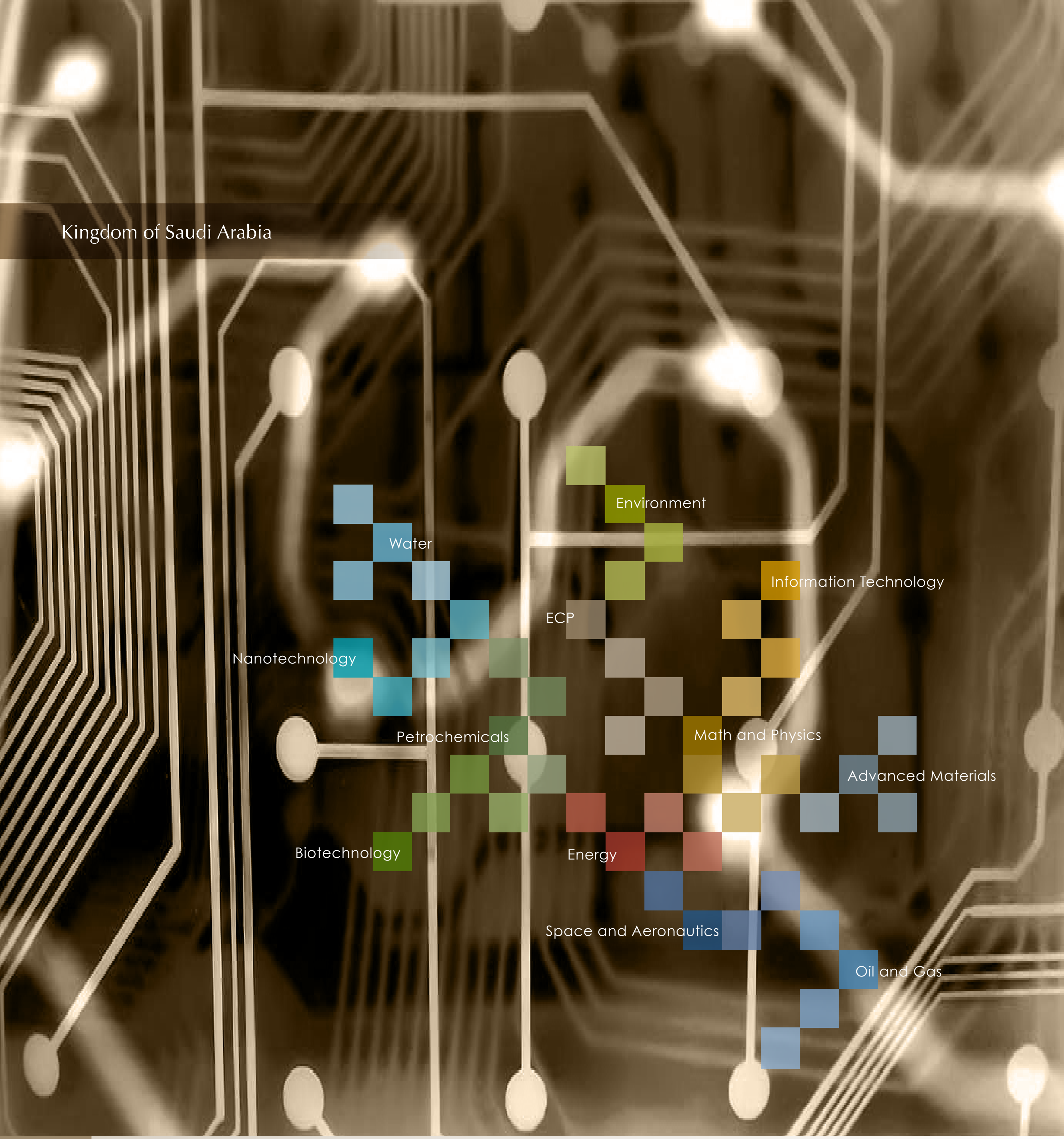
Kingdom of Saudi Arabia



Strategic Priorities for Electronics, Communications and Photonics Technology Program

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Executive summary

The National Science and Technology Policy was approved by the Council of Ministers in 1423 H (2002 G). Then a five year implementation plan was developed which encompassed eight major programs including the strategic technology program. The strategic technologies program consists of eleven technology programs targeted for localization and development. This plan is for one of these technology programs, i.e. the Electronics, Communications, and Photonics (ECP) Technology Program.

ECP technologies are particularly broad in scope and are used in virtually all applications. As a result, the focus of the Electronics, Communications and Photonics program has been narrowed to four initiatives and six special technologies. These initiatives and technologies were selected based on the specific needs and objectives of the Kingdom of Saudi Arabia. The following are the recommended initiatives and technologies:

- Wireless Communications and Wireless Sensor Networks:
  - RFID.
  - Body Sensor Networks.
  - Oil & Gas pipeline monitoring.
  - Condition-Based Maintenance.
  - Software Defined Radio.
  - Cognitive Wireless Networks.
  - UWB (Ultra Wide Band).
- Information Security:
  - Quantum Cryptography.
  - Quantum Computing.
  - Cryptography.
  - Emission Control and Shielding.
- Lasers and their Applications:
  - Optical Memories.
  - Surveillance.

- LIDARs (Laser Radars).
- Advanced MEMS Sensors & Actuators:
  - Optical MEMS.
  - High Performance Actuators.
  - Micro fluidics.
  - Inertial Sensors.
- Recommended technologies:
  - Integrated circuits (ICs).
  - Microwave systems.
  - Reconfigurable computing.
  - Printed circuit boards (PCB) Fabrication & Design.
  - Electro-optics.
  - Digital signal processing (DSP).

The strategic plan as presented is the result of a number of workshops conducted in 1428H (2007G). Stakeholders from various public and private sectors with vested interests in ECP technology development in the Kingdom participated in the series of workshops. An important byproduct of the workshops was the development of new partnerships between strategic stakeholders in the Kingdom. These have positively influenced the development of the S&T ECP plan.

Introduction

Background

King Abdulaziz City for Science and Technology (KACST) was directed by its charter of 1986 to "propose a national policy for the development of science and technology and to devise the strategy and plans necessary to implement them." In accordance with this charter, KACST launched a comprehensive effort in collaboration with the Ministry of Economy and Planning (MoEP), to develop a long-term national policy on science and technology. In July 2002, the Council of Ministers approved the national policy for science and technology, "The Comprehensive, Long-Term, National Science and Technology Policy."

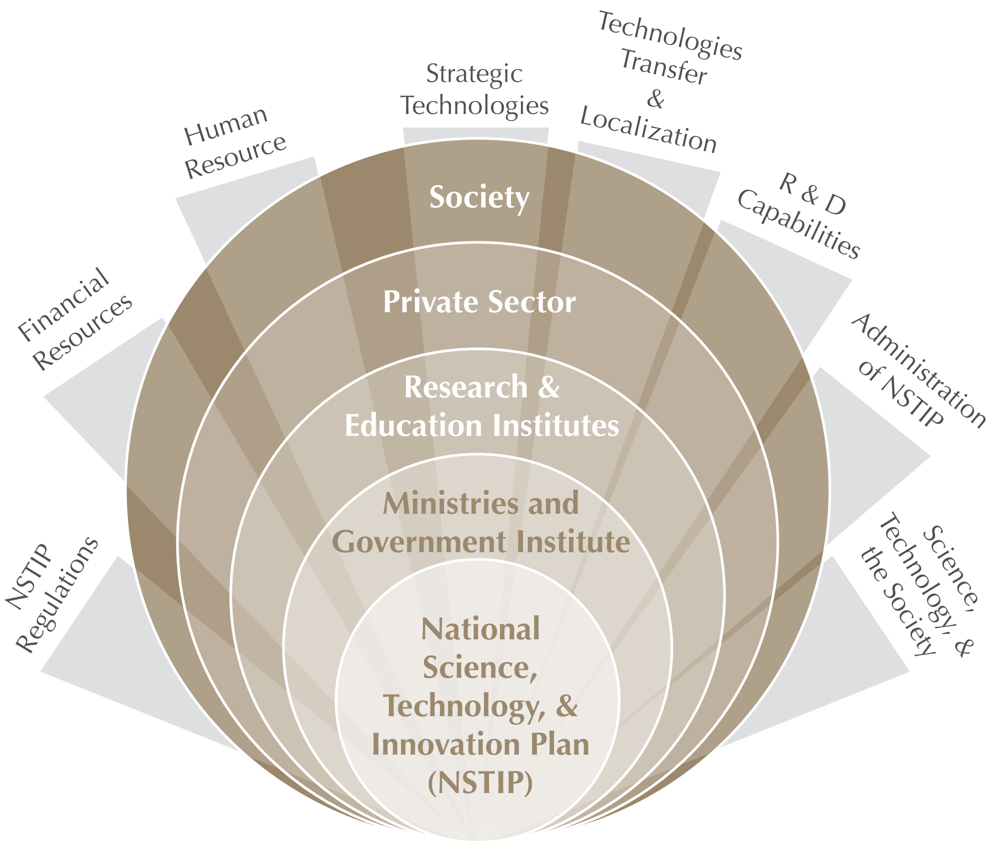
KACST and MoEP, in collaboration with relevant stakeholders, developed the national plan for science, technology and innovation (STI) under the framework of the Comprehensive National Science and Technology Policy. The plan outlined the focus and future direction of science, technology, and innovation in the Kingdom, with considerations to the roles of KACST, the universities, government, industry and the society at large.

The plan encompasses eight major programs, depicted in figure 1, as follows:

1. Strategic and advanced technologies
2. Scientific research and technical development capabilities
3. Transfer, development and localizing technology
4. Science, technology and society
5. Scientific and technical human resources
6. Diversifying financial support resources
7. Science, technology and innovation system
8. Institutional structures for science, technology and innovation

Introduction

Figure 1: Science and Technology Programs



In the "Strategic and Advanced Technologies" program, KACST is responsible for 5-year strategic and implementation plans for 11 technologies:

1. Water
2. Oil & Gas
3. Petrochemicals
4. Nanotechnology
5. Biotechnology
6. Information Technology
7. Electronics, Communication, & Photonics
8. Space and Aeronautics
9. Energy
10. Environment
11. Advanced Materials

Each plan establishes a mission and a vision, identifies stakeholders and users, and establishes the kingdom's highest priority technical areas for implementation.

Introduction

Program Scope

The breadth of the Saudi Arabian National Policy for Science and Technology spans 20 years. However, the ECP program presented here focuses on only the first five years. The ECP program is to implement the proposed plan through performing projects that shall deliver prototypes and/or products that can be commercialized immediately by an appropriate private sector partner or delivered to appropriate incubators for further industrialization efforts. The research projects and the development of commercial applications are to serve knowledge generation and transfer.

The principal concepts employed by the ECP program are the following:

- **Technology Development:** involves developing new technologies that are non-existent, or currently unavailable in the Kingdom. Technology development may involve some basic research.

- **Technology Localization:** involves research and education required to strengthen the absorptive capacity of the Kingdom. It emphasizes the development of local technical human resources and policy structures to promote the acquisition of beneficial foreign technologies and the generation of new technologies in the Kingdom.

- **Technology Transfer:** involves scientific and technical support for transferring technologies into the Kingdom. The program will emphasize the development of local capacity to prevent a dependence on foreign technologies.

A new Strategic Management Office (SMO) will be formed to manage the ECP program. Stakeholders from key institutional sectors of the Kingdom will be represented in the program. These include representatives from industry, related engineering departments in the universities, and the related government agencies.

Plan Development Process

The data and discussions in this report are results of a number of workshop sessions and studies that have all been carried out throughout the year 1428 H, corresponding to 2007 G. In addition to KACST ECP management, stakeholders from various public and private sectors participated in the workshops. A strategic planning consultant was contracted to act as a facilitator to educate the stakeholders about the main elements and mechanisms of strategic planning. In addition to the stakeholders, several well known international scholars and consultants were invited to the workshops. Some of the scholars had participated in similar planning exercises in their own countries. They contributed knowledge of the current state of the art in technology and research in various ECP areas and provided input to forecasting future research and market trends. Some of the consultants have also shared their insights into the research-to-market process. An important byproduct of the workshops was the formation of valuable partnerships among several stakeholders as well as with international institutions.

Key Needs of KSA

The Kingdom of Saudi Arabia is not as highly ranked in electronics, communications, and photonics technologies relative to other nations of comparable size and wealth. In order to improve the ranking of the Kingdom and meet domestic needs in these technology areas, there must be a broad improvement in the infrastructure and knowledge base within the Kingdom. Under the framework of the National Science and Technology Policy, the broad needs of the Kingdom are identified as follows:

- **Self reliance:** The Kingdom needs to be self reliant in certain critical technologies as a matter of national security as well as in its ability to sustain economic and social strength. As examples for such critical technologies are information security and communication networks.

- **Economic diversification:** The Kingdom needs to further develop and diversify its economy. Domestic competence in ECP fields can lead to the diversification in niche sectors of industries in the Kingdom.

- **Accelerated development:** In the current global environment of increasing networking, the Kingdom needs to close the knowledge gap between itself and the leading developing countries. Accelerating the development of a knowledge economy and closing the gap with other countries will strengthen the ties between the Kingdom and the world.

Stakeholders Roles

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

Table 1: Stakeholder Roles

Stakeholders	Role
KACST	■ Plan, coordinate and manage the program
	■ Conduct applied research, technology transfer and prototype applications development
	■ Manage and participate in national projects
	■ 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.
Universities	■ Create new basic and applied scientific knowledge
	■ Train students in science and engineering
	■ Host and participate in Technology Innovation Centers
	■ Participate in collaborative projects
Independent or Government Specialized Research Centers	■ Create new applied scientific knowledge
	■ Participate in collaborative projects
Ministries and Government Agencies	■ Implementation of new technologies in ECP
	■ Identifying research themes
	■ Contribution in developing some technologies through advanced training
	■ Testing of technologies to be localized and/or developed
	■ Provide input to program on government R&D needs
	■ Reduce regulatory and procedural barriers to R&D and innovation
	■ Support R&D in universities and industry

Stakeholders	Role
Private Sector	• Develop and commercialize products & processes resulting from the program.
	• Communicate company needs to program
	• Support and participate in collaborative R&D projects.
	• Support and participate in the Technology Innovation Centers
	• Provide additional financial support
	• Identifying market challenges
	• Contributing with technical information
	• Contributing in identifying priorities

Analysis of Comparable ECPP R&D Institutes

In 2007, KACST launched an organization-wide strategic planning effort to better align its R&D priorities with the national needs of the Kingdom of Saudi Arabia. To support this effort, an analysis of comparable international research institutions related to electronics, communication and photonics was conducted. The five institutions examined, listed in the table 2, reflect a broad range of research activities, corresponding with KACST's own R&D activities.

Table 2:

Selected Electronics, Communication and Photonics Research Institutions	
Institute	**Country**
Defence Science and Technology Organization (DSTO)	Australia
Communications Research Center Canada (CRC)	Canada
The Industrial Technology Research Institute (ITRI)	Taiwan
Defence Science and Technology Laboratory (DSTL)	United Kingdom
National Institute of Standards and Technology (NIST) Electronics and Electrical Engineering Laboratory (EEEL)	USA

These institutes differ substantially in size and research focus. Staff size varies significantly from more than 200 at CRC to more than 6,000 at ITRI. The research foci vary substantially, reflecting each institute's mission and status as part of a larger governmental "parent" organization or as a relatively autonomous or free-standing institution. Two research organizations, Australia's Defence Science and Technology Organisation (DSTO) and United Kingdom's Defence Science and Technology Laboratory (DSTL), are housed within their national defense agencies and focus on R&D related to national security needs and interests. The other three research institutions either focus on civilian electronics, communication and photonics uses, or on industrial applications and requirements.

A full description of these laboratories' programs can be found in a separate document.[1]

Analysis of ECPP publications and patents

The overall field, "electronics, communications & photonics", as well as sub-topics, were defined in close consultation with KACST researchers and other KSA stakeholders. "Electronics, communications, and photonics" is a multidisciplinary field built on several key enabling technologies. The KSA electronics, communications, and photonics program identifies seven major enabling technologies: integrated circuit (IC) design / very large scale integration (VLSI), radiofrequency (RF) and microwave (MW) systems, antenna design, electro-optics, digital signal processing (DSP), printed circuit board (PCB) fabrication and design, and reconfigurable computing. KACST researchers defined these enabling technologies and provided detailed lists of keyword terms that were used to query publication and patent databases.[2] Electronics, communications & photonics is a fast moving field, so the scope of this study was restricted to only recent publication (2005-2007) and patent (2002-2006) activity in the seven KACST defined fields.

There is general agreement that publications and patents strongly correlate with scientific research capacity, although publication and patent counts alone do not fully represent 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. These include forward citations (the frequency at which publications and patents are cited by others), which are a measure of impact, and co-authoring relationships, which are an indicator of scientific collaboration. Together, these indicators provide measures of collaboration, globalization and impact of science and technology research in fields related to the KSA electronics, communications & photonics program.

1 Strategic Review: Electronic, Communication, and Photonic Technology. Report prepared by SRI International for KACST.

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.

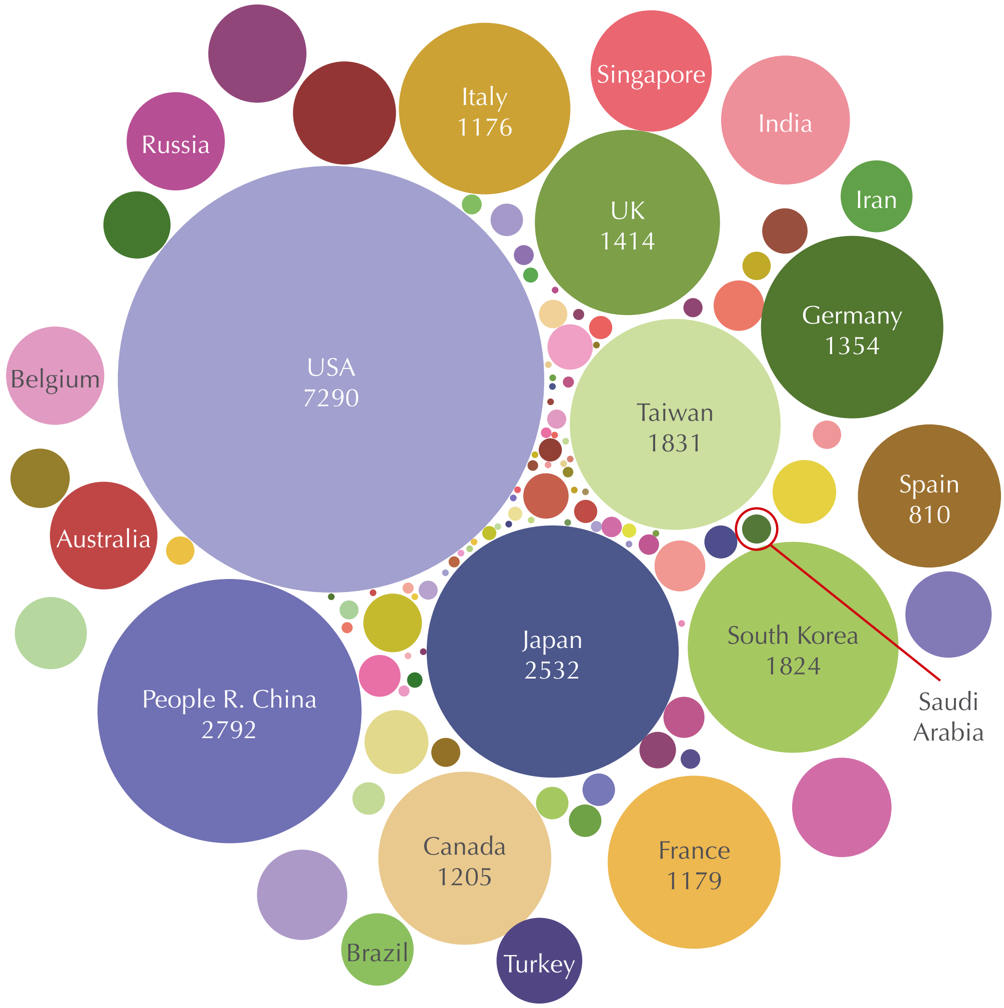
3 Seminal research in the use of publications as a measure of scientific productivity includes A.J. Lotka, "The frequency distribution of scientific productivity," Journal of the Washington Academy of Sciences, vol 16 (1926); D. Price, Little Science, Big Science, (New York: Columbia university Press, 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.

Findings

Global Electronics, Communications & Photonics Publication Activity

Between 2005 and 2007, there were 26,251 articles published worldwide in electronics, communications & photonics fields related to KSA research priorities[4] The United States was the world's largest producer of related articles, generating 7,290 articles over this time period. The People's Republic of China was second, producing 2,792 articles followed by Japan, Taiwan, and South Korea with 2,532, 1,831, and 1,824 articles, respectively. Saudi Arabia was the 46th largest producer of electronics, communications and photonics publications, producing 37 articles. Figure 2 shows the number of publications produced by country over this time period.[5]

Figure 2: ECP Publications (2006-2007)



4 Throughout this report, "electronics, communications & photonics" refers only to the subset of electronics, communications & photonics defined by the KSA research priorities.

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, IC design / VLSI accounts for the largest number of electronics, communications, and photonics related publications, followed by RF and MW systems, antenna design, electro-optics, DSP, PCB fabrication and design, and reconfigurable computing.

Table 3: Electronics, Communications, and Photonics Sub-Topics

Sub-Topic	Publications
IC Design / VLSI	9834
RF and MW Systems	6705
Antenna Design	5004
Electro-optics	3142
DSP	1875
PCB Fabrication and Design	1213
Reconfigurable Computing	909

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. Between 2005 and 2007, Australia had the highest average publication impact of all countries at 2.28 followed by the United States (2.19), Norway (2.14), and Sweden (1.76). The average publication impact for Saudi Arabia was 0.46 with 17 citations of 37 articles. Table 4 presents publication and citation counts for benchmark countries.[6]

6 Benchmark countries include global leaders in terms of total electronics, communications & photonics output in addition to a list of specific countries provided by KACST.

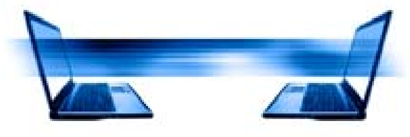
Table 4: Benchmark Country Publication Impact (2005-2007)

Country	Publications	Total Citations	Average Publication Impact
Australia	467	1065	2.28
USA	7290	15930	2.19
Norway	80	171	2.14
Sweden	384	675	1.76
Canada	1205	1986	1.65
UAE	18	29	1.61
Ireland	141	196	1.39
Indonesia	6	8	1.33
Finland	307	371	1.21
Peoples R China	2792	3055	1.09
Taiwan	1831	1957	1.07
South Korea	1824	1878	1.03
Turkey	279	281	1.01
India	653	635	0.97
Egypt	95	89	0.94
Iran	205	163	0.80
Thailand	69	34	0.49
Saudi Arabia	37	17	0.46
South Africa	48	22	0.46
Malaysia	70	30	0.43

The most cited article with a KSA author "Optimization and characterization of electromagnetically coupled patch antennas using RBF neural networks,"[7] which was cited five times by other papers, was co-authored by authors affiliated with institutions in KSA and Egypt.

7 Mohamed, MDA, Soliman, EA, El-Gamal, MA. 2006. Optimization and characterization of electromagnetically coupled patch antennas using RBF neural networks. J. Electromagn. Waves Appl., 20 (8): 1101-1114. (RBF is radial basis function)

Strategic Context



Electronics, Communications, and Photonics Research Organizations

Electronics, communications, and photonics R&D publications are produced at several thousand research institutions in nearly 110 countries. As shown in table 5, the three institutions producing the largest number of publications related to electronics, communications, and photonics R&D are the University of Texas (401), the Chinese Academy of Sciences (387), and Tsing Hua University (332). The Chinese Academy of Sciences produces the greatest number of both RF and MW systems and electro-optics publications. National Chiao Tung University is the leading producer of IC design/VLSI publications. The University of Texas produces the greatest number of DSP articles. The City University of Hong Kong is the leading producer of antenna design related publications. National Cheng Kung University is the leading producer of PCB fabrication and design publications. Nanyang Technological University produces the greatest number of reconfigurable computing related publications.

Table 5: Global Electronics, Communications, and Photonics Research Organizations (2005 – 2007)

Institution	Total Publications	Average Impact	IC Design & VLSI	RF & MW Systems	Antenna Design	Electrooptics	DSP	PCB Fabrication and Design	Reconfigurable Computing
Univ Texas	401	1.85	177	70	94	31	40	15	17
Chinese Acad Sci	387	1.44	80	145	21	114	22	10	4
Tsing Hua University	332	0.69	164	83	47	21	19	20	6
Natl Chiao Tung Univ	326	0.80	212	73	30	19	13	9	3
Natl Taiwan Univ	314	1.39	200	110	17	25	11	11	8
Nanyang Technol Univ	302	1.16	118	80	66	29	29	17	19
Georgia Inst Technol	286	1.68	137	82	55	28	15	16	7
Univ Tokyo	241	2.20	96	38	21	56	31	8	1
Univ Calif Los Angeles	238	2.37	97	42	66	31	24	5	14
MIT	224	2.65	84	76	26	45	3	6	8
Stanford Univ	220	4.11	88	70	32	34	9	3	4
Univ Florida	219	2.26	111	67	25	27	10	10	8
Korea Adv Inst Sci & Technol	217	1.44	124	75	21	17	7	19	3
Natl Cheng Kung Univ	203	0.94	82	60	22	22	5	32	8
Indian Inst Technol	196	0.66	88	27	37	20	17	5	17

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. International collaboration is calculated as the average number of countries represented per publication, based on authors' addresses. Figure 3 plots a country's level of international collaboration (horizontal axis) against the average impact of its publications (vertical axis). Countries such as Norway and Australia which show significant international collaborative activity also tend to produce papers with a higher average impact.

Figure 3: International Collaboration and Publication Impact (2005-2007)

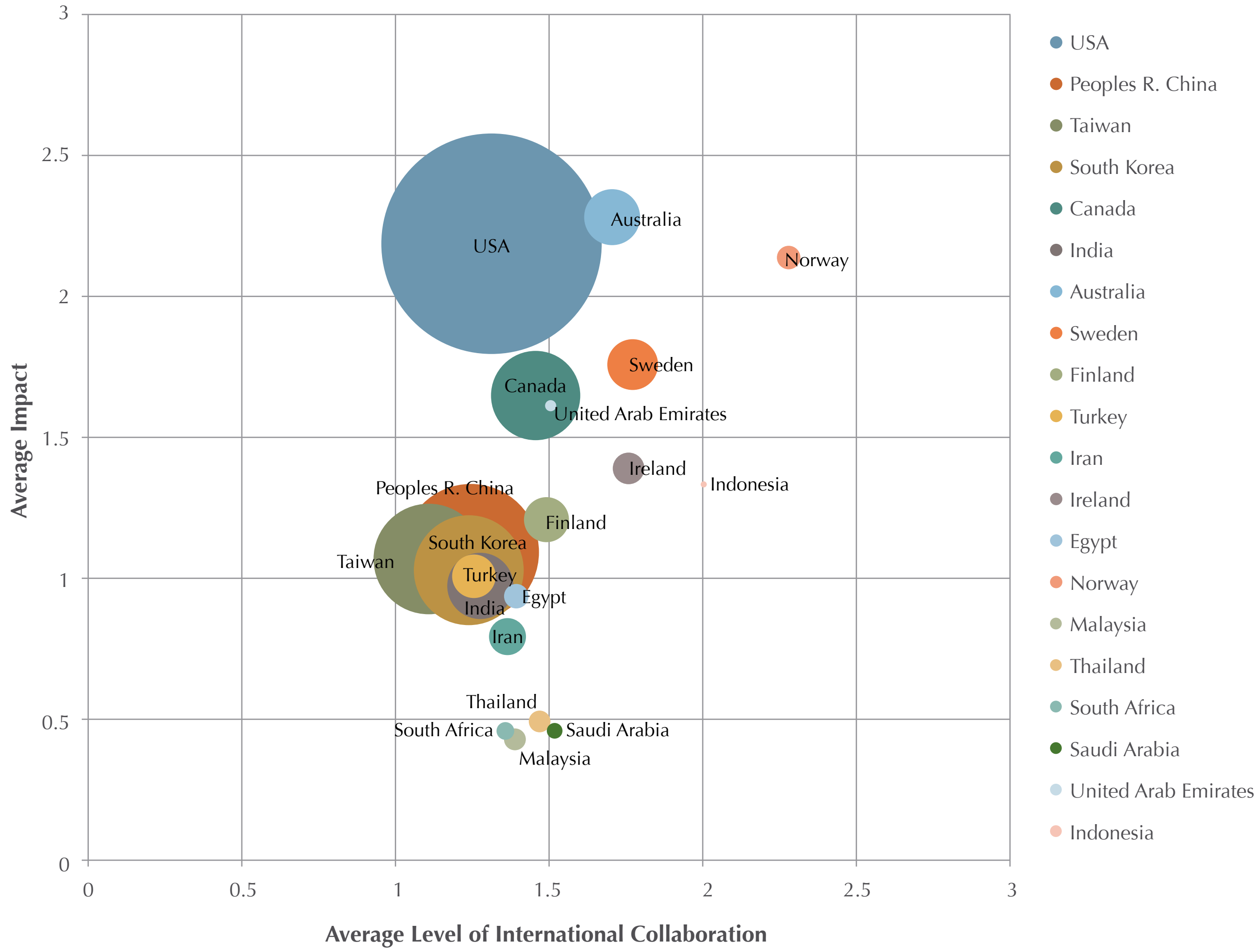


Table 6: KSA Publication Collaborators (2005 - 2007)

Country	Number of Publications
Canada	6
Egypt	4
USA	3
Algeria	1
Belgium	1
India	1
Kuwait	1
Sudan	1
UK	1

KSA Collaboration Activity

As shown in table 6, KSA-affiliated authors collaborated on more than one article with authors from: Canada (6 publications), Egypt (4 publications) and the United States (3 publications). KSA authors collaborated on one article with authors from: Algeria, Belgium, India, Kuwait, Sudan, and the United Kingdom.

Electronics, Communications & Photonics Journals

Table 7 below presents journals with the highest number of publications from 2005-2007 in the subfields of electronics, communications, & photonics as defined for this study.

Table 7: Electronics, Communications & Photonics Journals (2005 - 2007)

	Journal	Publications
Antenna Design	MICROWAVE AND OPTICAL TECHNOLOGY LETTERS	766
	IEEE TRANSACTIONS ON ANTENNAS AND PROPAGATION	691
	IEEE ANTENNAS AND WIRELESS PROPAGATION LETTERS	235
	ELECTRONICS LETTERS	227
	IEEE TRANSACTIONS ON WIRELESS COMMUNICATIONS	216
	IEICE TRANSACTIONS ON COMMUNICATIONS	169
	JOURNAL OF ELECTROMAGNETIC WAVES AND APPLICATIONS	135
	IEEE TRANSACTIONS ON MICROWAVE THEORY AND TECHNIQUES	117
	PROGRESS IN ELECTROMAGNETICS RESEARCH-PIER	109
	IEEE ANTENNAS AND PROPAGATION MAGAZINE	96

Strategic Context

	Journal	Publications
RF & MW Systems	IEEE TRANSACTIONS ON MICROWAVE THEORY AND TECHNIQUES	369
	MICROWAVE AND OPTICAL TECHNOLOGY LETTERS	258
	IEEE MICROWAVE AND WIRELESS COMPONENTS LETTERS	255
	OPTICS EXPRESS	245
	IEEE JOURNAL OF SOLID-STATE CIRCUITS	218
	APPLIED PHYSICS LETTERS	175
	IEEE TRANSACTIONS ON ANTENNAS AND PROPAGATION	173
	IEEE PHOTONICS TECHNOLOGY LETTERS	131
	ELECTRONICS LETTERS	121
	OPTICS LETTERS	116
Reconfigurable Computing	MICROPROCESSORS AND MICROSYSTEMS	35
	IEEE TRANSACTIONS ON VERY LARGE SCALE INTEGRATION (VLSI) SYSTEMS	29
	RECONFIGURABLE COMPUTING: ARCHITECTURES AND APPLICATIONS	23
	JOURNAL OF VLSI SIGNAL PROCESSING SYSTEMS FOR SIGNAL IMAGE AND VIDEO TECHNOLOGY	19
	IEEE TRANSACTIONS ON COMPUTER-AIDED DESIGN OF INTEGRATED CIRCUITS AND SYSTEMS	15
	IEICE TRANSACTIONS ON INFORMATION AND SYSTEMS	12
	IEEE TRANSACTIONS ON COMPUTERS	11
	JOURNAL OF PARALLEL AND DISTRIBUTED COMPUTING	10
	JOURNAL OF SYSTEMS ARCHITECTURE	10
	ACM TRANSACTIONS ON DESIGN AUTOMATION OF ELECTRONIC SYSTEMS	10
IC Design	IEEE JOURNAL OF SOLID-STATE CIRCUITS	755
	IEEE TRANSACTIONS ON CIRCUITS AND SYSTEMS I-REGULAR PAPERS	306
	IEEE TRANSACTIONS ON ELECTRON DEVICES	301
	IEEE TRANSACTIONS ON CIRCUITS AND SYSTEMS II-EXPRESS BRIEFS	264
	IEEE TRANSACTIONS ON VERY LARGE SCALE INTEGRATION (VLSI) SYSTEMS	240
	ELECTRONICS LETTERS	235
	IEICE TRANSACTIONS ON ELECTRONICS	234
	IEEE TRANSACTIONS ON MICROWAVE THEORY AND TECHNIQUES	227
	ANALOG INTEGRATED CIRCUITS AND SIGNAL PROCESSING	224
	IEEE TRANSACTIONS ON NUCLEAR SCIENCE	212

	Journal	Publications
PCB Fabrication and Design	MICROWAVE AND OPTICAL TECHNOLOGY LETTERS	43
	IEEE TRANSACTIONS ON ADVANCED PACKAGING	36
	IEEE TRANSACTIONS ON MICROWAVE THEORY AND TECHNIQUES	35
	IEEE TRANSACTIONS ON ELECTROMAGNETIC COMPATIBILITY	34
	MICROELECTRONICS RELIABILITY	32
	IEEE TRANSACTIONS ON ANTENNAS AND PROPAGATION	31
	IEEE MICROWAVE AND WIRELESS COMPONENTS LETTERS	27
	IEEE TRANSACTIONS ON COMPONENTS AND PACKAGING TECHNOLOGIES	25
	IEICE TRANSACTIONS ON ELECTRONICS	20
	INTERNATIONAL JOURNAL OF ADVANCED MANUFACTURING TECHNOLOGY	20
Electrooptics	APPLIED PHYSICS LETTERS	162
	OPTICS EXPRESS	155
	IEEE PHOTONICS TECHNOLOGY LETTERS	136
	JOURNAL OF LIGHTWAVE TECHNOLOGY	88
	JAPANESE JOURNAL OF APPLIED PHYSICS PART 1-REGULAR PAPERS BRIEF COMMUNICATIONS & REVIEW PAPERS	81
	JOURNAL OF APPLIED PHYSICS	72
	PHYSICAL REVIEW B	72
	OPTICS LETTERS	65
	OPTICS COMMUNICATIONS	54
	MOLECULAR CRYSTALS AND LIQUID CRYSTALS	41
DSP	IEEE PHOTONICS TECHNOLOGY LETTERS	73
	IEEE TRANSACTIONS ON INSTRUMENTATION AND MEASUREMENT	53
	JOURNAL OF LIGHTWAVE TECHNOLOGY	51
	IEEE TRANSACTIONS ON INDUSTRIAL ELECTRONICS	46
	JOURNAL OF VLSI SIGNAL PROCESSING SYSTEMS FOR SIGNAL IMAGE AND VIDEO TECHNOLOGY	35
	IEEE TRANSACTIONS ON NUCLEAR SCIENCE	33
	EURASIP JOURNAL ON APPLIED SIGNAL PROCESSING	30
	IEEE TRANSACTIONS ON POWER ELECTRONICS	28
	IEE PROCEEDINGS-ELECTRIC POWER APPLICATIONS	23
	IEEE TRANSACTIONS ON SIGNAL PROCESSING	22

Electronics, Communications & Photonics Patent Activity

Between 2002 and 2006, there were 12,947 electronics, communications, and photonics-related patent applications filed with the United States Patent Office (USPTO). As shown in table 8, the majority of these (6,394) listed at least one inventor from the United States. Other countries with a significant number of inventors include: Japan (2,828 applications), South Korea (889 applications), and Taiwan (653 applications). No electronics, communications, and photonics related patent applications listed an inventor from Saudi Arabia over this time period.

Table 8: Information Technology Patents (2002 - 2006)

Country	PCB Fabrication & Design	IC Design / VLSI	Antenna Design	RF & MW Systems	Reconfigurable Computing	Electrooptics	DSP	Total
United States	216	1610	1362	1991	358	468	586	6394
Japan	45	1091	428	593	4	487	231	2828
South Korea	37	309	282	185	1	43	56	889
Taiwan	53	290	152	101	2	30	37	653
Germany	28	175	129	124	13	78	37	571
Canada	12	27	98	132	19	14	28	317
Finland	0	2	81	44	2	3	9	136
Sweden	1	9	51	51	1	2	5	117
China	7	12	27	18	1	21	7	91
Australia	3	6	21	14	1	7	10	58
India	1	21	3	10	4	0	9	47
Ireland	3	5	4	11	6	0	0	28
Malaysia	7	3	1	3	0	0	0	14
Norway	0	3	5	2	0	3	0	13
South Africa	0	1	1	7	0	1	0	10
Thailand	0	2	1	0	0	0	0	3
Turkey	0	1	2	0	0	1	0	3
Egypt	0	0	0	1	0	1	0	2
Indonesia	0	0	0	0	0	0	1	1
Iran	0	0	0	1	0	0		1
Saudi Arabia	0	0	0	0	0	0	0	0
UAE	0	0	0	0	0	0	0	0

While the majority of electronics, communications, and photonics-related patent applications are defined as individually owned patent applications (7,938 applications) by the United States Patent Office, institutions are designated as the patent assignee on a significant number of applications. As shown in table 9, International Business Machines Company is listed as the patent assignee on 243 electronics, communications, and photonics related patent applications followed by Samsung Electronics (239 applications), Seiko Epson Corporation (176 applications), and NEC Corporation (153 applications). The top three most cited electronics, communications, and photonics related patent applications are all designated as individually owned patents.

Table 9: Leading Electronics, Communications, and Photonics Patent Assignees (2002 - 2006)

USTPO Assignee	No. of Patents Apps.
Individually Owned Patents	7938
International Business Machines Corporation	243
Samsung Electronics	239
Seiko Epson Corporation	176
NEC Corporation	153
Fujitsu Limited	104
Broadcom Corporation	102
Matsushita Electric Industrial Company	63

SWOT Analysis for KSA ECP Technology Program

This section presents the strengths, weaknesses, opportunities, and threats (SWOT) analysis of the ECP technology program. Strengths and weaknesses are internal to the organization while opportunities and threats are defined as external to the organization. For the purpose of this analysis, the “organization” includes KACST, universities, other government agencies, and companies.

SWOT Analysis for the ECP Program		
Internal	**Strengths:** ■ Availability of financial support and the strong growth of the national GDP ■ Availability of political support ■ Availability of raw materials needed for ECP industries	**Weaknesses:** ■ Weakness of communication structures among all beneficiaries and stakeholders ■ Difficulties in acquiring technical support ■ Absence of coordination between R&D bodies ■ Weak technology development culture ■ Difficult patent organization and registration ■ Scarcity of well trained and experienced human resources (and the difficulty of attracting them to work in R&D fields) ■ Scarcity of success stories in this field
External	**Opportunities:** ■ Abundance of electronic peripherals and the immediate need for them in a very wide spectrum of applications ■ Long term benefits call for localization and development of these technologies ■ Reducing dependence on important technologies ■ High return of investments in ECP technologies	**Threats:** ■ Scattering the efforts in many sub-tracks, which may result in loosing focus ■ Contradictions resulting from fuzziness of roles with respect to different stakeholders ■ Confidentiality of some of the technologies to be localized ■ The rapid global development of ECP technologies

Higher Strategy

This section provides the vision for the Kingdom in ECP research and innovation, and the mission, values, and strategic goals for the program.

Vision

The vision for KSA ECP research and innovation is:

To be among the leading countries in the region in the fields of Electronics, Communications and Photonics through an integrated and proactive approach to developing the technological, knowledge-based, and managerial infrastructure in the Kingdom.

This vision focuses on the establishment of an effective innovation system in which research and innovation can lead to economic and social benefits for the Kingdom. To achieve this, it is essential to have strong and mutually beneficial linkages between universities, government, and industry.

Mission

The mission for the KSA ECP research and innovation program is:

To construct an efficient and effective system in localizing and developing Electronics, Communications, and Photonics technologies through formulation of modern scientific applications and methodologies that contribute in elevating performance, reducing costs, broadening strategic alliances, expanding investing opportunities and empowering specialized personnel and experts.

Program Values and Culture

To achieve excellence, the program will develop an internal culture based on the following values:

- Integrity.
- Sincere drive for excellence and proficiency.
- Creativity and innovation.
- Teamwork and collaboration.
- Quality.
- Loyalty.

Program Strategic Goals

The program's strategic goals are aligned with the objectives of the National Policy for Science and Technology and the key needs of the Kingdom. The following are the ECP program strategic goals for the next 5 years:

- Acquisition of high value added technologies.
- Bridging gaps between all stakeholders and beneficiaries.
- Establishing advanced labs.
- Promoting research.
- Updating curricula.
- Qualifying of human resources.
- Opening of new investment and market opportunities.
- Forming new specialized employment opportunities.

Program Initiatives and Technologies

The ECP program categorized its activities into initiatives, and technologies. "Initiatives" are defined as application areas involving many technical specialties. For example, an RFID project may need researchers working in the areas of communication systems, RF, and IC design and may need DSP, PCB, IC, and RF labs and equipments as well. By contrast, the program uses "technology" to mean a single technical discipline. This single discipline can serve many other fields and initiatives. For example, a single reconfigurable computing chip can be used to build devices for communication, customer electronics, and all the others defined above.

The stakeholders selected both initiatives and technologies by applying selection criteria. The following section describes the selection criteria and the selected initiatives and technologies.

Selection Criteria

The selection criteria were based on three categories of impact -– strategic, economic and scientific. These criteria are derived from the national policy for science and technology (NPST). The national policy defines the general objectives for the implementation framework and determines the evaluation criteria.

Strategic impact

Strategic impact criteria are those which help determine whether individual technologies and initiatives have a direct impact on the Kingdom's security and essential infrastructures and resources. The following are the criteria used to judge strategic impact:

- Need for self-reliance.
- Ability to develop / recruit human resources.
- Availability / accessibility of technology.
- Ability to localize / develop technology.
- Long-term viability.
- Breadth of application domain.
- Future growth potential.
- Economic diversification potential.
- Business opportunities potential.
- Ability to create / localize jobs.
- Contribution to national image.

Economic impact

Economic impact criteria are those which help determine the degree to which ECP technologies and initiatives contribute to and impact the growth and diversity of the Kingdom's economy. In addition to considerations of contribution to the Kingdom's economy, the criteria are designed to filter programs that have the potential to positively affect the wealth of individual Saudi citizens. The following are the economic impact criteria:

- Breadth of application domain.
- Future growth potential.
- Economic diversification potential.
- Availability of committed beneficiaries.
- Business opportunities potential.
- Ability to create / localize jobs.
- Lower financial capital required.
- Expected return on investment (ROI).

Scientific impact

Scientific impact criteria are those which help determine the impact of potential ECP technologies and initiatives on the Kingdom's scientific and technical capability. The following are the criteria used:

- Contribution to national image.
- Contribution to the scientific body of knowledge.
- Ability to localize / develop technology.
- Future growth potential.
- Long-term viability.

Selected Initiatives

Information Security

With the growing sophistication of data communications and networking, the risk of knowledge, identity, and information thefts is increasing dramatically. Also, the global economy is transforming into a "knowledge-based economy." These realities have raised the importance of "information security", which is considered a national security matter in many countries.

Improving the infrastructure for information security and communications within the Kingdom is vital for the continued improvement of its industrial base. ECP fields such as data encryption, intruder detection and advanced communications technologies are necessary components for developing such an infrastructure.

Key elements of the Information Security initiative include:

- Quantum cryptography.
- Quantum computing.
- Cryptography.
- Emission control and shielding.

Wireless Communications & Sensor Networks

The development of Wireless Sensor Networks (WSNs) is a new technology platform. Recent advancements in wireless communications and electronics have enabled the development of low-cost WSNs. The sensor networks can be used in critical applications such as health care, home, security, energy, ecology and environment. Nearly all oil and gas companies use wireless technologies for field monitoring and automation applications, such as pipeline operation and wellhead monitoring. Most of these are wireless technologies that are outdated and expensive. The oil and gas industry will spend $200 million on WSNs over the next three years, according to ON World. The Kingdom has made an early commitment to wireless communications and needs to continue to develop these technologies to take full advantage of the possibilities.

Key elements of the Wireless Communications and Wireless Sensor Networks initiative include:

- RFID.
- Body sensor networks.
- Oil & gas pipeline monitoring.
- Condition-based maintenance.
- Software defined radio.
- Cognitive wireless networks.
- UWB (Ultra Wide Band).

Lasers and Their Applications

Photonics, the applications of light energy whose basic unit is the photon, involves the fields of optics, laser technology, materials science, and information storage and processing. Photonics research has migrated from being almost exclusively associated with large research laboratories into mainstream industrial and university settings. The reduced capital necessary to undertake photonics research has lowered the barriers to entry and made it accessible to countries, such as the Kingdom, that are developing their science and technology capacity. Research in photonics, lasers and their applications are relevant across several sectors of the economy such as information technology, healthcare, security and safety, and lighting.

Key elements of the Lasers and Their Applications initiative include:

- Optical memories.
- Surveillance.
- LIDARs (Laser Radars).

MEMS Sensors & Actuators

Microelectromechanical systems (MEMS) promise

to revolutionize many product categories by bringing together silicon-based microelectronics with micro mechanical systems, making possible the realization of complete systems on the micro scale. There are several applications relevant to the industrial needs of the Kingdom. It is an enabling technology for the development of smart products that can be used, for example, in oil and gas, petrochemical, and water research applications. Continued development of MEMS technologies will be necessary to complement research initiatives in other areas critical to the needs of the Kingdom.

Key elements of the Advanced MEMS Sensors & Actuators initiative include:

- Optical MEMS.
- High Performance Actuators.
- Micro fluidics.
- Inertial Sensors.

Selected Technologies

Integrated Circuits (ICs)

Miniaturizing of electronic components started changing the consumer electronics and research domains especially after the introduction of the planar technology. With this technology, it became possible to realize an increasing number of electronic components on the same chip. The term Integrated Circuit (IC) refers thus to the electronic device composed of an electronic circuit realized by the use of planar technology on a single chip. As a result of the aforementioned improvements the capabilities of ICs has continued to grow while the cost is being reduced.

As is reported in several market analyses, the electronics market growth is several times larger than the global GDP growth. As a matter of fact, the electronics industry has reshaped the economies and societies of several nations. In the electronics market today, there are three main categories that electronics companies fall under: fabless companies, foundries, and integrated device manufacturers (IDM).

Fabless companies design, produce and sell their products but they outsource the fabrication and packaging of their products. The capital required is about $5 million; this form is the most suitable for the Kingdom.

Pure-play semiconductor foundries provide the fabrication for fabless design companies. They fabricate their customers' designs and protect their customer's intellectual property. The typical cost of a foundry can be more than $3 billion and the running and upgrade cost is in the range of several hundreds of millions of dollars. Success of such a model is a function of several factors among which are the supporting policies of the nation.

Integrated Device Manufacturers provide the complete set of functions including design, testing, fabrication and packaging of micro-electronic devices. These are the largest companies in terms of scale and capital.

Microwave Systems

Microwave (MW) systems are those working in frequencies ranging from few hundred megahertz to tens of gigahertz. Microwave systems have many applications, including radar, antenna, MW imaging, and telecommunication systems. The systems require relatively few general components and the scale of costs are considerably less than those associated with microelectronic devices. Given the array of important applications, the development of technical capacity in microwave systems in the Kingdom is critical. The design and fabrication of these components is crucially needed in the Kingdom and their technologies should be transferred and localized.

Reconfigurable Computing

There are two main computational paradigms: the Von Neumann (microprocessor) paradigm and the ASIC paradigm. In the microprocessor computational paradigm, the hardware is fixed and the function implemented varies. In ASICs, both function and hardware are fixed. ASICs are well designed to very efficiently perform specific functions but lack flexibility. Microprocessors exhibit very high flexibility, but they are orders of magnitude slower than their ASIC counterparts. Microprocessors also consume more power per computation because of their extra peripherals designed to provide flexibility. In addition, the non-recurring engineering cost invested in producing an ASIC is considerably larger than the cost of a DSP.

Reconfigurable computing has emerged as a solution to bridging the flexibility, efficiency and cost gaps between microprocessors and ASICs. Reconfigurable computing is the term used to describe the set of architectures and technologies developed to minimize the cost and increase the flexibility of complex computing solutions. Currently, the most successful reconfigurable computing solutions are Filed Programmable Gate Arrays (FPGAs). The FPGA market is growing steadily making it easier to realize new computing applications.

Printed Circuits Board Fabrication and Design

Electronic systems are composed of several interconnected components, such as analog and digital ICs, in order to achieve their required functionality. The platform that is used to realize this functionality is called a printed circuit boards (PCB). PCBs provide the physical integrity and strength the system needs, and provide the basis for the interconnections. To realize the huge amount of routing needed on a board, several layers of interconnects are used. The boards are highly specialized to accommodate the required interconnectivity at the very high frequencies at which these components operate, the different types of the signals being transmitted, and the huge number of pins from the onboard components. Special design rules and techniques are used to ensure integrity and reduce the unwanted parasitic effects of electrical signals being passed between components.

Electro-optics

The global market for optoelectronics is growing rapidly. This growth is driven by the enormous impact optoelectronics and laser technology are having on low cost communication technologies, high quality printing, digital audio recording, and other applications. The optoelectronic market is expected to grow from US $16.2 B in 2006 to US$ 19.8 B in 2009 according to the World Semiconductor Trade Statistics.[8] This typically includes all the semiconductor devices in which optical electronic interaction takes place, especially the semiconductor lasers, optical detectors, optoelectronic couplers, displays, Light Emitting Diodes LED's and so on. Given the tremendous growth in the field of optoelectronics and the broad set of applications that are relevant to improving the quality of daily life, developing strong capacity in optoelectronics is an important effort for the Kingdom to undertake.

Digital Signal Processing

In the digital domain, it is possible to achieve a lot through digitally processing the signal. Processing of digital signals can be either achieved by building dedicated ASICs (Application Specific Integrated Circuits) or a microprocessor. Nowadays, with the recent advancements in the electronics industry, it became possible to digitize the signals at early stages and at higher frequencies. This makes it possible to implement special algorithms enabling achievements that were not possible previously. By using Digital Signal Processors, changing and upgrading the implemented algorithm can be done with reduced time and cost.

Digital Signal Processors (DSPs) are a special family of low cost microprocessors that are tailored to save energy and area. For efficient use of DSPs, embedded systems design techniques are essential for realizing many applications especially in communications and entertainment industries. The DSPs and the DSP applications' markets are constantly growing, covering quite a wide spectrum of products.

Special Remark about Fabrications

In all of the above technologies, efforts should be concentrated in the design. As market reports show, considerable gains and profit can be made on the design level while outsourcing the manufacturing part. At later stages directing some resources in fabrication side can be reconsidered.

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[8] May 30, 2007 news release.

Operational Plans

Operational plans include plans for governing portfolio management, technology transfer, quality management, human resources, communications and risk management.

Portfolio Management

The ECP Research and Innovation Program will include a variety of projects with different goals and objectives. The program will be managed to achieve a balance across multiple objectives. Some factors to be considered include:

- Short term versus long term objectives (i.e. filling immediate skill gaps versus long term human resource development).
- Meeting the needs of existing companies versus establishing new technology-based industries in the Kingdom.
- Developing a portfolio of low-risk incremental projects and high risk/high return projects.
- Balancing national needs with the individual needs of the major stakeholders.

The program manager and advisory committee will review the program to ensure that it maintains an appropriate balance among these factors.

Technology transfer plan

The ECP research and innovation program will follow internationally recognized best practices in technology transfer. Key elements of the program that are designed to facilitate technology transfer are:

- Involvement of users in program design. This occurs through user participation in planning workshops and user involvement in the ECP advisory committee. It is well recognized that user involvement in the research design

leads to research and outcomes that are more likely to meet the needs of users, and thus are more likely to lead to successful innovation.

- The use of university/industry centers as hosts to major research efforts. Industry and university partnership in these research centers will encourage university based basic research to be focused on user needs, increasing the likelihood of technology transfer. These centers will also transfer knowledge to industry though the training and graduation of students (who have been trained on problems of interest to industry), who then take jobs in companies or form their own companies.
- Linkages to technology incubators. Linkages between the ECP program and technology incubators will provide the structure for the transition from research to new businesses and will connect investors with promising new ECP business opportunities.

Quality management plan

The ECP research and innovation program will follow 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 university-based research centers and projects.
- Annual reviews of technology development projects to ensure that milestones are being met.
- Routine (every 5 years) ECP program evaluations 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

As noted in the SWOT analysis, the limited technical workforce is a critical obstacle to the success of the ECP Technology Program. The availability of skilled workers, including researchers and technical managers, is likely to limit the growth and success of KSA ECP programs. The plan will require substantial numbers of ECP professionals, including additional researchers, technical managers, and technical leaders at KACST, universities, and public and private organizations. A central task of the program management function will be to address this issue.

To achieve the goals of the program, KACST will need to hire or develop additional program managers with the skills to lead national programs. Universities and companies will need additional researchers and engineers with the skills to develop innovative technologies. Initially, KACST will have to rely on the importation of foreign talents. To do this KACST will need additional flexibility with respect to international recruitment policies. As part of the activities in this plan, the ECP program will:

- Analyze ECP human resource issues and advocate changes to improve the quality of math and science education in primary and secondary education.
- Work with the other agencies to improve the quality of undergraduate ECP education, especially at regional universities.
- Work with new universities to develop research and education programs that meet the Kingdom's ECP research and innovation needs.
- Work to change policies to allow more international hiring, to bring specialized expertise to the Kingdom.
- Support training for researchers to become R&D managers and leaders.

At the undergraduate and especially at the graduate levels, this plan is designed to help increase the numbers of ECP researchers through its emphasis on university-industry centers. These centers are designed to train new students with research and innovation skills needed by research organizations and industry.

Communications management plan

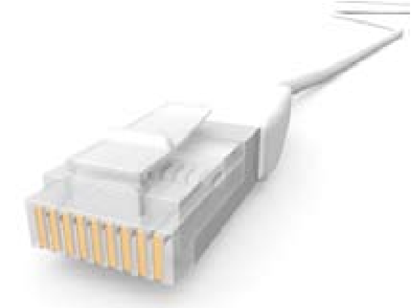
The purpose of the communications management plan is to provide appropriate information to the program participants and stakeholders. One element of the communications plan is to improve communication throughout the KSA ECP research and innovation community and to expand collaboration among members of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

- The establishment of a public website with information on program goals, accomplishments, funding opportunities, and other news.

n Periodic workshops with users and stakeholders to define future program needs.

- Adoption of Public announcements for requests for proposals (for university centers, grants, and pilot application development programs).
- Sponsorship of workshops, conferences, and professional society activities to expand communication and networking throughout the community.
- Encouragement of presentations 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.



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 potential risk 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. .
- Delaying or phasing in some program elements.
- Expanding the pool of people with needed skills through education and training programs, such as university ECP research centers (see human resources plan).

Another potential risk is the adoption of overly ambitious goals. The approaches to addressing this potential outcome 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.

Market risk is the possibility that projects, while technically successful, do not lead to commercialization because of poorly understood or changing market conditions. Addressing this risk involves the following:

- Designing programs based on carefully considered market needs.
- Continuous monitoring of international technology and market developments.
- Continual readjustment of plans in response to changes in the environment.

Financial risks of insufficient funding and cost overruns are ever present, especially in research projects. Addressing financial risks involves careful program planning, executing due diligence and monitoring, and early identification of possible cost overruns. Another financial risk is due to changes in the plan or funding due to political or policy changes. It will be important for the ECP program management to maintain open communication with policy leaders to ensure they are aware of the accomplishments of the program and to get early warning of any policy changes that may affect the program funding.

Implementation of the Plan

Within KACST, the ECP program manager will be responsible for the overall execution of the plan. Some portions of the plan may be managed by other parts of KACST. For example, the technology innovation centers and technology incubators may be managed by the Technology Development Center, which may specialize in the management of these kinds of programs. In this case, the program manager's role will be to provide technical input to the design and evaluation of these programs rather than to manage.

Many aspects of the plan represent new functions, especially in developing and managing national technology programs that include industry and universities and may involve international collaborations. 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, KACST staff members will visit similar programs in other countries to discuss their management practices and lessons learned.

The ECP Advisory Committee will oversee the implementation of the plan. It will meet approximately four times a year and review progress in the program based on the key performance indicators. The advisory committee will also sponsor and oversee studies of emerging areas of ECP, 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 ECP research and innovation network in the Kingdom.

Key Performance Indicators

Program Infrastructure

- Developing Human Resources:
- - Percentage of HR Requirements Fulfillment.
- - Average Job Spec and Employee Qualification Gap.
- - Personnel Turnover Rate.
- - Saudization Percentage.
- Developing Organizational Culture:
- - Values Adherence Indicator.
- - Sponsorship Quality Indicator.
- - Culture-building Incentives Efficiency.
- - Change Management & Continuous Improvement Indicators.
- Effective Financial Management:
- - Program Return on Investment (incl. estimates of intangibles).
- - Average Difference between Planned and Actual Projects Costs.
- - Average Difference between Planned and Actual Work Processes Costs.
- Developing Work Processes and Systems:
- - Approval of Proper Program Administrative Charter.
- - Level of Strategic Objectives Fulfillment by Projects and Work Processes.
- - Results of Program International Benchmarking.
- - Number of Competition Awards Granted to Program.
- - Automation Level of Work Processes and Systems.
- Provision of Laboratories and Equipment:
- - Percentage of Available to Required Labs & Equipment.
- - Quality Indicator of Lab Information Management System (LIMS).
- - Lab & Equipment Operation & Maintenance Efficiency Measure.
- Developing Knowledge Management System:
- - Number of Knowledge Contributions by Specialists per Month.
- - Size of Used Knowledge Assets (Documented and Acquired).
- - Number of Monthly Activities by Communities of Practice Resulting in Knowledge Contributions.
- - Efficiency of Information System Supporting Knowledge Management.

Implementation of the Plan

Program Internal Operations

- Technologies Selection:
  - Level of Strategic Objectives Fulfillment by Selected Technologies.
  - Rate of Project Cancellation in Projects Portfolio.
- Establishing Strategic Partnerships:
  - Percentage of Activated Strategic Partnerships to Total Required.
  - Average Performance Indicator of Activated Strategic Partnership.
  - Percentage of Local Organizations Supporting Program Research.
  - Percentage of Investment by Beneficiaries in Program Research.
  - Number of Patents Obtained by Strategic Partnerships.
- Technology Development:
  - Conducting Fundamental Research:
    i. Percentage of Fundamental Research that Supported Applied Research.
    ii. Number of Innovations Leading to New Applications through Fundamental Research.
    iii. Number & Quality Indicator of Papers & Graduate Degrees through Fundamental Research.
    iv. Number of Patents Obtained through Fundamental Research.
    v. Quality Indicator of Confidential Fundamental Research (prevented from publishing).
  - Conducting Applied Research:
    i. Percentage of Applied Research Resulting in Prototypes, Pilot Plants or Applied Solutions.
    ii. Number & Quality Indicator of Papers & Graduate Degrees through Applied Research.
    iii. Number of Patents Obtained through Applied Research.
    iv. Quality Indicator of Confidential Applied Research.
  - Building Pilot Plants:
    i. Percentage of Implemented Pilot Plants to Total Designed Through Applied Research.
    ii. Percentage of Pilot Plants Leading to Production Line or Solution.
    iii. Number of Patents Obtained through Pilot Plants.
- Technology Localization:
  - Conducting Localization Research & Studies:
    i. Percentage of Applied Research Resulting in Localized Technologies.
    ii. Average Efficiency Indicator of Localized Technologies Compared to Original Technologies.
    iii. Percentage of By-Product Technologies Resulting from Localized Technologies.
    iv. Number & Quality Indicator of Papers & Graduate Degrees through Localization Research.
    v. Number of Patents Obtained through Localization Research.
    vi. Quality Indicator of Confidential Localization Research.
  - Building Localization Pilot Plants:
    i. Percentage of Implemented Pilot Plants to Total Designed Through Localization Research.
    ii. Percentage of Localization Pilot Plants Leading to Production Line or Solution.
    iii. Number of Patents Obtained through Localization Pilot Plants.
- Technology Transfer:
  - Evaluation of ready technologies:
    i. Percentage of ready technologies leading to production lines or solutions.
    ii. Number of ready technologies passed on to localization and development.
    iii. Average efficiency of products resulting from transferred technologies.

Program National Operations

- Working with the Incubators:
  - Percentage of Technologies, Prototypes and Pilot Plants Adopted by Incubators from Total Offered.
  - Percentage of Financial Return from Program Products to Total Incubators Return.
- Working with the Technology Innovation Centers (TIC's):
  - Percentage of Pre-Incubation and Production Prototypes Developed with TIC's to Total Offered.
- Working with the Program Beneficiaries

  (This domain is out of direct Program operations. Performance Indicators will be developed with Beneficiaries participation during Program execution).
- Supporting National Goals

  (This domain is out of direct Program operations. Performance Indicators will be developed with concerned authorities' participation during Program execution).

Appendix A: Plan Development Process

The process of developing this plan included three two-day general workshops and several extensive meetings of the national team members that focused on ECP innovation needs in the Kingdom and on defining programs to meet those needs.

The following are the national team members and their affiliations.

ECP Research and Innovation National Team Members

Name	Organization
Dr. Abdulhameed Al-Sanee	King Saud University
Dr. Abdullah Al-Zeer	King Saud University
Dr. Salam Zumo	King Fahd University for Petroleum and Minerals
Dr. Saad Al-Shahrani	King Fahd University for Petroleum and Minerals
Dr. Rabah Al-Dhaheri	King Abdulaziz University
Dr. Khalid Al-Nabulsi	King Abdulaziz University
Dr. Montasir Sheikh	King Abdulaziz University
Dr. Majeed Al-Kanhal	CITC
Dr. Abdulrahman Al-Oraini	Saudi Telecomm
Dr. Abdulrahman Al-Oraini	Saudi government
Dr. Hassan Al-Shahrani	Saudi government
Eng. Awad Al-Juhani	Saudi government
Eng. Abdulaziz Al-Tuwaijiri	Saudi government
Eng. Faihan Al-Otaibi	Saudi government

Appendix A: Plan Development Process

Name	Organization
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Eng. Saleh Al-Rusayes	Saudi government
Eng. Jamaan Al-Zahrani	Saudi government
Eng. Mohammad Al-Hazani	Saudi government
Dr. Abdullah Al-Musa	Saudi Telecomm Co.
Mr. Saad Al-Mazrou	Saudi Telecomm Co.
Eng. Sulaiman Al-Wulaii	Saudi Aramco Co.
Eng. Ahmad AL-Damigh	Saudi Aramco Co.
Dr. Khalid Al-Bayari	Advanced Electronics Co.
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ECPP faculty	King Abdulaziz City for Science & Technology

International Consultants

Name	Organization
Prof. Mohammad Wahiddin	Malaysian Institute of Microelectronic Systems (MIMOS) & International Islamic Malaysian University
Prof. Abdulrasheed Monir	ICMic
Prof. Samir Al-Bader	Imperial College of Science , Technology, and Medicine
Dr. Na'eem Dahnoun	University of Bristol
Prof. Manfred Gleisner	Darmstat University of Technology
Dr. Thomas Hollstein	Darmstat University of Technology
Dr. Tudor Morgan	Darmstat University of Technology
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Prof. Ridha Khalil	Si-Ware Systems
Dr. Bassam Sa'adani	Si-Ware Systems

Appendix A: Plan Development Process

ECP KACST Planning Team Members

Name
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Dr. Abdulfattah Obied
Dr. Fahhad Alharbi
Dr. Sami Alhumaidi
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