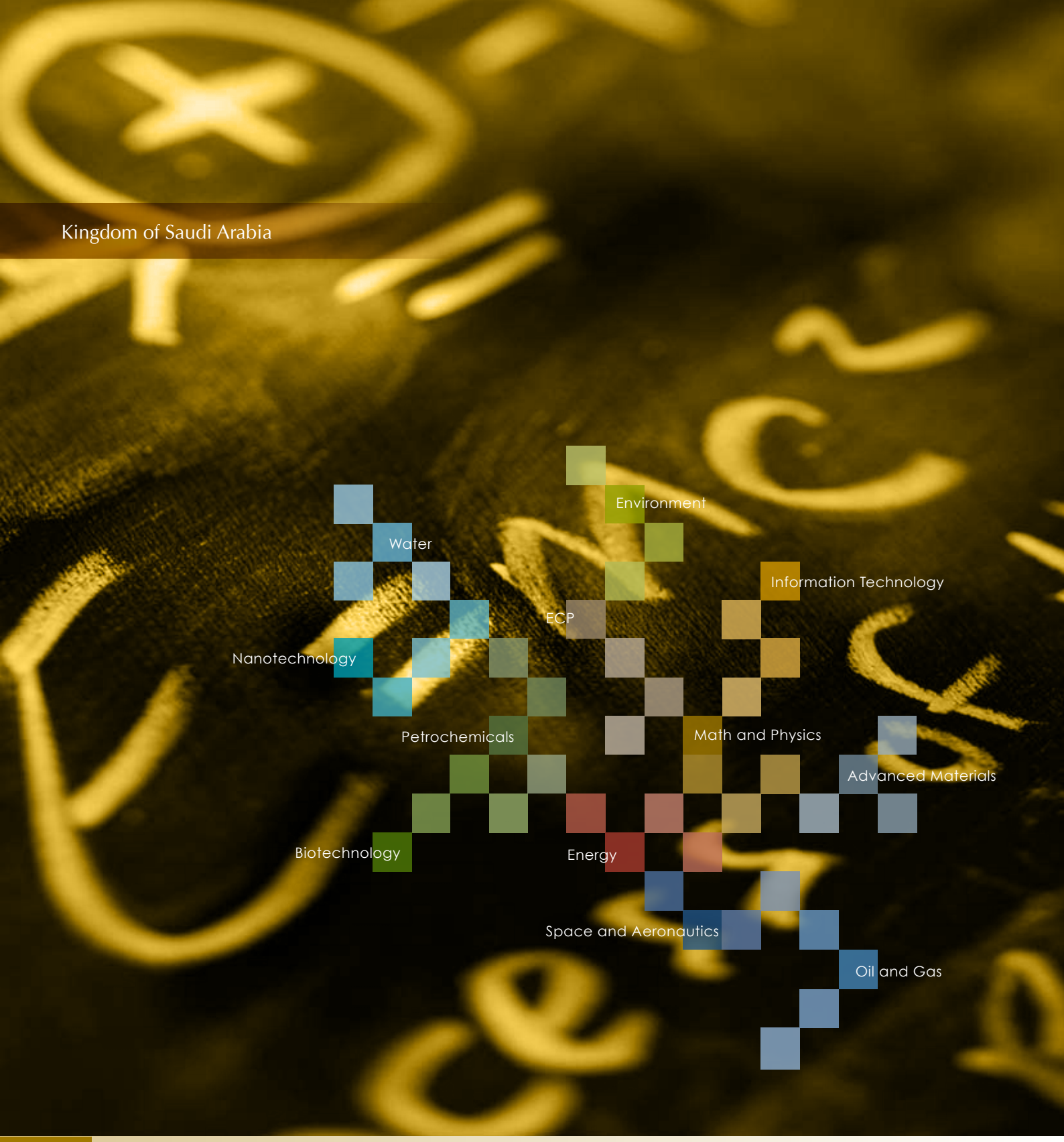
Kingdom of Saudi Arabia



Strategic Priorities for Mathematics and Physics Program

مدينة الملك عبدالعزيز
للعلوم والتقنية KACST
King Abdulaziz City for Science and Technology

Kingdom of Saudi Arabia
Ministry of Economy and Planning
http://www.mep.gov.sa

Kingdom of Saudi Arabia

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Ministry of Economy and Planning

Strategic Priorities for Mathematics and Physics Program

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Executive Summary

The National Policy for Science and Technology (NPST), approved by the Council of Ministers in 1423 H (2002G), defined 11 programs for localization and development of strategic technologies that are essential for the Kingdom's future development. Although mathematics and physics is not one of these 11 strategic technologies, KACST leadership recognized the importance of math and physics as the foundation of other physical science and engineering fields and asked the National Center for Mathematics and Physics (NCMP) at KACST to put together a national plan for the field. This document defines and sets forth the strategic priorities for the National Math and Physics Program (NMPP).

Unlike other strategic technologies identified in the NPST, the National Mathematics and Physics Program is not geared towards the swift commercialization of technology or short term economic growth. Instead, the program emphasizes basic and applied research as a platform to support physical science and engineering within the Kingdom. Success in the strategic technologies requires a technically trained workforce well grounded in mathematics and physics. In addition, many of the sciences that underlie the strategic technologies, such as computer modeling, geophysics, materials science, fluid dynamics, nanotechnology, and nuclear medicine rely heavily on math and physics. The NMPP will enhance the Kingdom's competency in the foundational disciplines of mathematics and physics and will strengthen the Kingdom's technical workforce.

Basic and applied research in mathematics and physics are also useful to enable the Kingdom to participate in international collaborations in some of the most advanced areas of science and technology, such as high energy physics. Competency in math and physics also improves the international prestige of the Kingdom in science and technology.

This plan for the NMPP was developed by KACST's NCMP in collaboration with an array of national stakeholders within government, industry and universities. Their vision for mathematics and physics in the Kingdom is:

Executive summary

The Kingdom of Saudi Arabia will have strong capabilities in mathematics and physics research that will: provide a strong foundation for other fields of physical science and engineering; support the Kingdom's mathematics and physics education needs; enable active international collaboration on equal footing; and attract top talents to mathematics and physics fields.

The mission for the National Math and Physics Program is: *To promote excellence of research and education in physics and mathematics through:*

- *Conducting basic and applied research and providing research services.*
- *Leading the development and implementation of the national mathematics and physics plan.*
- *Supporting research collaboration and communication.*
- *Building research infrastructure, including major facilities.*
- *Supporting education and training in mathematics and physics.*
- *Promoting public understanding of mathematics' and physics' role in technology.*

The plan's advisory committee determined two priority areas to be pursued by the Mathematics and Physics Program: Condensed Matter Physics and Applied Mathematics. These two areas were selected because of their relevance to the special needs of the Kingdom. Medical physics is another area where there are clear needs in the Kingdom. Nuclear and Accelerator physics, high energy physics, and quantum information are other areas of interest.

The areas in Mathematics and Physics that have been identified, which are expected to enhance the strategy technologies for the Kingdom are:

- Nuclear and High Energy Physics.
- Quantum Information.
- Condensed Matter.
- Medical Physics.
- Accelerator Physics.
- Numerical Analysis.
- Optimization.
- Applied Mathematics.

The National Math and Physics Program has four three central elements:

- *NCMP Math & Physics Research*, which includes research in key areas of math and physics, as well as program planning and fellowship support.
- *Math & Physics Research Support*, which provides math and physics research grants to universities.
- *Math & Physics Education and Outreach Program*, which includes a variety or activities to strengthen math and physics in research and education through workshops, math and physics Olympiad, teacher training, research, and curriculum development.
- *Major Research Facilities*, which will develop, build, and operate major shared-used physics research facilities for the Kingdom, enabling university, industry, and KACST research as well as international collaboration.

The National Math and Physics Program will be overseen by the National Math and Physics Advisory Program, which will review progress towards the programs objectives, and periodically recommend changes to the program in response to developments in the field.

Introduction

Background

The King Abdulaziz City for Science and Technology (KACST) was directed by a 1986 Royal Decree to "propose a national policy for the development of science and technology and to devise the strategy and plans necessary to implement them." In cooperation with the Ministry of Planning, KACST was charged with preparing and implementing the National Comprehensive Long-Term Plan for Science and Technology. The Plan spans the period 2001-2020. As the specific elements of the Eighth Five-Year Development Plan (2006-2010) have been formulated in detail, KACST is developing strategic and implementation plans for key science and technology areas.

KACST is responsible for developing 5-year strategic and implementation plans for 11 strategic technologies identified in the national science and technology plan. These are:

- Water
- Petrol & Gas
- Petrochemicals
- Nanotechnology
- Biotechnology
- Information Technology
- Electronics, Communication, & Photonics
- Aerospace and Aeronautics
- Energy
- Environment
- Advanced Materials

Each plan is expected to establish a mission and vision, identify stakeholders and users, and determine the highest priority technical areas for the Kingdom of Saudi Arabia (KSA). Each plan should also address technology transfer, human resources, and budgets for the next 5 years. Although mathematics and physics is not one of the 11 strategic technologies identified in the national science and technology plan, KACST leadership, recognizing the importance of math and physics and their role as the foundation of other physical science

and engineering fields, asked the National Center for Mathematics and Physics (NCMP) at KACST to put together a national plan for the field.

This plan defines a vision for mathematics and physics research and education for the Kingdom; identifies key needs; assesses strengths, weaknesses, opportunities, and threats; and defines a set of programs that can meet these needs. It represents, for the first time, a plan for mathematics and physics based on input from the stakeholders for mathematics and physics research in the Kingdom. These include other centers and institutes at KACST, companies, government agencies, and medical centers that may need research services in the fields of mathematics and physics, as well as the universities and other research organizations that conduct mathematics and physics research.

Importance of Math and Physics

There are many reasons why government supports basic and applied research in math and physics. One is prestige and national pride, as can be seen by the prestige countries gain from having Nobel Prize winners. Another is that mathematics and physics are the foundation of the other physical sciences and engineering. Even though mathematics and physics may not lead directly to economic development through the commercialization of technology, they contribute indirectly through education and through the importance to other areas of technology.

There are many examples of research institutes that conduct fundamental research in math and physics but do so with a focus on areas that provide economic benefits. For example the Physics Laboratory at the National Institute of Science and Technology (NIST) in the United States is the home of three Nobel Laureates, yet their work is supported because of its ultimate contribution to serving industry through better measurement and standards. NIST also provides calibration services for standard unit measurement tools. The National Basic Science Institute in Korea also focuses on providing research services for users and stakeholders. Although there is increased public pressure around the world for investment in basic and applied research to be justified in terms of its social impact, such justifications can be made by tracing the contributions of basic and applied research to social and stakeholder benefits.

Plan Development Process

The plan received input from stakeholders at a one-day stakeholder workshop on June 27, 2007. The purposes of the workshop were to identify the key mathematics and physics R&D needs in the Kingdom, to determine the priorities and timeframes for the R&D, and to determine the appropriate role of KACST and other stakeholders in conducting the R&D. According to the workshop participants, this is the first attempt in the Kingdom to obtain input from the stakeholders for national planning in mathematics and physics. The workshop focused primarily on identifying the key mathematics and physics R&D and education needs in the Kingdom. Following the workshop, NCMP organized an advisory committee to provide input on the direction of the NCMP and to advise NCMP on details such as the timeframe and the shape of specific programs. The advisory committee members and workshop participants are listed in Appendix 1.

Strategic Context

The following are the international trends that are incorporated into this strategic plan:

- Increased public pressure for basic and applied research to contribute to economic and social benefits.
- Increased S&T collaboration at all levels, which is essential in the development of solutions to large scale problems.
- Intense competition for the leading scientists and engineers -- countries compete to attract their expatriates and foreign scientists and engineers to their research institutions.
- Increased concentration of capacity in a few facilities in high energy and nuclear physics, due to the scale of facilities needed to pursue the frontiers of knowledge.
- Continued importance of physics as the foundation for other "hot" technology areas (e.g., nanoscale technology, optoelectronics, etc.)
- Increased importance of mathematics research for IT security and other IT applications.

Strategic Context

Stakeholders Roles

The stakeholders for the National Math and Physics Program include KACST, KSA universities, various independent or specialized research institutes, other government agencies, primary and secondary schools, and private companies. Table 1 shows the roles of these stakeholders in the program.

Table 1: Stakeholders roles

Stakeholder	Role
KACST	■ Plan, coordinate and manage the program
	■ Conduct research and knowledge transfer
	■ Manage and participate in national projects
	■ Support international collaboration
	■ Provide training and fellowships for researchers
	■ Provide support for university and industrial participation in national projects
	■ Provide and manage national research facilities
	■ Provide advice and services to government on science and technology
	■ Advocate policy changes to improve research and education
	■ Provide research opportunities for teachers and Students
Universities	■ Create new basic and applied scientific knowledge
	■ Train students in science and engineering
	■ Participate in collaborative projects
	■ Train math and physics teachers and conduct research on educational improvements
	■ Provide research opportunities for teachers and students
Independent or Government Specialized Research Centers	■ Create new applied scientific knowledge
	■ Participate in collaborative projects
Primary and Secondary Schools	■ Work to improve math and science education
	■ Support teachers who excel at math and science teaching
Ministries and Government Agencies	■ Provide input to program on government R&D needs
	■ Reduce regulatory and procedural barriers to R&D and innovation
	■ Work to improve K-12 math and science education
	■ Support R&D in universities and industry
Private Sector	■ Develop and commercialize products & processes resulting from the program.
	■ Communicate company needs to program
	■ Support and participate in collaborative R&D projects

Analysis of Comparable Mathematics and Physics Centers

As part of the background work for this plan, the planning team reviewed several mathematics and physics research centers from around the world. The specific centers were selected to demonstrate a variety of significant characteristics such as research foci, organizational structure, capacity building strategies and mechanisms for linking research to industry. The following five institutes examined:

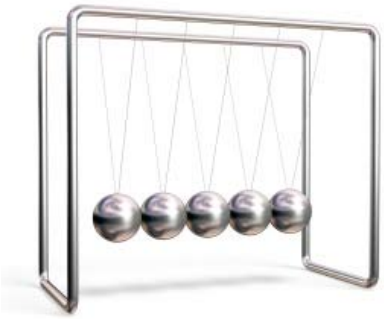
- Abdus Salam International Center for Theoretical Physics (ICTP), Italy.
- National Centre for Physics (NCP), Pakistan.
- National Institute of Standards and Technology (NIST) Physics Laboratory (PL), United States.
- Institute of High Energy Physics (IHEP), Academy of Sciences, China.
- Korea Basic Science Institute (KBSI), Korea.

The research foci of the five institutes vary substantially, reflecting the variation of their missions, as well as the national circumstances that shaped their establishment and continue to influence their operations. Table 2 highlights the fields of research on which each institute focuses its efforts. The institutes' research agendas demonstrate a few overlapping subjects as well as many individual specialties that reflect the breadth of their collective research foci. Among the research areas shared by all five institutes are high energy physics and advanced computing. Research priorities at all five institutes emphasize the importance of high energy physics because the most fundamental quest of physics is to understand the constituents of matter and the laws governing their interactions. Furthermore, modeling and simulation, which are becoming a bigger part of research in physics, require advanced computing. Computing is also critical for research collaboration, dissemination of results, and day-to-day research activities.

Table 2:

Areas of Focus	ICTP	NCP	NIST	IHEP	KBSI
Applied Physics	✓		✓		✓
Condensed Matter and Statistical Physics	✓	✓	✓		
Geo Physics	✓				✓
High Energy Physics/Particle Physics	✓	✓	✓	✓	✓
Multidisciplinary Laboratory	✓				✓
Time and Frequency			✓		
Fluid Mechanics and Plasma Physics	✓	✓			
Atomic Physics	✓	✓	✓		
Advanced Computing, Modeling, and Simulations	✓	✓	✓	✓	✓
Nanoscale Science and Engineering	✓	✓	✓		✓
Electron and Optical Physics	✓		✓	✓	✓
Ionizing Radiation			✓	✓	
Bio Physics	✓		✓		✓
Mathematics	✓				✓

Strategic Context



The five institutes demonstrate the variation of research foci as well as the variation of national needs in the countries in which they operate. As indicated by this table, the establishment of the National Center for Mathematics and Physics will position the Kingdom to collaborate with an international network of institutions focused on a variety of fields related to mathematics and physics. A complete assessment of these research centers is available in a separate document. [1]

Analysis of Mathematics and Physics publications and patents

Mathematics and physics R&D is a multidisciplinary field that spans several distinct research and application areas such as: applied physics, applied mathematics, optics, and instrumentation. The overall field, "mathematics and physics", as well as sub-topics, were defined in close consultation with KACST researchers and other KSA stakeholders who provided detailed lists of keyword terms that were used to query publication and patent databases.[2] The KSA mathematics and physics program identifies seven sub-topics: high energy physics, quantum information, condensed matter, medical physics, numerical analysis, optimization, and applied mathematics. The scope of this study was restricted to only recent publication (2007) and patent (2002-2006) activity in these fields.

There is general agreement that publications and patents strongly correlate with scientific research output, although publication and patent based indicators do not fully measure the quality or scope of research. Nonetheless, publication and patent activity have long been used as indicators for knowledge creation and research output.[3] Several indicators are presented below, including number of publications and patents, forward citations (the frequency at which

1 SRI International. "Strategic Review: Math and Physics". September 2007.

2 ISI Web of Science and Delphion were queried for scientific publication and U.S. patent application data, respectively. The ISI Web of Science is a database of peer-reviewed articles in major scientific journals from around the world. Delphion is a searchable database of global patent activity, including the U.S. Patent and Trademark Office (USPTO). The USPTO is one of the world's major granters of patents and it has been argued that the U.S. market is so large that most important inventions from around the world are patented there.

3 Seminal research in the use of publications as a measure of scientific productivity includes A.J. Lotka, "The frequency distribution of scientific productivity," Journal of the Washington Academy of Sciences, vol 16 (1926); D. Price, Little Science, Big Science, (New York: Columbia university Press, 1963); J.R. Cole and S Cole, Social Stratification in Science, (Chicago: The University of Chicago Press, 1973); J. Gaston, The reward system in British and American science, (New York: John Wiley (1978); and M.F. Fox, "Publication productivity among scientists: a critical review," Social Studies of Science, vol 13, 1983.

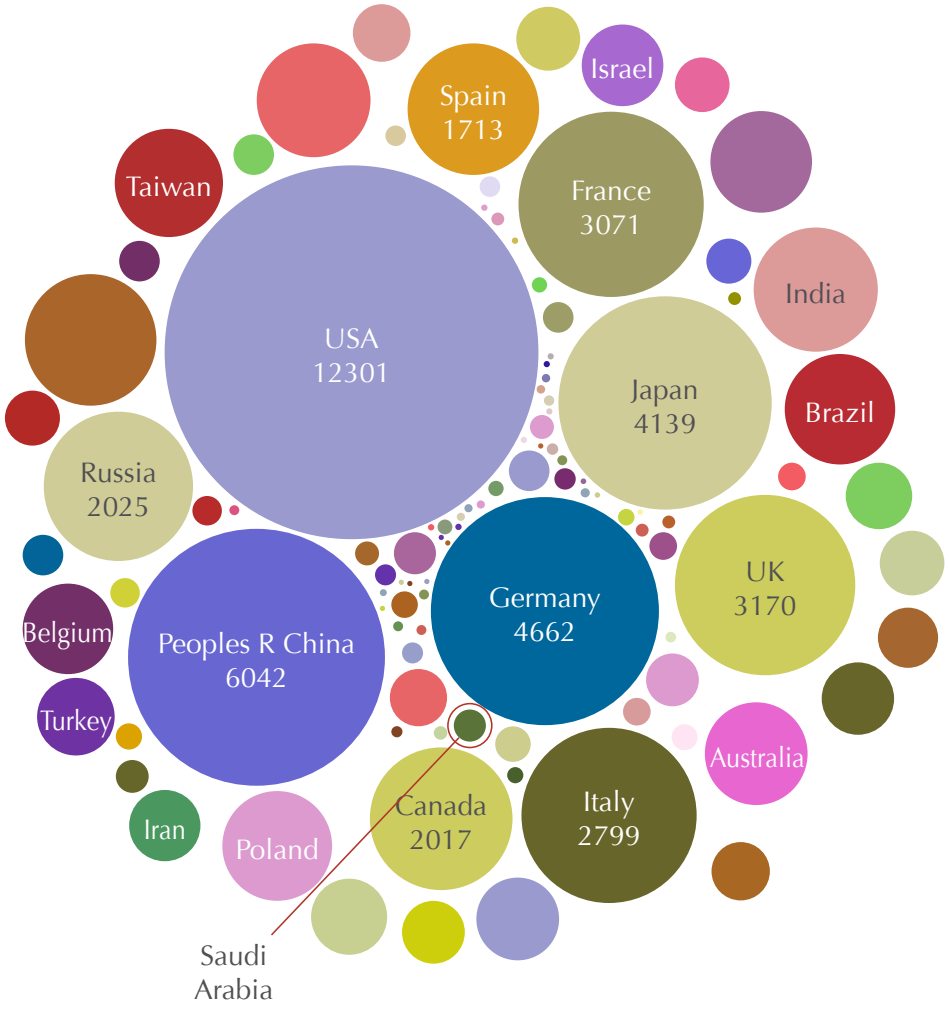
publications and patents are cited by others), and co-authoring relationships. Together, these indicators provide measures of output, impact, and collaboration in fields related to the KSA mathematics and physics program.

Global Mathematics and Physics Publication Activity

In 2007, there were 45,938 articles published worldwide related to the KSA mathematics and physics priorities.[4]

The United States was the world's largest producer of related articles, generating 12,301 articles over this time period. The People's Republic of China was a distant second, producing 6,042 articles, followed by Germany and Japan, with 4,662 and 4,139 articles respectively. Saudi Arabia was tied for the 46th largest producer of publications, producing 104 articles in ISI-indexed journals. Figure 1 shows the number of publications produced by select countries over this time period.[5]

Figure 1: International Math and Physics Publications



4 Throughout this report, "mathematics and physics" refers only to the subset of mathematics and physics defined by the KSA mathematics and physics program.

5 A publication is assigned to a country if any of the publication's author's affiliations are located in that country. Because publications often have multiple authors, a single publication may be assigned to multiple countries. Aggregate figures, such as total global publication output, count each publication only once, but adding up sub-totals may yield a result larger than the reported total due to multiple counting.

As shown in table 3, condensed matter accounts for the largest proportion of mathematics and physics related publications (12,262) followed by high energy physics (11,731), numerical analysis (8,381), applied mathematics (6,686), medical physics (4,370), quantum information (3,460), and optimization (2,863).t.

Table 3: Mathematics and Physics Sub-Topics (2007)

Sub-Topic	Publications
Condensed Matter	12262
High Energy Physics	11731
Numerical Analysis	8381
Applied Mathematics	6686
Medical Physics	4370
Quantum Information	3460
Optimization	2863

Benchmark Countries

Average publication impact is calculated as the number of citations of articles from a particular country divided by the total number of articles published by authors from that country. For instance, a country that published 50 articles that were cited 100 times would have an average publication impact of two. In 2007, Lebanon had the highest average publication impact of all countries at 1.00 followed by Yemen (0.75), Germany (0.74), and the United States (0.72). The average publication impact for Saudi Arabia was 0.55 with 57 citations of 104 articles. Table 4 presents publication and citation counts for benchmark countries. [6]

6 Benchmark countries include global leaders in terms of total mathematics and physics output in addition to a list of specific countries provided by KACST.

Table 4: Benchmark Country Mathematics and Physics Publication Impact (2007)

Country	Publications	Total Citations	Average Publication Impact
Lebanon	21	21	1.00
Yemen	4	3	0.75
Germany	4662	3429	0.74
USA	12301	8801	0.72
France	3071	1930	0.63
Qatar	12	7	0.58
Saudi Arabia	104	57	0.55
Japan	4139	2108	0.51
Turkey	592	210	0.35
Peoples R China	6042	2091	0.35
Syria	9	3	0.33
UAE	32	9	0.28
Iran	478	129	0.27
Bahrain	9	2	0.22
Jordan	34	5	0.15
Oman	14	1	0.07
Kuwait	13	1	0.04

Mathematics and Physics Research Organizations

Nearly 4000 institutions in 128 countries produced mathematics and physics publications in 2007. As shown in table 5, the three institutions producing the largest number of publications related to mathematics and physics are the Chinese Academy of Sciences (977), the Istituto Nazionale di Fisica Nucleare (669), and the University of Paris (648). The Chinese Academy of Sciences is the number one producer of articles in condensed matter, numerical analysis, and applied mathematics. The Istituto Nazionale di Fisica Nucleare was the leading producer of high energy physics related publications. The University of Texas was the largest producer of medical physics-related publications. MIT produced the greatest number of optimization-related publications while the University of Science and Technology of China was the leading producer of quantum information-related publications.

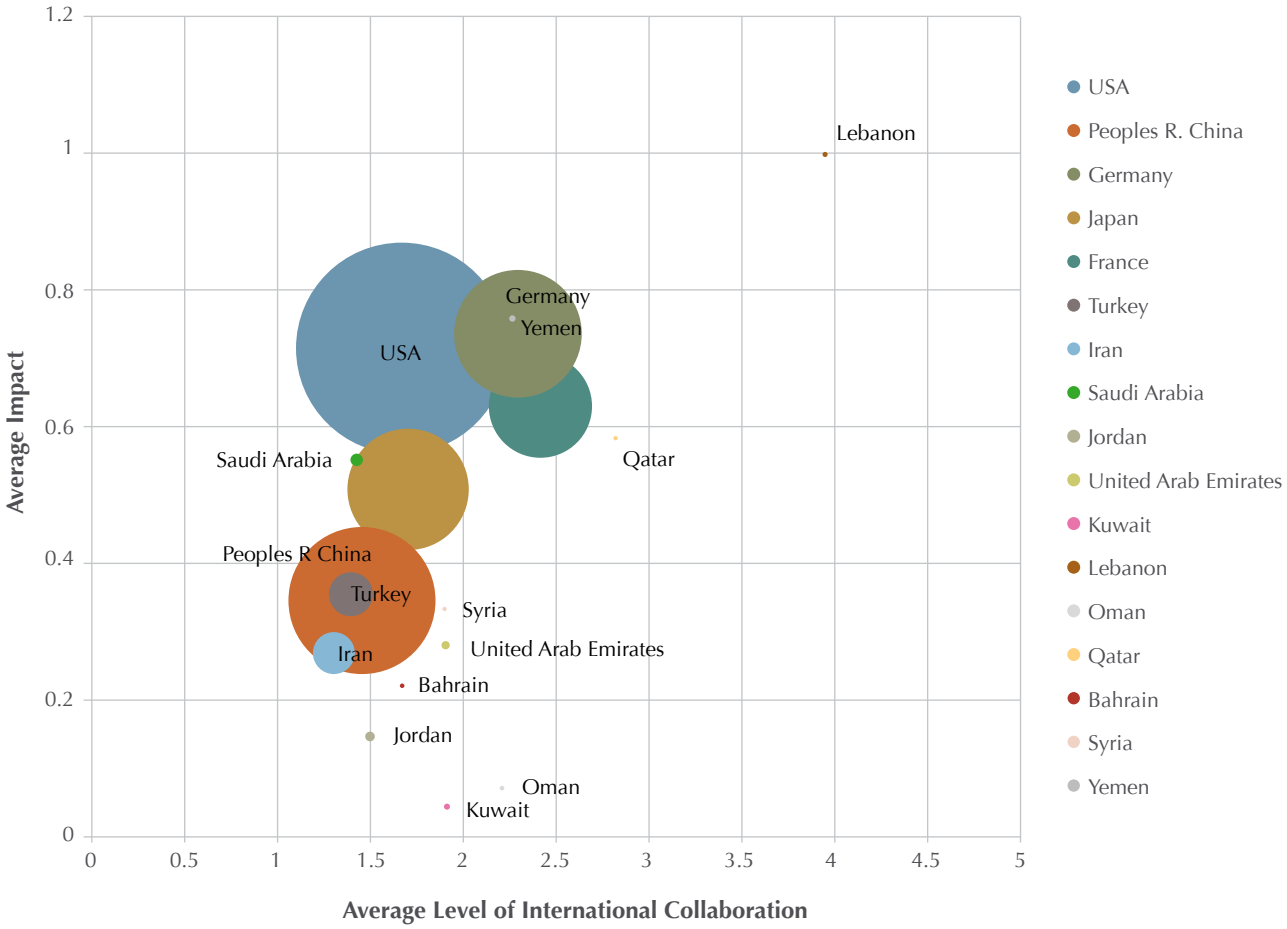
Table 5: Global Mathematics and Physics R&D Organizations (2007)

Institution	Total Publications	Average Impact	Condensed Matter	High Energy Physics	Numerical Analysis	Applied Mathematics	Medical Physics	Quantum Information	Optimization
Chinese Acad Sci	977	0.42	397	266	106	99	37	105	34
Ist Nazl Fis Nucl	669	0.82	95	538	23	20	32	35	1
Univ Paris	648	0.77	115	339	88	71	30	42	15
Univ Texas	596	0.69	90	186	104	49	128	36	31
Univ Tokyo	588	0.82	235	258	46	37	15	35	7
Russian Acad Sci	574	0.29	246	171	46	88	22	34	9
CNRS	462	0.75	160	185	45	40	19	32	14
Univ Sci & Technol China	410	0.67	103	114	64	46	10	110	17
Tsing Hua University	400	0.57	134	98	75	53	13	34	21
Kyoto Univ	371	0.70	145	134	50	26	27	14	9
Univ Illinois	354	0.85	71	158	58	37	12	15	18
Tohoku Univ	351	0.67	176	116	35	18	12	19	8
MIT	351	0.99	83	152	26	36	10	43	35
Univ Calif Berkeley	338	0.88	76	162	41	25	13	23	21
Osaka Univ	327	0.56	138	126	27	19	17	20	1

International Collaboration and Publication Impact

For countries with a similar level of publication activity, those countries with a high level of international collaboration also tend to produce publications with a high level of impact. In this study, international collaboration is calculated as the average number of countries represented per publication, based on authors' addresses. Figure 2 plots a country's level of international collaboration (horizontal axis) against the average impact of its publications (vertical axis). Countries such as Germany and France, with relatively high levels of international collaborative activity also produce papers with a higher average impact. Saudi Arabia has a level of international collaboration close to 1.5, and has an average impact close to that of Japan and the United States.

Figure 2: Mathematics and Physics Collaboration and Publication Impact



KSA Collaboration Activity

As shown in table 6, authors affiliated with KSA institutions collaborated on a significant number of articles with authors from: Egypt (14 publications), the United States (5), Algeria (4) and Canada (4). KSA-affiliated authors collaborated on two publications with authors from: India, Italy, Pakistan, the People's Republic of China, the United Kingdom, and the United Arab Emirates.

Table 6: KSA Publication Collaborators (2007)

Country	Number of Publications
Egypt	14
USA	5
Algeria	4
Canada	4
India	2
Italy	2
Pakistan	2
Peoples R China	2
United Kingdom	2
UAE	2

Mathematics and Physics Journals

Table 7 presents journals with a significant level of publication activity related to KSA mathematics and physics sub-fields in 2007.

Table 7: Mathematics and Physics Journals (2007)

	Journal	Publications
Applied Mathematics	JOURNAL OF MATHEMATICAL ANALYSIS AND APPLICATIONS	239
	APPLIED MATHEMATICS AND COMPUTATION	202
	NONLINEAR ANALYSIS-THEORY METHODS & APPLICATIONS	136
	JOURNAL OF COMPUTATIONAL AND APPLIED MATHEMATICS	100
	PHYSICAL REVIEW A	85
	PHYSICS LETTERS A	85
	CHAOS SOLITONS & FRACTALS	75
	INVERSE PROBLEMS	73
	IEICE TRANSACTIONS ON FUNDAMENTALS OF ELECTRONICS COMMUNICATIONS AND COMPUTER SCIENCES	63
	COMPUTERS & MATHEMATICS WITH APPLICATIONS	62
Condensed Matter	PHYSICAL REVIEW B	818
	IEEE TRANSACTIONS ON APPLIED SUPERCONDUCTIVITY	618
	PHYSICA C-SUPERCONDUCTIVITY AND ITS APPLICATIONS	549
	APPLIED PHYSICS LETTERS	459
	JOURNAL OF APPLIED PHYSICS	257
	PHYSICAL REVIEW LETTERS	247
	JOURNAL OF MAGNETISM AND MAGNETIC MATERIALS	184
	SUPERCONDUCTOR SCIENCE & TECHNOLOGY	175
	JOURNAL OF PHYSICS-CONDENSED MATTER	152
	PHYSICAL REVIEW A	151

	Journal	Publications
Numerical Analysis	COMPUTER METHODS IN APPLIED MECHANICS AND ENGINEERING	133
	LINEAR ALGEBRA AND ITS APPLICATIONS	118
	INTERNATIONAL JOURNAL FOR NUMERICAL METHODS IN ENGINEERING	112
	APPLIED MATHEMATICS AND COMPUTATION	111
	JOURNAL OF PHYSICS A-MATHEMATICAL AND THEORETICAL	97
	JOURNAL OF COMPUTATIONAL PHYSICS	88
	JOURNAL OF SOUND AND VIBRATION	84
	JOURNAL OF COMPUTATIONAL AND APPLIED MATHEMATICS	74
	JOURNAL OF MATHEMATICAL ANALYSIS AND APPLICATIONS	71
	PHYSICAL REVIEW E	69
Math and Physics	INTERNATIONAL JOURNAL OF RADIATION ONCOLOGY BIOLOGY PHYSICS	220
	NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH SECTION A-ACCELERATORS SPECTROMETERS DETECTORS AND ASSOCIATED EQUIPMENT	159
	MEDICAL PHYSICS	158
	PHYSICS IN MEDICINE AND BIOLOGY	116
	RADIOTHERAPY AND ONCOLOGY	89
	RADIATION RESEARCH	73
	HEALTH PHYSICS	59
	NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH SECTION B-BEAM INTERACTIONS WITH MATERIALS AND ATOMS	57
	INTERNATIONAL JOURNAL OF RADIATION BIOLOGY	43
	CANCER RESEARCH	42
Quantum Information	PHYSICAL REVIEW A	633
	PHYSICAL REVIEW LETTERS	235
	PHYSICAL REVIEW B	203
	JOURNAL OF PHYSICS A-MATHEMATICAL AND THEORETICAL	119
	PHYSICS LETTERS A	92
	COMMUNICATIONS IN THEORETICAL PHYSICS	81
	CHINESE PHYSICS	78
	APPLIED PHYSICS LETTERS	78
	OPTICS EXPRESS	75
	NEW JOURNAL OF PHYSICS	74

	Journal	Publications
Optimization	EUROPEAN JOURNAL OF OPERATIONAL RESEARCH	96
	JOURNAL OF OPTIMIZATION THEORY AND APPLICATIONS	47
	JOURNAL OF GLOBAL OPTIMIZATION	43
	APPLIED MATHEMATICS AND COMPUTATION	42
	IEEE TRANSACTIONS ON POWER SYSTEMS	32
	SIAM JOURNAL ON OPTIMIZATION	30
	INDUSTRIAL & ENGINEERING CHEMISTRY RESEARCH	29
	COMPUTATIONAL OPTIMIZATION AND APPLICATIONS	25
	MATHEMATICAL PROGRAMMING	23
	OPTIMIZATION METHODS & SOFTWARE	23
High Energy Physics	PHYSICAL REVIEW D	1014
	JOURNAL OF HIGH ENERGY PHYSICS	542
	PHYSICAL REVIEW C	472
	PHYSICS LETTERS B	445
	NUCLEAR PHYSICS A	375
	PHYSICAL REVIEW B	339
	PHYSICAL REVIEW LETTERS	336
	EUROPEAN PHYSICAL JOURNAL C	225
	EUROPEAN PHYSICAL JOURNAL A	190
	PHYSICAL REVIEW A	170

Mathematics and Physics Patent Activity

Between 2002 and 2006, there were 6,966 mathematics- and physics-related patent applications filed with the United States Patent Office (USPTO). As shown in table 8, the majority of these listed at least one inventor from the United States. Other countries with a significant number of inventors include: Japan, Germany, and the United Kingdom. There were three mathematics- and physics-related patent applications that listed an inventor from Saudi Arabia over this time period. Two of these "Absolute public key cryptographic system and method surviving private-key compromise with other advantages"[7] and "Highly luminescent color-selective nanocrystalline materials"[8] were cited once by other patent applications. The first of these lists Shaik, Cheman of Saudi Arabia, as the sole inventor while the second involved collaboration between five inventors from Saudi Arabia, Spain, and the United States.

7 Shaik, Cheman. U.S. Patent Application # 20020186848, 2002.

8 Bawendi, Moungi, Jensen, Klaus F., Dabbousi, Bashir O., Rodriguez-Viejo, Javier, Mikulec, Frederic Victor. U.S. Patent Application # 20040033359, 2004.

Table 8: Mathematics and Physics Patents (2002-2006)

Country	High Energy Physics	Quantum Information	Condensed Matter	Medical Physics	Numerical Analysis	Optimization	Applied Mathematics	Total
United States	83	139	653	1410	210	258	1622	4287
Japan	21	39	239	443	81	19	334	1160
Germany	6	17	94	180	10	15	87	389
United Kingdom	2	23	50	40	15	1	110	230
France	4	9	11	101	13	4	79	214
China	0	0	5	7	0	10	20	42
Turkey	0	0	0	5	0	0	1	6
Saudi Arabia	0	0	1	0	0	0	2	3
Bahrain	0	0	0	0	0	0	1	1
Iran	0	0	0	0	0	0	0	0
Jordan	0	0	0	0	0	0	0	0
Kuwait	0	0	0	0	0	0	0	0
Lebanon	0	0	0	0	0	0	0	0
Oman	0	0	0	0	0	0	0	0
Qatar	0	0	0	0	0	0	0	0
Syria	0	0	0	0	0	0	0	0
UAE	0	0	0	0	0	0	0	0
Yemen	0	0	0	0	0	0	0	0

While the majority of the mathematics- and physics-related patent applications are defined as individually owned patent applications (4,577 applications) by the United States Patent Office, some institutions are designated as the patent assignee on a number of applications. As organizations with established track-records as inventors in math and physics fields of interest to the Kingdom, these institutions could be future targets for collaboration. As shown in table 9, International Business Machines Corporation is listed as the patent assignee on 134 mathematics and physics applications followed by GE Medical Systems Global Technology Company, LLC, Microsoft Corporation, and Toshiba Corporation.

Table 9: Leading Mathematics and Physics Assignees (2002-2006)

USTPO Assignee	No. of Patents Apps.
Individually Owned Patents	4577
International Business Machines Corporation	134
GE Medical Systems Global Technology Company, LLC	94
Microsoft Corporation	67
Toshiba Corporation	58

One of the patent applications that lists a KSA-based inventor, "Highly luminescent color-selective nanocrystalline materials," lists Massachusetts Institute of Technology as the patent assignee while another, "Method for XZ-elliptic curve cryptography,"[9] lists King Fahd University of Petroleum and Minerals as the patent assignee. The third KSA mathematics and physics related patent application is designated as an individually owned patent.

9 Ibrahim; Mohammad K. U.S. Patent Application # 20050195973, 2005.

Mission and Vision

This plan defines a national mathematics and physics program for Saudi Arabia. The following presents a vision of the desired state of mathematics and physics in the Kingdom five to ten years in the future.

The vision for mathematics and physics in the Kingdom is: *The Kingdom of Saudi Arabia will have strong capabilities in mathematics and physics research that will: provide a strong foundation for other fields of physical science and engineering; support the Kingdom's mathematics and physics education needs; enable active international collaboration on equal footing; and attract top talents to mathematics and physics fields.*

A key aspect of this vision is that it is focused on mathematics and physics research capabilities, conducted by both KACST and universities. Strong research capabilities will provide a strong foundation for other fields of physical science and engineering, as well as computer science. The near-term vision for the Kingdom is not to be strong in all areas of mathematics and physics but to start building capabilities for research and education.

The following is the mission for the Math and Physics Program:

The mission of the National Mathematics and Physics Program is to promote excellence of research and education in physics and mathematics through:

- *Conducting basic and applied research and providing research services.*
- *Leading the development and implementation of the national mathematics and physics plan.*
- *Supporting research collaboration and communication.*
- *Building research infrastructure, including major facilities.*
- *Supporting education and training in mathematics and physics.*
- *Promoting public understanding of mathematics' and physics' role in technology.*

Mathematics and Physics Research and Education Priorities for Saudi Arabia

The mathematics and physics research and education priorities for the Kingdom focus on areas where there are special needs in the Kingdom or where there are existing human resources. The Mathematics and Physics Advisory Committee identified condensed matter physics and applied mathematics as two priority areas where the Mathematics and Physic Program should focus first. Medical physics is another area where there are clear needs in the Kingdom. In other areas, such as accelerator physics, and high energy physics, and quantum information, the needs are less clear and the NCMP should take small steps in building capabilities in these areas. The following are descriptions of these areas.

Condensed Matter Physics

The field of condensed matter deals with the synthesis and characterization of any atomic or molecular clustering systems. These systems can vary in size from nano or even sub-nano-structures to the level of the bulk materials with the variation of the ordering from completely disordered (amorphous) to highly ordered clusters, such as single crystals. Physical characterization of condensed matter involves the determination of its structural, electronic and electrical, mechanical, magnetic, thermal, and optical properties. This field spans the spectrum from basic scientific research to applications. It provides a deep understanding of the properties of matter and explores the use of novel phenomena in various applications.

The Kingdom of Saudi Arabia would benefit from the field of condensed matter physics in different ways. The areas of important needs for the Kingdom include:

- Optical, magnetic physics.
- Codes to predict property of nanomaterials.
- Physics of solids at the nanoscale.
- Electronic state and transport at quantum size limit.
- Material properties, fluids, and magnetism.
- Physics of free radical systems.
- Spintronics.
- Synthesis of materials.

Applied Mathematics

Applied mathematics is a branch of mathematics concerned with the application of mathematics in a wide range of disciplines in various areas such as science, technology, business, and commerce. It solves problems that arise in a wide variety of fields including physics, biology, economics, finance, Earth science, and computer science.

A central activity in applied mathematics is developing mathematical tools and models to understand natural and human systems. Applied mathematics translates the physical world into algorithms – mathematical procedures

– that allow computers to attack bigger and more complex problems and to solve these problems faster than humans can alone. The algorithms developed in applied mathematics power high-fidelity simulation and analysis of physical, chemical and biological processes, describing them in discrete terms that computers can calculate.

Demonstrating its awareness of the increasing importance of applied mathematics, Saudi Arabia should participate in the development of applied mathematics through applications in industry, science, and engineering. In the years ahead, Applied Mathematics research will focus on algorithms that take advantage of computers, which will allow scientists to consider research never thought possible, such as predictive simulation of the physical properties of novel materials. Some of the areas in which applied mathematics can help include:

- Cryptography.
- Epidemiology.
- Statistics.
- Econometrics/financial mathematics.
- Risk analysis for insurance.

Medical Physics

Medical physics is the science of applying physics principles in medicine. It is an interdisciplinary field that mainly deals with medical imaging for diagnostic purposes and radiotherapy. It uses physics tools to help better diagnose diseases at the early stages, and to offer patients proper treatment. In addition to clinical practice, research in medical physics is focused on solving real clinical problems and developing existing and novel techniques in therapy and imaging. Therefore, medical physics has a very important role to play in the Kingdom of Saudi Arabia. With the high number of hospitals and medical centers throughout the Kingdom, the demand for trained clinical practitioners as well as researchers and developers in the field of Medical Physics is increasing substantially.

Accelerator Physics

Much attention has been focused on small accelerators since the development of high frequency alternating voltage. In an accelerator, an ion (or electron or proton) is injected into an accelerating tube. KACST has recently been able to design and construct accelerator tubes for electrostatic accelerators. Accelerators have many research applications, ranging from generating x-rays to the level of revealing properties of trace elements.

High Energy, Cosmology and Astroparticle Physics

High energy physics is primarily concerned with the fundamental processes at the elementary particle level. These processes and their properties are revealed at energy scales of about 1 GeV and higher. The fundamental processes of elementary particles play an important role in the creation and in the evolution of the universe according to the big bang theory. Two years ago, KACST, on behalf of Saudi Arabia, signed an agreement with CERN concerning participation in research in high energy physics.

Quantum Information

This is a new field based on the fundamentals of quantum mechanics that has potential applications at a small scale level, including computer compartments and communication. KSA should be involved in this field to gain experience and participate in the applications and the development from the early stages. This may allow KSA to participate on manufacturing devices based on the trends in this field.

SWOT Analysis for KSA Mathematics and Physics

This section presents a SWOT (strengths, weaknesses, opportunities, and threats) analysis of the Saudi Arabia Mathematics and Physics Program relative to achieving its vision. In a SWOT analysis, terms are defined as follows:

- Strengths: attributes of an organization that are helpful to achieving the objective.
- Weaknesses: attributes of an organization that are harmful to achieving the objective.
- Opportunities: external conditions that are helpful to achieving the objective.
- Threats: external conditions that are harmful to achieving the objective.

Strengths and weaknesses are defined internal to the organization while opportunities and threats are as external to the organization. For the purpose of this analysis, the "organization" is the Saudi Mathematics and Physics Program, including KACST, universities, other government agencies, and companies.

SWOT Analysis for KSA Mathematics and Physics

	Helpful	Harmful
Internal	**Strengths:** ample financial resources some good researchers universities with some capabilities beginning of some international linkages opportunity for NCMP to design and lead national plan	**Weaknesses:** weak physics and math education difficulties attracting best students low enrollment in graduate studies weak research infrastructure lack of culture of research underutilization of women low quality of education for women lack of flexibility/bureaucracy weak R&D in industry
External	**Opportunities:** full participation in world science by Saudi researchers through information technology recognition of importance of research in government demand by some financial institutions for mathematicians	**Threats:** lack of public understanding lack of job prospects constraints in needed reforms difficulties attracting leading researchers to the Kingdom international competition

The overall strengths of the Kingdom in mathematics and physics are its financial resources, some good researchers and universities with capabilities (although limited), and established international linkages.

There are several weaknesses. Research institutes, including universities, government, and industry, do not rank among the top worldwide institutions. Human resources for mathematics and physics research are generally weak. Human resource regulations are inflexible, making it difficult to hire and retain good people in government. Education in mathematics and physics at the K-12 level is not strong and the Kingdom lacks qualified mathematics and physics teachers. The public image of a career in mathematics or physics is not attractive in the Kingdom and therefore it is difficult to attract good students to these fields. For example, the low enrollment rate of graduate students in mathematics and physics poses a great challenge for the research capabilities of universities.

A culture of research through competitive research grant programs in universities is not yet firmly established. Due to various cultural and legal barriers, women are underutilized in mathematics and physics as well as in general science enterprises. The quality of education women receive is weak compared to the education men receive.

SWOT Analysis for KSA Mathematics and Physics

Statistics collected by the U.S. government show that between 1980 and 2004 1,551 Saudi nationals received doctorates in science and engineering fields from U.S. universities; 44 of these doctorates were in mathematics and 34 were in physics. In addition, there are additional doctoral recipients from the universities in the European countries and other parts of the world.

Saudi researchers have insufficient collaboration with others in the Kingdom, their counterparts in industry, or in other countries. R&D in industry is generally weak and there is little track record of successful innovation or of successful implementation of industry-government-university initiatives.

The Saudi national strategy to invest more heavily in S&T provides opportunities. There is the potential to collaborate with international mathematicians and physicists through both existing and newly established linkages. The advance of information technology can help Saudi researchers to participate in the international community of scientists through the Internet, E-learning, shared use of data and facilities, advanced computing, and other means.

The main threat is that international competitors are not standing still, and, indeed, seem to be moving faster than Saudi Arabia. There is a lack of public understanding, including by the mass media, of the importance of mathematics and physics as a foundation of research and education in physical science, engineering, and computer science. It is difficult to attract Saudi expatriate as well as foreign scientists and mathematicians to the Kingdom.

The initiatives in this plan have been designed to take advantage of the KSA strengths and to address the weaknesses, while keeping aware of the opportunities and threats. To take advantage of the KSA strengths, programs have been designed to focus on areas of special KSA needs, and to build on existing capabilities. To counteract the weaknesses, programs have been designed to build capabilities step by step, to train students and researchers in mathematics and physics, and to expand industry-government-university collaboration as well as international collaboration.

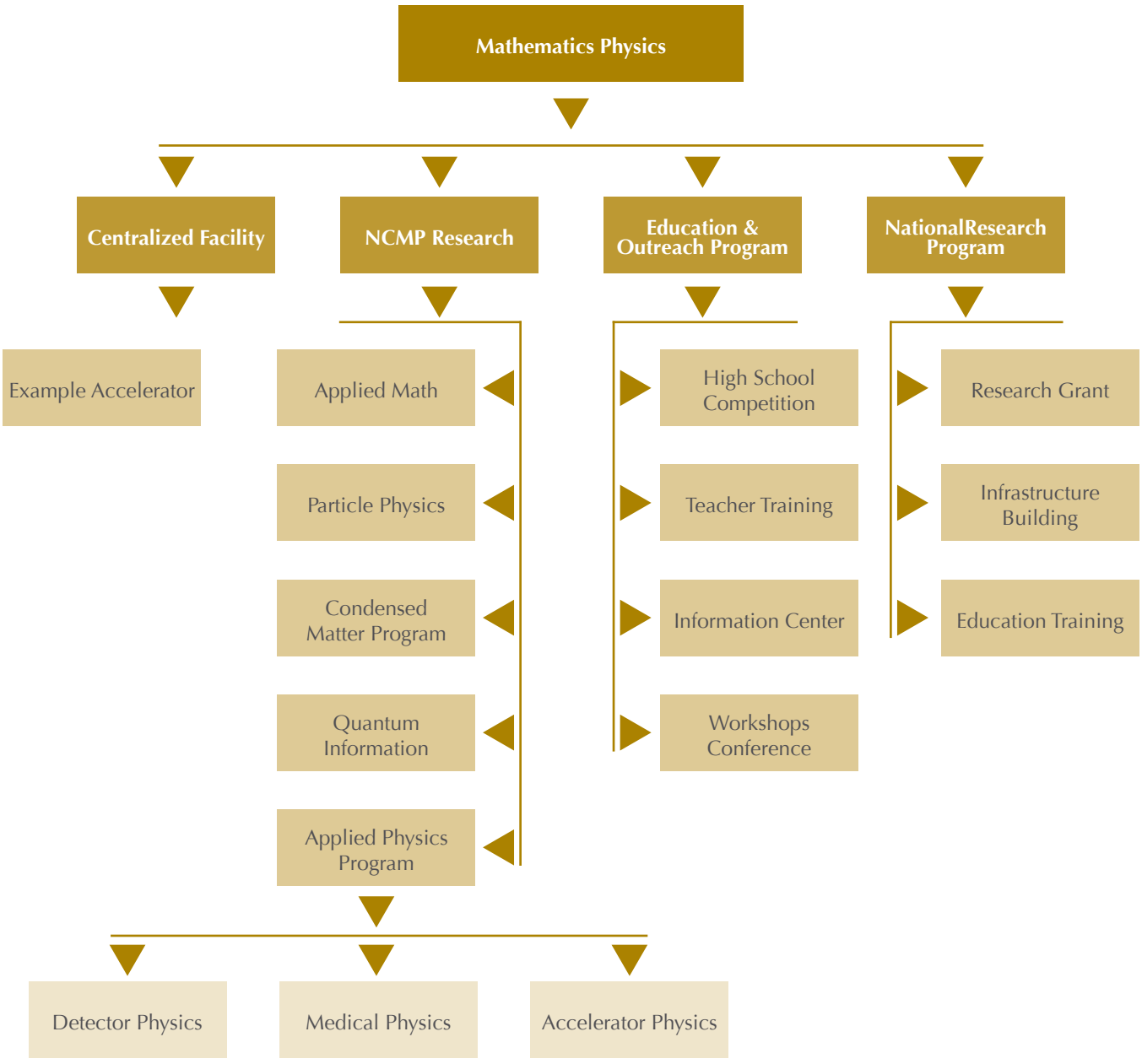
The Proposed Mathematics and Physics Programs

Overview

Figure 3 provides a schematic diagram of the proposed mathematics and physics programs. It shows four programs through which NCMP and the mathematics and physics community can achieve the national vision and mission. The four programs are:

- NCMP Math & Physics Research.
- Math & Physics Research Support.
- Math & Physics Education and Outreach.
- Major Research Facilities.

Figure 3: National Mathematics and Physics Programs



NCMP Math & Physics Research

Charter and Scope

Having a strong research capacity at NCMP will serve the Kingdom's interest by providing research services, managing research facilities, providing leadership for the mathematics and physics community, and improving the quality of mathematics and physics education in the Kingdom. The program will provide postdoctoral positions, undergraduate student internships, and graduate student research assistantships at NCMP, and will support a visiting scholars program. NCMP will also support the National Mathematics and Physics Advisory Committee, which includes members from the international mathematics and physics community.

Strategic Goals and Objectives

The strategic goals is to strengthen in-house research capacity in order to allow NCMP to become a leading regional research center in a broad range of mathematics and physics areas and to be recognized for its world class expertise in areas of special importance to the Kingdom. To build research capacity at NCMP, it is necessary to create a critical mass of researchers, including students, postdocs, and visiting researchers in each of the following areas:

- Condensed matter and statistical physics (solid state physics group).
- Applied mathematics (cryptography group, number theory group).
- Nuclear and high energy physics.
- Quantum information.
- Applied physics (accelerators physics group, medical physics group).

A goal is for NCMP to become a lively place where bright students and promising young researchers (postdoctoral fellows and young faculty) compete to visit for either short term (e.g. summer internships) or long term periods (e.g. one or two year visiting scholarships).

A short-term objective is to conduct a study to determine the needs for research services for the Kingdom. This study will assess the existing capacity of NCMP and address how the research groups at NCMP should grow and in what order, based on clear needs and interests expressed by stakeholders and taking into account limited resources.

Roles of Key Partners

NCMP, which is a part of KACST, will play the lead role in building its own research capacity; the role of universities and industry will be minimal in this effort. Other institutes and centers of KACST will be the stakeholders and consumers of NCMP research services, and therefore should participate in planning the strategic direction of NCMP.

Math & Physics Research Support

Charter and Scope

This program aims to promote a culture of research in universities around the Kingdom by providing the basic infrastructure for research in mathematics and physics.

Strategic Goals and Objectives

This program has several goals and objectives.

- Determine existing capabilities KSA math and physics research capabilities. The C.V.s of current mathematics and physics researchers will be collected, coded, and studied. Saudi researchers will be surveyed to gain their assessment of the current capabilities of the Kingdom.
- Establish a competitive research grants program to help university faculty members invest more time in research. We propose that the research grants be used to enable faculty to reduce their teaching load, hire

graduate students or postdoctoral fellows, and provide supplemental income in the summer.

- Advocate policy changes in universities to allow faculty to spend more time on research. Activities under this objective include a study of barriers to research at universities and recommend changes.
- Establish a postdoctoral fellowship program to support university research. Postdoctoral positions are integral to the creation of a research community at universities. Many countries consider postdoctoral fellowships a cost effective way of improving research capabilities.
- Develop a research intensive doctoral program (jointly with a foreign university with an international reputation) in math and physics. Mathematics and physics are not currently included among the technical focus areas at KAUST, and so an exemplary research-focused mathematics and physics PhD program in the Kingdom should be established at another university.
- Establish an undergraduate research experience program. Research experiences can provide undergraduate students with an experience of the excitement of research and may attract bright students in mathematics and physics to graduate school and on to careers as researchers. The research experience program should involve undergraduate students in actual research, from design and execution to presentation of the results in meaningful ways. The research experience program can be designed as a summer institute or during the academic year.
- Support research collaboration and communication in math and physics. Programs such as scientific visits, scientific symposia and workshops are an expansion of existing NCMP programs. In addition to current NCMP programs, the program will support university researchers to organize their own scientific meetings on a case by case basis.

Roles of Key Partners

- University faculties will submit proposals for competitive research grants and for the undergraduate research experience programs and will perform such projects.
- KACST will write request for proposals (RFPs) for those programs, select awardees through a peer review process, guide university faculties, and generally manage those programs.
- Industry can participate in undergraduate research experience programs by becoming a hosting institution for students. Industry can also host postdoctoral fellows or support universities in the creation of postdoctoral positions.

Math & Physics Education and Outreach

Charter and Scope

This will be a coordinated national program to improve mathematics and physics research and education that includes scientific workshops, special seminars, training courses, K-12 teacher training program, research experiences for K-12 teachers, mathematics and physics competitions for high school students, and research grants that support curriculum reform, improvement of text books, and creation of content of e-learning

- Scientific workshops.
- Special Seminars.
- Training courses.
- K-12 teacher training program.
- Research experiences for K-12 teachers.
- Mathematics and physics Olympiad.
- Research grants that support curriculum reform, improvement of text books, and creation of content of e-learning.

Improved mathematics and physics education will benefit the Kingdom by:

- Providing a good foundation for students to study science and engineering.
- Providing a model for improving K-12 education for other fields of science and engineering through teacher training, certification, and research participation programs.
- Strengthening overall science and mathematics education in the Kingdom if these programs are expanded into all areas of science, mathematics, and engineering education at K-12 levels.

Strategic Goals and Objectives

The strategic objectives for the program are to:

- Improve mathematics and physics education at all levels so that students are better prepared to study science and engineering in college and beyond.
- Involve university faculties in improving K-12 mathematics and physics education through various programs, including research on effective curriculum, improved text books, and e-learning materials.

The program will involve:

- *K-12 teacher training courses*. This program will support universities to provide math and science training courses for K-12 teachers, typically held over school holidays. Teachers who successfully complete the training program should be provided incentives in the form of promotions or salary increases.
- *Research experiences for K-12 teachers*. This program will enable teachers to participate in mathematics and physics research at the university laboratories or at NCMP. This will increase the expertise of teachers and allow them to convey the excitement of research into their own classrooms.
- *National Mathematics and physics Olympiad*. This program is currently managed by NCMP. NCMP may consider expanding this program to include elements of experiments and scientific research (e.g. science fair), in addition to traditional paper and pencil tests in a classroom setting.
- *Research grants that support curriculum reform, improvement of text books, and creation of content of e-learning*. In this program, the focus is to encourage university professors to engage in research to improve mathematics and physics education in the Kingdom by producing high quality materials and curriculum reform.

Roles of Key Partners

- KACST will fund and manage the national program, including program planning, funding allocation, and establishing and evaluating performance targets.
- Universities will provide training and research experience programs where teachers can not only renew their existing knowledge of mathematics and physics, but also participate in on-going cutting edge research to enable them to convey the excitement of research in the classroom.
- The Ministry of Education and the Ministry of Higher Education will collaborate with KACST as partners and will provide co-funding for part of these programs.

Major Research Facilities

Charter and Scope

This is a national program to develop, build, and manage major research facilities and equipment in Saudi Arabia. The facility or facilities (it is not yet determined if there will be a single facility or several) will support researchers in universities, industry, and other government agencies who are engaged in physics research, as well as other science and engineering research and development efforts that require the research equipment. This in turn will strengthen the national system of innovation in the Kingdom.

The Proposed Mathematics and Physics Programs

Strategic Goals and Objectives

The purpose of this program is to establish a major research instrumentation facility or facilities for physics research that can also serve researchers in physics and other fields, and can put Saudi Arabia on the map within the international physics community.

Program components include the design, development, construction, management, and training of "customers" who want to use the facilities.

NCMP will develop a plan for the Major Research Facilities that includes:

- Creating an inventory of current facilities.
- Studying the Kingdom's future needs and gaps.
- Developing procedures for sharing the facility.
- Developing a plan to acquire/build facilities.
- Acquiring/building the facilities.
- Considering building cyber infrastructure for remote use of the facilities.

Several examples of the needed instruments that were suggested during the NCMP workshop included:

- A tandem electrostatic accelerator.
- A supercomputer (advanced computing).
- A research reactor.
- A high power magnet.

Roles of Key Partners

- NCMP will lead the efforts for a feasibility study of the needs, management, construction, and administration of the research facilities.

- Universities, through the competitive peer review process, can co-manage research facilities with NCMP. It may be desirable to view the management of the major research facilities project as a challenge for the entire physics community in the Kingdom, mobilizing community support and strengthening the community in the process. The Physics Society can play a strong role in the feasibility study as well.

- This program will be coordinated with other KACST institutes and national S&T plans, including those in mathematics and physics (accelerators and research reactor) and information technology (supercomputing).

- Industry and other government agencies can participate if their needs are met through the construction of the facilities.

Operational Plans

Operational plans include a knowledge transfer plan, a quality management plan, a human resources plan, a communications plan, and a risk management plan.

Knowledge transfer plan

The mathematics and physics program should have an effective knowledge transfer plan so that the results of research in mathematics and physics contribute to the strengthening of the Kingdom's scientific capabilities. Key elements of the program that are designed to facilitate knowledge transfer are the following.

Involvement of stakeholders in the program design. This occurs through stakeholder participation in the planning workshop, and in the mathematics and physics advisory committee. It is well recognized that stakeholder involvement in the research design leads to research and outcomes that are more likely to meet the needs of stakeholders, and thus are more likely to lead to successful knowledge transfer.

Knowledge transfer through workshops, education, training, exchange, publications, research services, and consulting to the technology programs. Knowledge transfer can occur in various ways. The most significant method of knowledge transfer is through the movement of people. Various exchange programs such as internships, postdoctoral fellowships, and visiting scholarships are effective means of knowledge transfer. Scholarly meetings, publications, and the use of Internet

are also effective transfer means. The movement of people and information should cross geographical and institutional boundaries to be truly effective.

Quality management plan

The mathematics and physics program will follow international best practice quality management processes for science and technology programs. Elements of this plan include:

- Advisory committee review of the overall program design and budget.
- Competitive, peer-reviewed selection processes for projects.
- Annual reviews of research projects to ensure that milestones are being met.
- Periodic (every 5 years) evaluation of the mathematics and physics program conducted by a review committee supported by an experienced evaluator.

Procedures will be developed for disclosing and managing potential conflicts of interest among reviewers. In many cases, some international experts will be used on review panels to reduce possible conflicts of interest and to provide an independent external assessment.

Human resources plan

The availability of skilled people, including both researchers and technical managers and leaders, is likely to be a limiting factor in the growth and success of the KSA mathematics and physics program. The program will require substantial numbers of additional researchers at KACST, at universities and at companies.

This plan is designed to help increase the numbers of mathematics and physics researchers over the long term through its emphasis on education and training of mathematicians and physicists at every point along the pipeline – K-12 schools, undergraduate, graduate, and postdocs. These programs are designed to train new students with research skills needed by research organizations and industry.

In the short-run, other strategies to expand the human resources for the mathematics and physics program are:

- Changes in policies to allow more international hiring to bring specialized expertise to the Kingdom.
- Training for researchers to become R&D managers and leaders.
- Training of lab technicians.

Communications management plan

The purpose of the communications management plan is to provide appropriate information to the program participants and stakeholders. One element of the communications plan is to improve communication throughout the KSA mathematics and physics community and to expand collaboration among members of the community. Aspects of this include:

- There will be a public website with information on program goals, accomplishments, funding opportunities, and other news.
- Periodic workshops will be held with users and stakeholders to define future program needs.
- Requests for proposals (for university centers, grants, and pilot application development programs) will be announced to the public.
- The program advisory board will review and comment on the program, and advisory board reports will be made public on the website.
- The program will sponsor workshops, conferences, and professional society activities to expand communication and networking throughout the community.
- Presentations on the program will be made at national and international conferences.

Another element of the plan is to define appropriate

communications within the management structure of the plan. It is especially important that information about risks or difficulties in the program, such as delays, lack of resources, or non-attainment of goals be rapidly communicated to higher levels of management. A general principle is that management should never be surprised by bad news.

Risk management plan

The program presented here is an ambitious program that will challenge the capabilities of the Kingdom. There are several types of risks that could prevent attainment of program goals, including technical risks, market risks, and financial risk. One source of technical risk – risk to attainment of technical goals – is the lack of adequate human resources to implement the program. Approaches to managing this risk are:

- Changing policies to attract people with the needed skills. This may involve raising salaries and recruiting internationally.
- Delaying or phasing in some program elements if people cannot be hired.
- Expanding the pool of people with needed skills through education and training programs.

Another cause of technical risk is overly ambitious goals. The approaches to addressing this risk are to have an independent review of technical goals to ensure they are feasible and to adjust technical goals if milestones are not being met. Another risk is that regulatory barriers may prevent efficient execution of the projects. For example, delays in being able to import or obtain scientific supplies may hold up projects. There also are risks due to lack of flexibility in project execution – it is important to be able to modify research projects as new knowledge is gained or better approaches become available. Another risk is that quality of performance will be poor due to lack of competition. To address this risk, a competitive research grant program should be implemented and adequate rewards should be given to those who perform well.

The market risk is that projects, while scientifically successful, do not contribute to strengthening the national innovation system and do not result in knowledge transfer if researchers are not in communication with people who will use their research results. Also there is a risk that the results of research will not be disseminated widely and will not reach people who may use them. Here, the market refers to the market of ideas, not products.

A way to address this risk is through:

- Designing programs based on carefully considered needs of the Kingdom.
- Monitoring international developments in mathematics and physics fields.
- Continual readjustment of plans in response to changes in the environment.

Financial risk is the risk of unavailability of funds or of cost overruns. The way to address risks in this area is through careful program planning and monitoring, and early identification of possible cost overruns.

Implementation of the Plan

Within KACST, the NCMP will be responsible for the overall execution of the plan. Many aspects of the plan represent new functions for NCMP, especially in developing and managing national research and education programs that include universities and international collaborations. A major task for the first year of the program will be, in addition to detailed program planning, for NCMP to acquire or develop the necessary skills through hiring or training. Although it is critical to rapidly start new research programs, it is essential to build the skills necessary to lead and develop these programs, and to plan them carefully. As part of the initial activities under this plan, NCMP staff members will visit programs of a similar nature elsewhere in the world to discuss their management practices and lessons learned.

The National Mathematics and Physics Advisory Committee (MPAC) will oversee the implementation of the plan. NCMP will charter MPAC, which will consist of 6 to 8 members to be appointed by the director of NCMP, who will also appoint the committee's chair. Members will serve three-year terms, renewable once, with the terms staggered so that approximately one-third of the terms come up for renewal each year. MPAC will include members from the international scientific community outside of the Kingdom. NCMP may eventually establish a separate international mathematics and physics advisory committee if there is a distinct and clear need for two separate advisory committees. At the beginning, however, a single committee with a few members from the international scientific community will be established.

MPAC will meet approximately four times a year and review progress in the program and approve updates to the plan as necessary. Key performance indicators will be established for each subprogram. General performance indicators include:

- Number and impact of math and physics publications in the Kingdom.
- Number and level of presentations in international conferences.
- Number of cases of NCMP and universities providing math and physics-

Implementation of the Plan

based technical assistance to industry or other KACST institutes.

- Changes in policies (described previously) to improve research in universities.
- Extent of domestic and international math and physics research collaborations.
- University and industry use of major research facilities.
- Numbers of math and physics advanced degrees awarded.
- Number of teachers who complete math and physics training.
- Number of teachers who obtain research experiences.

In the near term, the committee will monitor the establishment of the program and projects, and progress of the projects towards their milestones.

The advisory committee will also sponsor and oversee studies of emerging areas of math and physics, to serve as the basis for developing new program areas. This plan is intended to be a dynamic document that will be updated at least annually and more frequently if required. In addition to the advisory committee input, it is expected that workshops with the research community, users, industry and other stakeholders will also contribute to both a continual evolution of the plan as well as a stronger math and physics research and education network in the Kingdom.

Appendix 1: Advisory Committee Members

Prof. Riazuddin
Director General of the National Centre for Physics, Pakistan
email: riazuddin@ncp.edu.pk

Prof. Katepalli R. Sreenivasan
ICTP director, Italy
email: director@ictp.it

Dr. Fahad Jalawi
Mathematics Department, King Faisal University,
email: fjalawi@hotmail.com

Dr. Abdulaziz D. Alhaidari
Saudi Shoura Council, Saudi Arabia,
email: haidari@mailaps.org

Prof. Fawzi A. Al-Thukair
Mathematics Department, King Saud University
email: thukair@ksu.edu.sa

Dr. Nouar Tabet
Physics Department, KFUPM, Saudi Arabia
email: natabet@kfupm.edu.sa

Dr. Hamad Alhendi,
Department of Physics and Astronomy, King Saud University
email: alhendi@ksu.edu.sa

Dr. Ali Mohamad
President of the Saudi Physical society, King Khalid University,
email: ahajry@kku.edu.sa

KACST Planning Team Members

Name
Hamoud H. Alharbi
Okla S. Al-Horayess
Mohammad A. Bahmaid
Hassan Al-Ahaidib

Tel 488 3555 - 488 3444
Fax 488 3756
P.O. Box 6086 Riyadh 11442
Kingdom of Saudi Arabia
www.kacst.edu.sa

King Abdulaziz City for Science and Technology

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