African Institutes for Mathematical Sciences: Building a Knowledge Base For African Security

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In this paper we explore the role of scientific and technical education in addressing security issues on the African continent. We adopt a definition of "security" that emphasises the well-being of the citizen rather than that of the state, and that encompasses both military and non-military threats. Security and development are interlinked, and this paper will emphasise the need for an effective African technical infrastructure to address these twin issues. To this end, we argue for the establishment of a pan-African network of mathematical institutes, relying on open-source software and educational tools as well as improved communication links throughout the continent. We emphasise the crucial role played by free and open-source tools in improving communication links on the continent. As a case study, we analyse the recently founded African Institute for Mathematical Sciences in South Africa. This unique project is characterised by three main characteristics: a commitment to pan-African cooperation, innovative, project-based teaching methods, and exclusive reliance on open-source software and educational material. We analyse to what extent it can serve as a model for future capacity building initiatives. Finally, we outline the proposed African Mathematical Institute Network, or AMI-Net. This network of interconnected institutes will help to build the scientific and technical knowledge base necessary for sustained African development. We offer suggestions for the implementation of the project, and show how it can contribute to the overall security infrastructure.

It is hardly a matter of controversy that many African countries have failed to capitalise on their enormous potential in the years since independence. Sub-Saharan Africa, in particular, suffers the highest infant mortality, the highest AIDS incidence, and the severest poverty-related issues of any region in the world. Northern Africa, as well, is plagued by corruption, repressive government, and internal conflict. Therefore, the "Africa" we refer to encompasses the whole continent, not simply the area south of the Sahara. The countries of the region are linked

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together by history and by the problems of the present day; it therefore makes sense that security policy for the region must address cross-continental issues.

Issues of security and development are intertwined, and it is often difficult to define them separately. Threats to security do not necessarily take a military form; AIDS, malaria, inadequate sanitation, poor access to education, and economic exclusion would be high on anyone's list of Africa's woes. Poverty has a destabilising effect, and scarce resources inevitably lead to conflict. In this paper we define "security" to mean a guarantee of protection from both internal and external threats. Citizens are not secure when states go to war; nor are they secure when diseases ravage their villages or when they are denied access to a livelihood. We see a secure continent as the responsibility of governments and of individuals, and envisage economic development and a higher regional standard of living as important steps toward achieving this goal.

The response to these security issues must necessarily be multi-faceted. The problems facing Africa are large and complex; no single solution will be adequate for the entire population. However, small, focussed projects can have a significant impact. In this paper we will discuss one such project and how it fits into the development picture. First, we will provide a brief overview of the major security threats facing the continent and show how progress in combating them may be made by an educated, well-trained science and technology workforce. Second, we will illustrate a successful example of capacity building in the mathematical sciences and technology, and finally we will discuss how it may be extended to serve a larger segment of the population. While science education cannot alone solve the continent's problems, it can help to empower those most qualified to find the solutions. For that alone, we believe it is worthy of significant, directed investment.

Threats to Security

Historically, African states have faced a range of security issues since independence. Competition over resource-rich areas like the eastern Democratic Republic of Congo and the Nigerian oilfields has been intense, leading to conflicts that wreaked havoc in the newly created states and continue to simmer in the present day. These conflicts have transcended the boundaries drawn by the colonial powers, involving a range of nation-states and ethnic groups. Additionally, these arbitrary boundaries have contributed to internecine conflicts between ethnic and cultural groups, culminating most famously in the Rwandan genocide and the Biafran civil war. Matters have not been helped by incompetent or corrupt local governments too frequently characterised by "Big Men"-tyrants like Zaire's Mobutu Sese Seko and Uganda's Idi Amin [3]. Present-day Africa has inherited the aftermath of these troubles, and must bear the additional burden of competition in an increasingly globalised world.

Conflicts over resources are enhanced by poor or unsustainable management of the environment coupled with the effects of global climate change. Particularly in northern Africa, climate change and ecosystem degradation pose serious threats to regional security. Desertification and poor management of dry-land ecosystems affect approximately two billion people worldwide. Overgrazing and pollution of scarce water supplies pose a serious problem for the large proportion of desert dwellers living in poverty, and migration of populations from degraded areas can exacerbate political or ethnic conflict, as in the Darfur province of Sudan [4]. With the loss of dry-land biodiversity comes the loss of indigenous knowledge, as local plants and animals used in traditional healing and industry become rare or extinct. Additionally, food stocks may be catastrophically reduced as land suitable for livestock grazing and food production is depleted. It is estimated that 20 percent of dry-land in this region is degraded every year, a figure that is increasing with time. Researchers believe that such land can be restored to 50-75 percent of its previous productivity [5], but the support for locally-based research and implementation is virtually nonexistent. While hardly a panacea, reclamation of this depleted land can help to alleviate the security situation in the region.

Recently, reporting on resource-based conflicts on the African continent has been displaced in the Western media by a new focus on global health. Bolstered by donations from two of the world's richest men, Bill Gates and Warren Buffett, NGOs and public health professionals have led a new battle to eradicate deadly diseases. It is certainly true that AIDS, malaria, and other diseases have enormously devastating effects for individuals, and that massive intervention is needed to prevent the destabilisation of societies. However, as a recent article in Science points out, "there is no architecture for global health" [2]. Competition and poor communication between drug and vaccine distribution agencies means that often goals are not met. The lack of epidemiological models and on-the-ground data coupled with poor technological infrastructure mean that medical help often fails to reach those who need it most. The lack of well-equipped African research facilities and trained personnel leads to over-reliance on Western expertise and aid. American and European pharmaceutical companies focus on the diseases that affect those populations, often neglecting the diseases rampant on the African continent. Similarly, reliance on Western public health officials prevents African governments from setting their own priorities for treatment and vaccination. It is not surprising that this approach leads to deep distrust of imported medications. Unless indigenous research and development are supported, calls to boycott the polio vaccine and to replace anti-retroviral drugs with potatoes and garlic will gain more credence.

The lack of a communications infrastructure on much of the continent serves to further hinder treatment and prevention efforts. In fact, poor connections between different areas have destabilised individual countries and entire regions. With the exception of artificial, Western-mediated coalitions designed to enforce Cold War spheres of influence, the history of modern Africa has been one of conflict rather than cooperation. Put simply, circumstances have made it impossible for some groups to communicate with others. Transport links and roads between neighbouring countries are often degraded or nonexistent, and some rural areas lack any transport infrastructure at all, particularly in inclement weather. Virtual communication, as well, is often difficult or impossible. Internet bandwidth costs are prohibitively high, sometimes exceeding comparable services in the USA by a factor of ten [6]. Landline phones are poorly served, and mobile technology, while rapidly embraced by the public, still has not penetrated many rural areas. Even when computers have been brought into schools, the staff has rarely received the training necessary to make effective use of them in their lesson plans. In some cases computer labs sit unused or are sold for scrap metal. The shortage of computer scientists, as with the shortage of transport engineers, logistics experts, and telecommunications engineers severely hampers the communication situation on the continent. This, in turn, exacerbates cultural differences, hampers trade efforts, and poses a low-level but long-term threat to security.

It is clear that the lack of trained and well-equipped African staff severely hampers development efforts on the continent. Many of the developing world's problems demand innovative solutions which cannot be imposed from outside. We argue that any serious attempt to improve the security situation must focus both on developing this knowledge base and on fostering cooperation between disparate groups. Science, by its very nature, tends to foster collaborations and improve links between nations and cultures. In the following sections we will discuss the role of science and technology in development, and outline specific measures that can be taken.

Role of science and technology in development

Obviously, a stable and secure African continent requires good governance, fair trading policies, strong economic leadership, and improved relations between different ethnic and cultural groups. No single policy or donation can improve the security situation and promote sustainable development. However, science and technology underpin industrialisation and informed policy choices. An educated workforce coupled with a stable job sector can promote the development and opportunity so crucial to regional security. Technical knowledge builds roads and computer networks; it coordinates effective aid efforts and develops economic policy. While not a panacea, scientific and technical education can help to build the framework necessary for development and security.

We cannot stress enough that such expertise must be local and sustainable. Reliance on outside experts often leads to inappropriate development or waste of precious funds. Often development projects mediated by westerners take the form of prestige projects-the under-used international airports in Maseru and Lubumbashi, for example, or the hydroelectric dams built in Ghana. Additionally, aid workers ignorant of local customs may direct efforts and funding toward well-intentioned yet inappropriate projects, such as unread surveys of local wildlife. Finally, without a strong coordinating local presence, aid projects may seem arbitrary and scattershot, as with shipments of stiletto heels and American football equipment to refugee camps in southern Sudan. A highly trained local presence will help to ensure that foreign development aid maximises its effectiveness.

The importance of science and technology cuts across political and cultural borders, and is recognised at the highest levels of government. In July 2001, the African Union (formerly the Organization of African Unity) adopted a strategic framework for the development of the entire continent. The New Project for Africa's Development, or NEPAD, seeks to achieve the Millennium Development Goals through continent-wide cooperation [9]. NEPAD stresses the importance of science and technology, and has identified five main platforms, which are:

1. Biodiversity, Biotechnology and Indigenous Knowledge
2. Energy, Water and Desertification
3. Material Sciences, Manufacturing, Laser and Post-Harvest Technologies
4. Information, Communication and Space Science Technologies
5. Mathematical Sciences

The presence of the Mathematical Science platform is intended to strengthen the other areas of focus. Mathematics is the language of all science; modern technologies universally rely on algorithms and methods developed by mathematicians. Mathematical knowledge allows scientists to analyse data and to develop theories that predict future events. Capacity building in mathematics and science is therefore crucial to achieving security, stability and development on the continent.

We argue that specific steps can be taken to create a pan-African science infrastructure, based on the mathematical sciences, in order to address these security threats and mediate responsible development. In particular, we fully support the creation of a network of institutes characterised by an innovative teaching style, the use of free and open-source software tools, and a focus on pan-African collaboration. In the following sections we will discuss the implementation of such a network, and show its benefits for the African continent.

Current state of technical education

Even the richest Western universities struggle to balance their need to support useful research with their obligations to educate their students. Many African universities face the additional obstacles of war, instability, corruption, and under-funding. In recent years, the University of Kinshasa in the Democratic Republic of Congo has been forced to shut down, sometimes for periods of up to one year. A former lecturer at a university in Angola observed, "I would have loved to keep teaching. But after a year of not being paid anything I had to take another job to support my family". The cost of internet bandwidth is often ten times what it would be in the United States. Lack of interest and enthusiasm from students is not often an issue– it is estimated that staff numbers in Nigerian universities must increase by fifty percent in order to keep pace with swelling enrolment [6]. However, the pool of suitable lecturers and funds available to pay them has not grown at a commensurate rate.

Students we interviewed often criticized the rigid, "Victorian" teaching styles employed at many schools, colleges, and universities on the continent. "We were never allowed to ask questions," observed one Nigerian student. A Congolese student said, "we just wrote down what the lecturer said and then memorised it." The lack of resources, poor salaries, and inadequate training opportunities make university lecturing and research an unappealing prospect for many, and those that do choose to teach find themselves struggling with overlarge classes and poor equipment. The environment at many educational institutions does not seem to encourage questions, individual training, and creative thought-essential qualities for scientific researchers.

Additionally, unpaid salaries and the lack of security in many countries have contributed to a "brain drain", with many bright African scientists, mathematicians, and health professionals choosing to work abroad. While initially devastating for the countries left behind, this mass migration creates a prosperous, educated diaspora and a potential pool of trained professionals to draw upon for development purposes. The creation of a stable job sector and outlets for technical expertise on the continent could effectively tap this human resource, luring many professionals home. However, until there is a stable knowledge base and a sustainable education infrastructure, this return will remain a pipe dream.

AIMS

The African Institute for Mathematical Sciences (AIMS) was founded in 2003 to address these issues. Located in Muizenberg, Cape Town, South Africa, AIMS attracts postgraduate students from all over the continent. In its first year of operation, 2003-4, 30 students from 11 African countries graduated from AIMS. In 2005 41 students from 16 different countries graduated from the program, and last year AIMS graduated 44 students from 18 countries [8]. The number of women students continues to increase each year, from just 6 in 2004 to 15 this academic year. Students leave AIMS with superb preparation for further study or employment in the quantitative sciences. However, each AIMS alumnus we interviewed cited the friendships and scientific collaborations they made with students and faculty as the high point of the experience. As one student said, "we were taught all Muslims were suicide bombers. Now I can say Muslims from Sudan, Egypt, and Kenya are my best friends". The intensity of the course coupled with its success at attracting the brightest mathematics students on the continent helps to build the networks which will allow African science to thrive in the future.

Facilities and Physical Plant

The AIMS building is a former hotel located in Muizenberg, a sleepy suburb of Cape Town. On the ground floor is a communal dining hall and large lecture theater. Students and teaching staff live in rooms on the top floors, fostering an extraordinarily open environment in which lecturer-student interactions are frequent, even late at night and early in the morning. Additionally, students may access a well-stocked library and computer lab on the first floor.

Numerous AIMS alumni cited the facilities as the best aspect of AIMS after the friendships and collaborations developed. The AIMS computer lab boasts state-of-the-art PCs and a broadband internet connection, allowing students access to a number of online journals, educational sites, and other resources. Most importantly, from the first day of instruction students are immersed in free and open-source software, which we will later argue is crucial to the technological development of Africa as a whole.

The AIMS Course

The year is divided into three parts. Initially, the emphasis is on fundamental problem-solving techniques. Students receive preliminary training in approximation and estimation techniques as well as an introduction to the structure of mathematical proof. These courses, in addition to providing an open environment for learning, allow students to experience methods of teaching which may differ drastically from traditional recitation-based lecture courses. Students work in groups on complex problems such as estimating the deflection of light by the sun due to general relativity or on working out proofs crucial to branches of mathematics as disparate as geometry and probability theory. During the subsequent "skills semester", students are required to follow a series of three-week courses which run in parallel. These include core skills such as programming in Python or C, basic mathematical methods, probability and differential equations as applied to epidemiology. No traditional exams are set; instead, students work on a variety of challenging problems. By the end of the third month of the course, students who may have never seen a computer before can write data-compressing code and solve complex equations numerically. Additionally, group work builds trust and collaborations between students of different nationalities naturally form.

The second semester allows students to choose areas of specialisation or to explore more branches of the mathematical sciences. Around twenty courses are offered, of which students can choose at minimum eight. These include pure mathematics such as topology and group theory, fluid dynamics, quantum physics, financial mathematics, applications to biological sciences, and further work in computer science and programming. Again, lecturers are encouraged to assess students through projects and challenging assignments rather than through traditional written examinations.

The final third of the year is devoted to individual essays, supervised by faculty members at one of the three local universities or by volunteers from as far away as Oxford. Students write an essay of thirty to fifty pages, in English, on a mathematical topic proposed by a supervisor. While original research content is not necessarily expected, some students' essays have become the basis of masters and doctoral dissertations. Often the essays involve a large amount of programming or software development, allowing students an opportunity to apply skills learned throughout the year. At the bare minimum, each report must be submitted in the LATEX typesetting language, the technological lingua franca of the mathematical science community. Past topics have included mathematical modelling of effective AIDS vaccine distribution, fluid mechanics with applications to oil extraction, and calculating the optimal use of limited internet bandwidth. A complete archive of past students' essays may be found online at http://www.aims.ac.za/resources/archive.

Although a small institute, AIMS has ambitious goals and has been largely successful at achieving them. First, it seeks to alleviate the "brain drain" by facilitating links between African universities and the rest of the world. By creating a pool of well-trained and well-connected scientists, AIMS helps to link Africa to the global scientific community. Second, AIMS alumni are encouraged to stay in contact with each other, even as they return to their countries of origin. In time, it is hoped that this will help build a critical mass of researchers working in collaboration across many regions of the continent. Third, AIMS alumni will bring to their home countries a new appreciation of interactive teaching and collaborative learning, which will help to improve secondary and post-secondary technical instruction in their home countries. We will now turn our attention to the specifics of this teaching method.

Teaching Methodology

The teaching staff at AIMS is drawn from a pool of international experts and from the finest universities in Africa. In fact, far more lecturers have volunteered to teach at AIMS than can ever be used. Each lecturer commits to spending three weeks teaching an intensive course–not to do their own research or to enjoy a South African holiday. Every teacher brings their own strengths to the course, and every lecture is unique. However, the most effective courses are characterised by some common factors.

AIMS is a unique institution and calls for a unique teaching style. Because the goal is to create world-class researchers in the span of only nine months, only the most effective methods can be used. The traditional lecture format is unsuitable because it is too passive; the diversity of the student body demands a more personalised approach. Lecturers at AIMS are therefore encouraged to adopt a more interactive style. While requiring infinitely more effort and preparation than traditional lectures, this approach is often far more rewarding [6].

Each entering class contains students of widely differing backgrounds, abilities and interests, which poses a significant challenge for the first few lecturers. The initial emphasis is therefore placed on improving and sharpening problem-solving skills. While many students are easily able to solve standard problems and recite formulae, few feel comfortable with posing their own questions and developing their own methods. To foster creativity, lecturers encourage students to work in small groups and share their ideas. This also serves to break down barriers between students from different cultural backgrounds. Instead of memorising proofs, students are asked to devise their own. Rather than lists of formulae, students are presented with challenging physical problems. To develop physical intuition, students estimate the number of grains of sand on Muizenberg beach and work out the diameter of the moon based on its angular size. The introductory courses emphasise intuition, educated guessing, and collaboration– essential skills in the real world of science and engineering.

Students are encouraged to break seemingly insurmountable problems down into a series of simple, logically related sub-problems. By the end of the introductory period students feel more comfortable with uncertainty and have begun to trust their own creativity. Subsequent courses build on this foundation, teaching students the essentials of the subject area while challenging them with complex assignments and projects. One former student noted, "we learned in a way quite unlike anything I'd experienced before... AIMS classes were interactive, full of questions from students, questions from lecturers." Students are treated as peers and equals; the aim is to break down the traditional lecturer-student barrier in order to promote a more active research environment.

This interaction is helped by the "hot-house" nature of AIMS. Students, a tutoring staff of 4-6, visiting lecturers, and researchers all live together in one building, enabling teaching to happen 24 hours a day. This allows great flexibility in scheduling, particularly during the Ramadan months when the Muslim students must fast during the day. In addition, the informal nature of instruction means that it is easy to hold optional evening classes on anything from the history of the Sudan to programming tips to AIDS biology. Students are encouraged to help one another; those from Anglophone countries often help others with their English, and those who have a stronger background in one particular area will assist those new to it. Over meals and into the evening hours students and teachers discuss culture and religion as well as mathematics, enhancing the learning experience greatly. As one student said, "AIMS feels like family."

Free and Open-Source Software

The AIMS computer lab runs exclusively on Free and Open Source Software (FOSS). Although this software is famously "free as in speech, not as in beer", because FOS software tends to be inexpensive as well as easily modified, it fits in perfectly with the AIMS mission.

Many computer labs in Africa are dependent on expensive proprietary software which cannot be modified or updated without considerable cost to the users. Proprietary software cannot be easily customised and is usually developed exclusively to serve the needs of Western individuals and businesses.

Free software refers to "software which can be used, copied, studied, modified and redistributed without restriction". FOSS is inexpensive and lends itself easily to customisation and innovation. It is therefore perfectly suitable to the needs of African scientists and technological innovators. Although some members of the free software community dislike the equating of this term with the label "open-source," at AIMS and subsequently in this paper, we use the terms interchangeably. The key to the idea is to facilitate the free modification and distribution of source code in order to help create technological solutions relevant to African development.

The flagship example of FOSS, the Linux operating system, runs on all AIMS computers. Developed by Linus Torvalds, Linux provides a stable platform on which to run countless free software applications. It is easily installed and lends itself well to networking. Ubuntu Linux, the distribution used at AIMS, was developed to be especially user-friendly, and AIMS students receive training on how to install and introduce this system to new users. Past AIMS students have then gone on to secure funding for Linux or Unix-based labs at their home universities, which they are then well-equipped to manage.

In addition to familiarity with the Linux environment, AIMS students learn to program in C, Octave, and Python, to create HTML webpages, and to use the *emacs* text editor and LATEX text processing language. These skills, in addition to being prerequisites for entry into the international mathematical community, allow students to begin to develop software for their own uses. Example projects include translating the Linux platform into various African languages, writing an equation solver for use in epidemiological modelling, and using Python's visual mode to create educational software for basic physics lessons. In a few months, students who may have never seen a computer before acquire the skills needed to customise software for their own purposes.

Recently, the popularity of such sites as *Wikipedia* and *WikiTravel* has drawn popular attention to another kind of free software, the *wiki*. These sites allow anyone to edit or contribute information. While *Wikipedia*, in particular, has struggled with several high-profile incidents of vandalism, a recent Nature study found that the accuracy and completeness of the site rivalled that of the venerable Encyclopaedia Britannica. Smaller *wikis* report little problems with vandalism, and allow experts to communicate with each other and to publicise new developments in their fields. AIMS has adopted a *wiki* approach to teaching programming, publishing editable tutorials and introductions to various FOSS applications online. These tutorials allow former students and experts to contribute to the education of current students, and are constantly monitored by the community to prevent vandalism or factually incorrect information from appearing.

So why is open source software so vital for science? In the introduction to *Voices from the Open Source Revolution*, Chris DiBona, Sam Ockman, and Mark Stone point out:

> Science is ultimately an Open Source enterprise. The scientific method rests on a process of discovery, and a process of justification. For scientific results to be justified, they must be replicable. Replication is not possible unless the source is shared: the hypothesis, the test conditions, and the results. The process of discovery can follow many paths, and at times scientific discoveries do occur in isolation. But ultimately the process of discovery must be served by sharing information: enabling other scientists to go forward where one cannot; pollinating the ideas of others so that something new may grow that otherwise would not have been born [7].
> Where scientists talk of replication, Open Source programmers talk of debugging. Where scientists talk of discovering, Open Source programmers talk of creating. Ultimately, the Open Source movement is an extension of the scientific method, because at the heart of the computer industry lies computer science.

This shared method benefits both the industrial and scientific communities. Science gains a ready platform for distributing its ideas, and industry gains a wellspring of freely available ideas and innovations from which to construct new products and services. Ultimately, the free availability of information will help Africa to become competitive in the global economy, as well as turn the focus of technological innovation towards the real problems of the continent.

A student from the Democratic Republic of the Congo summarised the importance of FOSS: "Open-source is the spirit of AIMS. It stands for cooperation and helping each other. It opened our minds".

AMI-Net

The AIMS model's success is mostly due to the small, focused nature of the individual institute and of its ability to draw students and lecturers from all over the continent and the world. It is not initially obvious how to build upon this success. Merely enlarging the South African Institute would compromise the possibility for individual tutoring and interactions between students and faculty so integral to its success. Likewise, merely creating copies throughout the developing world would hinder each individual institute's ability to draw students from outside its particular region. The best solution yet put forward is the African Mathematical Institutes Network, or AMI-Net [1]

The stated objectives of AMI-Net are as follows:

1. To help build a new generation of African scientists and technologists with excellent quantitative problem solving skills.
2. To strengthen the teaching of mathematics and science, especially at university level.
3. To prepare students for research across a wide range of scientific disciplines.
4. To build a critical mass of mathematical scientists, connected via the internet and working in collaboration across Africa.

The purpose of AMI-Net is to build upon and enrich existing resources. In order to support the NEPAD Science and Technology platforms, it is essential to develop a knowledge base on the continent. AMI-Net will use the Internet and Free/Open Source software to link several mathematical centres, or "Nodes". Each selected Node of the Net will be equipped with at least 40 fast PCs, a firewall, a server, printing and copying facilities, and a generator to ensure availability of electricity. To securely manage this, at least one dedicated computer officer must be on staff. Additionally, each Node will be equipped with a library and a lecture theatre. Initially, AIMS will serve as the hub for this activity, and will help to facilitate the exchange of students and lecturers among the nodes.

Eventually, it is hoped that AMI-Net will consist of 15-20 nodes which each serve a local region. We intend that the governing Board of each node will include representatives from all corners of the region it serves. Each node will be autonomous, but will be connected to the others and share resources freely. In particular, collaborations, facilitated perhaps by internet videoconferencing, will be encouraged in order to strengthen the network. Visiting lecturers from overseas will be encouraged to visit more than one Node, and student exchange programs will encourage inter-region collaboration.

The process of selecting the Nodes is already in progress. Expressions of interest have been put forward by institutions in Benin, Botswana, Cameroon, DRC, Ethiopia, Ghana, Kenya, Madagascar, Malawi, Mozambique, Nigeria, Rwanda, Senegal, Sudan, Tanzania, Uganda, Zambia, and Zimbabwe. In December 2006 the AMI-Net Board, consisting of representatives from five regions of Africa, will begin site visits to select the initial Nodes. It is expected that the initial network will consist of AIMS and three to five nodes, with additional nodes added on a yearly basis. Each selected node will receive a substantial grant to cover start-up costs, but will be encouraged to seek steady sources of funding from the public or private sectors in the future.

In short, the AMI-Net model replicates the success of AIMS while allowing each regional institute to retain a unique character. It is, we believe, an important step toward building the knowledge base so crucial to Africa's sustainable development. Through excellent teaching, free exchange of ideas, and access to modern computer technology, AMI-Net should help Africa to utilise its human resources in order to realise its potential.

Conclusion

The African Mathematical Institute Network provides a viable framework for improving science and technology in Africa by focusing on the basic building block– mathematical and quantitative skills development. It is our hope that within twenty years the alumni of these institutes will constitute a large body of highly qualified, innovative scientists, university professors, entrepreneurs, and inventors. The graduates of AIMS, and those they teach, will be catalysts for changes in the African economy and security infrastructure. They will provide the knowledge and skills to develop creative solutions to the continent's problems, and will be able to rely on a strongly connected community of other researchers that stretches beyond the boundaries of their countries. These benefits will come from a comparatively small investment financially, but will lay the foundation for a highly improved education and technology sector continent-wide. No single program will provide the people of Africa with security and stability, but it is our hope that AMI-Net will enable those with great ability to contribute greatly to their continent's well-being.

Notes

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