A National
Theoretical Physics Facility
for South Africa

A proposal for the establishment of a South African

National Institute for Theoretical Physics (NITheP)

by the Organization of Theoretical Physicists (OTP)

supported by the South African Institute of Physics (SAIP)

Submitted to DST and NRF November 2004

Proposal drafted by a Working Committee of the OTP elected at the AGM of the OTP, Bloemfontein, 1 July 2004

- HB Geyer (Chair) – University of Stellenbosch
- M Braun – University of Pretoria
- R de Mello Koch – University of the Witwatersrand
- FJW Hahne – AIMS & STIAS
- KK Müller-Nedebock – University of Stellenbosch
- F Petruccione – University of KwaZulu-Natal
- JAP Rodrigues – University of the Witwatersrand

Alternate members

- N Chetty – University of KwaZulu-Natal
- JW Cleymans – University of Cape Town

Endorsements and support for the proposed South African NITheP

"I would like to give my strongest endorsement of the proposal to establish a Theoretical Physics National Facility at STIAS, with satellites at Witwatersrand and Kwazulu-Natal.

It is internationally recognised that a theoretical physics institute of the proposed type plays an essential driving role in the development of a broad science program. Theoretical physics is cheap, but has an impact well beyond its cost. It is a continual source of new ideas and sophisticated techniques which drive the most creative science. It also brings with it involvement in a global community of researchers who are constantly searching out and creating new scientific disciplines.

Outstanding examples of such centers include the KITP at Santa Barbara, and the Isaac Newton Institute at Cambridge. Both were started as experimental ventures and both are now recognised as highly cost-effective successes where a number of key scientific breakthroughs have been made.

The team proposing the National Facility has an excellent track record, both in the quality of their own research, and in organising programs such as the Chris Engelbrecht Summer School. The plans are well thought out and will interface well with other new initiatives such as the African Institute for Mathematical Sciences, bringing the opportunity to enter high level research to bright students from all backgrounds.

If funded, I have confidence that this team will build an institute of the highest international quality, which South Africa will be proud of. I encourage them to aim high: there is no reason why the South African National Facility in Theoretical Physics cannot, in a short space of time, become known as one of the best such centres worldwide."

****Neil Turok Chair of Mathematical Physics, Cambridge and Chair of the Council of the African Institute for Mathematical Sciences (AIMS)*

"I am happy to endorse strongly the proposal to establish a National Institute for Theoretical Physics in South Africa. As a lecturer at two of the very successful Chris Engelbrecht summer schools in theoretical physics, I am very much aware that while there is no dearth of talent in theoretical physics in South Africa, it is scattered both between sub-disciplines and between institutions, so that it is difficult to achieve a "critical mass" in any one area or place. In addition, I am conscious that that theorists in neighboring African countries are often working in considerable isolation. I believe the proposed Institute would be of enormous help with both these problems, and I am pleased to give it my strongest support."

****Tony Leggett (Nobel Laureate 2003, University of Illinois)*

"I strongly endorse the establishment of an Institute for Theoretical Physics in South Africa. As you know, I was the founding Director of the NSF Institute for Theoretical Physics (now named after donor Kavli) in 1979. Almost 8 years ago I participated in one of the Engelbrecht Summer Schools in South Africa.

The effects of the US Institute for Theoretical Physics in the US and elsewhere have been most invigorating. With good planning and adequate funding, I am confident that a similar effect (on a quantitatively smaller scale) is possible in South Africa. I wish you much success in your efforts."

****Walter Kohn (Nobel Laureate 1998 and KITP Santa Barbara founding director)*

".. (establishing) a National Institute of Theoretical Physics in South Africa, particularly if it actively works to build connections with theoretical physicists throughout the country, will be a major step in building the ***scientific infrastructure*** and community that is so important in facilitating scientific excellence and the development and growth of good students."

**Carl Wieman (Nobel Laureate 2001, JILA, University of Colorado)*

"I am writing to endorse the proposed National Facility in Theoretical Physics in South Africa. In order for South Africa, or any other nation, to have a strong community of scientists, it is essential to build from the ground up. No effort can succeed if it is aimed narrowly at some specific area. The cross fertilization of ideas between the fundamental sciences like Theoretical Physics, and applied science is essential to success. Without a vibrant community of scientists working on the frontiers, the best young people will leave and go to places where stronger intellectual communities exist.

I also feel it is essential to the health of science that all people are represented among the participants and researchers. Unfortunately the representation of Africans is not what it can be, but a good facility in South Africa could provide a nucleus for the further growth of an African physics community. The National Facility seems like a wonderful opportunity to start such an enterprise in Theoretical Physics. I for one would be very excited to participate in such an effort."

****Leonard Susskind (Stanford University and Initiator of the African Theoretical Physics Postdoctoral Program)*

I support the NITheP initiative because I see the advancement of physics depending on both theory and experiment/observation, and most crucially upon their interaction. This proposal deals with one side of the problem and I congratulate the theorists on their coherent and well argued document. In consolidating existing strengths they build a firm foundation for the advancement of physics theory and put themselves in a strong position to support growth on the experimental side. Training and the development of expertise are given the prominence they must have, in view of the needs of the country and the continent. I particularly like the split location over three centres, Stellenbosch, Gauteng and Durban. Although it will be a challenge to keep the three linked and interacting with each other there is a need for geographical spread, both for the students and for the potential interaction with engineering and astronomy as well as with others in physics. Furthermore, the proposed structure should prevent any one centre from becoming parochial or inward looking. There is little doubt in my mind that the future of physics in South Africa depends on our greatly strengthening the experimental side of the subject. However, this must not be to the detriment of theory which, although often less visible, is equally important. Furthermore, the development of experimental facilities is complex and will take time - indeed it should not be rushed. I hope that the NITheP idea will not be left to stagnate while other plans are put together — it is too good for that.
The proposal is particularly exciting in view of possible developments in astronomy. We are currently considering how best to construct an Institute of Astronomy in support of, and to train students for, SALT, SKA and H.E.S.S. In view of the importance of astronomy in South Africa this must involve technology development and theory as well as observational astronomy. There is clearly potential for developing the theoretical side of this venture in partnership with NITheP.

Patricia Whitelock (SA Astronomical Observatory and Past President: SA Institute of Physics

"South Africa can be proud of a long tradition of theoretical physics, with continuing world-class activity in some areas. The proposed Facility would strengthen collaborations between scientists within the country and outside, and would admirably complement, on the research side, the recently established African Institute for Mathematical Sciences, whose main focus is high-level education."

***Sir Michael Berry (Physics Department, University of Bristol, UK)*

"I am writing to express my strongest support for the establishment of a National Institute for Theoretical Physics in South Africa. Until last year my knowledge of South African physics was limited to the Chris Engelbrecht School which has regularly identified timely topics, brought together a very prominent collection of leaders in the area, assembled a diverse audience and finally published proceedings. (I learnt my critical phenomena from Michael Fisher's published 1982 lecture at this school.) My view is now much more intimate, following my visit this January to lecture in the 15th Chris Engelbrecht School. I saw once again the high quality of speakers, a wide participation in the student body and tremendous hospitality. I cannot overstress the impact of such an encounter and how much it has contributed to my positive perception of South Africa as a strong player in international physics and a marvellous place to go to.

The proposed Institute is bound to be a success, given the past performance of the proposing team and given that the time is ripe for it. I just came back from a celebration of the 25th Anniversary of the KITP in Santa Barbara. No one will dispute that the KITP has mightily contributed to Theoretical Physics in the US. I am planning another visit to KITP soon, just as I will visit the Institute in South Africa once it is formed.

The decision to go ahead is what the younger generation in the US will call a "no brainer", meaning it so obviously is the right thing to do. You will get more bang for your buck this way than with any other. "

****Ramamurti Shankar (Huffman Professor of Physics, Yale University)*

"The Abdus Salam International Centre for Theoretical Physics, which focuses on developing countries, has accommodated about a 100 000 visiting scientists in the last 40 years; even this number falls short by more than an order of magnitude compared to an ideal based on 1 scientist per 1000 members of the general population. Thus we all have a lot of work to do.

Especially in Africa, there is an even higher need – the work required is vast and the need immense. This argues strongly in favour of a cost-effective activity like the one you are envisaging. It is worthy of support. While offering assistance to the needy scientists, we should keep high levels of quality in mind, else everything is a waste. Your enterprise is well set to qualify on this front as well.

I am therefore highly supportive of your endeavour and wish you success. When it does fly, I am sure that ICTP will find many points of intersection and cooperation. I look forward to it."

***Katepalli Sreenivasan (Director: Abdus Salam International Centre for Theoretical Physics, Trieste)*

As Director of the Institut de Mathématiques et de Sciences Physiques, an African Institute and graduate school for Mathematics and Theoretical Physics in Benin, I declare my full endorsement of the establishment of a National Institute for Theoretical Physics in South Africa as an opportunity of promoting basic sciences for African development.

***Jean-Pierre Ezin (Director, IMSP Benin)*

I visited 2 years ago several places in South Africa. I fully support the idea of establishing a National Institute for Theoretical Physics in this country. This will provide very good possibilities of cooperation between the various excellent groups working in this field. It will also allow students to be in contact with the best experts coming from all over the world, providing in this way a great stimulation for the development of Theoretical Physics in South Africa.

**Claude Cohen-Tannoudji (Nobel Laureate 1997, Professeur au College de France)*

I strongly endorse the proposed National Facility for Theoretical Physics in South Africa. It is essential that South Africa take the lead at building modern science in Africa, building on its excellent intellectual capital and reaching out to the rest of the continent. Although many components of such an effort are required, it is essential to promote excellence in the basic sciences and to ensure a vibrant scientific community working at the frontiers of science. The National Facility is a major step in that direction.

I also recommend that the Facility cooperate fully with the recently established African Institute for Mathematical Sciences. Education and research must go hand in hand.

****David Gross (Nobel Laureate 2004 and Director, Kavli Institute of Theoretical Physics, Santa Barbara)*

As a major representative of an entire continent, it is essential for South Africa to harbour a thriving scientific community, and research in Theoretical Physics must be an inseparable part of that. By actively participating in the international endeavour to unravel the mysteries of Nature, such as the complexities of the Cosmos, the Quantum World of the Atom, and the mysteries of the sub-atomic Universe, South Africa demonstrates to the people of Africa what the rewards are of high quality education at all levels. In a troubled world, proper education at all levels should receive the utmost priority.

Presently, we do have small but excellent groups of theoretical physicists here in South Africa, but much more can be done in order to establish representatives of all branches of theoretical physics in Africa. The realization of a new National Institute of Theoretical Physics at the STIAS, as proposed, is definitely an important next step in the right direction. I fully agree with what my colleagues Neil Turok, Tony Leggett, Walter Kohn, Leonard Susskind, Michael Berry, David Gross and others have said in their reports: given the necessary support, the team employed at this Institute will have all that is needed do ground-breaking work, strongly competing with the most advanced centres anywhere in the world.

**Gerard 't Hooft, Utrecht University, the Netherlands*
(1999 Nobel Laureate in Physics)

* = keynote plenary lecturer at SA Institute of Physics Annual Conference
** = visited SA in recent past
*** = lecturer at the Chris Engelbrecht Summer School in Theoretical Physics

Executive Summary

Background

In South Africa new initiatives within a broad Science and Technology policy have recently been launched. It is clear that the realisation of such projects in the long term requires the underpinning of and by fundamental research work.

In contemporary science many new developments are of an interdisciplinary nature and Theoretical Physics demonstrably often plays the role of a keystone component.

Theoretical Physics has not only provided the basic framework for our understanding of the physical world in terms of quantum mechanics, relativity and quantum field theory, but in the past has contributed to all aspects of intellectual property – understanding, development and practical realisation – concerning diverse fields such as electronic communication (from early valves to diamond based transistors), metallurgy and steel manufacture, nuclear energy, and medical imaging and diagnostics from X-rays and sonar to magnetic resonance. Today it contributes to, or has initiated, fields like nanotechnology, biotechnology, information technology, quantum computing and cryptography, intelligent materials, and contemporary metallurgy. In fact, by its very nature Theoretical Physics is interdisciplinary and a central contributor to the development of a competitive advantage in an increasingly technology oriented century.

Theoretical Physics research and community initiatives in South Africa are enjoying considerable recognition and appreciation within the country and abroad. High level research in this field is being conducted in a small number of centres in the country, ensuring contributions in various key fields. Research outputs and extensive contacts abroad testify to activities of an internationally competitive and often leading quality.

Fundamental physical concepts and their mathematical and computational implementation form the common basis for the activities in these centres. Numerous connections to related mathematical and computational disciplines and to experimental work also exist. In addition to basic research, graduates in this field are sought in diverse fields such as the mining industry, financial and banking sectors and information technology.

Under the auspices of the Organization of Theoretical Physicists, and with funding from the NRF, the community of theoretical physicists has been addressing the equally important issues of education, representation and collaboration. One central part to this has been organising a long-standing series of Summer Schools in Theoretical Physics, which have brought international experts to South Africa to address students and faculty members on the most current and dynamic research in the discipline.

International Panel of Experts

With the support of the Department of Science and Technology (DST) and the National Research Foundation (NRF) the South African Institute of Physics (SAIP) commissioned an international panel of experts to investigate the Status of Physics in South Africa. In a substantial report the panel comments on the achievements of and challenges to the discipline.

One of the panel's main, and urgent, recommendations (Recommendation 4.11 (Exec 12)) is: "The state of theoretical physics is characterized as internationally competitive in some areas, but there is fragmentation and a coherent policy is needed. 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."

National Facility for Theoretical Physics

In this document we propose the establishment of a National Institute of Theoretical Physics (NITheP), its vision and mission spelled out in section 2.

Institutes of Theoretical Physics (or sub-disciplines) exist the world over and often play an indispensable role in the broad mathematical sciences. Such institutes often have a skeleton staff of highly esteemed researchers and postdocs and furthermore serve as a type of user facility, similar to large experimental laboratories, by hosting research programs in which researchers from all over the world participate (typically 2-3 months). Shorter workshops and seminars are often organised. Public visibility and interaction also often play an important role.

In India Institutes such as Harish-Chandra (in Allahabad), the Bose Institute (Kolkata) and the Indian Institutes of Technology have played a major role in retaining researchers of international stature and also in attracting back those who had established themselves abroad. The Indian example is of particular importance to South Africa which shares the unfortunate situation of large discrepancies of educational level among its population. Other well-known examples include the Kavli Institute for Theoretical Physics in Santa Barbara and the Institute for Nuclear Theory in Seattle (USA), the Newton Institute in Cambridge (UK) (which includes broader mathematical sciences) and the Abdus Salam International Centre for Theoretical Physics (ICTP) in Trieste (Italy), with its expressed aim to "foster the growth of advanced studies and research in the developing countries".

We recommend that a South African National Institute of Theoretical Physics be established and phased in over a period of three years. It should comprise a central facility with a director, together with research and organising staff which would work in close association with two regional facilities. Together these units form an autonomous National Institute with the mission to produce high-level research and expertise, to develop capacity, to stimulate local communication and to actively promote participation from all South African communities as well as from the African continent.

A number of contingent developments and opportunities will allow the Institute to become fully operational on an estimated annual budget of R5-6 million.

Conclusion

Our report below outlines more expansively the mission, vision and strategy of such a new Institute for the discipline.

The present time of showcasing scientific and technological flagship projects in South Africa is ideal for the establishment of such an Institute – Theoretical Physics is well positioned to contribute through a NITheP to the national priorities and development of intellectual property in key technologies of the 21st century.

On the one hand the discipline offers unique opportunities to build capacity in the physical sciences, while at the same time providing an ideal training ground for building mathematical skills in the broad areas of mathematical modelling, mathematical approximation and numerical computation. On the other hand the theoretical physics community has considerable international recognition as researchers (as measured by publications, NRF ratings and international collaboration), as well as a shared vision to offer a strong and coordinated research and post-graduate training base.

The proposed NITheP will allow the existing expertise to join into a national network that will strengthen and increase the coherence of theoretical physics activities in South Africa, bring about greater cost effectiveness through a sharing of resources, and establish a more effective and focused contribution to capacity building.

The year 2005 has been declared the International Year of Physics by UNESCO and IUPAP in celebration of Einstein's three momentous contributions to physics in 1905, which includes the announcement of special relativity. It presents an ideal opportunity to launch the South African National Institute of Theoretical Physics. A number of recent Physics Nobel Prize laureates have either lectured at the Chris Engelbrecht Summer School or delivered keynote lectures at the annual SA Institute of Physics conference. It is not inconceivable that it may be possible to involve some of them for such an occasion.

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1. Preamble

Panel recommendation and process of response

This proposal is a direct response to main recommendation 12 of the executive summary of the International Panel Report on Shaping the Future of Physics in South Africa:

"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."

(The complete analysis of the International Panel on which the above recommendation is based, is appended here as appendix A.)

In order to respond to this recommendation, the Organization of Theoretical Physicists in South Africa, operating with its own constitution since 1970 and as one of the specialist groups of the SA Institute of Physics, conducted e-mail exchanges and discussions leading to an open invitation to all OTP members to attend a one-day workshop in Stellenbosch on 7 June 2004 (or make written submissions) to discuss the implications of the recommendation and possible responses. This meeting was attended by 14 representatives from 6 institutions, ie the Universities of Free State, KwaZulu-Natal, Pretoria, Stellenbosch, Western Cape and Witwatersrand. The previously circulated agenda provided for two main discussion points:

- Role of a National Theoretical Physics Facility and requirements for its functioning
- Models which can fulfil the stated needs and requirements, and the way forward.

Already at this meeting, as elaborated in this document, the model of a "physical realisation" of the International Panel's recommended National Facility, to be complemented by two regional centres, emerged as an attractive and feasible model for the proposed Institute. Feedback from this meeting was circulated among OTP members and it was agreed that a Working Committee would be elected at the OTP AGM which took place in Bloemfontein in July 2004 during SAIP2004. This committee was given a mandate to prepare a written proposal for the establishment of a National Theoretical Physics Facility, to be circulated for comment by the membership before formal submission.

Successes on which to build

South African public policy is emphasizing the growth of economic sectors in which scientific expertise makes fundamental contributions. It is generally acknowledged, internationally and locally, that a strong research and skills base in the mathematical and physical sciences is essential for an effective and competitive high technology based economy. The Science Policy of the South African government recognises this fact, and it is demonstrated by the commitment of the Department of Science and Technology to building this capacity in the African context. This is borne out by investments made in institutes such as the African Institute of Mathematical Sciences (AIMS), support for the Southern African Large Telescope (SALT) project and support for a local bid to host the international Square Kilometer Array project. The merit of high level mathematical and physical sciences as a national priority seems to be beyond question, also in as far it contributes to the building of direly required mathematical capacity in South Africa and Africa.

The role the discipline of physics plays both directly and indirectly in many of these endeavours led to the tabling of the report on "Shaping the Future of Physics in South Africa" by the international panel of experts. The report highlighted the current and past achievements of the relatively small community of physicists and the relevance of the subject in our times. In addition to the recommendations on education and demographic diversity it is recommended in the report that structures be enhanced or established for more extensive collaborative work.

Amongst other considerations, this proposal very directly addresses the growing local need to coordinate and complement a strong research program with a well developed strategy for human resource development generally, and with respect to redress in particular. A National Facility will indeed allow a number of long standing and recent capacity building initiatives to be consolidated, coordinated and/or expanded, with the potential of significant impact on, and international support for, the mathematical sciences.

Existing activities and recent initiatives within the Theoretical Physics community which must have contributed to this line of thinking by the International Panel include:

- a series of graduate level annual summer schools in theoretical physics (10 day format) supported by the NRF. It commenced in 1981, has international standing and attracts international students, with recent increased African participation, presently supported by the Ford Foundation. This is a forum which can respond to international developments on a short time scale and has done so with good effect; it has often led to fruitful longer term contact between local students and international researchers lecturing at the schools;
- international workshops associated with the above summer school series, leading to the establishment of a postdoctoral *African Theoretical Physics* program (ATPP) at the Stellenbosch Institute for Advanced Study (STIAS), financially supported by Stanford University, SLAC and the Flora Family Foundation, initially for a 3 year period. Three postdocs have recently been appointed, including two Africans. The Wits and Stellenbosch groups are presently actively involved in this program. There are furthermore firm indications of support by eg the Abdus Salam ICTP for future workshops, initially linked to the summer school on *Nanoscale Physics*;
- the *African Institute for Mathematical Sciences (AIMS).* Theoretical physicists played a key role in the establishment of AIMS and members of the proposing consortium are involved in AIMS at each level of activity – from (part-time) director, through council and executive committee to teaching levels;
- well established international cooperation, often funded at least partially from external sources and South African bilateral agreements.

At this time it has become possible to draw extensively from international expertise (and from scientists in the South African diaspora). This can be seen in the reception of initiatives such as the African Institute for Mathematical Sciences. Furthermore, the community of physics theorists can contribute and become involved in international developments in the field. Also, in the light of the recommendation of the International Panel, the time is ideal for the creation of a facility to integrate, enhance and optimise the role of theoretical physics in South African science.

Research focus areas

The choice of research focus areas will have to be determined by three considerations: (i) local expertise, (ii) national priorities and (iii) international developments. Local expertise in high energy physics/string theory, quantum field theory/condensed matter physics, together with open quantum systems (which includes developments around quantum information), puts these topics strongly on the agenda. They are also very much part of the international focus.

The South African astronomy (via initiatives such as SALT, and possibly SKA) and laser physics/optics experimental programs are expected to expand significantly in the near future and links to these programs will have to be addressed. A relatively neglected area in South Africa which also requires attention is the link between theoretical physics and biological fields.

We foresee a research program which develops from its present strengths and is actively managed to address themes from the national agenda as sketched above. Even if a specific field is not directly represented in the research portfolio of the National Facility, it can still be actively supported and promoted through activities such as workshops and summer schools, as is already the case.

2. Mission and vision statements

Mission Statement

The mission of the National Institute of Theoretical Physics in South Africa is:

1. To identify and pursue high-level research projects and expand existing expertise in the fields covered by Theoretical Physics in South Africa;

2. To act as a national and African user facility for Theoretical Physics which optimises communication and collaboration between the existing centres of expertise and stimulates joint initiatives in line with international developments;

3. To promote equitable participation from all communities in South Africa in Theoretical Physics programs and to strengthen ties with similar communities on the rest of the African continent in line with the NEPAD vision;

4. To provide a source of expertise which can feed into broad national scientific policies and goals.

Vision Statement

The National Institute of Theoretical Physics leads and coordinates research programs and fosters education in Theoretical Physics which allows South Africa to play its rightful international role in a truly fundamental scientific field.

It is a stimulating national and African user facility for Theoretical Physics and links South Africa and the continent to an international family of Institutes of Theoretical Physics and similar institutions where its programs are recognised for their excellence in research and innovative role in the education of theoretical physics, especially in underrepresented communities.

3. Physical Structure and Motivation

The mission statement identifies four types of activities for the National Institute of Theoretical Physics: (i) conducting high level research, (ii) initiating and coordinating programs at various levels to fulfill its role as a user facility, (iii) playing an active role to enhance and support teaching and training in theoretical physics and related mathematical sciences and, (iv) acting as a source of high level expertise to inform and guide national priorities.

To achieve this NITheP will be able to draw on the example of a number of international institutes with similar goals. With some variation the model of a dedicated institute comprising a director, a small and internationally established research staff of a few full-time members, and a number of postdoctoral fellows, together with a reasonable infrastructure, seems to capture the essence and address the minimum requirements. Apart from conducting its own research program, such institutes then also host and support short to medium term specialised programs and workshops which involve participants from the international community, drawing on topics sourced on an international basis.

As already pointed out in the International Panel Report, such a model, adapted to local needs and priorities and with an African focus, seems to be a good starting point. However, given the relatively small base from which the South African initiative can be launched, it will be difficult to achieve active support of formal tertiary programs and enhance representivity in Theoretical Physics if all resources and activities are concentrated in a single locality. A model of a central facility with some regional support and activities seems better suited to achieve these goals and we believe that it can be made operational without unrealistic financial implications.

The model we propose is therefore shaped to serve the goals already set out and to take maximum advantage of a number of contingent developments as set out below. In particular, we propose that a central facility be established at the Stellenbosch Institute for Advanced Study (STIAS) (see http://www.stias.ac.za) where it will be possible to take advantage of existing and developing physical facilities with modest expenditure, while maintaining complete autonomy. In addition two regional centres should be established in Gauteng and KwaZulu-Natal at respectively the Universities of the Witwatersrand and KwaZulu-Natal.

This geographical distribution reflects the realities of the centres of gravity of established activities in Theoretical Physics in South Africa. Within a distributed model this also gives near optimal possibilities to interact with and support university programs directed towards Theoretical Physics.

Recommending STIAS as a host for the central NITheP facility is based on the following considerations:

- STIAS is actively serving the wider academic community in South Africa and Africa, as provided for in its governance structure. Its stated main objectives are (i) To advance the cause of science and scholarship, (ii) To focus on Africa and (iii) To strengthen the research capacity of the region and the continent. These objectives are clearly completely in line with the NITheP vision for Theoretical Physics.
- STIAS already hosts the postdoctoral African Theoretical Physics Program which is funded internationally and presently involves three postdoctoral fellows, with active guidance and participation by the Theoretical Physics groups at the Universities of the Witwatersrand and Stellenbosch.
- It is envisaged that within the next 12 to 18 months a significant office and lecture room/workshop facility will be established at STIAS, with on-site accommodation being planned in the longer run. At present STIAS programs typically involve a visiting group of program fellows and shorter term participants. In future they will be provided with office space and associated infrastructure in the new complex. Preliminary discussions have been held with the STIAS Director who has indicated that a model where NITheP occupies and uses a number of offices (6-8) and a seminar room in the complex on a continuous basis, while making intermittent use of additional facilities for specific needs, eg during workshops, short courses or summer schools, could be negotiated and would indeed be welcomed.
- The close proximity of Stellenbosch to the African Institute for Mathematical Sciences (AIMS) in Muizenberg (see http://www.aims.ac.za) will make it very practical for NITheP researchers and postdocs to be involved in the teaching program at AIMS which annually draws on a panel of local and international lecturers who propose topics for lecture courses and research essays on an invitation basis. In general the respective programs at NITheP and AIMS, which offers a formal postgraduate qualification, will be able to complement each other very meaningfully. In this regard it is worth pointing out that in the planning and establishment of AIMS, theoretical physicists played a major and significant role and continue to do so.
- A strong Theoretical Physics Group exists at the Department of Physics in Stellenbosch (an Institute for Theoretical Physics exists since 1984 and four chairs in Theoretical Physics exist at present), and has provided leadership to the OTP for more than three decades. Another strong group is established at the University of Cape Town.
- Stellenbosch can offer a particularly attractive environment to visiting researchers from Africa and abroad.

Existing research programs at the Universities of the Witwatersrand and KwaZulu-Natal, and active participation in the activities of the OTP, make them natural choices for regional activity of NITheP. At the same time their geographical positions will enhance national activity and visibility and complement the facility at STIAS very well.

Theoretical Physics at the University of the Witwatersrand also has a relatively long tradition, particularly strong in string theory and aspects of condensed matter theory, with links which, as in the case of Stellenbosch, go back to erstwhile research groups at the Atomic Energy Board

(later Nuclear Development Corporation) and the Council for Scientific and Industrial Research (CSIR). The theory groups at both of the latter institutuions were dissolved in the 1980's. A strong group at Wits is complemented by a revitalised program at the University of Pretoria (with a recent chair appointment) and an active but small group at UNISA.

While there had been some activity in Theoretical Physics at the University of KwaZulu-Natal for a number of years, especially in theoretical plasma physics, the recent creation of a new chair has already lead to a marked expansion of the Theoretical Physics program and coordination on the national level. A strong activity at UKZN is in open quantum systems where a new group in quantum technologies is being build up.

4. Implementation

1. The strategy to implement the vision of a strong community of theoretical physicists in South Africa which is both centralized and distributed (both real and virtual) Is to establish a National Institute with the main central facilities at STIAS and to create regional facilities in Gauteng and in KwaZulu-Natal
2. The National Institute is to be headed by a director who will be based at the Central facility.
   (a) The director is appointed on a full-time, fixed-term contract.
   (b) The central facility also has one administrative member of staff.
   (c) Part-time directors will be appointed from and in the regional facilities of the Institute. We envisage this to occur by buying out 25% of the time of the appointed person from her or his institution together with funding for secretarial time.
   (d) The director is responsible for activities, such as workshops, summer schools, conferences, coordination of scientific visitors and research activities at the central facility as well as for communication with the regional facilities.
3. The regional facilities are responsible for the local involvement of lecturers, local workshops and activities as well as providing access to local students. The regions also host local post-doctoral researchers appointed from the funding of the National Institute.
4. We envisage the Central Facility to be a hub of research
   (a) with several full-time, fixed-term contract appointments of experienced researchers
   (b) and a constant presence of post-doctoral researchers
   (c) and researchers spending sabbaticals or attending workshops over the term of, typically, a few months.
5. Mechanisms will be designed to expedite the personal and scientific communication between researchers of different regions.
6. We envisage a total of 8-10 post-doctoral fellows to be appointed by the Institute, their appointment being phased in over one to two years.

A key resource of the proposed NITheP is human capital and therefore the development of human resources will be a key element of the NITheP's activities. As theoretical physics skills students in the physical sciences, while at the same time training them in the broad mathematical skills of mathematical modelling, mathematical approximation and numerical computation, the skills profile of these students is just that required in many domains of a modern high technology based economy.

In practical terms the training of students must of course proceed through existing undergraduate and graduate programs. However, by offering short courses, summer schools and workshops, where we have gained experience, and by linking to the teaching program at AIMS, the scope of this education, as well as the target group, is considerably extended. Indeed, previous summer schools have attracted African students and participants through more than one source of financing (established links with Benin, Zambia and Morocco exist e.g.). On numerous occasions such schools have also led to contact between local students and academics from international institutions where the students became post-graduates or post-doctoral research fellows. Maintaining or expanding existing links with collaborators in industry (where experience also exists) furthermore gives students valuable exposure to potential employment situations.

In connection with the Chris Engelbrecht series of summer schools we mention that (see also http://www.sun.ac.za/summerschool) it has achieved international recognition through the status of its choices of topics (pre-empting Nobel awards on several occasions), the status of its international panels of lecturers (including to date 4 subsequent Nobel laureates, most recently in 2004, and many other internationally honoured physicists) and the publication on most occasions of its School Proceedings in the internationally respected *Springer Lecture Notes in Physics* series. Recent and planned topics include *Quantum Computing and Communication* (2001), *String Theory, Quantum Gravity and Cosmology* (2002), *Nanoscale Physics* (2004) and *Advanced Scientific Computing* (2005). Linking workshops to a specific school topic (as in the recent past) will be actively pursued as a mechanism to bridge training and research.

The proposed NITheP, in co-operation with the African Theoretical Physics Program and through existing individual links, can consolidate a support structure in which young researchers can build their research careers through mentorship by established and experienced researchers (keeping contact through shorter and medium term visits), with the eventual aim of establishing a network of mentors throughout Africa. We also anticipate that NITheP will help stem the tendency for some the very best South African students who have completed a masters degree in Theoretical Physics here to continue their PhD studies at some of the elite universities abroad. A strong PhD program remains an essential component of any successful reseach program.

In summary, we are convinced that the proposed NITHeP offers an international quality and visionary program of capacity building in the crucial area of the broad mathematical sciences, particularly in the African context.

5. Governance

While existing National Science Facilities may clearly provide models of governance, it seems that the model we propose requires a novel approach guided by the mission and the strategy of implementing the vision of NITheP. In particular, in order to position and establish NITheP as an institution recognized among similar institutions internationally, and acting as a national and continent-wide user facility which runs workshops and programs drawing on international participation and expertise, it appears essential to involve international experts in the formal structures. In short, NITheP's governance will require input from both the national and the international communities of theoretical physicists. The local community should be in control of setting the goals and the general operation of NITheP.

In this respect the governance structure of the recently established African Institute for Mathematical Sciences (AIMS) may provide a good model where a Board of Trustees consisting of national and foreign members sets the broad policy for the institution. On the other hand, the daily running is controlled by a local institution on an agency basis.
(In the case of AIMS, the University of Stellenbosch is the legal parent for matters like human resources contracts, fixed property ownership and for financial control and auditing.)

The South African Centre of Epidemiological Modelling and Analysis (SACEMA) also requires some novel structure which will allow participation in the projects by members from a variety of institutions on an equal basis while being part of the administrative and legal structure of a host institution. The structures for NITheP and SACEMA may turn out to be quite similar with similar challenges of finding a workable solution.

6. Business plan

The business plan is divided into two phases, *viz* the preparation and establishment phase and the operational phase over the first three years. In both cases the main actions to be taken are listed and overall costs to each step is estimated.

First year preparation phase

The main facility is to be set up at the new research centre at STIAS. Assuming the funding for this new research centre is approved, as is envisaged by the end of 2004, the new centre should be completed by October 2005 and this gives a good time frame for setting up the NITheP. It has already been approved by STIAS that the NITheP would be able to rent a wing of the new building consisting of six to eight offices. NITheP would also have access to the conference facilities of the new STIAS centre on a sharing basis. Accommodation at STIAS is available in the interim in the existing buildings if this should become necessary. With this in mind it is envisaged to complete the set-up phase by the end of 2005.

Details of the proposed time frame are as follows:

1. Approval of NITheP proposal by DST be given by April 2005. This would include allocation of funds at the level shown in this plan.
2. First meeting of interim governing body takes place in June 2005. At this time the advertisement for position of director is finalized and the mode of operation is approved. The cost for this step is estimated at R60 000.
3. The director is appointed by September 2005 and provision for salary for 2005 and relocation is required and estimated at R180 000. The other positions are advertised in September 2005 costing R40 000
4. Move into new facility October/November 2005
5. Installation of computer network, workstations and other equipment. The cost is estimated at R250 000
6. Launch and international workshop December 2005/January 2006, costing about R300 000. This important event is crucial for the future planning and for forging lasting relations, nationally and internationally. The IUPAP proclaimed International Year of Physics in 2005 presents an ideal opportunity to enhance exposure of the launch and of NITheP as such. It should be possible to involve a number of high profile theoretical physicists, hopefully including a number of Nobel laureates in view of their previous involvement with eg the Summer School and continued active support.

Total cost for setting up in 2005: R1 million in which cost of the central facility and contingency is included.

Subsequent years of operation

It is planned to have the NITheP operational by January 2006, while some in-phasing will occur over two years. The director will then have taken office and will be giving academic leadership. An administrative officer will have taken full responsibility for all the administrative tasks from travel and accommodation arrangements to liaison with the different institutions involved in the endeavour. Three researchers on a three-year contract basis will be appointed during 2006. They will be required to cover various areas of research that need stimulation. It will also be their tasks to spend time at participating institutions to stimulate research projects and to assist in special teaching programs at these institutions as may be required.

By January 2006 the two regional facilities in Gauteng and in KwaZulu-Natal will have been established. In each case a part-time director will have been appointed as local leader. The task of these persons will be to assess the needs of the particular area, to address these with the aid of the resources of the main centre and to bring the benefits which the NITheP could have to the attention of interested parties in the region.

The NITheP will take the responsibility for organizing the present successful series of summer schools and other special workshops. In accordance with its mission it will be an aim of these meetings to introduce new developments in theoretical physics to the South African science community.

A very important feature in capacity building is to allow young researchers to establish

themselves in their field of expertise and for this reason a fairly large post-doctorial program is planned. These post-docs will be appointed by the NITheP but they may be placed at other centres for part of the time or even fully. Decisions in this respect will be taken on the basis of where the expertise in the particular field of research resorts. It will take at least one year before the planned positions are filled and this implies that the planned expenditure can be phased in over two years.

The NITheP will also be responsible to monitor the number of young people entering the field and here, like elsewhere, particular attention will be required to ensure that many more students from the underrepresented groups are encouraged and assisted to enter the field of theoretical physics. This should be done by a system of bursaries. But this will not be enough. The staff of the NITheP will have to be required to draw students into the field and to meet young people who are not normally exposed to the field. The bursary fund which is required for this purpose can be phased in over two years as it will take some time to recruit good candidates.

All in all it is envisaged that researchers and postdocs at NITheP spend about 20% of their time directly in teaching related activities, in particular also at the regional facilities

In order to ensure that all theorists benefit from the NITheP, a substantial mobility fund is required. It would be counterproductive if all theoretical physicists would migrate to the Western Cape in order to be near the main centre. They are needed at the institution at which they are currently teaching and interacting with various colleagues. If they can travel to the central facility frequently, they can benefit from the contact in terms of their own career and they can carry the acquired knowledge and skills back to their home environment.

7. Budget

Appendix A: A Role for Theoretical Physics in South Africa (Section 4.11 quoted from the International Panel Report on *Shaping the Future of Physics in South Africa*)

"The community of theoretical physicists in South Africa is one of considerable topical diversity and in many cases possessing a well-regarded international profile. While a small portion exists outside of traditional university physics departments, on balance its distribution of locations is not as broad as in countries higher up the Technical Achievement Index (TAI). To a very good approximation the nation's theoretical physics community only exists within its universities.

This community, however, faces some challenges that inhibit its being more fully engaged in directions coupled to national goals and permitting it to have an even higher international standing. Although there are many quite accomplished individual investigators, in general, research groups in comparison to more highly placed TAI-scale nations are sub-critical in size. Individuals are often quite isolated within their physical environment. This difficulty has, in fact, long been recognized by the community and one of its responses has been to hold the "Chris Engelbrecht Summer School in Theoretical Physics." This has been the major attempt to permit the community to be kept abreast of the latest international developments.

The fractured status of this sort of existence seems to contribute to an overall lack of coherence in the South Africa's effort across an array of topics within theoretical physics. There is a pressing national need to assist this community maintain its international competitiveness and link more effectively to national needs. There is a model that might prove useful to alleviate this situation.

In other nations, centres have been created to gather groups of theoretical physicists together in order to meet pressing needs. In 1930, there was created near Princeton University in the U.S. an organization denoted as the Institute for Advanced Study [18]). This organization was envisioned as providing an environment dedicated entirely to the encouragement, support and patronage of learning through fundamental research and definitive scholarship across a wide range of fields. This institution became the home of Albert Einstein when he emigrated to the U.S. This model has been replicated at a number of locations around the world, with the newest such being the Stellenbosch Institute for Advanced Study [19]. However, a further distillation of this sort of model seems more appropriate to the specific needs of the South African theoretical physics community. In general the Institutes for Advanced Study direct their attentions to far broader areas of investigation.

National goals with respect to applied physics or engineering directions have a long history of requiring the nation to establish national laboratories facilities such as iThemba and NECSA. However, there is an obvious missing piece to efforts where theoretical physicists are expected to contribute.

There is no South African theoretical physics user facility. A similar situation existed in the U.S. until their National Science Foundation (the equivalent to the NRF) recognized the need for such a facility in the 1980's. This led to the establishment of the Institute of Theoretical Physics (ITP) affiliated with the University of California at Santa Barbara, now called the Kavli Institute of Theoretical Physics or KITP [20].

The establishment of such an entity in South Africa would offer the possibility of providing a long-term coherent stability to the community. There must be some attributes from which this organization cannot stray:

a. The overall reach of this organization must be national in scope.

b. It must not become the "property" of any subgroup of the South African theoretical physics community. It should provide for establishing an end-to-end linkage of the community. At the minimum it should be charged with the responsibility of ensuring the information technological basis for supporting collaboration between members of the community.

c. The organization must coherently engage the theoretical physics community with areas of national needs and goals.

This point perhaps can be best illustrated by an example drawn from the experience of the KITP. The programme of KITP provides programmes of study that bring together groups of physicists to study recent developments of rapidly developing areas. One of the most active of these areas has been in biophysics. These programmes have become major avenues by which theoretical physicists in the U.S. have become contributors to investigations in the area of biophysics.

An additional need of this envisioned entity is to maintain very close links to members of the general physics community who are not themselves theoretical physicists. One of the repeated statements made to this panel was how isolated university physicists are from the needs of the nation. The proposed national theoretical physics user facility ought to possess mechanisms that can be used to break down this isolation.
The organization should be charged with maintaining the coherence of the national theoretical physics community. There is a likelihood that groups of theoretical physicists may develop within the country, who are not affiliated with the university system. STIAS is one possible model, but not the only one on the horizon for the nation.

One other model has recently been initiated in South Africa, the African Institute for Mathematical Sciences [21]. Although at present this is principally an entity that is educationally focused on the entire continent, it has been created principally by theoretical physicists, and should it (or an as yet to be created entity) evolve in a manner that establishes new communities of theoretical physicists, efforts should be made to engage them for purposes of national goals and needs through the national theoretical user facility."

[18] Institute for Advanced Study, http://www.ias.edu/

[19] Stellenbosch Institute for Advanced Study, http://www.stias.ac.za

[20] Kavli Institute of Theoretical Physics, http://www.kitp.ucsb.edu

[21] African Institute for Mathematical Sciences, http://www.aims.ac.za