It was transferred to the dti and later to DPE. Support outside these departments, particularly in National Treasury, was weaker and not enough was done to broaden political buy in.

C **Other shareholders**

Investors other than government proper included Eskom, the IDC, Westinghouse and Exelon. However, no shareholder agreement was concluded because the SA Government view was that SA should not give up hard won IP.

SKA relationship with SA government

A **DSI**

DSI/DST was and is the anchor department. The SKA has prospered through 6 Ministerial changes, remaining a flagship project.

B **Other departments**

From the outset key relationships were established with departments other than DST, particularly DIRCO and DoC.

C **Provincial Governments**

The Northern Cape and Western Cape governments are strong champions of the project.

RCP relationship with SA government

A

IAEA

RCP had a political trump card in the very strong support it was able to garner from the International Atomic Energy Agency (IAEA). This was based on medical applications of nuclear technology, as well as the global nuclear safeguards improvements achieved by the South African low enriched uranium technology. As a result, local political support was never in question.

B

Commercial strength

The RCP did not have the state funding that the PBMR had. In fact, it had largely to utilise its financial reserves built up through the sale of radioisotopes to finance the technology conversion. But this commercial viability was in fact a buffer against political caprice: money buys you independence.

PBMR and the market

A Energy planning

Although PBMR was highly suitable for smaller isolated towns it did not feature in national energy planning and the DoE regarded it as an R&D project.

B Eskom

Eskom had signed a letter of intent to buy 24 PBMR reactors. Subsequently this letter was withdrawn and an offer was made to purchase the first reactor for a nominal sum. After this, PBMR courted Sasol, proposing a process heat platform. However, nowhere in the world were regulations in place for the colocation of chemical and nuclear plants….

C Global

Globally the major vendors were focusing on marketing their large Generation III reactors. Small modular reactors such as PBMR were seen to be in the future. Regulators were also not ready. Much talk in PBMR was about suitability for Africa, which was not ready either.

SKA and the "market"

A **International**

The SKA has been prioritised by the national science infrastructure planning processes in a number of countries. Consortia consisting of over 100 companies from 20 countries were involved in technology down selection.

B **Local**

An ambitious HCD programme where over 1300 researchers and students have been funded to participate in SKA programmes has been undertaken over the past 10 years. In the latest call for proposals from the international community, 19 successful proposals have SA PIs

C **Successful prototypes**

The good performance of the prototypes has whetted the appetite of the global radio astronomy community.

RCP and the market

A **Commercial success**

NTP had developed a reputation as a reliable supplier of molybdenum-99 and other radioisotopes over several years and was exporting to 55 countries, using its internally developed BU shielded container, which was licensed in 50 countries. In fact NTP was one of the top four producers of radioisotopes in the world.

B **Diplomatic success**

The Canadian reactor at Chalk River, then the world's then largest supplier of moly-99, was shut down for major repairs in 2009, and South Africa was asked by the IAEA and various Pretoria based foreign ambassadors to step into the breach.

C **Receptive market**

So it was into a fairly receptive global market that, in 2010, NTP was able to introduce its first batches of low-enriched uranium derived moly. The political and commercial dividends were immense: here was the first country in history to have unilaterally abandoned its nuclear weapons programme now setting a new global safeguards standard in radioisotope production.

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Lesson 1 ***Get something done!***

Concrete needs to be poured as soon as practically possible! Unless political sponsors have something to show to the public, they are unlikely to deliver new resources. This is strongly linked to prototyping, which gives the chance for many ribbon cuttings. Project leaders got this wrong with the PBMR, right with the RCP and right with the SKA.

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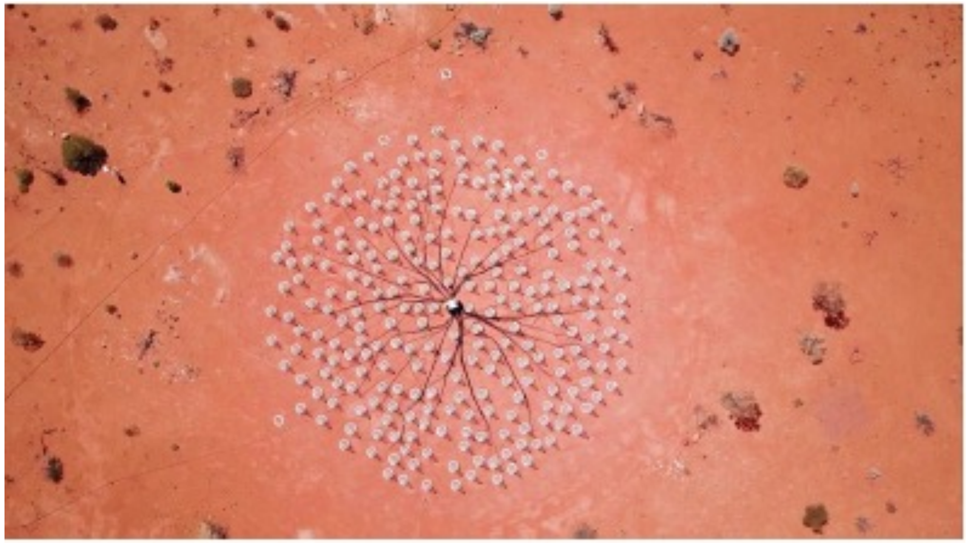
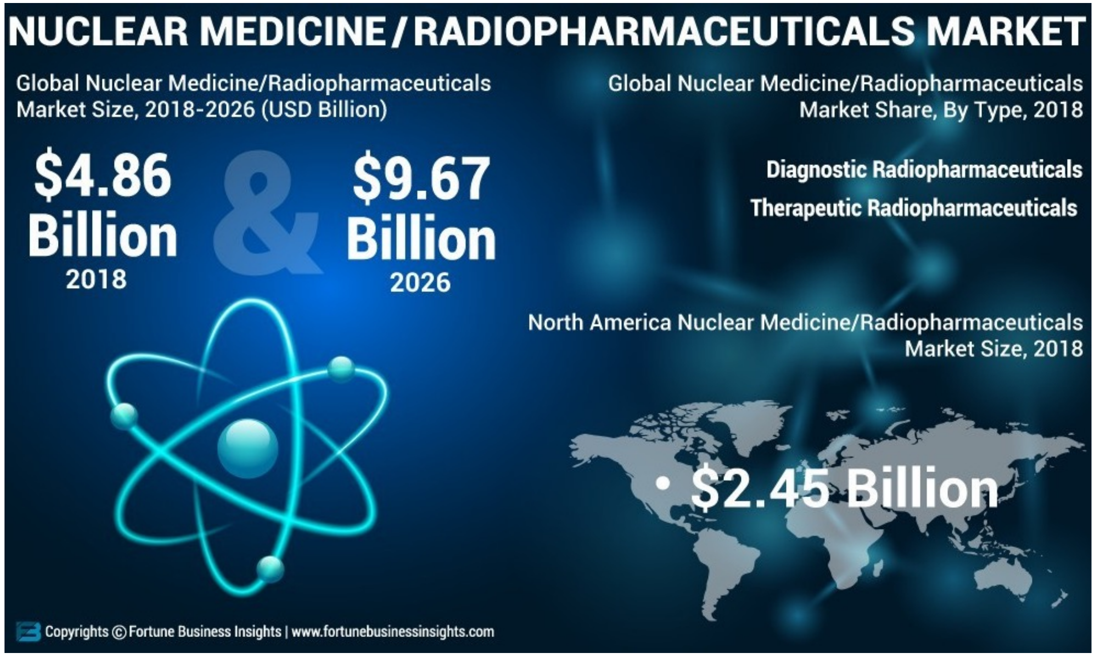
Lesson 2 *Don’t skimp on prototyping*

It is necessary to separate R&D from construction, otherwise the product keeps changing. The regulators will delay the project asking questions about the changes and require new tests, resulting in major cost escalation. In the case of the PBMR, this was the fatal error, based on impatience and exemplifying the old adage “more haste, less speed.” In contrast, both RCP and SKA have been models of patient progression from demonstration of concept, to prototype to precursor to the final product.



Lessons 3 ***Understand your market***

In the PBMR there was a very optimistic and unfocused view of the market. Was it power generation, was it supply of process heat? Was it small new nuclear countries, was it established nuclear nations? With RCP it was very clear, that its market was the big United States' radiopharmaceuticals market, based on support from the US Department of Energy and the Nuclear Security Agency. With SKA the market is primarily the radio astronomy and fundamental physics communities, with the main spin-offs being in big data.



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Lesson 4 ***Have more than one champion***

Building multiple strong alliances will give the project stability no matter what. The project leadership failed to do this in PBMR, relying politically on a single strong Minister whose political fate was linked to that of his principal. In the SKA and RCP, many lines upward were established.

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Lesson 5 ***Have the right culture***

In a large high-tech project a careful rigorous engineering culture needs to be fostered rather than a carelessly brilliant science culture or a military gung-ho culture. If every brilliant scientific idea is heeded, no concrete will ever be poured! Of course, new science can shake the foundations of a project. But there need to be very good reasons for changing an engineering game plan. Often strong contributors to high-tech engineering projects have a military technology background. The military is an environment where the fundamental urgency of the mission is seen to trump everything else. Regulators are seen as subordinate beings. But in the civilian world they have it in their power to slow projects down interminably, so caution and politeness should be the order of the day! The responsibility to direct organisational culture resides at leadership rather than management level. The delicate balance between getting the job done at all costs (military), doing the job right (engineering), and doing the right job (science) has to be top of mind for every leader of a high-tech project.




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Lesson 6 ***Understand your limitations***

Partners must be selected to complement one another and to share risk and their aspirations must be respected – greed manifested by trying to dominate is a cardinal sin. In the SKA, the balance of interests works more naturally, given the fact that with membership of the SKA come both rights and responsibilities. It is not in the interests of the project to let the costs blow up, but you also need to ensure that all members are more or less happy with the deal they've been handed. In the PBMR this was mismanaged. Because South Africa didn't want to share the dividends deriving from what was seen as largely locally developed intellectual property, it ended up taking on all the risk. And when there was a political shift, that risk was seen to be too large and the project was cancelled. In the RCP there were several partners, not all of whom had the same objectives, but fortunately those objectives were not incompatible. The IAEA wanted to promote the contribution of nuclear technology to global health enhancement. The South African government wanted to promote South Africa as a producer of disruptive technology and to encourage Necsa as a generator of foreign exchange. The US Government wanted to promote technologies that were compatible with their stringent post-9/11 nuclear safeguards requirements. Leading the project successfully involved making everyone feel they got what they wanted.

Thank you!

The material for this presentation was drawn largely from the paper cited below:

R. M. Adam (2020) *"Technology, policy and politics: critical success factors in high-technology infrastructure projects*", Social Dynamics, 46:3, 378-390, DOI: 10.1080/02533952.2020.1850619

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