Implementation and Costing of Recommendations of the International Panel on Shaping the Future of Physics in South Africa

1. Summary

The science and engineering base in South Africa is a major user of high technology – the innovative product of physics endeavours. In recent years the South African Institute of Physics has felt increasingly concerned with the state of support for physics, the interest in physics, and the impact that physics has on the economy of South Africa. Reflecting these concerns during the years 2001 to 2003, Council and in particular the then President of the South African Institute of Physics, engaged with the Department of Science and Technology and the National Research Foundation to initiate a process that would have as its ultimate result the repositioning of physics in South Africa. These three principals (DST, NRF and SAIP) collectively developed and launched the project to shape the future of physics in South Africa.

The project was to be both a review of the state of physics and a foresight into the future. An International Panel that was tasked to undertake the review and foresight operated under huge time constraints, consulted with various stakeholders and submitted their report to the SAIP, DST and NRF. Whereas the report does not propose concrete reforms, it advances a series of suggestions for future action by Council of the SAIP, the management of Physics departments and research centres, and the South African authorities, ranging from mechanisms for coordination, to policies for training of physics (scientists and engineers), to the identification of strategic projects in physics (science and technology).

The Physics community was invited to identify strategic initiatives that they wished to pursue, or projects that they consider important to be initiated by one or more of the stakeholders, based on the recommendations of the International Panel. It was also important that the projects be costed for budgeting purposes. The Council has considered these proposals, and where necessary, refined the project suggestions and proposals.

Not all of these recommendations require direct funding, while others are interdisciplinary in nature and will be funded by other means. However, they do require active engagement of the SAIP with the responsible institutions. Therefore, only direct funding that is required specifically for Physics is listed.

Each of the 14 Executive Recommendations of the Panel is listed, followed by suggestions for implementation and projected costs. A summary of the cost is provided at the beginning of the document. The projects are of such a nature that the regular funding for Science and Technology would probably not cater for these activities, and substantial additional funding, directed at these activities, is required. The SAIP Council is mindful of National initiatives in SET that might have similar objectives and would welcome the inclusion of our recommended projects in those initiatives.

Three priority categories are assigned. The highest priority (A) of the SAIP is the establishment of a full-time institute office (recommendation 15), to create an effective link of physics into society, while recommendations 1, 2 and 5 also need urgent attention and action. Recommendation 12 has already been approved in principle. Most of the recommendations will only come to proper fruition through the activities of this office. A good example is Recommendation 11 on infrastructure and equipment. Dedicated and well-coordinated attention is needed to make the country's significant pool of physics and interdisciplinary equipment optimally accessible to academia, in particular in the "small science" sphere.

The second part of the document summarises the responses that were received from the Physics community to the report. These responses have played a part in selecting the priorities.

A follow-up by the Management and Policy Committee is foreseen once responses from the DST and NRF are received. Important considerations then will be how to administer funding, given the high degree of diversity of the recommendations, and how to communicate the responsibilities to the various parties responsible.

H. Moraal, President SAIP — E.C Zingu, Past President SAIP

31 July 2005

2. Summary of costs

Priority	Recom-mendation	Activity	1st year	Average for Subsequent Years	5 year total
A	1	Primary and Secondary Education	190 000	217 000	624 000
A	2	Undergraduate and Postgraduate Education	370 000	89 250	727 000
C	3	Marketing of Physics in Industry	79 000	0	79 000
C	4	Public Understanding	2 250 000	2 871 000	13 736 000
A	5	Human Resource Development	7 833 000	9 997 000	47 821 000
B	6	Research Information Network	19 000 000	24 250 000	116 000 000
C	7	National Research Digital Library (costed elsewhere)	0	0	0
C	8	Flagship Projects (costed partially)	883 000	0	883 000
B	9	Long-term Strategy	0	0	0
C	10	Small Science	0	0	0
A	11	Infrastructure and Equipment	20 150 000	20 000 000	100 150 000
A	12	Theoretical Physics (costed elsewhere)	0	0	0
C	13	Technological Spin-off	0	0	0
B	14	Management and Policy Committee	20 000	20 000	60 000
A	15	SAIP Office	692 000	655 000	3 312 000
		Totals	**51 427 000**	**49 978 000**	**250 999 000**

Inflationary increases of 10% per annum, as published for the education sector, are included. Recommendations 9, 10 and 13 do not require new funding. Number 12 is already funded, while it was impossible to estimate the cost of 7 (the digital library).

Priority ranking:
A: Highest priority, request for immediate implementation
B: Implementation in the short term.
C: Future implementation

3. Implementation and Costing of Individual Recommendations

Each of the 14 Executive Recommendations of the Panel is listed in italics, followed by suggestions for implementation and projected costs. Where necessary, reference is made to sub-recommendations that form part of the Executive Recommendation. The organisations in square brackets were deemed by the Panel to be the main responsible parties.

1. ***Primary and Secondary Education.*** *In many countries, elementary and secondary school teaching of mathematics and science is a considerable worry. In South Africa this situation is exacerbated in the historically black schools. Although beyond the scope of this inquiry, we must flag this very serious situation. We acknowledge that steps are being taken to address this matter, but urge the relevant authorities to pursue it with even more vigour, as it is a crisis situation. Individuals in the physics community are to be commended for their activity in this regard, but more involvement is needed, particularly at the structural level. [SAIP, NRF, DOE*].

Implementation and Costing

Education is the cornerstone of every nation's economic vitality. Investment in education and training in science and technology appear to be a necessary condition for economic development. Technology benefits from investment in SET, through the constructive application of technology, depends on many other factors. A general education system with an effective science and mathematics curriculum for all students is therefore critical for supporting the South African industrial development. We believe that the new FET Curriculum (to be introduced in 2006) is intended to provide a more effective education. Many schools fail to provide this quality education. The reasons go beyond immediate indices of failure, such as poorly prepared teachers, low attendance, inadequate school buildings and inadequate curriculum materials, etc. Racial practices of the past have resulted in inequitable state funding and inadequate provisioning of schooling facilities. Funding for our public school system remains inadequate in many cities and rural areas and a renewed commitment to providing equal access to quality education for all learners, regardless of race, colour, national origin, gender, disability, poverty, or parental status, is required. We therefore recommend that the DoE in conjunction with the DST should ensure the following:

- Adequate funding is to be provided that will provide all learners with well qualified, appropriately paid teachers, sufficient and appropriate curriculum materials, including books, libraries, technology, and laboratories.
- Adequate funds to be provided to reduce class size.
- Recruitment of talented teachers to teach critical subjects such as Science and Mathematics in all schools, and especially in rural schools by offering incentives. We acknowledge that teachers are often unskilled or inexperienced, or qualified only in subjects that are no longer in demand. Due to chronic staff shortages, teachers are sometimes required to take classes for which they are untrained or ill prepared professionally.

Although there is no straightforward relationship between the resources that governments invest in their education systems and the success of their students, there is evidence that below certain thresholds in resources the quality of schooling deteriorates.

A long-term DOE strategy involving all Physics Departments and the SAIP is required to develop physics teachers and teaching materials. This development is for both pre-service and in-service teachers, as well as helping natural science teachers at lower levels with the physics component of science. In the USA, many Physics Departments offer special courses for teachers. In France, the French Academy of Sciences is actively involved in promoting activity-based science teaching in primary schools.

From 2006-2008 a new curriculum will be phased in for the FET (Grade 10-12) band. This curriculum will require a deeper understanding of physics than the previous curriculum. Even now, there are too few Grade 12 learners exiting the school system with a pass in Physical Science on Higher Grade, creating a bottleneck in the provision of potential scientists, engineers and technicians in the country. Without extensive urgent interventions, this situation will get worse when the new curriculum is introduced.

In the SAIP, Physics Education is represented by one of seven specialist groups, and there are a number of SAIP members who are active in the research area of Physics Education. The SAIP is therefore well placed to assist the Department of Education in providing preparation and support for teachers for the physics components of the new Physical Science curriculum. The SAIP has already negotiated with the DST to hold a two-day workshop in 2005 for representatives of all university Physics Departments in order to familiarise them with the new Physics FET curriculum as a first step in the development of courses for Physics teachers around the country.

Ongoing support will be needed for Departments of Physics to further develop and run courses for both in-service and pre-service teachers, focusing initially on the FET band. There are several ways to do this. Possibly one of the quickest ways to get such courses up and running would be to contract a small team of physics educators to develop course materials and then offer several additional workshops for representatives of Physics Departments and Science Education Units to train them in the use of the materials. The materials will need to include not only the relevant Physics content but also appropriate, activity-based teaching approaches which will be compatible with the outcomes-based education philosophy that underpins the entire new school curriculum. It is envisaged that Physics Departments will work closely with Education Departments in their regions of the country in order to ensure that the support offered to teachers is appropriate and is taken up by as many teachers as possible.

Estimated costs over three years:

Development of course materials

- Grade 10 R80 000 (2005)
- Grade 11 R88 000 (2006)
- Grade 12 R96 000 (2007)

Running of 2-day national workshops for training institutions (including accommodation, meals, transport, equipment)

- Grade 10 R100 000 (2006)
- Grade 11 R110 000 (2007)
- Grade 12 R120 000 (2008)

Representation of the SAIP at relevant workshops and on relevant committees organised by and with the Department of Education and DST

- R10 000 per year for three years

TOTAL COST R 624 000

Note: The Grade 10 materials should be developed in 2005, so courses for teachers can be implemented as early as possible in 2006, when they will be teaching the new Grade 10 curriculum.

2. ***Undergraduate and Postgraduate Education.*** *The long-term sustainable future of physics in SA depends on the country's commitment and investment in the development of a workforce that is representative of its demographic diversity. Evidence indicates that, while there is a rapidly growing cadre of physics students from previously under-represented groups, there are perceived difficulties that need to be addressed by the established physics community and by the funding authorities. Apart from financial barriers to both undergraduate and postgraduate study (addressed below), there are others matters of concern, such as that relating to the integration of students of different cultures into existing departments, particularly in regard to the transfer of students from HBU's to HWU's. These questions need to be addressed urgently, and interpersonal communication is of the essence. [University community].*

Implementation and Costing

Since the financial barriers are addressed in Recommendation 5, the remaining part of this recommendation is about the integration of students of different cultures into existing departments, particularly in regard to the transfer of students between institutions. This happens almost exclusively on the honours and MSc level, with no significant transfer happening while students are busy with their first degree. Therefore, the most important requirement is to identify the problems being experienced by students having completed their first degree, and shifting to other institutions for postgraduate studies.

The implementation of the issues around good communication, transfer between institutions, and departmental attitudes towards these, should consist of identifying all third-year students at all universities who are majoring in physics. Interview those at institutions with weak or no postgraduate programmes personally early in the year, to determine their capabilities and desire to study physics on the post-graduate level, and make them aware of all the possibilities. Follow-up is needed and the project must be repeated for five years. Funding requirements: Cost of transport and accommodation to travel to 10 universities for a 3-day stay, to conduct interviews = R 40 000 per year plus salary for 3 months = R 30 000, total R 70 000 per year. Total cost over five years = R 350 000 plus 10% inflation adjustment.

In its new constitution the SAIP created a student committee with the chair serving as student member on Council. This committee was constituted in July 2005, and it will serve an integral role in the investigation, particularly in the attitude and adaptation issue as it is perceived by students.

We also draw attention to **Sub-recommendation 4.2.1:** *The panel recommends that the Department of Education and the SAIP should conduct an audit of academic support programmes in "unplugging the Physics pipeline", and on the basis of their success the state should allocate targeted funding to HEI's for appropriate academic support programmes to develop the necessary Physics base for the country [DOE, SAIP].*

The SAIP is of the opinion that most of the major universities have exemplary foundation or academic support programmes with a high degree of success, but that the major problem starts when these students are released into the mainstream programmes. The mainstream curricula and the way in which they are taught there are often inappropriate to retain these students. The same also applies to mainstream students, and therefore the broader problem how to attract more students into Physics and how to retain them must be addressed. Both can be partially addressed through offering courses that students find interesting and relevant to their lives and future careers. At present, there is no forum at which physicists from all higher education institutions can discuss their curricula. There are a number of modern trends in physics offerings internationally, as well as developments in physics itself, but it is not known to what extent these trends are reflected in undergraduate physics curricula in South Africa. Some of these trends are discussed in the proceedings of a conference held in 2004, jointly sponsored by the SAIP and the International Commission on Physics Education, entitled "What Physics Should We Teach?" For example, there is a need to incorporate more contemporary physics topics, as well as the explicit development of a variety of cognitive, experimental and communication skills. There is also a vast body of literature on conceptual difficulties students typically experience with physics and how to address them.

A forum is therefore needed at which Physics Departments can discuss modern trends in Physics education, their own undergraduate curricula and what would be most appropriate for South African students who want to both make a contribution locally and be part of an international community of scientists. Part of the discussion should focus on the structure and contents of Physics courses that are appropriate for different audiences, such as foundation students, future teachers, users of physics (e.g. health and life science students), and future physicists. In the first instance, there should be an intensive, five-day workshop. There would be a few local and international plenary speakers, but most of the time would be spent in working groups, which would be expected to produce concrete recommendations. For future years, the SAIP is considering an additional day added on to the SAIP conference for continued discussions on curriculum and other educational matters.

Estimated costs (cost of transport to venue for local delegates excluded):

60 People x R 500/night (meals and accommodation) x 5 nights = R 150 000
3 Plenary speakers x R 25 000/speaker (all inclusive) = R 75 000
Venue hire @ R 4000/day x 5 days = R 20 000
Production of proceedings (printing and editing) = R 50 000
Administration (tel., fax, photocopies, etc) = R 5000

Total cost (one time) R 300 000

3. ***Marketing of Physics in Industry.*** *Job prospects in Physics are perceived by many young people to be poor, and this affects the take-up of the subject in schools and universities, but this is illusory. Both industry and business welcome them, for both technical and managerial careers, but this is not made apparent. The fault appears to lie on both sides, employers not making it clear that physicists are welcome to apply for their vacancies, and physicists not being sufficiently proactive. We recommend that the SAIP mount a "connectivity-campaign". [SAIP]*

Implementation and Costing

The implementation should consist of several parts:

Physicists in academia should be contacted for information of their past graduates. These graduates should be contacted for updated information about their status. Cost over 12 months: R18 000

Compile a list of key industries employing physicists. Identify physicists working there. Contact these physicists for updated information about their status. Work with the Human Sciences Resources Council.

Cost over 12 months: R24 000+ fee to HSRC of approximately R10 000

A final category would be "Unlikely jobs that physicists have been employed in". This would require more research and effort. Still, the contracted staff member should make an effort to track down physicists working in, for example, commercial banks. Cost over 12 months: R12 000

A database that is accessible should be established. The entire process of information gathering and storage and reporting must be sustainable for future years so that the database is regularly updated. Collaborate with the NRF. Implement a data capturing process whereby all graduate students who are currently in the system are tagged and surveyed on an annual basis. Cost over 12 months: R12 000

The task should involve gathering some information on international trends. Cost over 6 months: R3 000.

"Cost" above refers to payment to contracted staff. The contracted persons must have good inter-personal skills and good computer skills and data management skills. The person must be able to work independently. It is recommended that we employ different people (students?) to perform the different tasks, but the task must be supervised and managed by the new SAIP office in collaboration with the NRF.

Total cost: R 79 000

4. ***Public Understanding.*** *The "Public Understanding of Science" is increasingly important, not least for a democratic nation where the wide appreciation of science is vital. Much is being done but we recommend more, particularly as "the public" consists of many constituencies, all of which are important. [SAIP]*

Implementation and Costing

This action is wider than Physics alone and should continue to be funded as such (e.g. through SAASTA). The establishment of an SAIP office with a permanent staff would be essential to enable and co-ordinate these activities. This requires a skilled, experienced enthusiastic person with a physics background. It will probably be necessary to have more than one person to sufficiently develop all the activities below. Therefore, additional funding over and above the SAIP Office (Recommendation 15) is required. The Table summarises the activities and the target constituencies, and indicates where these may be relevant. The ordering does not necessarily imply relative merit.

		Constituencies						
Activities		Layper-son	Teach-er	Schol-ar	Indus-try	Govern-ment	Media	Acti-vist
	Science Centres	X	X	X			X	
	Science Competitions		X	X				
	SAIP Web-site expansion of services	X	X	X	X	X	X	X
	Targeted Interventions	X	X	X	X	X	X	X
	Newsletter More and expanded		X	X	X	X	X	X
	Construct formal Relationships		X	X	X	X	X	X
	Communication networks	X	X	X	X	X	X	X
	Maintain databases of specific information	X	X	X	X	X	X	X
	"Ask a Physicist"	X	X	X	X	X	X	X
	Feature writing						X	
	Popular Lectures	X	X	X				
	Outreach Visits		X	X				
	Facility Tours	X	X	X				
	Professional Services Register		X	X	X	X	X	X
	Media development	X	X	X			X	

Science Centres: Here the person from a given constituency makes the effort to visit the Science Centre. There seems to be widespread agreement based on quite impressive throughput figures that these are an excellent method for exposing large numbers of the public and scholars to science at a relatively low *per capita* cost. However, capital and running costs are large. For instance, SciBono has a construction budget of R150M. It is expected that no additional funding from a SAIP-related budgets will be allocated here.

Science Competitions: These should be expanded, to include projects (even for groups), beyond the Olympiads which currently play an excellent role. The budget must include administration, advertising, media, program development, assessment processes, honoraria for the organizers involved and travel arrangements for an award ceremony. The approved budget for the 2005 Physics Olympiad was R 108 000. This, plus one additional competition per year will cost R 200 000.

SAIP WWW-site – Expansion of Services: This would allow a website which aimed at something like the Institute of Physics site at www.iop.org. The site must contain real benefits for visitors (information, articles, access to services). Much of the material could be generated from activities already in place or mentioned in this document under additional budgets. It would be necessary to marshal information already available. Consequently, only the part salary of an expert senior physicist and a web-designer fee are necessary (R 100 000)

Targeted Interventions: Each constituency above can be targeted separately with current topical issues. In some cases, it may simply be a periodic intervention which flags the attention of the constituency to the spread of activities mentioned here. For example, attendance at meetings of the constituency group to draw their attention to a particular service (e.g. make schools aware of a database of visits, tours, lectures, programmes and information that is available from the SAIP web-site). In other cases, it may be necessary to make a more permanent linkage. For example, dedicate a team to meet with government and industry on an issue like the PBMR. This is mostly a manpower problem. However, some honoraria / part-time salary may be involved. (R100 000)

SAIP Newsletter – more and expanded: The on-line newsletter should grow and be targeted at the different constituencies. It could be run by the permanent SAIP office, and so be funded through that budget item.

Construct Formal Relationships: Here it is necessary for the SAIP office to identify all groupings within the various constituencies and establish formal relationships. This will include regular communication, distribution of the appropriate newsletter and collaboration over any common targeted issues.

Communication networks: This is something that will grow having drawn its material as a result of progress on other items. Lines of communication would be the www-page, targeted visits, meetings via the formal relationships and collection of the information facilitating communications in the online database.

Maintain Databases of Specific Information: The database would be online and accessible to all constituencies, via an authorization protocol if necessary. It would contain information useful to any constituency – expertise availability, facility availability, opportunities for liaison with any of the outreach activities, diary of important events, articles on topical issues, important linkages and gateways for science, contact information, careers information, funding linkages etc. This would be a core task of the SAIP permanent office.

"Ask a Physicist": This is a web based interface to e-mail participating Academics. It requires the initial design and set-up, and then regular maintenance. It will allow questions to be submitted through a structured process that identifies the target academic by fields and sub-fields. It can be directed to support teachers, scholars and an interface to business. It has a set-up and maintenance costs of R 100 000 per year, and will need housekeeping and evaluation.

Feature writing: This requires an interface to the science writers in South Africa. There are contacts, but these are sporadic, not regularly followed up and not developed. Science writers regularly require a list of accessible experts to assist them with specific articles. The process of generating material for articles and highlighting newsy science issues can also be nurtured. It would require co-ordination, also through the SAIP permanent office.

Popular lectures: These can become a regular feature of each institution. They would ideally be named lecture series, and develop a following. There are also itinerant lecture series "Physics on Parade" etc. These need partial support of R 50 000 per year for travel/accommodation expenses and honoraria.

Outreach visits: The various outreach programmes of the SAIP need to be co-ordinated and evaluated. A model for increased participation and proliferation of the programs needs to be developed. The model needs to be developed in conjunction with the regional Science Centres as well as the appropriate Provincial Education Department and all linked together by a MoU. A regular budget for these programs is necessary. A culture of outreach in students must be nurtured (This is how the profession is renewed and how the minds of future stakeholders are shaped). It requires a champion co-ordinator as well as regular funding. This could be seed funding, as the programmes can be done together with business. (R200 000 co-ordinator plus R 1M per year)

Facility tours: This is a matter of co-ordination through the new permanent office of the SAIP via its www-site. It could be part of the STYLE schools programme. Each tertiary institution, scientific based industry, government laboratory or similar institution would volunteer an accessible contact with whom groups seeking a tour could liaise with. No budget is necessary. Institutions fund each visit internally.

Professional services register: This is again service that can be offered by SAIP via its www-site to support interaction with teaching as well as industry. No funding is necessary beyond the resources of the SAIP permanent office.

Media development: This relates to posters, publications and videos. For example, the SAIP has wanted to develop a Promotional Physics Video that South Africans can relate to for several years. One would need to employ the services of professionals in the media development. Much material is available. The regular media could also be involved in developing material for television if they could be persuaded it was interesting. (R 500 000 per year)

Total cost for public understanding: R 2 250 000 per year, plus 10% p.a inflation.

5. ***Human Resource Development: Bursary Scheme for Undergraduate and Postgraduate Studies.*** *There is considerable concern in the science community about the low level of remuneration in academe, school-teaching and student bursaries. In particular, we propose a revised bursary scheme with the intention of minimising the financial barrier for students to enter physics and to stay in physics, especially in comparison with competing career paths. The proposed bursary scheme is ideally based on the concept of free tertiary education for science students. We recognise the competing claims on national resources, but an upward revision of salaries and bursaries is essential. A serious "brain-drain" will result if salaries are kept low. [SAIP, NRF, DOE, Universities].*

The following sub-recommendations were made

1. *The state should introduce a bursary-loan scheme for students training as teachers of "scarce skills" such as physics.*
2. *Differential salaries should be introduced, with science teachers being paid a premium over and above salaries paid to teachers involved in subjects that are not designated as "scarce skills.*
3. *We recommend free education for all physics major students, and the replacement of race discrimination in bursaries by means tests.*
4. *Realising that strong measures such as these may not be immediately implementable, but without abandoning the rigorous position, we suggest as interim measures: (a) providing tuition and accommodation loans for all 3rd year students in Physics, which are transformed into bursaries for those completing their degrees in the minimum period (three years), (b) providing tuition and accommodation bursaries for all Honours students in Physics, including Medical Physics students.*
5. *We recommend that a much more vigorous policy of providing postdoctoral fellowships be pursued, and that special funds be made available for outstanding young scientists to develop new lines of research (existing funding for P-rated scientists does not provide adequately for equipment infrastructure).*

Implementation and Costing

The size of the R&D workforce in South Africa has been declining steadily since the early 1990's. Higher education in South Africa has not managed to attract sufficient young physicists into the universities to strengthen and expand our knowledge base. A regeneration of the scientific workforce, as well as broadened participation in scientific endeavours that include majorities of black and female physicists in research and academia, is required. The recently announced Women in Physics in South Africa project by DST is intended to attract and support women who were up to now underrepresented in physics activities. Various strategies have been initiated by the NRF to attract and support black students in science in general and it is hoped that their participation in physics will be increased. A number of flagship-type projects that will be strategic for South Africa have been launched or proposed in recent years. Some of these projects have been implemented and are nearing completion. Others have attracted consideration for feasibility studies. The projects include SALT, PBMR, SKA, a National Synchrotron Light Source initiative, Femtosecond Laser Facility, etc. Fundamental to all these projects is the need for human resources. The development of a critical sized user base as well as the expertise to develop some of these facilities is dependent on the necessary human resources being in place. In order to attract students into physics, career opportunities should be obvious and the study opportunities should be attractive.

Items (1) and (2) of the sub-recommendations are DoE responsibilities, while (3) is an ideal. Therefore, they are not costed here. However, we need to take the initiative to request our partners, the DST and NRF (perhaps through the MPC) to join us in engaging with DoE on these and other matters.

The projected cost for (4) is based on an estimate of the number of students who graduated in Physics in 2003, as submitted by individual departments to the SAIP: B.Sc. 145; B.Sc. Hons. 29; M.Sc. 18; Ph.D. 8. In the following the assumption is made that there are sufficient B.Sc. students, but that the postgraduate numbers should double. Thus, the estimated requirement is:

• 145 B.Sc. 3rd years @ R 15 000 (tuition only)	R 2 175 000
• 60 B.Sc. Hons @ R 30 000	R 1 800 000
• 36 M.Sc.@ R 40 000 x 2 years study period	R 2 880 000
• 16 Ph.D. @ R 65 000 x 3 years study period	R 3 120 000
• 16 Postdoctoral fellowships @ R 150 000 x 2 years (bottom scale lecturer)	R 4 800 000
Subtotal A	R 14 775 000

In 2003 the NRF funded the following numbers in Physics (these are numbers of bursaries per year; not number of persons as above):

• 2 B.Sc. 3rd years @ R 6 000	R 16 000
• 13 B.Sc. Hons + BTech Final @ R 8 000 (Grantholder bursaries)	R 104 000
• 7 B.Sc. Hons @ R 15 000 (Prestige & Equity bursaries)	R 105 000
• 13 B.Sc. Hons @ R 25 000 (Scarce Skills bursaries)	R 325 000
• 39 M.Sc. @ R 20 000 (Grantholder bursaries)	R 780 000
• 12 M.Sc. @ R 33 000 (Prestige & Equity bursaries)	R 396 000
• 23 M.Sc. @ R 40 000 (Scarce Skills bursaries)	R 920 000
• 35 Ph.D. @ R 30 000 (Grantholder bursaries)	R1 050 000
• 11 Ph.D. @ R 50 000 (Prestige & Equity bursaries)	R 550 000
• 11 Ph.D. @ R 65 000 (Scarce Skills bursaries)	R 716 000
• 12 Postdoctoral fellowships @ R 82 500 average	R 1 980 000
Subtotal B	R 6 942 000
Net cost (Subtotal A – Subtotal B)	**R 7 833 000**

Notes:

- The bursaries are the absolute minimum required to draw and retain true talent in the face of fierce competition from the professional and economic sciences, where tied bursaries of up to R 30 000 p.a. are offered for **first year** students.
- The largest component of the increased cost goes into B.Sc. and B.Sc. Hons. support. This forms part of what the Panel calls "unplugging the Physics pipeline".
- According to HoD statistics, 18 M.Sc. students (on average) are delivered per year. The NRF, however, lists 74 M.Sc. bursaries. These numbers do not match, unless M.Sc. students take four years on average to complete their degrees, or if the NRF numbers are the bursaries that are reserved (but not necessarily taken up). The same discrepancy holds for Ph.D's. These numbers therefore need to be revised and refined, and it means that the amount of R 5 943 000 is an upper limit.

6. ***Research Information Network.*** *We recommend the creation of a fast, inexpensive, broadband National Research Information Network to support non-commercial research. This is vital not only for the National Research Digital Library suggested below, but in order to permit the maximum exploitation by South African scientists of data provided by national investments similar in scope to the proposed Square Kilometer Array. Projects of this type are likely to be the trend of the future and the lack of a system like the NRIN will mean that the dissemination of high value knowledge skills will, at a minimum, be severely constricted. [NRF, DST]*

Implementation and Costing

The cost of internet usage is calculated as follows. North-West University (Potchefstroom campus) generated 7 811 GB of traffic for the year from July 2004 to June 2005. Of this traffic 8% was national, and since the cost of national traffic is much lower than that of international traffic, the cost structure is determined by international traffic alone. The School of Physics and the Unit of Space Physics generated 1,67 % of this traffic, i.e. 130 GB per year. The cost structure is not only determined by the total amount, but primarily by the peak usage of bandwidth. Analysis of this usage reveals that, at the current cost of raw bandwidth, the cost for Physics Potchefstroom users was R 7850 per month, or R 94 000 per year. The School of Physics and the Unit for Space Physics have 9 active, full-time lecturers/researchers plus their infrastructure of support staff and postgraduate students. This group is probably weighted towards the heavier users. We therefore estimate that the current usage for all Physics departments and research institutions around the country will be 20 times as large, i.e. R 1 880 000 per year. The North-West

University IT department advises that the potential need is 10 to 20 times larger than this current usage to put scientists on a comparable level with their international colleagues. Therefore, the total need for Physics in South Africa at current prices is estimated at between R 19 M and R 38 M per year. The lower number is costed in the summary.

(Attention is drawn to the problem that in some cases the problem includes payment of institutional electricity accounts, and access to computer laboratories. In those cases "access" means much more than the internet connection, i.e. that the facilities are available to students and staff, and that they are functional.)

7. ***National Research Digital Library.*** *We recommend the creation of a National Research Digital Library Resource. Such a structure would provide subscription to electronic journals that will be accessible over the internet, and hence available to all universities (both staff and students), and selected non-commercial researchers. If the physics programmes of this nation are to be competitive, this is a vital need. It is clear that such a resource will have a transformational nature also, since even remotely located Universities will also be able to access the latest research findings, with the caveat of the necessity of ready internet access. [NRF, DST]*

Implementation and Costing

A workshop regarding the creation of a NRDLR was held in 2004 at the NRF, in collaboration with the Coalition of South African Library Consortia (COSALC). The CSIR and the University of Pretoria are busy with a feasibility study on the South African Research Information System (SARIS, draft document of 15 November 2004 available). Money for the study was allocated by the Ford Foundation, and their report is expected in 2005. This project also involves DoE, DST and DTI. A central facility should probably be situated in Pretoria/Johannesburg. It is suggested that an appropriate facility could be the NRF, as this certainly would fall within the mandate of the NRF. It is envisaged that all tertiary institutions and national research facilities will form part of the NRDLR, and provide some financial assistance for annual costs of subscribing to the journals. Funding would also have to be provided by government probably through the DoE, DST and DTI. These departments, together with the NRF, would then form the governance of the NRDLR. Tertiary and research institutions currently spend about R 100 million on electronic sources (SARIS information).

It is proposed that the SAIP join forces with SARIS, as this venture has already done a lot of groundwork towards a central digital library facility in South Africa. The annual cost of subscribing to ScienceDirect and other Physics related electronic journals is ~ R 70 million. Together with operating costs, the cost of such a centre would be in the order of ~ R 100 million.

It was impossible to get an accurate estimate of Physics-specific costs within the limited time available.

8. ***Flagship Projects.*** *The Panel noted with pleasure the overall level of research and the existence of some excellent projects, although relatively few in number. Particularly impressive is the attitude of researchers towards the new "flagship projects" - projects that we applaud. We recommend that these projects be seen both to act as a focus for much of the scientific work in their respective areas, and to provide links to apparently unrelated branches of physics. [SAIP, DST, Physics community]*

Implementation and Costing

In the course of the survey, and in part because of its recommendations, several new flagship projects in South African Physics have been established, or are being planned at present. The most notable ones are: (a) an Institute of Theoretical Physics (see recommendation 12) which has been approved in principle by DST, (b) a Frontier Programme in Astronomy, currently being set up between the community and NRF/DST, (c) a Centre of Excellence in Strong Materials with the main hub at the University of the Witwatersrand, (d) a commitment towards the Square Kilometre Array, and (e) a DST driven initiative for a South African Synchrotron Light Source. All of these are funded through separate channels.

In addition to these, the SAIP endorses an initiative from its Lasers, Optics and Spectroscopy Specialist Group (attached), to develop a strategy for Femtosecond Laser Research and Applications in Africa. The suggested vision is to establish a high power femtosecond laser "flagship" facility for interdisciplinary femtosecond science, although the establishment and roll-out could be step-wise. Femtosecond lasers lend themselves to a parallel and modular approach of deployment and the facilities can be phased and scaled according to need and availability of funding. One logical approach would be to have a two-stage approach, with a first phase development (up to 10 – 30 TW) followed by a second phase extending the power to the finally anticipated ultrahigh power level (1 PW). This initiative is driven by scientists mainly from the Universities of Stellenbosch and the Witwatersrand, together with the National Laser Centre and has the support of the African Laser Centre. This initiative requires the following funding to develop a strategy for this proposed "flagship" project:

Contract fees	305 200
Travel (including summer school lecturers)	187 600
Accommodation (including summer school and ALC conference)	329 600
Venue costs	17 900
VAT	42 728
Total	R 883 028

This funding is for strategy development only; part of this strategy is to access funding from other sources.

9. ***Long-term Strategy.*** *The onus is on the physics community to develop a long-term strategy for the subject, which addresses national developmental priorities as well as keeping the research internationally competitive. Such a strategy should, inter alia, aim at optimising both access to and the efficient use of, expensive equipment, and to facilitate the use of existing expertise by encouraging collaboration, thereby reducing the barrier to innovation. This may lead to the establishment of a limited number of other "flagship" projects and/or National User Facilities (NUF's) on a scale more comprehensive than hitherto, and with an emphasis on facilitatory governance. Proposals for such projects should ensure a balance between funds for equipment, including its periodic updating, and those of staffing and maintenance. The concept of a NUF is described in more detail in Chapter 4 and Appendix 4 of the Report. [NRF]*

Implementation and Costing

The strategy is the joint responsibility of DST/NRF/SAIP and can only be implemented through a series of workshops and planning sessions. A two-day time slot immediately before or after the annual SAIP conference in the first week of July is ideal.

10. ***Small Science.*** *Preoccupation with flagship projects and National User Facilities should not lead to the neglect of other areas of research. International experience has shown that "small science" has not only been a major training ground, and the forerunner, scientifically, of many large projects, but has also been a major vehicle for innovation and intellectual property development. Thus there is a need for strong support for "small science", preferably in the context of collaboration. [NRF, SAIP]*

Implementation and Costing

Research students are the lifeblood of such efforts and their availability needs the most serious and immediate attention. There is a danger (a trend already) that flagship projects will draw junior postgraduate students (Honours and MSc) from campuses towards collaborative teaching and research programmes. A big attractor is that the bursaries in such programmes are larger than NRF Grant Holder Bursaries. Small science can only flourish if departments are able to maintain well-balanced postgraduate schools (honours through to post-doctoral level). They also need these students to assist with their undergraduate teaching programmes – this is world-wide best practice. Under the current subsidy rules universities will not support flagship projects that draw their students away. Equitable opportunities and funding for small vs. big science therefore needs serious attention in an interaction between the SAIP, NRF and DST, with strong representation form universities.

11. ***Infrastructure and Equipment.*** *There is considerable concern about the state of the research infrastructure. According to the data received, much of the equipment in university departments is out of date or inadequate. The Panel recommends that SA makes a rational investment in modernizing its research infrastructure to meet the scientific requirements, as well as with the objective of training the future generation of young scientists and engineers with globally competitive skills. The Panel recommends that appropriate mechanisms for funding and optimal utilization of existing resources be put in place at all levels of the scientific needs. [NRF, DST, Department of Education]*

Implementation and costing

The National Research and Technology Audit developed a database of research equipment and generated a scenario of the status of such equipment in 1998. The equipment infrastructure for research was characterised as old, not enabling South African researchers to compete effectively internationally. Since 2000 no targeted capital programme existed in government to address the crisis in research equipment that was evolving, particularly in the higher education sector. However, the Technology and Human Resources for Industry Programme (THRIP) has contributed just over R100 million (R34 million government and R63 million (industry) for expensive research equipment during the period 2000 to 2002. In recent years, the Innovation Fund has funded substantial research equipment that was determined to be necessary for the projects.

The lack of adequate and state-of-the-art equipment impacts negatively on the training of human resources with adequate skills in physics and related disciplines. South Africa has embarked on several flagship projects which are dependent on expertise in physics or requires the support of physics. The South African Large Telescope (SALT) and the Pebble Bed Modular Reactor (PBMR) are but two such projects. Several initiatives have been launched to explore the feasibility of major facilities or bidding for locating international projects in South Africa. These include the National Synchrotron Light Source, the Square Kilometer Array, the Femtosecond Laser Source, and others. Research in associated fields of physics is essential to support the large facilities that are being planned or about to be commissioned. Such research in physics will require state-of-the-art equipment.

A study is required to identify the crucial fields of physics that are required to support or supplement all these new strategic facilities that have attracted considerable investments from government. This should be followed by a due diligence study to determine the state of research equipment available in South Africa and accessible elsewhere, that could be used to support or complement the new facilities. A national equipment strategy, based on the NRF equipment strategy of 2004 should then be initiated to ensure that strategic fields of physics are strengthened to support the technological development in the country. It should lead to a National User Facility. Cost effective mobility grants and inter-institutional usage form the most important parts of this strategy. The study would also identify other equipment in physics research laboratories that require replacement to enable researchers to remain internationally competitive.

The SAIP office (Recommendation 15) is imperative for the success of this strategy. It needs to be driven by the Physics community itself to ensure credibility and ownership, and to facilitate regular report-back to the community. The annual SAIP conference, such as the day before or after this conference, provides the ideal opportunity. If the office is established soon, the first workshop can take place in July 2006.

Cost:

- Review and due diligence study. This should be assigned to a small team (say 3 persons) co-ordinated by the SAIP office. Cost: R150 000.
- Equipment and infrastructure workshops at the annual SAIP conference require no direct costing.
- Replacement Fund. This would depend on the identified needs. A high resolution, high voltage electron microscope, for instance, would cost R 24 million. Therefore, the cost for critical replacements of much-needed, but currently outdated equipment is at least R 20 million per year.

12. ***Theoretical Physics.*** *The state of theoretical physics is characterised as internationally competitive in some areas, but there is fragmentation and a coherent policy is needed in the nation. We recommend the establishment of a National Theoretical Physics Facility (either real or virtual); the theoretical physics community will then be able to respond nimbly to national science policy initiatives. [NRF]*

Implementation and Costing

A proposal for the establishment of a South African National Institute of Theoretical Physics (NITheP) by the Organization of Theoretical Physicists (OTP) was endorsed by the SAIP, and approved in principle by DST through seeding money that was granted in June 2005. Projected costs at the time of submission were R 3,5M, R 4,7M, and R 5,6M for 2006, 2007 and 2008. Since this project is already in the pipeline, it is not costed in the summary.

13. ***Technological Spin-off.*** *An important effect of physics research projects is technological spin-off. Advanced research projects not only bring immediate "rewards" to industry and commerce in the form of orders for technologically advanced equipment, but they also raise the possibility of new, previously unforeseen, developments. "Astro-technology" is an excellent example and we recommend that it be used as a prototype, and that physicists make use of the structures that encourage links to industry and innovation. [NRF, DST, SAIP]*

Implementation and Costing

An extensive network for the support of innovation, industrialisation and commercialisation is in place. It consists of programmes such as Thrip, the Innovation Fund, and the Special Programme for Industrial Innovation, operated by the NRF, DTI, and IDC. These programmes each have their own criteria, but generally they focus on support from the stage of patent registration/functional demonstrator to a production data pack. The issue here is not the direct availability of funding, but rather an education amongst scientists to build the bridge between these two phases through proper project management and systems engineering. Training courses, for instance offered by the Innovation Fund are available. All the relevant information is available on the web page of the Department of Science and Technology at http://www.dst.gov.za/programmes/research_funding/research_funding.htm.

This recommendation does not require any direct funding.

14. *Management and Policy Committee.* *We recommend that the Management and Policy Committee should remain in existence as a monitoring body, and that the SAIP, DST and NRF should report back to it in a year from now. The MPC should inform the community on the extent to which the Panel's recommendations have been implemented. [MPC]*

Implementation and Costing

The SAIP takes the initiative with the submission of this document to the other two partners (DST, NRF). It is envisaged that the first report-back meeting to the MPC will take place on the basis of the response received from these partners.

Travel and subsistence costs for 10 people of R 20 000 per year for three years.

(15.) *SAIP Office.* *This recommendation did not have a number in the Executive Summary of the Panel's document.*

It is recommended that funding be made available (from DST) for a restricted period (say 5 years, renewable) to enable an office with a full-time secretariat of a small number of "employees" to be formed. They would be responsible for implementing the programme of the Council of the SAIP, which would include serving physics and physicists nationwide. Special emphasis would be placed on:

- developing a national strategy for physics;
- increasing public awareness;
- interfacing with government departments on science issues;
- interfacing with and improving the lot of physics teachers, particularly in schools;
- forging stronger links between universities, national facilities, science councils, industry and commerce;
- ensuring a greater acceptability of a physics training for posts in industry and commerce;
- improving students' access to information on both bursary sources and employers;
- making sure that both the joys of physics and the availability of jobs are known in schools and elsewhere; and
- monitoring the implementation of reviews such as this and reporting back to the community.[DST, NRF]

Implementation and Costing

It is essential that the SAIP has such a permanent office if it is to be an effective body in the service of physics and society. The office would serve to link the physics community with its stakeholders and thereby facilitate the impact of physics on the national development agenda. The ideal location would be in close association with DST and/or NRF, allowing it to act as a conduit between the physics community and the policy makers. In the long run we see the office becoming a vibrant self funding operation of the nature of, e.g. the Institute of Physics in the UK. In the short term the appointment of an Executive Officer plus administrative assistance would go a long way towards enabling SAIP to function as the voice of physics in South Africa. The Executive Officer will take a leading role, under the guidance of the Council, in developing a strategy that will ensure a flourishing future for physics in South Africa. Specific responsibilities will include:

- Identifying public issues in which physicists should make a contribution;
- Supporting the teaching of physics at all levels;
- Supporting physicists in all professions and careers;
- Furthering the public appreciation of physics;
- Writing reports on issues of interest, as directed by Council;
- Ensuring that prospective employers understand the value of physics and physicists;
- Keeping database information on the employment of physicists in all professions;
- Fund raising;
- Identifying opportunities (e.g. jobs, grants, scholarships, equipment, etc) and bringing them to the attention of the membership;
- Liaising with other organization both nationally (e.g. DST, dti, DoE, NRF …) and internationally (e.g. IoP, IAP, NSBP …);

- Taking broad responsibility for communications with the public and particularly with the media;
- Participating in meetings of Council.

The public outreach, marketing and support responsibilities are the most important and are described in much more detail under recommendation 4.

Qualifications: PhD in physics or a closely related discipline and several year's relevant experience, e.g. in industry, academia or government. The Executive officer must have a passion for physics and a clear understanding of the potential of physics to support development in Southern Africa. (S)he must also be self motivated, self reliant and an extremely good communicator.

The preliminary budget given below is for 2006 and assumes that the officer operates within the NRF conditions of service. Office space and basic logistical support, IT, security, electricity, etc to be provided by hosts (DST/NRF) – no cost is included for this, although we assume a levy would be payable to the host institution. While a component for travel is included, because interacting with people will be essential, there is no attempt here to finance special projects or conferences.

Annual	R
Salary (including pension, medical aid, etc)	460000
Administrative/secretarial assistance	100000
Travel	40000
Stationary, printing, computer requisites etc.	10000
Phone, fax, post etc.	3000
Refreshments	2000
NRF/DST Levy	50000
Total	**655000**

Start-up Costs	
Recruitment	15000
Furniture	9000
Computer Requirements (Laptop, printer, flash disk etc)	13000
Total	**37000**

The SAIP has committed an amount of R 100 000 in its budget for 2006 for this purpose.

RESPONSES BY PHYSICS DEPARTMENTS AND SAIP SPECIALIST GROUPS
to
RECOMMENDATIONS OF THE INTERNATIONAL PANEL ON THE FUTURE OF PHYSICS

(Received October 2004)

Physics departments and SAIP Specialist groups were requested to respond to the recommendations in the Future of Physics report, with the specific request for information on:

1. A prioritised list of recommendations that they consider important to be implemented in order to achieve the objectives. Their opinions would guide the various stakeholders in developing a strategy to implement the key recommendations.
2. A list of recommendations that their department/specialist group is considering implementing, or that have already been implemented.

Responses were received from:

1. University of the Free State
2. University of the Western Cape
3. University of Stellenbosch
4. North-West University (Potchefstroom Campus)
5. University of Port Elizabeth
6. Port Elizabeth Technikon
7. University of South Africa (Astronomy Department)
8. Specialist Group Astrophysics and Space Science
9. Specialist Group Condensed Matter Physics and Materials Science
10. Specialist Group Theoretical Physics
11. Specialist Group Lasers, Optics and Spectroscopy
12. Specialist Group Education
13. Specialist Group Applied and Industrial Physics
14. Physics Students

These responses are summarised as follows:

A. Recommendations that are strongly supported (In order of most frequently mentioned.)

1. Importance of education at secondary and primary schools, and of teacher training.
UWC, UPE, UNISA, US, EDU, NWU, STUDENTS
2. Links with industry and other groups.
APPLIED, UWC, UPE, SSPMS, ASTRO, CMPMS, EDU
3. Central laboratory/equipment facilities — UWC, UPE, CMPMS, ASTRO
4. Importance of broadband links, a central digital library, and the Saris initiative.
UWC, ASTRO
5. Establishment of an SAIP office — APPLIED, NWU
6. Free tertiary education for physicists (as a scarce skill). — ASTRO
7. Audit of academic support programmes in South Africa. — UPE

B. Shortcomings of the report

1. No mention of the importance of Physics Education research. — UWC, EDU
2. Concern that too little consultation/background work has gone into the flagship concept. — US
3. No recommendation about Physics as a separate school subject. — EDU
4. The section dealing with "women in physics" is unacceptable. — ASTRO

C. General comments

1. Many of the recommendations cannot be followed up by individual members of the community unless the relevant funding bodies take note of the recommendations. ASTRO
2. There is a lack of critical mass in research areas, too many small and diversified departments/activities. Need to form a smaller number of larger, stronger departments and provide only service courses at other campuses. ASTRO
3. SKA ambitions will grow cross-discipline interactions. ASTRO
4. Astronomy in SA provides numerous examples of how an apparently "blue-skies" science can lead students to financially and intellectually rewarding careers. ASTRO
5. Students are not convinced of the benefit of student physics societies. STUDENTS
6. Students do not perceive funding during study as their biggest problem, but finding a job afterwards. STUDENTS
7. Physicsts are not empowered to become technology transferers. APPLIED

D. New projects/initiatives as a result of/aligned with the recommendations

1. The Theoretical Physics Specialist Group/Organisation of Theoretical Physicists focuses on the recommendation concerning the establishment of a National Theoretical Physics Facility. A committee is writing a proposal, asking for endorsement by Council on 29 October 2004. THEOR
2. The Lasers, Optics and Spectroscopy Specialist Group is in the process of identifying femto-second laser research as an interdisciplinary flagship project. A steering committee is drawing up a proposal to be submitted to DST by the end of October 2004, and endorsement is sought from Council on 29 October 2004. LASER
3. The establishment of an Institute of Astronomy on the grounds of the SAAO in Cape Town as a University National Facility is being discussed. ASTRO

E. Initiatives taken by departments and specialist groups

Teaching, Recruitment and Outreach:

1. Active involvement (leadership role) of the Education Specialist Group in the final form of the FET Physics curriculum. EDU
2. Departments are actively involved in recruitment programmes. Holiday work for students is standard practice, as is the attempt to enable third year students to attend the annual SAIP Conference. Departments continue to play an active role in obtaining funding for students. If students fail to qualify for funding, NRF Grantholder bursaries are used to fund such students. Schools are invited to initiate science societies. PETech, UWC, UPE, UNISA, UNW, EDU
3. Establishment of a Physics Olympiad from 2005. EDU
4. Improved teacher/physicist interaction (Physics on Parade) as from 2005 EDU
5. UPE has registered academic programmes with SAQA, implemented in conjunction with the Department of Science, Mathematics and Technology Education (SMATE) at UPE. The department is willing to assist with the training of school laboratory assistants, in collaboration with SMATE. UPE
6. The Physics Departments at UWC and at Zululand University have started a graduate school in Applied Physics in conjunction with iThemba LABS in 2004. There are two complementary endpoints, a Masters in Accelerator and Nuclear Science and one in Material Science. The honours year will be followed by a one-year Masters course with a full research thesis. Funding for such collaborative teaching should be made a priority. UWC
7. Bursary schemes at undergraduate level to attract students to postgraduate studies. NWU, PETech
8. The RTCC of the SKA makes provision for post-doctoral grants, and will pro-actively seek candidates for these grants. ASTRO

Marketing and public image

1. Awards Programme of the CMPMS and its media coverage. CMPMS

2. Minquiz Science quiz for secondary schools competition, radio and TV programmes (Semaka). CMPMS, UPE

3. PETech has invested in three astronomical telescopes for public viewing/lectures. The Physics Department of UPE has recently joined this initiative. PETech

4. Astronomy presentations with actual (mobile) telescopes on HET level. UNISA

5. Unisa has an introductory astronomy course from which all mathematics has been removed. Teachers could register for this module for non-degree purposes if they want to improve their astronomy knowledge. UNISA

Research

1. National/shared equipment is already being implemented for electron microscopes, atomic force microscopes, etc. Existing Innovation Fund projects are examples of such sharing of resources. UPE hopes to submit a proposal for the establishment of a national facility for High Resolution Electron Microscopy. UPE

2. The National Astrophysics and Space Science Programme (NASSP) is a consortium of SA universities and national facilities that has been set up to train MSc and PhD students. ASTRO

3. HartRAO plans to extend its National Facility mandate to include a microwave laboratory, a digital electronics laboratory and a configurable/high performance computing facility, freely available to academic researchers. ASTRO

4. Material Development and Characterization. This is built around the Center of Excellence project on Strong Materials led by Wits, but include many other initiatives at many universities. CMPMS

Applied Physics/Industry collaboration

1. UWC has initiated a number of research projects with direct applications, e.g. research on radon detectors for use in South African Gold mines, research into Bio-ceramics, innovative solar cells, and the use of natural radioactivity. Projects have been done for or with ESKOM, TELKOM, NAMPAK, SANS and the NNR. UWC

2. Both the Innovation Project of RAU/UPE/UP on cheaper solar cell material and the PBMR project have technological spin-offs, and bring academe and industry together. UPE

3. Photo-responsive Materials NRF Innovation Fund project for the production of cheaper solar cells is led by the group at RAU, together with UPE and UP. CMPMS

4. Pebble Bed Modular Reactor. Led by NECSA. Apart from the huge industrial impact, many other spin-off projects will originate from this project, where material properties need to be assessed. CMPMS
   The RTCC management of the SKA will identify partnerships and pro-actively drive industrial collaboration. ASTRO

5. HartRAO is increasing its user base in various ways - will engage engineering faculties in SA and extend interaction beyond Physics departments. The RTCC will provide mobility funding for SA researchers to participate in SKA-related work at HartRAO (and other institutions). The SKA will engage a wide range of scientists and engineers in the project. ASTRO

6. A major objective of the Astronomical Geographical Advantage Programme (AGAP) funding instrument from DST and the SKA RTCC is the establishment of a technology hub that is driven by the high technology requirements of astronomy. Many technologies used in modern astronomy have generic applications, and thus have commercial value. We are investigating the application of the "ASTRON model" where the RTCC would develop into a technology centre that would service the needs of international observatories and any industry that requires a high-tech partner. ASTRO

7. The Applied and Industrial Specialist Group undertakes to provide a forum for communication between industry and academia – in various ways. APPLIED