مدينة الملك عبدالعزيز
للعلوم والتقنية KACST

رؤيـــة VISION
2030
المملكة العربية السعودية
KINGDOM OF SAUDI ARABIA

ANNUAL REPORT
2016

1437 - 1438 H
Corresponding to 2016 G

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بسم الله الرحمن الرحيم

HRH King Salman bin Abdulaziz Al-Saud
Custodian of the Two Holy Mosques

HRH Prince Mohammed
bin Naif bin Abdulaziz Al-Saud
Crown Prince Deputy Premier Minister of Interior

HRH Prince Mohammad bin Salman Al Saud
Deputy Crown Prince Second Deputy Prime Minister

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Who are we?

King Abdulaziz City for Science and Technology (KACST) conducts applied scientific research, in order to serve the development of the Kingdom of Saudi Arabia, and provides scientific counsel at the national level. It has a major role in planning for science and technology in the Kingdom. It participates in the preparation of the National Plans of Science, Technology and Innovation, sets forth the required strategies for execution, and provides support to programs and projects related to scientific research. KACST also aims to develop national competencies and to recruit highly qualified specialists to help develop and control modern technology in order to serve the development of the Kingdom. Furthermore, it provides specialized scientific information services, scientific publications and the registration of patents. KACST aims to coordinate with government entities, scientific institutions and research centers in the Kingdom in applied scientific research and in the exchange of information and experiences. In addition, it develops partnerships through technological and scientific cooperation between the Kingdom and international scientific institutions.

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Values

- Integrity
- Loyalty
- Respect and appreciation shown to staff members
- Community service
- Excellence
- Teamwork
- Transparency


- Vision
- Mission

Vision

To be a world-class organization in science and technology, fostering innovation and promoting a knowledge-based society in the Kingdom of Saudi Arabia.

Mission

KACST works on developing and investing in the national platforms of science, technology and innovation in order to build a knowledge-based society which serves sustainable development in the Kingdom. The tasks and responsibilities of KACST include:

- Formulating policies and national plans for science, technology and innovation
- Coordinating national activities in science, technology and innovation
- Providing support for scientific research and technological development in the Kingdom
- Conducting applied scientific research and technological development
- Developing and strengthening cooperation and local, regional, and international partnerships for technology transfer and development
- Investing in technology development and its commercial processing
- Sponsorship, promoting and investing in intellectual property
- Providing advice and innovative solutions

Executive Summary

King Abdulaziz City for Science and Technology (KACST) continued to implement the programs, projects, and plans designed to establish and develop the science, technology and innovation system in the Kingdom. KACST was able to successfully accomplish a number of achievements during the year of the report.

Policies

Planning

Science, Technology, and Innovation Policy

The Council of Ministers' resolution (No. 411) was issued on 12/09/1436 AH, stipulating that KACST shall have a Board of Directors that replaces the High Commission that was cancelled by the Royal Decree (No. 1/69) issued on 09/04/1436 AH. The Board exercises the tasks and specialties previously assigned to the canceled High Commission. Moreover, Royal Decree (No. A/133), issued on 30/07/1437H, stipulated that the Minister of Energy, Industry, and Mineral Wealth shall head the board of KACST.

Science, Technology, and Innovation Plans

KACST was keen to achieve full compatibility between the objectives of "The National Policy for Science and Technology" and the objectives of "The Kingdom's Vision 2030". Hence, the initiatives approved in the National Transformation Program 2020 have become an alternative of the program of the National Plan for Science, Technology, and Innovation.

National Transformation Program 2020

KACST has a total of 30 initiatives in the National Transformation Program (NTP) 2020. Through these initiatives, KACST seeks to accomplish the strategies set forth in the program, which include: upgrading the infrastructure and its equipment, establishing valuable technology startup companies, promoting the capabilities of small and medium enterprises, providing technical consultation services to governmental organizations, developing and localizing technologies in sectors with large expenditure, supporting research and development to ensure the sustainability of the development and research system, and developing human capital to support research and development.

Coordination

Science, Technology, and Innovation System

The execution of the first National Plan for Science, Technology, and Innovation contributed in the development of the science, technology, and innovation system in the Kingdom through building a knowledge base, establishing infrastructures, creating a supportive environment for innovation, and promoting the relationships between the community and science.

International Agreements

During the report year, KACST participated in the meetings of all the established international conventions. Moreover, KACST signed a number of cooperation agreements, protocols, and memorandums of understanding with a number of countries and international organizations in the field of science and technology, including: a memorandum of understanding between KACST and Beijing University of Chemical Technology, a protocol between KACST and the Scientific and Technological Research Council of Turkey "TÜBİTAK", a protocol between KACST and the National Academy of Sciences of Belarus, a technological and scientific cooperation agreement between the Saudi Government and the Government of the Republic of Belarus, an agreement between KACST and Huawei Technologies Investment Co. Limited, an agreement between the Saudi Government, represented by KACST, and the government of China, represented by the Ministry of Science and Technology, a memorandum of understanding between KACST and China Satellite Navigation Office, and a memorandum of understanding between the Saudi Government and the Government of the Republic of Tajikistan.

National Committees

During the report year, KACST participated in the activities of many national technological committees such as the National Committee of Bioethics, the National Committee for Earthquakes, and the National Committee for the Kingdom's participation in Expo Show 2017 in the Republic of Kazakhstan.

Evaluation

Evaluation of Science, Technology and Innovation System

A number of key performance indicators were adopted to assess the progress in executing KACST initiatives in the National Transformation Program 2020. In the context of KACST's ongoing efforts to assess the science, technology, and innovation system, KACST's board commanded that KACST should develop monitoring and evaluation instruments for the national development and research system, and its impact on the national economy and development. This process aims at generating periodic reports on the system's performance.

The First National Plan for Science, Technology, and Innovation (Maarifah 1)

The total number of annually published scientific papers of the Kingdom has dropped in 2015 for the first time since 2008. This is mainly because of the termination of financial support for the research projects in "Maarifah 1" in the last two years. Although the number of scientific papers has not increased, the Kingdom maintained an increase in the quality of the published papers. Moreover, the number of submitted patents applications in 2015 has dropped by 45% compared to that of 2014. Thus, it is expected that this decline in the number of published papers and registered patents will continue in 2016 and 2017.

Resuming the scientific research support, with the launch of the Grant Programs for Universities and Research Centers, requires an average of 4% annual increase in the number publications to achieve the publication target, i.e., publishing 20,000 scientific research papers and obtaining 5000 patents by the end of 2020.

Technology Forecasting

Due to the importance of studying technology transfers, KACST has considered upgrading the existing future studies unit in KACST to become a national center for technology forecasting, aiming at conducting forecasting methodological studies on disruptive technologies in strategic areas and evaluating the risks and investment opportunities associated with them at the national and sectorial levels.

Research Support

Research Centers and Universities Support Program

This program is one of the KACST initiatives in the National Transformation Program 2020. The program consists of seven major programs; four of which constitute the supply side of the development and research system, and they are: the postgraduate students research program, the basic science research program, the applied research program, and the innovative research program. The other three programs, which are the research-oriented program, the industrial development program, and the industrial innovation centers program, represent the demand side of the system.

The Grant Programs for Universities and Research Centers aim, through implementing its seven programs, at meeting, by the end of 2020, its main key performance indicators, which include: number of published scientific papers (62,000), number of issued patents (3,700), number of technology companies emerging from universities (650), number of technology solutions for companies (400) and number of jobs generated by the technology companies (3,600).

Technological Logistic Support

Saudi Academic Network

KACST has established the international portal for the Saudi academic network to support scientific research in the Kingdom. In this year, the academic network was linked using internet networks 2 with international networks to enable local research and academic entities to communicate with their counterparts around the world. The network's total capacity was increased to eight GB/second, and most of the networking devices' components in Riyadh and Jeddah have also been upgraded to reach 80 GB/second, along with the continuous technical support for the quick response of the network requirements.

Information Services

KACST has continued to support scientific research in the Kingdom. It has provided multiple international and local sources and information systems that has a great role in facilitating the access of researchers and specialists to information and reliable scientific documents, promoting the quality of scientific production.

Core Labs

During the report year, KACST has established a "Core Labs Committee" to develop labs and provide a high quality research infrastructure. KACST possesses a number of advanced and specialized labs, basic facilities, and manufacturing workshops that provide support to researchers and developers from inside and outside KACST.

Scientific Awareness

Scientific Publication

KACST continued its scientific publications that include seven quarterly international scientific journals, in English, in several domains such as water, oil, and petrochemicals. These journals are issued with the international publisher "Springer". Two of them were included within the highly ranked international journals (ISI). Moreover, KACST has continued to issue a number of scientific journals in Arabic, including: the "Nature - the Arabic Edition" which is a monthly journal, "Al Faisal scientific" which is a quarterly journal, the "Technology and Science for Children" which is a quarterly journal, and "Technological Sciences" which is a quarterly journal. With regard to the support presented by KACST to researchers and specialists in writing books and translating the scientific books, the total number of written and translated books in the report year reached 186. KACST also published electronic copies of those journals on its website.

Events

KACST organized eight international conferences on advanced technologies, sponsored by 179 researchers and specialized scholars, from inside and outside the Kingdom. More than 6,400 researchers and specialists attended. Also, KACST organized 16 events including exhibitions, interviews and workshops attended by 13,970 people, and a number of specialized courses that were attended by 293 researchers and technicians of both genders.

Motivating Youth People

KACST has published 20 scientific books targeting school students, produced about 415 lessons, scientific games, films and interactive systems.

Social Media

The number of followers that KACST has across its social media accounts such as "Twitter", "Facebook", "YouTube", "LinkedIn" and "SnapChat", exceeded 170 thousand people.

Digital Production

KACST has produced three documentaries, which are available on its channel on YouTube, 124 short videos, which are less than half a minute, to explain various phenomena or to introduce scientific facts to a wider audience, and 17 audio files available for the public on the social media.

Research and Development at KACST

Transfer and Technology Localization

Through its institutes, national centers and Joint Centers of Excellence Program, KACST implements a large number of R&D projects in 13 sectors, which are:

Energy

KACST is implementing 24 projects in the areas of renewable energy, energy generation, energy storage, cooling systems, power efficiency, and energy simulation and modeling.

Water

KACST is executing nine projects in a number of water-related fields that include water desalination technologies, membrane technologies, water leakage detection, and water simulation and modeling.

Oil, Gas and Mining

KACST is implementing 18 projects in the areas of exploration technologies, extraction and production technologies, petrochemicals, carbon Sequestration, and clean fuel.

Advanced Materials

KACST is working on 19 projects in the fields of polymers, silicon, carbon fibers, alloys, composite materials and advanced materials applications.

Health

KACST is executing nine projects in many health-related fields that include genetic and inherited diseases, infectious diseases, stem cells technologies, Nanomedicine, and medical devices.

Communication and Information Technology

KACST is implementing 20 projects in the areas of electronics, radars and antennas, computer devices and frameworks, Internet of Things, software development, and big data.

Agriculture

KACST is executing eight projects in the fields of agricultural bioengineering, protected agriculture and water preservation technologies and biological control.

Building and Construction

KACST is working on six projects in the areas of construction automation systems and advanced construction materials.

Transportation and Logistics Services

KACST is implementing five projects in the areas of autonomous vehicles, traffic management systems, mobility simulation and modeling, and robotic transportation systems.

Environment

KACST is executing nine projects in many environment-related fields that include waste treatment, air pollution and global warming, advanced materials technologies for environmental purposes, and environmental modeling and simulation.

Space and Aeronautics

KACST is implementing 23 projects in the fields of aeronautics technologies, satellite technologies, remote sensing systems, and lunar crescent sighting.

Defense and Security

KACST is executing seven projects in the areas of advanced sensor technologies, radar systems, electronic warfare and control systems, cyber security, and robotics and intelligent systems.

Nuclear Science and Applied Physics

KACST is working on 11 projects in several fields including accelerants technologies, irradiation technologies, nuclear regulatory program, and applied physics.

Technical Leaders Program

This program is one of the KACST initiatives in the National Transformation Program. It aims at addressing the gap in national human resources on the level of technical leaders by training and qualifying a generation of leaders and decision makers in the vital technical fields in the kingdom. Such an objective is achieved by establishing joint centers of excellence with a number of leading international industrial and research institutions and universities. The course trains aspiring Saudi researchers in these academic and industrial institutions to increase their experiences and refine their research skills, making them worthy of entering the competition for acceptance to Master's and Ph.D programs in the highest ranked universities around the world.

The Technical Leaders Program, which is supervised by the Joint Centers of Excellence Program at KACST, contributed to the admission of more than 30 students in Master's and Ph.D programs at number of highest ranked universities that include Stanford University, Massachusetts Institute of Technology, Harvard University, University of Oxford, University of California, Los Angeles, University of California, San Diego, University of Bordeaux, and Imperial College London.

There are currently 15 joint centers of excellence, distributed throughout the world, in collaboration with big research institutions and universities in the field of scientific and applied research. These centers include:

Center for Complex Engineering Systems

This center was established via a joint cooperation with the Massachusetts Institute of Technology (MIT). It aims at improving our understanding of complex and dynamic systems in integrated fields such as energy, water, transportation, environment, and industry. It also aims at jointly conducting world-class research in the areas of environmental systems, big data analysis, decision analysis, and modeling and simulation technologies.

Center of Excellence for Astronautics & Aeronautics

This center was established through a partnership with the Stanford University. It aims at developing research and scientific infrastructures in the fields of space and aeronautics, space physics technology, satellite technology, unmanned aerial vehicle (UAV) technology, and flying robot technology.

Center of Excellence in Integrated Nanosystems

This center was established through a partnership with the Northwestern University. It aims at conducting research in various fields of Nanosystems including: energy storage technologies, energy harvesting, molecular electronics, Porous materials for membrane technologies, and drug delivery technologies.

Center of Excellence for Advanced Materials and Manufacturing

This center was established through a partnership with the University of Cambridge. It aims at conducting research in these areas: high performance infiltration grown bulk superconductivity for applications, advanced materials for inkjet-based additive manufacturing, fabrication of a solar water splitting device, and carbon Nanotube membranes for water desalination.

Center of Excellence for Green Nanotechnologies

This center was established through a partnership with the University of California, Los Angeles. It undertakes frontier research and development in the areas of nanotechnology and Nanoscience for future electronics and energy devices. The center tackles major issues of scaling, energy efficiency, energy generation, and energy storage faced by the electronics industry.

Center of Excellence for Telecom Applications

This center was established through a partnership with the University of California, San Diego. It aims at conducting research on the areas of multi matrix antennas, advanced networks recognized in software, Internet of Things, and the fifth generation of the system of multi inputs and outputs.

Center of Excellence of Nanomaterial for Clean Energy Applications

This center was established through a partnership with the University of California, Berkeley. It aims at conducting research in the areas of porous Nanomaterial preparation technologies, isolation collection and storage of gases, traditional and photo catalysis, and preparing porous secondary compounds.

Center for Microwave Sensor Technology

This center was established through a partnership with the University of Michigan. It aims at conducting research in the areas of designing and building composed direction radars, and semi-conductors technologies, and wire transfer of energy.

Solid State Lighting Center of Excellence

This center was established through a partnership with the University of California, Santa Barbara, to conduct research in the areas of advanced photoelectric technologies, low consumption light emitters, safe wireless communication, and water sterilization technologies.

Center of Excellence for Earth and Space Science

This was established through a partnership with the California Institute of Technology (Caltech) and National Aeronautics and Space Administration (NASA). The aim of this center is to develop satellite technologies and use the data to deal with the challenges of studying crust and underground deformities and groundwater reservoirs.

Decision Support Center

This was established via a strategic partnership with Boeing. It aims at providing innovative solutions for the defense, security and civil sectors by achieving the maximum efficiency in conducting studies and developing advanced tools for modeling, simulation and analysis, and by providing a model environment that simulates reality.

National Research Partnerships

KACST seeks to coordinate with the national authorities and institutions to develop national research partnerships, in order to exchange information, and conduct trainings in fields that are commensurate to the development requirements in the Kingdom, such as energy, water and wildlife.

Saudi Energy Efficiency Center

Established in 1431H within the administrative framework of KACST. It aims at rationalizing and raising energy consumption efficiency, and uniting efforts among the governmental and non-governmental entities in this field. The center is directly connected with the head of KACST. The center's achievements during the report year include finalizing the energy rationalization codes for low and high buildings with the Saudi Building Code National Committee. Other achievements include executing mechanisms of thermal insulation for buildings, preparing reports on cars fuel economy to demonstrate the commitment of manufacturing companies to reducing emissions, and updating the electronic gate application to review cars fuel economy.

KACST-SEC Joint R&D Center for the Distribution Sector

A memorandum of understanding was signed, during the report year, between KACST and the Saudi Electricity Company to establish the center at the KACST headquarters. It aims at activating research partnerships and jointly conducting research and implementing projects in the distribution sector, while also focusing on the quality of electrical energy and protection systems in distribution networks. The center also focuses on integrating all renewable energy sources, and providing technical and professional training courses.

Joint Research Center for Desalination Using Renewable Energy

During the report year, an agreement was made between KACST and the Saline Water Conversion Corporation, to establish a joint program for desalination research using renewable energy in order to localize desalination technologies. More specifically, the center aims at developing and dealing with high efficiency membranes, developing desalination technologies by using renewable energy technologies, increasing the efficiency of desalination stations, and improving their performance.

Joint Center for Wildlife Research

During the report year, KACST established a center to transfer and localize research technologies in wildlife, in cooperation with specialized international centers of excellence. KACST plans to coordinate and cooperate with the relevant government authorities and research centers in the Kingdom to avoid duplication of any efforts. The main goal of this center is to develop technologies for protected areas, and maintain the marine biological diversification in the Kingdom.

Innovation Support

Saudi Patents Office

The number of the patent applications submitted to the office until the end of 2016 was 25,581, 82% of which have been completely processed, whereas the number of submitted industrial model applications was 6,932, 97% of which have been completely processed. The total number of submitted applications in 2016 increased by 35,7%, compared to that of 2015, which is mainly due to the increased number of applications from foreigners. The patent applications of Saudi citizens in 2016 constitute about 31% of the total number of applications, compared to 53% in 2015.

Incubators and Accelerators

With its initiatives in the National Transformation Program 2020, KACST intended to increase the number of companies emerging from its incubators to 600 companies that can contribute to the creation of 3,600 jobs. KACST supports innovation and invention by activating and developing technological business incubators through a number of programs that include BADIR Incubator for Information and Communication Technology (which incubated 26 projects and produced six projects), BADIR Incubator for Biotechnology (which incubated five projects and produced two projects), and BADIR Incubator for Advanced Manufacturing program (which incubated 14 projects and produced one project). In addition, KACST launched the first business accelerator that supported seven emerging technology companies, and established an inventors' office to provide specialized consultation services to the Saudi inventors. Moreover, the Saudi network of business incubators and individual investors network has continued to provide services to support incubators and entrepreneurship in the Kingdom.

Technological and Industrial Development Support

In order to support the initiative of innovation and industry, KACST has established the Technological Development Center to provide all services needed to transfer KACST's projects to industry and increase the quality of its outputs to the level that makes ready for the market. KACST has also launched a technology consultation initiative in order to benefit from the national experts, and the technology capabilities that exist at KACST. This initiative will provide technology and industry-related consultation services to solve problems and increase the production of Saudi factories. In addition, KACST has launched another initiative to support small and medium-sized technology enterprises to promote their level and participate in the local content.

Commercialization of R&D Outputs

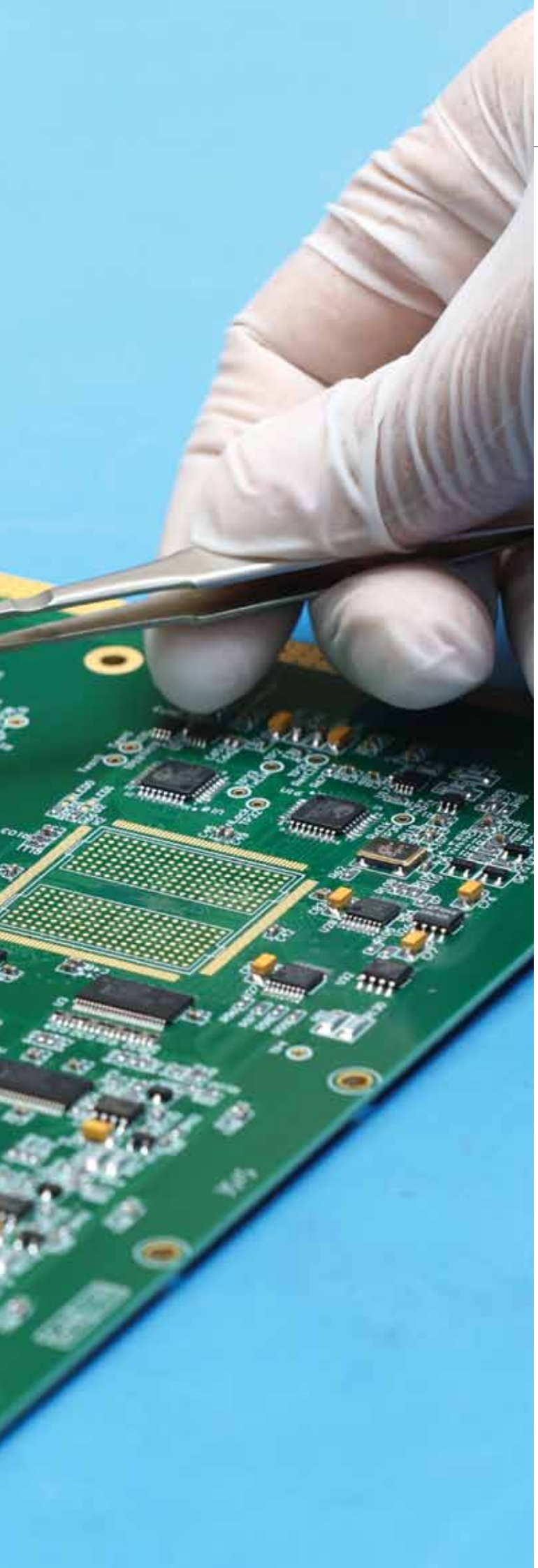
Commercial Services

Commercial services focus, through the Saudi Technology Development and Investment Company (TAQNIA), on the quick wins that include the products and integrated services that already exist at KACST, in order to generate revenues as quickly as possible. The focus will be on the sectors where the Kingdom has global leadership in such as water, energy and advanced materials, or those sectors where the Kingdom can achieve self-reliance such as health and communication and information technology. During the report year, a number of agreements were made on some projects including the production of the first Saudi aircraft in cooperation with Ukraine (AN-132), the first independent energy station in the Kingdom with 50MW capacity (Layla IPP), and the development of absorption technologies - desalination of salt water and a cooling station for absorption technology (AD). A number of agreements were also made on several other projects including: the joint project between Turkish Armed Forces (Aselsan) and TAQNIA Defense and Security Technologies (DST), and a helicopter project for the Kingdom (Sikorsky).

Science, Technology and Innovation Policy

1 | Science, Technology and Innovation Policy

- Planning for Science, Technology and Innovation in the Kingdom
- Coordination between Research and Scientific Institutes in the Kingdom
- Evaluation of Scientific Research and Innovation Outputs



Science, Technology and Innovation Policy

The Council of Ministers Resolution (No. 411), was issued on 12/09/1436H stipulating that King Abdulaziz City for Science and Technology (KACST) to have a Board of Directors to replace its High Committee

Introduction

To ensure that KACST achieves its objectives, the Board of Directors will carry out the tasks previously assigned to its resolved High Committee by a Royal Decree (No. A/69) on 09/04/1436H. KACST plays a vital role in supporting and enhancing scientific research and innovation that serves development in strategic sectors such as energy, water, agriculture, mining, etc. In addition, KACST provides technical support to public and private sectors through its highly qualified personnel. The Royal Decree (No. A/133) issued on 30/07/1437H stipulated that the Minister of Energy, Industry, and Mineral Resources to head KACST's Board of Directors.

Given the challenges faced by the Kingdom, and in accordance with the objectives of Saudi Vision 2030, KACST set forth its vision to be a world-class organization in science and technology, fostering innovation and promoting a knowledge-based society. To realize this vision, KACST works on the development and investment in the national system of Science, Technology and Innovation (STI) through the following four functions and responsibilities: policy, support, research, and innovation.

To develop the STI policies, KACST executes 3 functions: Planning, Coordination, and Evaluation.

- Planning: KACST formulated the National Policy for Science and Innovation as well as developed the National Science, Technology, and Innovation Plan (NSTIP). In addition, KACST has launched 30 initiatives, through the National Transformation Program 2020, with the objective of enhancing the local content contribution and increasing the value retained in these sectors.
- Coordination: KACST coordinates several national activities in STI such as signing a significant number of international agreements and participating in many national committees throughout the years.
- Evaluation: KACST monitors the performance of STI activates in the KSA and forecasts technologies.

1.1 | Planning for Science, Technology and Innovation in the Kingdom

- Science, Technology and Innovation Policy
- Science, Technology and Innovation Plans
- National Transformation Program 2020

Science, Technology and Innovation Policy
Planning

In accordance with Saudi Vision 2030, KACST has aligned the National Science, Technology, and Innovation Plan with its initiatives in the National Transformation Program 2020 (NTP 2020).

STI Policy

The Royal Decree issued in 1406H directed KACST to propose a national policy for the development of science, technology, and innovation, in addition to developing the necessary strategies and plans to implement this policy. KACST thus began, in collaboration with the Ministry of Economy and Planning, developing the National Policy for Science and Technology in the Kingdom of Saudi Arabia. The policy was approved by the Council of Ministers in 1423H, to embody the Kingdom's vision and its fundamental strategic plans, ensuring the continuous sustained developmental efforts to enhance the STI ecosystem activities, all while providing a framework of appropriate priorities, options and policies for each planning phase, building the Saudi knowledge society and knowledge-based economy.

The strategy of implementing the National Science, Technology, and Innovation Plan consists of setting four five-year plans directed to realize certain strategic objectives:

- The objectives of the first national plan, which ended in 1435H, was to establish infrastructure for science, technology and innovation in the Kingdom.
- The objectives of the second national plan, which will end in 1440H, is for the Kingdom to be a pioneer in the field of science, technology and innovation in the region.
- The objectives of the third national plan, which will end in 1445H, is for the Kingdom to become a leading country in science technology and innovation in Asia.
- The objectives of the fourth national plan, which will end in 1450H, is for the Kingdom to join developed STI countries and transform to a knowledge-based economy.

Planning

- STI Policy
- STI Plans
- NTP 2020

Coordination

- Science, Technology and Innovation System
- International Agreements
- National Committees

Evaluation

- Evaluation of Science, Technology and Innovation System
- Standards of Science, Technology and Innovation System
- Technology Forecasting

Science, Technology and Innovation Plans

KACST started the implementation of the first National Plan for Science, Technology, and Innovation (Maarifah 1) in 2007. By the end of the first plan in 2014, it was clear that the plan achieved its main objective in creating the infrastructure of the science, technology and innovation system, and contributed to boosting the Kingdom's position at the top of the list of ranked countries in the region, helping it assume an advanced position among all Arab countries in science, technology and innovation. In addition, remarkable growth in many global indicators such as number of patents, number of peer reviewed papers, and number of citations, which are considered the main outputs of scientific research, was observed. As a result, the Kingdom leads Arab countries in scientific publications as well as achieving high ranks in the quality of publications.

KACST prepared the second National Plan for Science, Technology, and Innovation (Maarifah 2), which will end in 2020, with the objective of setting the Kingdom to be a pioneer in the field of science, technology and innovation in the region, and to bridge the gap between research and industry in Kingdom. A wide range of national stakeholders as well as global consultants were engaged in the development of Maarifah 2. The second NSTIP plan was restructured during the NTP 2020 labs to be aligned with the objectives of the ambitious Saudi Vision 2030. As a result, KACST's approved initiatives in the NTP replaced the second National Plan for Science, Technology, and Innovation (Maarifah 2).

National Transformation Program 2020

"Saudi Arabia's Vision 2030" was adopted as a methodology and roadmap for economic and developmental action in the Kingdom of Saudi Arabia. "Saudi Arabia's Vision 2030" encompasses—in a number of domains—strategic objectives, targets, outcome-oriented indicators, and commitments that are to be achieved by the public, private, and nonprofit sectors. The Council of Economic and Development Affairs has established an effective and integrated governance model to translate the Vision into various implementation programs that will accomplish its goals and directions. The programs will be launched successively, according to the requirements of Vision.

In order to build the institutional capacity and capabilities needed to achieve the ambitious goals of "Saudi Arabia's Vision 2030", the National Transformation Program 2020 was launched across 24 government agencies including KACST. The program's strategic objectives are linked to interim targets for the year 2020 and the first phase of initiative implementation will be launched in 2016 and will be followed every year by phases involving more public agencies.

NTP Objectives:

- Identifying the strategic objectives and targets of participating entities.
- Translating strategic objectives into Initiatives for the participating entities.
- Promoting joint actions toward the achievement of common national goals.
- Contribution to job creation.
- Contribution to strengthening partnerships with the private sector.
- Contribution to maximizing local content.
- Contribution to digital transformation.

To achieve work sustainability and maximize impact, the program has employed a number of enablers that help increase the level of professionalism and ensure smoother workflow including transparency, institutionalization and specialized support.

Science, Technology, and Innovation Policy - Planning

KACST Strategic Objective	Key Performance Indicators	Relevant Vision 2030 Objectives
Enhance the infrastructure and facilities necessary for the development of local content	Number of establishments needed to develop local content	• Create an attractive environment for both local and international investors and enhance their confidence in our economy • Enhance competitiveness of energy sector
Establish emerging technology companies with added value to contribute to the increase of local content	• Number of jobs being generated by start-up companies in incubators • Number of jobs being generated by start-up companies in universities • Number of tech-companies emerging from incubators • Number of tech-companies emerging from universities through the Innovative Companies Program	• Create an attractive environment for both local and international investors and enhance their confidence in our economy • Boost entrepreneurship • Develop IT sector
Strengthen the capability of small and medium-based companies to contribute to the increase of local content	Number of companies that were served or have their capabilities enhanced	Create an attractive environment for both local and international investors and enhance their confidence in our economy
Provide technical consulting services to government sectors	• Number of consulting projects in the targeted sectors that have been submitted • Customer satisfaction for consulting services provided	Improve performance, productivity and flexibility of public authorities
Localization and development of technology in large domestic spending sectors	Number of localized and developed technologies in targeted sectors	• Develop IT sector • Develop mining sector • Develop Oil & Gas sector • Enhance competitiveness of energy sector
Support research and development to ensure the sustainability of the local content development system	• Number of published peer-reviewed research papers from scientific institution in the kingdom • Number of patents issued by the kingdom	• Provide citizens with knowledge and skills to meet the future needs of the labor market • Boost entrepreneurship
Support local content through development of nationally-qualified professionals	Number of technical experts who have been skilled	• Provide citizens with knowledge and skills to meet the future needs of the labor market • Develop youth skills and leverage them effectively

NTP Operating Model

The Council of Economic and Development Affairs and the 24 participating government entities worked hand in hand to prepare and launch the National Transformation Program. Other government agencies, such as the Ministries of Interior and Foreign Affairs, were invited to take part in planning the initiatives, coordinating efforts, and producing high-quality and realistic outcomes. The phases of the program's operating models include:

- Identifying the challenges in fulfilling the vision and establishing 2020 Interim targets
- Developing initiatives designed to reach the strategic objectives.
- Developing detailed implementation plans for the initiatives.
- Promoting transparency in the publication of targets and outcomes.
- Auditing, continually improving, launching new initiatives, and adding new participating entities.

NTP Launching

The first phase of the National Transformation Program was launched across 24 government agencies, including the ministries represented in the Council of Economic and Development Affairs and a number of public entities associated mainly with the strategic objectives of Saudi Arabia's Vision 2030. Other entities were also invited because the ministries deemed their presence important for achieving strategic objectives of the Vision.

KACST's Strategic Objectives in the National Transformation Program 2020

- Enhance the infrastructure and facilities necessary for the development of local content.
- Establish emerging technology companies with added value to contribute to the increase of local content.
- Strengthen the capability of small and medium-based companies to contribute to the increase of local content.
- Provide technical consulting services to government sectors.

	N	Key Performance Indicators	Measurement Unit	Targeted 2020
Research Support	1	Number of published peer-reviewed research papers from scientific institution in the Kingdom	Research (annual)	20,000
	2	Number of patents issued by the Kingdom	Patent (accumulative)	5,000
Technology Transfer and Localization	3	Number of localized and developed technologies in targeted sectors	Technology (accumulative)	125
	4	Number of establishments needed to develop local content	Establishment (accumulative)	17
	5	Number of technical experts who have been skilled	Expert (accumulative)	350
Innovation	6	Number of tech-companies emerging from incubators	Company (accumulative)	600
	7	Number of jobs being generated by start-up companies in incubators	Job (accumulative)	3,600
	8	Number of tech-companies emerging from universities through the Innovative Companies Program	Company (accumulative)	800
	9	Number of jobs being generated by start-up companies in universities	Job (accumulative)	4000
	10	Number of companies that were served or have their capabilities enhanced	Company (accumulative)	400
	11	Number of consulting projects in the targeted sectors that have been submitted	Project (accumulative)	200
	12	Customer satisfaction for consulting services provided	Percentage (%)	80

- Localization and development of technology in large domestic spending sectors.
- Support research and development to ensure the sustainability of the local content development system.
- Support local content through development of nationally-qualified professionals

KACST KPIs in the NTP

During the NTP workshops, KACST conducted a comprehensive survey for all initiatives and linked them with accurate KPIs to easily and accurately evaluate the accomplishment level for each initiative. These KPIs are distributed according to KACST's strategic objectives. They took care of evaluating development and research indicators, such as the number of published and reviewed scientific papers, registered patents, and technologies that were developed. They also looked at innovative indicators, such as the number of young technological companies and human resources performance indicators, such as the number of technological jobs generated from these companies, and many other indicators. KACST prepared 12 KPIs to evaluate the performance.

These are:

- Number of published peer-reviewed research papers from scientific institution in the kingdom.
- Number of patents issued by the kingdom.
- Number of localized and developed technologies in targeted sectors.
- Number of establishments needed to develop local content.
- Number of technical experts who have been skilled.
- Number of tech-companies emerging from incubators.
- Number of jobs being generated by start-up companies in incubators.
- Number of tech-companies emerging from universities through the Innovative Companies Program.
- Number of jobs being generated by start-up companies in universities.
- Number of companies that were served or have their capabilities enhanced.
- Customer satisfaction for consulting services provided

KACST Initiatives in the National Transformation Program 2020

KACST proposed 30 initiatives within the National Transformation Program, to support its vision for the future of science, technology and innovation in the KSA. Each initiative belongs to one of three pillars: research support, technology transfer and localization and innovation.

- **Research Support Initiatives**

R&D Support Program for Universities and Research Institutions

The Research Support Program funds the basic research or what is called also theoretical research. It is the methodological study oriented to expand knowledge horizons or understand the basic sides of the observed facts and phenomena, without determining certain applications, when beginning research. This research contributes to the establishment of knowledge and provides the scientific basis to be represented in the future in the development and applied research. The basic research program will be open to all researchers, but a mechanism will be adopted for the classification of research to regulate the presentation and analysis of results. The number of supported basic-research projects in this program will be decreased and high quality applied research will be increased.

Product Development Program to Establish Local Suppliers

The program aims to support joint projects between the research and private sectors to establish high quality small and medium sized enterprises that will develop products that contribute to maximizing the local content and the commercial and economic benefit from the technological potentials in the research sector. Up to 7 billion riyals was invested in R&D over the last seven years with promising outputs and commercial and economic opportunities. Moreover, the program seeks to benefit from these investments and outputs by newly established companies to develop high added value services and products.

Program to Stimulate Young people to Get Involved in the Areas of Science and Technology

This program launches a comprehensive group of initiatives to support science, technology, engineering and mathematics in public education, and develops and encourages research activities at universities. It increases communication about science and technology in the society.

Program of Industrial Innovation Centers

These centers aim to create partnerships between research institutions and the private sector in order to develop services and products that contribute to increasing the competitiveness of national companies, and the promotion of the local content. The program also aims to support the establishment of the appropriate atmosphere to develop the local content. It does this by: developing next generation technologies; supporting research cooperation efforts between universities and industry; transferring knowledge in the KSA; strengthening the university research; and improving science and engineering education in the KSA. It follows international best practices and brings them to the KSA.

- **Technology Transfer and Localization Initiatives**

Localization and Transfer of Energy Technology

KACST undertook an integrated program to develop and produce solar energy technologies. The aim of this was to support industry in the Kingdom and to development new technologies that reduce oil and gas consumption, by encouraging entrepreneurship. Through these initiatives, KACST seeks to minimize solar energy production expenses based on the former successes in this field. Previously KACST managed to produce solar energy at 18 Halala per kilowatt/hour, and seeks to reduce this to 12 Halala during coming years. In addition, the program is determined to support the Saudi Electricity Company and Saudi Aramco in their endeavors to increase the localization of equipment and spares in the 5 next years. KACST is also involved in providing expertise in energy generation research and development to test the duty circles and components of gas turbines. Also, the program could contribute to well-establish exercises to manage solid waste in the KSA by building a utility to test how to transform solid waste into gas.

Rationalization of Energy Consumption Through Light Emitters in Buildings and Roads

This initiative aims to assist in decreasing electricity energy consumption through gradual conversion to low consumption light technology using light emitters made of Gallium nitrate in the KACST

laboratories. These kind of materials pave the way to achieving the required objective, i.e. to produce a white light with high efficiency, five-fold consumption less than the normal illumination, and a life-cycle that exceeds 25 thousand operating hours. It also provides practical and effective solutions for efficiency decrease issues with the increase of the current. This initiative deals with the new regulations of the Saudi Energy Efficiency Center and the Saudi Standards, Metrology and Quality Organization. The benefit will be gained from KACST's accumulative experiences in this field and its partnership with King Abdullah University of Science and Technology and University of California - Santa Barbara.

Localization and Transfer of Water Technology

Saline water desalination is a strategic alternative for drinking water supply for KSA. The Kingdom produces more than 18% of global production of desalted water, but the work on localizing water desalination technologies industries hasn't been achieved over the last few decades. So, KACST undertook work on localizing a number of desalination technologies starting from the designation of stations and development of many research tracks for all kinds of desalination, working in cooperation with many international research centers. The initiative includes topics such as water desalination, waste water systems, water network and treatment. Specifically, the initiative will address the following technologies: micro-filtration for water treatment, development of RO for sea water treatment, and development of low pressure RO for tertiary treatment.

Reduce Water Leakage by Monitoring the Water Pipeline Networks

This initiative aims to use advanced technologies in communication and information technology to develop an integrated system to protect long water pipelines, and monitoring water quality through wireless sensing networks. These includes a group of sensors which assess acceleration and heat and take analytical photos by infrared sensors, in addition to automatically generating the operating energy for the sensors by transforming the movement energy from the work environment.

Localization and Transfer of Oil and Gas Technology

This program develops 6 sub-technologies:

- Developing continuous surveillance technologies for carbon storage and subsurface changes in oil and gas fields;
- Developing multi frequency radar systems for supporting oil and gas explorations;
- Developing Nano gelatin particles to support petroleum production efficiency;
- Developing seismology data registration appliances for sandy regions;
- Developing advanced liquids flow patterns to increase liquids and raise efficiency in low pressure gas reservoirs.

High-Efficiency Clean Fuel Production

Based on the accomplished research in the previous years, this initiative aims to develop a model to produce catalysts to get clean fuel without sulfur and nitrogen, and to develop the production of the fuel additives that will improve its features, and help create an environment free from dangerous materials that can affect health. This fuel was successfully created with Saudi Aramco.

Localization and Transfer of Mining Technology and Advanced Materials

KACST seeks to transfer and localize advanced materials and mining technologies by establishing collaborations between the related sectors and companies in the Kingdom, in order to promote added value and reduce waste in the energy sector. KACST will also focus on supporting the future economic strategy of the KSA and transferring the advanced technologies into the industrial sector.

Localization and Transfer of Health Technology

This programs aims to reduce healthcare costs, by completing the mapping of the Saudi genome to cover 100 thousand citizens in the KSA. It also aims to develop an integrated interactive information system to limit common genetic disorders in the Saudi community, which have a high cost to health services. The program seeks to limit diabetes mellitus and treat it in the KSA, by developing the potential of using a continuous gauge of glucose for Saudi health providers, and determining the main factors for the best management of this disease.

The initiative is also looking to localize and develop technologies to manage communicable diseases by establishing an integrated system of policies, procedures, orders, factories and labs that aim to quickly explore these diseases and take the necessary procedures to contain them and produce medicine and vaccines.

High-Protection Memory to Store Information and Digital Signature for Secure Government Transactions Device

USB flash drive memories are mostly used in the government authorities, and most of them are vulnerable to viruses and interpenetration. Hence, the locally made device and which is consistent with the systems of the Ministry of Communication and Information Technology, aims to issue the Saudi digital certificates to preserve information secrecy through providing coding technology and digital signature for the government authorities that enables the user to maintain information secrecy and verify clients' identity. It will also preserve data safety from default or change, allowing users to do business, operate, and send e-mails safely. The manufacture of this product is underway at KACST and a number of parts have been created and are being used in the experimental stage.

Regulatory Framework to Promote Open Source and Free Software

KACST is determined to formulate systems that support large and middle software manufacture quality, and contribute to reduced costs and localized technology. This includes expanding the free and open-source software, and increasing private sector efficiency to execute high quality software according to global standards. This requires the coordination of efforts to formulate laws and a regulatory framework.

A National Enterprise Resource Planning (ERP) System

Government entities and the private sector spend large amounts on managing their resources in similar ways. This initiative aims to establish a united open-source system with a low cost that can be designated and continuously developed. KACST has great capabilities in this field, and it is heading a committee to handle this subject along with many authorities, such as the Ministry of Communication and Information Technology. This has led to many recommendations being formulated from this project.

Big Data for Strategic Planning Platform

Government entities including the Ministry of Economy and Planning and the General Authority for Statistics have a huge amount of data with different sources. This initiative seeks to establish an integrated technological stage that includes tools to prepare, store, analyze, and film the big data. This system enables the government authorities to have easy access to useful information to help them in strategic planning and decision making.

Low-Cost Communication Network for Internet of Things (IoT) Applications

Public and private sectors spend huge amounts on their business and on providing services at the right time. Government authorities, such as those regulating electricity, water, and gas, waste a lot of their resources. This initiative uses the IoT applications to cover Riyadh with LPWAN technology, as it can accommodate a huge amount of data consistent with energy saving sensors, which reduces pressure on communication networks with very low cost compared to the normal alternative.

Corrected Aerial and Panoramic Imaging

KACST has met many needs in aerial imaging on many occasions. There is a duplication and repetition in taking pictures which has resulted in unnecessary expenditure. Since KACST is the responsible for supplying all sectors with space photographs this initiative considers the addition of aerial picturing to KACST's responsibilities. This will lead to a 50% reduction in costs overall and prevents duplication of efforts. It seeks to prepare infrastructure to be able to provide this services for sectors.

Artificial Satellite Communication System to Prompt Applications Electronically to Government Agencies

Antennas with mechanical direction are used between ground stations and satellite, such as VSTA, in most government authorities. The suggested product is based on a laptop-sized electronic device that can be directed to track satellites without mechanical antenna. It can also be modified to use on vehicles such as cars, ships, planes and drones due to its small size. KACST developed a lab model, and successful tests were made for communication across satellites. KACST aims to complete the development, locally manufacture the parts and create a production line to make 100 devices as a first step.

Localization and Transfer of Building and Construction Technology

Components for dwellings are made in specialized factories using automation and robots are used to transfer them to building locations. They are made at competitive cost and with local staff, which reduces foreign manpower. It also aims to improve sustainability standards in buildings by applying

systems to save energy and adopt integrated efficiency with renewable energy in future and current buildings. This leads to the development of sustainable buildings. The aim is to establish a production line with localized technology.

Localization and Transfer of Transport and Logistics Technology

It seeks to localize and transfer technology to maximize local content in transportation and logistics services, by developing integrated transportation systems inside cities, especially large ones. It seeks to reduce accidents and jams and decrease fuel consumption, by establishing advanced, low cost computer systems and by participating in technological counsels to identify the specifications to support information technology that can control logistic services. It will also improve transportation storage and delivery technology to reach optimum delivery speed.

Smart System for Monitoring Greenhouse Gases in the Kingdom

If carbon emissions are not limited, the dryness and high temperatures in the region will make it an unbearable place to live. The KSA is aiming to reduce emissions before 2030 but it is hard to do so without having monitoring systems to work out the worst emissions areas. It seeks to establish a smart system to monitor gases that cause global warming in the KSA by using low cost connected units. Decision makers will see areas that need quick intervention and make regulations to curb those emissions.

Technical Leaders Program

To solve the current gap in the national human resources, KACST established the Technical Leaders Program to prepare leaders for technological development through the best international institutions. Through this program, KACST has prepared graduates who have a passion for technological development, for PhDs at top-tire universities. And, it has developed highly capable industry leaders such as CEOs in small and medium sized enterprises, to get them ready for occupying roles in product development and at high levels of technology management.

Enhance Equipment and Facilities Necessary for the Development of Local Content

It seeks to establish ten national labs to promote the local content and provide many other services for public and private sectors. These labs take part to increase the added value of the industrial sector through the conducted research. They serve lots of sectors, including: energy, water and others.

- **Innovation Initiatives**

Technical Consulting Program

It seeks to benefit from the national competencies and the available technological capabilities at KACST through providing technological consultation services that are included within the KACST field of expertise, including: energy, water and others.

Workshops Program for Prototype Development

It aims to establish three initial models development centers in the major cities in the KSA to support manufacturers in developing new products and try them in a suitable environment in a way that supports small and medium sized enterprises.

Program to Raise the Manufacturing Capacity of Small and Medium Sized Enterprises

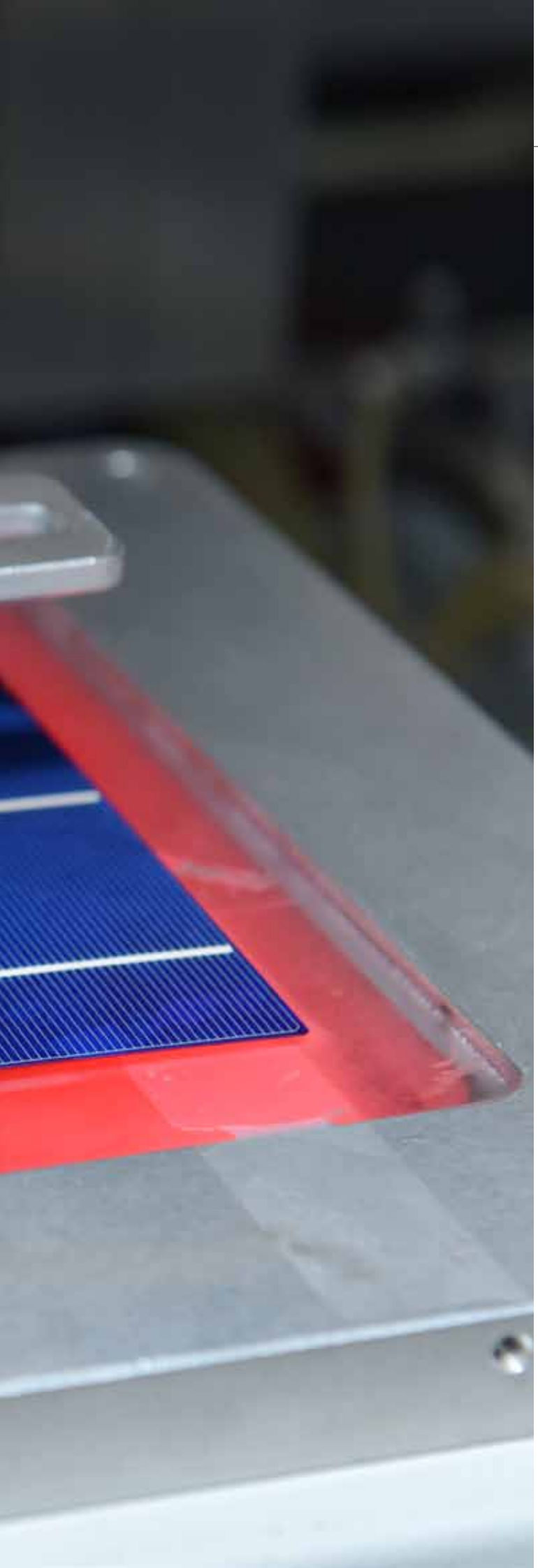
It seeks to provide a group of technological services such as technological consultations. It includes the complete technological promotion of the small and medium sized enterprises, in order to qualify them to contribute to the local content and develop products of quality in good quantity. It will provide definite support services for the small and medium sized enterprises, such as providing a major center, supporting industrial and technological qualifications, providing consultation services, and helping them to develop policies.

Business Incubators and Accelerators Program

It seeks to support the establishment of small and medium technological companies with large growth rate to contribute to the creation of jobs and diversify the national economy via the BADIR program belonging to KACST. Badir's five accelerators and incubators provide high quality services for information technology, communication, biological technology and young projects of advanced manufacturing. They seek to accelerate the growth of young Saudi projects by providing thought and funding at the same time. Also, they aim to assist young technological projects to skip the difficult challenges during various growth stages, and help with the creation of job opportunities.

1.2 | Coordination between Research and Scientific Institutes in the Kingdom

- Science, Technology and Innovation System
- International Agreements
- National Committees



Science, Technology and Innovation Policy
Coordination

King Abdulaziz City for Science and Technology is keen to coordinate with all related parties, in order to achieve useful outputs for society.

Science, Technology and Innovation System

The implementation of the First National Plan for Science, Technology and Innovation has contributed to the development of the science, technology and innovation system, by building a knowledge base, creating an innovation environment and developing science within society. The system consists of research institutions and national research centers, that aim to create research excellence and developing partnerships with international research institutions. This forms the scientific pillar required for the transformation into a knowledge-based society. It includes also, technology transfer and innovation support institutions, aimed at filling the gap between research and development activities and aspects of economic activity, through the supporters of technology transfer and localization, working on market accessibility. This is done with technology products of a high quality, centers for innovation and entrepreneurship and business accelerators, to train and support the owners of the innovative ideas, accelerate the transfer of inventions to the market, support different enterprises and support innovative business research. It also contains the organizational framework institutions, which govern the system through the general policies that guarantees the transformation of knowledge and technology and the development of financial resources for research. The preparation of qualified human resources, to develop high quality research, support innovation technology transfer and localization of technology, is an important pillar to support the system through steering institutions towards increasing the number of Saudi youth to enter the knowledge market. Finally, establishing a culture of dialogue to increase the awareness of science and technology, is a requirement to support the system and a role entrusted to all related-entities.

Planning

- STI Policy
- STI Plans
- NTP 2020

Coordination

- Science, Technology and Innovation System
- International Agreements
- National Committees

Evaluation

- Evaluation of Science, Technology and Innovation System
- Standards of Science, Technology and Innovation System
- Technology Forecasting

International Agreements

Joint Committee Meetings

- The seventh session of the Saudi-South African joint committee, in South Africa, during the period from 5-6/6/1437H.
- The second session of the Saudi-Belarus joint committee, in Minsk, on 13/8/1437H.
- The third session of the Saudi -Poland joint committee, in Warsaw, during the period from 9-13/5/ 2016.
- The ninth session of the Saudi-British joint committee, in Riyadh (Preparatory meeting) on 10/7/1437H.
- The third session of the Saudi-Portuguese joint committee, in Riyadh, during the period from 17-18/1/1438H.
- Participation by the Department of International Cooperation
- The preparatory meeting of Gulf Week events, on 25/11/1436H.
- The seventh World Forum of Science, in Hungary, during the period from 22-25/1/1437H.
- The third session of the Joint Saudi-French Coordinating Committee, in Paris, during March 2016, and attending the preparatory meeting on 15/4/1437H.
- The high-level Conference on Intellectual Property of Countries along the Silk Road Economic Belt, in the Chinese Capital, Beijing, during the period from 16-17/10//1437H.
- Representing KACST in the Education Task team, of the Saudi-Turkish Coordination Council.
- Workshop between KACST and the Swedish research centers, during the period 29-30/1/2016.
- The meeting of the Federation of Arab Scientific Research Councils, at its 37th session, in Kuwait City, during the period from 13-14/12/2016.
- The meeting of the 1st Arab Leadership Dialogue on Science Advise to Governments, in Amman, Jordan, during the period 14-15/3/1438H.

Agreements

- The MoU between KACST and the Beijing University of Chemical Technology signed in Riyadh, on 5/3/1438H, with a view to cooperating in scientific and technical research, in selected areas of common interest.
- The protocol between KACST and The Scientific and Technological Research Council of Turkey "TÜBİTAK", signed in Ankara, on 29/12/1437H, with a view to cooperating in areas of natural sciences, industrial research, development and innovation, engineering, technology, medical and health sciences, agricultural sciences as well as social and human sciences-related research.
- The protocol between KACST and The National Academy of Sciences of Belarus, signed in Minsk, on 1/7/2016 AD, to cooperate in order to widely implement the outcomes of joint scientific activities.
- The agreement on science and technology cooperation between the Government of the Kingdom and the Government of the Republic of Belarus, signed in Minsk, on 11/8/1437H, with a view to cooperating in areas of energy, agricultural and production technologies, medical and pharmaceutical technologies, nanotechnology, biotechnology, information and communication technologies and modern materials.
- The agreement between KACST and the Saudi Huawei Investment Technology Co., Ltd, signed on 21/1/2016, in order to establish future communication centers for LET and 5G technologies.
- The agreement between the Government of the Kingdom, represented by KACST, and the Government of China, represented by the Ministry of Science and Technology, signed in Riyadh, dated 9/4/1437H.
- The MoU between KACST and the China Satellite Navigation Bureau, signed in Riyadh, dated 9/4/1437H, in order to cooperate in the fields of the BeiDou Navigation Satellite System.
- The memorandum of understanding between the Government of the Kingdom and the Government of the republic of Tajikistan, signed in Riyadh, dated 23/3/1437H, in order to enhance, expand and strengthen the exchange and cooperation in science and technology.

National Committees

National Committees of Bio Ethics

By Royal Decree (No. 7/B/9512) dated 18/5/1422H, The Custodian of the Two Holy Mosques ordered the creation of a national committee, the National Committee of Bio and Medical Ethics, later renamed the National Committee of Bio Ethics, by Royal Decree (No. M/59) dated 14/09/1431H. The Committee seeks to develop and monitor compliance with bio and medical research ethics and standards, to improve and enhance all health, preventive, diagnostic, therapeutic, psychological aspects of life, while preserving human dignity, elevating charity, justice, individual and societal rights, in alignment with the Islamic Shari'a, and the traditions and essence of the culture of the Kingdom. Its interests would also include bio medical research ethics, and its application in hospitals, universities, research institutions, and all related public and private sectors.

The Custodian of the Two Holy Mosques has issued the Royal Decree (No. M/59) dated 14/9/1431H, on implementing the law of (System of Ethics of Research on Living creatures), set by the National Committee of Bio Ethics. This Law aims at setting the general principles and controls necessary for dealing with "Living Creatures", parts thereof, or their genetic material in research, in light of applicable professional ethics not conflicting with Shari'a. By Royal Decree (No. 122512 /M/10) dated 29/1/1433H, the President of KACST, ordered the creation of the executive regulations of the system. The committee held, in the year of this report, 18 meetings, including major, executive and sub-meetings and other meetings of the Monitoring Office for Research Ethics. Some of the outcomes: 1) Submit observations of SFDA on the regulations. 2) Create several task forces to perform various tasks related to the system, the executive regulations and some of the controls issued by the committee. 3) Adopt a unified mechanism and additional controls (under the umbrella of the system) to confirm the registration of local committees. 4) Communicate with whoever has bio-related research queries, via the e-mail of the National Committee. 5) Discuss the Committee's main activity for 1438H. 6) Discuss the tasks of the Monitoring Office for Research Ethics. 7) Discuss the initial recommendations of the workshop. 8) Adopt the initial recommendations of the workshop "Individuals genetic structure based-medicine ethical aspects". 9) Register of 528 researchers, giving a total of 872, now of both genders.

The Technical Committee for the Work of Plastic Standards

The mechanism of the technical team system dedicated to prepare the Saudi standards and technical regulations (QMS-WI-07-05) was adopted in 17/10/1435H, in collaboration with the Saudi Standards, Metrology and Quality Organization (SASO). The committee seeks to develop the process of the Preparation of Saudi standards and technical regulations for plastic, and present its specification-related videos. It aims also to review, periodically, the Saudi standards and technical regulations which have been issued already, which found to be in need of review or which received comments, in order to ensure compliance with national requirements international standards.

Task Force on Implanted Medical Devices Standards

KACST is a member of the National Task Force on implanted medical devices standards, headed by the Food and Drug Administration (FDA). It intended to prepare and adopt the standards and technical regulations issued by the FDA, and adopt the international standards of implanted medical devices products.

The National Commission for Seismology

KACST is a member of the National Commission for Seismology, headed by the Saudi Geological Survey. Other members include KSU, KFUPM, and KAU. The commission is dedicated to follow up the seismic situation in the Kingdom, and monitor seismic activity, through the national network. Established following Royal Decree (No. 228) dated 13/08/1425H, by the Council of Ministers.

Committee of Hazardous Substances in Air, Sea and Land Entry Points

Established in 14/04/1431H, in order to study the situation of the hazardous substances in air, sea and land entry points, and prevent their accumulation. In addition, to find the appropriate mechanism to expedite the completion of its procedures and take the necessary measures to evacuate all ports of the accumulated hazardous goods.

The Advisory Committee of the Petroleum Engineering Departments Council at KSU and KFUPM

The National Petroleum and Gas Technology Center participates in the advisory committees of the Petroleum Engineering Departments Council, at King Saud University and King Fahd University of Petroleum and Minerals, that deal with all activities of the administrative departments, the study plans and the scientific guidance. It concentrates on the organizational structure and schedule of the newly established faculty in KFUPM, in which the disciplines of Earth Sciences and Petroleum Engineering were merged.

The Saudi Committee of layers-related succession in the Kingdom

KACST participates in the Saudi Committee of layers-related succession in the Kingdom, dedicated to unify the names of the rock layers in the Kingdom, headed by the Geological Survey Authority, with the participation of several entities.

The Scientific Committee of Technology Innovation Center on Carbon Capture and Storage at KFUPM

KACST continues to be a member of the scientific committee of technology Innovation Center on Carbon Capture and Storage at King Fahd University of Petroleum and Minerals, within the Technology Innovation Centers Program. This committee works to study and update the center's directions, study and approve the scientific activities, and supervise the study and arbitration of research proposals, periodic and final technical reports, submitted to the center, in addition to all scientific matters related to the implementation and formation of the center.

The National Committee of the Kingdom's Participation in the 2017 Expo in the Republic of Kazakhstan

KACST is a member of the National Committee on the Kingdom's Participation in the 2017 Expo, which will be held in the Republic of Kazakhstan, with the participation of several governmental agencies. This committee works to prepare and supervise the Kingdom pavilion in the exhibition, in accordance with the Kingdom's position, and highlight its pioneering role, vision and goals in the field of energy.

Inter-Agency Committee on Radiological and Nuclear Emergencies

Several meeting were held, in coordination with King Abdulaziz City for Atomic and Renewable Energy, related to the revision of the national plan on the response to radiation and nuclear emergencies, readiness of the parties participating in the plan, in addition to put an-end-state vision of the requirements and tasks of the participants in the plan.

1.3 | Evaluation of Scientific Research and Innovation Outputs

- Evaluation of the Science, Technology and Innovation System
- Evaluation Standards of Science, Technology and Innovation System
- Technology Forecasting

Science, Technology and Innovation Policy

Evaluation

KACST plays a vital role in advancing the R&D ecosystem in the Kingdom through support, promotion, and execution.

Evaluation of the National System of Science, Technology and Innovation

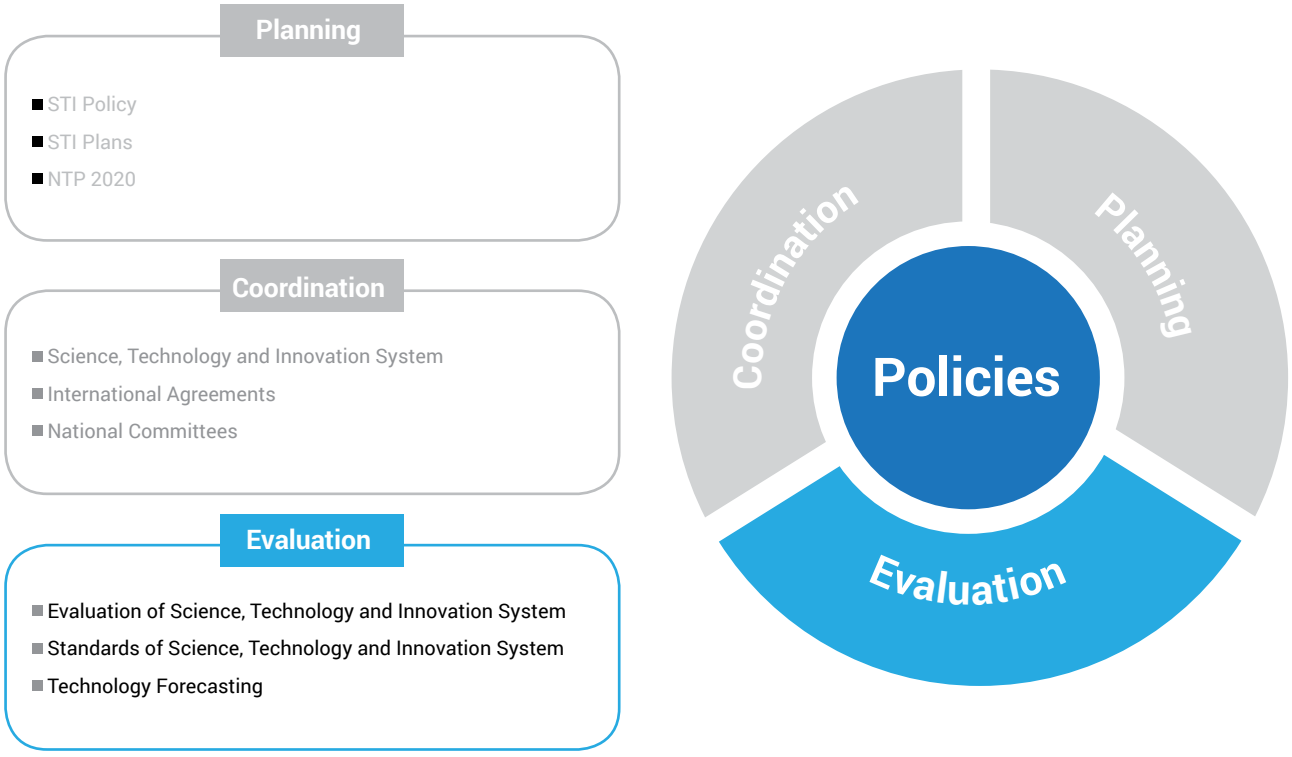
One of the major objectives of Saudi Vision 2030 is for the Kingdom to have a diverse and a prosperous economy. Both knowledge and innovation that are based on scientific R&D have become key necessities to ensure the Kingdom's transition from natural resources-based economy towards a comprehensive knowledge-based society and economy.

The R&D ecosystem in the Kingdom consists of several components including: the policies and regulations for science, technology, and innovation; the inputs and outputs of key performance indicators (KPIs) related to R&D; and the outcome and the developmental and economical impact of R&D.

It is well-known that KACST plays a critical role in advancing the R&D ecosystem in the Kingdom through:

- Formulating policies and national plans for STI in the Kingdom.
- Coordinating national activities in STI in the KSA.
- Providing support to scientific research and technological development in the Kingdom.
- Conducting scientific research and technological development.
- Developing and strengthening cooperation and local, regional, and international partnerships for technology transfer and development.
- Investing in technology development and its commercial processing.
- Sponsorship, promoting and investing in intellectual property.
- Providing advice and innovative solutions.

The Board of Directors of KACST has requested, in their first meeting, that KACST should develop monitoring tools and KPIs to evaluate the R&D ecosystem and assess its outcome and impact in the Kingdom. KACST Board of Directors have also requested KACST to submit periodic reports on the performance of the R&D ecosystem to them.



The Evaluation Criteria of the R&D ecosystem in the Kingdom

KACST is continuously working on the development of techniques to measure the factors related to R&D activities. In addition, KACST is working on assessing the performance of the components that affect the ecosystem as a whole, using the following mechanisms:

- Periodically collect specific, accurate, and reliable measurements to identify the factors related to the performance of the research, development, and innovation ecosystem.
- Develop a set of key performance indicators to monitor the success of the R&D ecosystem as well as to identify gaps.
- Develop monitoring tools to evaluate the economical and social effects of R&D activities.
- Submit periodic reports on the performance of the R&D ecosystem to KACST's Board of Directors.

The First Science, Technology, and Innovation Plan (Maarifah 1)

The implementation of the first Science, Technology, and Innovation Plan (Maarifah 1), which started in 2007 and ended in 2014, has had a great effect on the R&D activities in the Kingdom. As a result of implementing Maarifah 1, remarkable growth in many global indicators was observed. These include number of registered patents, number of published peer-reviewed papers, and number of citations, which are considered the main outputs of scientific research. This growth resulted in making the Kingdom leads the Arab countries in scientific publications (papers and patents) as well as achieving high ranks in the quality of publications.

As shown in Figure 1, the number of scientific publications has increased dramatically with the inception of Maarifah 1 in 2008. In particular, for the period 2008 to 2014, the number of published papers has tripled. That being said, the number of scientific publications has slightly dropped in 2015 (when compared to 2014). This drop is concurrent

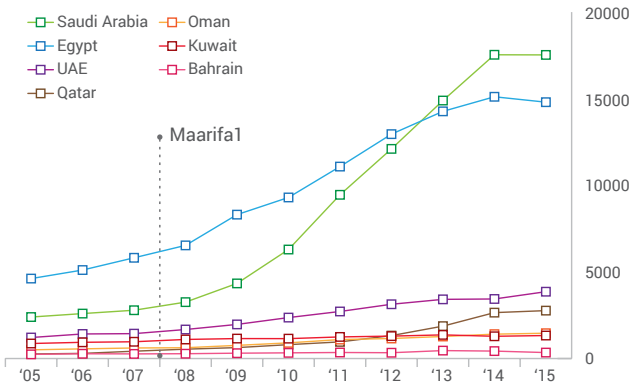


Figure 1: Number of Scientific Publications
Source: Scimago

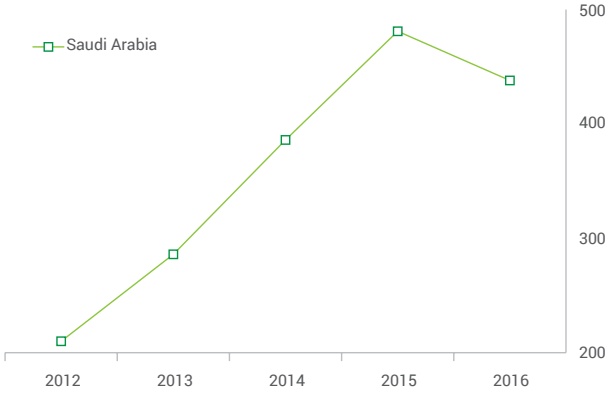


Figure 2: Number of Scientific Publications in Nature Index
Source: Nature Index

with the lack of funding for approved projects of Maarifah 1 that took place in 2015. In addition, this dropping trend is expected to continue in 2016 and 2017 for the same aforementioned reasons.

These findings are compatible with the results reported in Nature's Index, which is a database of author affiliation information collected from research articles published in an independently-selected group of 68 high-quality science journals. As shown in Figure 2, the number of scientific publications in the Kingdom (based on Nature's Index) has dropped by more than 8.5% in 2016 compared to 2015.

It is expected that the R&D activities will pick up pace with the launching of the "Universities and Scientific Centers Support", which is one of KACST initiatives in the NTP 2020. This initiative consists of seven programs that are targeted to support R&D projects in the Kingdom. KACST has announced that the official launching of this initiative will be in April 2017. By implementing these programs, KACST is looking forward to achieve one of its NTP KPIs (i.e., to reach 20,000 published peer-reviewed research papers by Saudi scholars by 2020). Although, KACST is launching this initiative in April 2017, it is expected that its effects on number of publications will be observed by the end of 2018.

Despite that the number of scientific publications did not grow in 2015 compared to 2014, the Kingdom has maintained a steady growth in the quality of publications index, as shown in Figure 3. The ranking of the Kingdom in the citations index has grown in the period of 2011 to 2015 to reach 1.18, while it continued to grow in 2015 by reaching 1.38, exceeding the global normalized rate.

The Kingdom has witnessed a remarkable growth in the number of filed and registered patents in conjunction with launching Maarifah 1 in 2007. The growth can be observed clearly starting from the year 2009, as shown in Figure 4. The number of filed patents continued to grow steadily until 2015, where it dropped by 45% compared to 2014. The suspension of the financial support by Maarifah 1 has contributed to this drop.

It is expected this dropping trend will continue in 2016 and 2017. For the registered patents, the Kingdom has seen a 10% growth in the number of registered patents in 2015 compared to 2014, which hints to the high quality of the filed patents.

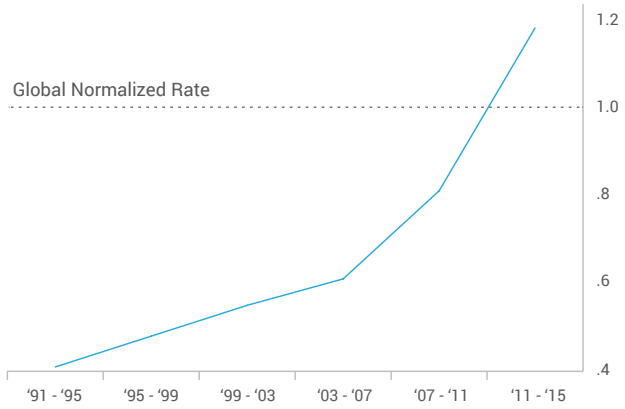


Figure 3: The Normalized Citation Impact (NCI)
Source: Research Performance Index Report 2016 - KACST

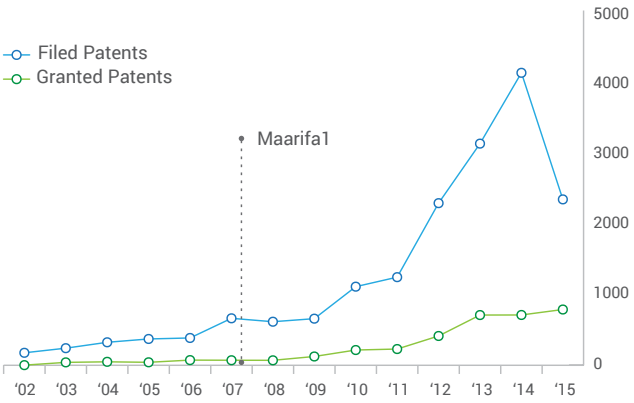


Figure 4: Deposited and Granted Patents
Source: World Intellectual Property Organization (WIPO) Report

With the launching of KACST's initiative in the NTP 2020 to support research and innovation conducted by universities and research centers in the Kingdom, it is expected that the number of filed and registered patents will pickup again in the near future.

As part of KACST's KPIs in the NTP, KACST has put a target of 5000 patents to be registered by Saudis until 2020. KACST has designed new programs targeted for the research and innovation community in the Kingdom to help achieve this target.

In regard to other indicators, the Kingdom has reached an advanced position in the "Global Innovation Index", which is maintained by the World Intellectual Property Organization (WIPO). In this index, Saudi Arabia is ranked first among the Arab countries, third in the region, and 43rd in the world. It is expected that the Kingdom continues to maintain a good position in this index in the upcoming years.

Technology Forecasting

Tremendous technological progress over the last few decades has significantly changed the way people live. Nowadays, we live in a very fast-paced world in which we witness several disruptive technologies each year. Many of these technologies have reshaped different parts of the industry and the job market, making it important for countries to foresee such changes and readjust their policies and investments plans as fast as possible.

Given the importance of such disruptive technologies, King Abdulaziz City for Science and Technology restructured its Future Studies Unit to be a National Center for Technology Forecasting that will replace the resolved unit within KACST. This restructuring decision has been embraced by the Board of Directors of. The National Center for Technology Forecasting (NCTF) aims at conducting systematic studies on disruptive technologies and evaluating its risks and investment opportunities.

Scope of NCTF

The scope of the National Center for Technology Forecasting includes the following tasks:

- Conduct studies on disruptive technologies in strategic areas and evaluate the risks and opportunities associated with them at the national and sectoral levels.
- Study international experiences in disruptive technologies, and suggest how to benefit from them.
- Organize and conduct workshops, seminars, and surveys on disruptive technologies.
- Establish a comprehensive national database for disruptive technologies and technology forecasting.
- Develop KPIs for technologies and enhance the quality of its data and information in coordination with the stakeholders.
- Produce and publish reports on technology forecasting.
- Conduct training in the field of technology forecasting in coordination with the stakeholders.

Deliverables of NCTF

The deliverables of the National Center for Technology Forecasting include:

- An annual strategic report that presents the most recent disruptive technologies worldwide.
- Biannual technical reports that present the latests disruptive technologies in specific sectors, e.g., energy, water, ICT, etc..
- The National Center for Technology Forecasting portal which allow users to learn more about such disruptive technologies.
- Consultation services for different public and private sectors stakeholders.

Scientific Research Support

2 | Scientific Research Support

- Grants Program for Universities and Research Centers
- Technical Logistics Support System
- Scientific Awareness

Scientific Research Support

Scientific support services have great importance to the advancement of nations, due to their obvious role in creating a productive scientific environment for all spectrums of society.

Introduction

KACST provides scientific support services in the light of its mandated functions and responsibilities. It coordinates the national activities of science, technology and innovation, and provides grants for scientific research and technical development in the Kingdom. KACST's scientific support services include: the Grants Program for Universities and Research Centers (GPURC), the technical logistics support system; and the scientific awareness.

Grants Program for Universities and Research Centers: KACST has prepared, in cooperation and coordination with a number of national stakeholders and international expertise, seven key grants program from the perspective of supply and demand in the labor markets.

Technical Logistics Support System: KACST has established the international portal for the Saudi academic network and added a number of international lines with a total capacity of 8 GB/ second. It has also supported advanced research infrastructures, established and managed central laboratories and manufacturing workshops, and created prototypes to enhance the culture of collaborative scientific research and to facilitate the accessibility of researchers from inside and outside KACST to advanced scientific equipments in a convenient way.

Scientific Awareness: KACST communicates with different segments of society in order to establish an attractive and stimulating environment for scientists, researchers, and relevant members of the public. Services that raise scientific awareness include: organizing and supporting a number of international scientific conferences, organizing training courses for specialists from the scientific research communities, and publishing international scientific journals, some of which are included in the list of high impact journals in the Kingdom's strategic technologies such as water, oil, gas, biotechnology, nanotechnology, renewable energy, petrochemicals, and smart systems.

2.1 | Grants Program for Universities and Research Centers

- Graduate Research Program
- Basic Research Program
- Applied Research Program
- Research Innovative Program
- Targeted Research Program
- Industrial Development Program
- Industrial Innovation Centers Program

Scientific Research Support

Grants Program for Universities and Research Centers

Supply-based programs are those that are executed to provide scientific/ technical solutions to current and future challenges facing the labor market. Demand-based programs are those that are executed at the request of government or private agencies to address urgent challenges, using scientific technical solutions.

Introduction

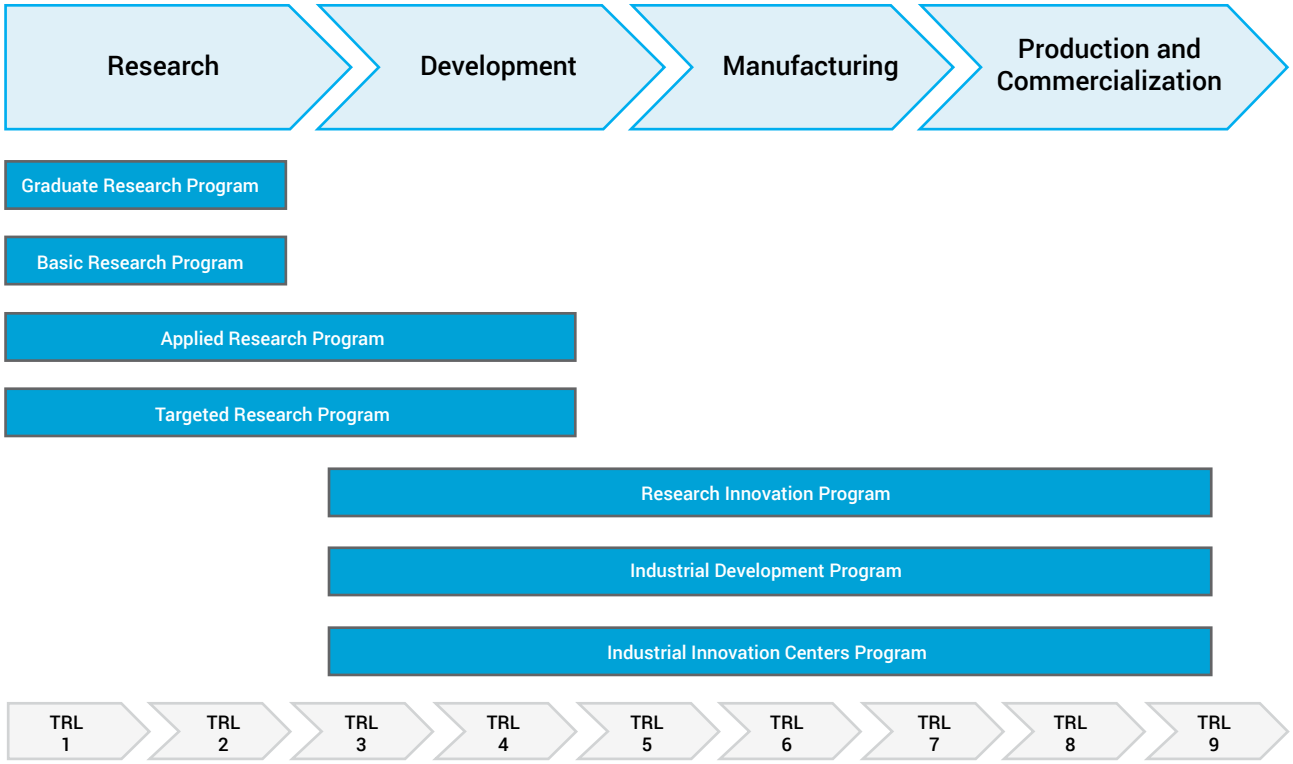
The Grants Program for Universities and Research Centers (GPURC) has been adopted as one KACST's initiatives in the National Transformation Program 2020. The program aims to enhance the infrastructure needed to develop local technological content and support R&D, to ensure the sustainability of the local technological content development ecosystem in the Kingdom. This is strategically interrelated to the Kingdom's Vision 2030 as it will help provide citizens with the knowledge and skills needed to meet future labor market needs, and support entrepreneurship.

The GPURC aims to achieve a set of key performance indicators by the end of 2020. These include: number of published scientific papers, number of patents issued, number of technology companies emerging from universities, number of technical solutions produced from the technology companies;and number of job opportunities created by the technology companies.

The GPURC targets many beneficiaries, including:

- Graduate students at national universities.
- Ph.D and MS holders.
- Universities and research centers.
- Public and private sectors.
- Small and Medium-sized Enterprises (SMEs).

KACST's supervision of the GPURC is aligned with its mandated functions and responsibilities, i.e., coordinating the national activities of science, technology, and innovation, and providing support for scientific research and technological development in KSA. This program is a result of a major national effort led by KACST with involvement from national stakeholders and international experts.



Structure of the Grants Program for Universities and Research Centers and its Relationship to the Innovation Cycle

The GPRUC consists of 7 main programs that are based on the supply and demand perspectives of labor market. The supply-based programs, which are executed to provide scientific/technical solutions to current and future challenges facing labor market, include the following:

- Graduate Research Program.
- Basic Research Program.
- Applied Research Program.
- Innovation Research Program.

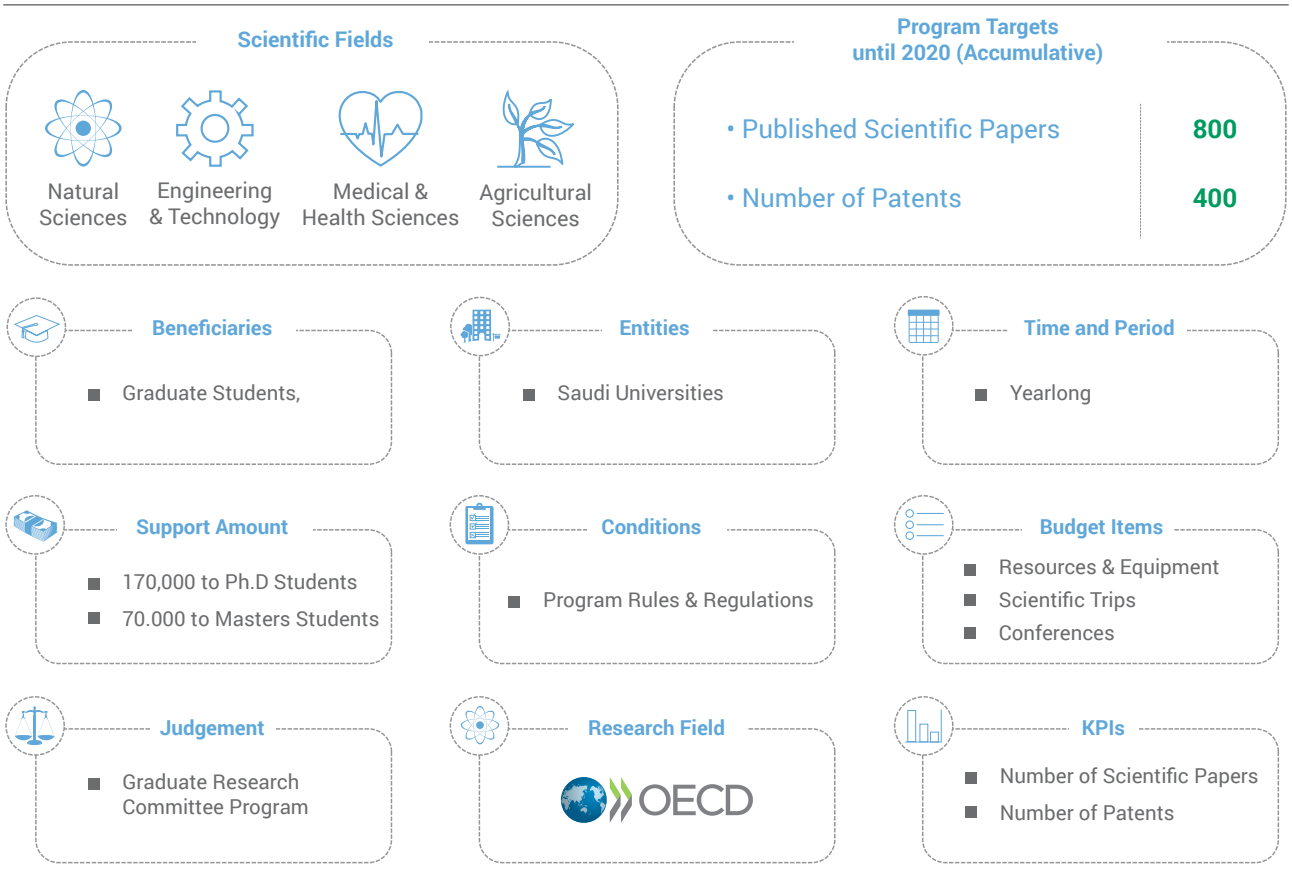
On the other hand, the demand-based programs, which are executed at a request of government and private agencies to address urgent challenges using scientific technical solutions, include the following:

- Targeted Research Program.
- Industrial Development Program.
- Industrial Innovation Centers Program.

The development of the GPURC has been built on a system that supports innovative ideas starting from basic research to the development of high value-added products via four main stages: research, development, manufacturing, production and commercialization.

The distinction of the GPURC is based on its reliance on a performance point system (PPS) to assess the implementation efficiency of the funded projects. The PPS has the following characteristics:

- Setting a minimum target output for each program that each grantee is required to achieve.
- Targeted outputs include including scientific publications, patents, created jobs, technology startups, and technical solutions for industry.
- The nature of the grants program.
- Additional financial rewards are given to researchers when they exceed the minimum targeted output.



First: Graduate Research Program

The Graduate Research Program is a new strategic program in the national research and development support ecosystem. It is a long-term strategic investment aimed at developing a set of scientific skills needed to boost Saudi Arabia's position among leading countries in the field of science, technology and innovation.

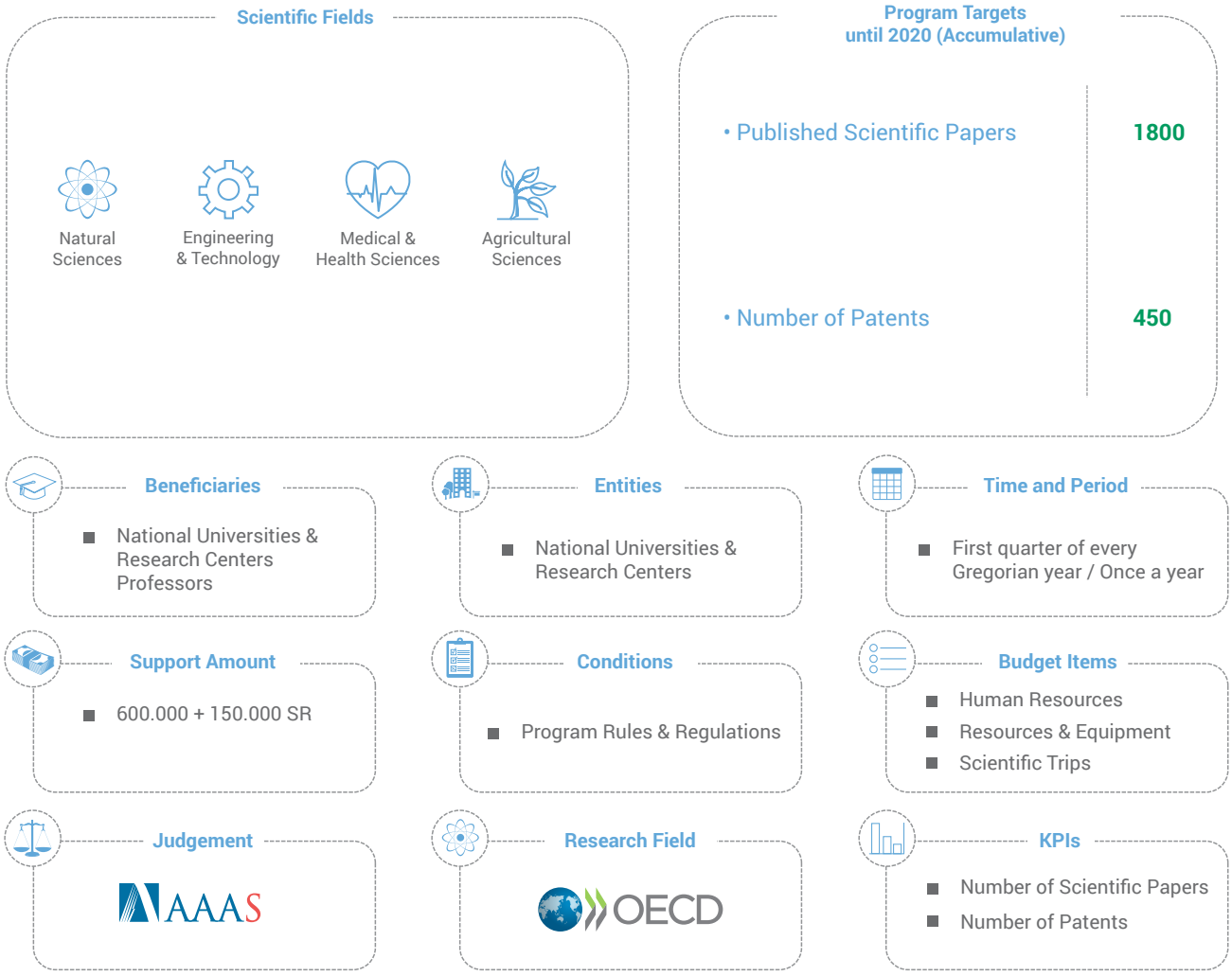
This program works - in general - by providing financial support to Saudi graduate students. It also provide the required technical assistance, including devices and equipment for the implementation of Masters and Ph.D research. This research is based on R&D approaches related to production and manufacturing problems.

The program's goals include the following:

- Encouraging outstanding graduate students to conduct world-class research in various sciences according to advanced scientific knowledge worldwide.
- Developing scientific skills to elevate the Kingdom's status as a pioneer in science, technology and innovation.
- Supporting modern scientific and technological discoveries and playing a role in establishing the necessary foundations for building a knowledge-based society and economy.
- Enhancing the culture of implementing joint research among graduate students in universities, government and private agencies, to ensure harmony among them.

Graduate students in Saudi universities can utilize this program to cover the costs of obtaining their Master and Ph.D degrees. The program's performance indicators until 2020 include the publication of 800 scientific papers and 400 patents in the main areas of the program, namely: natural sciences, engineering and technology, medical and health sciences, and agricultural sciences.

Scientific Research Support - Grants Program for Universities and Research Centers



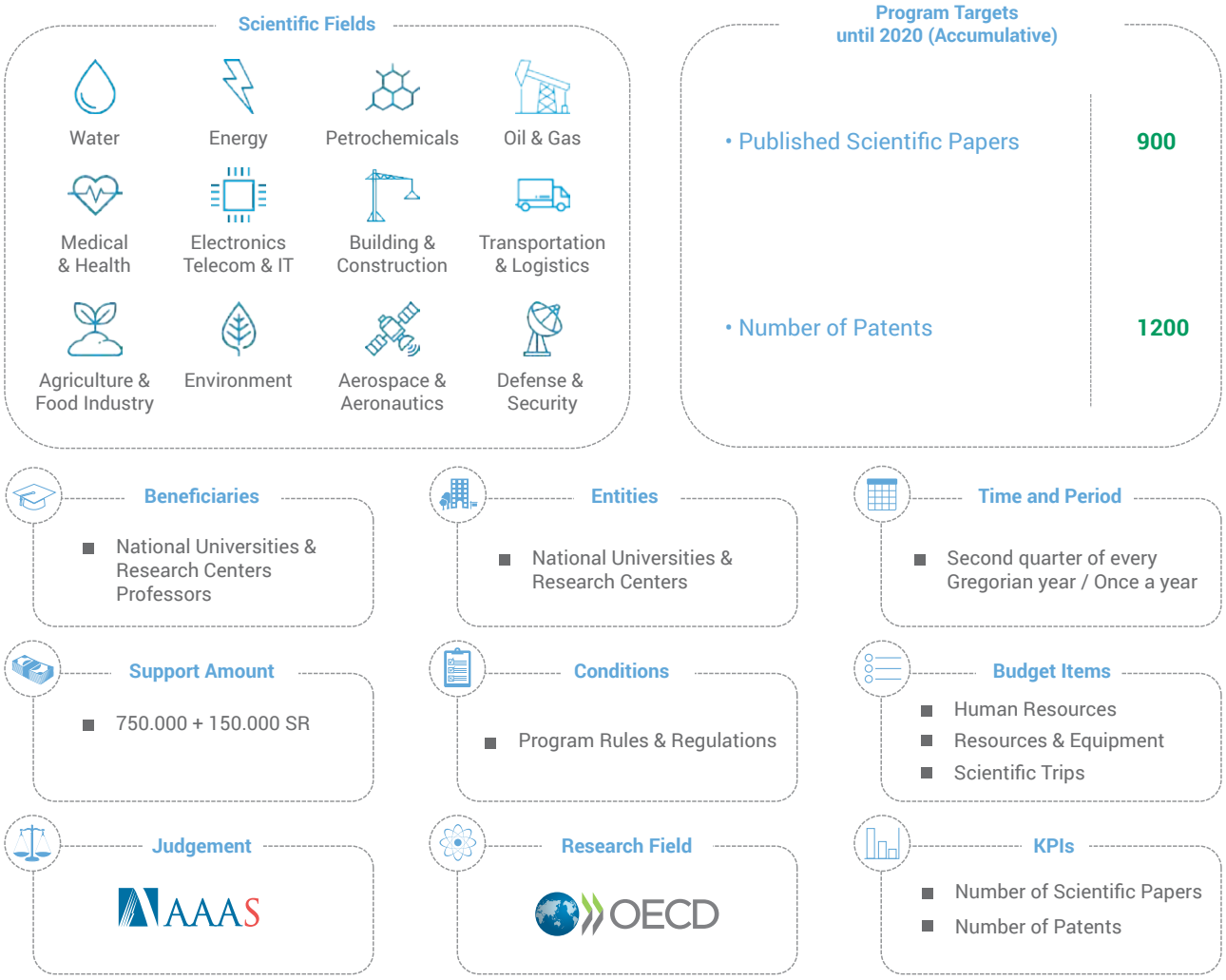
Second: Basic Research Program

This program, a strategic long-term investment, aims to develop a set of scientific skills required to put the Kingdom within the group of leading countries globally, in the fields of science, technology, and innovation. The program aims to conduct high level scientific research at the cutting edge of all scientific fields, in order to contribute to new discoveries, and to play a role in building the necessary scientific pillars required to improve the research environment in the Kingdom, and achieve the country's vision of building a knowledge-based society and economy.

The program's goals include the following:

- Encouraging distinguished research leaders to conduct research in the fields of basic science, according to the latest scientific knowledge worldwide.
- Encouraging promising researchers to develop original high-risk research ideas.
- Developing scientific skills to promote the Kingdom's position as a leading country in the fields of science, technology, and innovation.
- Supporting the newest scientific and technological discoveries.
- Enhancing the participation of Master and Ph.D students in the implementation of basic research in Saudi universities.
- Enhancing the culture of joint research among teams in universities and national research centers, and ensure harmony amongst them.

Researchers in universities and national research centers can benefit from this program. The targeted KPIs by 2020 include the publication of 1800 scientific papers and registering 450 patents, approved in the main areas of the program, namely: natural sciences, engineering and technology, medical and health sciences, and agricultural sciences.



Third: Applied Research Program

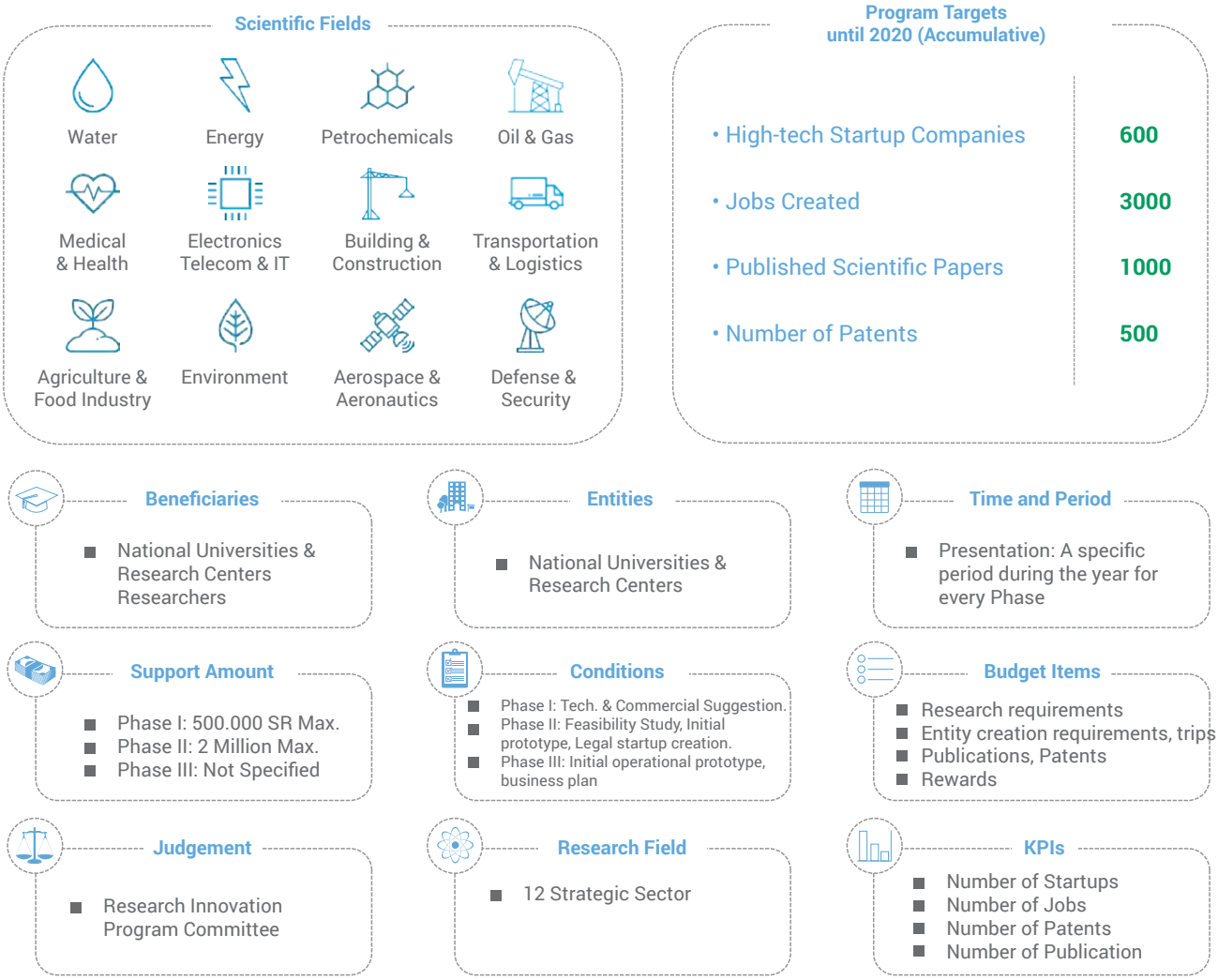
Applied research is an effective way to meet the Kingdom's need to develop a strong research activity that focuses on achieving important national, social, and economic goals. This program aims to support specific research in areas that serve the Kingdom's goal of enhancing and diversifying national income sources.

The program's goals include the following:

- Building national capacities in specific strategic areas leading to the creation of national and long-term industries in the overall context of sustainability.
- Developing competitive research focusing on major health and social issues.
- Promoting the development of long-standing and long-term relations between universities and industry.
- Achieving the Kingdom's vision of building a knowledge-based society and economy.
- Supporting universities in developing a strategy for their scientific research, and to play a major role in the National Transformation Program 2020.

Researchers in universities and national research centers can benefit from this program. The targeted KPIs by 2020 include: registering 900 patents, publishing 1200 scientific papers in the approved main areas of the program, namely: water, energy, oil and gas and minerals, petrochemicals and materials, health and medicine, space and aeronautics, agriculture and food-industries, building and construction, information and communication technologies, environment, defense and security, and transportation and logistics.

Scientific Research Support - Grants Program for Universities and Research Centers



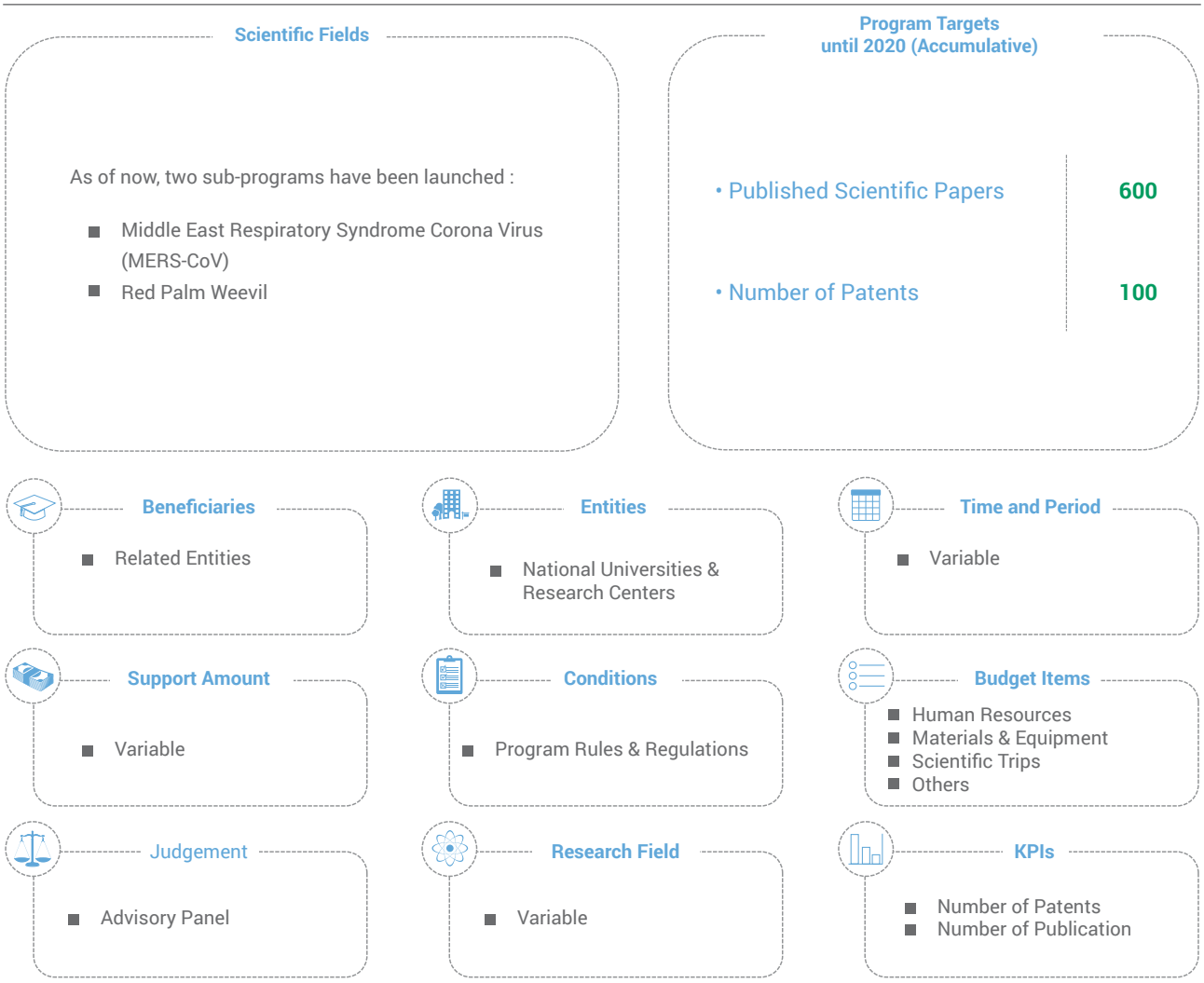
Fourth: Research Innovation Program

The Research Innovation Program is a new strategic program in the national research and development support ecosystem. It aims to support researchers and research centers in the Kingdom to develop technological innovations by transferring research to the prototype development stage, and then to the production and marketing stages. The program also aims to create and develop technology startup companies, and to create thousands of job opportunities which will contribute to the economic development of the Kingdom.

The program's goals include the following:

- Bridging the gap between research and industry, and helping researchers reach the production and marketing stages.
- Finding solutions to the main research and development challenges in the Kingdom.
- Improving Saudi competencies to work in high technology fields.
- Motivating technological innovation in research institutions.

All researchers in the national research centers and universities can benefit from this program. The targeted KPIs by 2020 include: establishing 600 technology startup companies, creating 3000 jobs, publishing 500 scientific papers, and registering 1000 patents in the fields of the program, namely: water, energy, oil and gas and minerals, petrochemicals and materials, health and medicine, space and aeronautics, agriculture and food-industries, building and construction, information and communication technologies, environment, defense and security, and transportation and logistics.



Fifth: Targeted Research Program

The Targeted Research Program falls under the demand-based programs, and targets issues of national interest in the short and medium term. The program aims to coordinate national efforts to find solutions to pressing issues through research and development.

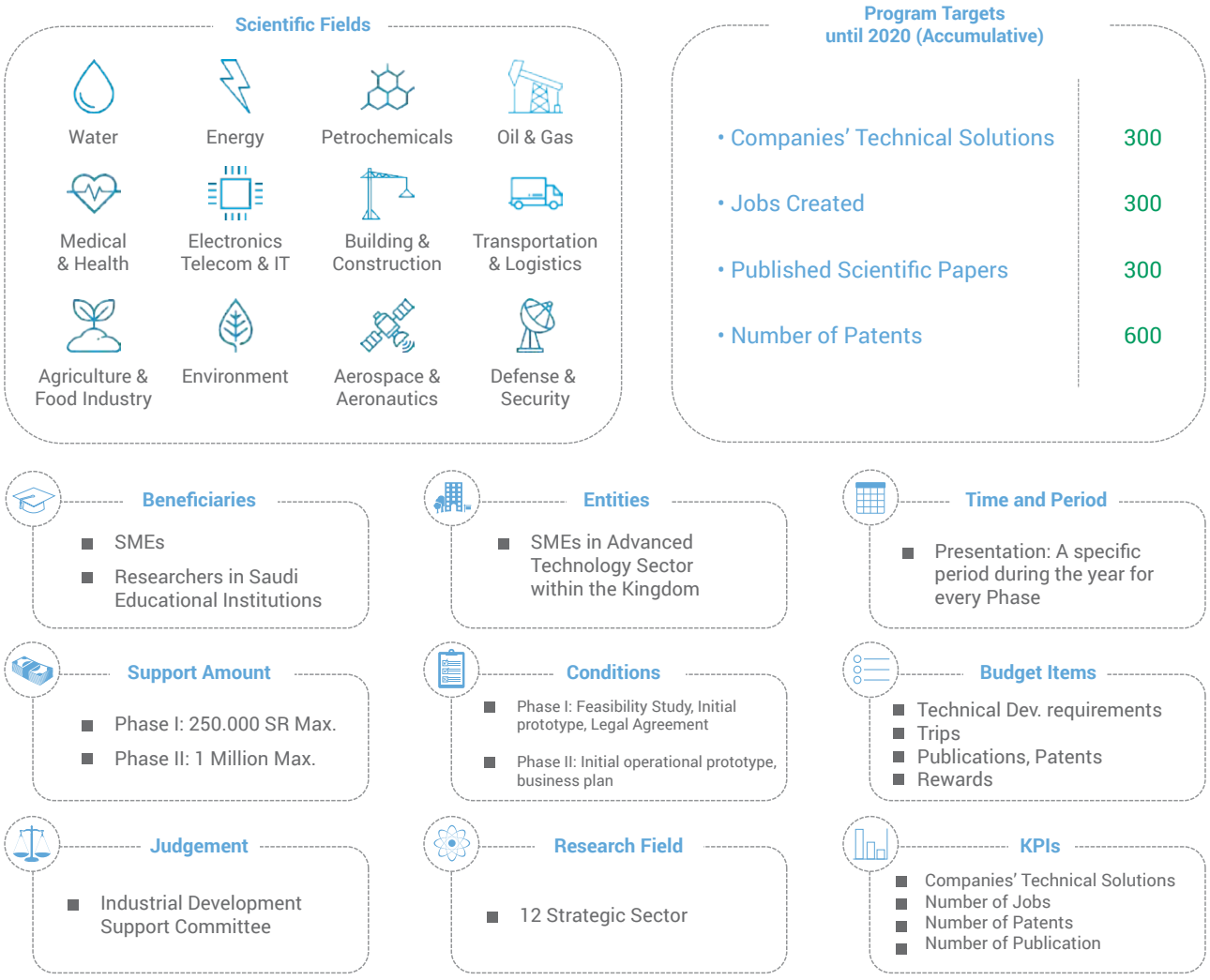
The program's goals include the following:

- Providing a portal through which topics (sub-programs) are advertised, launched, and completed, with relevant stakeholders.
- Committing to the highest standards in evaluation and assessment to facilitate the ability of the program to achieve its planned goals for the sub-programs.
- Encouraging top tier research institutes to conduct research on topics that are of immediate importance to the Kingdom.

Fields of the program vary depending on the nature of the problem, and researchers can apply for each field through its portal. As of now, two sub-programs have been launched:

- Middle East Respiratory Syndrome Corona Virus (MERS-CoV).
- Red Palm Weevil.

Scientific Research Support - Grants Program for Universities and Research Centers



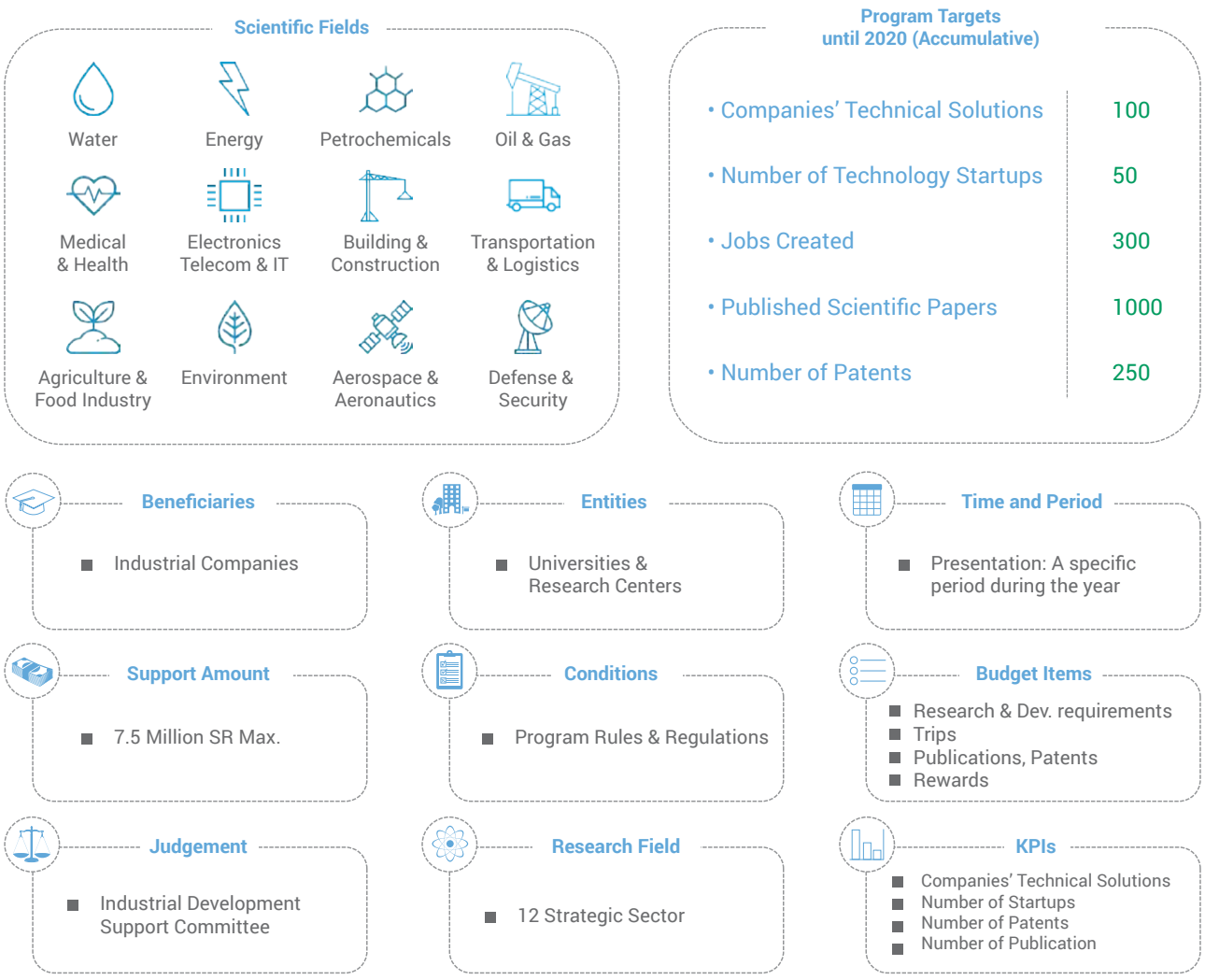
Sixth: Industrial Development Program

The Industrial Development Program is a new strategic program in the national research and development support ecosystem. It aims to support technology-based small and medium enterprises in the field of innovation, and to support research and development capabilities which will contribute to the local technological content in the Kingdom. The program will enhance the contribution of small and medium enterprises to local production by providing research grants aimed at creating and developing cost-effective technologies.

The program's goals include the following:

- Promoting the competitiveness of advanced technologies in the private sector.
- Motivating technological innovation in small and medium enterprises to ensure sustainable growth.
- Increasing private sector share of innovative products.
- Finding research and development solutions to the challenges facing the private sector.
- Developing Saudi competencies to work in high technology fields.

The SME sector and researches in national research centers and universities can benefit from this program. The targeted KPIs by 2020 include: providing 300 technical solutions for companies, creating 300 jobs, registering 600 patents, and publishing 300 scientific papers in the program fields, namely: water, energy, oil and gas and minerals, petrochemicals and materials, health and medicine, space and aeronautics, agriculture and food-industries, building and construction, information and communication technologies, environment, defense and security, and transportation and logistics.



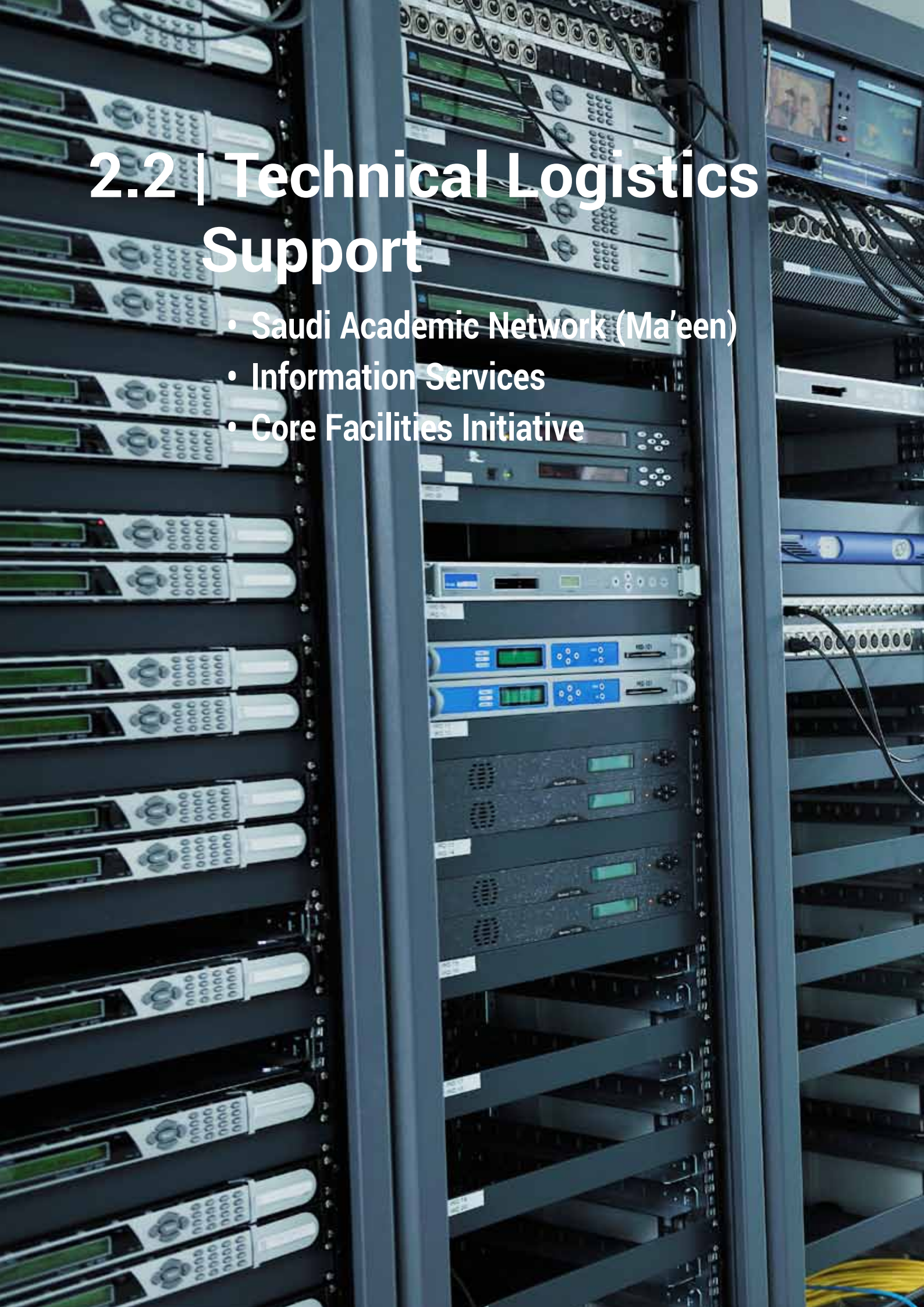
Seventh: Industrial Innovation Centers Program

The goal of the Industrial Innovation Centers Program is to create links between universities and private sector institutions in order to support localization efforts through technological development. The program aims to enhance high quality research in order to solve the problems facing industry by developing research partnerships between industrial institutions, research institutions, and KACST. It also aims to contribute to the development of products and services in order to increase the competitiveness of national companies, and to develop the local content.

The program's goals include the following:

- Providing solutions to problems facing industry in the Kingdom.
- Linking researchers to industry in order to intensify research and development efforts and develop the local content.
- Encouraging and facilitating the participation of the industrial sector in research and development partnerships.
- Strengthening the university research related to industry in the Kingdom.

Many industrial companies can benefit from this program. The targeted KPIs by 2020 include: providing 100 technical solutions for companies, establishing 50 technology startup companies, creating 300 jobs, registering 250 patents, and publishing 1000 scientific papers in the program fields, namely: water, energy, oil and gas and minerals, petrochemicals and materials, health and medicine, space and aeronautics, agriculture and food-industries, building and construction, information and communication technologies, environment, defense and security, and transportation and logistics.



2.2 | Technical Logistics Support

- Saudi Academic Network (Ma'een)
- Information Services
- Core Facilities Initiative

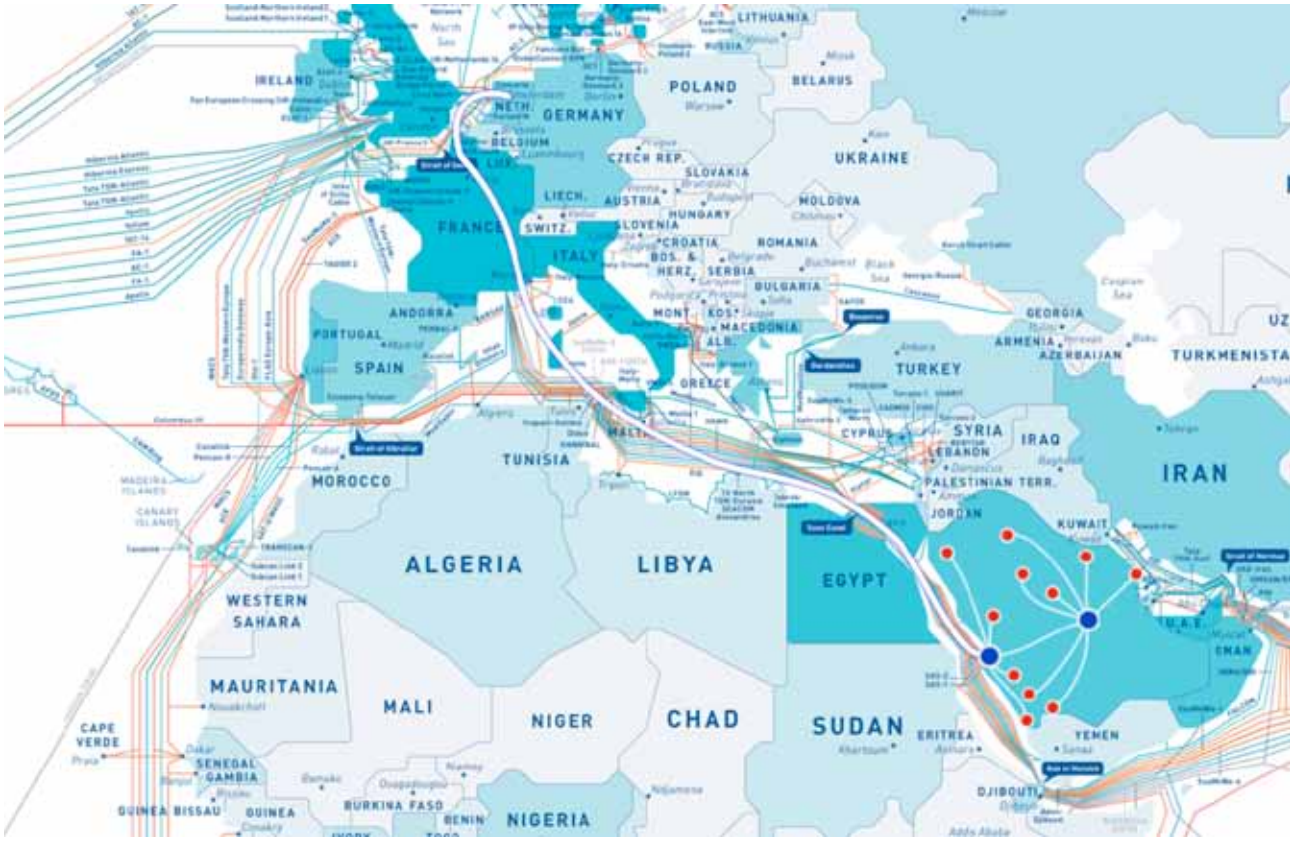
Scientific Research Support
Technical Logistics Support

The reliance of researchers in many R&D institutions on the existing tools and services at KACST has increased significantly over the last two decades.

Believing that KACST plays an important role in supporting scientific research in the Kingdom, the International Gateway of the Saudi Academic Network was established this year, by connecting to Internet 2 Academic Network, through the Amsterdam Internet Exchange, one of the largest Internet exchanges in the world, using submarine lines. This was to enable academic and research institutions to communicate with other academic networks around the globe, and to announce the launch of the Saudi Academic Network. In 2016, KACST also added a number of international Internet lines with a total capacity of 8 Gbps, to absorb the increased demand for Internet services, and to double customers' Internet capacities. Moreover, most of ISU's network components, in both Riyadh and Jeddah, were upgraded to the latest and more advanced technology, allowing them to carry network traffic of 80 Gbps. A technical team working 24/7 is also available in order to respond quickly to the requirements of the network or to incidents reported by the customers.

KACST has provided accessibility to national and international sources and information systems, which has allowed researchers and information specialists to be able to obtain reliable scientific documents. This has contributed to the promotion of quality scientific research produced for KACST and for the Kingdom. In recognition of the importance of central laboratories and shared basic utilities, KACST has strongly supported advanced research infrastructure, and established and managed the central laboratories and manufacturing workshops. KACST also creates prototypes to promote a collaborative multidisciplinary scientific research culture, and to grant researchers in the Kingdom access to advanced scientific equipments.

KACST provides a large number of highly specialized laboratories equipped with the latest laboratory techniques and high-quality technical experts.



First: Saudi Academic Network (Ma'een)

Many countries work on organizing and preparing access to scientific research pursuant tools through academic networks. These are known as specialized networks dedicated to supporting the needs of national research and educational scientific societies.

Academic networks are independent entities working on enabling collaboration between universities and research centers in areas supported by the networks and their services.

As KACST provides internet services in the Kingdom, and recognizes the importance of academic research, it has become the entity designated by all international academic networks to present the Saudi academic network, in order to link universities, research sectors and academic sectors with major international companies and research institutes.

The Internet Services Unit at KACST works on the Saudi Academic Network project that increases the educational effectiveness by providing speed and efficiency in transferring data among its subscribers, therefore allowing them to benefit from the available applications and research services.

Academic networks vary depending on the geographical location. There are national, regional and international networks. The most famous international networks are: (Internet 2) in North America, (Giant 2) in Europe and (TIEN 3) in Asia.

The following objectives can be achieved through an academic network:

- Connecting education and scientific medium nationally and internationally, which will enhance cooperation in research, education, and knowledge for universities, research centers and digital libraries.
- Allowing easy access to information within one technical environment.
- Reducing subscriptions cost for digital libraries.
- Establishing a technical environment that provides variety of services to enable researchers and academics to do their work and test new technology. In addition, it will save time and money to support their needs.
- Enhancing education by facilitating higher quality dedicated internet speed to transfer data among users, and by the use of the applications and the research services.

COUNTRY	ACADEMIC DESTINATION	GBYTE
US	Internet Archive (Publications), US	3,459
DE	State Higher Education Network Baden- Wuerttemberg (BelWue), DE	1,229
DE	German Weather Service DWD-AS , DE	876
US	National Oceanic and Atmospheric Administration	844
US	National Library of Medicine, US	450
GB	JANET Jisc Services Limited, GB	87
IT	The Italian Academic & Research Network - GARR, IT	77
IE	Ireland›s National Research & Education Network , IE	70
US	US Geological Survey, US	67
US	University of California at Berkeley, US	66
JP	Japan Advanced Institute of Science and Technology, JP	52
US	Stanford University, US	34
US	National Aeronautics and Space Administration, US	30

• Network Usage

Network usage has increased recently. The utilization rate reached 3 Gigabyte of data; more than 30 entities have been visited using the network during the last year.

• The Most Prominent Services Provided by the Academic Network

- Network Virtualization Service

KACST is considered one of the first organizations to utilize network virtualization technologies in the Kingdom and the Arab region. Network virtualization is a new concept, which enables the creation of entire networks in software. This technology comprises different services ranging from load balancing, firewalls, routing, and switching, in addition to connecting to other virtual and non-virtual networks.

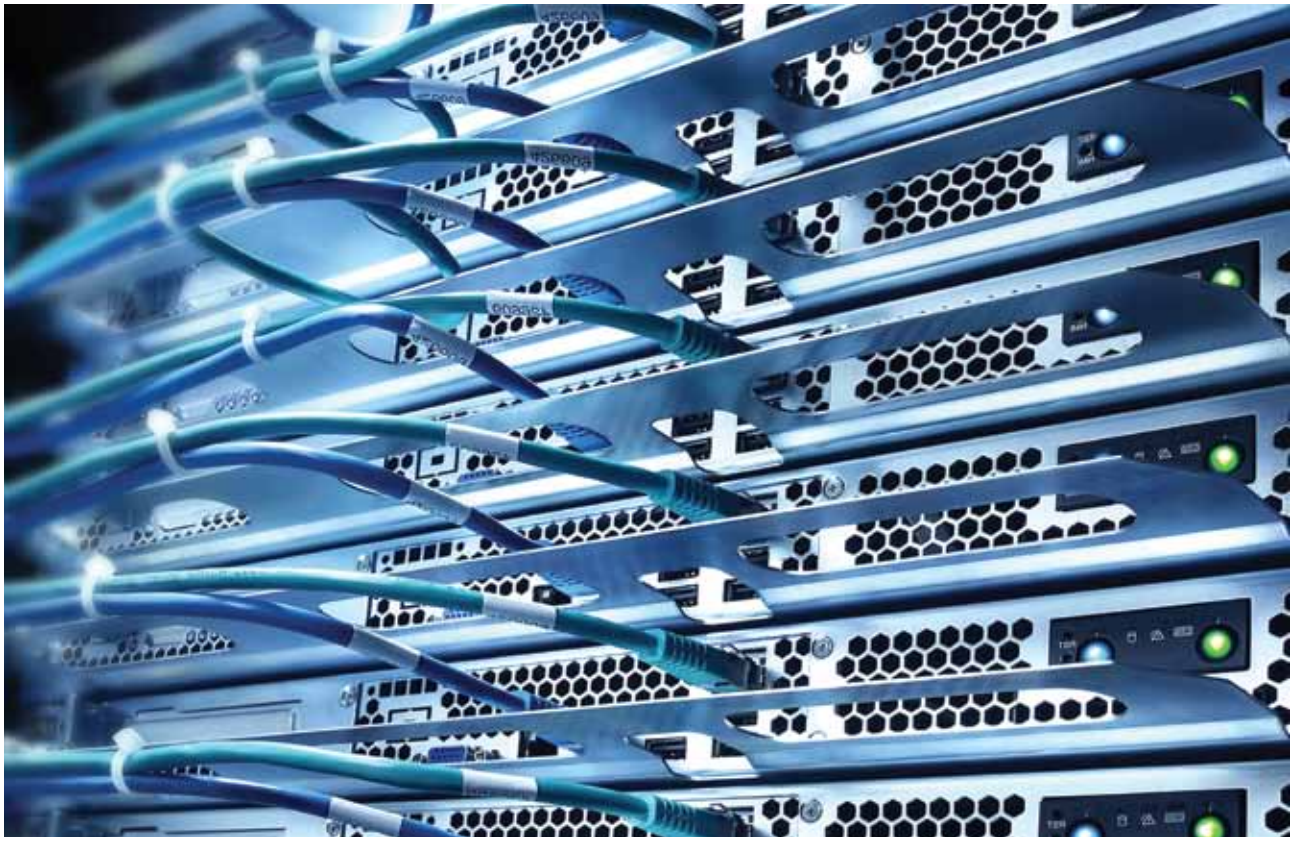
In the year of the report, KACST implemented network virtualization for all of its customers. Its successful implementation became a reference for its customers and other parties interested in applying it in similar environments.

- Managed Backup and Recovery Services

Backup and recovery solutions are a critical component of any disaster recovery plan. They help customers protect their valuable data from accidental loss and/or recover their data from an earlier time depending on data retention policies. In the year of the report, KACST provided a complete backup and recovery solution that benefited hosted servers that are managed by customers. Furthermore, the service has been experimented with by different customers and gained a high level of satisfaction.

- Two Factor Authentication

Two-factor authentication (2FA) is a method of confirming a user's claimed identity by using a combination of two different components. This ensures stronger security while allowing customers to access different services at different locations and times. In the report year, KACST provided 2FA as a standard for its customers to access their cloud services with the highest possible security levels, pushing toward more advancement in information security.



- Load Balancing as a Service

Load Balancing as a Service (LBaaS) is very useful for managing online traffic by distributing workloads across multiple servers and resources. This will allow customers to maximize their workload performance and help prevent overload to provide users with a seamless experience. In the report year, KACST provided the LBaaS for its customers. The service has been experimented with by many customers and gained a high level of satisfaction. Customers also showed interests in using the service.

- Network Security Vulnerability Assessment

The Information Security Unit (ISU), conducted an in-depth security audit, vulnerability scanning and inspection of potential points of exploit on customers' computers or networks to identify security holes. This service was applied for 23 organizations. It detects and classifies system weaknesses in computers, networks and communication equipments, and predicts the effectiveness of countermeasures.

- Website Scanning Service for ISUs' Customers

Websites have become effective in ensuring the quality of services provided, making them within the range of cyber threats. This has led to the development of the website scanning and test service. The Internet Service Unit (ISU) tests web applications for security vulnerabilities during the development process. ISU has been working to address the problems of 68 websites (that have 3822 ongoing links) hosted by the unit or owned by the customers.

- Activation of Early Warning System for Cyber Attacks

ISU established a comprehensive security system to manage information security and provide early detection services for threats and cyber attacks and to respond to security incidents. The service can be given to customers connected with the ISU and it includes:

- Monitoring of suspicious behavior and activities.

- Monitoring systems, applications & servers at risk.
- Evaluation of the weaknesses of servers, applications and added systems, and the best technical methods for remediation plans will be given.
- Detection of illegal intrusions by activating and using HIDs intrusion detection system.
- Participation in an international security intelligence platform to exchange data and information on online and cyber threats around the world, and pass it on to the customers of the ISU. Based on that, we passed 6 threats alerts to 6 customers connected to the ISU.

- Implementing and Deploying the Unified Security Management and Monitoring Platform

Through this platform, the data is linked and analyzed from multiple sources within the ISU and outside, in order to obtain more details about the latest security alerts or threats for the ISU or its connected customers. Any security alerts are followed up and the results are passed to the competent security teams to be handled by unifying the services of the information security operation centers to the participating parties. Two call centers were connected and now operate as a unified Security Operations Centers.

- Security Consultation Service

The ISU participated in an in-depth security investigations with different government and academic agencies as well as studying information security projects and evaluating them for 6 government agencies.

- 'Dhaif' Service

KACST offers to the subscribers of the network a web-hosting service with suitable space sizes and integrated infrastructure of state-of-the-art devices and advanced software programs, information security and connection speed. This service also detects the software programs of websites before launching them, in order to identify the security breach and to avoid any potential hacking attempts. The number of users of this service has grown rapidly throughout the year of the report by 28%.

- 'Hefz' Service

KACST enables internet subscribers to save their electronic data and to create a backup in KACST which can be retrieved when needed. This service characteristically provides information security, speed of data transfer and technical support. The number of authorities that have benefited from this service in the year of the report increased by 6%.

- Khabar' Service

KACST provides an academic news service to contribute to building an academic society that is aware of the latest scientific news and activities. The subscriber can access this information through the website, and/or follow the Khabar account on Twitter.

- Field Visit Services

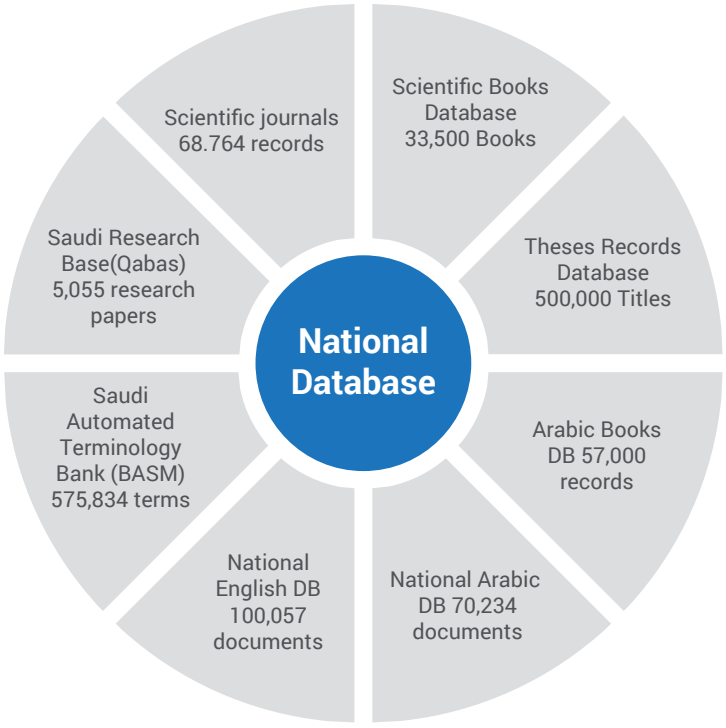
KACST technicians visited universities and government agencies to introduce KACST internet services and provide technical support to its customers. During the year of the report, the number of field visits reached 21, including 10 visits for the purpose of collaboration with relevant entities, and 11 visits to identify clients' technical problems and provide appropriate solutions.

- Obtaining Innovation Award in Information Technology (CIO 100)

This award is granted to leading Middle East organizations utilizing information technology to gain maximum value and improve the quality of their businesses. The award demonstrates the organization's capabilities of applying the latest technologies to improve operations and reduce costs. It also shows that the organization has used recent technologies of 2016 in innovative ways and in line with the organization's business strategies toward improving work and operational efficiency, and the evolution of electronic services toward technological excellence in all work areas.

In the report year, KACST won the CIO 100 Award for innovation in Information Technology for making one of the best 100 innovations in Information Technology in the Middle East. One of the main factors for winning this award was the successful implementation of the VMware NSX solution.

Establishing and Updating National Databases



Second: Information Services

- **Saudi Research Base (Qabas) & Scientific Monitoring Department**

- Saudi Research Base (Qabas)

This is a national electronic database covering all fields of scientific research supported in KSA.

Qabas aims to preserve and document scientific research funded by the research support entities in the Kingdom, in order to regulate and organize research grants, rationalize financial support and obtain indicators of research performance. It will also help support decision making through the creation of databases for research, researchers, experts, supporting entities. This will enhance cooperation and communication in the scientific research community, coordination among research institutes, knowledge of the topics and previous studies that have been discussed, and ensure that material support is not repeated for one topic of research by more than one side. The content of the database is currently funded by KACST, and it contains 5,055 research papers and more than 31,000 registered experts. KACST is seeking to develop an appropriate mechanism for listing all funded research to achieve its objectives.

- Scientific Monitoring Department

This is one of the new departments of the General Directorate of Information, which aims to collect, analyze, organize, compare information about scientific research activities in the Kingdom, and produce the results in the form of reports and indicators that enable the understanding of scientific research trends in Saudi Arabia.

- Saudi Automated Terminology Bank

BASM is a four-language automated encyclopedic dictionary that allows researchers and translators to effectively and quickly find Arabic terminology for English, French and German terms. BASM is responsible for creating an inventory of scientific and technical terms that have been Arabized, and entering them into a database according to the standards of documentation used in international institutions and databanks. This is in addition to the inventory of non-Arabized terms which are Arabized according to the standards and conditions of the formal Arabic used by linguistic and scientific assemblies. They are then classified according

to their subjects and documented on the bank's system.

The accomplishments of this year are: the implementation of a review plan for more than 105,000 terms, including deleting and updating, bringing the number to a total of 575,834 terms, covering 225 specific scientific fields, the addition of 2,000 new terms, and the transfer of records to a new database in order to launch the new portal of BASM.

- Digital Library Department

KACST library provides specialized information services to researchers and scientists. The library arranges books, periodicals and other sources of information. The library manages information in the fields of science and technology, and has a total of 1,192,264 information sources, of which 5,756 were added during 2016. The library uses the MARK 21 global system and includes the following: 33,500 scientific books, 500,000 records, 68,764 scientific journals, 560,000 scientific articles and documents, and 57,000 Arabic books.

- Reference and Extension Services

KACST library allows researchers to take the advantage of the library reference service and Internet facilities. In the year of the report, 370 book s were borrowed, 300 books were viewed, 260 hours of Internet usage were provided, and 2,100 books were granted as gifts.

- eBooks & Beneficiaries Organizations

- 93,882 scientific and technical eBooks have been provided by international publishers. In 2016, 12,575 eBooks were added.
- There have been numerous beneficiaries of the information services provided by the department. These include: 81 scientific and academic institutions in the Kingdom; and 12 international scientific and research institutes that also received and exchanged knowledge and information. During the year, 4 lectures were held on the uses of information systems offered by KACST.
- The Technical Support Department supports the information technology infrastructure of the Directorate General of Information. During 2016 it provided the following: 75 requests for technical support to servers, 255 requests for technical support to the Directorate General of Information Administrations, and 73 requests for technical support to outsource companies.

- Beneficiaries Services Unit

Information Services is considered one of the most important elements in supporting scientific research. Therefore, KACST has worked hard to obtain and make available all the necessary sources such as national and international information services, approved full text scientific documents for researchers, research centers and academia. KACST is providing information services for all researchers as follows:

- Information Services and Search Requests: during the year of the of 2016, KACST processed a total of 50,503 requests made by researchers and information seekers.
- Providing scientific and technical documentation: 62,252 scientific and technical documents were supplied directly to the researchers and scientists of the research institutes. The total number of scientific and technical documents that have been utilized was 178,673 in the year of 2016.
- One Click: KACST provides the One Click service to researchers and information seekers to save them time when trying to find out information. One Click manages the digital sources and information resources system through the comprehensive unified One Click search interface. This was utilized by a total of 4,298 information seekers during 2016.

- National Databases

KACST aims to document the intellectual and scientific production, and collect, classify, and process the technical terminologies and store them electronically. KACST also aims to build local databases and to support national scientific research activities, providing these databases with the latest information in order to assist researchers in carrying out their research.

- Arabic Database

This department is tasked with accumulating, categorizing, and referencing Arabic scientific and technological documents. It is also responsible for storing these documents and making them accessible for academic researchers. The Arabic Database has so far added 4,363 documents, which brings the total of stored documents to 70,234, covering scientific fields.

- English Database

This department is tasked with accumulating, categorizing, and referencing English scientific and technological documents. It is also responsible for storing these documents and making them accessible for academic researchers. The English Database has so far added 6,816 documents, which brings the total of stored documents to 100,057 covering scientific fields such as physics, engineering, humanities, agriculture and medicine.

KACST MAIN CAMPUS LABS

1. High Performance Computing Facility
2. Cybersecurity Lab
3. Anechoic Chamber Facility
4. Genomics Core facility
5. Scanning Electron Microscopy Core Facility
6. Petroleum Special Core Analysis Laboratory
7. Internal Combustion Engine Laboratory
8. Reverse engineering laboratory
9. Satellite Integration Cleanroom
10. Mechanical Fabrication Workshop
11. Water Quality Laboratory
12. Mass Spectrometry Core facility
13. Geophysical Data Analysis Laboratory
14. Routine and Advanced Rock Analyses Laboratory

SATELLITES LABS

1. Certified Solar panel Testing Laboratory (Solar Village)
2. Air Conditioner Testing Laboratory (Solar Village)
3. Electronics Laboratory (Al-Orobah)

Core Facilities Initiative

Central laboratories and core facilities have become increasingly important and strategic for research and development institutions. The last two decades have witnessed a marked shift towards using more complex expensive equipment and sophisticated systems in various R&D areas. This has led to both rapid evolution and increased-utilization of institutional and nationwide central laboratories and core facilities models.

Core facilities are now being recognized as important and essential strategic infrastructure elements, required for enhancing R&D competitiveness in thriving and successful institutions. Core facilities typically provide researchers with access to highly specialized and cutting-edge equipment and services that are otherwise too expensive to run within individual research laboratories, or require high technical expertise. In addition, core facilities provide skilled and highly trained personnel capable of efficiently running equipment, performing complex experiments, training users, analyzing and extrapolating experimental data, and providing expert scientific and technical recommendations for researchers and users.

Goals of Core Facilities Initiative

Realizing the strategic importance of central laboratories and core facilities, KACST has devoted more efforts to develop and upgrade its infrastructure and to establish and manage new core facilities and advanced fabrication and prototyping workshops. KACST aims at catalyzing and promoting a collaborative, multidisciplinary R&D culture within the Kingdom. KACST has a large number of highly equipped and advanced laboratories and workshops that already provide researchers within KACST and beyond with state-of-the-art technologies and services. In this regard and in its efforts for continuous improvement, in line with the Kingdom's futuristic vision, KACST has appointed a 'Core Labs Committee' that includes members from all KACST's research institutions and several other administrative and support departments. The main goal of the 'Core Labs Committee' is to establish and develop a Core Facilities Program in KACST to achieve the maximum and most efficient utilization of financial and human resources in KACST laboratories, and to help in establishing state-of-the-art R&D infrastructure of international standards.

ELEMENTS OF SUCCESS

VISION

- Achieve maximum possible utilization of KACST's infrastructure and resources.
- Promote and catalyze multidisciplinary/interdisciplinary R&D.

MISSION

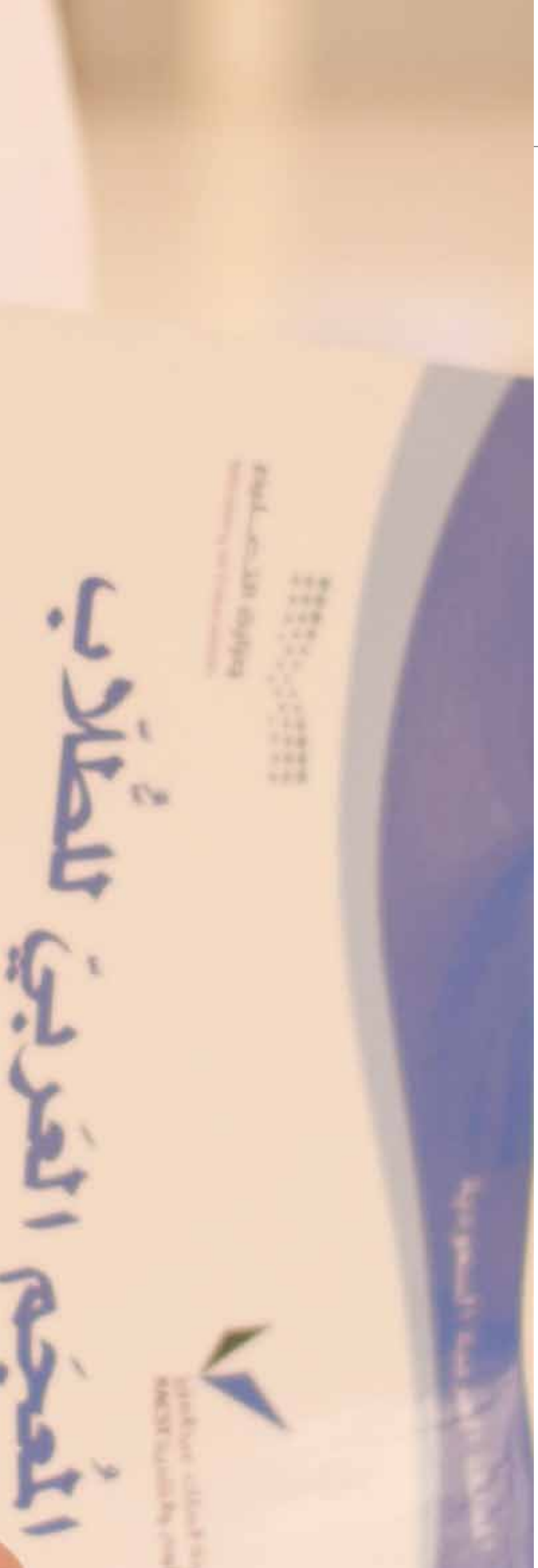
- Maximize performance and competitiveness.
- Achieve maximum and ideal utilization of KACST's resources, and increase efficiency related to equipment purchase, equipment utilization, maintenance, and service contracts.
- Promote and optimize protocols for performing complex research.

The Core Facilities Program aims to:

- Conduct comprehensive assessment and evaluation of KACST's laboratories, facilities, and infrastructure.
- Identify repeated R&D themes, duplicated laboratories in the same field, and unnecessary duplications and redundancy of equipment and staffing.
- Propose groundwork guidelines to reorganize, restructure, merge, and consolidate laboratories and facilities to achieve maximum-possible utilization of resources.
- Develop and propose mechanisms and systems to upgrade existing core facilities and recruit qualified technical staff.
- Work towards the establishment of new core facilities (national and local).
- Develop a core facilities management system and an online searchable dynamic database for KACST laboratories and core facilities.
- Establish a dedicated training network and development program for core facility personnel.
- Update KACST's purchasing and procurement process to avoid duplicate purchase of expensive equipment.

2.3 | Scientific Awareness

- Scientific Publishing
- Events
- Motivating Young People
- Social Networks
- Digital Production



Scientific Research Support

Scientific Awareness

KACST aims to communicate with society and publicize its efforts and scientific achievements, promoting confidence in national scientific capabilities. It also disseminates scientific knowledge among society in order to create an appropriate environment for the graduation of national competencies specialized in science and technology.

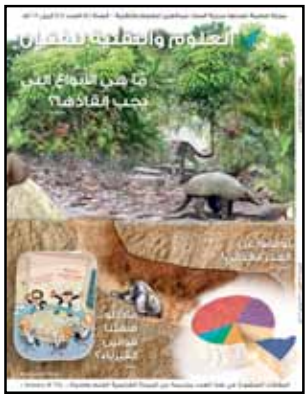
Introduction

KACST communicates with the public in order to produce an attractive and encouraging environment for scientists and researchers. KACST aims to provide an environment that nurtures scientists to perform their research, and publish their results. In order to compete on the global stage, KACST publishes a number of international journals in English, detailing scientific and technological trends. In addition, KACST supports the translation of the Arabic edition of Nature Magazine, one of the most prestigious international magazines, and has made it available to universities and to the public in two forms: paper and digital.

In addition, KACST translates and publishes the "Science and Technology for Juniors" magazine for the K-12 students. It also encourages authors and translators to publish scientific books enriching the Arabic and international library, and provides public libraries and specialists with paper copies, along with digital copies accessible on KACST website.

KACST regularly organizes a number of international conferences specialized in advanced technologies. Saudi researchers and leading international scientists meet their counterparts from around the world and facilitate the sharing of international best practices and experience. KACST also holds a number of training courses in various fields.

KACST conducts scientific outreach activities involving society, including the annual Science and Technology Week held in Riyadh and other parts of the Kingdom, to showcase the latest technologies developed by KACST, along with other scientific developments of interest to the Kingdom.




Scientific Publishing

KACST has issued a number of scientific publications targeted to various segments of society. These publications create a channel between researchers and the general public which bridges the gap between the scientific community and the society.

KACST works with the global publisher “Springers”, to publish seven quarterly scientific journals in English on technologies of interest to the Kingdom, such as water, oil and petrochemicals.

All KACST’s journals are followed-up by Thomson Reuters, which classifies journals globally, and two journals have been included in high impact journals (ISI). These journals publish the results of the latest research in their fields, in addition to being available to researchers from within the Kingdom to publish in them. They also provide details of the latest technologies available around the world.

KACST supports a number of scientific journals in Arabic and publishes others. One of the journals it supports is “Nature Arabic Edition”, a monthly journal aimed at university students, and the quarterly “Al-Faisal Scientific” journal, which is targeted to the general public. It also publishes the quarterly Journal “Science and Technology for Juniors” targeted to the K-12 students, and another quarterly journal entitled “Science and Technology”.

In addition, KACST supports researchers and specialists to author or translate scientific books. The number of authored and translated books has now reached 186. KACST sends its hard copies to universities and public libraries, and provides electronic copies to the public on its website. The number of downloaded books has exceeded 400,000. These books are aimed at various segments of the society, from children to specialized researchers.


Journal of Petroleum Exploration and Production Technology
SpringerOpen
Materials for Renewable and Sustainable Energy
Applied Nanoscience
Applied Water Science
Applied Petrochemical Research
nature
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Complex & Intelligent Systems
3Biotech
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CRISPR
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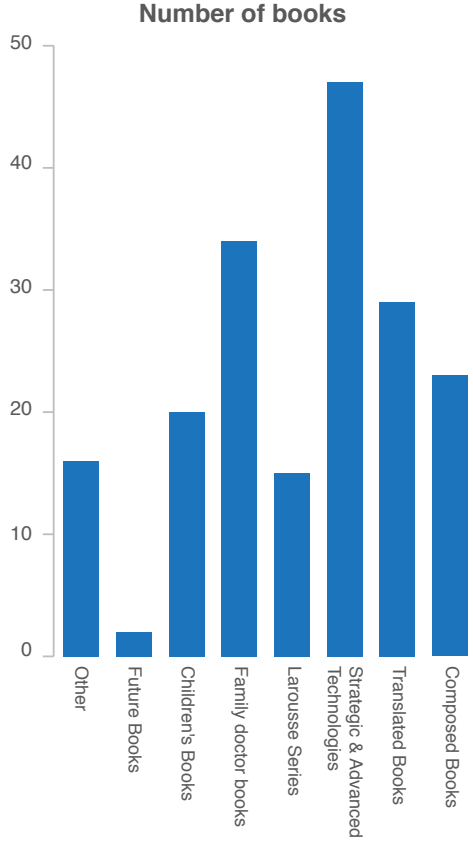
Number of books
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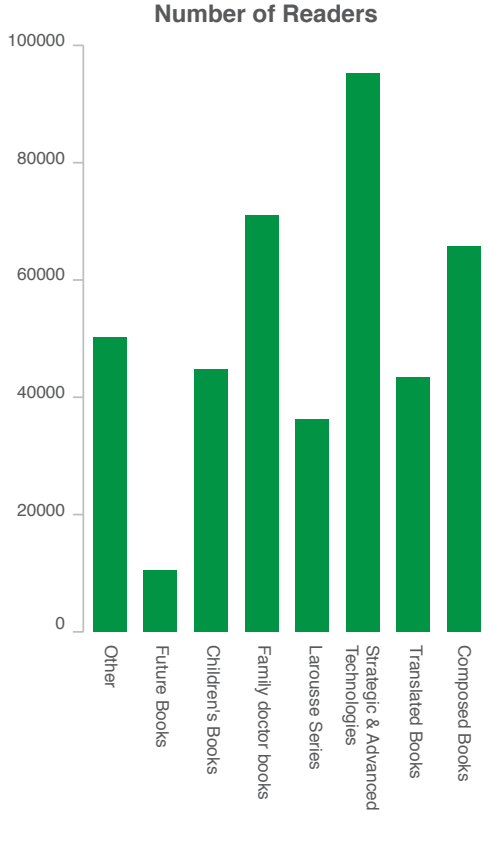
Other
Future Books
Children's Books
Family doctor books
Larousse Series
Strategic & Advanced Technologies
Translated Books
Composed Books


Number of Readers
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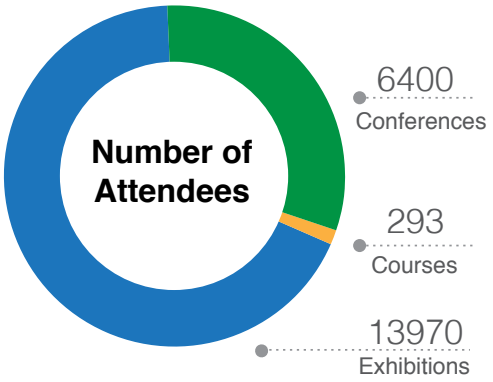
Other
Future Books
Children's Books
Family doctor books
Larousse Series
Strategic & Advanced Technologies
Translated Books
Composed Books

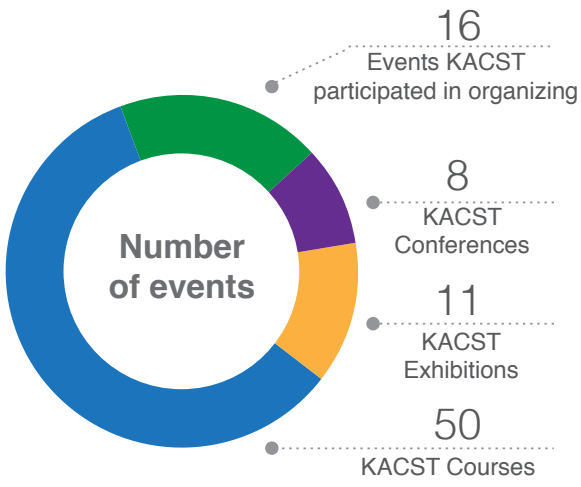
Events

KACST organizes a number of annual events attended by those interested in science and technology, from K-12 students to specialized researchers. In 2016, KACST organized 8 international conferences on specialized technologies such as biotechnology, nanotechnology and high-performance computing, attended by 6,400 students and researchers, and 179 researchers and specialists from inside and outside the Kingdom participated by presenting their work.

KACST also organized 16 events including exhibitions, meetings, workshops and seminars, attended by 13,970 people.

KACST is supporting and contributing to the organization of national scientific events including conferences, seminars and exhibitions. In the year of the report, the number of such events reached 16, ranging from conferences and exhibitions, to festivals and forums. KACST also holds a number of specialized science and technology courses such as genetic engineering, industrial intelligence, industrial engineering and chemical production. KACST organized 50 courses attended by 293 researchers and technicians of both genders.





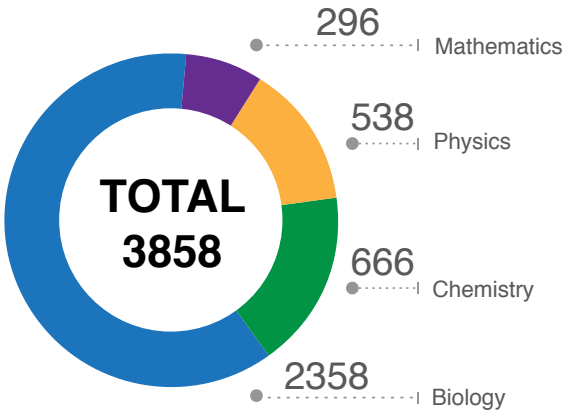
Motivating Young People

KACST recognizes the importance and role of young people in the scientific and technical progress of society in the medium and long term. For this reason, KACST has worked developing programs to help motivate young people to become future scientists. It also sets up programs for summer training, schools visits and holds scientific events that allow the youth to attend and participate.

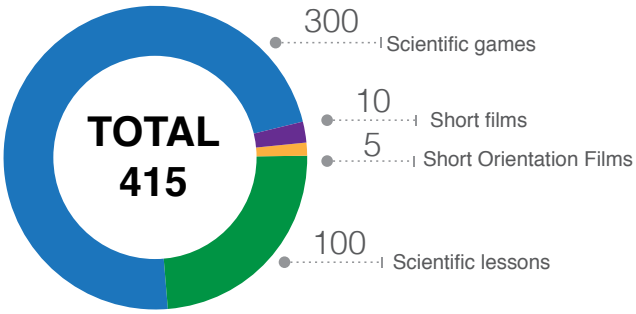
KACST published 20 applied science books directed at school students, distributed them in hard copies, and made them available digitally to be downloaded.

KACST provides interactive digital content such as virtual labs in chemistry, physics and mathematics, which have reached 4,155 people. The content includes lessons, science games, movies and interactive systems.

Scientific Content
(Student participations at the portal)



KACST Production



KACST program on Saudi 1 Channel

KACST program on UFM Radio

@kasct

@kasct_ar

Kasct_ar

KacstTV

Kacst.ar

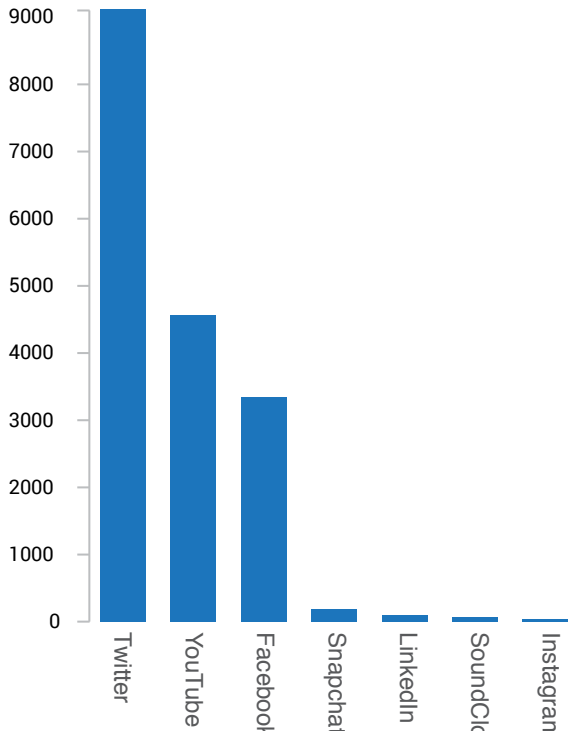
Kacst

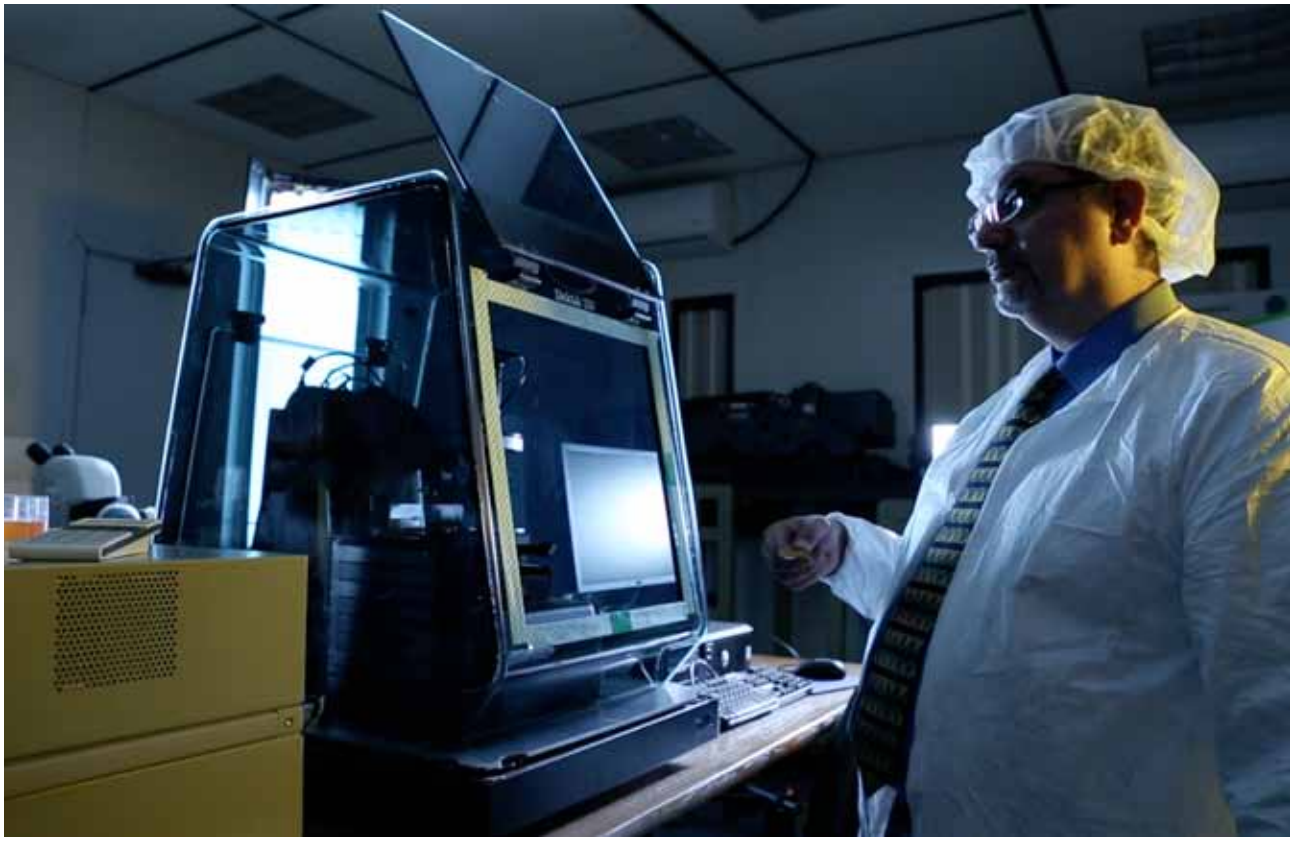
Social Networks

Social networks are one of the most important sources of information and knowledge these days. Saudi society is one of the leading nations in social media use. The Kingdom provides the communication network infrastructure which facilitates access to the content available on these social media channels. KACST has an account on many of these networks such as Twitter, Facebook, YouTube, LinkedIn and SnapChat. In the year of this report, the number of followers to KACST's accounts exceeded 170,000 people. KACST uses its accounts on these social networks to spread scientific knowledge among people, to interpret scientific phenomena and technical applications and explain them in easily understandable language and styles to the general public. KACST's messages, tweets, and video and audio clips, carry its news and scientific achievements, in addition to information on what has been achieved globally, to keep its followers up to date on the latest scientific developments.

KACST responds directly to inquiries through its accounts on these networks, making it easier for members of the public to obtain accurate scientific and technical information.

Number of followers on social media





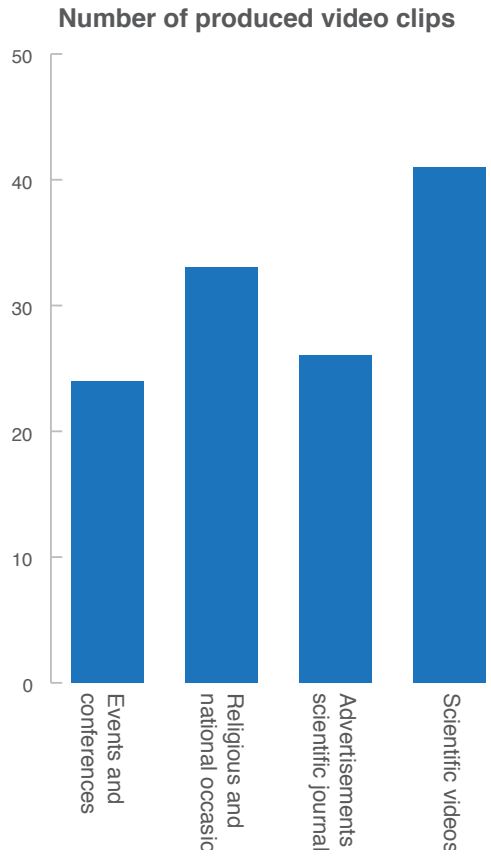
Digital Production

KACST produces digital scientific content in several ways to reach the largest possible audience, with the aim of spreading knowledge and scientific awareness among society.

KACST produces documentary films of up to half an hour to explain scientific discoveries or achievements, and such films have won awards such as the Almarai Award for Global Creativity.

In 2016, KACST produced three documentaries, which are now available on its YouTube channel. The institution also produces short clips to explain a phenomenon or scientific fact, and displays these on KACST's internal and external screens, and also on social networks. In 2016, KACST produced 124 clips.

In addition, KACST offers information services for people with disabilities, and its publications are summarized in audio recordings and available to everyone on the SoundCloud website, where they can be listened to, downloaded and saved for later. In the year of the report, KACST produced 17 audio clips.



Research & Development

3 | Research & Development

- Technology Transfer & Localization in Strategic Sectors
- Technical Leaders Preparation Program
- National Research Partnerships

Research and Development

It is well-recognized that the support and development of scientific and technical research will create knowledge. This knowledge will allow countries to develop products and services and hence, provide them with the ability to prosper and grow economically.

Introduction

The execution of KACST's National Transformation Program 2020 initiatives is carried out by the research and development (R&D) activities conducted by KACST's national institutes and centers, and KACST's Joint Centers of Excellence Program. The R&D activities in KACST are promoted by three main themes:

- The selection of research projects in accordance with the Kingdom's strategic sectors.
- The preparation of technical leaders to support the development of local content.
- The promotion of national research collaborations.

The research projects in KACST are conducted through the national institutes and centers as well as the Joint Centers for Excellence (JCEs) in several strategic sectors such as energy, water, advanced materials, etc.

In addition, to support the preparation of technical leaders that are capable of supporting the development of the local content, KACST established the Joint Center of Excellence Program to provide a world-class venue for conducting research in strategic sectors for the Kingdom while enabling young Saudi talents to become more technologically competitive as well as being a primary source for innovation and intellectual property generation in the Kingdom.

Additionally, to promote national research collaborations, KACST coordinates with national institutions and entities to exchange information and experiences and to ensure proper training for Saudi talent.

3.1 | Technology Transfer & Localization

- Energy
- Water
- Oil, Gas, and Mining
- Advanced Materials
- Health
- Communication & Information Technology
- Agriculture
- Construction
- Transportations & Logistic Services
- Environment
- Space & Aviation
- Defense & Security
- Nuclear Sciences & Applied Physics

King Abdulaziz City for Science and Technology (KACST) focuses on conducting applied and development research in 13 strategic sectors. The main objective of these research activities is to address pressing issues in the Kingdom.

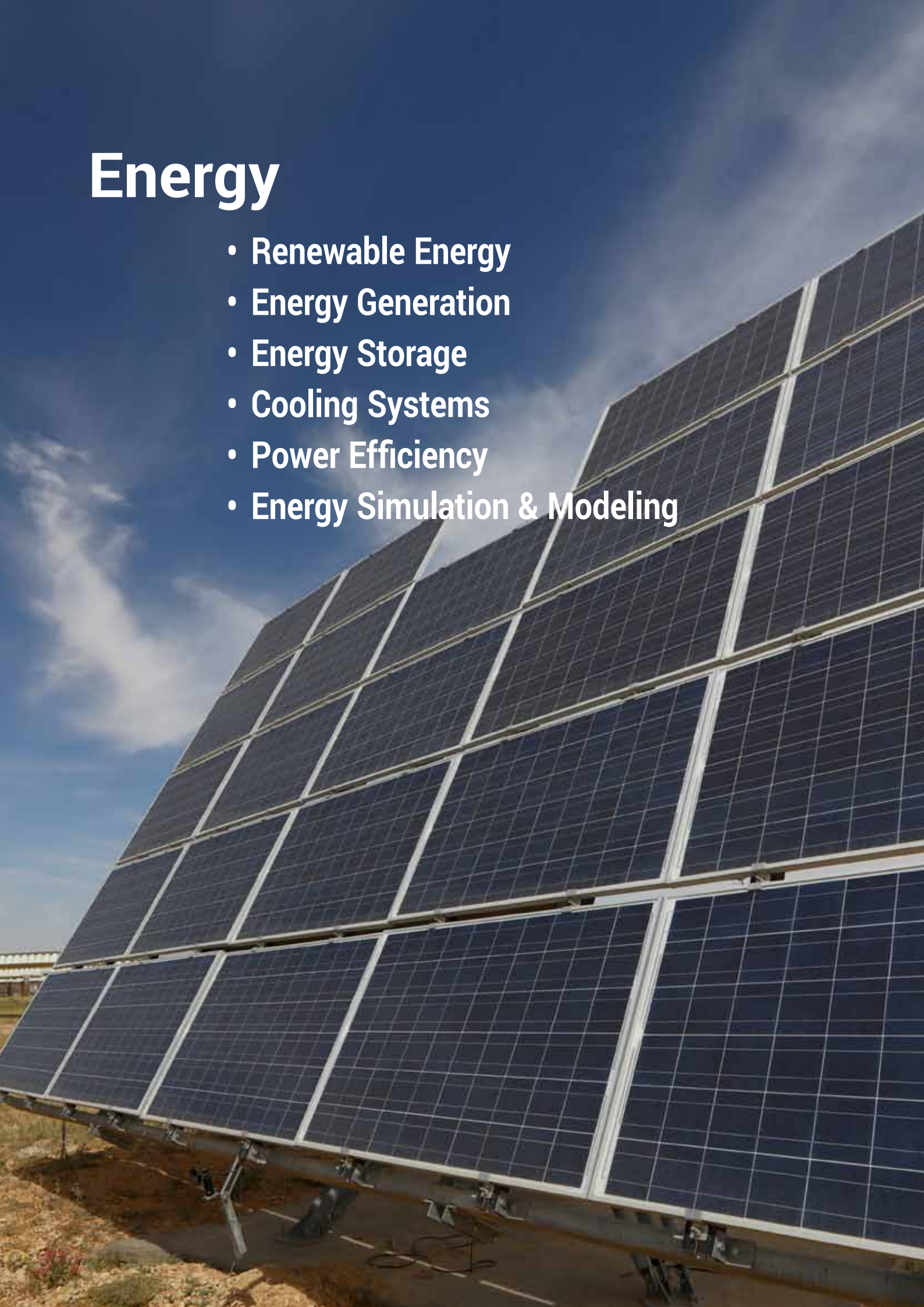
Introduction

The Joint Centers for Excellence and the national institutes and centers within KACST are conducting applied and development research in several key sectors in the Kingdom (e.g., energy, water, etc.). These research activities will empower the Kingdom, in the long term, to establish and develop competitive national industries and services at a global level, thereby increasing the Kingdom's self-reliance in these strategic sectors.

Based on previous studies and multiple discussions with different stakeholders, KACST has identified 13 key sectors with the objective of enhancing the local content contribution and increasing the value retained in these sectors. The 13 sectors that have been identified by KACST include: energy; water; oil, gas and minerals; advanced materials; health and medicine; ICT; agriculture; building and construction; transportation and logistics; environment; nuclear science and applied physics; space and aeronautics; and defense and security.

In addition, these sectors are divided into three main themes:

- The first theme - global leadership: this theme includes sectors that the Kingdom has a competitive advantage in, e.g., energy; water; oil, gas and minerals; and advanced materials.
- The second theme - self-reliance: this theme includes sectors in which the Kingdom is spending large amounts of money, e.g., health and medicine; ICT; agriculture; building and construction; transportation and logistics; environment; and nuclear science and applied physics.
- The third theme - national security: this theme includes military and national security sectors, e.g., space and aeronautics and defense and security.



Energy

- Renewable Energy
- Energy Generation
- Energy Storage
- Cooling Systems
- Power Efficiency
- Energy Simulation & Modeling

Energy

KACST plays a leading role in the energy sector, focusing on research and development in the field of electric energy generation and its associated systems.

Introduction

Saudi Arabia is going through a period of population growth and development in various industrial and service sectors leading to a growing demand for energy and its resources. KACST has been actively participating in research and development in the field of power generation, storage and optimal utilization, through the Water and Energy Research Institute. The institute has a group of Saudi specialists and many research laboratories with advanced equipment, all of which has played a major role in providing high value products to meet the growing national energy needs.

Solar energy is one of the most important sources of alternative energy. This has led the Water and Energy Research Institute to conduct many research projects to find innovative technological solutions to produce solar energy with high economic efficiency. The institute's work also contributes to the optimal utilization of energy resources and to protecting the environment from the consequences of energy use, by developing renewable energy storage technologies, providing energy solutions for remote areas and improving energy technologies to meet the harsh environmental conditions in the Kingdom. The institute also conducts research in the areas of combustion and engines, plasma applications, fuel cells and batteries, and automotive technology. In addition, the institute conducts research in electrical power systems focusing on alternative sources, power conversion and control systems. Further work is done on power electronics which represent the basic tool for advanced electrical measurements, improving voltage stability, increasing the power factor and providing remote control. This leads to the enhancement of traditional and smart electrical networks.

Another pillar of the institute's work is the research and development of refrigeration and air conditioning systems by improving the basic components of air conditioners in order to increase the efficiency of the electrical energy consumption of these devices.

Reliability Lab for Solar Panels Testing

This lab is one of KACST labs accredited by the ISO/IEC 17025 for lab testing and calibration.

The lab is the first of its kind in the MENA region and is capable of testing photovoltaic (PV) panels under IEC standards. It was accredited by the Gulf Accreditation Center (GAC) at the beginning of 2017 for ISO/IEC 17025, in order to be recognized by stakeholders in the Gulf countries.

The lab is coordinating with the Saudi Standards, Quality and Metrology Organization (SASO), to be recognized as a national lab in order to participate in safety and efficiency tests for PV products entering the Saudi Market.

It also coordinates with KACST's Conformity and Certification Body to publish the "National Regulation for Photovoltaic Product Qualifications", on national solar energy projects.

The lab introduces testing services for government and private sectors projects in PV systems, to assure they can operate safely and efficiently, without external environmental effects degrading power production over time.

Development of High Efficiency GaAs Based Solar Cells

High efficiency multi-junction GaAs based solar cells are utilized in concentrator photovoltaic module systems. Higher efficiency can be obtained by changing the effective band gaps of the three junctions, but the choices of materials and approaches to achieving so are very limited.

To overcome this challenge, dilute nitride material has been developed to obtain the desired band gaps to obtain over 40% efficiency.

The unique advantage of the dilute nitrides is that the bandgap and lattice constant can be tuned independently, allowing bulk material lattice matched to Germanium or GaAs over a wide range of bandgaps.

Commercial Solar Junction concentrator cells with efficiencies of 43.5% have been achieved as a result of higher output open circuit voltage, which keeps system-level resistive wiring losses in check.

The team of this project aim to extend the advantages of these cells by introducing new structures where the band gaps are controlled according to the geographical location where the CPV system is to be installed.

Ultra-High Concentrated Photovoltaic System - UHCPV

KACST has been working on developing Concentrated Photovoltaic technologies (CPV) since the late 1970's. This led to manufacturing and installing the world's first Ultra High Concentrated Photovoltaic system (UHCPV) with a concentration ratio of 1600 suns. The system consists of primary lenses made of poly (methyl methacrylate) with an efficiency of 97%, high efficiency multi-junction solar cells that can reach 44.2%, and passive cooling systems that lead to achieve module efficiency of 33%. Through this project, many UHCPV systems have been installed and monitored in the last six years in different locations in Saudi Arabia as well as in New York and Denver. The team working on this project was granted over 18 patents and successfully published a large number of scientific papers.

Solar PV Modules Manufacturing Assembly Line 100 Mw

In 2010, KACST built the first semi-automated solar PV modules line in the Kingdom, with an annual capacity of 14 Mw. This line has been given the ISO 9001 Quality Management System certification. The PV modules product has also achieved accreditation according to the international standards IEC 61215 and IEC 61730.

In 2016, KACST expanded the production capacity and became fully automated, reaching 100 Mw annual production capacity, with the latest automatic technology used in the world in order to produce high quality solar panels.

A Saudi qualified and experienced team is operating this line and maintains it to a high quality level.

The factory is producing PV modules such as MONO and Ploy Crestline cell with different power outputs. Moreover, the factory is producing the back contact PV modules (MWT) which are a new and promising technologies that are suitable for high-temperature environmental conditions.

Energy Harvesting – Solar Cells A and B

The objective of this project is to synthesize wholly synthetic macrocycles that are robust, thermally stable, redox-active and exhibit semiconducting properties. Accordingly, it can be hypothesized that a wide-variety of parameters affect the performance of the organic macrocycles in energy harvesting devices which include (i) rigidity / flexibility of the redox-active units, (ii) distance between the redox-active units, (iii) geometry, (iv) chirality of the centers with redox-active unit and/or (v) the energy match between various identical or non-identical redox-active units that are present in the macrocycle. Despite continued efforts, the exact structure–performance relationship for efficient charge mobilities remains elusive.

To this end, the team of this project aim to synthesize various redox-active isosceles triangles which contain two classes of redox-active units within their triangular macrocycles. In the quest to advance our understanding of how the molecular composition of various classes of non-identical redox-active PMDI, NDI and PDI units within the isosceles triangles affects the properties associated with (i) the through-space electron sharing, (ii) the solid-state packing and (iii) the energy harvesting properties, two chiral isosceles triangles were designed and synthesized (−)-2PMDI-1PDI-Δ and (−)-2NDI-1PDI-Δ.

The new technology being developed in this project is based on the highly pi-conjugated perylenediimide subunits which have strong absorption in the visible region. This absorption can be easily adjusted by substituting the PDI units with various electron rich or poor components. The incorporated PDI subunits are known to exhibit strong fluorescence in solution but not in the solid-state because of the aggregation-induced quenching effect. However, by incorporating in a triangular macrocyclic geometry, we show here that we can achieve remarkable solid-state fluorescence where the quantum yields are close to unity. Finally, the structure-performance relationships of devices fabricated using this series of diimide-based molecular triangles will be investigated. The previous technologies developed were based on the redox-active pyromellitic or naphthalene diimide subunits which are neither easy to reduce nor absorb the visible light necessary for high efficient organic photovoltaic devices.

Design and Implementation of a Static Var Compensation System

This is a collaboration project between KACST and Saudi Electricity Company (SEC), for the installation of a 16MVAr Static Var Compensation (SVC) system for voltage regulation at an area called Alhassah, 350 km from Riyadh, and another 3MVAr 12-Pulse configuration SVC system at an area called Durma, 100 km from Riyadh. These areas suffer from consistent under voltage and frequent deep voltage events particularly in the summer time. The project started in 2011 and the two installed systems showed remarkable improvements in the local voltage profiles. More than 10,000 customers are served in these two areas.

The SVC technology is advanced and only a few companies around the world can build such systems at the medium voltage level. Electricity service providers, industrial plants, load centres and other similar customers particularly in remote areas, are usually in need of such technologies. The fact that these systems are designed and built by a national team contributes significantly to the local content enhancement.

Data Analytics of Smart Meters

This project is conducted under the KACST-SEC Joint Research and Development Centre for the Distribution Sector, which is located at KACST. It aims to use the data collected from smart meters installed by SEC in order to branch out several applications, different from the default ones, that can improve grid reliability, efficiency, enhance the operational economy, and at the same time accommodate all commercial opportunities that these smart meters bring.

This research project proposes a solid data framework that has tools and techniques for smart meter data collection and analysis. The framework uses data from smart meters, after being pre-processed, to execute applications particularly designed to enhance distribution grid economic operation, improve system design, and unlock business opportunities for SEC.

Work on this project started in 1438 H (2017 G), and several field visits have been conducted to the locations of some smart meters. Data from smart meters is currently available at the center's lab, where different application tools are used to analyze it.

Electrical Power Quality Measurement Devices

The project aims to design power quality devices for precise electrical measurements that are compliant with international standards. The devices are used to assess the quality of the electrical power system by analyzing the electrical inputs to calculate quality indicators. In addition, the devices are synchronized with time in order for the analyzer to investigate the incidents and their propagation accurately. They capture the voltage events (sags/ swells, and interruptions) which are then used to assess the service and measure its quality. These devices also can measure temperature, wind speed and the intensity of solar radiation and other measurements that are needed in the electricity industry. A number of devices have been installed in different locations in the national electricity grid for field testing and they are working very successfully. These devices are designed and manufactured at KACST and their hardware and software structures can be developed further to perform other functions.

Smart Grid Technologies - Development and Localization

Smart Grid technologies include advanced metering, communication, control, and automation. These are all essential for advancing Saudi's current electrical power system. One of the important advancement areas is the accommodation of renewable energy resources, especially at the electrical distribution network. The development of Smart Grid technologies requires building local human capabilities and advanced laboratories through collaborative efforts between research and industry.

This project is part of the collaboration between KACST and the Saudi Electricity Company (SEC) under the Joint Research and Development Center for the Distribution Sector. Under this project, an advanced Smart Grid technologies laboratory has been built at KACST campus. This lab is used for the development and testing of new technologies to solve technical problems that face SEC in operating and maintaining the electrical distribution network. Researchers and engineers from KACST and SEC work together in this center promoting a productive model of collaboration between research and industry in Saudi Arabia.

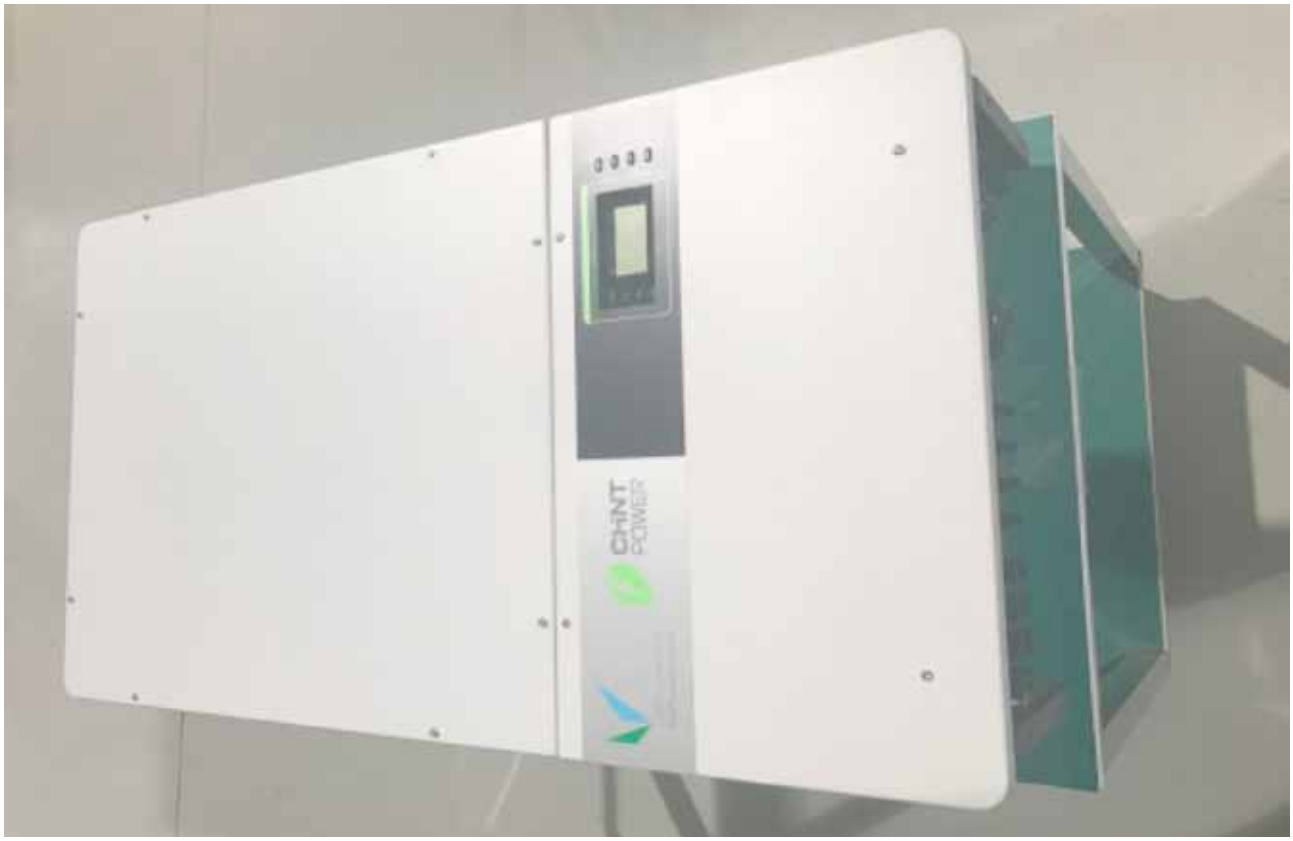
Smart Monitoring System for Distribution Networks

This project is part of the KACST-SEC Joint Research and Development Center for the Distribution Sector. It aims at installing an intelligent monitoring system with multi-capabilities to monitor MV feeders of the distribution substations, which will improve network planning and reliability. Additionally, weather data will be collected to assist in network forecasting and analysis studies. The project will be supported by appropriate means of communication, either by satellite or by using GSM network. The project began with the installation of a lab prototype for the purpose of testing and continuous updating. SEC is highly interested in collecting accurate measurements for its distribution networks in order to improve its performance and facilitate future expansion, and pays attention to power quality indices.

In the first phase of this project, the system will be installed in one of the distribution substations in Al-Quwaiiyah city. Then, in the second phase, it will be expanded to cover all distribution substations in Riyadh area.

Multi-Structural Power Stage and Control Platform for Voltage Regulation

This project aims to design and implement a multipurpose STATic synchronous COMpensator (STATCOM) platform. The focus will be on the power electronics design, which includes a comprehensive power system and network modelling and analysis. The system is used for several applications such as power factor improvement, reactive power compensation, voltage regulation, flicker reduction, interconnection stability, and other applications. It involves a lab prototype, in the KACST MV advanced laboratory, that will be subjected to extensive testing according to international standards. It will then be moved to a real environment which is a remote area powered by a PV farm, that requires voltage regulation due to the volatility of solar radiation and weak connection points. The STATCOM technology is very advance and is potentially needed in the electricity sector around the world. The project is part of a five year agreement between KACST and the Saudi Electricity Company to install advanced voltage regulators at the medium voltage level in the distribution network, in order to solve consistent voltage and reactive power compensation problems.



Smart Grid Controller for PV System

The objective of this project is to design and implement a Smart Grid controller for controlling a Photovoltaic generation system to be installed at the distribution level. The controller is designed to monitor and control PV systems in order to improve the reliability and efficiency of the distribution network. In the first phase of this project, two controllers have been designed and installed at two schools in Riyadh. This phase is completed and the developed hardware and software were installed and connected to the monitoring station at the KACST campus. This phase was done in collaboration with the Saudi Electricity Company and the Ministry of Education. The second phase of this project has started this year in which the system is to be installed in one of the large mosques in Riyadh. The design and implementation of major equipment has started and it is expected to be completed by next year. The beneficiaries of this project include: the Saudi Electricity Company, the Ministry of Energy, the Electricity and Cogeneration Regulatory Authority, and the private sector.

Inverters Production Line and Assembly

In 2016, KACST established an inverters production line and assembly at Solar Village in cooperation with China Power Company. This 30kw inverter can be used commercially and in PV power plants.

These inverters are grid tie and suitable for use at schools and on mosque roofs and in small PV power plants from 1-3MW. The efficiency of this inverter is considerably high, i.e., 98% efficiency. This device is competitive with its counterparts in the world in terms of accuracy, efficiency and life time. It has been assembled and tested in KACST and has been installed in the smart grid project in cooperation with the Saudi Electricity Company. This device will also be installed at Souq OKAZ in Taif . This device has many PV panels with 635 V DC and it gives 400 V AC with 60 Hz.

Energy Storage – Batteries and Supercapacitors

The energy storage project is aimed at achieving major advances in the development of rechargeable batteries. The research focuses on the development of novel organic-based electrode active materials (small molecules and coordination polymers) for the production of high energy as well as power density, and more environmentally friendly electrodes/ batteries.

Among present battery technologies, Li-ion batteries (LIBs) are the best performing ones because they store a large amount of energy for their size. Presently, LIBs are expanding their territories from small electronics to large-scale applications, including hybrid electrical vehicles and utility grids. It is likely, however, that the lithium reserves are not going to be sufficient to support LIBs scalabilities for grid applications. Furthermore, LIBs are relatively expensive for large-scale applications, on account of the transition metal (e.g., Co, Ni) used in the electrode. Along these lines, organic rechargeable batteries (ORBs) are an attractive alternative to LIBs, because of the abundant sources of carbon footprint and low cost, and environmentally benign processes.

The use of organic electrode-active materials offers a number of advantages over their inorganic counterparts, namely: the ease of tuning of their material properties, high power capability, and a renewable supply of lighter materials. Therefore there is a growing trend of moving towards more environmentally friendly alternatives for energy storage.

In this project, researchers have shown that the addition of microporous redox-active organic macrocycles shows outstanding electrochemical performance in cells. Our studies have uncovered that the naphthalene di-imide triangle can be charged and discharged at rates significantly higher than observed in other organic-based electrode-active materials. This observation is important because enhanced rate performance has been a perennial goal in battery technology, where high power density is critical.

With the cultivation of new and recent collaborations, as well as continued developments in molecular architectures, it is the ultimate goal of this project to realize new emergent materials that deliver the promise of intellectual property with sustained commercial application.

Innovative Second Generation of Sodium-Nickel Chloride Battery

This project aims to develop an energy storage system with a view to increasing its performance, reducing production costs, and adapting to hot climatic conditions, to be one of the most attractive technologies for renewable energy storage.

It focuses on the fabrication of a new design of a Sodium Nickel Chloride (NaNiCl2) Battery with a capacity of 3kWh. The second phase is to develop a battery with high capacity (15kWh) to reduce production costs and increase reliability, by using a new design for sealing the cell through active brazing and battery management system (BMS). This project also aims to fabricate a new planar design of batteries to increase the active surface area which could then lead to the achievement of higher power and energy densities.

During the period of the project, some of the battery manufacturing equipment and materials have been supplied. Staff have been trained to operate equipment such as the laser welding machine.

Sodium-Ion Batteries: New and Cheap Way of Energy Storage

Li-ion batteries have been considered as one of the most promising candidates for energy storage due to their high energy density and cycle stability. As an alternative technology, Na-ion batteries potentially offer a lower cost, and a safer and more environmentally friendly battery system in comparison with the Li-ion system. The anode part becomes the main drawback of the commercialization of the Na-ion batteries because the typical graphite employed in Li-ion batteries does not intercalate Na+ ions. This is related to the large size of the Na-ion, which is 372% that of a Li-ion, and thus makes it impossible to simply adopt recent knowledge and strategies developed for high performance Li-ion batteries directly onto Na-ion batteries.

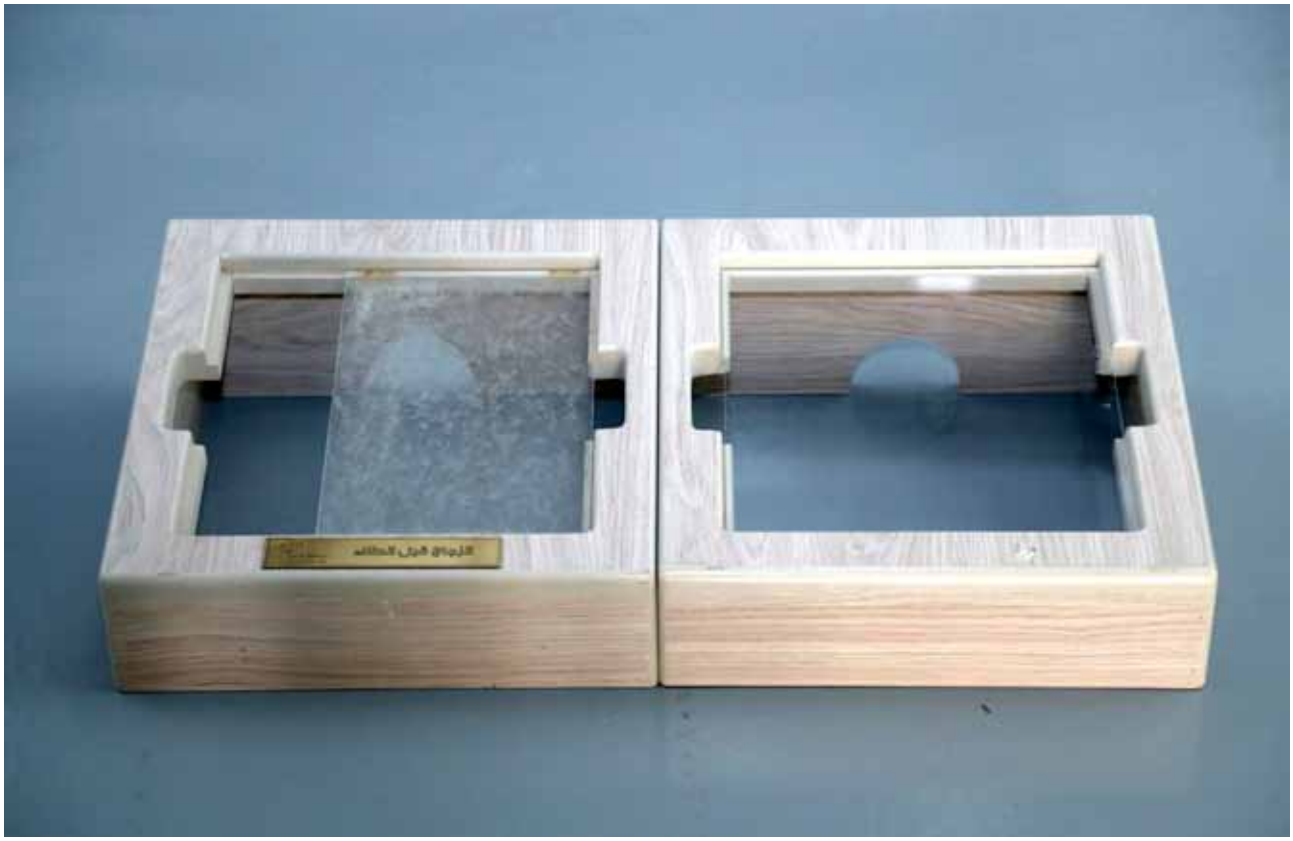
The objectives of the current phase in this project are to develop capable anode and cathode materials for Na-ion batteries which can be used in both organic and aqueous electrolytes, with detailed characterization and electrochemical performance tests, in order to develop synthetic approaches for high-performance anode and cathode materials for aqueous sodium-ion battery systems.

Adsorption District Cooling Multi-Generation

About two-thirds of the electric energy generated in Saudi Arabia is used in buildings and two-thirds of that is used by air-conditioning. This is a consequence of the severe climatic conditions in the Kingdom. The demand for electricity as a result of increasing population, expansion, and development plans, has increased. The increasing cost of energy and adverse impact on the environment by energy production, have all contributed significantly to finding means to seriously reduce energy consumption in buildings. Multi-Generation for District Cooling Technology (MG-DC) is based on adopting sorption cooling technologies to enhance overall efficiency of stand-alone combined energy generation sources working for district cooling networks. MG-DC implements the development of cutting edge technology in the area of compressor chillers, AB-sorption chillers, AD-sorption chillers and combined heat and power units, to enable achieving maximum energy efficiency independently of energy demand profile. This MG-DC project provides consulting services for the development of innovative, high efficiency, or 100%, solar power based district cooling technology, in areas covering various demand profiles from residential and commercial sectors to industrial use.

A Novel Solar Desiccant Air Conditioning System

Enormous amount of energy is consumed by air conditioning systems during the summer in the Kingdom of Saudi Arabia. The current most effective form of air conditioning is the mechanical vapor compression system (MVC). In the air-conditioning peak demand period in Saudi Arabia the electricity consumption might reach more than 70% of the installed capacity of the national power generation. On the other hand, the simple desiccant enhanced evaporative air conditioning system provides drastic energy savings over the MVC system. It is necessary to emphasize that the net fresh water consumption by the indirect evaporative cooling part in the system is much less than the amount of water consumed in a conventional evaporative cooling system. The main objective of this project is to design, construct and test two systems. The first is a complete solar desiccant air conditioning unit consisting of a desiccant dehumidification system, indirect evaporative cooler, solar thermal and PV systems for hot humid areas. The second is a solar PV operated indirect evaporative cooler for hot dry areas.



Dust Repellent Coating on Solar Panels

The objective of this project is to develop dust repellent coating materials suitable for different weather conditions experienced in the Kingdom. Dust repellent coating materials containing silicon dioxide particles in the size range of 5-20 nm will be prepared by sol-gel method. The glass panels will be coated by dipping them in coating solution, which will be followed by hardening the coating in a 500 degree centigrade oven. Six different sites and weather conditions over the country were selected to evaluate the dust repellent properties. The transparency coated glass panels were positioned in a tilted direction in order to evaluate the solar cell applications. The coated glass efficiency will be improved by more than 10% when using the developed coating solution. In addition, cleaning efforts will be reduced and the solar cell will be more protected from UV rays. A pilot planet will be designed and established at Solar Village for applying the coating solution on large size solar cell panels (1m * 2m).

Carbon Nanotubes for Solar Thermal Selective Surfaces Project

Saudi Arabia is burning a lot of oil for domestic energy and a large proportion of this consumption is used for air conditioning. To reduce domestic fuel consumption, renewable solar energy can make a significant contribution. This project aims to develop energy-efficient solar absorber devices that are suitable for Saudi-Arabian climatic conditions. An absorber device will consist of a new solar selective coating, based on Carbon Nanotubes, and other functional Nanocoatings, to enhance the total energy efficiency of such a device. Furthermore, technologies for production will be developed to achieve low cost processing. By providing highly efficient solar absorber devices to the Saudi market, circulation of renewable energy technologies for air conditioning (solar cooling) and generating domestic hot water (solar thermal) is expected to be increased, resulting in decreasing total domestic fuel consumption.

Development and Enhancement of Light Emitting Diodes

The Kingdom of Saudi Arabia currently uses ~10 GW, or more than 18%, of its electricity production for lighting. Current lighting technology in the Kingdom is based on highly inefficient incandescent lighting (10-15 lumens/watt) that produces undesirable heat.

The transformation to solid-state lighting (SSL), with an ultimate theoretical efficiency of ~300 lumens/watt (lm/W), will correspond to nearly zero energy consumption for lighting while simultaneously reducing air conditioning loads. Nonpolar and semipolar III-nitride light-emitting diodes (LEDs) show promise for meeting this goal by providing viable and rationale solutions to efficiency "droop" and the "green gap". The purpose of this project is to develop and improve the local capabilities for device growth, material characterization, device fabrication, and on-wafer measurement of high-performance GaN LEDs for next-generation SSL systems.

The project aims to develop blue LEDs with a peak external quantum efficiency (EQE) of >75% and an efficiency droop of <10% at 350 A/cm2.

Rationalize Energy Consumption Through Light Emitting Diodes

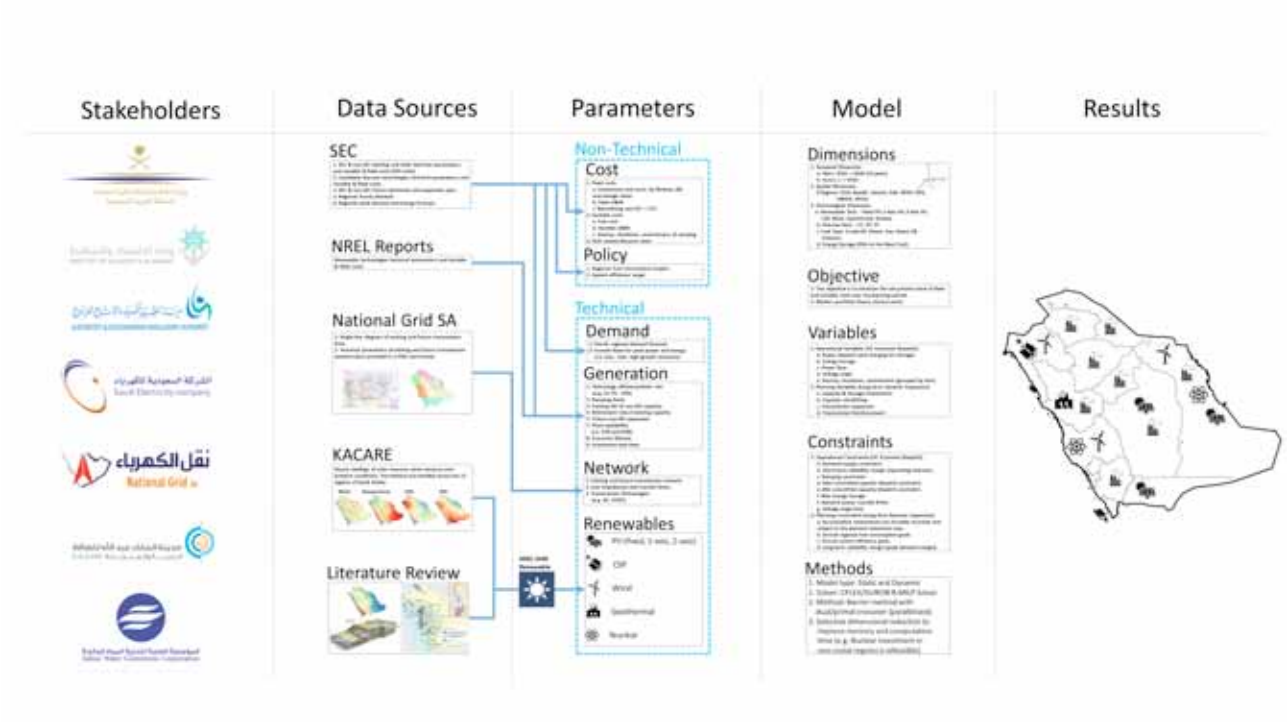
Lighting for buildings and roads consumes about 20% of all the generated electricity in the world, which is equal to about 1.144 TW. This huge amount of energy costs about 300 billion dollars and is accompanied with the emission of around 410 tons of carbon dioxide.

Currently, Saudi Arabia consumes about 10 GW for lighting which represents about 18% of the total generated electricity.

Developing alternative lighting sources that can lower electricity consumption is aligned to the requirements for the energy sector detailed in Saudi Vision 2030. The objective of this project is to utilize national expertise to build an assembly line for light emitting diode fixtures to be used for building and roads.

The ultimate goal is to exploit the outcome of this project to initiate investing opportunities in the field of advanced industry which will assure the ownership of advanced technology and also promote jobs for young engineers and technicians.

Along with the project goals, the aim is to work with government partners to reduce energy consumption by gradually using low power Solid State Lighting.



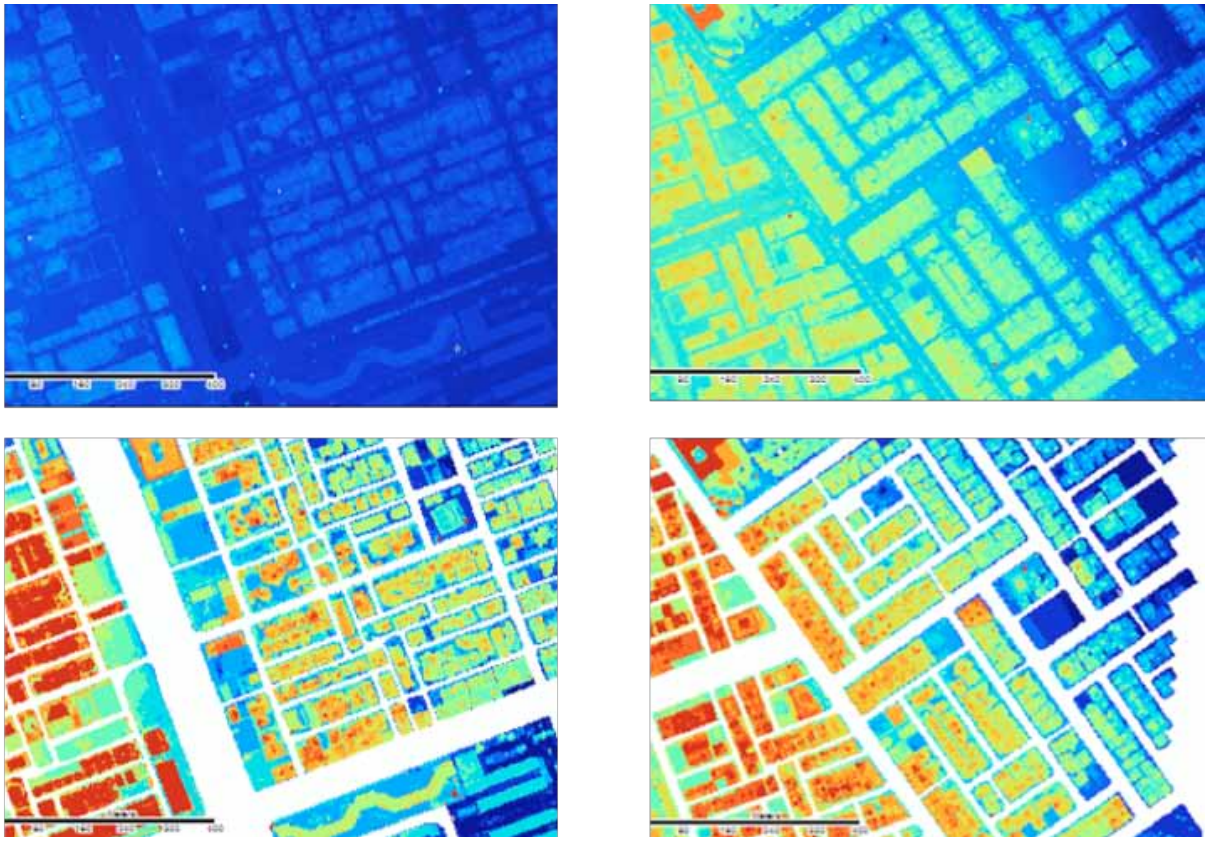
National Power Network System

The Center for Complex Engineering Systems (CCES) in collaboration with the Water and Energy Research Institute (WERI), Massachusetts Institute of Technology (MIT), and Saudi Electricity Company has developed a high-fidelity long-term strategic planning tool for renewable technologies in the Saudi power system called SUPER. The name stands for Sizing, Ultimate Placement, Expansion, and Reinforcement of Generation and Transmission Infrastructures (SUPER).

KACST's SUPER has been designed to find the optimal sizing, portfolio selection, timing, and placement of renewables to ensure maximum economic benefit, reliability, and minimum capital and operational costs. The decision support system relies on a rich Saudi-specific database to capture existing generation and transmission infrastructures, technical specifications, capital and operational costs, and measured renewable potential. Additionally, KACST's SUPER can be expanded to examine the economic viability of large-scale storage to enhance the penetration and reliability of renewable power generation.

This decision support system will aid stakeholders in achieving an integrated long-term planning in a unifying framework. The planning challenges primarily stem from renewables temporal intermittency, spatial diversity of renewables potential, seasonally-varying synchronicity between peak demand and peak renewables generation, capacity credit of renewables, transfer limits between center loads, technical limits of dispatchable generation, and regional fuel availability.

Due to its strategic location, significant renewable potential, and rapidly growing demand for electricity in the region, Saudi Arabia can export electricity to neighboring countries. The export of electric power depends on the establishment of a competitive local market for electricity, which is an attempt to solve and mitigate distortions in the local market resulting from government energy subsidies. To assess the possibility of the Kingdom exporting electricity, CCES have studied the possibility of exchanging energy between the GCC countries by reviewing the transmission lines between the Kingdom and its neighbors, and identifying the basic organizational steps necessary to establish a regional electricity market through mathematical modeling.



Urban Energy Modeling

The Kingdom of Saudi Arabia is witnessing rapid urban development and growth in electric power demand, which requires the country to provide new and innovative solutions to develop and maintain its electricity infrastructure in a sufficient and sustainable manner, as well as to support decision makers in taking the necessary actions to rationalize and manage the use of electricity.

The objective of this project is to provide an advanced model of urban energy based on the development of complex algorithms, that accommodate the context of building designs in the Kingdom of Saudi Arabia in its various regions, using LiDAR data as an input to develop an integrated three-dimensional model of Riyadh city automatically, quickly and cheaply.

The urban model used for the simulation of electrical energy consumption depends on the construction of building templates to take into account the building materials used, and data showing the behavior of the occupants in the buildings. With the design of building templates and integrating them in the three-dimensional model of the city, the urban model of the city can predict electric power consumption and the feasibility of installing solar panels as well as its output. The model can also estimate the energy consumed in the construction of buildings and can predict the walkability and the possibility of using bicycles (bikeability) in neighborhoods. The behavior of building occupants also contributes to the consumption of electricity and the formation of a mathematical model that simulates the behavior of the inhabitants was done in this project as well.

The engineering model also contributes to the knowledge of patterns of electric power consumption and in finding the optimal integration of distribution network systems for electric power. This helps individuals achieve partial independence in obtaining electricity, and reducing the burden on the national grid. The engineering model aims to investigate and increase the economic potential in the installation of solar panels, which contributes to the alleviation of the financial burden of electricity bills and also reduces the burden on the national grid for electric power.

Water

- Water Desalination Technologies
- Membranes Technologies
- Leakage Detection
- Water Simulation & Modeling

Technology Transfer and Localization
Water

Water is one of the most important substances on earth, especially in the Kingdom where deserts cover a large portion of its area. Hence, it is crucial to develop new technologies that not only deliver pure water but also utilize less energy and resource.

Introduction

KACST has great interest in the development of desalination technologies and has also funded several projects that aim at developing water technologies such as osmotic membranes, porous membranes, and ultrafiltration membranes that are used in several water technologies related fields.

Water technologies are divided into several types, such as water desalination, and each has many branches and divisions. Each technique is applied depending on the amount of water to be produced, to the energy needed for operation as well as water quality needed, and several other considerations. Water treatment technologies are considered important for the purpose of removing various contaminants that are harmful to humans, or to agricultural or industrial purposes. Water treatment technologies, on the other hand, are divided into several branches, depending on the required quality of water produced. For example, filtration technologies using organic and inorganic membranes are the most widely used technologies for removing particulates and organics with large molecular weights. Physical and chemical oxidation treatment technologies are also important and can be used for removing harmful chemical compounds in water.

The goals of the National Center for Water Treatment and Desalination Technology at KACST are:

- Development and localization of water treatment and desalination technologies.
- Research collaboration with local and international research institutes.
- Establishment of a database for water treatment and desalination technologies.
- Development of efficient pilot plants, experimental rigs and technical products for water treatment and desalination.
- Recruitment of talented scientists and engineers in water technology.

Design and Construction of Mobile Pilot Plant

The aim of this project is to find a reliable method for evaluating different sites for water treatment and desalination that can be applied for commercial plants. The project will also evaluate different types of reverse osmosis membranes with different sizes and different operational conditions. For this reason, a smart mobile pilot plant was designed in a way that can be used for multiple kinds of water treatment and desalination processes. This mobile pilot plant can be used to study multiple locations either for seawater or well water, to assess the pretreatment process based on sand filtration or modern methods such as ultrafiltration. This pilot plant is operated by a fully automated system (SCADA) to control and monitor the operational parameters.

For this purpose, a mobile pilot plant has been designed with a production capacity of 3 m^3/day to test and check suitable sites for desalination plants as well as testing the pretreatment process using various types of chemicals and feed water in order to reduce the treatment cost and produce high quality water.

Lithium and Vanadium Recovery as By-Product of Desalination Plants

Rare earth metals, such as cobalt, vanadium and indium or the more abundant lithium became the limiting bottleneck of several new technologies. Lithium is a components of Li-Ion-batteries such as an electric vehicles. Also, Vanadium is a strategic metal for large-scale energy storage (Redox-Flow-Batteries). The aim of the project is the development of new concepts for the efficient recovery of valuable compounds (e.g. lithium and vanadium) from concentrated brines as by-product of desalination plants. Electrochemical concepts will be targeted, as an ionic separation is expected to be more efficient if an electric field is applied. The selectivity towards lithium will be managed through lithium-ion-conductive membranes.

Advanced materials are the key components for the proposed technology. Ion-selective membranes and electrodes will be developed and tested in electrochemical cell set-ups towards selectivity, stability, efficiency and costs.

In case of success, this project will be able to provide the technology for exploiting the most abundant source for rare metals (seawater) or even recovering valuable metals from waste (brines as by-product of desalination plants).

Carbon Nanotubes for Water Desalination

This project is a collaboration project between KACST, KAUST and MEDAD, to establish the first industrial scale pilot to produce 100 m³/day of fresh and cooling water using solid adsorbed materials.

The plan is to have a design of a hybrid adsorption desalination (AD) and multi effect desalination (MED) unit, partially extracting the waste heat from the flue gas and hot water of radiators from the electric generators. The waste heat is used then to power the AD+MED cycles producing water with a nominal capacity of 100 m^3/day.

Renewable energy using waste heat produced by different industrial process is the key factor to improve the energy efficiency and consumption in the industrial field.

In this project, KACST collaborates with KAUST, TAQNIA and MEDAD, to design and manufacture the main parts of the unit as well as operate and maintain the plant. This project is considered as one of the most promising technologies and is the first stage of an integrated solution for the transfer, localization, development and manufacture of adsorption desalination in the local region, aligned with Saudi Vision 2030.

Water Desalination Plant Powered by PV Solar in Alkhafji

KACST in collaboration with the Saline Water Conversion Corporation (SWCC), Saudi Electricity Company, and other related authorities, is undertaking a project to construct the first solar seawater desalination plant in the Middle East that can produce 60,0000 m³ / day of desalinated water, at Alkhafji city located in the Arabia Gulf coast.

The plant is powered by electrical energy provided by solar cells. The production date of this project is scheduled to be at the end of 2017. During the study and designing stage, the climate and other impact factors were taken in consideration. The solar PV panels were manufactured from the production line at KACST in collaboration with two local manufacturers.

This project is considered as the first stage of the King Abdullah Initiative for Solar Desalination Plant Technology that aims to secure water and reduce the water production cost compared to the traditional technologies.

Carbon Nanotubes for Water Desalination

The aim of this project, which is conducted in collaboration with Cambridge University, is to produce and optimize the properties of Carbon Nanotubes (CNTs) that will be used to fabricate membranes to be used in water desalination. Research on water desalination and purification has shown that CNTs can be used in water desalination plants. When sea water passes through CNTs, only water molecules pass through the membranes, leaving salt ions behind, and giving us in the end water with a high level of purity. The preliminary simulation study shows that water molecules can easily pass through CNTs that have a diameter of about 1.38 nm, whereas sodium chloride ions (Na+ and Cl-) cannot pass through them even though they are significantly smaller in size than the CNT membranes. This is in line with the results of previous studies that showed the effect of wetting area around the ions on their inability to pass through carbon nanotubes. There are ongoing studies to investigate the effects of carbon tube length, packing density, pressure differentials and finally the diameter of said carbon nanotube on water flow rate. Earlier in this project, CNTs were produced using an apparatus found at the University of Cambridge, where two types of tubes were produced:

- Two-dimensional tubes.
- One-dimensional straight tissual tubes.

Moreover, CNTS were tested and profiled and they proved their efficiency and potential in the field of membrane fabrication.

In the latter stages of this project, a number of membrane forms will be manufactured using carbon nanotubes and, ideally, the best membrane sample should satisfy the following specifications:

- Membranes should be in the form of tubes and the space between the tubes should be filled with a chemical substance.
- Membranes should be flat and the tubes should look like a sheet of paper and should be reinforced with a chemical substance.

After that, saline water will be pumped into the tubes in order to measure water flow and salt rejection by these tubes. Then, this membrane will be characterized using a number of advanced equipment, the most important one is the advanced electronic microscope.

Development of Novel Hollow-Fiber Membrane for Water Desalination

This project aims to develop a novel hollow fiber (HF) polymeric membrane for water desalination. The project is carried out in cooperation with SRI-International, USA.

The project outputs will have an impact on reducing the cost of desalination in the industrial sector.

This novel (HF) membrane uses a new material which has high mechanical properties, temperature resistance and has shown some indication of chlorine and fouling resistance which minimizes the need for frequent membrane cleaning during operation, and maximizes membrane life.

The first phase of this project will perform the experiments and development necessary to increase its efficacy to produce high water with high salt rejection and to confirm chlorine resistance and fouling tendency. This will be followed by the transfer of technology, followed by the production of membranes at an industrial level.

This new technique, made of polybenzimidazole (PBI) hollow fiber membranes, has excellent resistance to chemicals and has a high thermal stability of up to 200°C, in addition to its high mechanical properties.

Membrane Technology – Desalination and Fuel Cells

For water desalination, we aim to develop anti-fouling barriers for commercial polyamide (PA) membranes based on novel supramolecular and hybrid covalent/mechanically interlocked architectures. Our goals are to (i) promote and support water security, public health and economic development for the Kingdom, (ii) improve the current technology to reduce cost, enhance performance, and increase the efficiency of water treatment, and (iii) minimize the environmental impact.

Fuel cell technology is an alternative and renewable clean energy source that converts chemical energy into electrical energy. It is unique in being both a method and portable energy as well as a mass energy production. Proton-exchange membrane fuel cells (PEMFCs) are one of the most promising candidates, for their high performance and environment-friendly properties (producing water as the only byproduct). The efficiency of PEMFC rely mostly on proton exchange membranes (PEMs), which are more efficient than a traditional engine. Indeed, in comparison to the 30% efficiency observed for the internal combustion engine, PEMFCs exhibit high power conversion efficiencies of up to 60%.

Optimal Solution for Monitoring Water Pipelines

Up to 60% of water is wasted annually due to leakage of pipes. This contributes as a major factor in the water crisis around the world. Additionally, Saudi Arabia is a desert country with no permanent rivers or lakes. Reliance on coastal desalination means water supply infrastructure is a strategic issue. Given the length of the transmission network and desert environment, it is unlikely that pipelines could be guarded by conventional methods. Consequences can only be mitigated using rapid response strategy, which must involve locating and repairing damaged pipes.

This project proposes the development of a smart sensor network system for long distance water pipeline monitoring applications. A network comprises of a set of small sensor devices (nodes) that are deployed in an ad-hoc way and that co-operate for sensing a physical phenomenon. Collected data is transferred between nodes through the network to the central station. The solution requires research and development in several areas including: sensor development, communication protocol implementation, full system integration, cloud based, and research for fabrication of nodes.

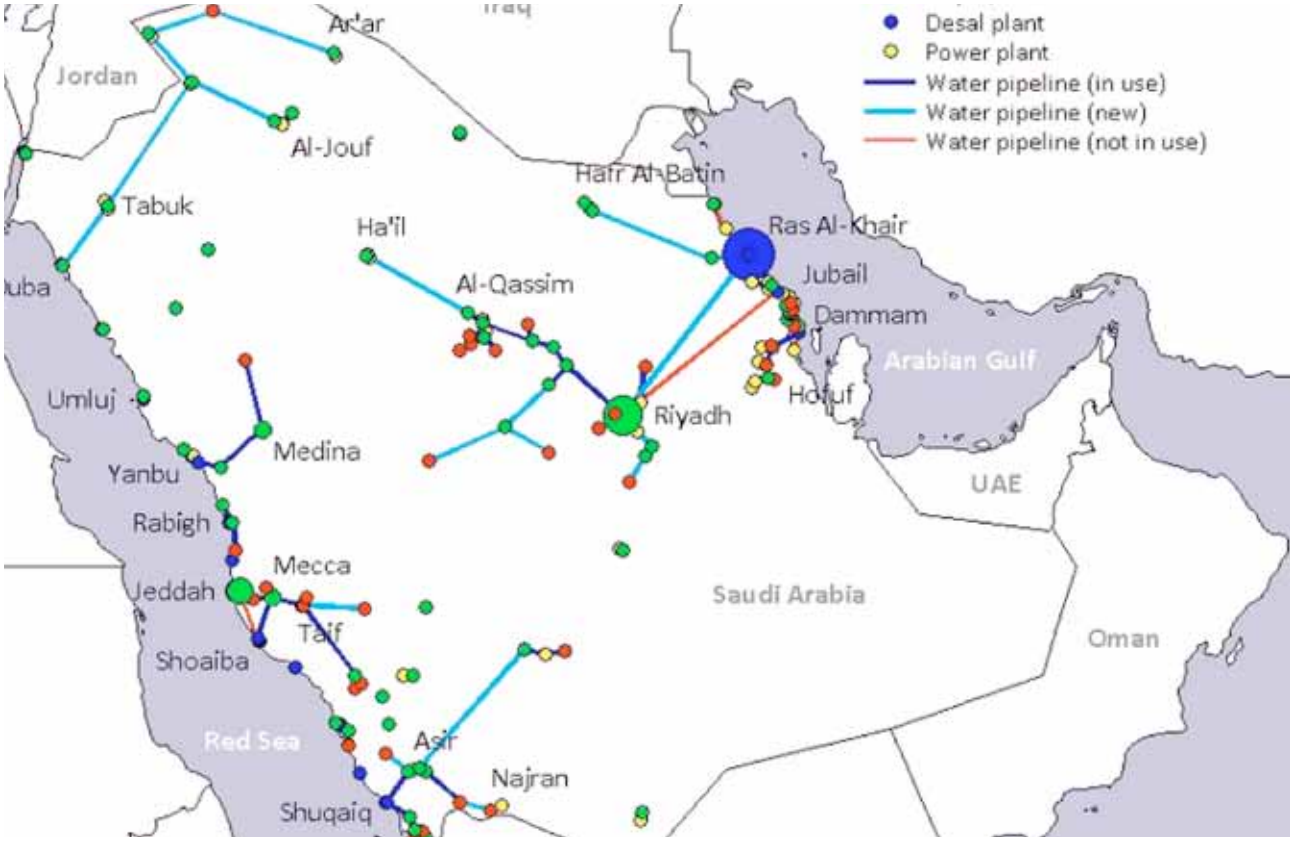
Development of Antiscalant Materials for Thermal Desalination Plants

The aim of this project is to synthesize friendly and efficient water soluble antiscalant materials that can be used to prevent or minimize scale formation in thermal desalination plants.

Different polymerization processes will be applied to develop these materials that work in an efficient way.

A comprehensive evaluation of these polymers will be performed and compared with commercial materials. Chemical and physical characterization methods will be used to evaluate the physical properties and chemical composition of these materials. The inhibition process of the synthesized materials will be evaluated experimentally at different parameters similar to the desalination conditions. Researchers at the National Center for Water Treatment and Desalination Technology at KACST will be trained on the preparation procedure, characterization and evaluation methods.

The outputs of the project are the synthesis of antiscalants from local materials and its application in desalination plants in the future. The Saline Water Conversion Corporation (SWCC) and oil drilling companies will benefit from these materials.



Study of Water Resources

The project aims to study water resources by modeling underground water, providing information about the balance between the use and re-feeding of underground water levels and the sustainability of underground water reservoirs in the current and possible future climate. The project provides results to decision makers and people of interest in the public and private sectors in the Kingdom.

Satellite images will be used to observe crust deformities and soil moisture near water reservoirs. Geological structures of the water reservoirs and special measurements for the depth of underground water reservoirs can be used, too. Field data will be continuously collected from the site to determine the locations of geological changes of earth deformities, like cracks and chemical measurements of water from underground water reservoirs, and to determine the depths of these reservoirs and underground geology. Future activities can also include seismic studies of underground shallow and deep groundwater basins and thermal imaging to determine the locations of groundwater flow and drainage. The study is expected to provide information about the balance between the use of groundwater levels, re-feeding of these levels, and sustainability in current and possible future climate.

The Inter-Regional Water Inclusive Wealth Model

This project aims to assess the inclusive wealth (IW) of the country. This was previously performed by the U.N. in 2012 and 2014, investigation the distribution of the wealth in the Kingdom and its transformation from one form of capital to another. The role of solar desalination, renewable energy, and agriculture in enhancing the IW of Saudi Arabia by 2050, were also assessed.

The project produces a comprehensive model to simulate the interacting sectors in Saudi Arabia while utilizing a Geographic Information System (GIS) approach and an interface to enable collaboration between stakeholders within regions to effectively negotiate the best plans for equitable development across the Kingdom. This project combines the Inclusive Wealth (IW) framework that captures the performance of stocks (natural, produced, and human capital), side by side to the Computable General Equilibrium (CGE) framework that tracks the flows and distribution of resources throughout the Kingdom in a system-of-systems implementation. This methodology thus captures the dynamics between regions while putting emphasis on water resources.

Oil, Gas, and Mining Technology

- Exploration Technologies
- Extraction & Production Technologies
- Petrochemicals
- Carbon Sequestration
- Clean Fuel

Technology Transfer and Localization

Oil, Gas, and Mining Technology

Oil, gas, and minerals are essential resources for the energy industry and are vital factors for improving the economy in many countries. It is therefore important to develop new technologies for this sector.

Introduction

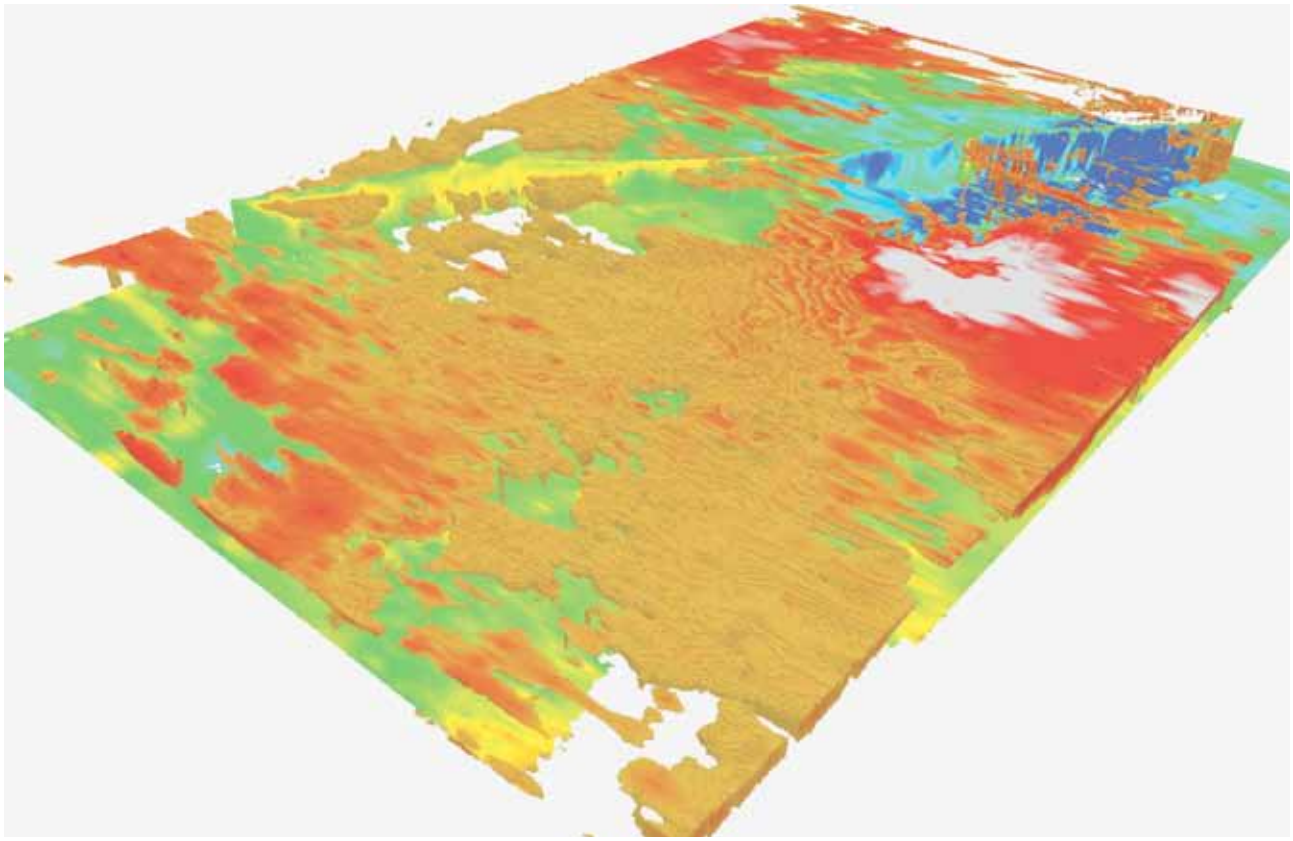
Oil, gas, and mining technologies play significant roles in providing sufficient amounts of energy required worldwide. Thus, exploration and production technologies have developed enormously in terms of innovation and manufacturing.

The Kingdom of Saudi Arabia is the main oil producer in the world, and contains massive amounts of mineral deposits. The Kingdom relies heavily on oil and gas to produce electricity and for water desalination. Therefore the development of innovative technologies to enhance these processes are of high importance and high value to the Kingdom.

Scientific research in the Kingdom is focusing on certain key sectors and development fields. The National Center for Oil and Gas Technology is carrying out projects focusing on the following: improving oil and gas production; enhancing Earth imaging and exploration: subsurface geophysical modelling, the development of drilling methods, and oil, gas, and mineral explorations.

The National Center for Oil and Gas Technology seeks to reinforce scientific research efforts in the fields of oil, gas, mining explorations, and production, in the Kingdom, and to play a significant role to localize and transfer these technologies in order to ensure sustainable production patterns by making these technologies economically feasible. The center's interests are combined into five research orientations that can be summarized as:

- Oil and gas explorations and production.
- Subsurface geophysical modeling and inversion.
- Enhanced oil recovery.
- Reservoir simulation and characterization.
- Minerals exploration technology.



The Saudi Arabian Glass Earth

This project is in the pilot stage of a multi-year earth observation research and development initiative that aims to provide clear geological and hydrological information from a vast area of the Kingdom. The project includes key contributions of all studies relating to infrastructure management, groundwater resources, minerals and geothermal energy, and oil and gas exploration. The complete project involve the acquisition, processing, and interpretation of airborne electromagnetic, gravity, and magnetic data over 7,700 km^2 in the study area south of Al Madinah. A finalized Glass Earth Model has been built, as we have identified the potential geothermal and mining targets that exist in the area, which do not have any surface expression and can only be detectable with the modern high-resolution geophysical methods provided by this project. These targets may be associated with gold, zinc, and copper, which can be found in the Precambrian rocks of the Arabian shield in the western part of the Kingdom. To explore these targets in more details, we have recommended a follow-up by applying several geophysical ground measurements.

Development of a Low-Frequency Radar System for Mineral Exploration

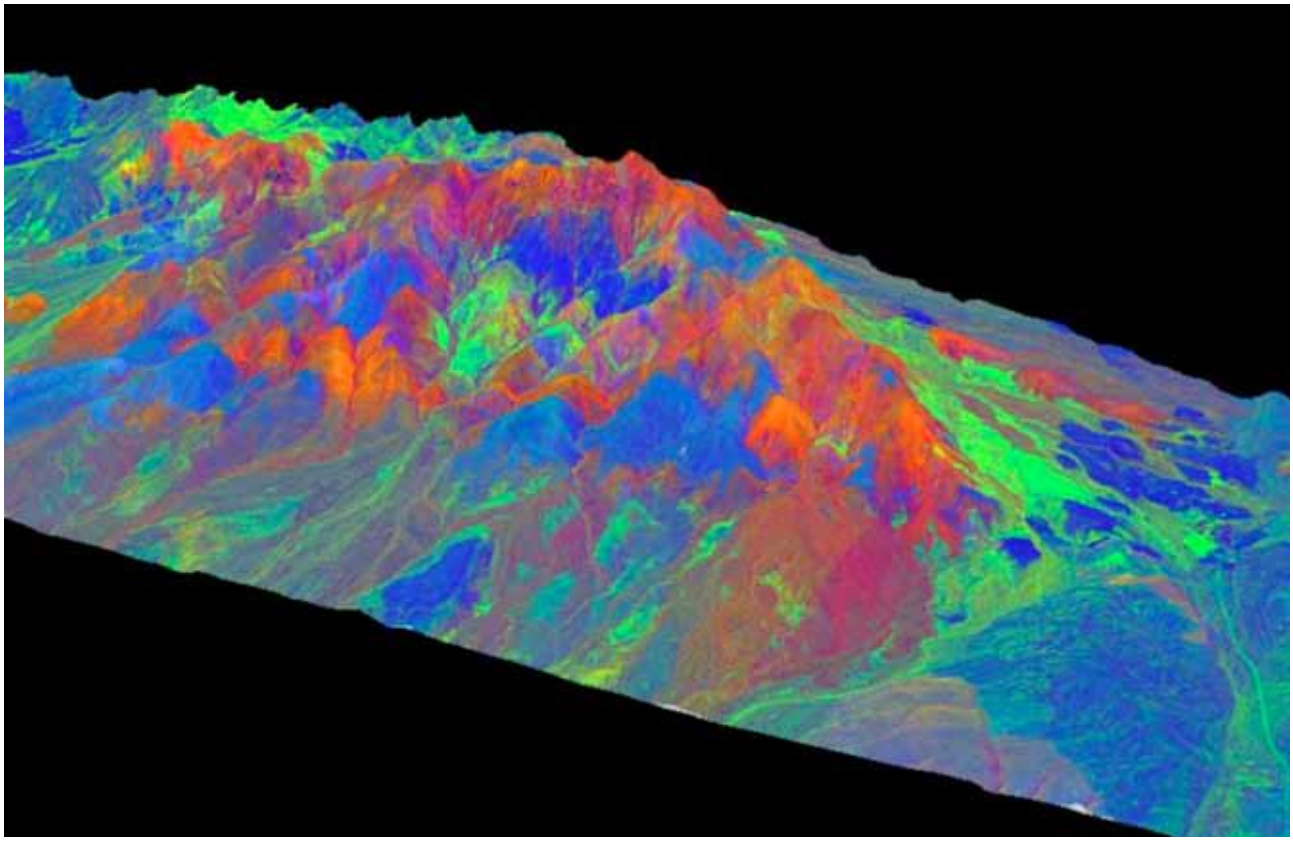
The rapid advancement of ground radar penetration systems and the technology associated with the design of the radar components is a research topic that targets many applications, including studies of crustal deformation and natural resource research. Developments in this field focus on the creation of a system capable of generating low-frequency electromagnetic waves, that ensure the production of high-quality signals that penetrate deeper into earth. The project aims to design a ground-penetrating radar system that combines the following features: low-frequency generation, a single antenna, and multiple sensors to record data at different distances. These features will lead to better Earth coverage to explain the rock properties of the sub-surface. The radar data will provide a valuable contribution to oil and gas exploration by improving the best estimations of weathering layer changes for seismic static correction.

Developing a Technology for Monitoring Carbon Sequestration

This project aims to develop a new technology for monitoring oil and gas reservoirs, as well as water aquifers in Saudi Arabia. The project also aims to develop this technology to monitor carbon sequestration during enhanced oil recovery. Based on its location near Riyadh, its geological features, and water depth, the Alawaseea water pumping area was selected for the study. In this project, completed this year, a specially designed seismic source was developed to monitor the water aquifer and the effects of water pumping on the frequency and amplitude of seismic waves. Continuous seismic data generated by the developed seismic source were collected. High-resolution seismic surveys were conducted on the study area for comparison. Based on the data analysis, time-lapse models were obtained during water pumping periods. The results show that the seismic waves generated by the continuous seismic source were affected by the water pumping process. The results were presented and published in related conferences and journals. This project was achieved in cooperation with Japan Cooperation Center, Petroleum.

Enhance Geophones for Sand Surface

Seismic methods have the potential to excel in delineating the sub-surface near deep geological layers with a resolution not offered by any other technique. This resolution has led seismic techniques to be employed first in geophysics applications in most oil, gas, and perhaps recently in mining explorations. Geophone coupling is still a big issue in seismic acquisition, requiring some developments in sensor techniques and in communicating the data over large areas, especially in sand regions. The team of this project aims to enhance geophones for sand surfaces with high coupling characteristics and a high level of surface/ground/terrain coupling, allowing for easy mobility and operation compared to conventional acquisitions. The design will focus on providing long spear-type mounts to allow for the better coupling and recording of low-frequency signals and provide a sensor that is commercially feasible. In addition, this design of a sand geophone can solve the problem of complex environments, as it is the case in the Kingdom, with its desert and large sand dunes.



Development of Borehole Mining Exploration Technology

This project aims to develop a geophysical data logging system that will help in well drilling and groundwater, mineral, oil, and gas exploration. A computer system with a number of applications will help to collect data from different well environments with a design ensuring the quality of the acquired data. The project also aims to create a seismic energy source to be used for oil, gas, and mineral production wells and it will operate at frequencies ranging from 30 Hz to 30 KHz to overcome some wavefield problems at this bandwidth. For example, the complex environment of production wells is the main challenge in producing high-quality signals. This environment includes stainless-steel casing and wellbore fluids, borehole annulus, and other materials induced during drilling, such as the drilling mud and gravel. The hydraulic parameters and mineral characteristics of the formation are two of the most important outcomes that can be achieved by the project, and its results may serve many sectors, including oil, gas, mining, groundwater, and geotechnical companies.

Full Waveform Inversion Techniques for Mineral Exploration Applications

This research project is concerned with the development of a full waveform inversion approach focused on the near surface. Despite the many challenges presented by waveform inversion, its ability to resolve the near surface problems considering the available recording spread length, is outstanding. The resulting velocity model has high-resolution information capable of mapping caves and other features of the Earth's sub-surface. However, such an implementation requires some modifications to the current operation to include phase unwrapping, scattering angle filtering, and Laplace damping. The main objective of this project is to utilize wave-modeling technology to explore minerals and unconventional oil and gas with consideration of the role of other applications such as in the detection of groundwater sources, calculating the time of arrival of seismic waves in rough areas (sands), and to obtain sharp images of the sub-surface.

Thermal Fracturing Technology for Unconventional Reservoirs

Hydraulic fracturing in unconventional formations involves the use of highly pressurized water to create a complex network of fractures that allow the flow of reservoir fluids from unconventional reservoirs to the wellbore. Saudi Arabia is an arid country with the potential for an acute water shortage. It is mostly desert with no permanent rivers and little rainfall. Water is scarce and extremely valuable, and with the country's rapid growth, the demand for water has grown, despite a scarce and dwindling water supply. Moreover, water can cause significant formation damage, which can present as clay swelling and relative permeability effects stemming from capillary fluid retention. The concept of waterless thermal fracturing rests on the idea that a very cold liquid (i.e., liquid nitrogen) or a very high temperature (i.e., plasma) can induce a fracture when brought into contact with a rock formation. This study will develop a system to control the processes of injecting those waterless materials into the production wells to obtain better results.

Nanoparticle Gel Technology in Enhanced Oil Recovery

Excess water production and low oil production rates are two major issues that lead to early well abandonment and unrecoverable hydrocarbons in a mature well. Oil recovery is the product of displacement efficiency (ED) and sweep efficiency (ES). Enhanced oil recovery (EOR) methods are focused on increasing either ED by reducing residual oil saturation or ES by correcting reservoir heterogeneity. Gel treatment and low salinity water flooding (LSWF) are two principle EOR methods. Each has limitations that can largely be avoided by combining the two methods. The objective of injecting nanoparticle gel is to reduce the volume of water produced with the oil, but it can also result in improved ES. This project proposes the development of a cost-effective novel EOR technology for extremely heterogeneous reservoirs by coupling the two technologies into one process. The ultimate objective of this project is to provide a comprehensive understanding of the combined technology and to identify where and how the technology can be applied most acceptably through laboratory experiments and field demonstration tests.

Sustainable and Efficient Catalytic Process for Oil Refineries

The aim of the project is to develop a new technique for the extraction of olefins, aromatics and sulfur compounds from gasoline produced by the catalytic cracking processes in the liquid phase. It also aims to develop an effective and selective material for extraction and to find out the optimum conditions for the extraction process.

In the first phase of this joint project between KACST and the University of Oxford, a new laboratory extraction technique has been developed to extract selectively olefins, aromatics and sulfur compounds from catalytic cracking of gasoline.

In the second phase of this project, a bench top pilot will be prepared for the extraction process, and catalysts will be prepared and their physical and chemical properties will be studied along with their activity and selectivity to benefit from the olefins and aromatic compounds extracted by their interaction with methanol and their conversion into fuel in the range of gasoline. The project will also look at the optimum conditions and selective material for extraction.

Direct Selective Oxidation of Light Alkanes to Oxygenates

The project aims to develop catalytic processes for the direct selective oxidation of light-hydrocarbons to oxygenates. The activation/oxidation of small alkane molecules originating from natural gas or renewable resources continues to be interesting and important for both academic research and industrial production, since the direct utilization of these abundant and cost-effective hydrocarbons offers suitable and sustainable pathways to higher value chemicals and fuels. Novel catalysts will be developed based on catalytic particles on nanostructured supports. The preparation of the nanostructured supports and the synthesis of the catalysts will be studied and the catalysts characterized in details by a range of physico-chemical techniques, to achieve a fundamental understanding of the parameters controlling the generation of the active materials. The catalysts will be evaluated systematically for selective oxidation of methane and ethane over a wide range of reaction conditions using various oxidants in both continuous and transient reactor systems. The effect of reaction conditions will be investigated extensively to establish the optimum parameters for the highest yield and the highest selectivity towards oxygenates production.

Converting Bunker Oil, Vacuum Heavy Residue and Crude Oil into Olefins

Heavy oil or vacuum residue is complex, black in color, highly dense, and extremely viscous in nature. These materials contain high amounts of impurities such as heteroatoms and large organic compounds like saturates, aromatics, resins, and asphaltenes, making it difficult to exploit in conventional oil refineries. This type of oil is found in large quantities in Saudi Arabia and all over the world. Converting this type of oil into high value chemical materials is a strategic goal for the Kingdom and for the world.

This project aims to develop an innovative technology for the conversion of heavy oil and refining residues in a one-step reaction, into light olefins (ethylene, propylene and butelene) using a catalytic cracking process. The research team at KACST is working to develop highly selective catalysts and to optimize the reaction conditions for converting heavy oil and refining residues into the desired compounds.

The low price of heavy oil and vacuum residue and the high economic value of the target products make this project very competitive compared to similar technologies in petrochemical industries.

Microwave-Enhanced Conversion of Crude Oil and Naphtha to Chemicals

The aim of this research project is to develop new petrochemical technology based on microwave-dielectric heating to convert the crude oil and naphtha to high-value chemicals, which will give the crude oil a competitive advantage compared to the other chemical feeds in petrochemical industries.

This project was launched in 1438H by KACST-Oxford Petrochemical Research Centre (KOPRC), which combines the unique capabilities and expertise of KACST and the Chemistry Department at the University of Oxford. The main scope of this joint project is to design and develop nano-solid based catalysts, as well as the development of a new or unconventional process assisted by microwave-dielectric heating for the selective cracking and dehydrogenation of crude oil into valuable light olefins, which can be used as basic and intermediate building blocks for the petrochemicals industries.

The outputs of this project can be utilized by many national stakeholders such as Saudi Aramco and SABIC, which will give a positive economic impact. Moreover, many job opportunities would be created for young Saudi citizens.

Novel Thin Film Alloys for Gas and Energy Applications

Every year, billions of Saudi Riyals are spent on capital replacement and control methods for corrosion infrastructure particularly in oil and gas energy sector at the Kingdom. This is due to the extreme operating conditions e.g. high temperature and pressure, and using high acid and alkaline concentration. As a result high corrosion rate is obtained and led to a swift damage to factory production lines hence increases the cost of production.

This project is aiming to provide a solution of corrosion in the infrastructure in oil and gas energy by producing novel thin film alloys that has a superior corrosion resistance. In the first phase, a technical solution will be developed to deliver superior protective coating compared to hard chromium, without using Cr+6 baths. Public and government agencies having already recognized the extremely harmful impact of Cr+6 in both human health and environment (cancers, respiratory problems, contamination of aquifer etc) have begun to enact legislations and regulations against hard chromium plating in order to protect public health and workers involved with handling chromium plating. Chromium plating results in toxic mist, and creates sludge containing high concentrations of Cr+6. The plating baths and rinsing tanks both contain large quantities of hexavalent chrome and their disposal contradicts to environmental restriction. The proposed coating is based on nickel salts. The use of nickel salts instead of extremely hazardous hexavalent chromium will relieve the electroplating industry from the health and environmental problems that the latter causes. In addition, the corrosion behavior of the electrodeposited MgB2 will be examined using indoor electrochemical measurement. Besides the Ni-P coatings reinforced with high modulus particles of MgB2 and tungsten oxide will be explored.

In the second phase, Electroplating technique will be used to produce a Cu/TiO2 metal matrix coatings and these would exhibit anti-microbial properties under indoor light due to photo catalysis and retard the growth of bacteria.

Development of Efficient Processes for Heavy Oil Utilization

The change in crude oil quality around the world has affected the petroleum-refining industry in such a way that current and new refineries are being re-designed to process heavier feedstocks. These new feeds are characterized by high viscosity, density, and boiling point, low API gravity, high amounts of impurities (sulfur, metals, nitrogen, asphaltenes) and low distillate yields, which make them more difficult in terms of production, processing and upgrading compared with light crude oils. Moreover, the extraction and refining of heavy oils generates as much as three times the total CO_2 emissions compared to conventional oil. Contrarily, the demand of light distillates for producing the so-called clean fuels is increasing throughout the world. These circumstances place not only refineries but also research centers, catalyst manufacturers and process developers in a great dilemma. They need to adapt and design future technologies for properly producing, processing and upgrading heavy oils. Processes for upgrading heavy oils can be broadly divided into carbon rejection processes (such as coking, visbreaking, and other processes such as solvent deasphalting) and hydrogen addition processes (such as hydrotreating, hydrocracking, hydrovisbreaking and donor-solvent processes). Carbon rejection redistributes hydrogen among the various components, resulting in fractions with increased hydrogen/carbon ratios and fractions with lower hydrogen/carbon atomic ratios. On the other hand, hydrogen addition processes involve reaction heavy crude oils with an external source of hydrogen and result in an overall increase in the hydrogen/carbon ratio. The current technologies of heavy oils conversion into more valuable products, including many processes with different characteristics such as thermal cracking, FCC, hydrocracking, gasification and so on, enabling the effective utilization of heavy oil. However, these technologies are still facing some technical challenges, which make them very expensive, such as the high content of sulfur and nitrogen, over cracking, coke formation, and low yields of the desired products. The research team in this project aims to:

- Develop new methods for heavy oil extractions.
- Explore novel processes and robust catalysts for upgrading of heavy oil.
- Synthesize an efficient catalyst with appropriate support to remove sulfur in the ultra-deep hydrodesulfurization of fuels.
- Reduce CO_2 emissions produced from heavy oil processes.

New Technology to Produce Hydrogen from Heavy Oil for Fuel Cell

This project depends on the development of a specific process for the production of hydrogen through the cracking of crude oil, heavy oil or heavy hydrocarbons, using microwave technology. In the first phase of this joint project between KACST and the University of Oxford, a process was developed to produce hydrogen from heavy hydrocarbons and was published in the journal of Nature.

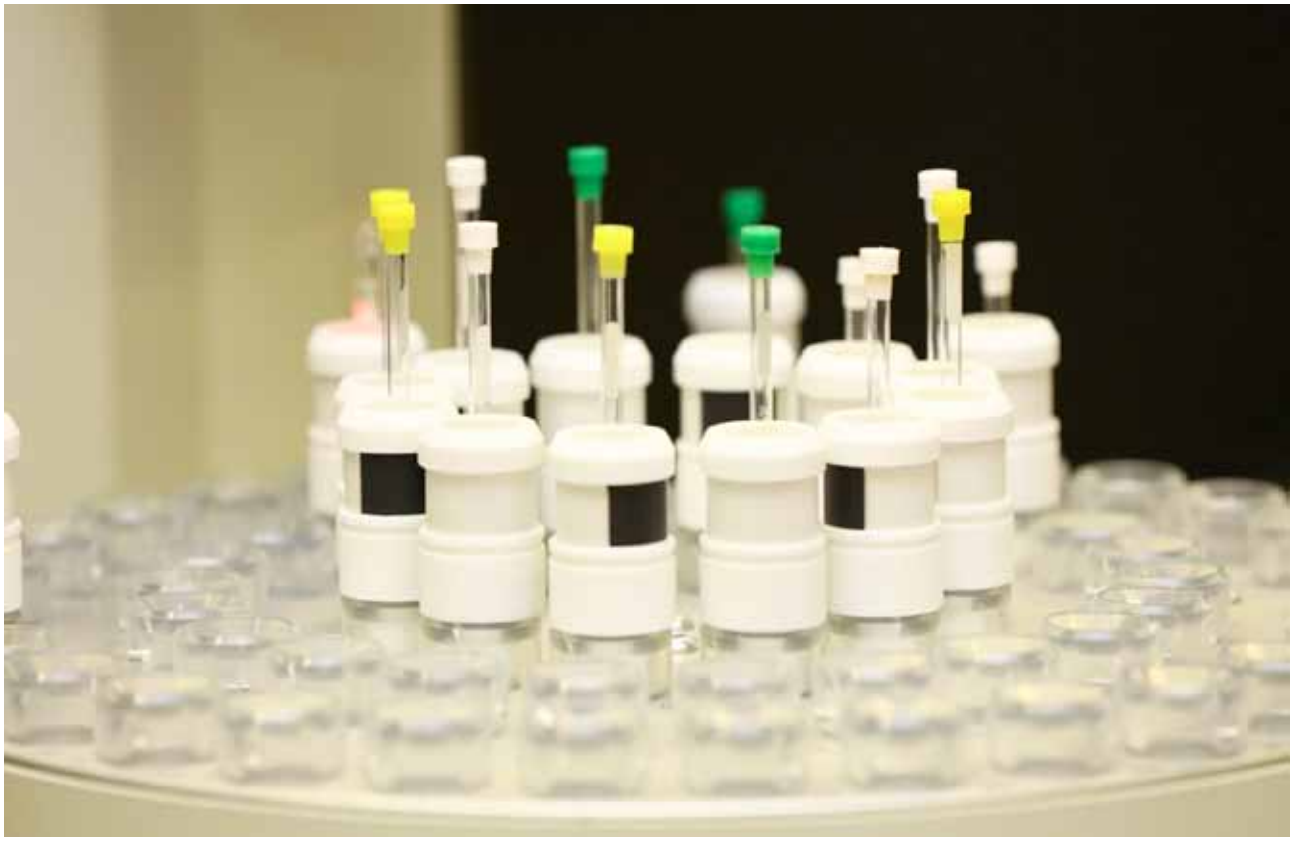
The aim of the second phase of this project is to design and construct a reactor based on microwave radiation for localization of this technology to produce high-purity hydrogen in large quantities from crude oil. In addition, the project will aim to develop catalysts and test their activity and selectivity in the cracking process of crude oil using microwave radiation and to find out the optimum conditions of pressures, temperatures and proportions of the reactants in order to simulate industrial processes.

In this stage, equipment and materials needed to design the microwave reactor and to build a bench-top pilot plant have been secured, in addition to testing the catalysts and studying the properties of the crude oil.

Fuel Additives for the Production of High Efficiency Clean Fuel

The project aims to develop effective catalysts and new technology to produce environmentally friendly additives as alternatives to those currently used in gasoline and to produce efficient, pollutant-free, clean fuel. In this project, equipment and materials have been prepared. In addition, a laboratory bench-top pilot plant was installed and calibrated to test the catalysts in a gas phase using continuous flow fixed bed reactors. Some types of catalysts have been prepared and tested under different variable conditions to produce fuel additives with high conversion.

The catalyst is environmentally friendly and the conditions of its use in the process of producing clean fuel is efficient, economical, easy to prepare and handle, and not corrosive compared with other commercial catalysts. The additives are free of oxygen compounds, which improve the combustible characteristics of fuel and reduce its consumption and emissions of harmful gases and pollutants to the environment. It also performs better than the additive currently used in the market.



Nano Materials for Clean Energy Applications

In this project, different classes of crystalline porous solids, metal-organic frameworks (MOFs), covalent-organic frameworks (COFs), and zeolitic imidazolate frameworks (ZIFs), were designed and synthesized to develop solutions to challenges in renewable and cleaner energy. The new crystalline porous frameworks have high surface areas (2,000-10,000 m^2/g) with unique chemical, physical and mechanical properties. The research team's activities can be summarized as follows:

- They have successfully synthesized metal-organic frameworks (MOFs) with high chemical flexibility, by introducing various and multivariate functional groups to their interior. We are undertaking efforts to design MTV-MOFs for potential use of gas storage, which showed its ability for gas storage with good efficiency.
- The selective capture of carbon dioxide in the presence of water is an outstanding challenge, because the CO2 adsorption process is competitive to adsorption of water in a flue gas. To overcome this challenge, there are two strategies; one is to introduce chemisorption sites into the framework, another is to make hydrophobic pores to exclude water from the pores. The team's efforts are devoted to synthesize noble porous solids that enable high efficiency carbon capture and regeneration with minimum energy inputs.
- Methane is the main constituent of natural gas; however, the catalytic conversion of methane to useful feedstock chemicals (such as acetic acid and methanol) is a long-standing challenge. The team believe that a catalytic system combining the high activity of homogeneous catalysts and the ease of use of heterogeneous catalysts is a promising strategy to realize gas-to-liquids reactions with high efficiency. To this end, the team is undertaking efforts to synthesize a new type of heterogeneous catalysis, where metal nanocrystals are embedded in single nanocrystals of MOFs. They are also anticipate that such core-shell type materials are helpful to elucidate the mechanism of catalytic reactions.
- To synthesize MOFs for practical applications (e.g. storage), a large quantity of materials are necessary. The team has synthesized 100-1Kg of MOF materials.

Advanced Materials

- Polymers
- Silicon
- Carbon Fibers
- Alloys
- Composite Materials

Technology Transfer and Localization

Advanced Materials

KACST plays a leading role in many fields related to materials science and its strategies and seeks to transfer modern technologies in this sector and localize them in the Kingdom.

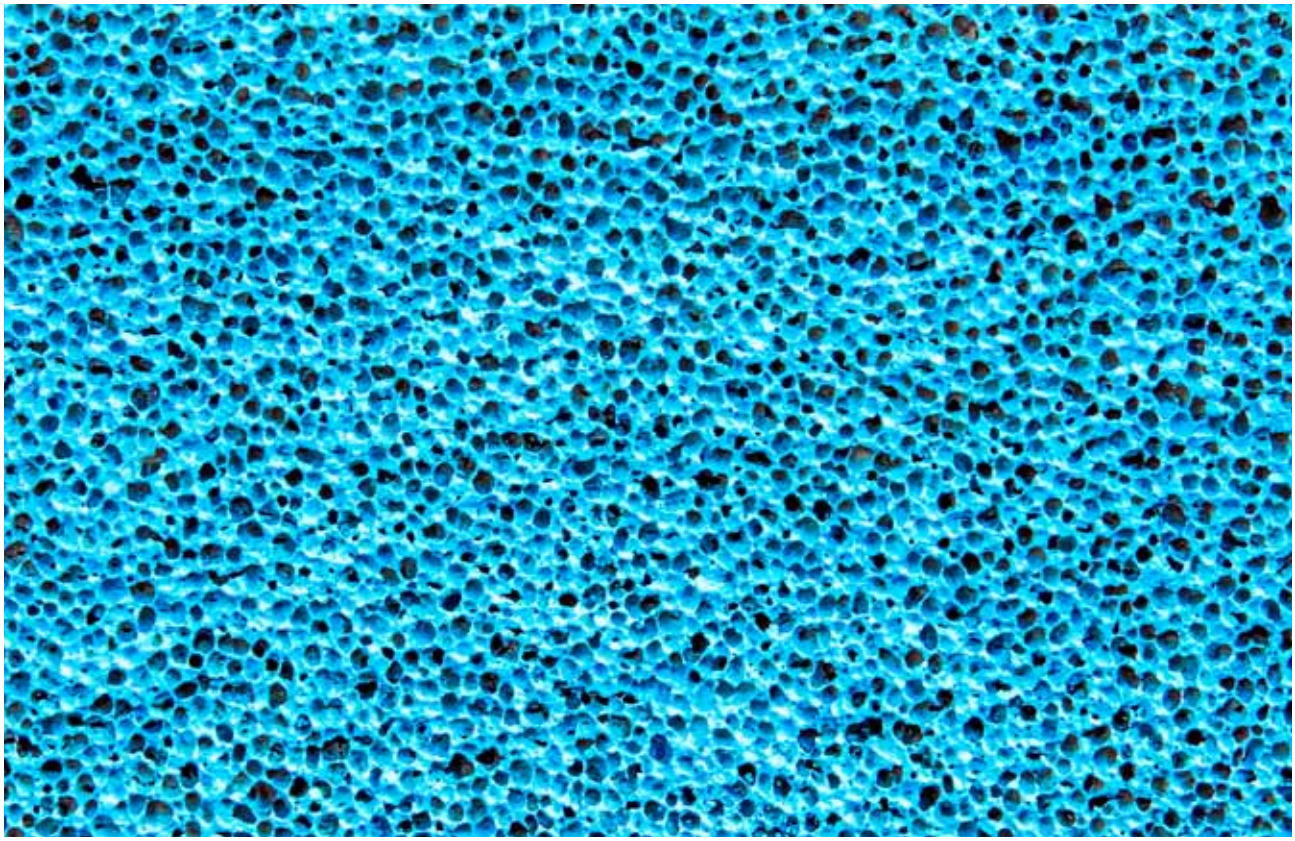
Introduction

KACST has realized the importance of materials science and its wide and promising applications in all industrial fields. Through the Material Science Research Institute (MRSI), KACST has worked on promoting research and development in many fields related to this sector, equipping laboratories, constructing infrastructure, and developing cooperation with various local and international scientific centers, with the aim of developing new technologies that contribute to the Kingdom's economy and enhance its competitive position in this sector.

The institute plays a leading role in supporting the advanced materials technology, which links the structure and the composition of the internal material with its properties and uses.

Non-destructive tests were carried out at the MSRI which enabled researchers to identify the structure and characteristics of materials and to investigate the defects within them, so as to be able to improve their properties. This facilitates the development of technology, and the ability of materials and facilities to perform required functions during their service and operation.

The institute also aims to conduct research related to the petroleum and petrochemical industries which depend on the exploitation of natural resources in the Kingdom. It will monitor the progress of refining and petrochemical operations in order to support the industrial infrastructure and enhance self-sufficiency in research and development in the Kingdom. The institute plays a leading role in conducting joint research to find innovative technical solutions in the field of construction technology, that can help meet local and global demand. It also conducts national and applied research in areas where nanotechnology can be employed to develop various sectors such as energy, water, and telecommunications.



Porous Materials – Organocatalysis and the Sequestration of Trace Elements from Seawater

The modern day conveniences such as consumer devices and electric vehicles created an increasing demand for electrical energy production and storage systems. Those systems in turn have created a demand for a variety of elements including lithium, uranium and rare earth metals, which are used in lithium-ion batteries, nuclear power plants and solar cells respectively.

The demand for these elements is presently met by mining ore deposits in the Earth's crust. However, this approach has several drawbacks:

- The distribution of mineral resources is uneven, some of which is located in difficult-to-access regions.
- The industrial-scale extraction and processing of ore has a substantial negative impact on the environment.
- The available deposits of some scarce elements may not be sufficient to meet the increasing demands.

The oceans contain an enormous quantity of dissolved elements (including lithium, gold, silver, and rare earth elements) representing a possible alternative source for these industrially important resources. However, the concentration of the most valuable elements in seawater is low, and thus, large amounts of water must be processed to recover sizable amounts of these elements. This project aims to find economically feasible solutions to enable harvesting those valuable elements from the oceans.

The efforts, thus far, resulted in developing antifouling membranes for water desalination, porous materials for lithium-ion batteries, and highly stable nano-porous coordination polymers. Those materials can potentially be adapted to develop filters that selectively capture elements such as lithium from seawater.

Developing and Producing Exfoliated Graphite

Exfoliated graphite is chemically stable in severe environments, and has many other desirable chemical and mechanical properties rendering it ideal for composite material applications that relate to thermal barrier and charge storage devices. In the recent years, it has received attention as a filler in composites due to the prominent properties it imparts to the host polymeric matrices.

This project aims to develop and construct a joint facility between KACST and an international partner for producing exfoliated graphite at low temperatures with a production capacity up to 1kg per hour. The project consists of the following phases: creating preliminary and detailed engineering designs, procuring and developing the required equipment, conducting production tests to model the relationship between the production conditions and various properties of exfoliated graphite, delivering the equipment to KACST campus, installing, commissioning and providing the required training to produce the final product as per the required properties, capacity and energy consumption limits.

Production of New, Value-Added and Environmentally Friendly Polymers

The growth of polymers industry over the last two decades was fueled primarily by novel applications polymers made possible due to their low cost, high specificity and adaptability. Polymer products can be lightweight, hard, strong, and flexible, and can be designed to have special thermal, electrical, or optical characteristics.

Innovation is expected to drive future growth and continued economic prosperity in a polymer-based economy. The intent of this project therefore is to produce a variety of polymers for use in a wide range of applications. This projects consists of six subprojects: (1) development of post-metallocene catalyst, (2) development of advanced polymer composites for sensing applications, (3) preparation of polymers containing TiO2 pigments, (4) development of methods for noble-metal-free alkanes-oxidation to economically valuable fine-chemicals and polymers, 5) production and recycling of high quality graphene for energy storage applications.

Production Line of 800 Tons of Silicon

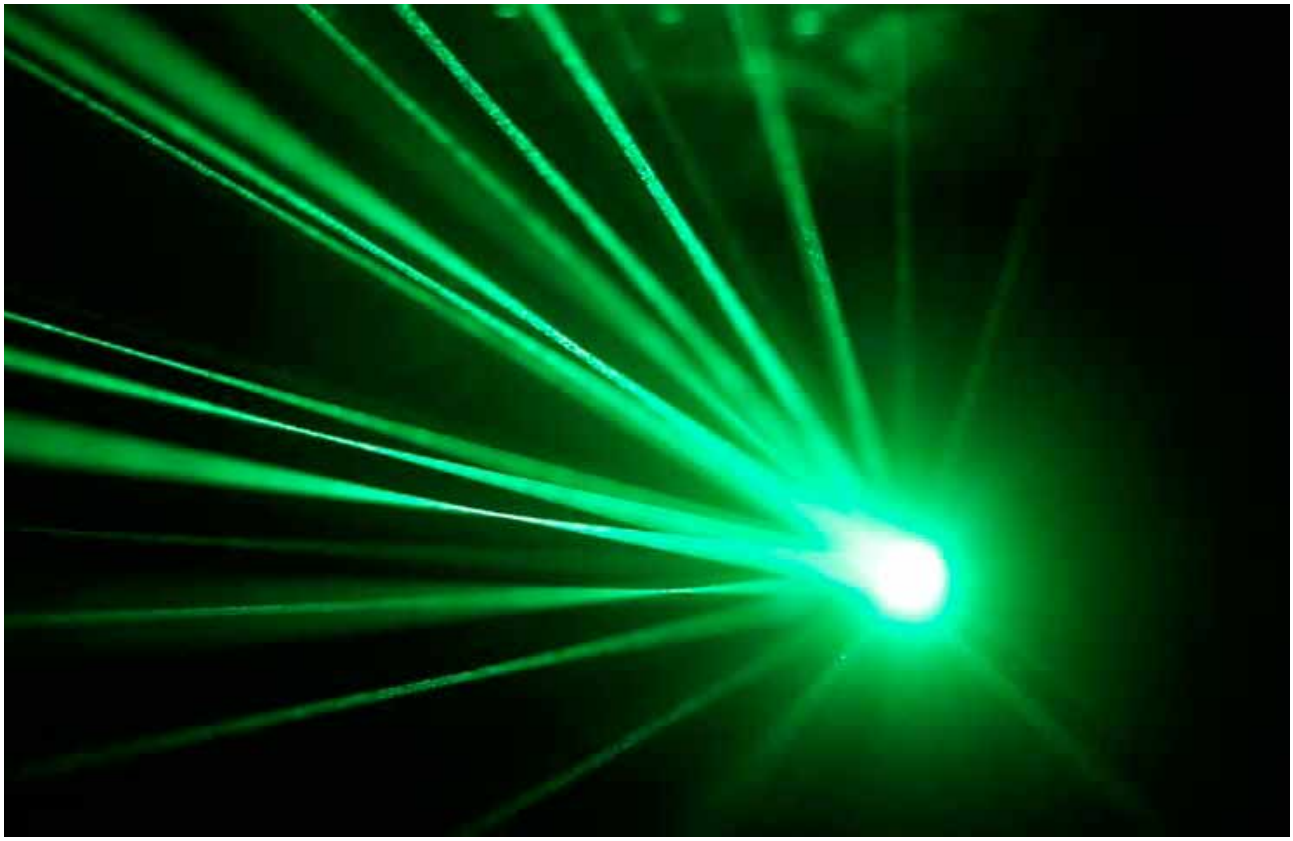
This project aims to establish a pilot plant to produce Silicon with a capacity of 800tons per year as part of a strategic collaboration with the Saudi mining company (Ma'aden) located in Ras Al Khair city. This plant will be designed to convert industrial waste from Ma'aden's phosphate factories, which represents a challenge to the company, into high purity Silicon, then to wafers used in the manufacturing of solar cells. This project is expected to span a four years period and to consist of two phases:

- Phase 1: Pure Silicon production from phosphate waste.
- Phase 2: Production of sufficient quantity of Silicon wafers to generate 120MW of electricity.

In addition, the project includes the development of a bench scale laboratory at KACST to produce Silicon with a production capacity of 10 tons per year. This laboratory will be used to train KACST employees to run the pilot plant, and to plan ahead and be prepared for operations problems. Moreover, this laboratory will enable further research in this field and will enable the experimentation with alternative products that are cheaper to produce than Silicon.

SRI Silicon Production Technology Transfer to KACST

The project aims to benefit from the transfer of SRI's technology in Silicon production from the SiF4-Na reaction and utilize it in the manufacture of solar cells at KACST. The program is divided into two main phases. The first phase aims to transfer SRI's technology, and laboratory experiments, whereas the second phase targets manufacturing. In the first phase, SRI will share the process of solar cell manufacturing. It will provide a detailed documentation of the chemical processes, the raw materials used in the manufacturing process, and the reactor used to conduct the chemical reaction. It will train KACST researchers on the technique of injecting the reactor with Sodium, and on the role of pressure and temperature control during this process. The main objective of this project is to transfer this technology to KACST, to apply it and to utilize it effectively. After the completion of the first phase, a group from KACST and SRI will develop a time plan and set targets as well as the estimated budget for the second phase. The second phase will involve the design and manufacturing of the pilot plant - to include a Sodium storage plant and reactor - and the process of separating the materials resulting from the reaction.



Photonics Integration Into Silicon

This project aims to obtain high quality GaAs thin films grown epitaxially on Silicon. This will help integrate optoelectronic applications to Silicon substrates. There are several major challenges that must be overcome. First, a very high density of dislocations are usually introduced at the interface stemming from the high lattice mismatch (4% for Si), which induces stress and cracking problems. These problems exacerbate by the large mismatch in the thermal expansion coefficients between Si and GaAs. Furthermore, as Si is a nonpolar semiconductor and GaAs is a polar semiconductor, the growth of GaAs on Si leads to high density antiphase domain formations.

The project concentrates primarily on the epitaxial growth and characterization of compound semiconductors, such as GaAs, on Silicon substrates. The objective of this project is to successfully realize high quality single-crystalline III-As epifilms on Silicon, yielding high performance and cost-effective light sources, such as light emitting diodes (LEDs), lasers, operating in the range of the important telecommunication wavelengths.

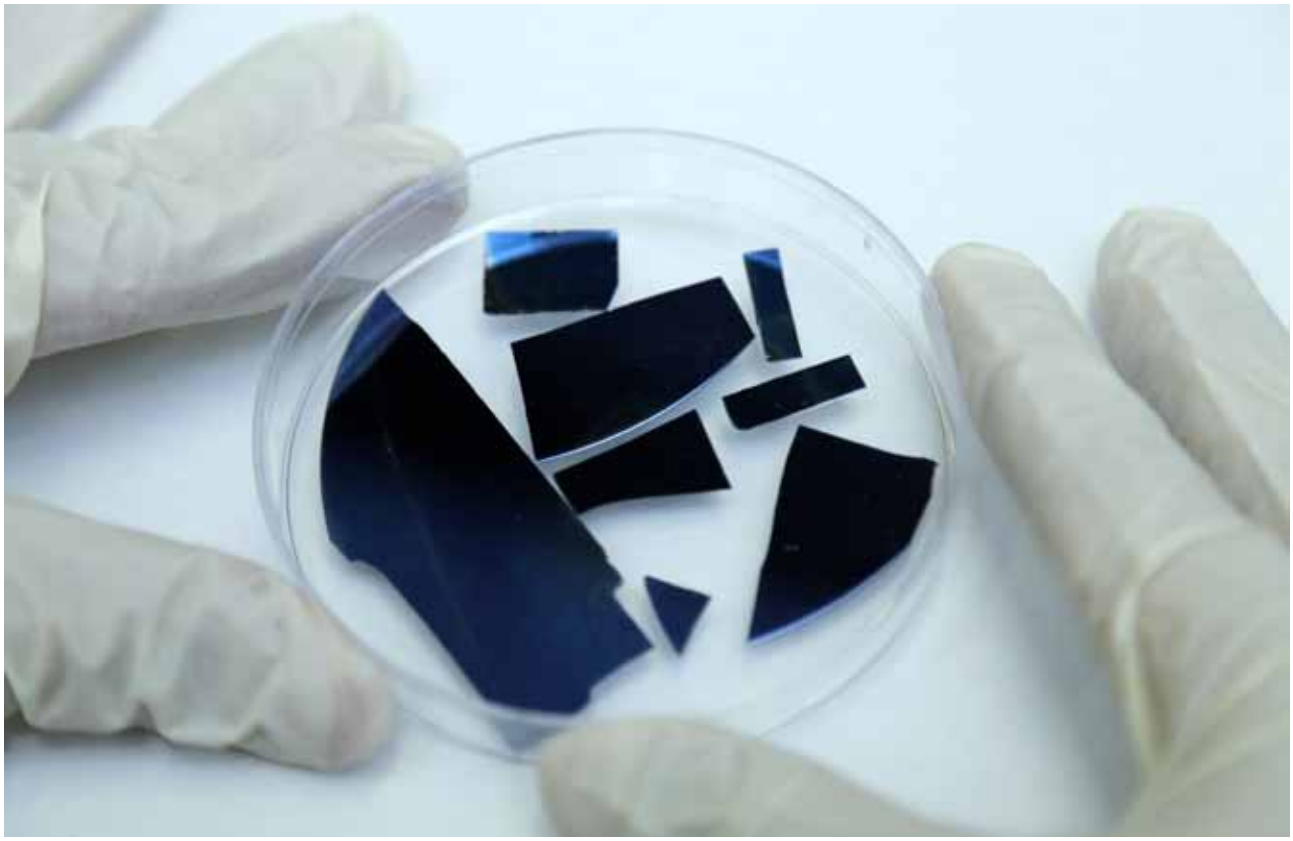
Development of Metal Oxides for Perovskite Solar Cells

Renewable energy technologies, especially solar cells, are expected to dominate in the future and complement fossil fuel technologies. Currently, cost is the main challenge towards competitive energy production using solar cells. However, Perovskite solar cells are very attractive because of their high absorption properties and low cost.

The objective of this project is to develop solar cells with efficiency exceeding 20%. A detailed study of the optical, chemical and electrical properties shall be performed to understand how these cells operate, so that better solutions are explored in order to enhance the cell performance.

One of the most important features of these cells is their reliability and stability, which guarantees proper operation under normal conditions. The stability can be further improved by adding non-organic materials to the organic materials that constitute the Perovskite films.

Another target is to develop lead-free environmentally friendly Perovskite solar cells.



Development of Equipment for Synthesizing Carbon Nano-Tubes

Carbon Nano-Tubes is chemically stable in severe environments, and has many other desirable chemical and mechanical properties rendering it ideal for composite material applications that relate to construction, petrochemical, military and aerospace industries.

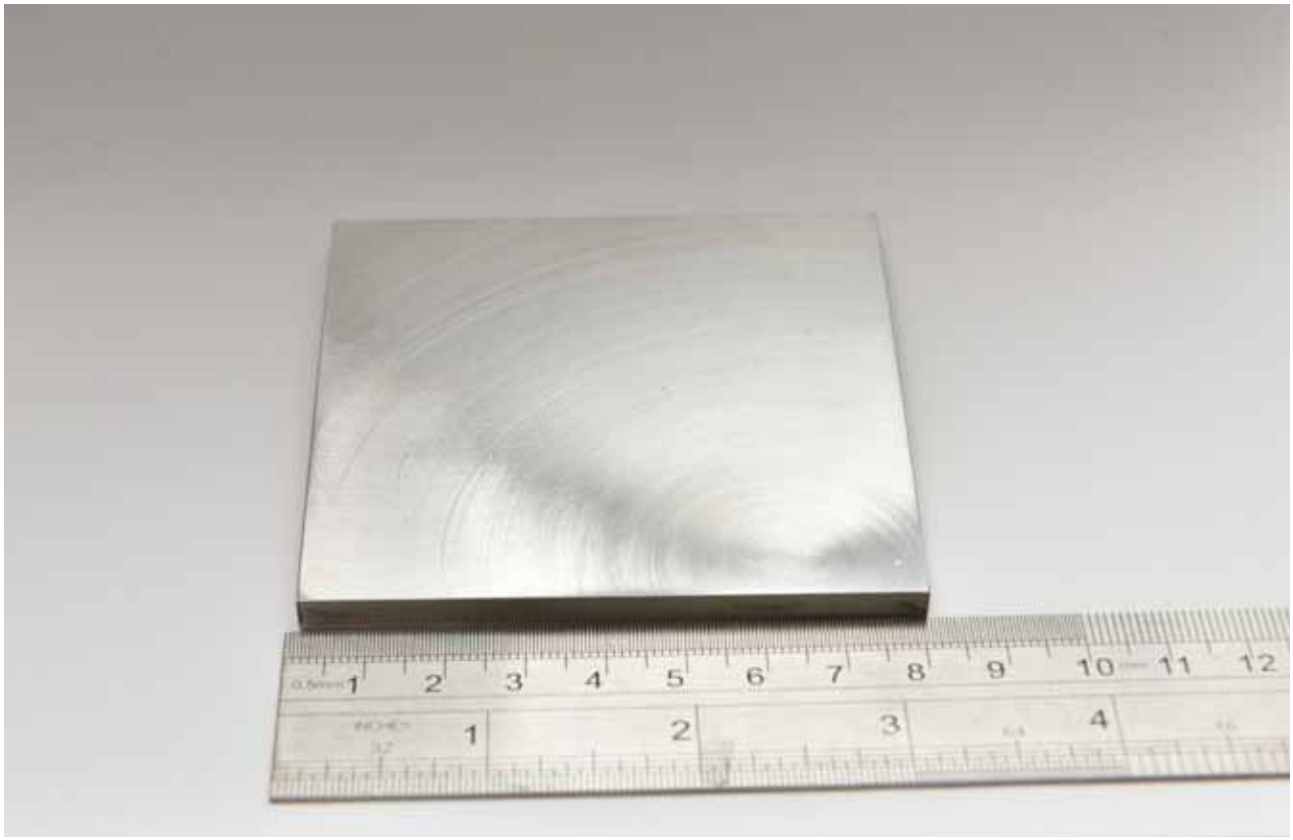
This project aims to develop and construct a joint facility between KACST and an international partner for producing Carbon Nano-Tubes with a production capacity up to 1kg per hour. The project consists of the following phases: creating preliminary and detailed engineering designs, procuring and developing the required equipment, conducting production tests to model the relationship between the production conditions and various properties of Carbon Nano-Tubes, delivering the equipment to KACST campus, installing, commissioning and providing the required training to produce the final product as per the required properties, capacity and energy consumption limits.

Developing and Producing High-Performance Carbon Fiber

This project is a collaboration between KACST and Clariant Inter Ltd Co. to develop and operate two identical pilot plants, one in the Riyadh area and one near Frankfurt, for the manufacturing of Carbon Fibers (CF) with a production capacity up to 1kg per day. Manufacturing processes include: polymerization of Acrylonitrile, spinning of Polyacrylonitrile yarn, carbonization and surface treatment.

Deliverables achieved in the first phase of this project include detailed technical and engineering plans that cover all manufacturing steps, equipment design and manufacturing, and production of carbon fiber with tensile strength 2.7GPa, tensile modulus 270GPa and diameter in the range of 7 to 9 microns.

In the second phase of this project, KACST and Clariant will work on installing and commissioning the CFT pilot plant located in Riyadh. The properties of the targeted CF that is going to be produced in this project are: tensile strength close to 4.2GPa, tensile modulus 220GPa and diameter between 7 to 9 microns.



Developing and Producing Metal Matrix Composites

The objective of this project is to develop and produce light metal matrix nanocomposite (MMC) bulks and coatings with high mechanical properties and ability in forming, machining and welding.

Aluminum alloy, Al5Mg, and titanium alloy, Ti6Al4V, will be selected as matrix, whilst the reinforcement choices will cover CNT, CF, and Al2O3 for Al5Mg and SiC, hydroxyapatite, Al2O3, and TiC for Ti6Al4V.

Powder metallurgy will be used to produce these nanocomposites. It is well-known that composites properties depend primarily on the characteristics (volume and size) and dispersion behavior of the second phase particles. Therefore, this project will concentrate on the reproducibility of the targeted composites. The targeted product is plates in shape, with a size in the range of 30cm x 30cm x 5cm. A detailed proposal covering this project has been submitted and is expected to be supported within the coming year (2018).

Metal matrix composites play major roles in material technologies that are related to numerous applications including energy, petrochemical, military, aerospace and aeronautics.

Developing Polymer Matrix Composite Reinforced with Carbon Fiber

The objective of this project is to develop and produce a Polymer Matrix Composite (MMC) reinforced with carbon glass fibers. The light-weight potential and the mechanical properties such as the structural stability, the load and impact resistance, and the reduced deterioration have to be improved regarding the demands of industries such as the automotive, aerospace, and wind energy industries. A comprehensive materials characterization, understanding, and improvement of the fiber-matrix interaction are key issues to improve the mechanical properties. This indicates that a faster and more efficient choice of favorable materials combinations and a better transferability to other applications and new technological areas can be accomplished. This project will involve developing and producing different components used in aircrafts (e.g., stringer) and an Airtrike with CF reinforced thermoset matrix. This project consists of several steps including the definition of the specification of a component, selecting carbon fibers and resin monomers, developing and optimizing the interaction between carbon fibers and resins, optimizing the infusion process, and manufacturing the targeted component. A detailed proposal has been submitted and expected to be funded by 2018.

Development of Composite Materials for Fire Resistance

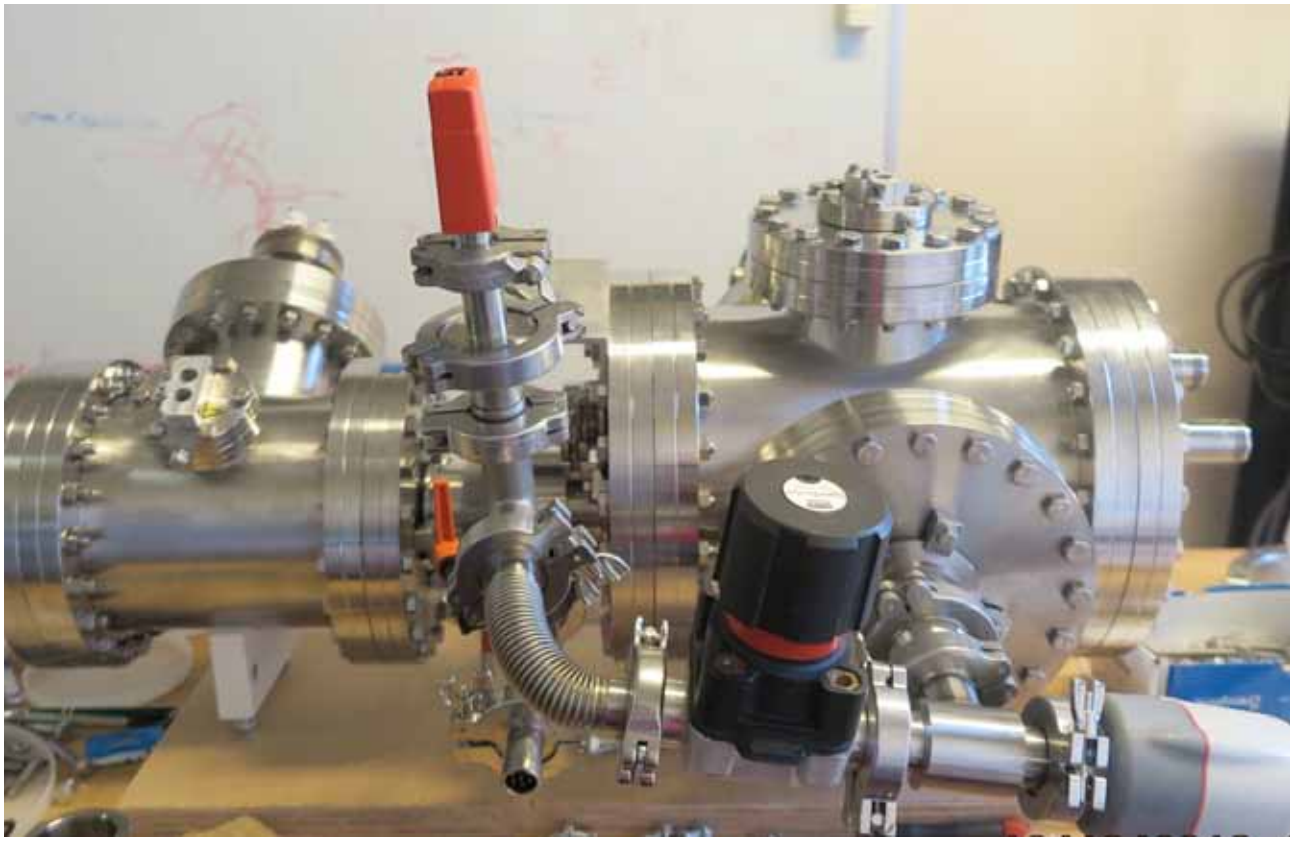
Ultra-High Temperature Materials (UHTM) are important for many applications ranging from spacecraft's to nuclear reactor's wall protection shields. These materials can sustain high temperatures ranging from 1000 to 3000°C with high chemical, mechanical and thermal stability. The importance of UHTM applications and their high demand drove an increase in research and development activities aiming to find competitive manufacture methods for UHTM.

The project aim is to create composite materials with high stability at UHT and deposit them on substrates such as graphite and Silicon wafers. Those materials maintain their chemical, mechanical and thermal properties, and maintain their shape without oxidation or corrosion under UHT conditions. In this project, cutting edge laboratory techniques are used to prepare materials such as Thermal Spray Coating and Photolithography, and to investigate their thermal and chemical properties. In addition, many types of materials such as polymers, metals and ceramics are used in order to achieve optimal results.

Advanced Applications of Porous Mineral Compounds

The project aims to design and prepare different kinds of metal pores for use in various industrial applications such as storage and production of clean energy, which is made possible by their distinctive properties compared to traditional materials. Storage of different types of gases is one of the promising applications for this technology. This makes the produced materials suitable for energy storage, clean energy production, and to capture and store greenhouse gases. Moreover, it has been found that there is a harmony between the optical, electronic, mechanical and chemical properties of Nano-particles, which makes them suitable for addressing a number of problems related to energy conversion.

The project studies the fundamental properties and applications of Nanocrystals, and in particular, the preparation of high quality Nanocrystals to be used in several applied fields. The physical, chemical, electrical and thermodynamic properties of those materials depend on the size and the crystalline form. This project, therefore, studies different methods for automatic and precise testing of the associated chemical and physical properties of Nano-particles.



AB-Initio Material Surface Investigation

This project aims to develop a high-resolution mass selection technique known as quadrupole mass filter. The apparatus is used to accumulate ions and cool them by collisions before being injected as packets into the electrostatic storage ring. The system consists of an ion source, a quadrupole mass filter, a special pulsed gate valve (aerodynamic chopper) and an Hexapole trap. This technique allows users to conduct experiments with large molecules used in medicine, medical diagnostics, and in atomic and molecular physics.

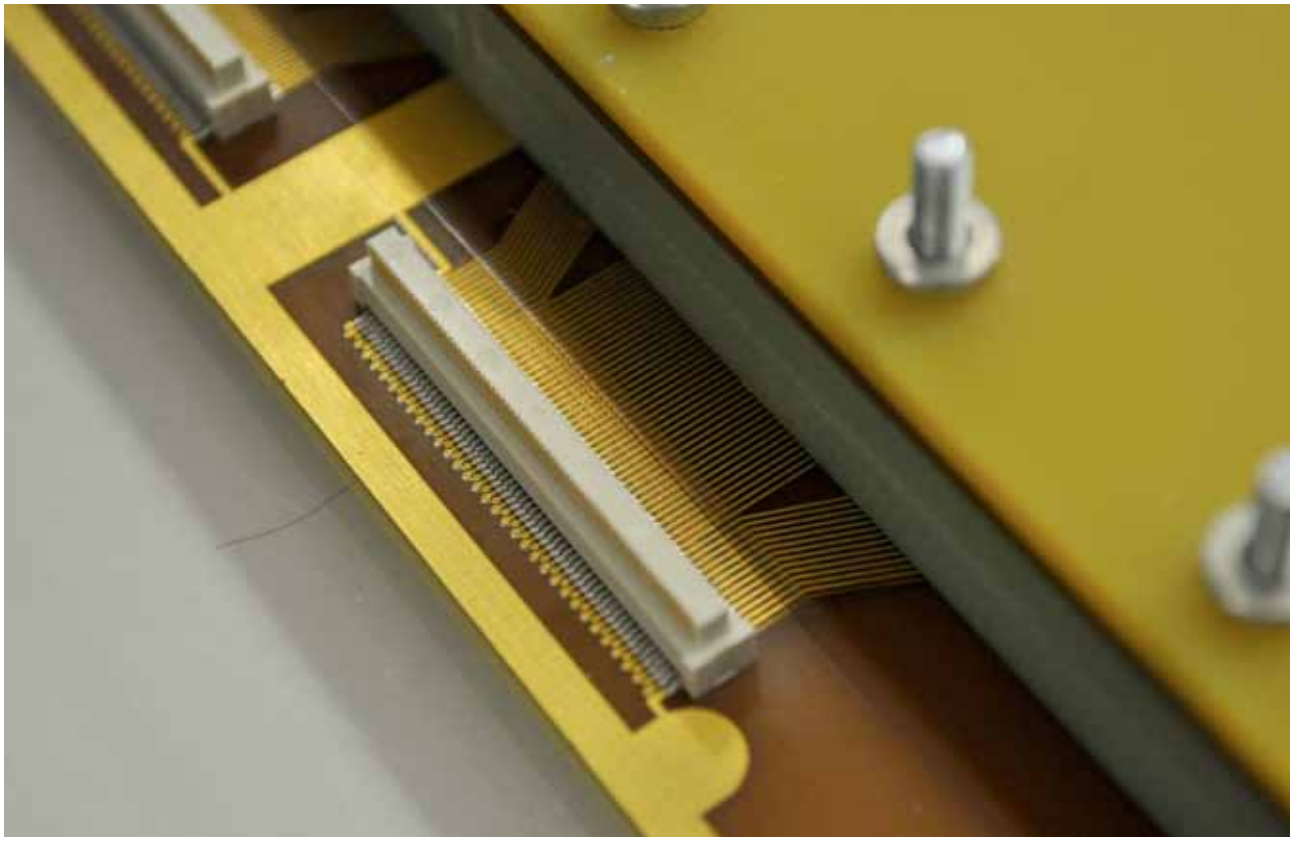
Due to the limitations of many current technologies in X-ray imaging, their usage has become restricted. For example, in order to obtain an image with a reasonable resolution, a high rate of X-ray flux must be used. On the other hand, a gas electron multiplier (GEM) detector, which is a branch of micro pattern detectors technology, is one of the promising tools in this area. It allows for high spatial resolution; up to 50micro meter. Hence, the goal of this project is to design and build a GEM system for medical imaging applications.

High Performance Infiltration Grown Bulk Superconductors

Superconductors are special materials that conduct electricity with zero Ohm resistance at very low temperatures, and thus has the potential to generate higher uniform magnetic field than that generated by the conventional permanent magnets.

There are various sustainable-engineering-applications applicable in Saudi Arabia, e.g., reducing the cost of connecting electrical generators, since superconductors can replace the conventional parts of the generators.

In this project, superconductors are grown by infiltration rather than melting to have more control over the physical properties of the fabricated superconductors. This approach has overcome the main disadvantages of melting fabrication; namely, the presence of porosity and shrinkage on the fabricated bulk superconductors. This project aims to develop two superconductor materials, YBCO and MgB_2, each having unique properties such as weight, trapped field capability and configurability. In addition, the last stage of the project aims to use those superconductors to design and build a magnetic separator.



Comprehensive Advancements of the Properties of Advanced Materials

In this project, theoretical and experimental methods are combined to develop advanced materials along with their applications. Gas-based sensors became global and domestic research targets due to the broadening of their applications in industry, environment and health.

The aim is to manufacture and develop gas sensors utilizing spin degrees of freedom using spin transistors. By controlling the spin in these materials, the expected applications can be expanded to include quantum computing and quantum information.

The other part of the study focuses on simulation and modeling techniques to improve material properties. Materials modeling using density functional theory (DFT) is possible because of the rapid advances in computers and simulation software. The strategy is to use DFT to develop materials for various applications such as solar cells, spintronics and gas sensing.

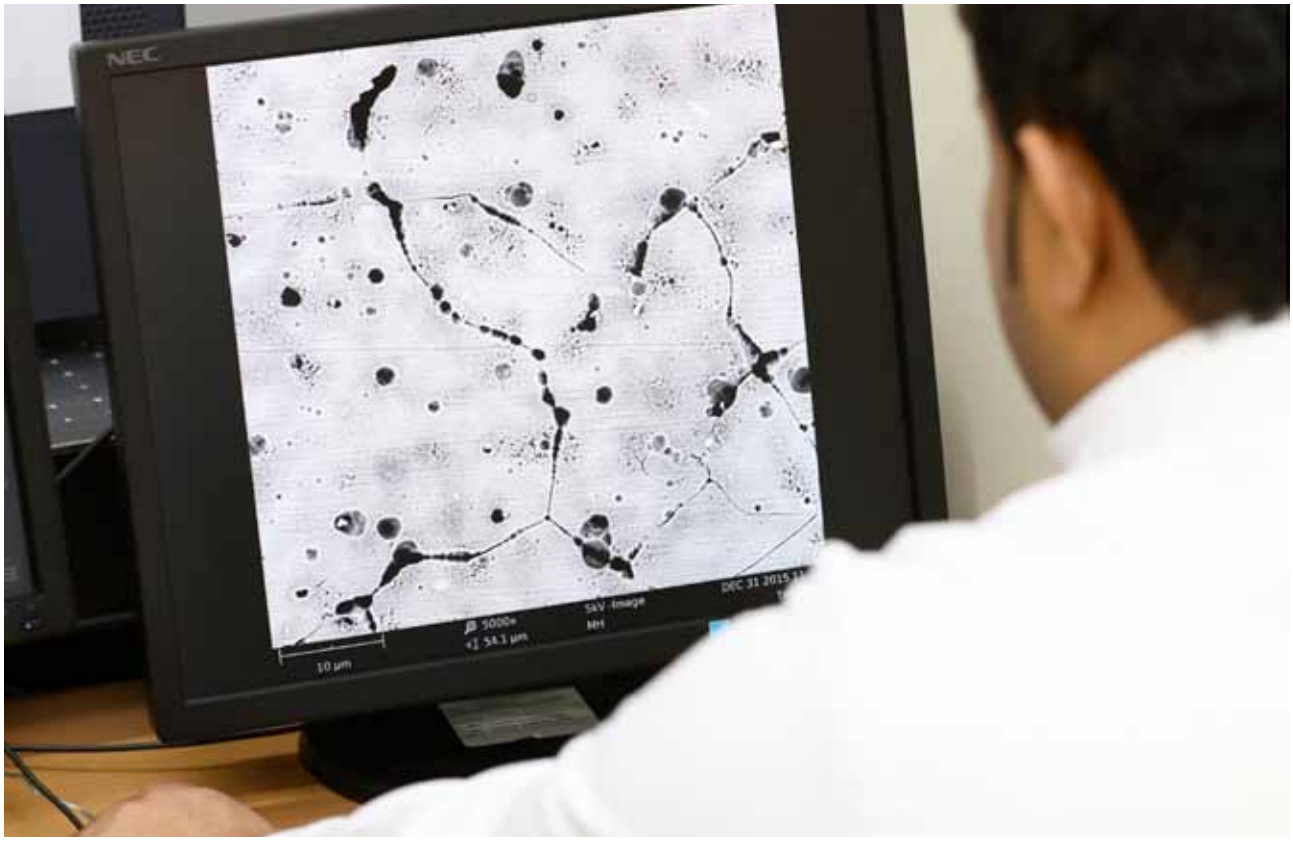
Accurate description of materials based on the theatrical studies can be used to infer appropriate models matching experimental results, which saves time and effort and reduces the cost substantially.

Fabrication of a Solar Water-Splitting Device

The project aims to produce photo-electrochemical catalysts and use them to develop semiconductor electrodes to split water using solar radiation in the visible range. These electrodes would then be used to develop electrochemical cells to produce clean hydrogen gas from renewable energy sources.

The first phase is aiming to improve the efficiency of water splitting using a novel photocatalyst, which consists of gold nanoparticles impregnated on a titanium oxide nanotube in the visible range. This approach is expected to markedly improve water splitting efficiency on the surface of the catalyst.

The second phase is to fabricate electrochemical electrodes containing titanium oxide nanotube on a conductive surface through a bottom-up approach. The project aims to produce these electrodes using Physical Vapour Deposition (PVD) and Chemical Vapour Deposition (CVD). Electrochemical measurements will be used to examine the efficiency of the photocatalyst in the presence of visible light. The last stage is to design separation cells, considering all related engineering and technology aspects. The success of this project will enable the connection of those cells with other energy sources.



Industrial Applications of Phosphate and Bauxite Ores and Residues

Enormous amounts of red mud and phosphogypsum are extracted worldwide each year as byproducts of aluminum and phosphate production. The storage of this solid waste contributes to serious environmental issues. On the other hand, those solids can be recycled, which is the objective of this project, and fed into other industries as raw materials adding value to the economy and contributing to a sustainable ecosystem. Industrial residues hold significant value for the national economy despite being less valuable than metallic ores. The income yield of the total production of these materials in the United States is twice that of the income from metals. Several industrial technologies were selected to study the potential applications for these residues and ore materials. Suitable and valuable industrial products will be identified based on the chemical and physical characteristics of these residues. Laboratory experiments will be used to verify economic value and feasibility.

Quantum Well Laser

The principal aim of the Quantum Well Laser project is to train Saudi engineers to fabricate Quantum Well Lasers in local laboratories using the Molecular Beam Epitaxy (MBE) growth technique.

The MBE reactor uses high purity III-V materials to fabricate lasers, LEDs, sensors, solar cells, oxide thin films and etc. for real world applications.

The project involves equipping the Saudi engineers with the principles used in selecting laser wavelength, selecting the proper materials, and training them on the design, growing, and fabrication of laser devices. Some of the already achieved outcomes of this project include the fabrication of 630nm (red laser) laser devices by Saudi engineers in a laboratory at the Nottingham University, and the design of electronic circuits necessary to operate the laser at KACST.

Health

- Genetic & Inherited Diseases
- Infectious Diseases
- Stem Cell Technologies
- Nanomedicine
- Medical Devices

Technology Transfer and Localization

Health

The world has faced, during progress and development, many challenges in different fields including the health sector. Scientists and researchers have persevered to find effective treatments for many chronic and serious diseases.

Introduction

The percentage of Saudi local expenditure in the Health sector is estimated to be 35%, whereas expenditure on imports was estimated to be 65%. Improving the health sector will contribute to reducing SAR 400 billion over the next five years. Through the National Transformation Program 2020, KACST has provided an initiative to localize and develop technology within the sectors that have large local expenditure. This initiative includes the localization and transfer of health technology to support and enhance the local content in this sector with the aim of reducing health care costs and training and qualifying national human resources specialized in health-related fields.

The health initiative consists of a group of specialized technical projects as follows:

- The Saudi Human Genome, which is a personalized and preventive medicine that aims to reduce health care costs using genome technology. This project depends on the localization and transfer of the Next Generation Sequencing that detects and determines mutations causing inherited diseases in the Saudi population.
- Localization and development of a technical platform to detect infectious diseases. This project aims to establish a national database for infectious diseases in the Kingdom of Saudi Arabia, that will contribute to the detection and control of infectious diseases.
- Localization and development of Nanomedicine that aims to localize the manufacturing of Nano-particles that can contribute to the study of diseases and treatment.
- Localization and development of stem cell technology that aims to localize modern stem cell technologies to treat and control the common chronic diseases in the Kingdom.

The Saudi Human Genome - Personalized and Preventive Medicine

The Saudi Human Genome Program (SHGP) is one of the largest projects in the National Transformation Program 2020. It aims to transfer and develop genetic testing that will have a positive impact on public health and the national economy. This program depends on the transfer and localization of the next generation sequencing which is used to detect mutations causing inherited diseases.

The program has developed 13 gene panels covering over 5,000 inherited diseases. The SHGP has sequenced over 10,000 samples from Saudi patients with inherited diseases that resulted in the identification of more than 2,000 variants underlying these diseases. More than 500 of these variants were present in multiple patients and could be considered as “Saudi mutations”. The presence of these mutations in the Saudi population has resulted in a significant incidence of newborns with inherited disorders, having relatively high mortality and morbidity. The economic and social cost to the Kingdom resulting from these disorders is very high. Conservative estimates place the lifetime healthcare cost to the community resulting from these 500 or so “Saudi Mutations” at SR 6.4 billion annually. The Ministry of Health has for almost 10 years conducted a mandatory pre-marital screening program for Sickle Cell Anemia, thalassemia and communicable diseases. This has been delivered through a network of 127 collection centers, 94 laboratories and 117 genetic counselling clinics. Importantly, 60% of couples who were founded to carry sickle cell or thalassemia genes have decided not to go ahead with a planned marriage; thus, reducing the likelihood of having children with inherited disorder. On the basis of this experience, expansion of this genetic testing could result in the significant reduction of infants born with inherited disorders. Conservatively, operation of this program, based upon the experience with current screening, would result in annual savings of SAR 3.84 billion in healthcare cost. In addition to the almost immediate benefits of the program outlined above, the SHGP will result in diagnostics beyond inherited diseases (such as cancer, transplantation, and infectious diseases), more effective treatment and lower costs through personalized medicine (pharmacogenetics) and targeted therapies (cancer), which are all aligned with the goals of the National Transformation Program 2020 and Vision 2030.

Localization and Development of the Infectious Diseases Control Technology Platform

The importance of this project has emerged after outbreaks of some infectious diseases. It was necessary to establish a program for the localization and development of an advanced technological platform for surveillance and control of infectious diseases. In addition to several effective research programs for the diagnosis of infectious diseases and for bacterial and viral vaccines. This project harnesses KACST's enormous capacity in technical applications and networks to document and record information of infectious diseases surveillance and prevalence in the Kingdom, and facilitates direct access to information for specialists from within and outside the Kingdom.

Through the National Center for Infectious Diseases Laboratory, the program will provide a fertile environment for the development of epidemiological and basic research on communicable diseases. This can be done by providing advanced equipment used for molecular analysis in the research of infectious diseases such as PCR, ELISA, Whole Genome Sequencing, and other biological and molecular tools that will be available to researchers and trainees from across the country. The Center will have the Biosafety Level Three Laboratories (BSL-3).

This is in addition to the mobile lab Biosafety Level Three plus (BSL3+), which contains advanced equipment to detect pathogens and conduct all necessary molecular and serological tests in a short period of time. Via these mobile laboratories endemic places can be reached in order to collect and analyze samples, and send results to the central laboratory in KACST within a short period of time.

KACST is keen to provide a suitable environment for the development of research on infectious diseases. The program will provide an overview of the latest developments related to communicable diseases in the Kingdom, promote community public health related to communicable diseases and outbreak awareness, and create an environment for joint cooperation and exchange of information with relevant health laboratories in different regions of the Kingdom. This program will assist the governmental health agencies to interpret the results in order to improve their ability to make decisions, and execute scientific research and surveillance.

Localization & Development of Nanomedicine

This project aims to establish a Nanomedicine research laboratory to facilitate the localization and development of Nanomedicine in the Kingdom. It will provide promising solutions to manage unmet medical challenges through synthesizing the next generations of Nano-formulations that are safe and capable of delivering drugs with both high precision and efficacy.

The program aims to invent novel nano-sized approaches to control the biodistribution of loaded drugs when administered in-vivo through magnetization. In addition, the program aims to localize smart Nano-formulations for targeted gene therapy. Nanomedicine-based technologies can revolutionize the diagnosis and treatment of medical diseases. The Nanomedicine research laboratory will be established, supervised and run by a qualified scientific team that is multidisciplinary, coming from various science backgrounds such as medicine, biology, chemistry, material sciences and engineering. The Nanomedicine research laboratory will be responsible for initiating research collaborations with academic and industrial research centers in addition to recruiting and training the next generation of Saudi scientists.

Drug Delivery – Therapeutics and Theranostics

Many drugs have failed clinical trial testing as a result of high-toxicity or poor bioavailability, but these issues can be overcome by preparing formulations that can control drug release rate or improve the bioavailability of the active pharmaceutical ingredient. This project aims to investigate the possibility of using the non-toxic, biodegradable and environmentally benign porous material known as CD-MOF. This material is a metal-organic framework (MOF) that is constructed from cheap and readily available γ-cyclodextrin (γ-CD) and salts such as potassium chloride. Given the porous nature of these materials, the goals of this drug delivery project are: (i) develop pharmaceutically-relevant formulations with well known non-steroidal anti-inflammatory drugs, (ii) develop methods using CD-MOF to separate drug mixtures in order to recover the pharmaceutically-active version of the drug, (iii) investigate means by which to control the rate of release of drugs within CD-MOF, and (iv) prepare CD-MOF formulations of drugs that have previously been found to be unsuitable for clinical use and determine if these formulations improve bioavailability of these drugs.

Differential Protein Adsorption onto Surface-Modified Chitosan Nanoparticles

Studying the interactions of Nanoparticles (NPs) with serum proteins is necessary for the rational development of Nano-carriers. Optimum surface chemistry is a key consideration to modulate the formation of the serum protein corona (PC) and the resultant immune response. We investigated the constituent of the PC formed by hyaluronic acid-coated chitosan NPs (HA-CS NPs). Non-decorated chitosan NPs (CS NPs) and alginate-coated chitosan NPs (Alg-CS NPs) were utilized as controls.

NPs were synthesized and incubated with bovine serum to form the NP-protein coronas. Their size and charge were analyzed by a dynamic light scattering device. The associated proteins were identified by gel electrophoresis and liquid chromatography. The identified proteins were subjected to the (Uniprot GO) database to classify them based on their function. The charges of naked Nanoparticles were positive. However, adsorption of both polyanions (HA or Alg) reversed the NPs charge density from cationic to anionic. The results shows that HA significantly reduced protein deposition relative to both CS and CS-Alg NPs. Unique proteins were identified for each Nanoparticles. Such differential protein adsorption might determine the circulation fate of targeted Nanomaterial delivery.

Studying of Cellular Toxicity of Chitosan Nanoparticles

Nanoparticles offer important biotechnological applications including drug delivery. It is important to rationally design Nanoparticles with minimum in-vivo toxicity. This project studies the cytotoxicity of CHO-k1 cells treated with either chitosan Nanoparticles (CS NPs) or hyaluronic acid-coated chitosan Nanoparticles (HA-CS NPS).

Cells were exposed to varying concentrations of CS NPs and HA-CS NPS. Concentrations of 2.5 and 0.25 mg / mL of CS NPs showed a decrease in cell viability. An increase in the secretion of lactate dehydrogenase (LDH) was detected at such high concentrations. The mitochondrial membrane potential was compromised as well with a significant increase in the activity of caspase-3. Interestingly, treated cells showed a transient elevation of the (SOD) enzymes; later depletion of SOD was observed at high concentrations. The team of this project has found that the toxicity of chitosan Nanoparticles could be reduced when coated with hyaluronic acid. CHO-K1 cells showed no apparent toxicity when exposed to HA-CS NPS.

Localization of Stem Cell Technology

Scientists and researchers have diligently tried to find a cure for many diseases such as cancer, renal failure, diabetes and liver diseases. There are many medical discoveries that vastly helped in the development of many pharmaceutical and therapeutical paradigms. Interestingly, the discovery of stem cells has gained a lot of attention due to their promising capabilities for treating many incurable diseases.

Stem cells are unspecialized cells that have the ability to differentiate into specialized somatic cells such as liver, muscle, blood and other cell types with specialized functions. Stem cells are also characterized by their infinite proliferative properties and hence act as reparative machinery to replace dead and malfunctioning cells.

Stem cell research is now considered one of the most reckoned medical research aspects as scientists have successfully transplanted stem cells and enticed them to differentiate into specialized cells for the treatment of different disease conditions. These specialized cells may also be used in vitro disease modeling to study and discover the effects of different pharmaceutical compounds.

One of the forefront applications of stem cell therapy is cancer treatment. The mesenchymal stem cells natural ability to head towards and infiltrate cancer niche has allowed researchers to genetically modify them to secrete cell death proteins. For example, tumor necrosis factor that can selectively target cancer cells and thus not attacking healthy cells, adds more value to using stem cells as cellular vehicles.

KACST plays a pioneering and fundamental role in establishing research partnerships with several advanced research centers around the globe to reach innovative therapies for different diseases that are becoming more prevalent in the Kingdom such as diabetes, obesity, and cancer, by using applications of stem cells research that have attained unprecedented global attention. Therefore, KACST has founded a national center specializing in stem cell research - the National Center for Stem Cell Technology “NCSCT”. The NCSCT will drive advanced applied research in stem cell and regenerative medicine through the creation of partnerships with different national research centers with main focus on technology transfer and localization, in pursuit of Vision 2030.

Translational Stem Cell Research

This project aims to establish a national joint program among local research institutes that conduct stem cell research, into the treatment of incurable diseases in the Saudi community, by studying these diseases and utilizing stem cell technologies.

The project has led to the establishment of coordination between government agencies and research centers in the Kingdom, to prepare the laboratories and infrastructure. Bone marrow has been isolated from lab animals to study the efficiency of stem cells in enhancing bone healing.

In parallel, in order to achieve another objective of this project, somatic cells from humans and animals have been isolated and reprogrammed into iPS cells to be used in different applications including studying genetic diseases and establishing novel protocols to induce stem cell differentiation into different cell types.

Production of Molybdenum -100 for Medical Purposes

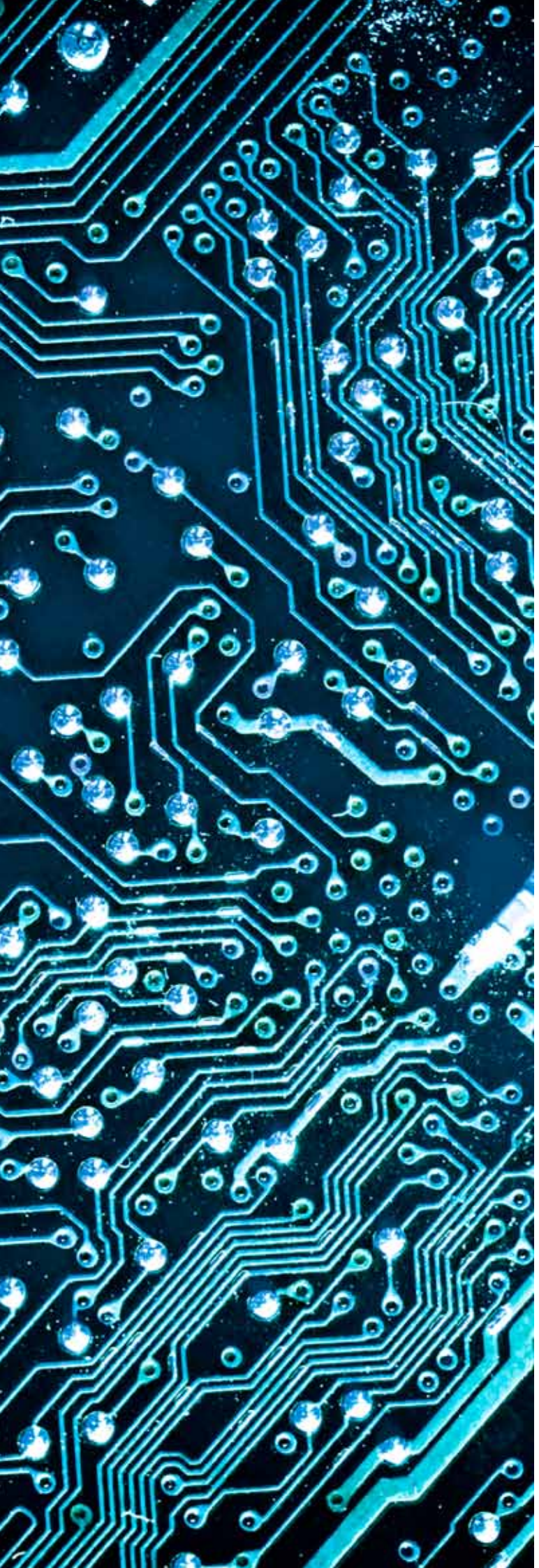
Technetium-99m is widely used for diagnosis and imaging in nuclear medicine, and can be produced by the cyclotron bombardment of molybdenum-100 targets. Therefore, within the scope of this project, molybdenum-100 targets will be produced and manufactured. There are three main stages to produce molybdenum-100 targets which are:

- Produce and manufacture raw materials.
- Enhance molybdenum-100 isotope concentration and purity.
- Molybdenum-100 deposition.

The above stages are well prepared, applying the latest technology along with the highest safety standards. The designs for these facilities have been proposed and the final cost of production processes has been estimated. The feasibility study has been conducted considering several laboratory experiments to investigate the main factors of molybdenum-100 production. Initially, 3 Kg of molybdenum-100 will be produced per year, which will satisfy the Kingdom's medical needs. The outcome of this project will benefit medical facilities operating in the fields of nuclear medicine.

Communication and Information Technology

- Electronics
- Radar & Antennas
- Computing Devices and Frameworks
- Internet of Things
- Software Development
- Big Data



Technology Transfer and Localization

Communication & IT

Communication and Information Technology (CTI) plays a major role in supporting productivity and economic development for many countries. Therefore, KACST is keen on developing advanced CTI technologies in areas that are important to the Saudi market.

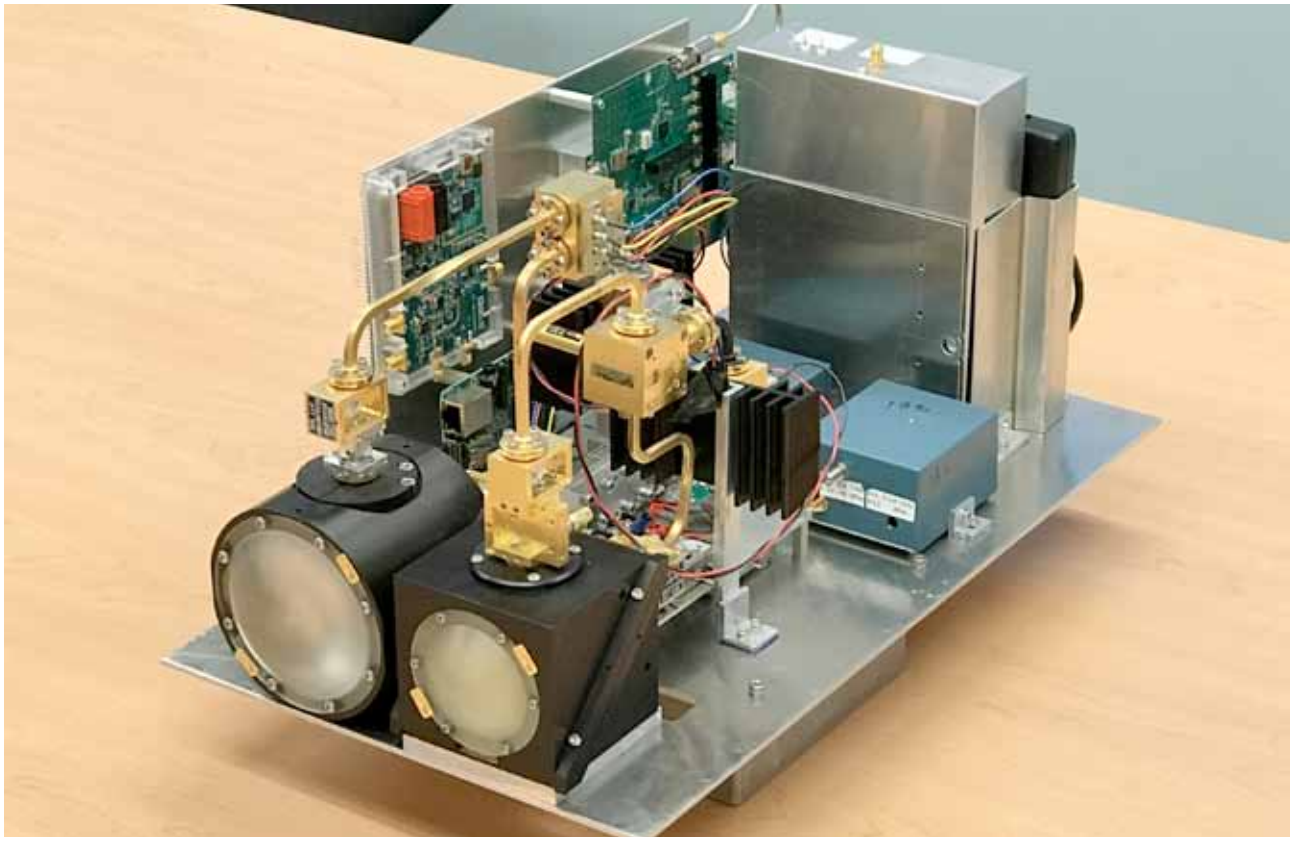
Introduction

CTI is considered an important area and a key motive to enhance productivity and economic growth for many countries. CTI is seen as an enabler for other technologies. As a result, KACST has worked on developing advanced communication and software systems and conducting research in various areas related to CTI. KACST has established lab facilities to conduct research in computing, communication and electronics.

Over the years, KACST has built its capability in the electronics area especially in designing digital and analog chips and also in designing electromechanical systems. KACST is working on designing electronics subsystems used in communication and control systems. Moreover, KACST is working on projects related to optics especially in laser, fiber optics, and thermal imaging applications.

In addition, KACST conducts research and development projects in areas related to computer networks, Internet of Things (IoT), software development and data analytics for different types of data including text, voice and image. It employs for such projects high performance computing facilities. These facilities are also available for users from outside KACST.

KACST has recognized the importance of Big Data application and its role in enhancing the quality of decision making and also in achieving development goals. As a result, KACST has worked on developing Big Data technologies aiming at building and developing an integrated smart platform for big data analytics. This platform is composed of tools and software for data analytics and it also has applications built to serve the needs of decision makers in various sectors. Additionally, this platform has visualization tools used to communicate the analysis outputs clearly and efficiently.



Tamkeen

The goal of this research effort is to develop the technology for fabricating compact, low-cost, and power efficient millimeter-wave radar imaging systems for autonomous vehicles and robotic platforms operating at Y-band (~ 240 GHz) frequencies. The autonomous navigation of land vehicles in urban and highway environments is a highly anticipated development that is expected to revolutionize ground-transportation systems. Obstacle avoidance, path planning, and target detections are very challenging tasks, especially in complex environments, and cannot be accomplished using a single sensor. High resolution radars with polarimetry capabilities can provide information such as the distance to the obstacle, its size, rate of approach, and some level of target identification in dark and inclement weather conditions that is not possible using other existing sensors. The work in this project is divided into three tracks as follows:

- Building continuous wave radar for target detection and classification.
- Studying the electromagnetic waves scattering from different objects at 220 GHz.
- Design and microfabrication of circuits operated at 220 GHz.

EMMAD2

EMMAD 2 is a device about the size of USB flash memory stick. It is compatible with the systems of the Saudi Ministry of Communications and Information Technology. EMMAD 2 is designed to conduct operations of Public-Key Infrastructure (PKI) such as producing and saving digital keys and use these keys in email encryption and signing. When using EMMAD 2 with PKI, users can prove their identity such as National ID, and digital signature to underlying services, enabling them to securely perform transactions.

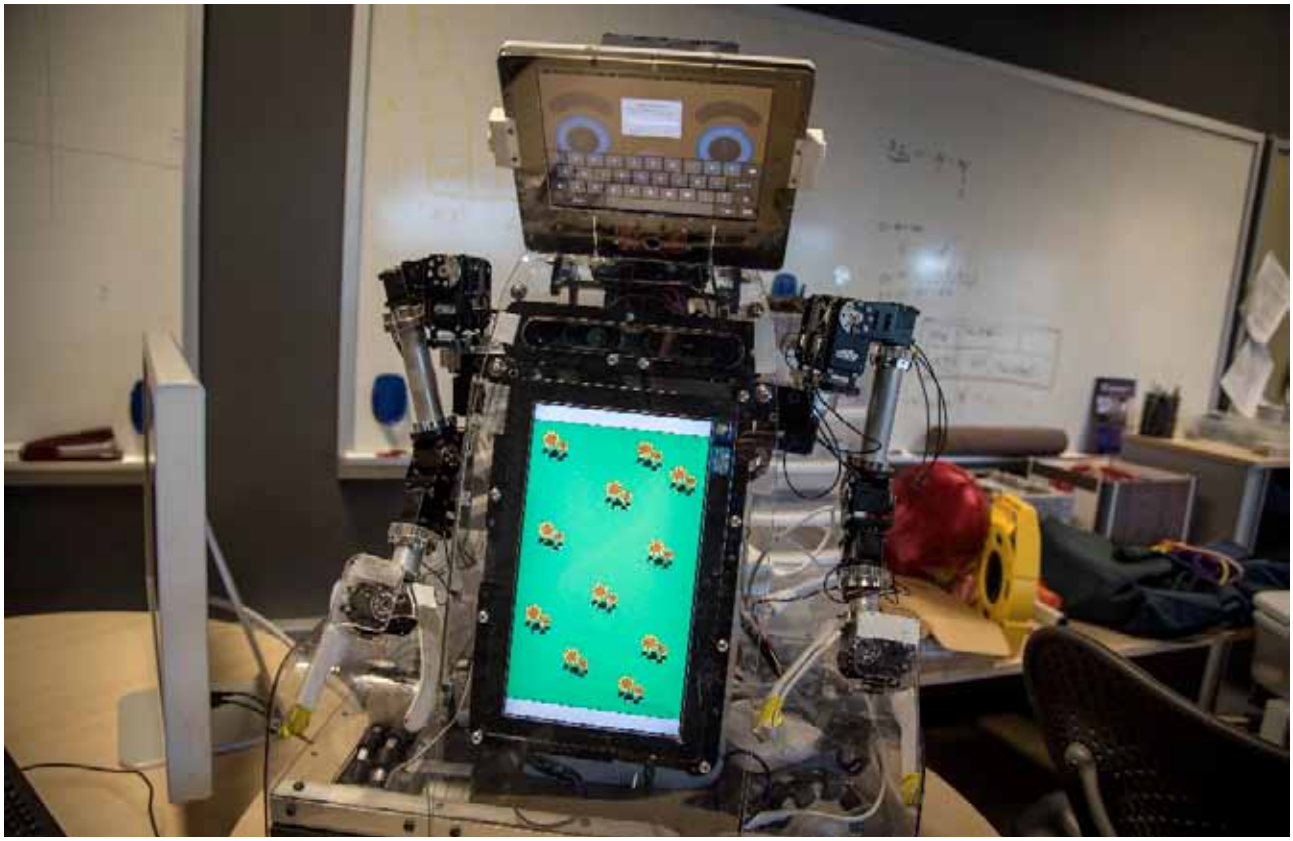
EMMAD 2 also includes special software features which were developed by KACST that allow the user to encrypt data inside EMMAD's token. EMMAD2 can be plugged into any personal computer or laptop via the USB port, with no need for any additional readers or specific extensions.

EMMAD 2 is certified by the U.S Federal Information Processing Standard, FIPS 140-2 for fulfilling the security requirements for cryptographic modules in level 3.

Designing and Manufacturing of a Secure Tablet (KTAB) for Government Agencies Usage

The objective of this project is to develop a mobile computing device suitable for the Saudi market. The development process goes through a deep market study and survey to conclude the best customization and optimization for Saudi Market needs. It also covers the price factor to reach a minimum of 20% off the price of competitor high-end devices. The most complicated part of this project is the chipset SoC which does the main functions of the tablet. It is also considered as the number one highest cost of any tablet BOM. The software can play an important role in tablet performance regardless of the hardware specifications. Hence, the project covered the design of all the different parts of the tablet, including industrial, mechanical, software and hardware designs. Building such technology from scratch can help to speed up technology transfer and the know-how process.

Currently, the final mechanical design has been completed along with the industrial design that includes the exterior look and feel. The blue color has been chosen for the general theme. Metal has been used for the build to give a solid and luxury feeling. The logos of KTAB at front and the chromed KACST logo at the back have been defined carefully. All software layers from drivers to android operating system to applications have to be studied precisely to be able to fix any bugs encountered during the design and integration stages. Hardware parts should be targeted a high-end tablet. Therefore, the MSM8939 Qualcomm chipset platform was chosen as the best option to use in KTAB for coding and learning process to examine the design limits in order to be able to make any future hardware design modifications and IC/sensors changes. The achieved activities included the determination of final specifications and features of the KTAB tablet. The infrastructure was partially completed by setting up servers and tools required for the design process. Multiple discussion sessions have been conducted with partner's expert team to finalize directions. In addition, after a few samples, KACST labs will be prepared with all testing equipment required to review the tablet's functions and power for the final CE certification and its local equivalent. These tests will be performed once the DVT (Design Validation Test sample) and EVT (Engineering Validation Test sample) are received.

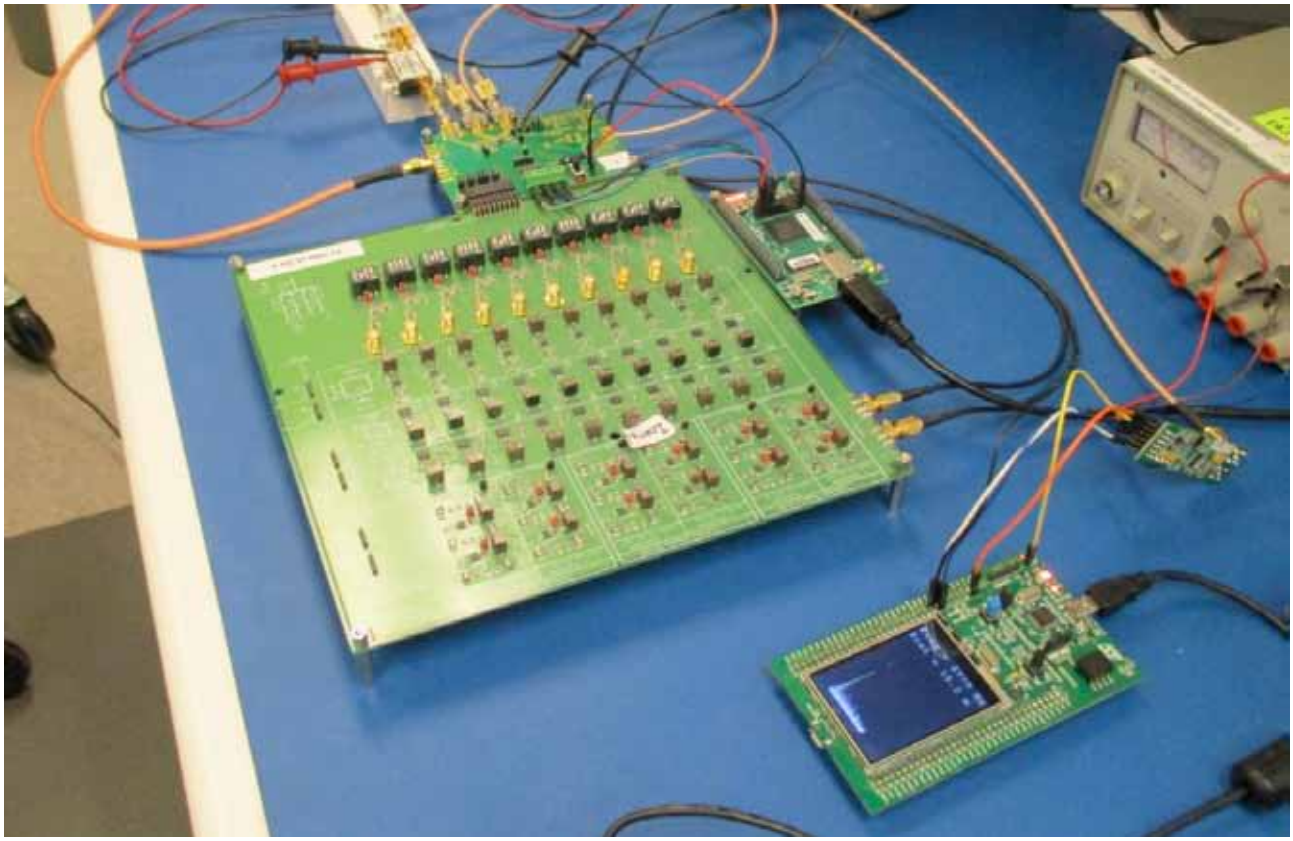


Software Defined Network (SDN)

Advanced defined networking technologies have become familiar and mature elements of research in modern wireless networks. Despite the abundance of solutions proposed in the academic community, which are based on a sophisticate theory of network optimization and cognition, the practices of wireless networking often diverge from utilizing these solutions and techniques. Today's networking solutions for first responders, vehicular networking, locality-based gaming, are far behind the promise of mobility, simplicity, affordability and efficiency originally envisioned as the "ad hoc wireless networking paradigm shift." And surprisingly, this is in face of two decades of important wireless networking research breakthroughs such as network coding, MIMO networking, and interference alignment.

Software defined networks are networks that can be controlled and structured by reprogramming. These networks can be separated between data routers and network management devices to improve performance. The application of software-defined networks in the wireless world is a major challenge and will help an external controller, that can manage and control the network, exploit the relationships between the observed protocols and network performance. This will improve local or end-to-end communications network, programmatically defined external control of network, data collection of network nodes available, the application of various automated learning techniques, including neural networks and deep learning techniques. The cognitive engine will be able to infer the future behavior of the network and make basic protocol to improve network performance decisions.

In this project, the team studied a mobile wireless network and predicted the movement of the nodes as variable network operators. The team also studied network behavior by simulation, and then designed techniques to address the lack of performance due to mobility. In the second phase, a software defined network test-bed was created. It consists of fully mobile nodes. This project will expand on prior work and address the problem of high wireless demands in high density areas in a comprehensive framework from foundational theory to simple deployable practices. Results obtained through this work will lead to better, more reliable network access in high-density areas and during high-demand periods, such as during special events or emergency situations.



High Security Identification Disk for Government Secure Transactions

Following the success of the current KACST project, EMMAD 2, which is compatible with the Saudi Ministry of Communications and information technologies systems, and has been used widely by the Ministry of Defense, other organizations have shown an interest in the product. This led to further improvements on the product, such as the addition of important software features and work on the product logistics, such as its size and cost. One of the goals of this project is to make a compact version (using different hardware), of the current EMMAD 2 product, that is cheaper to manufacture and smaller in size, and has improved and additional software as requested by current or potential clients. The project also includes integrating EMMAD 2 with security products previously produced by KACST.

Tahkum

The goals of this research project are to develop and demonstrate circuit techniques to enable single-chip CMOS processing for vehicular radar. Circuits will be developed for the 24 GHz and 77GHz frequency bands. Prototype devices will be fabricated in 40nm or 65nm CMOS and evaluated. The scope of this project concentrates on using circuit techniques for three main parts of radar design: wave generation, transmission and detection, and processing of the baseband signal. For the processing baseband signal, a custom designed analog-to-digital converter (ADC) will digitize the down-converted received radar signal.

The work in this project is divided into three tracks as follows:

- Waveform generation: phase locked loop circuit will be used to generate two waves at different bands.
- Radar waveform detection and amplification: power amplifiers, mixers, and LNAs will be designed to achieve good performance at higher frequencies.
- Analog-to-digital converter: both sigma-delta and pipeline ADCs will be considered for this task.

Phased Array Antennas

Satellite communications play an important role in the development of new communication applications in Saudi Arabia and around the world. The most important elements for satellite communication are antennas.

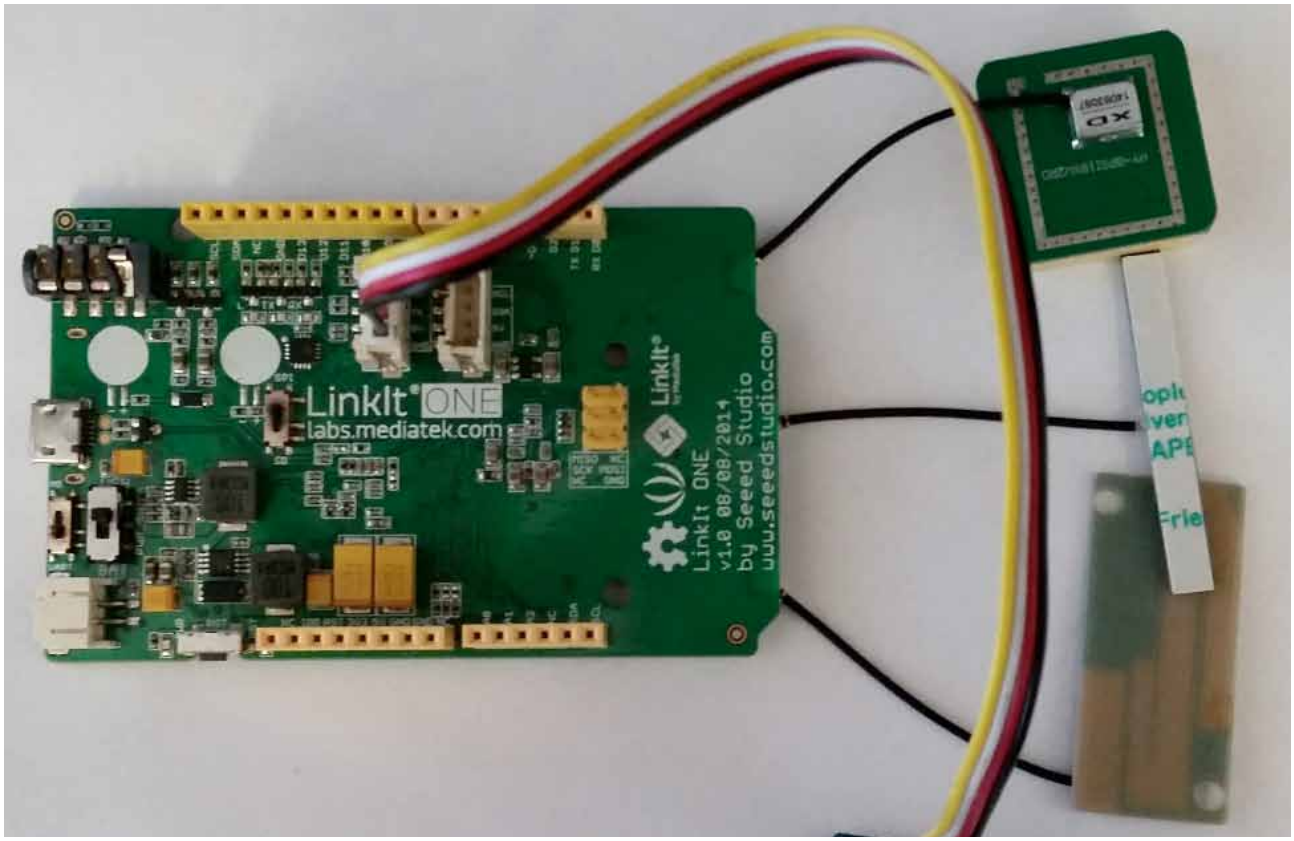
The multi-array antenna technology has the ability to create and electronically beam radiation waves in different directions without moving the antennas. The technology of phased array antennas is still in its infancy stage. There are several methods to take advantage of recent developments in phased array antenna technology and how it affects the performance, energy consumption cost, and how easy it is to connect to satellites.

The project aims to transfer and localize the Ka-band electronic self-guided phased array antenna technology in collaboration with the best research groups at the University of California, San Diego, specializing in Phased-Array Antenna technologies. The project also aims to strengthen the skills of KACST's researchers in the design and construction of similar devices. One of the applications of this project is to enable and facilitate satellite communication where the final product is characterized by high speed radiation guidance and a scanning angle of radiation ranging from ± 45 cm. The project consists of two main parts:

1. Design and simulation of the 8-channel integrated circuits responsible for directing and receiving electromagnetic waves. These circuits include the wave amplifier electronic chips, the Receive Equalizer, the Phase Shifter, and the Electronic Control Module. All designs and simulations have been completed and the chips will be manufactured for this part of the project for laboratory testing.

2. Design and construction of multi-layer (10 layers) high-bandwidth (10 GHz) radio frequency reception. This part of the project also contains the design of the Wilkinson power divider to distribute power evenly over radio reception units. Most of the designs for radio receivers, including the Wilkinson power divider, have been completed in preparation for the manufacturing and testing of the phased array antennas.

The two parts of the system will be integrated once the design and test phases are performed, creating the final prototype. This prototype will then be tested to measure all system variables such as rate gain, scanning angle, beamforming, and other characteristics.



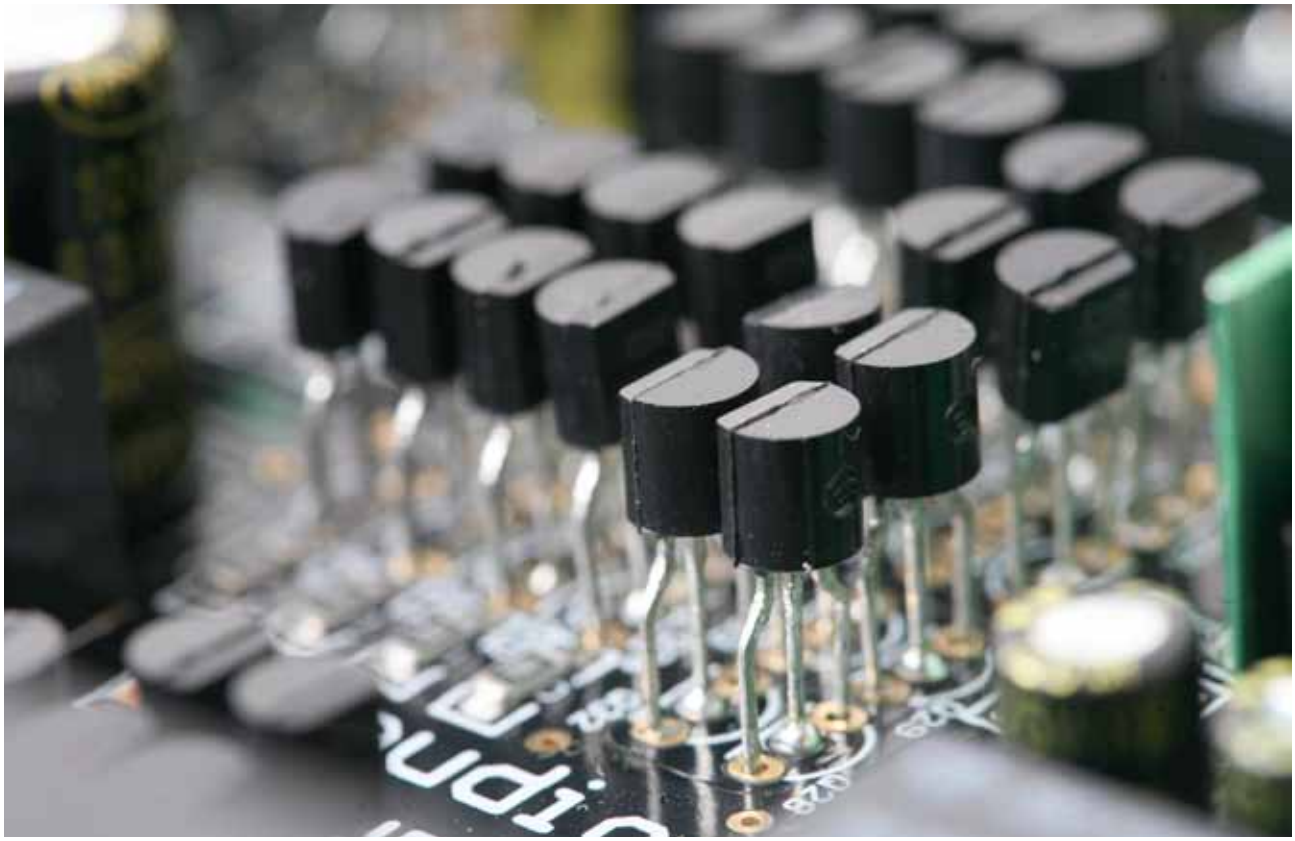
Massive Multiple Input-Multiple Output (MIMO) Systems

Large-scale antenna systems, also known as massive multiple-input multiple-output (MIMO) systems, are considered one of the main technologies to improve spectral efficiency, necessary to satisfy the explosive growth in demand for wireless services in next generation communication systems. Together with the push towards higher frequency bands (e.g., millimeter-wave) and small cell architectures, massive MIMO can greatly enhance the wireless communication capacity to improve quality of service via enhanced channel gain and multiuser diversity gain, while eliminating user interference. This project will investigate three subtopics of interest:

- Channel estimation for time-division duplexing (TDD) massive MIMO systems.
- Distributed massive MIMO optimal array design.
- Limited radio frequency (RF) chains.

There is a need to improve the use of available radio resources, which requires not only increasing the spectrum efficiency but allocating better spectrum. The team has focused on the resource allocation algorithms and control interference in heterogeneous networks which leads to more complex network scenarios. It is expected that the next-generation networks will be a network of intensive cells operating in the same frequency range. The performance improvements, based on the physical layer technologies, such as modulation, multiple antennas, was an important factor in the past, and it will continue to play an important role in the next generation albeit at a lower level. Developing techniques for estimating the channel downlink in a multi-input-multi-mass output system is a challenge because of the large number of antennas available at the main station.

The team aims to investigate novel semi-blind channel estimation schemes as channel estimation is beneficial for time-division duplexing (TDD) systems (for both uplink and downlink), making it an effective solution to the challenging pilot contamination problem. In addition, studying the trade-offs of different sub-array divisions and location patterns will provide useful guidelines for system deployment. The hardware complexity of massive MIMO necessitates consideration of architectures with lower complexity, so this project will also look to see if it is possible to reduce an RF chain by exploiting the low dimensional channel property in massive MIMO systems.

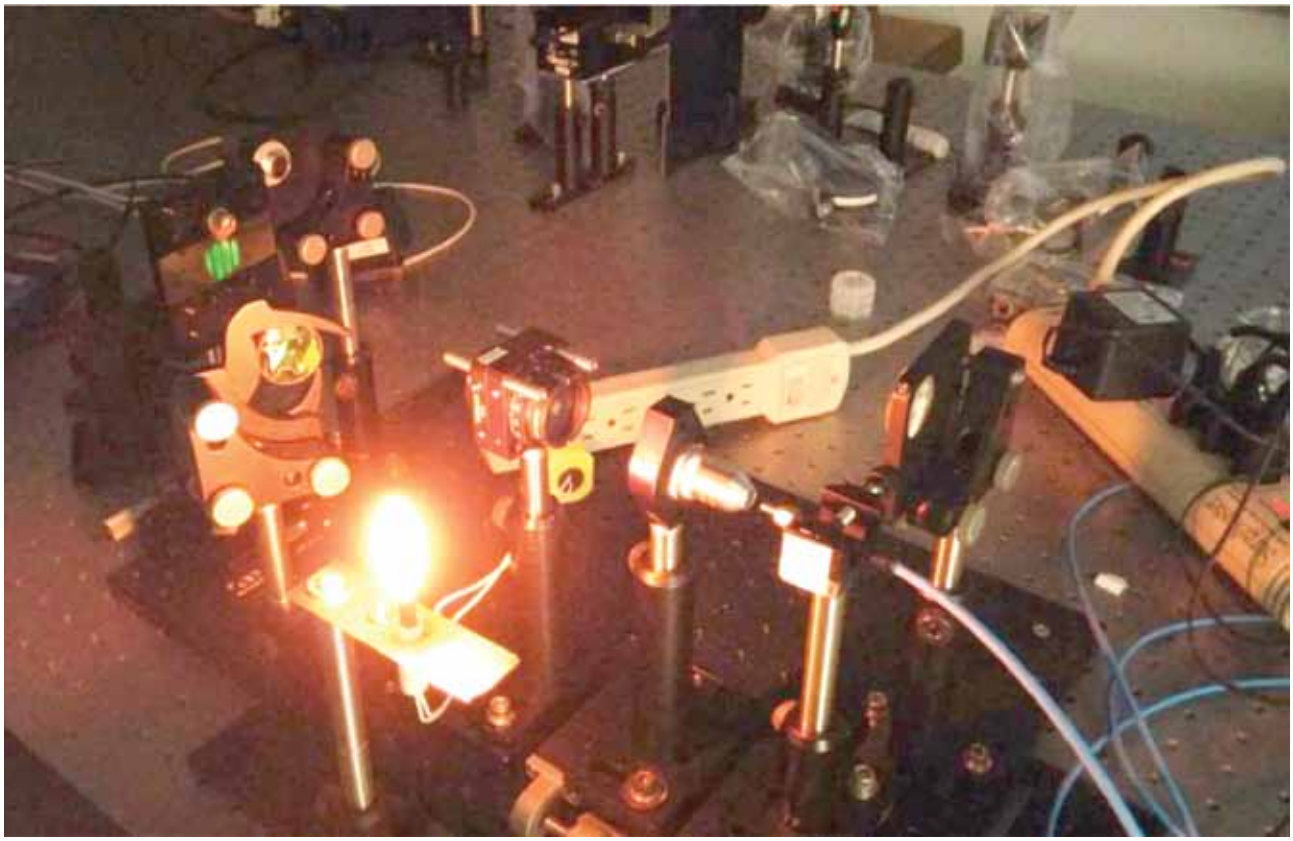


High Performance Transistors Based on 2-Dimensional Materials

The main objective of this project is to create high performance 2D vertical tunneling transistors with high current density and high current gain, which could potentially be used as high cut-off frequency (fT) and oscillation frequency (fmax) RF transistors. These transistors could also be made in flexible and transparent formats. High current density is required to obtain high performance RF tunneling transistor. In this sub project, either growing thin tunnel oxide (SiO_2 thickness is about 1~2nm) or using effective tunnel oxide (such as MgO and Gd_2O_3), is planned, to utilize for gaining high current density. The preliminary results show that using ultrathin SiO_2 as a tunneling barrier leads to an improvement from 10 mA/cm2 to 100A/cm2 in tunneling current from the emitter electrodes. The team of this project will focus on improving the contact between 2D materials and metal electrodes, which is regarded as one of the key areas in promoting the practical application of 2D materials in various electronics.

There are 3 sub-topics in this project as follows:

- Energy barrier engineering for improving current density: in order to achieve high current density, there are two alternative plans that may be adopted in tracking constraints. For the growth of ultrathin tunnel SiO_2, rapid thermal anneal (RTA) is needed. The growth temperature and time is important for such a thin tunnel layer. Various conditions will be tested in order to determine the best quality of tunnel oxide for the purpose of high current density.
- Contact engineering for semiconductor 2D materials: to investigate vertical transport between the 2D materials and bulk materials, vertical stacks of highly doped silicon (acting as an atomically flat substrate as well as an electrode), graphene (to eliminate the Schottky barrier) and metals will be fabricated.
- Phase transformation for low base contact resistance: phase transformation from the 2H phase to the 1T phase will lead to changes in the vibrational modes and binding energy of TMD material. Therefore, Raman spectroscopy and X-ray photoelectron spectroscopy (XPS) will be used to verify the transformation. Vertical tunneling transistors with 2H-TMD materials as the base region will be fabricated and characterized to investigate the effectiveness of phase transformation in improving both the DC and RF performance.



Molecular Electronics – Molecular Memory and Logic

For more than three decades computer hardware has evolved in a top-down manner. The number of transistors that can be placed on a chip, with a halving in cost, has increased exponentially, doubling approximately every two years. The top-down approach for miniaturization of circuit elements is now reaching its end and a revolutionary approach is needed for further improvment. It is anticipated that the future of nanoscale devices (below 100 nm) could well lie in the development of molecule-based electronics. The utilization of molecules as functional elements in molecular electronic devices (MEDs) is becoming an increasingly attractive research area given the fact that further size reduction of the circuit elements is turning out to be challenging with the conventional circuit elements. Miniaturization of electronic components will contribute to the development of more powerful supercomputers, as well as smart nanocomputers.

Molecular switches, namely, bistable Mechanically Interlocked Molecules (MIMs), have been explored as active elements in molecular switch tunnel junctions (MSTJs) for molecular memory applications. Most remarkably, these bistable molecular switches have been incorporated successfully into 160 kbit memory devices, demonstrating the promise that MIMs hold in MEDs.

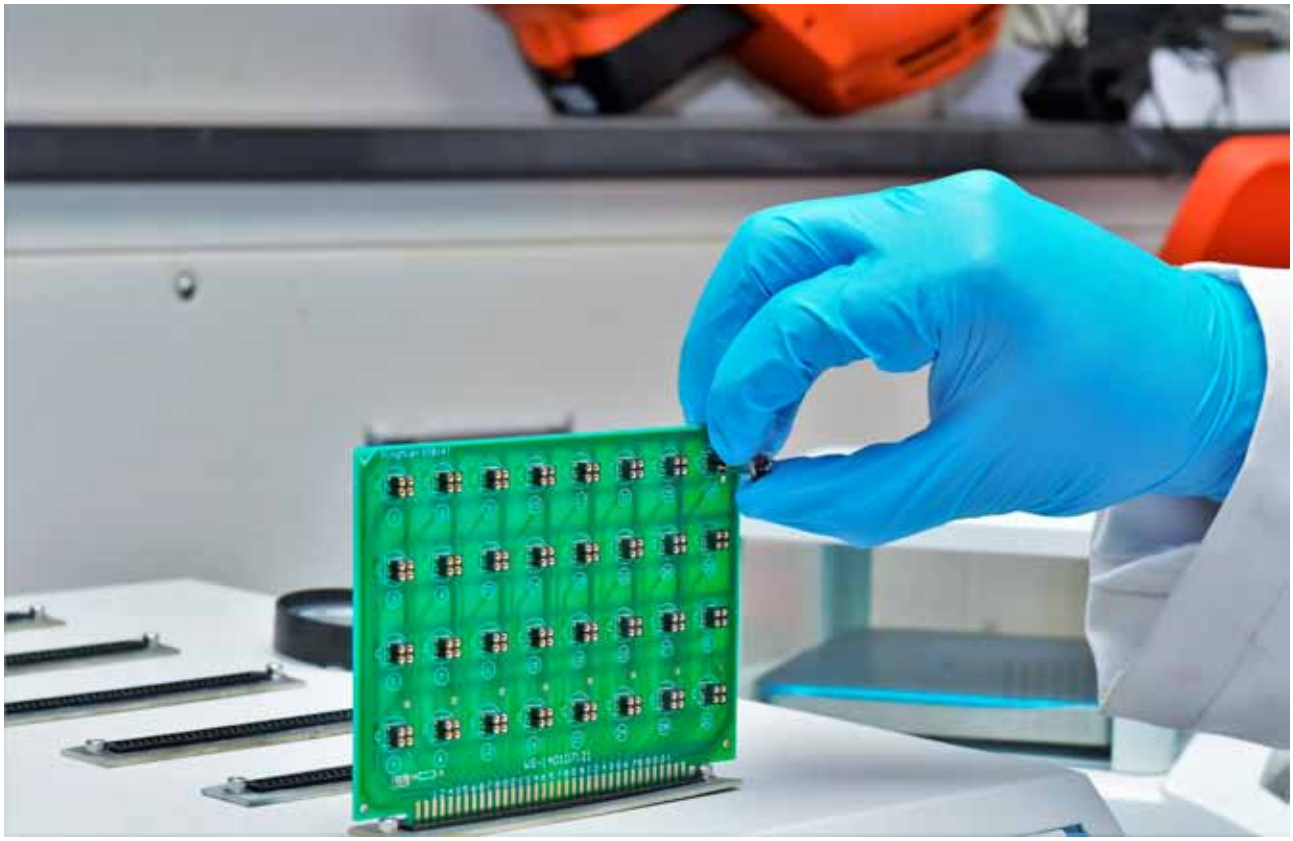
Despite the significant progress, there are still challenges that need to be addressed in these devices regarding their reproducibility and robustness as a result of the disorder and lack of robustness associated with self-assembled monolayers and polymer coating. These challenges are addressed in this project by utilizing a class of nanoporous materials, namely metal-organic frameworks (MOFs), as a form of mechanically robust, crystalline scaffolding for the assembly of switchable MIMs in dense, ordered arrays. The incorporation of MIMs into MOFs could allow to address individual molecular switches repeatedly in a highly porous and robust environment which, in turn, will increase the efficiency of MEDs.

Electro-Optics and Nanophotonics

Advanced electro-optics and nanophotonics are enabling technologies for applications in communications, computing, manufacturing, healthcare, and energy. Progress in this field has the potential to generate new knowledge, promote economic growth, create new industries, and provide technologies for new applications.

The Internet of Things (IoT) has created a huge and growing demand for bandwidths on datacenters that, as a consequence, has resulted in sustained growth in electrical energy consumption. Even with the improved overall efficiency of electronic processors following Moore's law, a more transformative improvement is required to increase bandwidth and reduce power consumption without compromising the growing data rates in data centers and metro communication systems. A consensus to achieve these future datacenter performance requirements is replacing metal interconnects by photonic link technologies due to its high bandwidth and low-power consumption. Indeed, there is a growing demand in cost-effective, complementary metal oxide semiconductor (CMOS)-compatible photonic integrated circuits (PIC) for transmission and optical circuit switching with emphasis on datacenter and metro applications. This project focuses on one of the key components for PICs, an optical modulator for data modulation/switching with very high speed. Specifically, this project will design, fabricate and characterize a CMOS compatible Mach-Zehnder (MZ) modulator based on free carrier plasma dispersion effects. Since the free carriers' effect is driven by capacity, it will lead to lower power consumption. Furthermore, since MZ configuration is non-resonant, it will allow the modulation of information on optical carriers in a wide WDM frequency grid.

High speed optical modulators, especially intensity modulators, are critical to the ongoing integration of optical components into a PIC. Due to their large nonlinear optical coefficients, materials such as GaAs, InP and LiNbO3 were among the first candidates considered for the realization of high speed devices. However, it has long been considered advantageous to realize optical modulation with higher bandwidths with lower power consumption in a CMOS-compatible material platform. In this context, ongoing research efforts will be focused on the design, fabrication and testing of high-speed modulators fabricated in silicon using CMOS. The results from this project will lead to more efficient optical modulators.



Smart Micro and Nano Sensors and Actuators based on Silicon Carbide

The aim of this project is to continue the ongoing cooperation program between KACST and MEMS Vision Corp. based in Montreal, Canada. The project will also provide advisory services and the training of highly qualified personnel from Saudi Arabia in the emerging and promising disciplines of micro- and nano-electromechanical systems (MEMS/NEMS), via the development of joint projects between the two sides. This will develop innovative and world-class competitive sensors, actuators and systems which can find applications in the oil, gas and aerospace industries.

This project aims to pursue the development of the following fully functional and characterized MEMS-based solutions:

- High-end accelerometers and gyroscopes for inertial measurement units (IMU's).
- High-end pressure sensors. Initially, a high-sensitivity and high robustness barometric pressure sensor will be pursued, capitalizing on the excellent characteristics of the SiC materials.

Low Power Nonvolatile Spintronics

The challenges in developing low-power spintronic devices based on spin-orbit engineering include:

- Experimental control to the atomic level of interfaces, thicknesses, and compositions of magnetic and non-magnetic layers.
- Theoretical understanding of the effects of materials choices and layer stack engineering, including spin-orbit interaction, band structure, and lateral confinements, on the magnetization dynamics and device behavior.

The focus of this project is on the engineering of spin-orbit interaction at interfaces, resulting in large voltage and current-induced torques on the magnetization. Based on the innovative material systems developed, devices utilizing their spin-orbit effects will be demonstrated and their performance will be assessed. State-of-the-art experimental facilities and theoretical techniques to address the challenges will be employed. Material stacks are developed using a two-chamber dedicated magnetron sputtering system with a capability of depositing up to 11 different materials without breaking vacuum. Device fabrication is performed at UCLA and CNSI's state-of-the-art facilities.

Low Power Wide Area Network for Internet of Things Applications

The Internet of Things (IoT) system consists of several basic components:

- Sensors and devices.
- The communication network used by sensors to transfer data to points of connection.
- A connection gateway with towers for data transmission.
- Platforms for data collection and storage as well as data analytics and visualization.

This project embraces the creation of an IoT network that covers the city of Riyadh, with a low-power network technology that allows for the transfer of data repeatedly and limitedly, allowing for the use of a large number of sensors with energy saving. This allows the operation of sensors for years without the need to recharge their batteries. The cost of using the network is low compared to the traditional alternative that focuses on voice calls and surfing the internet and media. This makes the cost of its use is good for certain applications including smart meters and other applications that do not require the transfer of large bytes instantaneously and continuously.

Internet of Things (IoT) for Environmental Applications

In this project, both teams from KACST and UCSD, will collect and compare the environmental information for the regions of San Diego and Riyadh. The environmental information to be compared in accordance with the agreement is temperature, humidity, and the degree of pollution by calculating the CO^2 ratio in the air. The system will focus on gathering information as needed in an interactive manner, with areas requiring measurement such as high density areas or traffic-intensive areas. This information is expected to be useful for urban planning and for measuring the effectiveness of environmental reform policies. In order to measure the health habits of the society by monitoring the daily activity rate, and based on the measured activity of individuals, it is possible to develop a community health index. The system utilizes applications in mobile phones to measure kinetic activity by collecting the number of steps. The aim is to target specific segments of society such as those with diabetes or triglyceride to encourage them to walk continuously.

Regulatory Framework to Promote Open Source and Free Software

KACST intends to submit a legislation that supports the use of open source of large and medium systems aiming to increase quality and decrease cost. Through open source, KACST's intention is to support small and medium enterprises by enabling free access to quality software which enables technology transfer. The legislation intends to improve the private sector's ability to compete by providing and committing to international quality standards. Therefore, KACST has recognized the need to amend the current government regulations to support the use of open source within the private and public sector. Currently, open source software is practically disfavored by many because of its lack of effective branding and misconception about quality. Yet, with legislation it would give open source a fair chance when competing with proprietary software products in the market. The legislation would also incorporate elements that demand certain level of quality from open source products and other closed systems, including proprietary products. Supporting open source software has great impact on technology transfer in the Kingdom. It will also allow talented software engineers to be exposed to a wide range of the most advanced software technologies with free access to its code.

Enterprise Resource - ERP

Saudi government agencies spend a lot on enterprise resource management systems, incurring duplication of effort and cost, working with a closed system that is difficult to customize. Therefore, the national ERP initiative aims to create a uniform open source system which is low cost, customizable, and lends itself to continuous development. The system is going to allow for the use of a system warehouse that enables code sharing and reuse. KACST has great potential in this field and it has been commissioned by the Royal Court to chair a committee to study this issue with a number of agencies including the Ministry of Communications and Information Technology. The study concluded with several recommendations, including this project. KACST offers its expertise in the most advanced technology in software development and modeling to enable the development of a low cost ERP system with open source versions for public use. The technologies that KACST intends to use not only reduce the cost of development but also increase quality. By using automation techniques, KACST believes it can reduce the cost of developing large systems by half.

Big Data Platform for Strategic Planning

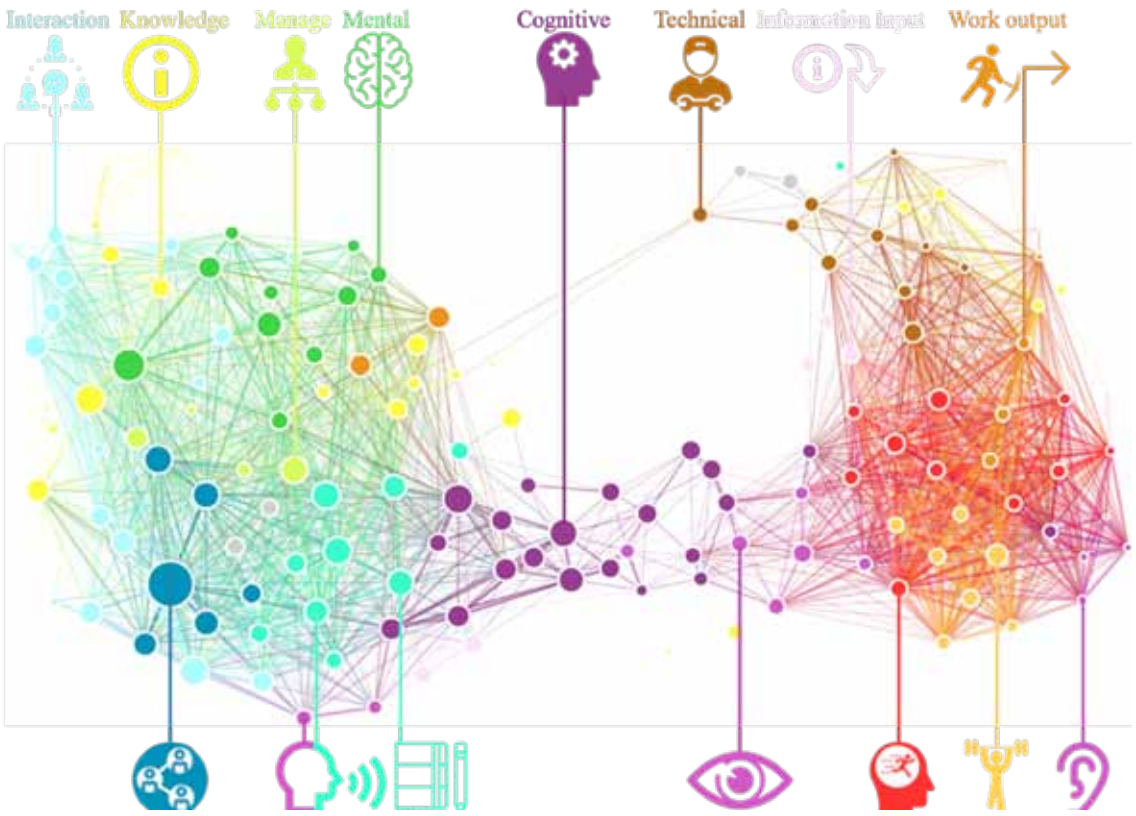
We currently live in an era where data is generated at a rapid pace, making it difficult for traditional databases and software techniques to process and store such data. Hence, this project aims at developing a big data platform that enables users to analyze their data and extract insightful knowledge that can lead to improved decision-making.

This platform will consists of multiple data extraction and transformation modules that can be used to transform data from its raw format into a format that can be easily understood by the subsequent components of the platform. In addition, the platform will also be equipped with different cloud computing techniques and parallel data processing frameworks that allow users to effectively process and store massive amounts of structured, semi-structured, geo-spatial, and/or temporal data. The platform will also contain several data processing techniques (such as machine learning capabilities, social-media analysis techniques, and simulation tools) that can help users analyze their data and visualize the results of their analysis in a variety of ways.

Complex Systems Computation Platform

Now a days, it is estimated that quintillion bytes of data are generated every day. 90% of the total data has been generated in the last two years, which tells us that our lives are surrounded by data. This project aims to build a platform that is capable of harnessing large-scale raw data to help the decision makers in forming a better future for the Kingdom.

The aim of this project is to develop an analytical suite that contains tools for managing and analyzing large-scale data. Those tools allow data scientists to build complex models such as computational and simulation models that scale for large data. Additionally, the platform allows the integration of several models to answer a larger complex question. Finally, the platform can generate the results in several forms such as reports, dashboards or even in geotemporal formats, which can help in the process of strategic decision making. These features help the stakeholders and decision makers to collaborate in tackling multi-disciplinary problems.



Innovation Space

Diversification of knowledge production and industries are key to generate inclusive and prosperous societies. Complex economies (economies with a capacity to produce a diverse gamut of sophisticated products) have higher levels of income and lower levels of income inequality. Saudi Arabia is ranked 60th on EIR, 84th in Innovation, 58th in Education, and 21st in ICT in the global ranks of the Knowledge Economy Index (KEI).

This project aims to explore the evolution of the research, technology and economic structures focusing on both global lessons and lessons for the Kingdom of Saudi Arabia. The research aims to develop conceptual and software tools to help strategic decision makers from several agencies develop a roadmap on how to move to new research fields, product industries, or education policies. These tools are context specific, and will provide advice based on the Kingdom's current research and productive structure.

Some of the previously documented tools and those that are being developed in the context of this project include the product space, the technology space, the research space, and the skill scape. The technology space for instance maps the correlation between technologies and establishes a measurable relationship between technology and the corresponding productive structure. Similarly, the skill scape maps the labor force by virtue of the skills, knowledge, and abilities of its workers, shedding light on their competitiveness, which depends on their ability to adapt to changing conditions, from computerization and industrial automation, to changes in labor demand.

The research methodology involves the usage of data collected from public entities and from online sources, and involves the development of new analytical methods, and software tools to infer knowledge production and diffusion patterns, in order to understand how resources and infrastructures constrain the production and application of knowledge in an economy. In the dynamic visualizations and interactive features of our recommender system, the Innovation Space project attempts to tackle the problem of understanding the social, technological, and institutional context of knowledge production and diffusion of innovation, by providing an integrated approach that addresses the interdependence of product, technology, research, and skill dimensions.

Agriculture

- Agricultural Bioengineering
- Protected Agriculture & Water Preservation Technologies
- Biological Control

Technology Transfer and Localization

Agriculture

Agriculture is one of the main pillars of the national economy of the Kingdom of Saudi Arabia. However, the agricultural sector uses about 90% of the total water consumed in the Kingdom.

Introduction

The agricultural sector receives direct and indirect support from the government through loans, agricultural land and petroleum derivatives. But despite that, Saudi Arabia imports most of its food from abroad amounting to around 100 billion riyals.

Although the Kingdom has made great leaps forward in agricultural production, the type of agricultural production carried out uses technologies that consume huge amounts of ground water. This is a serious threat to water security. It is therefore necessary to re-consider the agricultural development strategy taking into consideration the importance of national food security. Agricultural technology researchers at KACST aim to develop environment-friendly competitive agricultural technologies, and localize and develop them to allow sustainable agricultural development, and protect the food security of the Kingdom. KACST will support the Saudi agricultural economy to continue to provide various food sources via the following:

- Production of crop breeds of high productivity and quality and of limited water consumption by development of genetic technologies.
- Development of technologies that contribute to water consumption rationalization in agriculture such as a new design of greenhouses.
- Working with the concerned bodies to develop agricultural policies which contribute to the best consumption of water in the agricultural sector.
- Production of barley fodder of high production and quality, and limited water consumption through aqua agricultural technologies and tissue agriculture.

To accelerate work on these projects and to obtain quality outputs within a short period, a food security program has been launched for agricultural technologies in desert areas. This program aims to develop agricultural technologies to realize sustainable food security for the Kingdom, and to enhance economic development in collaboration with several government bodies, universities and agricultural companies.

Food Security Program

Despite the great leaps that Saudi Arabia has achieved in agricultural production, the technologies used still need a lot of underground water. This depletion may threaten the national water security. Therefore, it is essential to create a new agricultural developmental strategy considering the importance of food security.

The objective of this program is to develop agricultural technologies that will guarantee sustainable food security for the Kingdom. Among the challenges facing Saudi Arabia towards the attainment of food security is that the Kingdom consumes 40% of the world production of barley for the country's livestock industry.

To attain food security, it is crucial to search for agricultural technologies that consume limited quantities of water for animal fodder such as barley. This will guarantee the durability of agricultural development. Studies indicate that soilless farming or hydroponic farming for fodder production consumes limited quantities of water whilst giving high production rates. However, this technology needs big quantities of barley seeds. The conversion factor of barley is 1:8 (e.g., 1 kilogram of barley seed gives 8 kilograms of fodder). To lessen the use of barley seeds in each production cycle, a new tissue culture technology will be induced to the hydroponic fodder technology. This technology will allow the production of big quantities of fodder using less quantities of barley seeds.

The objective of this project is to secure food while preserving ground water. This will be attained through the implementation of the following programs:

- Development of fodder crops with high quality and production rates while consuming limited quantities of water through biotechnology.
- Developing technologies that will contribute to the rationing of water consumption in agriculture such as greenhouses and irrigation technologies.
- Working with the concerned sectors to develop the agricultural policies that will contribute to the optimum water consumption in the agricultural sector.
- The production of high quality barley with limited consumption of water through hydroponic farming and tissue culture.

Hydroponics Technology (without Soil)

Due to the steady increase in barley prices in recent years, and in order to achieve food security in the Kingdom, and to reduce reliance on imports, KACST has had to search for new technologies based on using limited quantities of water, to replace traditional methods of agriculture. An example of this is hydroponics, a technique using biotechnologies. It works by rotating water in closed rooms and a tight environment that is not affected by the external environment. It is solar powered and characterized by the abundance of production for the area used, while needing only a small amount of water and energy.

The study aims to achieve food security in the Kingdom without prejudice to water security. It also aims to develop the agricultural sector by innovating technologies that contribute to the rationing of water consumption and increase agricultural production.

There are manufacturing methods for producing green fodder that do not require agricultural land or soil, nor occupy a large area. They rely on the use of heat, humidity and light-conditioned rooms containing ponds placed at a distance above each other, where grains are grown (such as barley and oats). They are irrigated with water containing dissolved elements of fertilizer which helps to accelerate the growth of seedlings, so that they can become about 20-25 cm long in a week, and produce a large amount of green fodder in a small area.

It is possible to organize the cultivation schedule so that a daily output of green fodder is obtained. This technique is called hydroponics. The capacity of the units to produce fresh green feed is one ton per day throughout the year under any climatic conditions. Its consumption of water and fertilizer is very low compared to the consumption required to produce this quantity under normal field conditions. However, the high cost factor remains an obstacle against using this technique, yet it is very suitable in arid dry areas such as the Arab region.

The Production of Green Barley Feed Without Soil (Culture)

Cultured barley is of great importance in animal feeding, as it contains a higher content of protein than dry barley. The proportion of protein in cultured barley is 10% , and it is easily digested and absorbed by the animals. In addition, cultured barley contains a variety of nutrients that improve the quality of the animal feed and increase the digestion rate, and the rate of utilization by 95% compared to other feed varieties. Cultured barley has stored energy that is characterized by easy flow in the body and therefore does not cause animals to suffer from acidity problems.

As a result of the correlation between the prices of raw materials used in manufacturing, concentrated feed, and the world prices of these materials, as well as the high prices of other materials used in animal feed, it is necessary to consider using non-conventional feedstock as an alternative to concentrated feed. This would help reduce cost and achieve an appropriate profit margin, thus encouraging the continuation of the production process. The cultivated barley is the most suitable alternative since it saves about 50% on the cost of the animal feed.

Mutagenized Generations of Altaifi Roses in the Kingdom

This project aims to propagate the so-called advanced mutants, which are the results of irradiation on the original genetic source of AlTaifi roses. Certain radiation doses produced from radioactive sources have been used to cause random changes or induce mutations at the genetic level. In previous phases of this project, 5 mutagenized plants were produced and they are completely different from the original plant in terms of flower size (radius), number of petals, plant length and life cycle.

In the year of the report, a patent application form was submitted to the US Patent Office with a product code KACST491-1. Three greenhouses were prepared in the Agricultural Research Station in Al-Muzahmiya to host approximately 10,000 mutant adult plants for propagation. Distillation and oil pressing units were selected to be purchased and a workplan was developed to market the final product, which are diluted rose water and rose oil. This project will benefit companies and international experts interested in natural perfumes and fragrances.

Greenhouse Technology

Protected agriculture is an advance agricultural method for providing water and food securities, increasing productivity and growing vegetables all the year around. This type of agriculture has become one of the most important sectors of agriculture in the Kingdom. The project focuses on the optimal utilization and conservation of natural resources by applying the latest agricultural technologies. These would contribute to the water preservation and food security. Specifically, the goals of the project include the following:

- Design and test closed system greenhouses in which water can be condensed and recycled in hot climates.
- Apply new technologies that can be manufactured in the Kingdom for cooling and reuse of water.
- Work on standard design for greenhouses in the Kingdom.
- Inject carbon dioxide gas (CO_2) in the closed system greenhouses. The studies suggested that the production may increase by 200% under the sunny conditions of Saudi Arabia compared to production in traditional greenhouses. In addition, injecting greenhouse with CO_2 is an important source for disposing of CO_2 which is produced by Saudi Aramco in a commercial manner. This reduces the impact of CO_2 emission on the environment.
- Reuse the condensed water from the wet air inside the closed greenhouse to feed the cooling system pads. The extracted water is characterized by the fact that it is free of salts and this would solve the problem of salt build-up on cooling pads.
- Utilize the relatively cold air inside the closed system greenhouses after economical dehumidification processes to feed the cooling system. This would improve the efficiency of the cooling system for greenhouses.
- Reuse the irrigation and cooling water.
- Connect the closed system greenhouses with desalination and heating systems driven by solar energy and cooling systems operated by solar absorption. The combined systems represent a design that does not require the availability of an electrical network or a source of abundant water for cultivation. This technique will contribute to the preservation of many of the water resources that are wasted in other methods of agriculture.

Super Absorbent Polymeric Materials for Agriculture Use

The aim of this project is to develop environment-friendly super absorbent materials for agricultural use. Hence, organic and inorganic polymeric materials will be designed to absorb water and synthesized. During the project, the evaluation of commercially available materials for the same purpose will be performed in order to gain additional information and use for future comparison studies. Prepared super absorbent materials will be characterized using sophisticated analytical techniques and will be evaluated under different environments to improve properties.

Technology transfer through advance training on the preparation, characterization and evaluation of these materials will be considered.

The project is expected to have an extreme impact on knowledge about the manufacturing of super absorbent materials, which will then be applied in different type of plants to maximize water conservation during irrigation. Many organizations and authorities are expected to benefit from this project such as the Ministry of Environment, Water and Agriculture as well as the private sector.

Red Date Palm Weevil Project

The Red Date Palm Weevil (RPW) project aims to develop an acoustic device capable of detecting the RPW's presence inside the date palm trunk. In addition to implementing a smart trap to monitor the RPW in the field. The project has accomplished the following:

- Detailing the hours that the adult RPW were present in the field, which helps in scheduling the pesticides treatments.
- Building a database for the RPW sounds inside the trunk of the palm under a wide range of conditions. This can be utilized to create algorithms for the acoustic device.
- Utilizing the gene silencing technology to develop a control tactic for RPW in the field.

This project helps provide practical tools for controlling the RPW and protecting date palm production in the Kingdom. The Ministry of Environment, Water and Agriculture, MEWA, and KACST, are establishing a direct project for controlling the RPW, in cooperation with universities and research centers.

Biological Control Technology

The Red Palm Weevil is an agricultural pest with traits and abilities that are hard to be eradicated as of now. The RPW can cause severe harm to palm trees within a short period.

It infects the inner palm trunk, where it is shielded from environmental conditions such as high temperatures, low external humidity, biological enemies, pesticides and from being seen by human beings.

A palm tree suffering from a RPW infection shows no obvious symptoms, making it hard to be discovered at the beginning of the infection. RPW has spread to many areas in Europe, Asia and some regions of the United States of America within 30 years.

The ability to hide, the high destructive ability and the fast spread makes RPW a very dangerous pest that affects palm trees around the world. The rate of infection reached 1-5% in various regions of the Kingdom. The importance of this issue is the wide spread of infection and the difficulty in combating it. Several efforts were made internally and externally to find the best way to control or to eliminate the RPW but this requires more time, concentration and support.

KACST in coordination with the Ministry of Agriculture provided the necessary attention to this pest. It supported various projects and held several symposia and workshops at universities and research centers in the Kingdom.

These workshops included one on RPW: modern technologies and future dimensions on 14-15 Rabie the 1st 1428H, corresponding to 2-3 April 2007 in the presence of H.E. the Minister of Agriculture.

KACST has also supported several symposia on palm trees at King Faisal University in Alahsa, and supported several local research projects carried out by local researchers.

Building and Construction

- Construction Automation Systems
- Advanced Construction Materials

Technology Transfer and Localization

Building and Construction

The building and construction sector is facing new challenges represented by the demand for smart and low-cost buildings with a limited impact on the environment.

Introduction

The building and construction technology sector in Saudi Arabia has been improving in recent decades, as modern architecture, engineering and reinforced concrete frame structures replaced the traditional construction methods of mud and stone. In addition, the continuous improvement of technical development has helped promote the construction sector, which is considered second only to the oil sector in exploiting the abundant natural resources of the Kingdom for the production of a wide range of building materials including cement, concrete, bricks, ceramics, and glass, as well as composite materials.

This sector also provides a large number of jobs, with 35% of work permits accredited by the Ministry of Labor and Social Development, related to building and construction. The building and construction sector is a major drive to productivity and economic growth in many countries around the world including Saudi Arabia. The contribution of the construction sector in the gross domestic product ratio is approximately 13% of all other non-oil sectors, and enhances the competitive ability of the Kingdom towards sustainable development serving the community.

In this important sector, KACST has specified the following strategic goals:

- Transfer, localize and develop feasible and cost effective building and construction technologies.
- Enhance the quality and productivity of research in strategic areas relevant to safety and long-term service life of the structures.
- Develop sustainable, durable and environmental friendly structures based on the latest research and technological advancements.
- Encourage the construction industry to have professionals who add value to the development of building and construction technologies.

A Saudi Home in 30 Days

The increase in the demand for housing in the Kingdom is one of the main obstacles facing the achievement of the goals for the development of the housing sector over the coming years. This is exacerbated by the fact that a large majority of the Kingdom's population are under the age of 30, which means there is a particularly high rate of new households and thus big increase in the demand for housing.

One of the main obstacles to satisfying this demand is the high cost of building and construction. The Kingdom launched the Saudi Housing Initiative to contribute to the transfer, resettlement and development of the housing industry in the areas of construction, and to address the current and future housing challenges facing the Kingdom in terms of cost, efficiency and quality. Furthermore, sustainability standards will be applied to buildings through the use of energy-saving systems and the longevity of buildings will also be taken into account.

One of the most important features of the transfer, resettlement and development of this project is that it will allow increased opportunities for Saudization in the construction sector, thus reducing the amount of foreign labor used. It will also increase the opportunities of the local private sector, and will produce numerous residential units for future generations. The objectives of this project include:

- Transfer, localization and development of building automation systems.
- Design Structural framing techniques and composite materials.
- Develop Coating and thermal insulation techniques to reduce electricity consumption.

This project aims to conduct applied research, to achieve technical independence, develop experimental models, and enhance the participation of the industrial sector in national enterprises.

3D Printing Project

3D printers are a modern digital technology using jet ink technology, where 3D elements can be configured to carry out their layers until the final product is reached. 3D printers are capable of integrating workflows into different parts and materials in a single construction process. This project aims to understand the basic concepts of jet ink technology and to develop and discover new and modern manufacturing methods based on this technique.

The project is characterized by new research methods. The mechanical forces applied to the materials during the production process will be used to generate chemical reactions by breaking new bonds and building them, in order to obtain a modified product with specific physical and chemical properties. As a result, chemical and physical properties for every drop or layer created during production can be controlled. The current research team - at KACST and at the University of Cambridge - is studying the appropriate conditions (such as compression, concentration, viscosity) of some polymers to modify and improve their optical and conductivity properties by controlling mechanical stress and fluid flow rate to control the cutting of the selected polymer chain.

The preliminary results showed the possibility of breaking the chemical bonds of polymers, which confirms the ability to use the idea of mechanical chemistry, resulting in new chemical compounds with different physical properties from the raw materials.

The project also includes a research study to simulate certain conditions in laboratory experiments. This is a prospective study to determine the reactions and conditions appropriate to its creation. A number of researchers from KACST were trained at the University of Cambridge to build devices and mechanical chemistry equipment, and to develop some of the models related to the project. This training has led to some preliminary results that will be published by researchers at a conference in Liverpool, and also by the British Royal Society of Chemistry.

Dust Repellent Surfaces for Glass Panels

This project aims to produce inorganic films that can be applied to glass surfaces to expel dust and dirt.

The technology developed in this project can be used in different applications for easy cleaning of transparent and non-transparent surfaces such as glass facades, glass front, mirrors and other applications. Various bodies can benefit from these applications such as: glass factories; solar cells factories; car factories; lenses manufacturers, and others.

The tools and materials needed for the project were completed, and the tools in the laboratories for making films were started. Six locations were identified in different areas, and the dust-stained glass paint samples were applied on the metal plates that were manufactured locally, to test the coating.

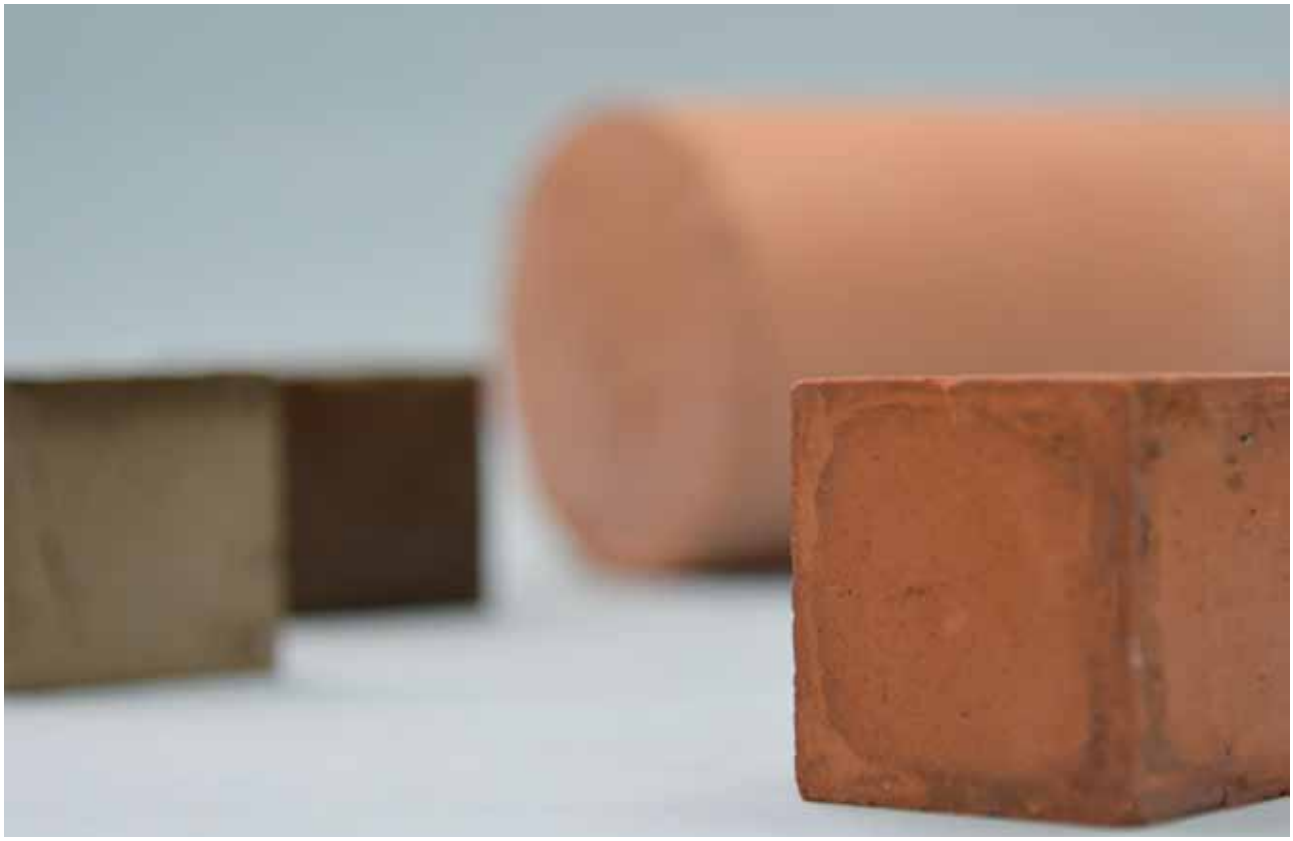
This project can also be used to transfer technology and establish close international cooperation between the Kingdom of Saudi Arabia and developed countries at the scientific and technical levels.

Nano Thermal Insulation Material-based Coating for Energy Efficient Glass

This project aims to develop and improve new coating methods for building glass, using nanotechnology. A microscopic coating of glass is placed that allows for high visibility transparency through the glass, while reflecting a large part of the infrared and ultraviolet rays.

The project also seeks to transfer and localize the technology of the modern and high-quality glass coating industry.

The project began in 2012, and it was successfully completed in 2016. By the end of the project, the optimum method of deposition of the micro-coating of the glass, using chemical vapor deposition technology, was reached, as well as new materials components suitable for the different coating layers. A heat transfer simulation program was also completed to compare new coating materials with traditional ones currently available in the market. The most important work of the project is to design and manufacture an integrated laboratory system for the installation of micro-glass coatings using the methods developed in the project.



Design & Development of Nanoclay-Polymer Composite Materials

This project aims to use kaolin, clay and pozzolan along with nanoparticles, to develop a geopolymer to be used as a protection coating for non-metallic materials like ceramic and concrete pipes. These materials then can be used to produce complex glass fibers and polymeric plastic to create non-metallic materials through the use of extrusion and winding techniques.

Geopolymer samples were produced using natural local materials. Many mechanical tests were made on the produced samples. To date 100% of this project has been completed. One of the most important outputs is the development of nanoparticles based on the use of technology in oil and gas applications, as well as the applications of protecting the roofs of the metallic and plastic products. This project is of benefit to the relevant bodies of the construction sector and pipe companies.

Developing Innovative Products of Polymers in Architectural Applications

The objective of this project is to establish an R&D industrial laboratory for polymers and their industrial compounds at KACST. The project aims to transform locally available raw materials into environmentally friendly, commercially viable, value-added and competitive products. The applications of these developed products are architectural and engineering applications, solar applications, advanced materials and household appliances.

In addition, the project aims to localize new technologies where KACST has the lead in developing such technologies at a national scale, supplying small and medium factories with the expertise and scientific consultancy to upgrade the specifications and quality of polymeric materials. This project will also address the production and processing problems to improve the quality of the final product of these materials.

Transportation & Logistics Services

- Autonomous Vehicles
- Traffic Management Systems
- Mobility Simulation & Modeling
- Robotic Transportation Systems

Technology Transfer and Localization

Transportation & Logistics Services

The transportation sector plays a leading role in raising the economic level for many countries around the world. Therefore, it is crucial to develop new mobility and logistics techniques that can increase the competitiveness of the Kingdom in this important sector.

Introduction

The transportation and logistics services sector is an important market in the Kingdom. According to Solidiance Co. report, the value of the Saudi transportation and logistics services sector was estimated to be 19 billion dollars in 2015. It is considered the biggest market in the gulf region, due to the strength of the Saudi economy and the high population density.

The Kingdom's Vision 2030 has focused on the continuous development of this crucial sector to promote the country's status in this field. This will be accomplished by establishing a vision to develop internal transportation networks and planning, and to utilize the Kingdom's distinguished location and status among other countries in the world, providing a unique logistics platform capable of becoming the main world trade center.

KACST was keen to introduce a special initiative in the National Transformation Program of 2020 to develop and settle transportation and logistics services technology. The initiative attempts to develop comprehensive transportation systems inside the Kingdom's cities, especially the major cities, to decrease the number of traffic accidents, heavy congestion, and fuel consumption. These objectives will be achieved by establishing advanced and low-cost computer systems. The initiative also aims to provide technical consultations on monitoring operations and logistics services. By studying creative solutions, such as the use of drones for logistics services. The initiative will also focus on developing self-driving trucks, given the total reliance on roads for the transportation of goods in the country, with a continually increasing demand on existing companies.

The Logistic System of Self Driving Trucks

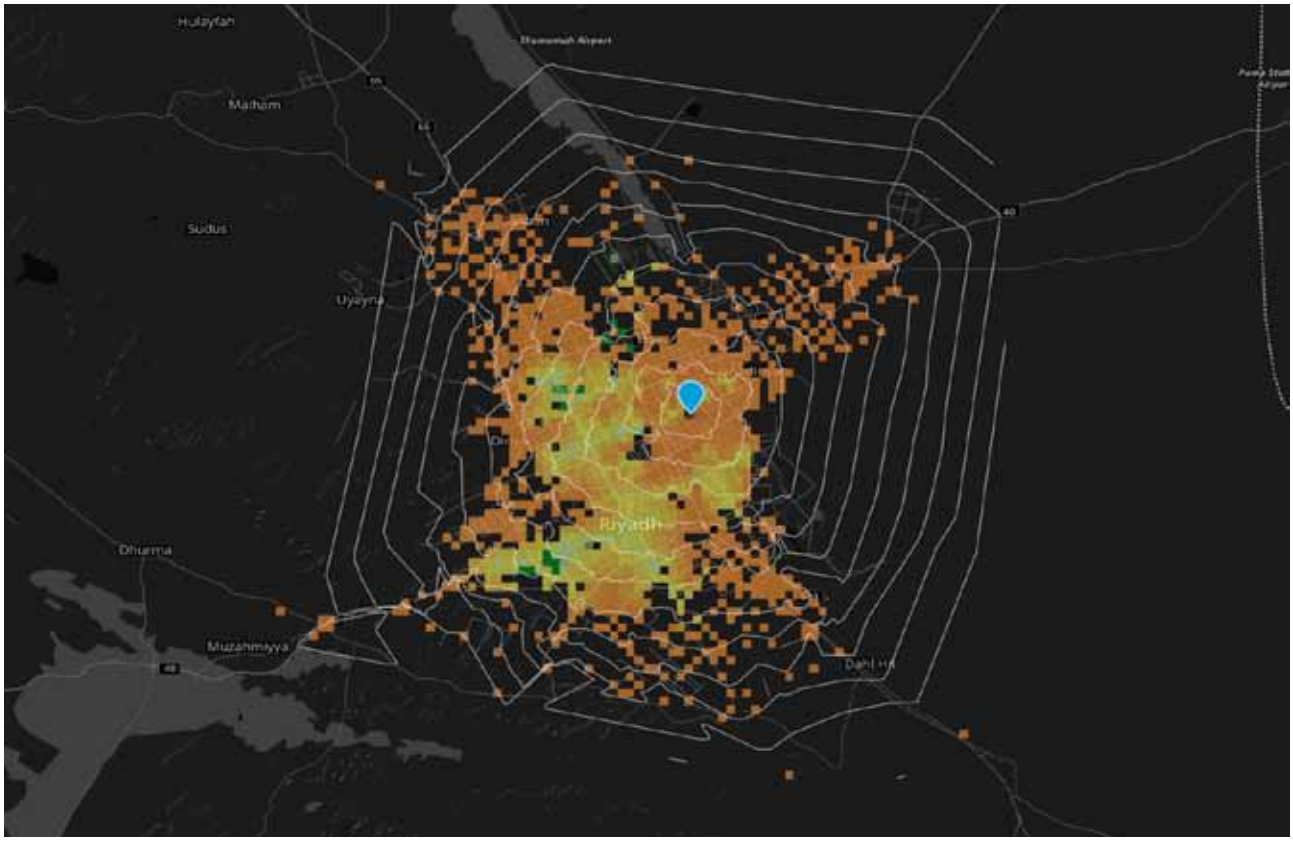
Self driving trucks have a high potential of impact on the transportation sector, due to their fundamental role in reducing human error rates as well as reducing pollution, and oil consumption. Therefore protecting resources, and contributing to the effective transportation of goods to be distributed in markets. The Kingdom is dependent on land transportation due to a lack of water, sea pathways, or railways, hence such trucks are important for Saudi Arabia. This project aims to build a primary model of auto driven trucks which opens horizons to establish an integrated transporting network that links ports of the Kingdom with special routes designed particularly for such trucks. This would help in upgrading the quality of transportation networks for goods inside the country. The project will focus initially on training human resources on necessary techniques to operate such trucks. The research team will carry out work to develop software programs for auto control which will enable trucks to operate in various situations and handle contingency positions and emergencies. This will be followed by testing the trucks in some sites in the Kingdom so as to ensure the efficiency of the software.

Virtual Traffic Lights (VTL)

This project aims to develop a high performance virtual traffic light (VTL) system to improve traffic flows in urban areas. It is being conducted in collaboration with Carnegie Melon University by installing VTLs on a small fleet of vehicles to be tested in one intersection on the first phase of the project to measure their efficiency and impact on congestion.

The second phase of the project expands to cover five intersections and 500 vehicles with VTL capabilities.

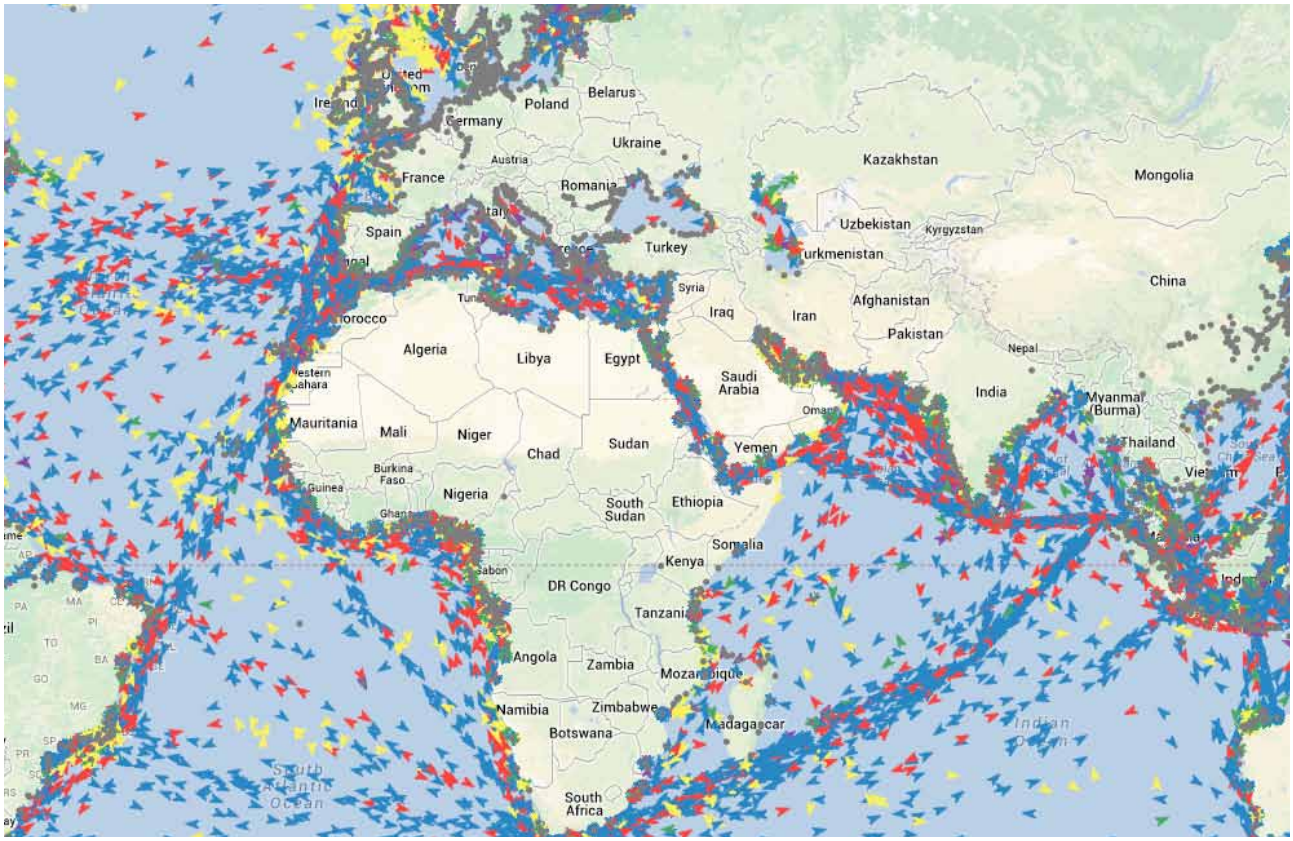
The last phase will include hypothesis testing for a period of six months for example to quantify the effect of this technology on multiple fronts such as home-work commute and traffic accidents, and to test its potential for use in toll roads and conduct traffic analysis.



Integrated Transportation Systems

The goal of the Integrated Transportation Systems project is to conduct a comprehensive study of the transportation infrastructure in Riyadh, a rapidly growing city that faces diverse challenges – urban sprawl, population growth and an increasing demand for the city's infrastructure in general and transportation specifically – that are each influenced by a variety of factors. The study addresses these complexities facing the transportation infrastructure of Riyadh and King Abdulaziz Project for Riyadh Public Transport. Accounting for the effects of social, environmental and demographic factors on public and private transportation use, the project investigates patterns of demand on the city's infrastructure, identifying its effects on and relationships with existing transportation systems. The goal of this project is to help assist decision-makers, urban planners and even individuals develop future plans based on a more comprehensive understanding of the current state of transportation in Riyadh. This work is expected to help the city manage urban growth and the continually increasing demand for infrastructure. The methodology includes various studies through the analysis of big data gathered from various government organizations and agencies as well as communications companies and social networks. The study combines a range of methods for statistical analysis with modeling and simulation of urban transportation, to understand the effects of increasing travel demand on the city of Riyadh.

The study takes advantage of widely used modern technologies to gather data that can help evaluate the demand on the city's transportation infrastructure, such as data on mobile phone usage, studies of traffic phenomena within the city and the use of data extracted from social media platforms. The study includes recommendations for the development of the city's transportation infrastructure and evaluation of the demand for different modes of transportation along with a comprehensive analysis of the city's urban landscape that can contribute to planning for future population growth and expansion. The project will ultimately help contribute to the planning of the King Abdulaziz Project for Riyadh Public Transport, currently the largest public transit project in the world.



Satellite-Based Commercial Vessel Tracking System (Sufun)

KACST aims at developing several end-to-end systems to track mobile objects to serve the transportation and logistics sector in Saudi Arabia.

Sufun is a Satellite-Based Commercial Vessel Tracking System that collects standard signals of the Automatic Identification System (AIS) sent by all commercial vessels around the world. These signals contain critical information such as the vessel's ID, speed, and status. Sufun develops a commercial payload that is launched onboard a satellite into a LEO orbit where it collects signals as it orbits Earth. The signals are stored onboard the satellite's storage system and then sent to the ground station on every overpass. Once all this data is downloaded to the ground station, it gets decoded, cleaned, and then linked to vessels metadata to identify characteristics such as physical attributes and ownership of each vessel. This information is conveyed to customers in a user-friendly manner using a web-based interface.

The first payload of this type was launched onboard SaudiComSat-7 satellite in 2007 as the first Satellite-based AIS payload in the world. Then, in 2014, the second payload was launched onboard SaudiSat-4.

The two payloads are operational and collect millions of signals every day from more than 30,000 unique commercial vessels from all around the world giving the system an advantage compared to shore-based terrestrial AIS receivers. The system is being used by several organizations in the government and private sectors in Saudi Arabia.

In 2016, the daily satellite-based data has been complemented by terrestrial data. KACST has installed a terrestrial AIS receivers on one of its locations on the Arabian Gulf and participated in an international service to share this data with more than 70 countries in the world. At the same time, the IT infrastructure of the system has been upgraded to cope with the huge amount of data that needs proper processing and storage. Also, several features have been added to the system based on user requirements to provide a proper user experience, performance and usability wise.

Also in 2016, the team has provided detailed and specialized reports to various government committees regarding specific maritime incidents.

Robotic Vehicles and Systems to Support Pilgrims' Mass Movement

This project aims to create a complete integrated system for the management of pilgrims' grouping and transportation in the holy places, to support field command units in handling emergencies that might occur during their journey, such as finding missing people and arresting intruders and illegals that might hinder the flow of movement. The system consists of unmanned vehicles that can collect data and take corrective actions in the field, and a central control room used for wireless communication and control. One type of robots to be used is flying robots (UAVs) for aerial monitoring and imagery to assist command units in forecasting and preventing complications. The other type is ground robots (UGVs) used for surveillance, search-and-rescue missions by using sensors and manipulators installed and fitted for various scenarios and conditions. All data collected and actions performed by the robotics units are sent to the central control room for review and approval. The system, when deployed, will lower the number of people needed in the crowd management unit and will increase the efficiency of the entire process. Also it will enhance emergency prediction and drop response time significantly.

The project aims to:

- Design and manufacture flying robots equipped with surveillance cameras to increase the efficiency of flight time and increase the capacity of additional loads and maintain stability for better imaging results.
- Design and manufacture a medium-sized robotic vehicle with several cameras, sensor and communication systems and with an automatic arm, a water disrupter and an explosive detector.
- Design and manufacture a transport vehicle containing a control room to manage operations for more than one robot at a time. It also includes tools and spare parts for emergency maintenance.

The project is expected to be completed by the end of 2020. The project team consists of consultants and researchers from the National Center for Robot Technology and Smart Systems at KACST and specialists from the Ministry of Interior. Taqnia for robotics and smart systems will work on manufacturing and commercializing the project's outcomes.

Environment

- Waste Treatment
- Air Pollution & Greenhouse Gases
- Advanced Materials Technologies for Environmental Purposes
- Environmental Modeling & Simulation

Environment

Countries all over the world encounter growing environmental challenges caused by increasing populations, accelerating urbanization, industrial, and economic growth. Therefore, it is vital to develop technologies capable of mitigating environmental issues.

Introduction

The Kingdom recognizes the importance of addressing environmental issues and providing suitable technologies. As a result, environmental technology was included in the Kingdom's development plan and in the National Science and Technology Strategy as being one of the most important areas for future sustainable development. KACST significantly encourages scientific research related to the environment and its current issues in the Kingdom, through transferring and developing advanced environmental technologies capable of enhancing the country's competitiveness in the global market.

On a national level, the strategic plan for the environment satisfies the Kingdom's vision for the environmental technology program that aims at creating sustainable environmental development by making strategic cooperation and partnerships agreements, leading to developing and localizing various advanced environmental technologies. These include air quality monitoring technologies, greenhouse gas mitigation technologies, wastewater remediation and reuse technologies, ground water treatment technologies, and desertification mitigation technologies.

Future environmental technology projects will focus on devising and developing the proper solutions for environmental issues and creating sustainable environmental development through on going and future projects.

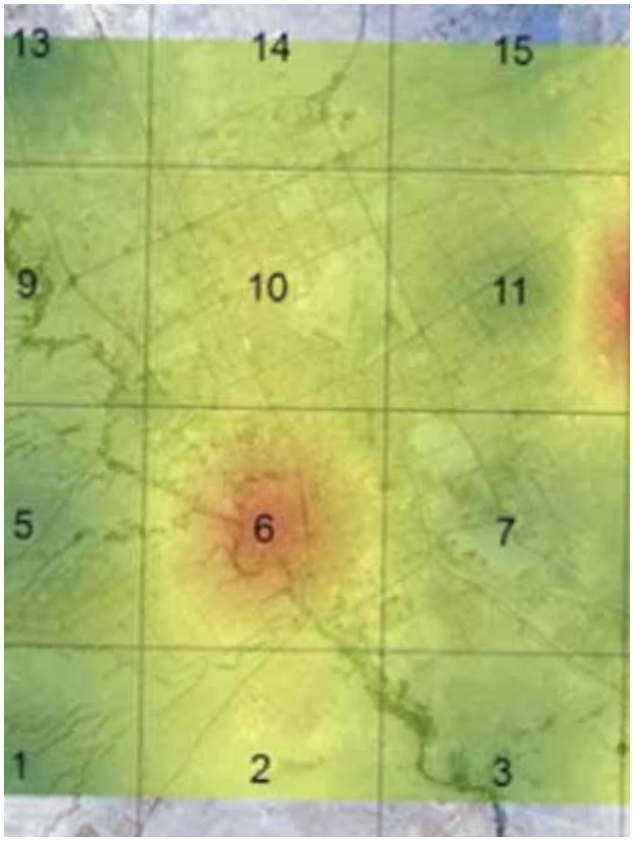
Waste Treatment by Plasma

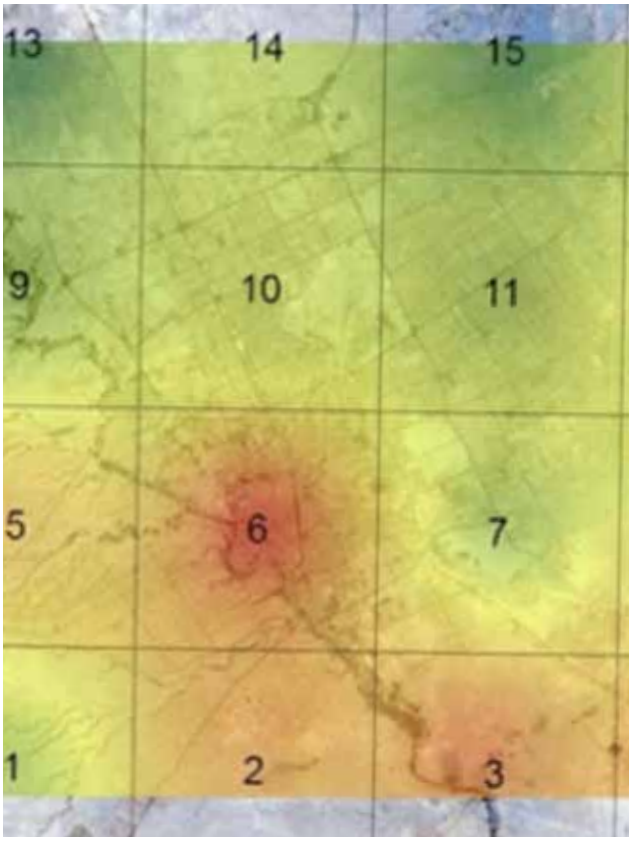
Based on previous experience in fly ash treatment due to burning fuel in desalination plants, it was found that thermal plasma technology can be used to treat a wider spectrum of waste including municipal solid waste, medical waste and a large amount of industrial waste. The technique has many advantages over traditional methods of burning such as the ability to destroy toxic substances that can not be destroyed by conventional combustion such as dioxins and furans which result from traditional waste burning process. Depending on the type of waste, it is possible to produce synthesis gas in appropriate quantities suitable for the operation of power plants, with a high efficiency cycle that contributes to reducing the cost of treatment. Alternatively it can be modified to liquid fuel used in transportation applications of all types, and to solid substance that can be used in construction. Although this technique has promising features, it still needs some development to overcome technical difficulties such as high initial cost, operating expenses, handling of high humidity waste and faults during operation. Several types of reactors use plasma for waste treatment.

During the reporting period, a mini-reactor was built using a plasma torch that is capable of processing waste samples from a variety of sources in a simplified manner. A more advanced project was also introduced within the National Transformation Program, which aims to develop a solid waste treatment pilot plant to test the aforementioned characteristics on an appropriate scale in regions around the Kingdom.

The proposed project consists of several phases. The first phase aims to evaluate a number of existing proposals and choosing the most appropriate ones for their development and application in the Kingdom. Second phase is the construction of a pilot plant of a suitable size to identify the expected problems during semi-commercial operation.

The third phase is to start operation of the plant that can process different types of waste and to develop technologies that utilize this waste in various applications. The final phase is a financial feasibility study based on the actual operation of the pilot plant.





Designing and Developing Air Pollution Diagnostic and Alarm System

This project aims at designing and developing a diagnostic alarm system for air pollution, using air pollution observational monitoring data for identifying air quality issues at early stages. This will facilitate sound planning and enable the right decisions to be taken concerning land use and industrial developments, thus avoiding continuous air pollution exposure.

This system incorporates various parameters including measurements of airborne particles and associated heavy metal, cation, and anion concentrations, as well as concentrations of the criteria pollutants. The system also identifies the spatial distribution of air pollutants over Riyadh urban area. For instance, the concentration levels of nitric oxide, nitrogen dioxide, carbon monoxide, and volatile organic compounds such as benzene, toluene, ethylbenzene, and xylene, and their impacts on ozone formation and its distribution, have been quantified and investigated in the various areas of Riyadh. In addition, concentrations of polycyclic aromatic hydrocarbons and their sources and temporal and spatial distributions have been characterized and their source apportionment has been quantified.

Smart System for Monitoring Greenhouse Gases

According to a recent articles published in Nature Climate Change in 2015, extremes of wet-bulb temperature, a combined measure of temperature we and humidity, in the Arabian Gulf region are likely to approach and exceed critical thresholds under the business-as-usual scenario for future greenhouse gas concentrations, and in absence of significant mitigation are likely to severely impact human habitability in the future. Recognizing the importance of this, Saudi Arabia has pledged to curb its carbon emissions by 2030.

This project aims to develop a smart system for monitoring greenhouse gases over the kingdom using low-cost monitoring units to help decision makers, and to continuously provide data through a network of sensors. The system also aims to identify the spatial and temporal patterns, trends of greenhouse pollutants and provide inputs required for atmospheric modeling and impact evaluation (on water, land, healthy and building materials), providing data trends in real time and ensuring compatibility with international measurements.

Air Pollution and Greenhouse Gas Technologies

Air pollution is a serious issue that is affecting our environment. This project is one of the initiatives of the National Transformation Program that aims to find innovative solutions to air pollution and greenhouses gases at the national level.

In order to achieve the balance between the industrial growth in the country and protecting the environment, the Kingdom gave environmental technology exceptional importance.

Air pollution and greenhouse gas technologies are critical to ensure environmental protection and proper conditions for a habitable planet and sustainable development. The expected outcomes of this project are:

- Identifying pollutants and attributing them to their sources, and identify the ideal strategy for pollution mitigation.
- Forecasting air quality in growing residential and industrial environment.
- Identifying ideal sites for future industrial developments to mitigate their environmental impacts.

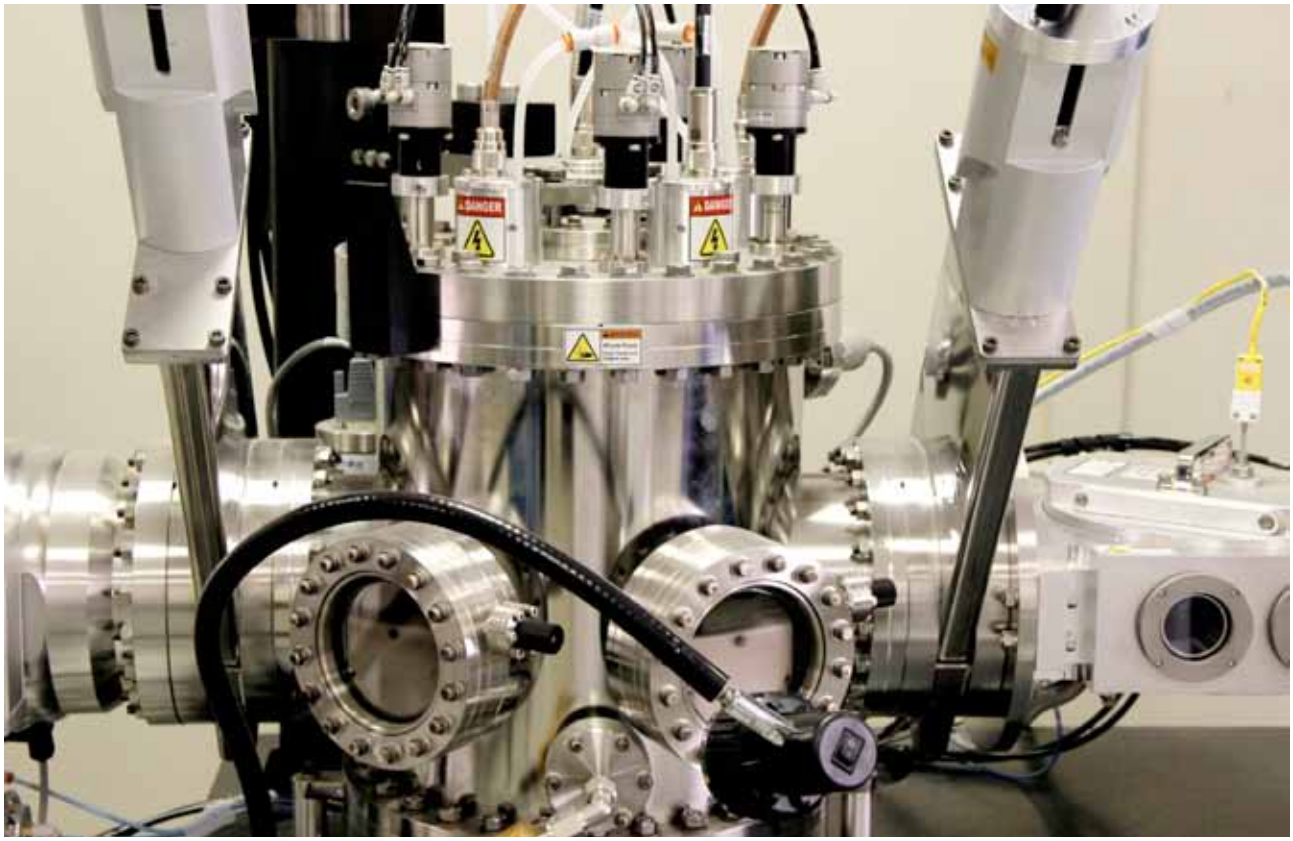
Groundwater and Soil Remediation Technologies

In this project, a technology was developed by the injection of chemical oxidants underground, supported by an activation zone of Nano-materials. Nano materials are spread around the injection well and attached on soil grains to create an activation zone.

This technique enables the breaking down of chemical bonds in the toxic organic compounds to convert them into non-toxic or less toxic compounds. This technology has a wide range of applications on several toxic and hazardous organic compounds including petrochemical materials, petroleum byproducts, industrial solvents, agricultural pesticides, and others.

Moreover, this technology is considered faster in remediation period compared to other competitive technologies, however, it is still at the preliminary stage of development.

This technique can be used to remediate the leaking from gas stations without the excavation of soil or the removal of underground storage tanks, and can be applied under industrial buildings without demolishing the structure.



Advanced Oxidation Technologies Using Nano Metal Particles

This project aims to develop advanced chemical oxidation techniques used in treatment of carcinogenic organic compounds by using a group of synthesized metal Nano-materials as catalysts of different oxidants. These materials are expected to be more stable and environmental friendly. The project is divided into several stages:

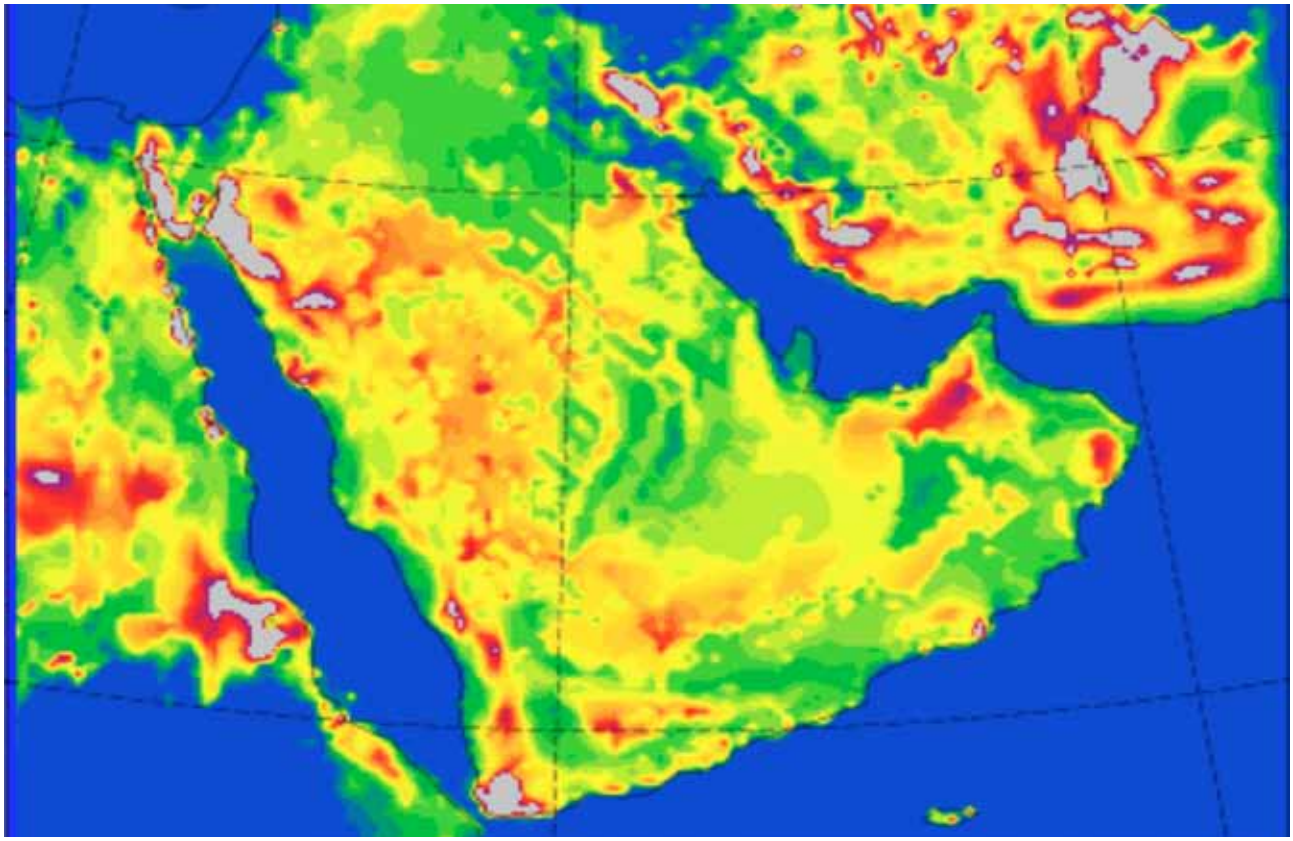
- Synthesizing mono Nano materials.
- Characterizing the synthesized Nano-materials to identify the properties using electron microscopies.
- Examining the reliability of synthesized materials as catalysts in chemical batch reactors.

The outcomes of this project are expected to have a positive impact in treatment of the carcinogenic organic compounds that might be present by leaking from underground storage tanks and petrochemical industries.

Two patents were filed so far from this project. One of them for the invention of an instrument to synthesize Nano materials under reduction conditions, and the other is for the invention of chemical laboratory equipment to dry Nano metal particles.

Highly Sensitive Detectors Using Metal Oxides Nanostructures

In this project, the laboratory at the National Institute of Applied Physics, has been equipped with Nano-deposition facilities to develop Nano-based sensors that are capable of detecting dangerous and poisonous gases at very low concentrations. For instance, metal-oxide Nanostructured semiconductors have been used as active material to sense some chosen gases. Further, some researchers from KACST have taken short training courses in making Nanostructured metal-oxide sensors and operating sensing characterization systems in both Korea and Shanghai Universities. The laboratory also has several metal oxide samples such as ZnO, SnO_2, LSMO and WO_3, that were prepared using different deposition methods in particular sputtering and hydrothermal reaction techniques. Finally, a home-made circuit has been built for outdoor gas detection which needs to be developed in future research projects. The performances of the fabricated sensors, which is affected by morphology, crystallinity, porosity, deposition technique and other properties of the Nanostructures, will be studied.

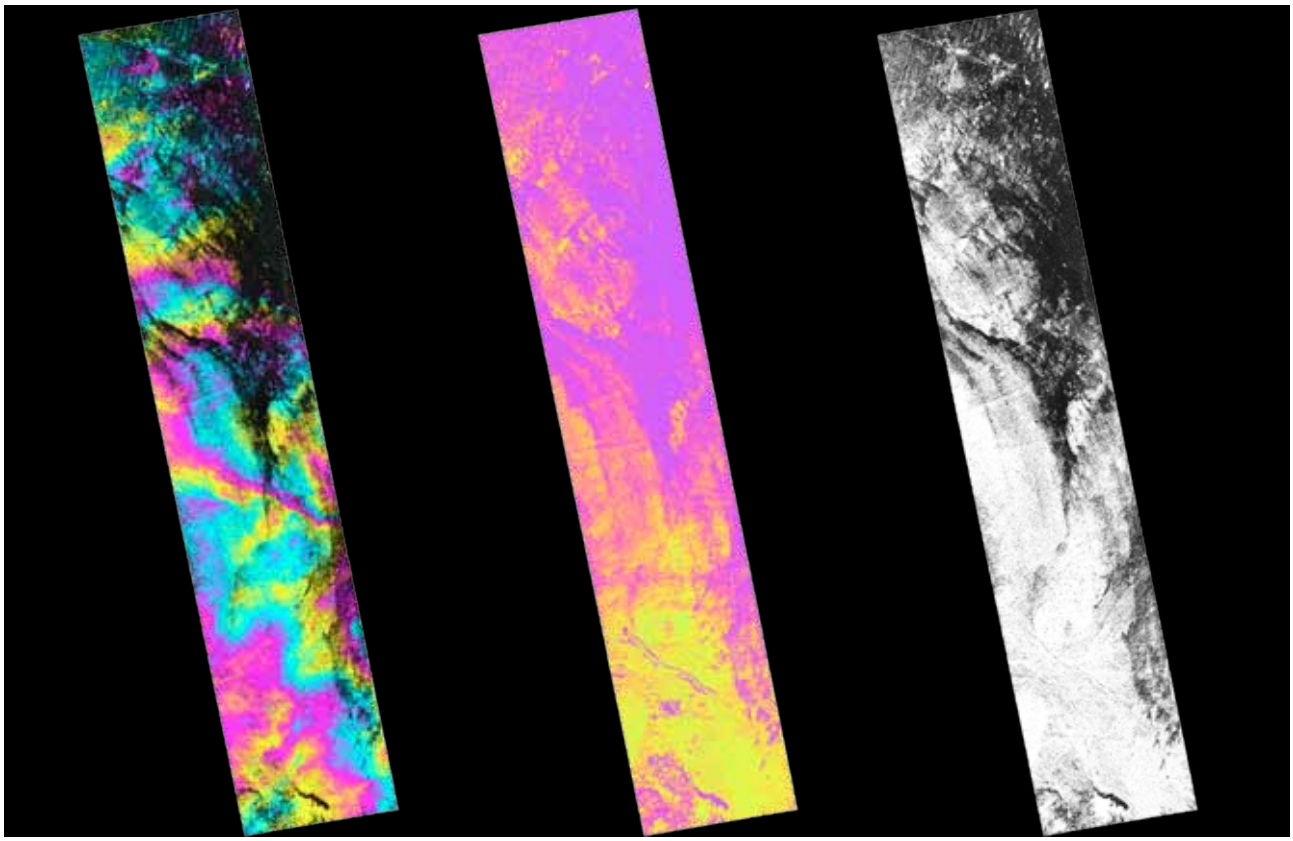


Sustainable Desert Greening

Located in one of the warmest and driest regions in the world, Saudi Arabia's harsh climate presents unique obstacles to meeting the energy and water needs of the country. We rely on desalination to provide more than 1 billion cubic meters of water each year, and as we build new infrastructure to meet demand, it can impact the surrounding environment in ways that are complex, expensive, and often unplanned. To effectively design sustainable and efficient infrastructure, it is crucial to account for the dynamic interactions between human activity and the surrounding environment. This can be captured by coupling detailed simulations of the Saudi climate with models of physical infrastructure such as water desalination and solar energy generation. Starting with desalination plant located in Al-Khafji as a fully integrated model to study the interaction between seawater desalination using solar energy and the impact of current and projected climate conditions on production.

The project relies on accurate climate simulations validated with satellite measurements and coupled with accurate simulations of water desalination plants and solar power plants. It also relies on experimental studies for dust characteristics and its deposition rate on solar panels, to determine the effect dust has on power generation.

The goal of this project is to study the interactions between the environment and built infrastructure. Using a set of models to simulate the dynamics of engineering processes and the surrounding environment, we are studying the effect of climate variation on desalination activity and the impact of brine discharge in the Gulf. To expand our understanding of the Saudi climate, we are using a combination of field studies and experiments to understand the physical and chemical characteristics of the region's dust and evaluate its impact on solar potential and the broader dynamics of our climate. In addition, spatial and temporal variation of dust and the increase rates on different regions across the country, are studied using satellite data and a network of ground based stations. This data is used in simulation models of different environmental processes and the performance of physical systems under such climatic conditions.



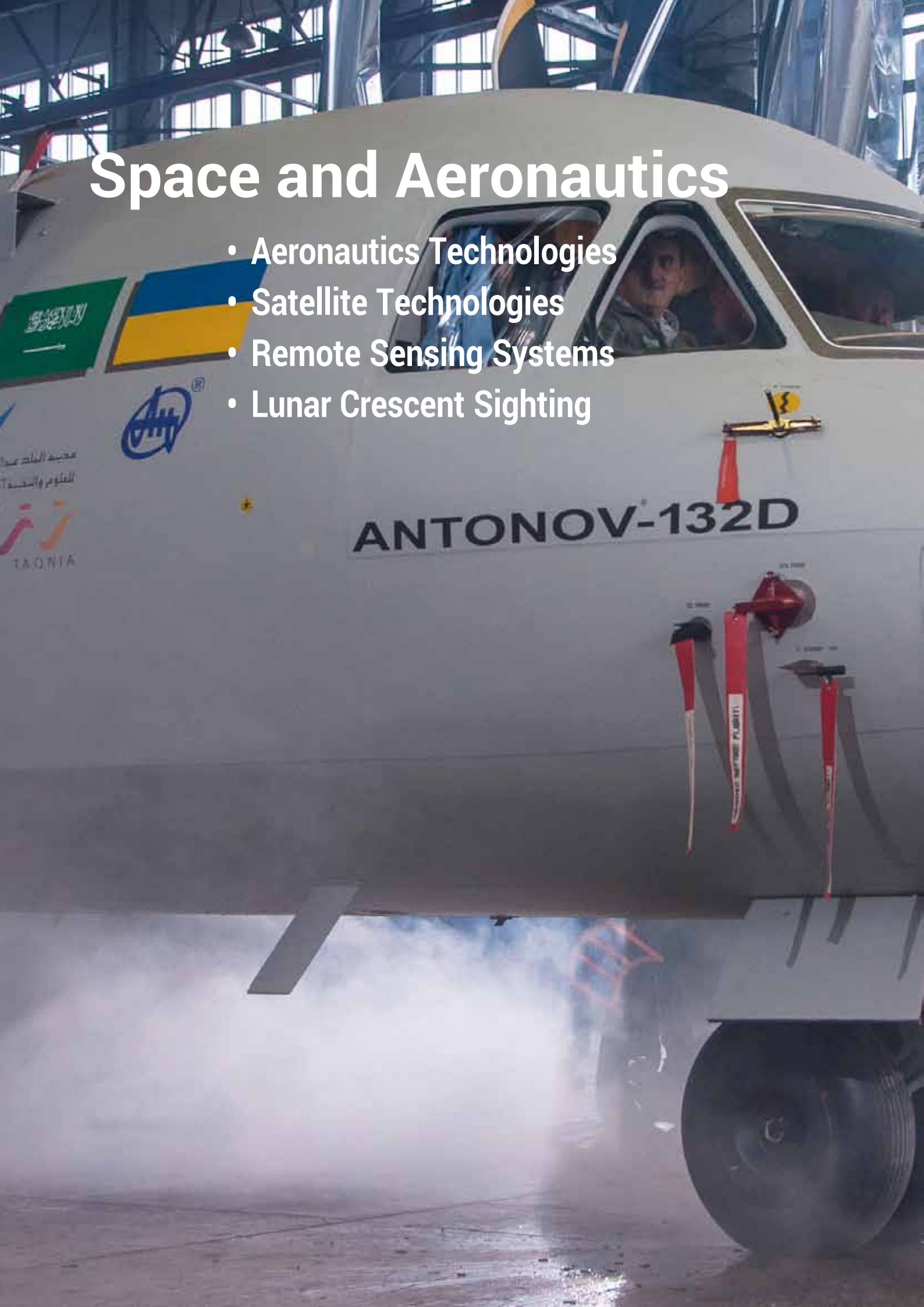
Study of Changes in the Earth's Surface

With the advanced developments in software, hardware, and satellites scientists are able to predict and monitor changes in the earth's surface and distortions caused by geological or industrial activities. These deployments aid in producing maps of the Earth's deformations, which can be used to mitigate natural hazards. This project aims to produce deformation maps in the Kingdom's surface due to natural and human-made disasters, using interferometric synthetic aperture radar (InSAR) technology. This project will help to strengthen the relative research infrastructure in the field of satellite imaging using InSAR technology by introducing hardware, software, and qualified staff to KACST.

To achieve these objectives, the research project requires the acquisition of high-resolution satellite data from different vendors to cover the entire area of interest, and then, this data will be analyzed by a geographic information system. Using continuous geodetic monitoring stations distributed throughout the Kingdom will validate and correct the final results.

The computing and processing environment has been built to include operating systems, several servers, and data storage. Although the study area will cover the entirety of Saudi Arabia and surrounding borders - the so-called Middle East Map (MEM) - the Riyadh region has been selected as a sub-region for processing the available Sentinel-1 A\B satellite data. The total size of the necessary data increases depending on the satellite orbit and its mission.

So far, the data size has reached 15 terabytes for the selected area. For interpretation proposes, we have communicated with many government agencies locally and globally to gather all relative information and establish a uniform database that includes geological maps, faults, soil types, seismic events, etc. We aim to use the Generic InSAR Analysis ToolBox (GIAnt) to produce temporal deformation maps of the Earth's surface for the area of interest. This study is a part of a collaboration agreement made between KACST and the California Institute of Technology (Caltech) through the Joint Centers of Excellence Program at KACST.



Space and Aeronautics

- Aeronautics Technologies
- Satellite Technologies
- Remote Sensing Systems
- Lunar Crescent Sighting

Space and Aeronautics

KACST seeks to strengthen the Kingdom's position in the field of Space and Aeronautics by cooperating with international agencies and centers on establishing advanced infrastructure, transferring technologies, and developing human capital.

Introduction

Since its establishment in 2000, the Space and Aeronautics Research Institute has been engaged in the localizing of various Space and Aeronautics technologies through its national centers that specialize in aeronautics technology, satellites technology, jet engines technology, astronomy, geodesy and navigation, and remote sensing.

In the field of aeronautics technology, KACST began an industrial technical alliance with the Ukrainian company Antonov and the Saudi Taqnia Aero Co. This alliance aims at transferring technology of use in the aircraft industry through developing, manufacturing and producing the multi-purpose Antonov 132 airplane.

The Satellite Center leads the national strategy of localizing the satellite industry in the Kingdom, by investing in building infrastructure and qualifying local human capital. The center provides end to end solutions starting from its mission requirements and design, to the development of essential satellite systems such as payloads, controls, communications and power systems.

The National Jet Engine Center focuses on the localization of jet engine technologies, including engine capacities, sizes and speed, that are designed according to their future application use.

The National Center for Astronomy seeks to achieve the vision of KACST in conducting research, studies, and in the development of astronomical applications that serve the needs of the Kingdom, such as the determination of lunar months, the study of solar activity and its monitoring, the interference between solar winds and the earth's magnetic atmosphere, and studies on the impact of magnetic storms on communications, electricity networks and geographic positioning systems.

The First Prototype of Antonov An-132

KACST inaugurated the first lightweight multi-purpose aircraft, Antonov (AN-132) in Kiev, the capital of Ukraine on Tuesday, the 20th of December 2016, under the patronage of His Excellency Pietro Borchenko the President of Ukraine, His Highness Dr. Turki bin Saud bin Mohammed Al-Saud, the President of KACST, and a number of officials from the Kingdom and the Republic of Ukraine.

The aircraft is capable of flying at 28,000 feet with a load of 9.2 tons, for a distance of 4,500 km at a maximum speed of 550 km per hour. Engineering studies were conducted to provide the aircraft with Pratt and Whitney PW 150A engines, advanced electronic and navigation systems, and many other modern systems that ensure high performance and quality standards to reach international markets.

The launch comes thanks to the technical alliance concluded by KACST with Antonov as part of its initiatives in the 2020 National Transformation Program to achieve the Kingdom's 2030 Vision. KACST owns 50% of the intellectual property of this aircraft.

Antonov is known for its extensive experience in manufacturing large-scale aircrafts for various applications. Therefore, Antonov experts were chosen to train young Saudi cadres to gain experience and develop and refine their skills and potentials. This agreement will allow the two parties to open new horizons for continued cooperation.

The aircraft production will be in parallel in both the Kingdom and Ukraine, and Saudi engineers and technicians along with their Ukrainian counterparts will participate in production lines.

Taqnia, together with KACST and Antonov, are working on transferring, and localizing technology and establishing infrastructure for the local aircraft industry to develop manufacturing capabilities. They will cooperate with specialized Saudi government-owned and private-sector companies. This cooperation will enable them to reduce procurement, training, operation and aircraft maintenance costs besides raising the aircraft manufacturing technical knowledge level and providing many job opportunities for young men and women in the Kingdom.

In the second quarter of 2017, the Kingdom's citizens will witness the first Saudi-Ukrainian plane flying over the country.

Development of Turbofan Engine TKF-500

The objective of this project is to transfer the technology for the turbofan jet engine TKF-500, and to indigenize in cooperation with the foreign partner.

The project aims to study the design and manufacture of turbofan jet engines, and to train Saudi nationals. The project consists of several stages: development, design, manufacturing, assembly, and testing. The engine is used in several applications such as private and small aircraft, UAV, and guided missiles. The reason for selecting this engine is that it has advanced technical specifications:

- Thrust up to 545 Kgf (5.35KN).
- The overall engine pressure rate is 8:1.
- Engine dimensions: length 1.4 m, diameter 40 cm.
- Total weight is 99.2 kg.
- The speed is greater than 0.9 times the speed of sound, while the maximum number of cycles is 27000 RPM.
- The engine is capable of operating under difficult operating conditions, where the temperature is between 40 to 55 degrees Celsius.

Development of Turbine Engine TK-200

The purpose of this project is to enhance the engineering capabilities of KACST researchers, excel in design, control performance, and developing the Engine Control Unit (ECU).

Specifically, the goal is to design a compressor and a perfect diffuser that increases the engine's reliability and performance. It also includes a control system with high specifications that allows for turning off the power supply from the engine before the completion of the engine calming process. After the engine is calmed, the control system will turn off by itself.

The TK-200 engine is a turbojet engine with a 230N (23.5 kgf) thrust. It is designed for small air vehicles with up to 20kg weight such as the unmanned air vehicles, air targets and precision-guided missiles.

The main technical specifications of the engine are:

- Maximum thrust: 230N.
- Maximum RPM: 112000 RPM.
- Weight: 2.37 kg.
- Dimensions: Length 350 mm, Diameter 132 mm.

Development of Jet Engine TK-80

The objective of this project is to gain the ability to produce turbojet engines, allowing self-sufficiency for this type of engines, as well as for other types.

Specifically, this project aims to develop the TK-80 Jet Cat small turbojet engine and manufacture it locally. The TK-80 Jet Cat engine has 97N thrust power and is designed for small air vehicles weighing between 8–15 kg, such as Unmanned Air Vehicles, air targets and precision-guided missiles.

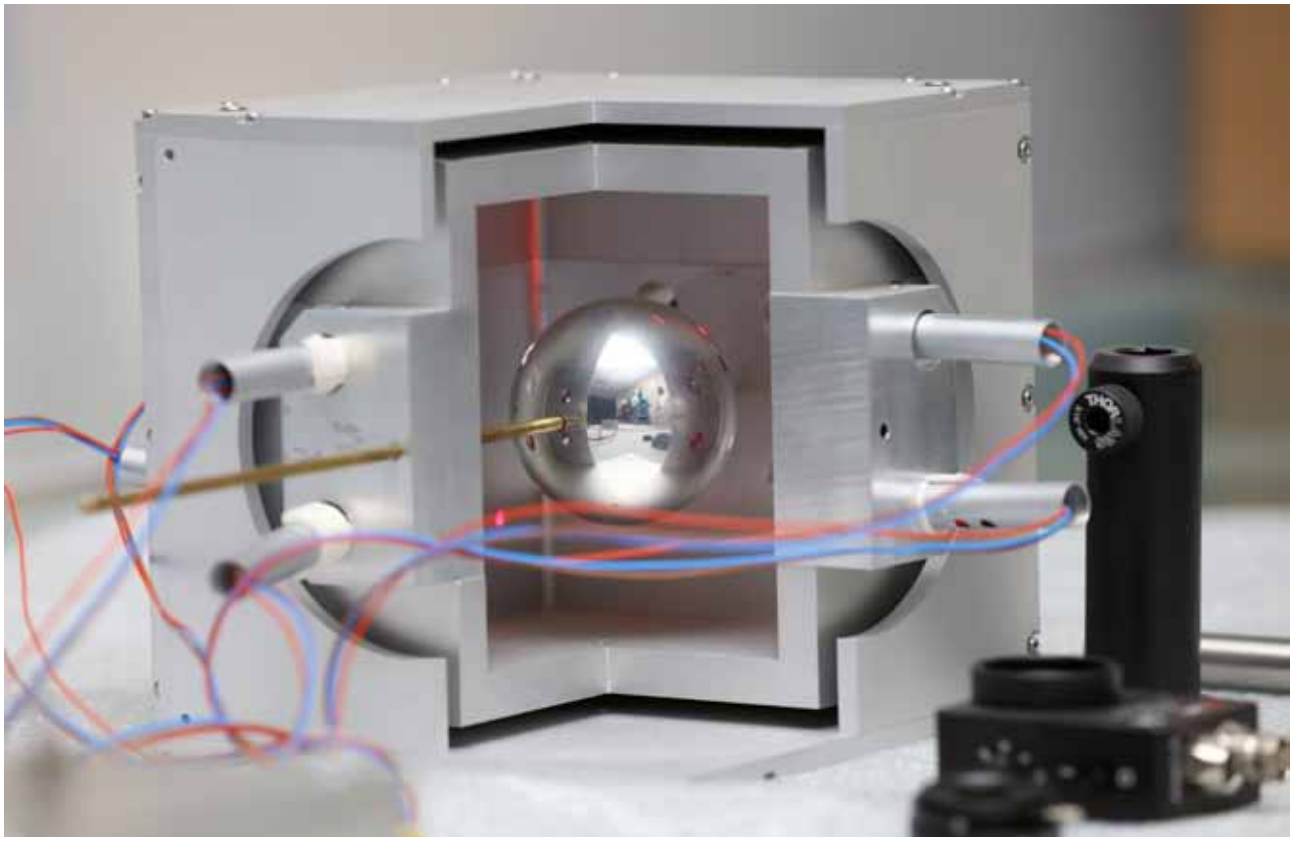
Similar to other small turbojet engine, the TK-80 consists of an air intake, radial compressor, annular combustion chamber, axial turbine and output nozzle. The main technical specifications for this engine are:

- Maximum thrust: 97N (9.9 kgf).
- Maximum RPM: 125000 RPM.
- Weight: 1.36 kg.
- Dimensions: Length 300 mm, Diameter 112 mm.

Studying the Dynamic Behavior of Micro Air Vehicles

The goal of this project is to develop a high fidelity computational technology that has the capability to accurately model and simulate the aerodynamic performance of micro air vehicle designs in the presence of atmospheric disturbance with verification procedures.

This software design allows for the study of air vehicle dynamics during wind gust disturbances, as well as the comparison with experimental results and real time tests. In addition, the design of aerodynamic perturbations, improved understanding of dynamic behavior for fixed and flapping wing movements that have high efficiency requirements for vehicle specifications. The software requires a high powered computing facility that will allow for quick solving of complex mathematical equations that describe the aerodynamic air flow, this can be achieved through the support of super computers that currently exists at KACST (SANAM) and at Stanford University. We have studied design variations with simulation models to obtain a higher precision and meet the project objectives.



Automatic Stall/Spin Recovery of Fixed-Wing and Autonomous Aircraft

This project aims to study the factors that cause stall-spin dynamic behavior for Unmanned Air Vehicles (UAVs) by analyzing the aerodynamic data measurements during complex maneuvers. Different types of sensors and measurements are implemented to better enhance the knowledge and the analysis of the behavior of UAVs when entering stall or spin modes. Experimental flight tests are executed to allow for system identification techniques and control design methods. Measured data such as pressure sensors are distributed on the vehicle structure, which are then analyzed and employed for aerodynamic modeling purposes. When the causes of the stalls and spins are pre-determined, automatic recovery schemes are developed to prevent UAVs from entering such a mode and hence keeping UAVs safe. Consideration of accident avoidance using altitude loss as a metric of prevention are novel in the approach and implementation. During the project, the causes of entering stall and spin modes were identified in better accuracy and automatic recovery control systems were developed.

Shortest Path to Space (SaudiSat-4)

This project aims to develop a highly reliable satellite platform that is capable of hosting various payloads. This can be achieved through development and qualification of the main subsystems at KACST's test facilities and then by launching them in certain missions. This approach enables manufacturing reliable satellites with lower costs and shorter lead-time.

The first outcome was the launch of SaudiSat-4 in 2014 with the UV-LED scientific experiment payload developed by NASA and Stanford University. The mission has been achieved successfully from KACST's ground station, and the experiment's data has been received and analyzed by the joint research team.

In 2016, the research team published the results in a paper, and published others detailing the nature of the payload and its thermal design and how it was achieved by the spacecraft.

In the same year, the engineering team upgraded several subsystems of the platform after carefully analyzing their performance in space. The upgraded systems will be used in future missions that KACST intends to launch soon.

Upgrading Satellite Development Infrastructure and Facilities

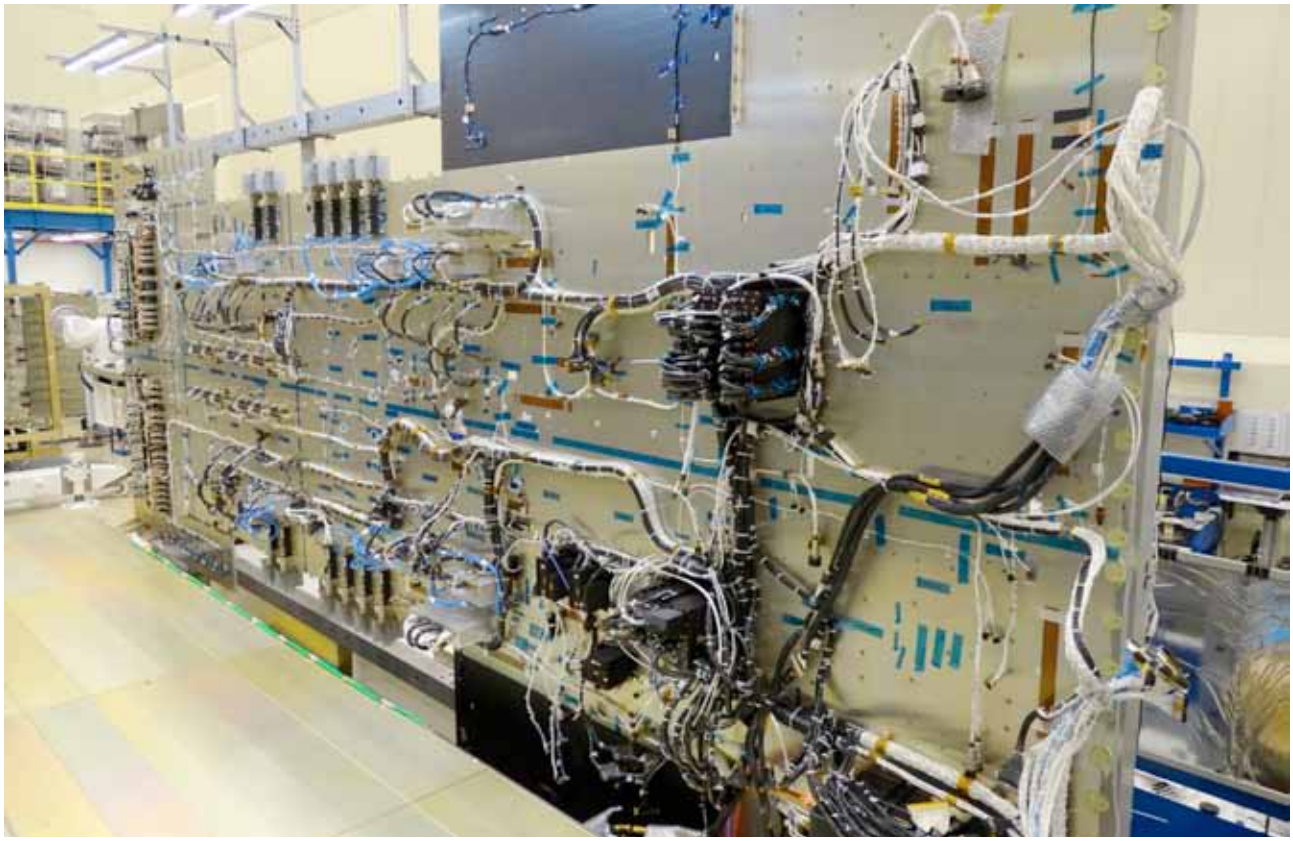
KACST is working on enhancing national capabilities to develop advanced satellite systems to serve national needs and to conform with the strategic plans to localizing of this industry. These efforts include upgrading facilities and infrastructures to develop, manufacture, test and operate satellites of larger scales and with more advanced capabilities.

In 2016, the Advanced Manufacturing Workshop was relocated to its permanent facility at KACST's campus along with commissioning new design, QA and simulation labs. The workshop is now capable of manufacturing advanced structures made of various materials.

At the same time, new clean rooms with ISO8 and ISO7 standards have been commissioned at KACST's main AIT building, to establish the following labs: Satellite Subsystems Integration and Test Labs, Electronic Systems Staking and Conformal Coating Labs, Thermal Paining Labs for Satellite Structures, and Extended Satellite AIT Labs.

KACST is also building state-of-the-art environmental test facilities that are capable of managing big satellites with a mass up to 5 tons. In 2016, all civil works for the new ETF have been completed. The electro-Magnetic compatibility Chamber has been installed inside the building along with the Thermal Vacuum Chamber. Also, the factory acceptance tests for the vibrations system and the mass properties measurement system have been carried out successfully and both systems will be installed in mid-2017. With such facility, KACST will have a comprehensive lab for any kind of environmental testing that could serve satellite development needs as well as other industries that require such capabilities.

On the ground station side, a complete upgrade plan has been commissioned with the vision to have an advanced ground station that is capable of operating a constellation of satellites simultaneously, efficiently and securely with its high-speed communication systems as well as the mission control system as more satellites are launched in the future. The factory acceptance tests for two antennas and civil works for their installation have been completed. Commissioning and full operations of the advanced ground station are planned for mid-2017.



Saudi GeoSatellite-1 (SGS-1)

The main purpose of Saudi GeoSatellite-1 (SGS-1) system is to provide secure satellite communications to several public and private organizations in the Kingdom, on Ka-Band frequency at geostationary orbital position 39° East. The SGS-1 system consists of the space segment, the satellite, the ground segment, the gateways, network operations center, and the data centers.

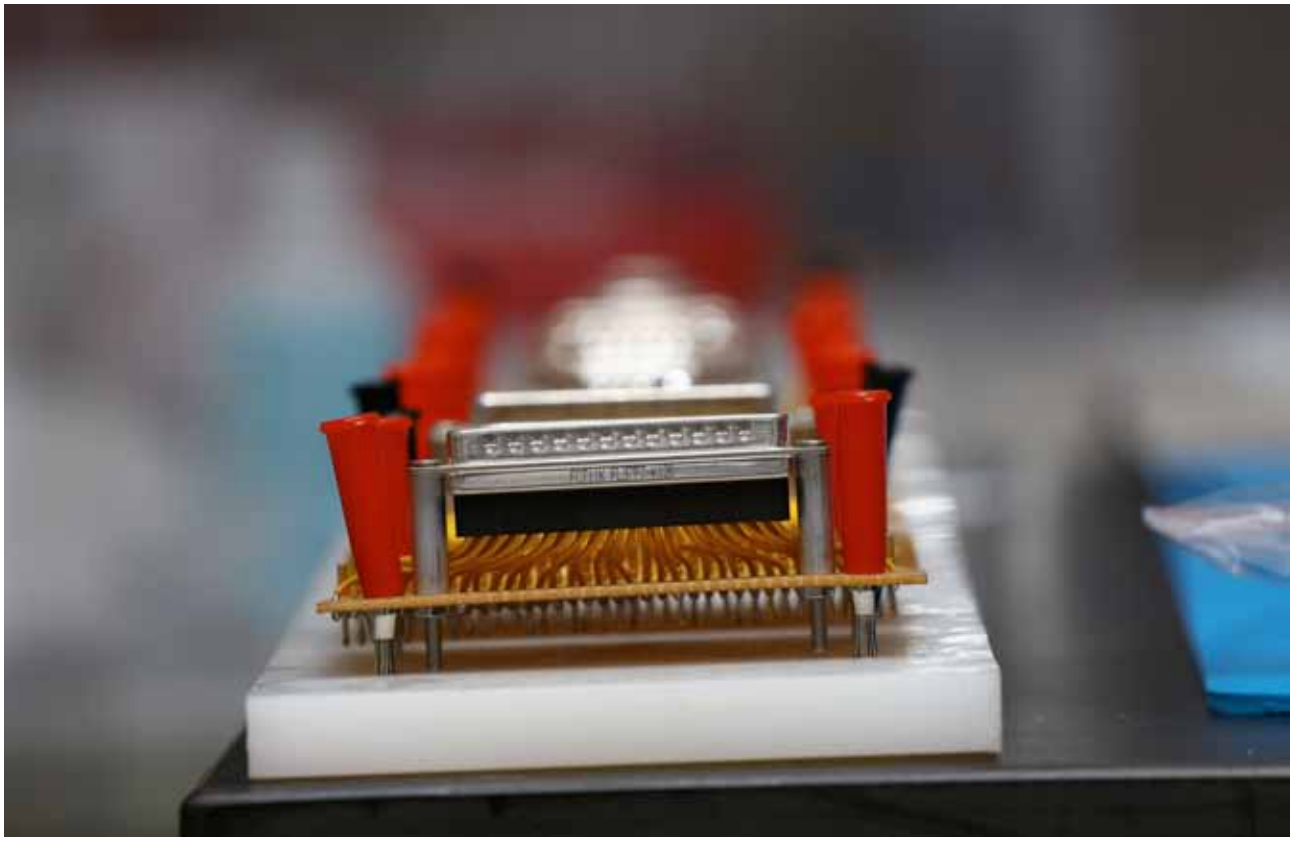
The space segment has been designed with a 15 years lifetime to carry multi-beam payload including two steerable beams. The payload has a 34 Gbps capacity covering the GCC, Middle East and North Africa (MENA Region) and Southern Europe.

In April 2015, Lockheed Martin was contracted to manufacture the SGS-1 satellite. The project is being managed by a joint team from the Space and Aeronautics Research Institute and the Information and Communication Research Institute at KACST. The team has representatives from user organizations from different government agencies. There is direct involvement in the day-to-day work by KACST's resident engineering team at Lockheed's facilities. Another engineering team is also working at Lockheed's laboratories on the assembly, integration and testing in preparation of the new satellite that will be launched in 2018 with Arian-5.

For the SGS-1 satellite, the preliminary and critical design phases have been completed and 80% of the subsystems have been manufactured and received. The satellite structure is in the assembly phase with 72% of the subsystems assembled to the north panel and 41% of subsystems assembled to the south panel. In parallel, the antenna subsystem and solar panels subsystem are undergoing the environmental and functional testing to be assembled to the satellite structure later.

With regard to the ground sector, a specialist joint team has been formed since last year and requirements have been defined and are consistent with the high-throughput system (HTS) and secure communication.

This year, KACST worked with its technical partner to design the ground sector using the national waveform that has been developed at KACST. Architecture design is on progress to reach final stage that should be implemented by an international company that will be selected at a later date.



Remote Sensing Satellite with Electro-Optical Payload

This project aims at developing an end-to-end remote sensing system with its space and ground segments, to serve several government organizations. This will be achieved by developing an electro-optical payload of high resolution with the satellite platform that is capable of meeting certain remote sensing mission's requirements. The satellite platform has been qualified in space with the SaudiSat-4 mission launched in 2014, and upgraded based on their performance in space.

The design, manufacturing and qualification of the platform's mechanical and electronic systems were completed last year. In 2016, the manufacturing and assembly of the payload's qualification model was completed, and all environmental tests (vibration and thermal vacuum) were carried out successfully to simulate the launch and orbit environments. Furthermore, the payload was integrated with the platform and all functional tests were completed to ensure compatibility of the mechanical and electronic systems.

Based on the results of the integration tests of the qualification models, the flight models are being manufactured and will be completely integrated in 2017.

In 2016, the launch campaign was kicked off with the launch agency. The launch campaign typically takes 18 months before the launch of the satellite to determine all the requirements associated with the orbit such as altitude and inclination, and the requirements associated with mechanical and electrical integration between the satellite and the launch vehicle. This phase was completed and the design and manufacturing of the launch vehicle has been started.

On the ground segment side, KACST is working with all stakeholders to build an efficient and cost-effective system that would serve them with a focus on raising the human and technical capabilities. The first phase of this work includes detailed studies of current status and user requirements with a consulting firm. Based on the user requirements, the system design has been developed and an RFP to implement the system has been tendered to international firms. The team is currently qualifying the best firm to implement the system.

Conceptualization, Innovation, and Planning for Earth and Space Sciences

"Eyes on Earth" is an application that represents global climate data on earth sciences through a fleet of satellites for National Aeronautics and Space Administration (NASA). KACST has just started to work with JPL to further improve the application. The application can demonstrate the vital markings of our plant, such as sea level rise, CO_2 concentration in the atmosphere, and ozone level in the South Pole. This application makes it possible to track the movement of water all around the world, using the gravity map from satellites (Grace). The crust's temperature map can also be used to check global temperatures, the hotness and coldness of certain locations on earth, and the levels of CO_2. The application can also track volcanic activities and forest fires. In addition, the application has a "latest events" feature, which enables users to review satellite images of natural disasters and recent events, such as algae blooms, sandstorms, and forest fires. Moreover, the application presents the current location and expected course and orbit of all earth science satellites owned by NASA that are still operating.

Miniaturized Autonomous Distributed Space System

The goal of this project is to develop a miniaturized distributed space system by launching many small satellites that communicate with each other to enable formation flying objectives. This space system will allow for a platform that advances both space science and planetary exploration. To achieve the formation flying objectives, an accurate navigation system must be implemented, an example of such system is with laser communication. In addition, attitude determination and control systems will be developed to meet the accuracy requirements where efficient propulsion systems are employed.

In addition, a Modular Gravitational Reference Sensor has been recently developed so it can be used in the next SaudiSat exploration which is made to be "Drag-Free" and only affected by the Earth's gravitational force. This type of device contains a floating spherical mass inside a box that is included within the satellite structure. The mass is not disturbed by the space drag while the satellite is still influenced by the drag. Thus, the location of the mass will be changed according to the force and the direction of the drag.

Manufacturing of Satellite's Solar Panels with Photo Voltaic Assembly

KACST is working on localizing the technologies that are related to solar panels manufacturing with Photovoltaic Assembly (PVA) technologies for space applications. A partnership has been formed with a leading company that specializes in this field to co-develop, co-own, and transfer the related technologies and facilities.

Photovoltaic assembly is proven to provide high-quality and cost-effective products for various satellite missions. Future national satellites will carry solar panels that have been manufactured locally. Moreover, the local and regional demand for such technologies can be met locally.

The project has been started with a detailed training program. The project team has been formed and 65% of the training program has been completed at the partner's standard facility to expose the project team to an ideal work environment and have the experience of working alongside professionals in the field.

On the facilities side, the technical requirements and the scope of the facilities have been determined. The location and the potential suppliers are being investigated.

Satellite Communication System for Electronic Government Applications

The project includes the design and fabrication of a portable antenna using the phased-array technology at Ka-band frequency. The project aims to:

- Develop the design of the prototype that was implemented in the Tawjeeh 2 project, to convert it from a model to a high quality product that fits the requirements of users in the civil and military sectors.
- Manufacture 20 devices in the first stage.
- Train the national team on manufacturing and assembly operations as well as on the necessary laboratory tests.
- Build an infrastructure to assemble as many components of the system as possible locally.
- Upgrade the existing laboratories at KACST to suit the requirements of the project tests.
- Conduct laboratory tests and quality tests for the system in KACST's laboratories and ensure that the product conforms to the highest specifications.
- Conduct field tests for the product to ensure that the system communicates with the satellite as required, and to test the product's ability to withstand local environmental conditions.

Saudi Post Supplying Satellite Images and Detection of Urban Changes

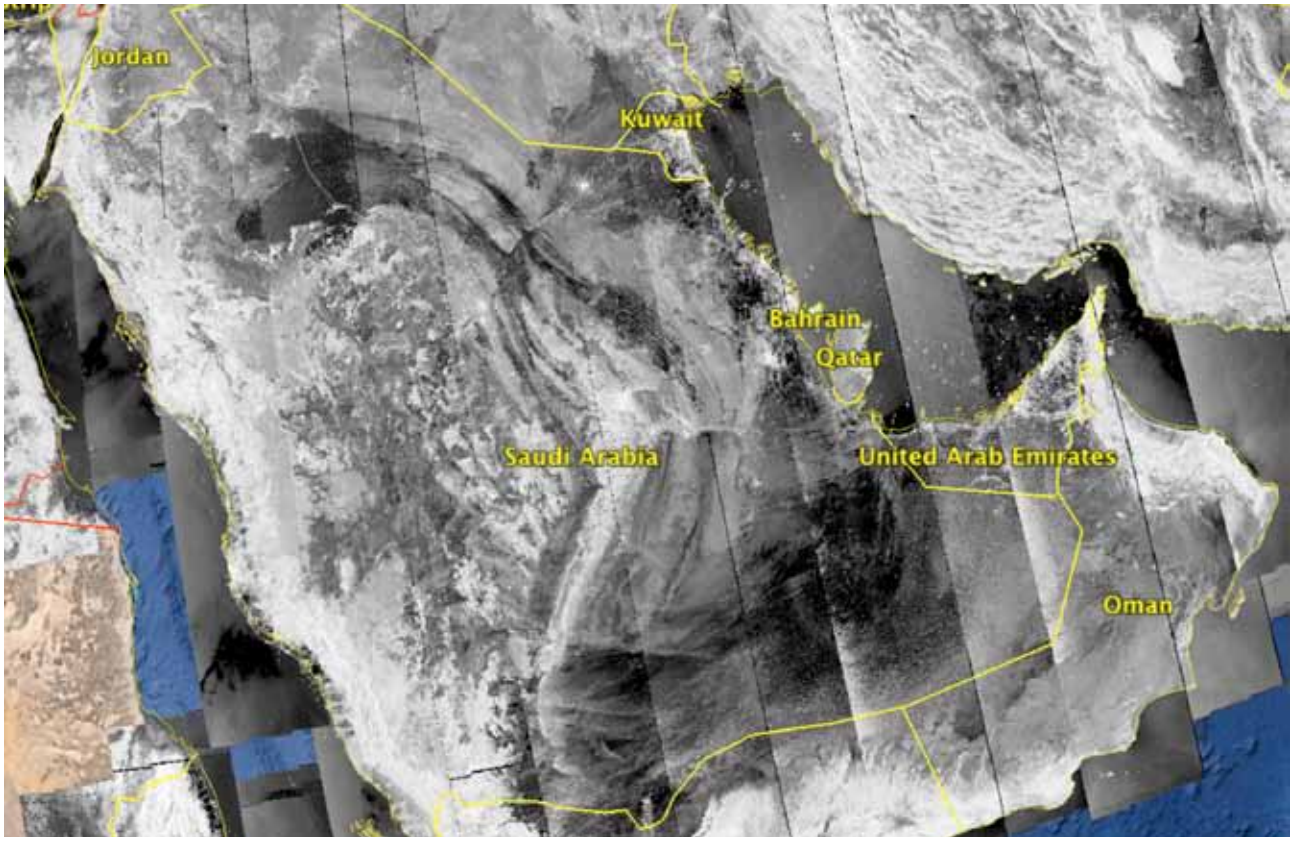
KACST has signed a joint cooperation agreement with the Saudi Postal Corporation to support the update of the national address infrastructure. KACST will provide the necessary satellite images to the Postal Corporation to update the main map of national addresses in a way that contributes to the follow-up of the urban changes in all the cities and provinces of the Kingdom. The agreement includes high contrast, vertically corrected, processing of satellite images to detect urban changes, ensuring the validity and quality of data. The project aims to:

- Provide Saudi Post with satellite images with a resolution of 1.5m to update the map of the Kingdom.
- Supply high resolution 0.5m corrected satellite images for urban areas.
- Provide reports showing locations of changes in urban areas based on medium-resolution 1.5m images.
- Produce reports on changes in urban and civilized areas in the Kingdom.

Dual Band Remote Sensing Radar Payload

This project aims to transfer and localize the dual band (X-Band, L-Band) synthetic aperture radar (SAR) technology, and the High-Resolution Camera (HRC) technology. In addition, the project aims to develop spacecraft subsystems that enables such SAR missions. These sub-systems include high-speed data processing, transfer and storage system, an attitude control and a high-speed downlink systems appropriate for the advanced operational capabilities of SAR missions. The project also includes a training program for KACST's team.

In 2016, several important steps of the development took place, including the continuation of the requirements review, then finalizing and approving it, and the designing and manufacturing of functional prototypes for testing purposes. These steps are done to confirm the ability to meet the operational requirements. Furthermore, prototypes of both the SAR antenna and processing units were built, including their firmware. Test plans, assembly, and integration plans were developed for the engineering model of the satellite payload. Preliminary design of the ground processing units is in place and their software development activity is ongoing.

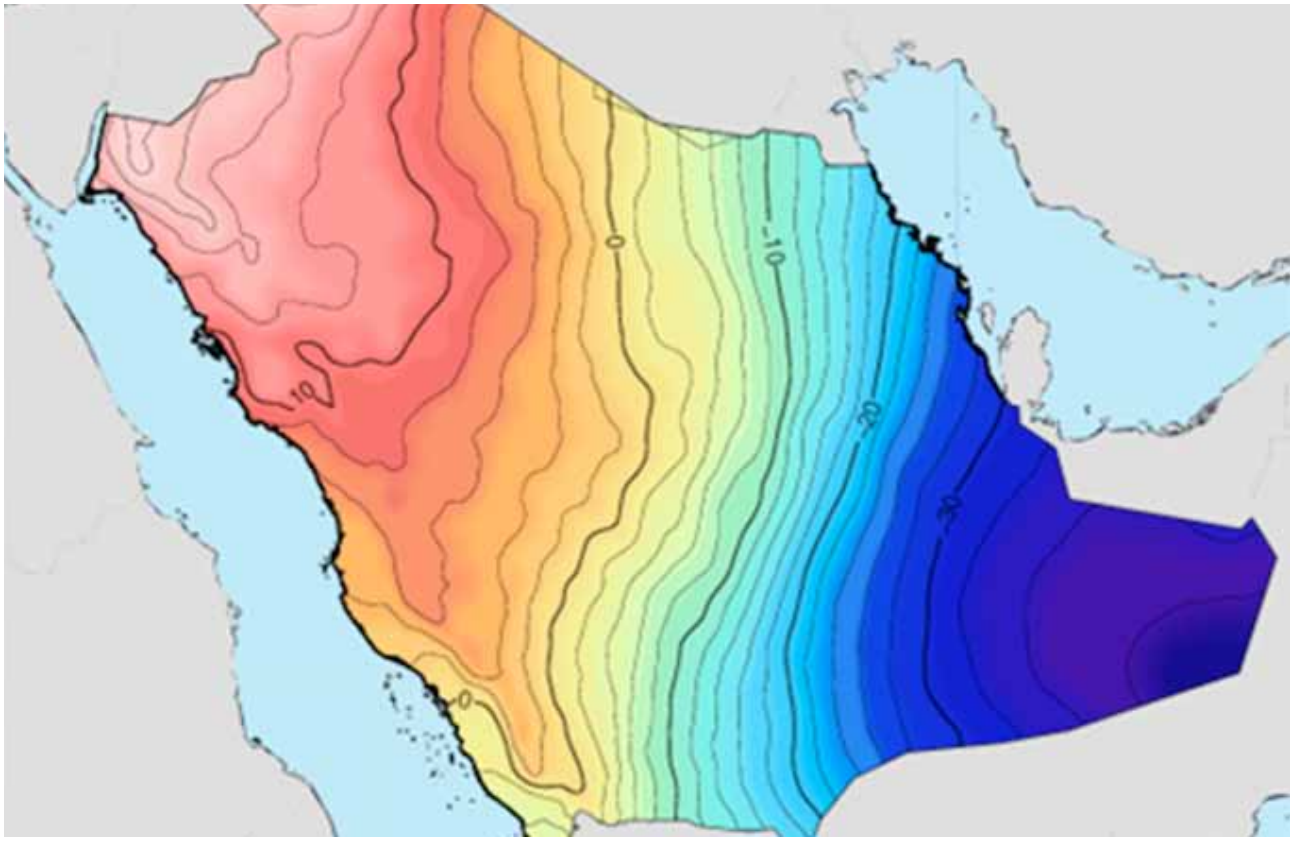


Satellite Image Analysis System

This project aims to develop an electronic system that enables experts to conduct automatic and rapid advanced studies on geodetic surveys by analyzing InSAR satellite images using special software and algorithms. The project provides simple tools via web services for a smooth and effective analysis of satellite images and data, whether they were stored outputs in the archive or urgent data requested by competent entities. The outputs of analyzing such data can be used in monitoring, rapid response to natural disasters, and changes in the crust, e.g., experts can use the analysis of geodetic survey images to detect deformities of large areas of the earth's crust. The detection is done with such high accuracy which allows the determination of the crust's sliding accompanying earthquakes, volcanoes, and floods. The analysis can also help in the detection of how these slides are distributed, which helps in determining areas damaged by natural disasters and evaluating the extent of the damage with great accuracy. An advanced analysis can help in determining, locating, and estimating groundwater, as well as determining oil reservoirs and measuring how the extraction process will affect the stability of the crust.

Geodetic survey data are often processed manually and slowly by using traditional means. This, therefore, hinders the benefit from the results of the analysis when it comes to supporting the urgent decisions commissions and individuals have to make upon a natural disaster, such as floods, earthquakes, and landslides. Moreover, the use of traditional methods usually requires knowledge, experience, and long-time investment to conduct the analysis.

The project aims to develop a system and a software that can analyze InSAR satellite images, seismic, and GPS data. Then process the data through mathematical equations and analytical algorithms to produce scientific products that enables experts to understand the reasons that led to surface subsidence. The results of advanced analysis of geodetic survey can reach a high level of efficiency and performance. This meets the needs of scientists and technicians for a modern output that enables them to support competent entities in making the right decision when natural disasters happen, as well as estimating damages and post-crisis rehabilitation.



Geoid Modeling from Satellites and Insitu Observations

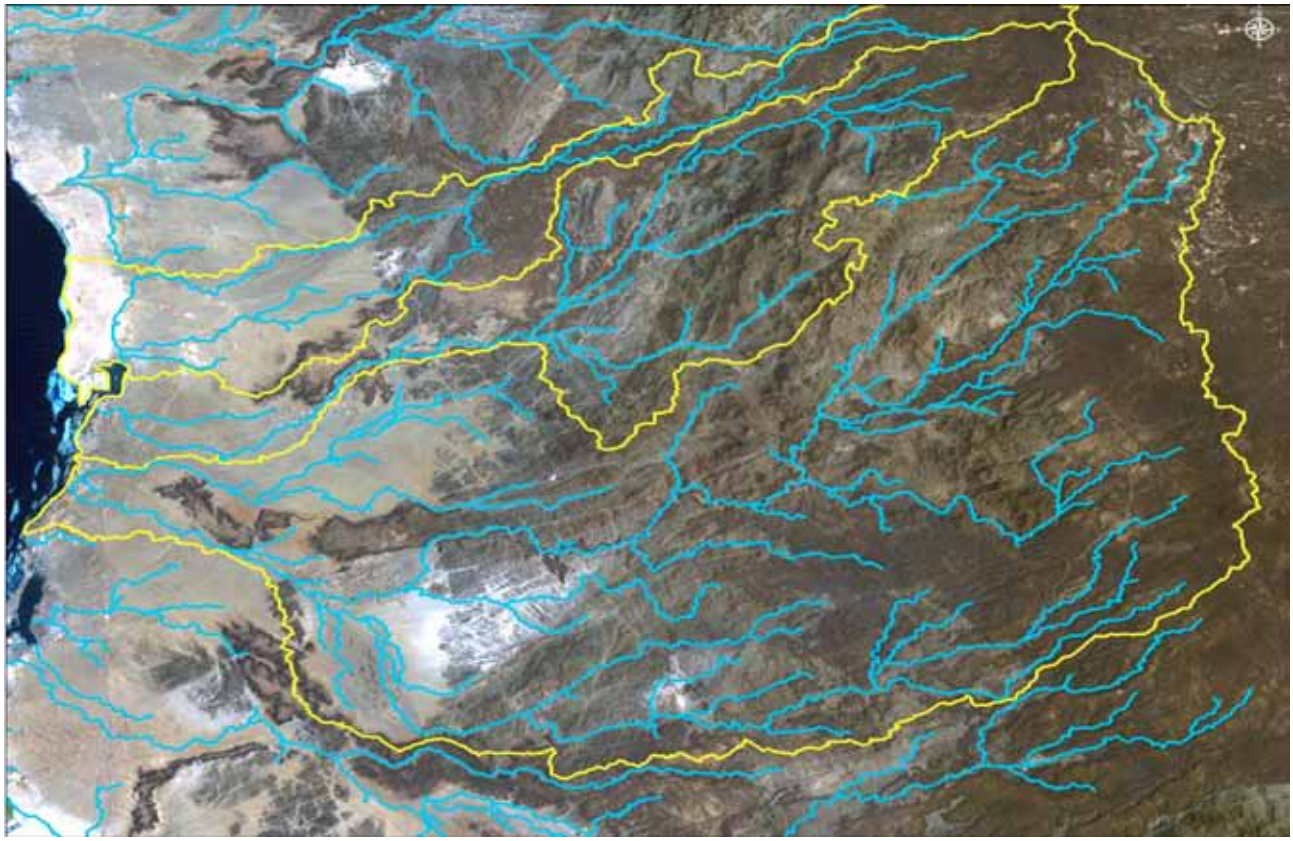
Due to the importance of a national geoid reference for accurate height determination in Saudi Arabia, KACST has initiated communications with national agencies, to form a joint team for geoid computations. This model will enable users in the Kingdom to obtain accurate height measurements, anywhere in the Kingdom, above the mean sea level. Multi in-situ observations from the European satellite, GOCE, have been used to compute the model with high accuracy. The team of the project is continuing to perform some field observations for accuracy checks, and the model will be released for the public with a user-friendly software interface in the future. There was cooperation with other national agencies to unify efforts towards producing a model that satisfies the requirements of infrastructure projects. An accurate scientific model has been implemented in conjunction with the GRAVSOFT software which has been developed in one of the European universities.

The project aims to localize Geodesy technologies and its effective applications in the computation of national geoid model for the Kingdom, and provide training for the national employees.

Arabian Plate Motion from Satellite Laser Ranging and GNSS

In order to define a national geodetic reference frame, as a base for consistency of national maps and geographic information systems (GIS), which are used by national agencies, KACST has been a member (represented by the Geodesy Center) of the national team for reference frame. KACST is supporting this project, with its resources, expertise and data, and via arrangements with national agencies to unify efforts, exchange data, and observations to support digital products in the Kingdom. Accordingly, KACST has established a network of 16 CORS stations distributed all over the country, which send the data via a communication network to Riyadh. Preparations are underway to establishing a data center at Oyainah to collect, backup, and check the data.

Data has been released to some agencies as part of the national team for the reference frame. Efforts are continuing to collect observations and apply quality checks for future computations and analysis when more data become available.



Preventing the Danger of Streams

The National Center for Remote Sensing Technology at KACST is working with the Saudi Geological Survey and the General Authority of Meteorology and Environmental Protection to conduct studies on areas exposed to the dangers of streams in terms of rainfall, the topography of the earth, population density, the volume of investments, the utilization and evaluation of the current situation of valley dams, drainage basins, and distribution of water ferry.

The center has completed its role in the production of satellite images, and has corrected them vertically with ground control points to obtain digital elevation models. This has enabled researchers to identify streams, know their directions, and identify the locations of water pools with high accuracy. These products have then been made available to the relevant government entities, each within its field of specialty, to complete the studies of the prevention of streams danger.

Geomagnetic Data Services for Fodder Farms

As per the Saudi Council of Ministers Decree no. 66, dated 25/02/1437H, to stop the cultivation of green fodder which is more than 50 hectares, and located in the sedimentary side, the Ministry of Environment, Water and Agriculture will build a database for green fodder farms in all regions of the Kingdom. This will include all types of crops grown, and it will be updated periodically. The Ministry of Environment, Water, Agriculture and KACST agreed to implement the geospatial data services project for fodder farms, and the project will be going for five years. It covers the winter and summer seasons of each year, and the areas of interest located in the sedimentary side are Riyadh, Eastern Province, Qassim, Hail, Al-Jawf, and Tabuk. The project requirements include calculating the area of the cultivation of fodder in the Kingdom, the creation of digital maps, and the construction of the geographical database, which involves the use of geospatial information systems technology.

Lunar Crescent Visibility and Sighting

KACST is involved in the Lunar Crescent Committees sighting in nine sites, which are Mecca, Medina, Riyadh, Qassim, Hail, Tabuk, Sadir and Shaqura.

KACST provides the necessary data about the sun and the moon in details, along with the devices required for the crescent moon monitoring such as telescopes and computers that guide the telescopes to aid with the crescent moon sighting. KACST publishes data about the crescent moon and distributes it to the relevant authorities.

The National Center for Astronomy is also working on a project to develop its observatories, and is developing observation devices for the crescent moon sighting. This project contributes to the development of imaging techniques used to monitor the moon, using a CCD camera, and the development of computer software used for image processing. A software program has been developed at the National Center of Astronomy for analyzing the observations data. Currently, the National Center of Astronomy's database of crescent observations contributes to establishing a standard model for Saudi Arabia in determining the possibility of early sightings of the crescent moon.

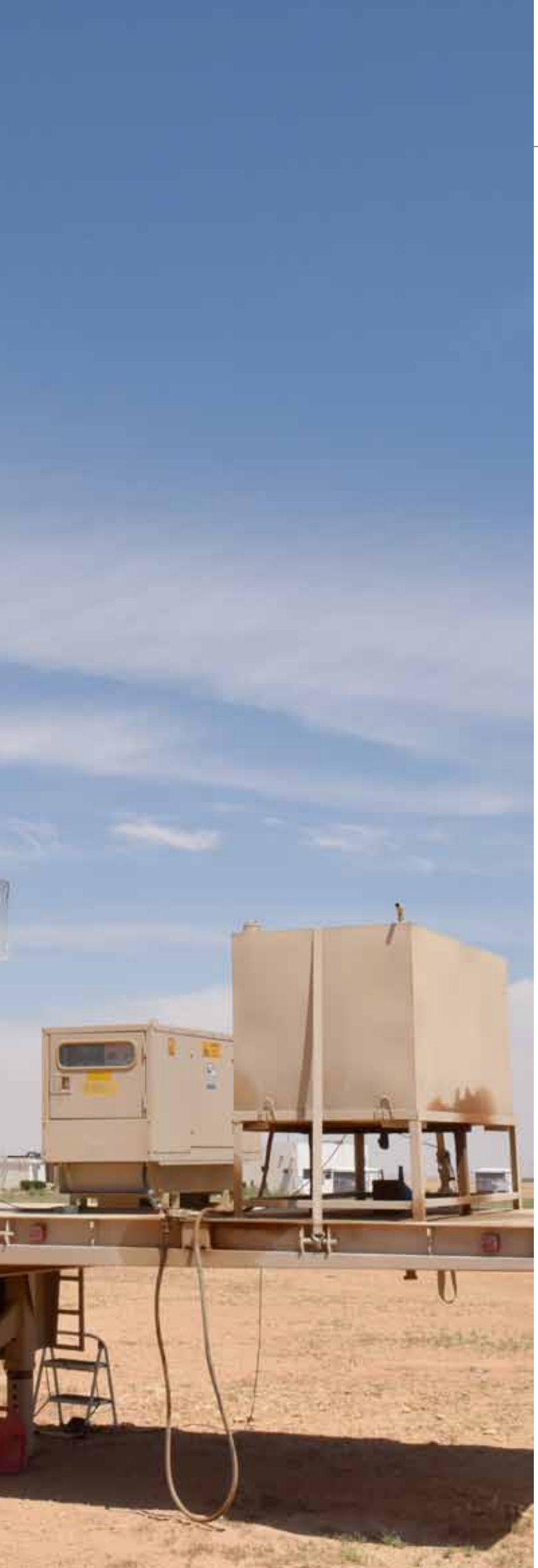
The results of this project will contribute significantly to understanding the basics of physics for the possibility of early sightings of the crescent moon.

Scientifically, determining the visibility of the crescent moon after Luni-Solar Conjunction is still difficult and represents a challenge based on several technical factors. Having a model that can accurately sight the first crescent moon is of high importance to Saudi Arabia.

This project aims to use computer models to enter the celestial mechanics with factors involving the refraction of moonlight in the atmosphere and the sensitivity of the human eye to radiation transferred from the atmosphere. This project contributes to determining the visibility of the first crescent moon sighting, and thus the beginning of lunar months. This can be done using highly sensitive cameras and depends on the size of the telescope used in monitoring.

Defense and Security

- Advanced Sensors Technologies
- Radar Systems
- Electronic Warfare & Command and Control Systems
- Cyber Security
- Robotics & Intelligent Systems



Technology Transfer and Localization

Defense and Security

KACST has started developing advanced defense and security technologies, in partnership with different institutions, in response to the challenges that the Kingdom faces because of various environmental factors.

Introduction

The defense and security sector is an important sector in the Kingdom. Thus, KACST, through its National Center for Electronics and Photonics Technology and its National Center for Sensor Technology and Defense Systems, in cooperation with global partners, has invested in all possible competencies to localize the latest global technologies. These efforts have resulted in the transfer and localization and then development of these technologies.

Radar and Electronic Warfare Technologies are considered the main actors in modern surveillance and armament systems, due to their ability to operate in all climatic conditions, their accuracy in sensing surrounding hazards, and their ability to collect information and to identify and disable threat if necessary. Command, control, communications, computer, intelligence, surveillance and reconnaissance are key technologies in modern defense and security systems. The programmable radios are one of the most advanced technologies in this regard. Laser technologies and their military and security uses are important tools that countries are keen to acquire, along with high-resolution thermal and night imaging techniques.

KACST conducts joint research with leading research institutions in order to achieve the following strategic objectives:

- Developing high value technology.
- Constructing an advanced engineering infrastructure.
- Building national capacities and competencies for the production of modern technologies.
- Promoting excellence in engineering research, systems engineering, research methods and project management.

Muasher 2

Muasher is a human tracking device designed and developed to be wearable on the arm. The device uses GPS to locate the device holder using satellite communication. This method allows the user to be tracked in areas without communication availability. The device also has a heart rate sensor to detect heart beats in order to make sure that the device holder is alive. It also monitors the wearers biometric results. The device has a two-way communication tool to allow the host station to be remotely configuration. The battery life will last for an average of 24 hours. It can potentially last longer depending on the transmission period. Another feature of Muasher is its distress button for an emergency call. This feature allows the holder to send an instant request for help. The battery can be replaced and recharged easily. Muasher is small in size and highly usable, with waterproof capabilities.

Oroq

This device is designed and developed to capture the hand palm vein. It works by sensing the blood Hemoglobin using the IR. The captured picture has a very low False Rejection Rate (0.01%), and False Acceptance Rate (0.0001%). This methodology works by placing the hand at a distance of 5 cm away from the sensor. The device design is highly usable to make the capturing technique easier for the user. The device comes with a touchable display to allow configuration, and to show the device information. Oroq is powered either through Ethernet or through a power supply. The device can also be hung on a wall or on top of a flat surface. The device memory is 32 GB and can be extended to be 64 GB. It has a trigger to control door access once the user is verified. The device is designed to be used for highly secured access areas and for more hygienic access options such as in hospitals.

Robotics Technology and Intelligent Systems

With the recent development in robotics industries, several companies, factories and military entities started deploying robotics platforms to perform precise and accurate tasks. This will decrease the number of human error, and saves money and lives of whom are involved in dangerous tasks. This project is initiated to transfer the knowledge of robotics and smart systems and to develop local platforms to be used in different scenarios. Recently a flying robot has been developed to control another robotic platform on ground. This flying robot has the capability to stay in flying mode for several hours thanks to the lightweight with the mix of battery and fuel engine. This robot is also used in exploration missions and take live pictures sent directly to the operation room to help other robotics platform on ground avoid obstacles and barriers. On the other hand, a development project of the platform MR110 is carried out to convert the initial prototype into real production with the collaboration of our Korean partner, Hanool.

Qeyas

This is a transportable electronic system which has been designed to measure radar cross-sections (RCS) of moving space or maritime targets. The system used a highly accurate calibration scheme to assure a very accurate result can be obtained. The system also has the capability to identify these types of targets by analyzing different radar signal characteristics. In order to cover most anticipated radars, the system operates on a wide frequency domain and can be easily moved to carry out in-field tests. Qeyas is equipped with optical cameras to track the target. The system can be used to create a database for friend or foe fighters. It can also provide logistical support to forces in battlefield situations by suggesting the appropriate areas for placing weapons and arms and identifying the appropriate angles for attacking targets. It can also be used to identify the efficiency of electronic tricks and deceptions.

Taba

This project aims at enhancing the national capacities in tracking air targets. The tracking system, which is a mobile radar, specialized for tracking air targets, offers a flexible working platform with high capabilities, that allows researchers to develop target tracking software.

The system consists of an advanced radar signal processor, equipped with the most-up-to-date algorithms specialized in processing radar signals, allowing the system to track more than two targets at the same time (within the radiation range). The system is also able to alter frequencies between signals, as it shows great flexibility at high speed, enabling the system to be an ideal research environment for those interested in developing algorithms for defense systems. It is also characterized with the easiness in adding or developing processing algorithms, due to its structure and the quality and ease of documentation.

The system is also equipped with a large memory to save the radar signals in a high capacity. It is provided with eighteen screens to display the radar signals, covering all its phases, and facilitate the implementation of research tasks. Digital cameras to follow-up and identify targets, are also included within the system.

The system consists of two separate rooms; one is dedicated to the devices and equipment, and the other is dedicated to the operation process. Such a design provides a suitable working environment for researchers.

The system is used as a research facility to develop tracking radars, and analyze the effects of natural occurrences on the radar. It can also be used, in the field of cyber warfare, as a tracking device, to identify the effectiveness of methods used in this war.

The project is aiming at developing a field radar tracking method, including a radar tracker in the Excel range with an optical sensor.

The data processing controls the patterns of the target information technology and help in selecting the waves and collecting data.

Sarab

Sarab is a small portable radar which can be easily mounted and moved onto a normal pick up vehicle. The radar is designed to be LPI (low prosperity of intercept) in order to make it difficult to be discovered by electronic support devices. Nevertheless, the system can still detect relatively small targets whether they are on ground, in water, or in the air. The system has two dimensional radars that are able to measure target range and the azimuth direction. The system can cover a complete 360 degrees angle with continuous scanning manner. It can detect flying targets up to an altitude of 10,000 feet. Sarab operates in different weather conditions to monitor small objects, and is used in continuous airspace monitoring operations at low altitudes, whether in a mountainous, coastal or even in desert regions. It can be used in land and coastline borders surveillance, and can be used as an efficient system in surveillance operations that require extraordinary fast presence.

Takhafi

The aim of this project is to develop a collaborative fundamental research program between KACST and Arizona State University (ASU), USA. The main goal of this program is to develop and advance electromagnetic (EM) scattering and antenna technologies. The program is to focus on EM scattering reduction techniques and antenna technologies using Electromagnetic Band-Gap (EBG) High Impedance Surfaces (HISs). Both areas are to concentrate on challenging low-profile and conformal flat and curved/flexible structures. Specifically, the main topics on this project are: RCS (Radar Cross Section) reduction using conformal and low-profile checkerboard EBG HIS surfaces, antenna array technology using EBG HIS conformal and low-profile structures, and beam forming and beam steering using Holographic Artificial Impedance Surfaces (HAISs). Moreover, this collaboration is aiming to build a high tech antenna lab at KACST. The lab will allow KACST researchers and students from different university to design, build, and test the flexible antennas.

Bayanat

This projects aims to build the electronic war information management system that has been designed fully by KACST for the Joint Electronic Warfare Center at the Ministry of Defense. The system is composed of a set of subsystems, including an electronic intelligence database and a signal intelligence database, that are equipped with the appropriate analysis tools, geographic information system (GIS), electronic document management system (EDMS), workflow system and reporting system. The entire system is protected by an appropriate set of mechanisms to enforce strong access control to the system. All the sub-systems have been integrated to function as a single coherent unit which helps in improving user experience and makes the system easy to use. The current system has the following features:

- It was fully developed locally by a Saudi team.
- It meets the standards of the Joint Electronic Warfare Center at the Ministry of Defense.
- It helps the employees at the Joint Electronic Warfare Center simplify their daily work at all stages.
- It helps in correctly assessing the current situation and making the right decision.
- It is easy to integrate with other systems.

Developing More Efficient Techniques for Authenticated Encryption

The main goal of this project is to put KACST on the international map of communities that compete on designing the most efficient security standards. The project studied the design and development of a very efficient cryptographic algorithm for two major types of applications: public networks (i.e., the internet) and ubiquitous and pervasive networks (e.g., mobile communications, and wireless sensor networks).

Most of the existing cryptographic algorithms are designed independently of each other to serve one property, either to protect the message secrecy (via encryption) or to protect its integrity. In addition, these algorithms are designed to run on both conventional computers with medium to large processing capabilities and on small devices (e.g., IoT devices) with limited capabilities.

This project comes in alignment with the strategic goal that was set by the Information Security Committee in KACST to build national capabilities in cryptography field and in designing national cryptographic algorithms to protect the information resources of Saudi Arabia.

Building KACST's capabilities in the field of information security

The project aims to construct and equip a national cybersecurity laboratory containing the latest scientific tools in the field of information and network security in order to support national research in this area and to be supportive of researchers and specialists in the field of information security. The lab will enable researchers to conduct research, simulate attacks and defense techniques, and perform threat analysis.

The project is expected to finish by the middle of 2017. The goals of the project are:

- To have a collaborative approach to the design, implementation and transfer of knowledge to the laboratory.
- To provide structured training for the center's employees.
- To empower the center's employees to obtain in-depth knowledge about how each stage of the laboratory is constructed and operated. This allows the employees to develop the necessary skills to effectively implement planning processes and to gain the ability to train new members in the laboratory.
- To form a key role in developing the cyber lab by building other security programs, as well as increasing cooperation with national and international organizations in the field of cybersecurity.

The lab will also provide consulting services to government agencies as well as training courses for those interested in encryption, information security and networks.

The project includes providing intensive training courses for all researchers at the center. These courses covered various major cybersecurity-related topics such as cryptography, digital forensics, reverse engineering, network security, application security and penetration testing. Training was provided by specialists and experts from different countries, such as Russia, Turkey, Australia and India. Researchers were also tested in order to verify the effectiveness of the training program, in assessments ranging from 3 to 6 hours, depending on the course. The aim of these tests was to evaluate the knowledge gained by the researchers and also provide them with a chance to practice the learning materials that were taught in the course.

Nuclear Science & Applied Physics

- Accelerator Technologies
- Irradiation Technologies
- Nuclear Regulatory Program
- Applied Physics

Technology Transfer and Localization

Nuclear Science & Applied Physics

KACST aims to achieve technology transfer, and development of nuclear sciences and applied physics, and create a scientific research infrastructure that serves the objectives of the Kingdom's Vision 2030.

Introduction

KACST has several research interests in nuclear technology (and its peaceful usage) and various physics fields. The aim is to localize these technologies and build national expertise that will help to achieve the national strategic plan.

Research activities in this sector focus on executing projects in agriculture, industry, and medicine through specialized personnel in diverse engineering fields, nuclear sciences, and physics. The availability of equipment, advanced scientific laboratories, and expertise, contribute to supporting the ongoing development plan to realize Vision 2030.

This sector also supports the national fundamental requirements of radiation monitoring and measurements; e.g., radiological baseline studies of the environment in areas involved with industrial and mining activities. Another field in this sector is irradiation technology which involves research in improving the properties of materials and products through irradiation, for the benefits of industry, medicine, and food sectors.

One of the fundamental fields in this sector is the technology transfer of nuclear accelerators and radiation detectors through localization, development, manufacturing, and reinforcement of the infrastructure for these technologies.

KACST has recently finished designing the first nuclear research reactor in the Kingdom, which involves participation from Saudi engineers and was done in collaboration with international companies in this field, and has just started the construction activities of the reactor. Such a reactor will help transfer and localize these technologies with the highest level of international nuclear safety and security.

Preliminary Designs for Compact Electron Linear Accelerator

This project aims to design, develop and build RF compact accelerator with enhanced features that will have different use-cases in a wide range of applications such as medical applications for imaging, security applications for scanning prohibited materials, and industrial applications for Non Destructive Testing (NDT). The compact accelerator prototype will be installed at KACST so that different research areas, such as biomedical physics researchers, can use it to achieve their development goals.

This project is a collaboration with advanced international institutes such as the Linear Accelerator Laboratory LAL at Paris-Sud University, France. In the current stage, the initial design with all the required features is almost complete. The simulations were performed for several cavities to identify the appropriate measurement methods. The project deliverables will benefit a number of organizations in the security, surveillance, medical and industrial sectors.

Manufacturing of Small Accelerators for Medical Purposes

Radioisotopes are one of the essential cornerstones of modern medicine. They can be used for both diagnostic and therapeutic purposes. The current project will entail the development and manufacture of a low cost 12 MeV compact high field-superconducting cyclotron for the local supply of PET Imaging Isotopes that will have the potential to make advanced medical imaging available in any hospital in KSA. In addition, the project will transfer the particle accelerator technologies to the Kingdom and will raise hospital capabilities in using advanced imaging techniques for diagnosis. The project will focus on the production of FDG (F18 isotopes) to be used in the Positron Emission Tomography (PET) scanner, which has wide applications such as early detection of cancer. This project will include full transfer technology that will provide the capability to produce unavailable isotopes such as C-11 or O-15. This project deliverables will benefit a number of private and public medical entities.

Accelerator Technology for Geological and Materials Studies

Due to the limitation of radioactive source applications, nuclear accelerator are considered one of the most powerful technologies nowadays. This project aims to establish a modern state-of-the-art facility to fulfil the high technology requirements for analysis and studies of geological and materials science using a nuclear accelerator technology (Tandetron Accelerator).

This technology is one of the most advanced tools in the world, and has a wide range of modern applications such as medical applications (diagnostic and treatment), industrial applications (improving and modifying industrial materials), carbon dating, which is an important tool for archaeological sciences (determining the age of antique materials), and security applications (forensic science).

This facility is considered as an essential instrument in many other areas of research such as structures in chemistry and biology studies or preformed sensitive trace element analysis in environmental studies. In addition, it will be available for the researchers in the Kingdom to use it in advanced research and applications.

Development of Composite Materials for Fire Resistance

Ultra-High Temperature Materials (UHTM) are considered to be highly important for many applications, such as spacecraft and wall protection shield in nuclear reactors. These materials can operate in temperatures ranging from 1000 to 3000°C; with high chemical, mechanical and thermal stability. The significance of UHTM applications and their high demand has initiated an increase in research and development activities to manufacture UHTM in various ways.

This project aims to create composite materials with high stability at UHT and deposit them on substrates such as Graphite and Silicon Wafers. These materials have a capability to be UHT without affecting their chemical, mechanical and thermal properties; and to maintain their shape without oxidation or corrosion. In order to achieve this goal, modern laboratory techniques are used to prepare these materials such as thermal spray coating and Photolithography. In addition, many types of materials such as polymers, metals and ceramics will be used in order to achieve the best possible results.

Nuclear Regulatory Program - Nuclear Regulatory Unit in KACST

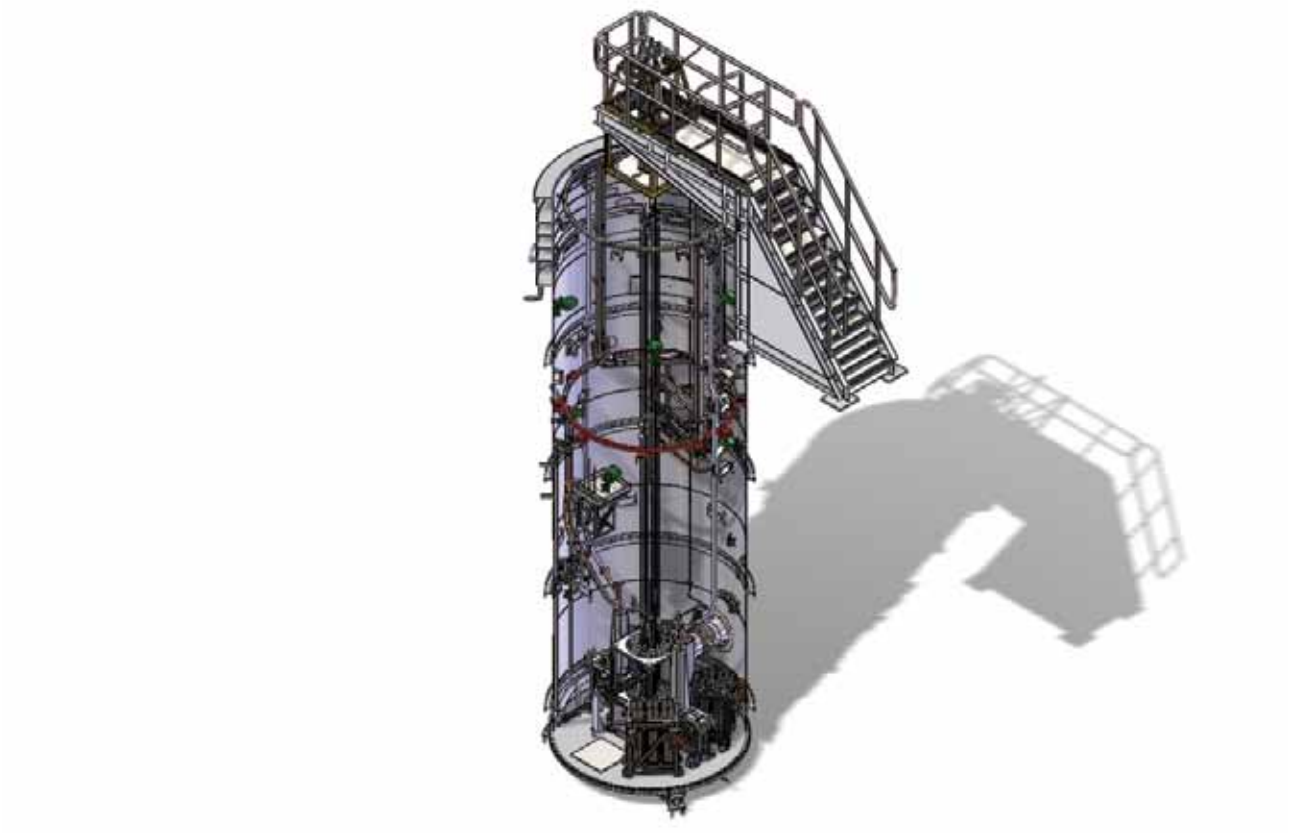
Based on the fact that KACST has recently begun constructing the first low power research reactor in the Kingdom, it is committed to sustain its responsibilities regarding the nuclear and radiological safety and security by conducting best practices that fulfill national requirements and instructions in accordance with international standards. Therefore, KACST has prepared and implemented an effective and comprehensive internal regulatory program including all policies and procedures regarding the use of radioactive sources, and how to ensure the safety of the practices and workers. In the year of the report, an inventory of radioactive in-use or stored, have been listed and verified, and an initial draft of safety instructions and materials accountancy procedures have been prepared. Also, radiological workers, practices, and facilities have been determined, described, and characterized, and personal dosimetry has been assessed. The functions and basic requirements of a radiation safety management database system were identified. Finally, nuclear and radiological security measures have been strengthen by finalizing the installation of radiation Portal Monitors (RPM) to detect any crossing of radioactive material or any other item contaminated by radiation.

Backscatter Mobile Scanner System (BMS)

A backscattered-based X-ray can overcome the limitation of the of the current X-ray inspection systems. The backscatter mobile scanner system (BMS) allows the inspection and screening of moving or stationary objects with a variety of sizes such as sea containers, vehicles, luggage, and people.

The current transmission imaging systems require that the tested object reside in-between the source and the detector, making it difficult to inspect moving objects in many cases. In contrast, the backscatter imaging systems place the source and the detector on one side of the object, providing more flexibility to the users.

Imaging using the BMS system is performed by scanning beam of x-rays over a target. At each position of the scanning pencil beam, scattered x-rays are collected by large detectors. The collected signals are then processed using a suitable algorithm to build the scanning images. The produced images of BMS can highlight the materials of the scanned objects according to the atomic number.



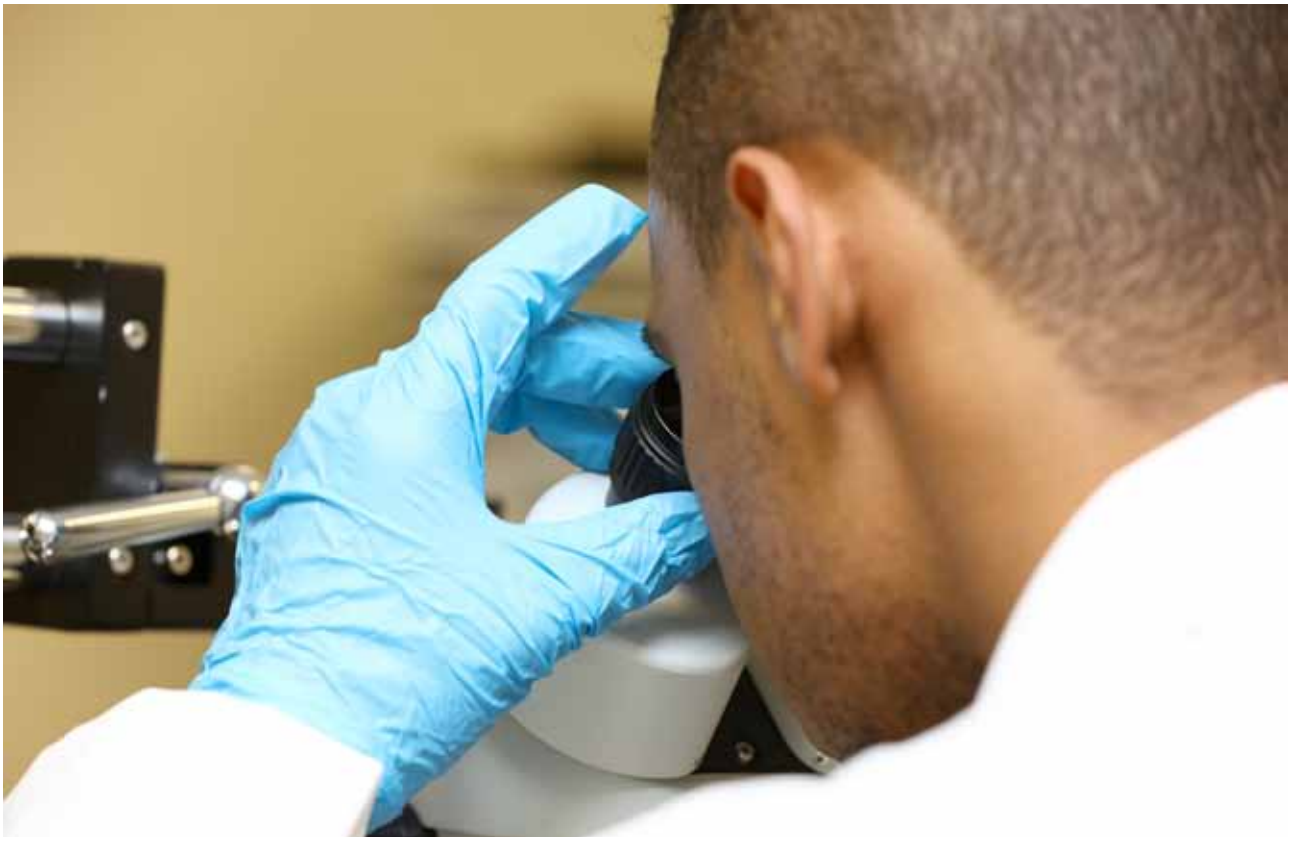
Manufacturing and Construction of the Low Power Research Reactor (LPRR)

The aim of this project is to build the first nuclear research reactor (LPRR) in Saudi Arabia. This multipurpose facility will support training and human resources development, facilitate nuclear scientific research, and develop and transfer nuclear technology to the Kingdom.

KACST specialists, in collaboration with international experts, have developed the specifications of the LPRR and the design of its components that include reactor core, reactor fuel, and the control and quality assurance systems. These developed specifications adhere to the highest national and international safety standards as recommended by the International Atomic Energy Agency.

The first phase of the project was concluded by analyzing the essential requirements, and preparing the final design and engineering drawings. This includes also acquiring the necessary licenses from the nuclear regulatory entity in Saudi Arabia (Saudi Arabian Atomic Regulatory Authority of King Abdullah City for Atomic and Renewable Energy) for the construction of the reactor building and manufacturing of all the nuclear components, e.g., reactor fuel and reactor pool.

To emphasize the importance of nuclear technology transfer to Saudi Arabia as part of Vision 2030, some national companies were enlisted to manufacture several of the highly-safe nuclear components, e.g., the manufacturing of the reactor pool and the preparation of high density heavy concrete used for reactor core shielding. This was achieved by inviting these companies and qualifying them to the highest requirements of the nuclear industry under direct supervision of international experts. The civil work construction of the reactor building was awarded to a local company after ensuring its ability to fulfill the highest standards applied in nuclear projects. The entire process of constructing and operating the reactor will be under direct supervision and inspection by the regulatory body of Saudi Arabia to fulfill the country's obligations towards the international treaties and agreements concerning nuclear materials. The project culminates with the training of reactor personnel to ensure safe operation, maintenance and optimum utilization of the reactor.



Stat-of-the-art Quantum Informatics Techniques

This project, which was conducted in cooperation with Texas A&M University (TAMU), aims to theoretically and experimentally study some physical systems under the umbrella of quantum optics and informatics. This field involves interactions between matter and light which can be limited due to the small size of the atom compared to the wavelength of light. This interaction creates the so-called quantum interference, which is one of the most mysterious features of quantum mechanics. Based on the above, emphasis has been placed on quantum lithography, quantum state weak measurement, and direct quantum communication. The collaboration resulted in many joint research workshops, several published research papers, and five patents. Most importantly, the project involved training Masters and PhD students at TAMU, and more than five of them are close to completing their PhD degrees. Also, some of the published work has been internationally recognized. The outputs of this project can benefit: research centers, communication centers, and encryption agencies in the country.

Relativistic Quantum Mechanical Model for Pion-Nucleon Interaction

The main objective of this project is to study the pion-nucleon scattering using instant forms of relativistic quantum mechanics, leading to a better understand of nuclear forces. The reason is that in order to explore the details of the pN interaction, it is necessary that the wavelength of the two particles in the barycentric system be relatively small. By the uncertainty principle, the position of a particle is indeterminate by the amount of the order of its wavelength. It is evident that if the pN interaction is to be explored at distances which are a small fraction of the pion the barycentric system, the particle can be used to probe details of the interaction Compton wavelength, and experiments must be performed at energies of several hundreds of MeV and beyond. Moreover, exploring the interaction puts an upper limit on the relative angular momentum. The maximum angular momentum will occur when its lever arm is equal to the range of the interaction.

Production of TC-99 Isotope for Nuclear Medicine

The objective of this project is to transfer and implement the technology of Technetium-99 (Tc-99) production for medical imaging applications using cyclotron. Tc-99 is the most widely used radioisotope in the medical imaging field. Currently, the Kingdom imports Tc-99 from international suppliers, resulting in a notable shortage due to issues associated with transportation, importing, and activity decay of Tc-99 prior to their delivery to end-users. The new rout of producing Tc-99 is to utilize the stable molybdenum-100 (Mo-100) as a starting material. Mo-100 will be irradiated using cyclotron with irradiation parameters finely tuned. By carefully monitoring various production aspects, the final Tc-99 product will be available with all international criteria being satisfied.

Currently, 80% of cyclotron's structural design and technical specifications are completed in collaboration with international experts. Initial testing of Tc-99 production will take place in the second quarter of 2019 and the final production will be in the third quarter of 2019. KACST's objective of this project is to guarantee continuous production of Tc-99 for local hospitals.

The Development of Quadrupole Mass Spectrometer for the Injection of Ions

The aim of this project is to develop a high resolution mass selection technique known as quadrupole mass filter. The apparatus is used to accumulate ions and cool them by collisions before injecting them as packets into the electrostatic storage ring. The system consists of an ion source, a quadrupole mass filter, a special pulsed gate valve (aerodynamic chopper) and an hexapole trap. Various electrostatic lenses are inserted between the elements. This technique allows users to conduct experiments with large molecules used in medicine and medical diagnostics as well as atomic and molecular physics. Moreover, the apparatus provides research opportunities for KACST research centers, universities, and the R&D units at the industrial entities. It will also serve as an ongoing complement to the Storage Ring program and as a training platform for future young researchers. The design and manufacturing of the system, as well as the control system, have been completed in the year of the report. The installation and initial testing is expected to begin next year.

3.2 | Technical Leaders Program

Research & Development

Technical Leaders Program

Technical Leaders Program aims to address the gap in national human resources on the level of technical leaders by training and qualifying a generation of leaders and decision makers in the vital technical fields in the Kingdom.

Introduction

KACST promotes research partnerships with international leading research and industrial institutions and universities, such as Massachusetts Institute of Technology, Stanford University, California Institute of Technology (Caltech), and Boeing Company through the Technical Leaders Program Initiative, which is part of the National Transformation Program 2020.

KACST has established 15 centers, distributed throughout the world, in collaboration with big research institutions and universities in the field of scientific and applied research. These centers work on research in the strategic areas that are important for the development and prosperity of the national economy.

The program is offering training and research opportunities, in order to introduce students and Saudi Scholars to research and scientific exploration, and help them acquire the needed practical experience. The program is offering a set of specialized training programs to gain research skills in specified fields, concerning the Kingdom's strategic techniques, including scholars training program, the advanced training program and the students training initiative.

At the time of publishing the report, a number of researchers of both genders, enrolled in the program, were accepted to complete their master's and Ph.D. studies in a prestigious university such as Massachusetts Institute of technology (MIT), University of Oxford, and University of Bordeaux and others. In addition, James Fraser Stoddart, the coordinator of the Joint Center of Excellence in Integrated Nanosystems at KACST and Northwestern University, has won, with two other scientists, the Nobel Prize in Chemistry for 2016, for their research in design fabrication of micro machines.

Center for Complex Engineering Systems

- Energy
- Information and Communication
- Transportation
- Urbanism
- Water

Technical Leaders Program

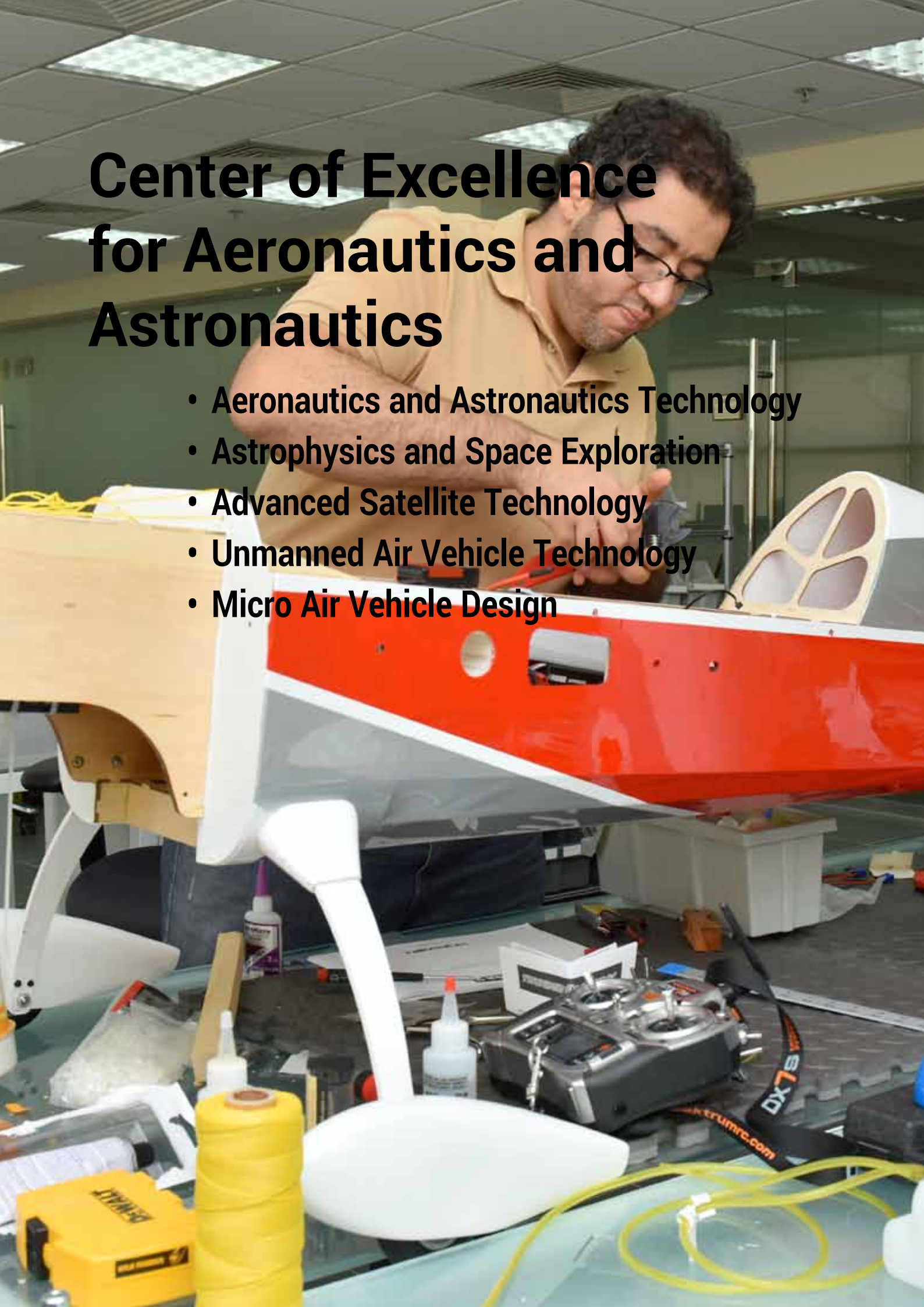
Partner: Massachusetts Institute of Technology

Center for Complex Engineering Systems was created to improve our understanding of complex and dynamic systems and to jointly conduct world-class research.

Introduction

The Center for Complex Engineering Systems (CCES) is a world-class international research program that strives to uncover fundamental principles and to develop new methods and tools such that complex, highly integrated systems can be modeled, designed, and managed more effectively than is possible today.

CCES aims to seed a new generation of internationally experienced scholars and to excite and inspire a new generation of researchers and engineers in pursuing complex systems as a research direction. In the spirit of cross-disciplinary and cross-cultural collaboration, one of the hallmarks of our research approach is to embrace intellectual risk, and to attempt to tackle issues that appear, at least in part, to be non-quantifiable, vague, overly complex or even unsolvable. Our scholars and researchers work diligently and creatively to solve previously intractable engineering systems problems by integrating approaches based on engineering, computation, and the social sciences, using new framing and modeling methodologies. One of CCES's overarching applied goals is to help position Saudi Arabia as a new leader in systems thinking and to assist it in tackling its society's challenges. Our research strikes the balance of facilitating the beneficial application of systems principles and properties, while ensuring that these solutions are sustainable in terms of social equity, economic development, and environmental impact.



Center of Excellence for Aeronautics and Astronautics

- Aeronautics and Astronautics Technology
- Astrophysics and Space Exploration
- Advanced Satellite Technology
- Unmanned Air Vehicle Technology
- Micro Air Vehicle Design

Technical Leaders Program
Partner: Stanford University

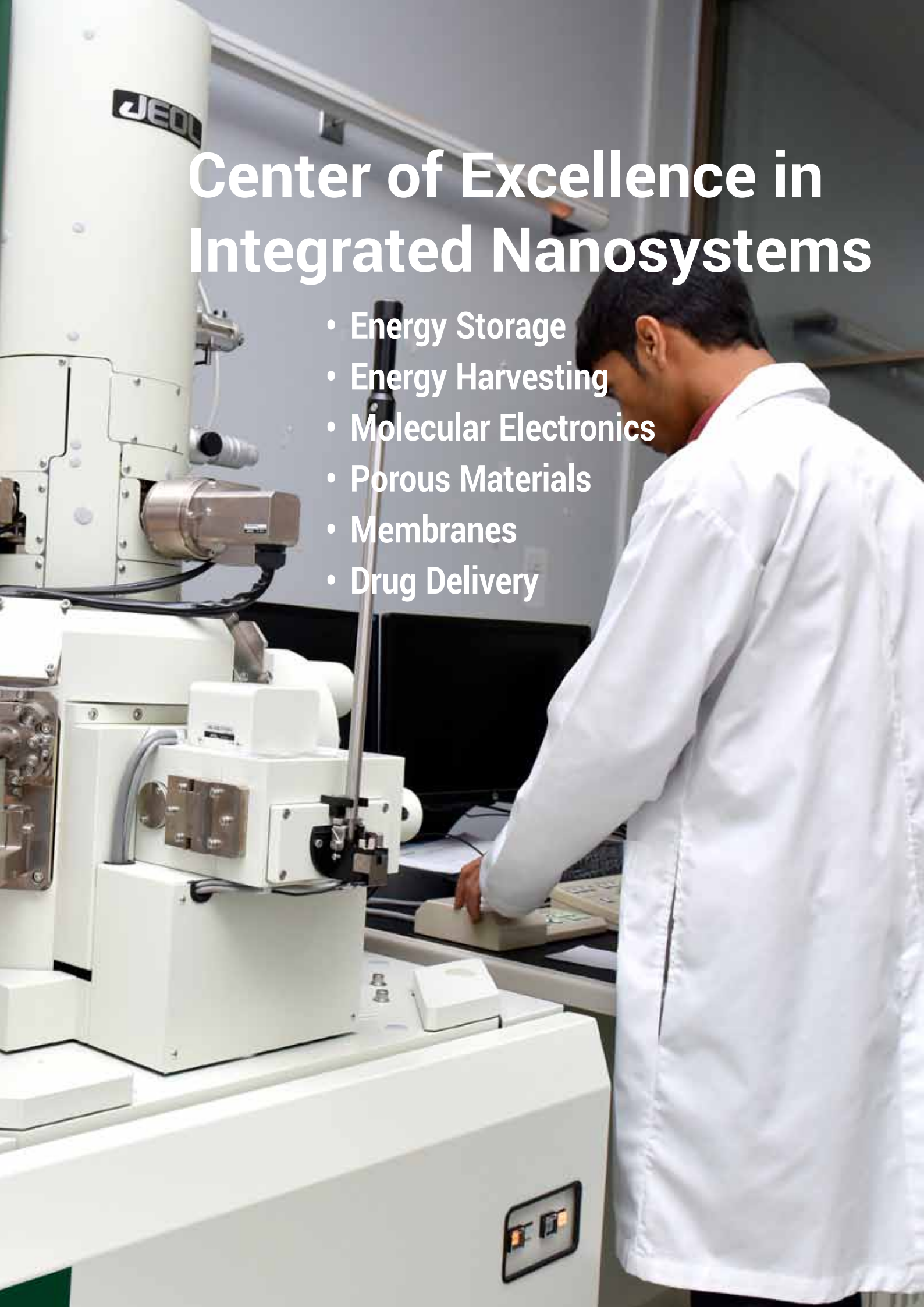
CEAA

The Center of Excellence for Aeronautics and Astronautics (CEAA) is a joint collaboration between KACST and Stanford University focusing on advanced space technology development and complex aircraft design research.

Introduction

The CEAA was established as a direct result of the joint collaboration efforts between KACST and Stanford University. The center is meant to strengthen KACST's ability to perform scientific research and advanced technology development, and to improving educational infrastructure in aerospace physics. As part of the center's objectives, there are a number of research projects that operate under the following themes:

- Advanced Space Technology Development: Improving satellite performance, efficient solar panel movements, communications and control systems.
- Astrophysics: Studying astrophysics-related topics such as gravity and its waves, and verifying the theory of relativity by using highly developed instruments with very precise measurements.
- Autonomous Flight for Unmanned Aerial Vehicles: Experimental study of system identification techniques that are based on machine learning algorithms to allow for automatic control schemes.
- Green Propellants: The development of environmentally friendly propellant combinations that are hypergolic and have performance levels near traditional storable propellants to be used in space applications.
- Computational Technologies: Such technologies allow for the prediction of the dynamic behavior of micro air vehicle models and simulate the aerodynamics to enhance the performance and design testing of these type of vehicles.



Center of Excellence in Integrated Nanosystems

- Energy Storage
- Energy Harvesting
- Molecular Electronics
- Porous Materials
- Membranes
- Drug Delivery

Technical Leaders Program
Partner: Northwestern University

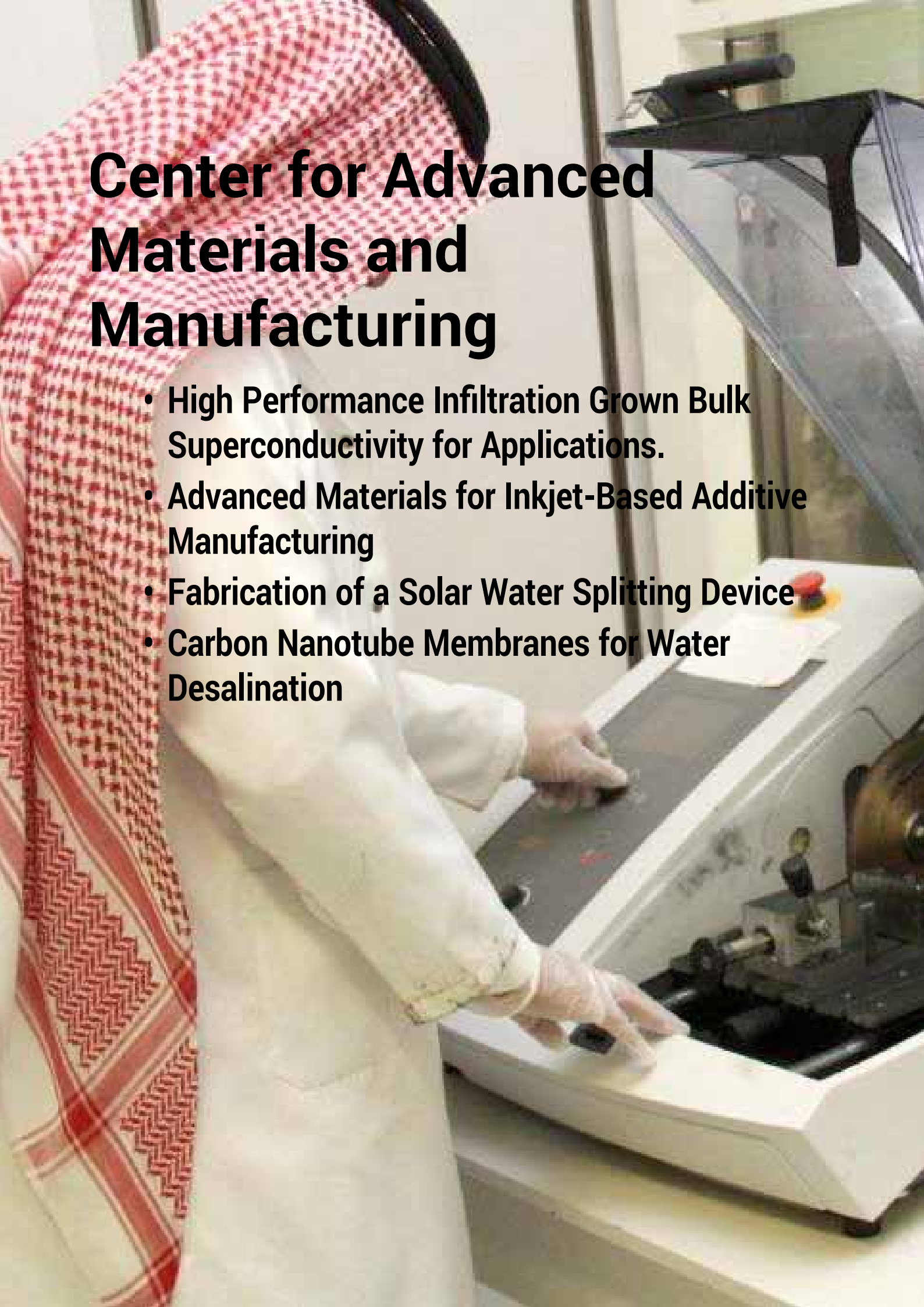
JCIN represents a collaborative research effort focused on nanotechnology and strives to ensure a Return on Investment (ROI) that will benefit the KSA and global society at large.

Introduction

The Joint Center of Excellence in Integrated Nanosystems (JCIN) between Northwestern University (NU) and KACST represents a world-class research center that encourages and promotes research in nanotechnology, steering the regional economy away from the current oil-based economy to a knowledge-based one. The research strategy for the JCIN focuses on conducting research in different areas of nanotechnology that have been identified by JCIN to be of important global commercial interest.

JCIN main goals include:

- To be the primary source for innovation and intellectual property (IP) generation in KSA.
- To create a pipeline for commercialization opportunities to national companies (e.g., TAQNIA) based on the applied research goals outlined in the National Plan for Science, Technology and Innovation set by KACST and the Ministry of Economy and Planning.
- To catalyze start-ups in the field of nanotechnology that provide a Return on Investment (ROI) to KSA.
- To establish laboratories in KSA to accelerate and strengthen the joint venture between KACST and NU.
- To enable the exchange of researchers each year between KACST and NU.
- To produce a strong achievement record of publications in high-impact, high-quality journals and invention disclosures or patents with high commercialization potential.



Center for Advanced Materials and Manufacturing

- High Performance Infiltration Grown Bulk Superconductivity for Applications.
- Advanced Materials for Inkjet-Based Additive Manufacturing
- Fabrication of a Solar Water Splitting Device
- Carbon Nanotube Membranes for Water Desalination

Technical Leaders Program

Partner: University of Cambridge

UNIVERSITY OF CAMBRIDGE

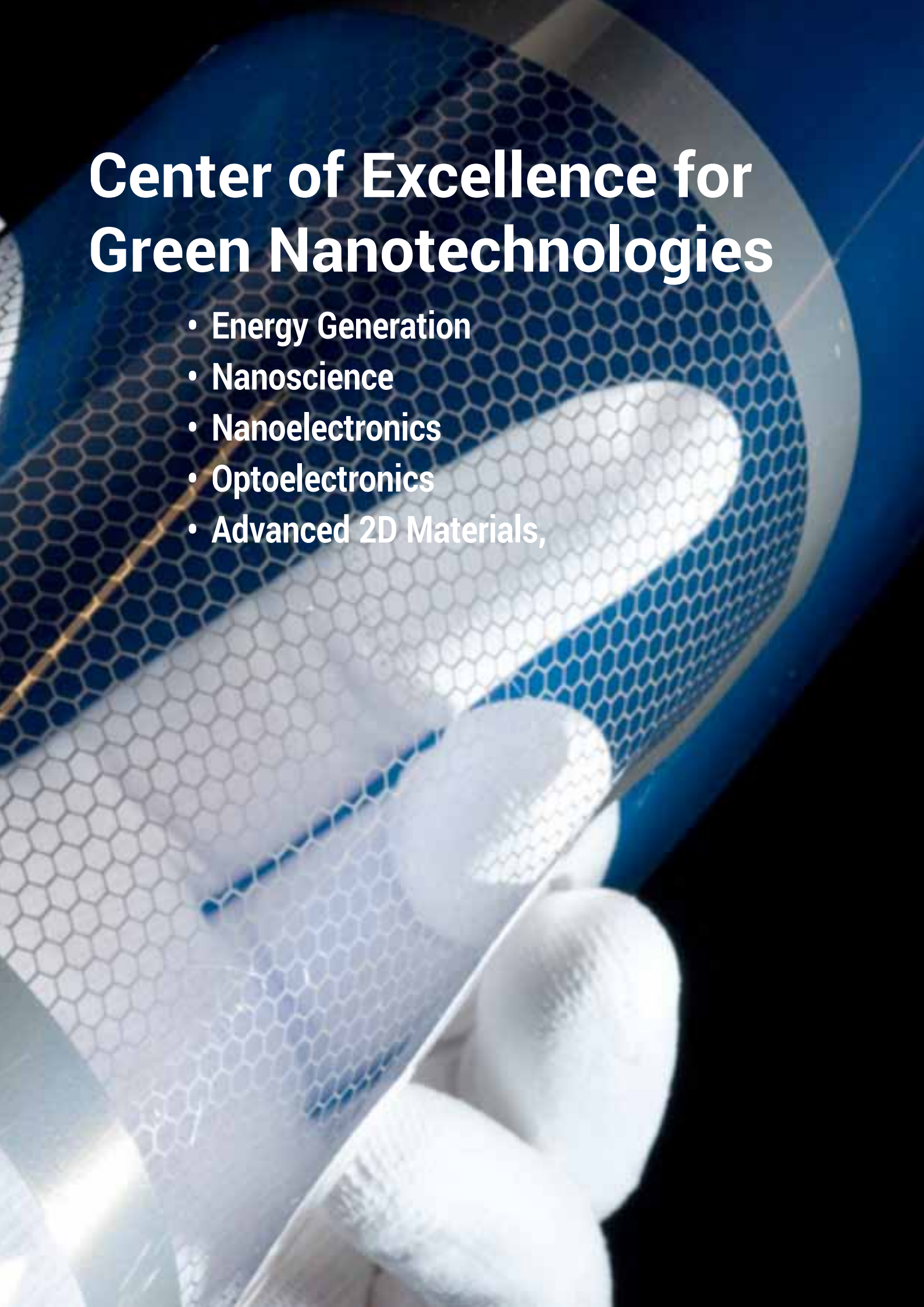
camm

Advanced materials and manufacturing are vital across all industrial sectors. The efficient production of both downstream and upstream petrochemicals depend on advanced materials and manufacturing.

Introduction

The aim of the KACST-Cambridge University Joint Center of Excellence (JCE-CAMM) is to provide a center for the collaborative research in advanced materials and manufacturing to support the long-term strategic plan of the Kingdom of Saudi Arabia to develop technology and infrastructure that has a vastly reduced dependence on non-renewable resources. This will be achieved through the exchange of information on current technical initiatives to establish a framework for future collaboration, to transfer technology from Cambridge to Saudi Arabia where appropriate and to coordinate visits between faculty and researchers between KACST and the University of Cambridge. This collaboration in its first phase has achieved numerous successful results, including four patents in LED technology. In addition, several scientific articles have been published in distinctive journals and conferences.

In the next two years, the center will be focusing on four technical areas: bulk superconductors, additive manufacturing, water desalination and solar hydrogen fuel generation. The first project is going to develop a bulk superconductivity for energy and heavy metals separation applications. Also in the energy sector, the center is developing novel low cost, high efficiency photo-electrodes and photocatalysts for practical water splitting via solar energy. The other projects are focusing on membrane manufacturing based on carbon nanotubes for water purification and additive manufacturing, which is an innovative manufacturing technology.



Center of Excellence for Green Nanotechnologies

- Energy Generation
- Nanoscience
- Nanoelectronics
- Optoelectronics
- Advanced 2D Materials,

Technical Leaders Program

Partner: University of California, Los Angeles

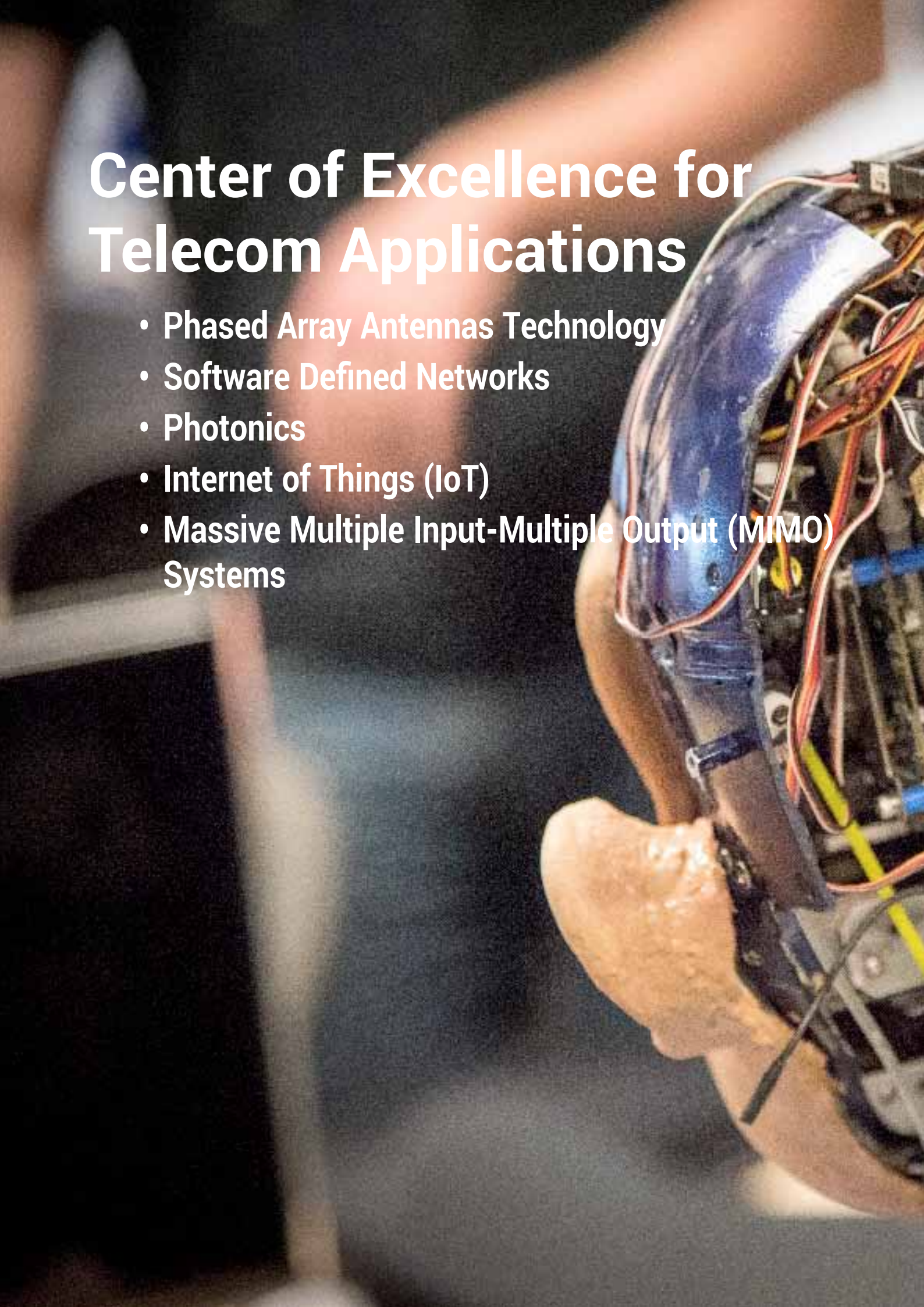
The Center of Excellence for Green Nanotechnologies explores the nanotechnology world, in collaboration with the University of California, Los Angeles, in the United States.

Introduction

The Center of Excellence for Green Nanotechnologies at KACST and UCLA (CEGN) undertakes frontier research and development in the areas of nanotechnology and nanoscience for future electronics and energy devices. CEGN tackles major issues of scaling, energy efficiency, energy generation, and energy storage faced by the electronics industry. Researchers in the center are innovating novel solutions through a number of complementary efforts that minimize power usage and cost without compromising electronic device performance. The approach is based on the integration of magnetic, carbon-based, organic, and optoelectronic materials and devices.

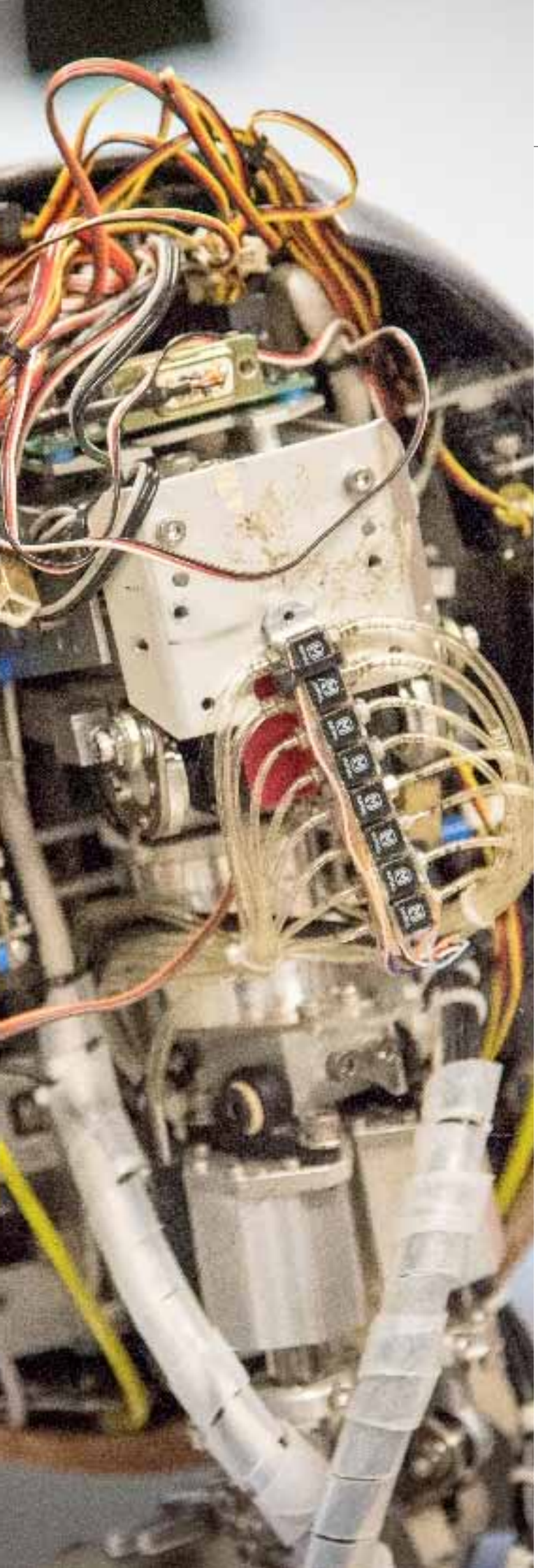
CEGN was founded in 2008 where the center was initiated with high frequency carbon Nanotube electronics, non-volatile memory devices, and organic photovoltaic devices. Since its inception, the center achieved remarkable progress in nanoscience and nanoelectronics. The first RF carbon Nanotube electronic devices have been achieved which unlocked a new horizon for high speed microwave electronics at the nanoscale.

The Center also focuses on creating a new industry in the field of semiconductors and electronics by collaborating with the energy sector, start-up companies, and local universities. By including local man power from different backgrounds, and using the current resources allocated at different institutions in KACST and local partners in energy industry and universities, it is possible to create a new and efficient local semiconductor industry.



Center of Excellence for Telecom Applications

- Phased Array Antennas Technology
- Software Defined Networks
- Photonics
- Internet of Things (IoT)
- Massive Multiple Input-Multiple Output (MIMO) Systems



Technical Leaders Program

Partner: University of California, San Diego

UC San Diego

CETA

The mission of the Center of Excellence for Telecom Applications at KACST and UCSD is to undertake research and development of applications for advanced telecommunications networks and the Internet of Things (IoT).

Introduction

The Center of Excellence for Telecom Applications (CETA) is a joint collaboration between the University of California, San Diego (UCSD) and (KACST). This center aims to work in advanced scientific research in the field of telecommunications and the IoT. It works to provide operators with the latest and advanced solutions that meet the requirements of various authorities in order to increase the efficiency of the communication networks and internet services in the Kingdom of Saudi Arabia and all over the world.

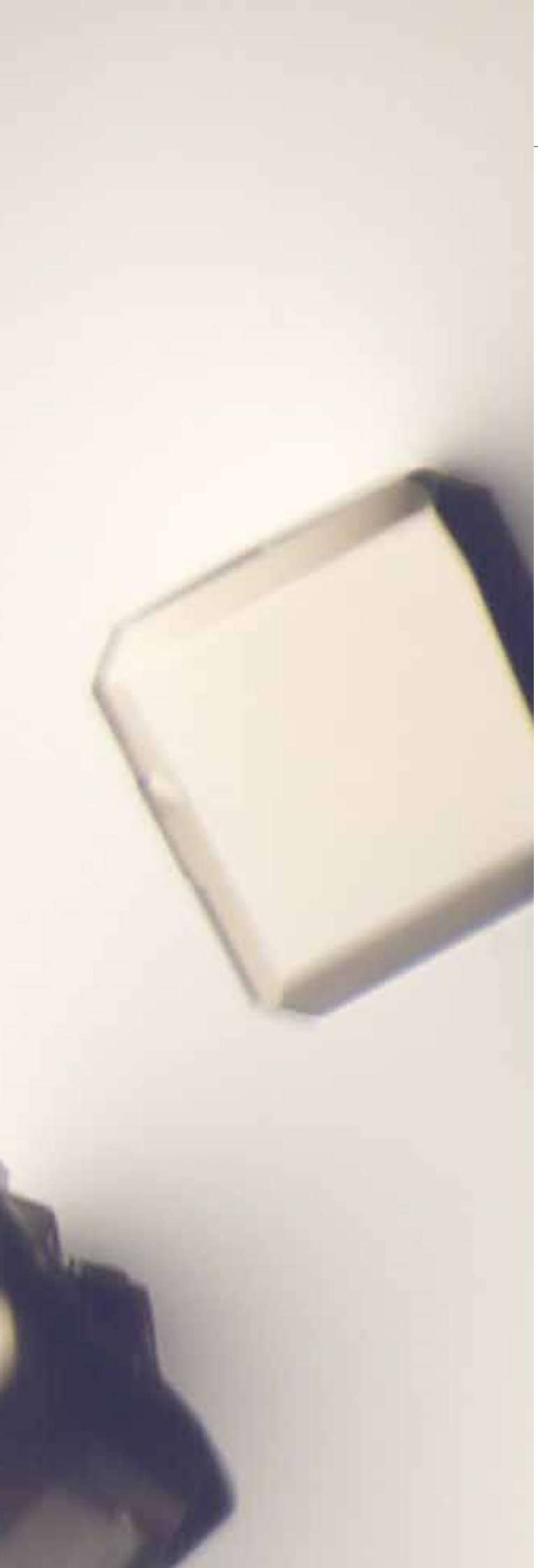
Its vision is to become a leading center in developing applications for telecommunication and the IoT.

The center has a number of tracks, all of which aim at enhancing the capabilities of scientific research in telecom and wireless applications and the development of human resources in this field. It aims to create a research environment based on a solid scientific base. All of these tracks enable Saudi researchers to participate in joint research with the university. It also allows the use of laboratories and equipment available at the university and participation in research on existing projects.

The center provides the right environment for the preparation of professional Saudi researchers and outstanding prospective graduate students by allowing direct interaction between the Saudi researchers and their counterparts at the University of California, from professors and university specialists, to increase educational knowledge and gain necessary experience.

Center of Excellence of Nanomaterial for Clean Energy Applications

- Nanomaterials Synthesis Technology
- Gas Capture and Storage Technology
- Gas to Useful Materials Technology
- Photocatalysis Technology



Technical Leaders Program

Partner: University of California, Berkley

Berkeley

CENCEA

KACST-UC Berkeley Center of Excellence of Nanomaterial for Clean Energy applications (CENCEA) aims to innovate nanomaterials to develop solutions to challenges in renewable and cleaner energy.

Introduction

The high global demand for energy is mainly satisfied through the burning of fossil fuels (86%), generating thirty-five billion tons of carbon dioxide annually. Since this amount is predicted to significantly increase in the foreseeable future, clean energy applications have recently attracted enormous societal, political and scientific interest.

Thus, the research interests at CENCEA are mainly focused on the synthesis of metal organic frameworks (MOFs) for use in different industrial applications. Owing to their exceptionally high surface areas, these materials can exhibit tremendous capacities for compressed gas storage, delivering the highest known storage densities for CH_4, C_2H_2, CO_2, and cryogenic H_2. A high surface area is also beneficial for gas separations, such as CO_2 capture, where it can ensure a high working capacity and, assuming good permeability, rapid adsorption because of the large gas-solid interface.

In addition, the Center focuses on connecting our basic understanding of the synthesis and properties of nanocrystals, in particular its use in different applications as its physical, chemical, electrical and thermodynamics properties depend on the size of its crystal. It should be noted that these materials would have a use in the efficient separation of hydrocarbons, carbon capture from flue gas, gas conversion to liquid fuels, and solar energy conversion.

Center of Microwave Sensor Technology

- Millimeter-Wave Radar for Autonomous Vehicles
- Wireless Power Transmission
- CMOS Circuits for Single Chip Vehicle Radar

Technical Leaders Program

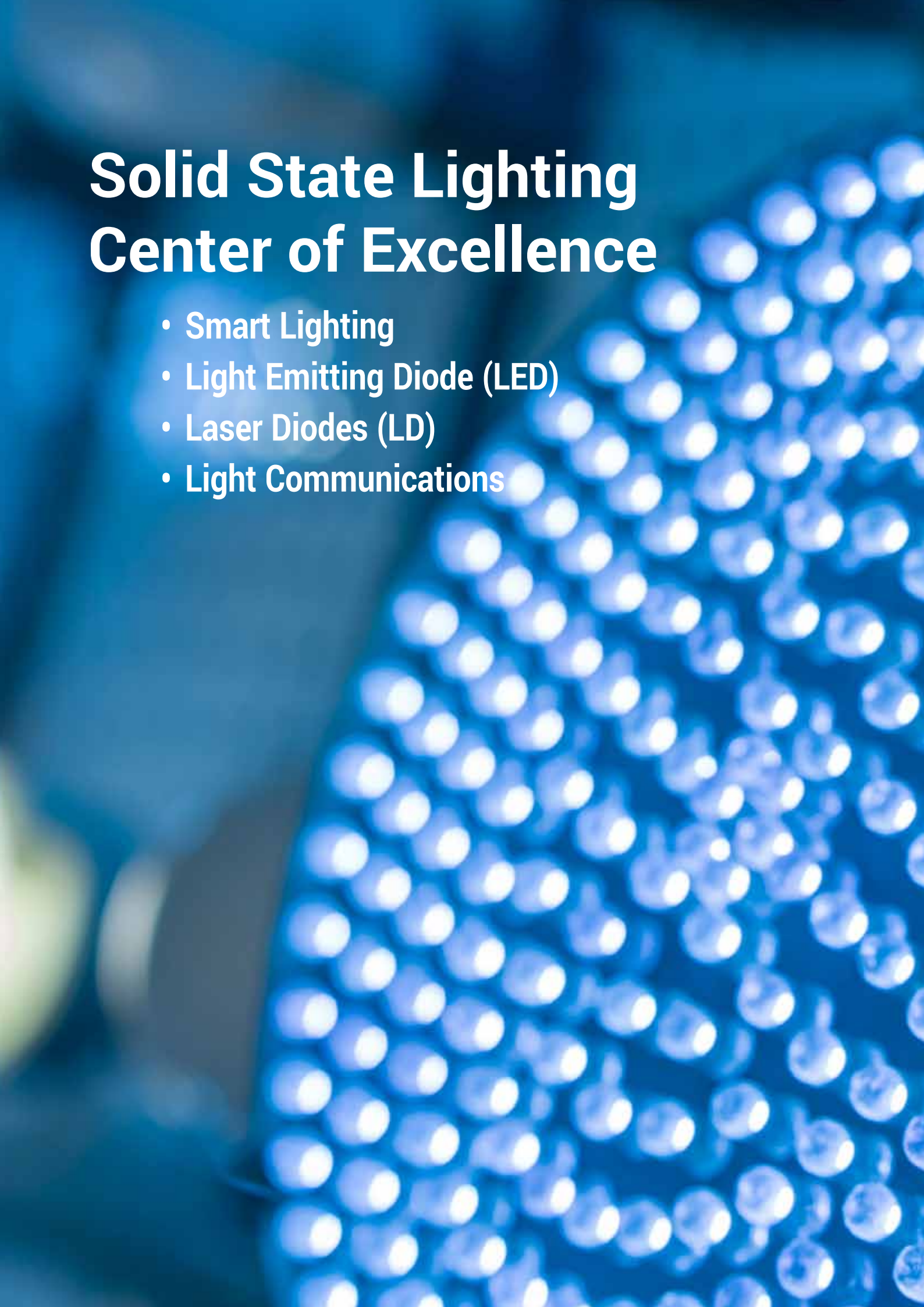
Partner: University of Michigan

The Center of Microwave Sensor Technology is a joint collaboration work between KACST and University of Michigan. It aspires to be a world-class leader in the development of the electromagnetic waves.

Introduction

Electromagnetic waves are one of the most important physical phenomena that enable us to study and interact with the world around us. It is the physical medium used in the field of wireless communications. Hence, there is almost no place in the world without electromagnetic waves. Furthermore, electromagnetic waves have many use cases in medical, military and industrial applications. On the other hand, they may cause serious diseases if they are misused, so their study and understanding of their nature is essential for the time being.

The Center of Microwave Sensor Technology is a technical partnership between the University of Michigan in Ann Arbar and KACST. The center aspires to become a global research laboratory in the field of generating and studying electromagnetic waves at microwave frequencies and millimeter frequencies. This center is operated by training Saudi engineers with international experts from the University of Michigan, to transfer and localize advanced technologies in the Kingdom of Saudi Arabia. The work is accomplished through several workshops held at the headquarters of the University of Michigan and at the headquarters of KACST resulting in the benefit of the experiences and laboratories of the University and building similar in the Kingdom. In addition, the center allows its researchers to pursue graduate studies at the University of Michigan, which is one of the best universities in the world in the field of electromagnetic waves.



Solid State Lighting Center of Excellence

- Smart Lighting
- Light Emitting Diode (LED)
- Laser Diodes (LD)
- Light Communications

Technical Leaders Program

Partner: University of California, Santa Barbara and King Abdullah University for Science and Technology

UCSB

The center combines expertise and resources from KACST, KAUST and UCSB to enable the ultimate efficiency and performance of solid-state lighting technology, to develop intelligent functionality and communication in lighting, and to educate the 21st century workforce in new lighting technologies.

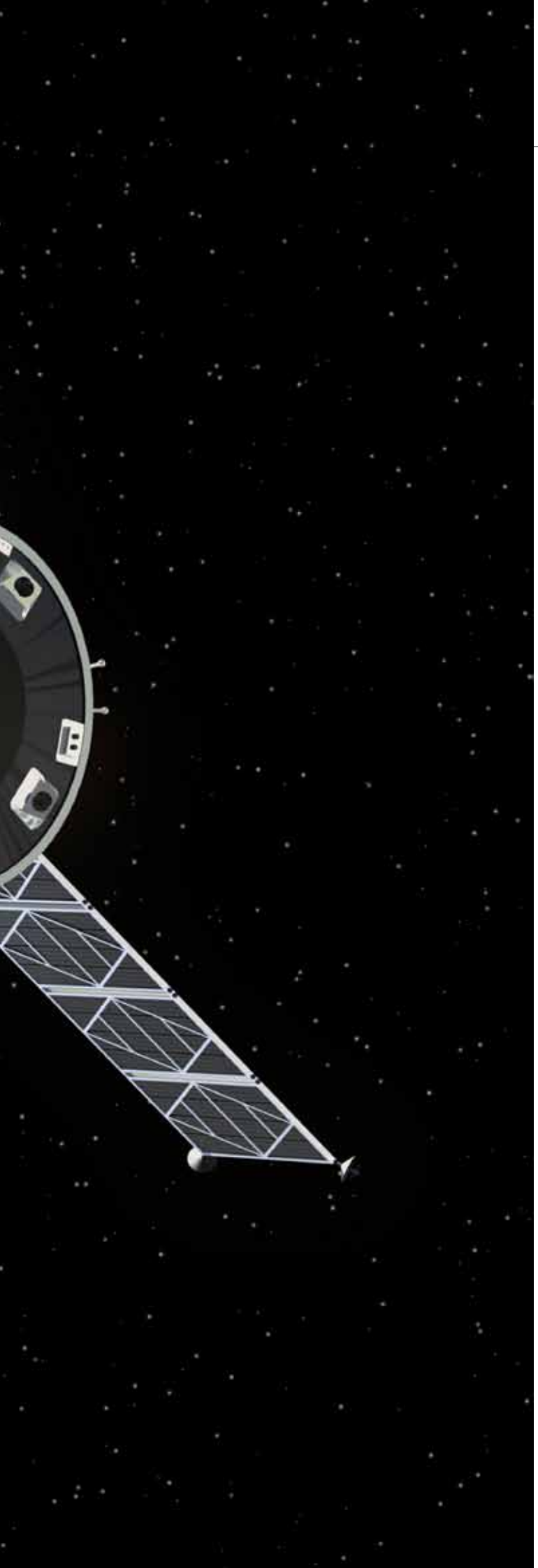
Introduction

The Kingdom of Saudi Arabia currently uses ~10 GW, or more than 18%, of its electricity production for lighting. Since much of the current lighting technology in the Kingdom is highly inefficient incandescent lighting (10-15 lumens/watt), nearly all lights produce a lot of heat which leads to added air conditioning loads. The transformation to solid-state lighting (SSL), with an ultimate theoretical efficiency of ~300 lumens/watt (lm/W), will correspond to low energy consumption for lighting while simultaneously reducing air conditioning loads.

KACST, KAUST and UCSB started to collaborate in solid state lighting (SSL) four years ago to develop advanced photonics technologies for SSL in Saudi Arabia. The establishment of this center will contribute to sustainable economic growth by the efficient utilization of human and energy resources. The primary goal is to assist Saudi-based companies and the Kingdom to develop next-generation SSL technologies. The center will also add new functionality to SSL, namely communication, and to pioneer revolutionary new approaches to SSL (e.g. - laser-based lighting and smart lighting). At the same time, work will continue on improving SSL efficiency (with an ultimate goal of 300 lm/W), reducing costs, and focusing on commercializing the of the developed technology in the Kingdom.

Center of Excellence for Earth and Space Science

- Groundwater Changes
- Terrain Changes
- Radar Systems Technology



Technical Leaders Program

Partner: California Institute of Technology - Caltech

Technologies used in the study of space and earth sciences go through an accelerated development stage in this digital era. Therefore, the concept of establishing the Center of Excellence for Earth and Space Science was born to increase the Kingdom's contribution in the field of space and earth research.

Introduction

The Center of Excellence for Earth and Space Science is one of the Joint Centers of Excellence Program, newly established in a partnership between KACST and the California Institute of Technology (Caltech) of National Aeronautics and Space Administration (NASA).

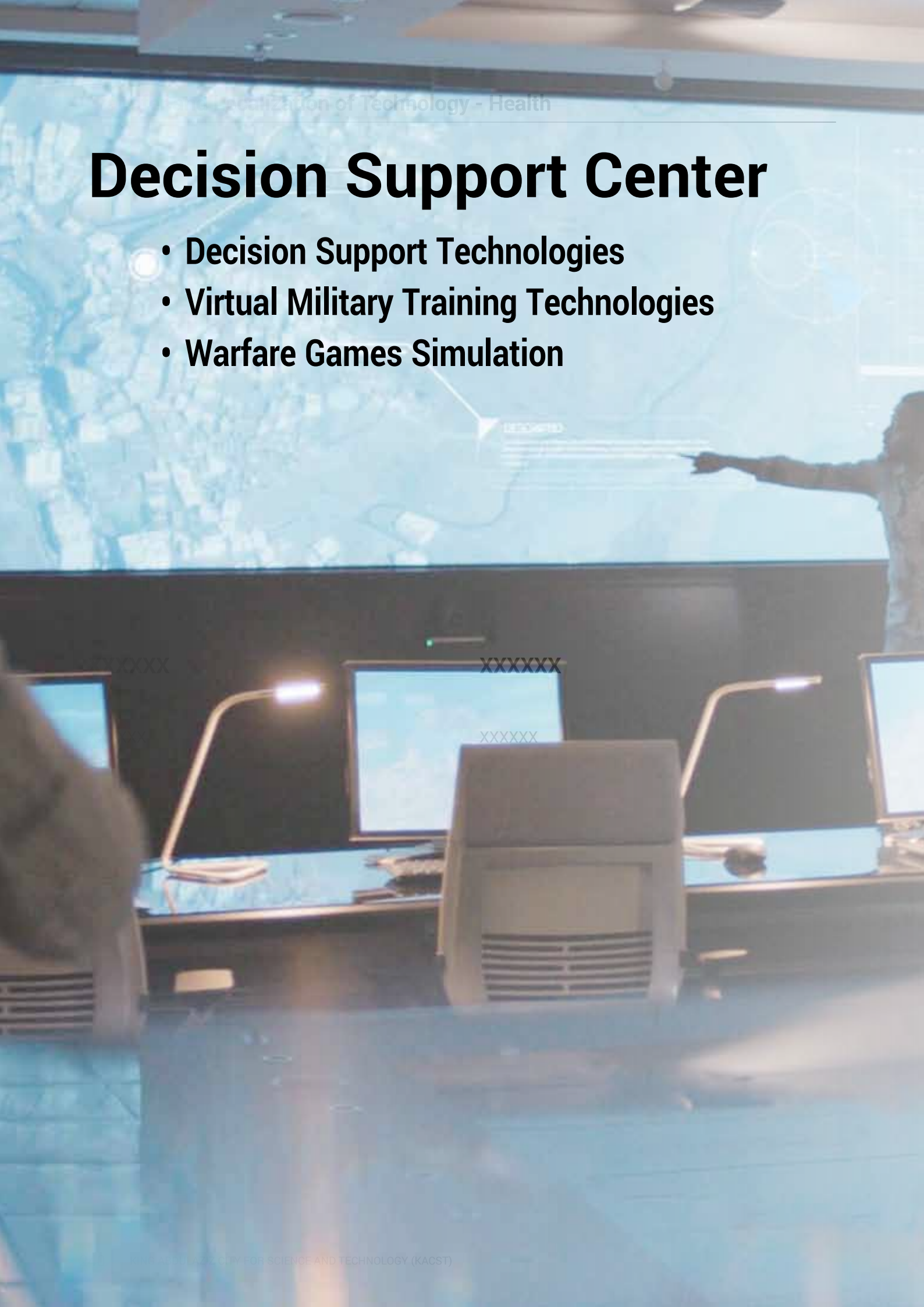
This scientific partnership focuses on collaboration between the Department of Geological and Astronomical Studies in Caltech and the Earth and Space Center in the Joint Centers of Excellence Program. The general goal of this center is to develop satellite technologies and use the data to deal with the challenges of studying:

- Crust and underground deformities, such as tectonic movements and understanding the changes in sand dunes, and studying flood pools.
- Groundwater reservoirs, by understanding the dynamics of these reservoirs and determining of its properties.

This cooperation has opened up possibilities for all researchers at the center and contributed to the facilitation of advanced scientific research and the exploitation of Caltech's available capacities.

Decision Support Center

- Decision Support Technologies
- Virtual Military Training Technologies
- Warfare Games Simulation



Technical Leaders Program

Partner: Boeing

In line with Saudi Arabia's Vision 2030 regarding the development of decision support mechanisms in defense and security fields, the Decision Support Center was established at KACST by a strategic partnership with Boeing, to become the national strategic center for supporting decision-makers using modeling, simulation and advanced analytical capabilities.

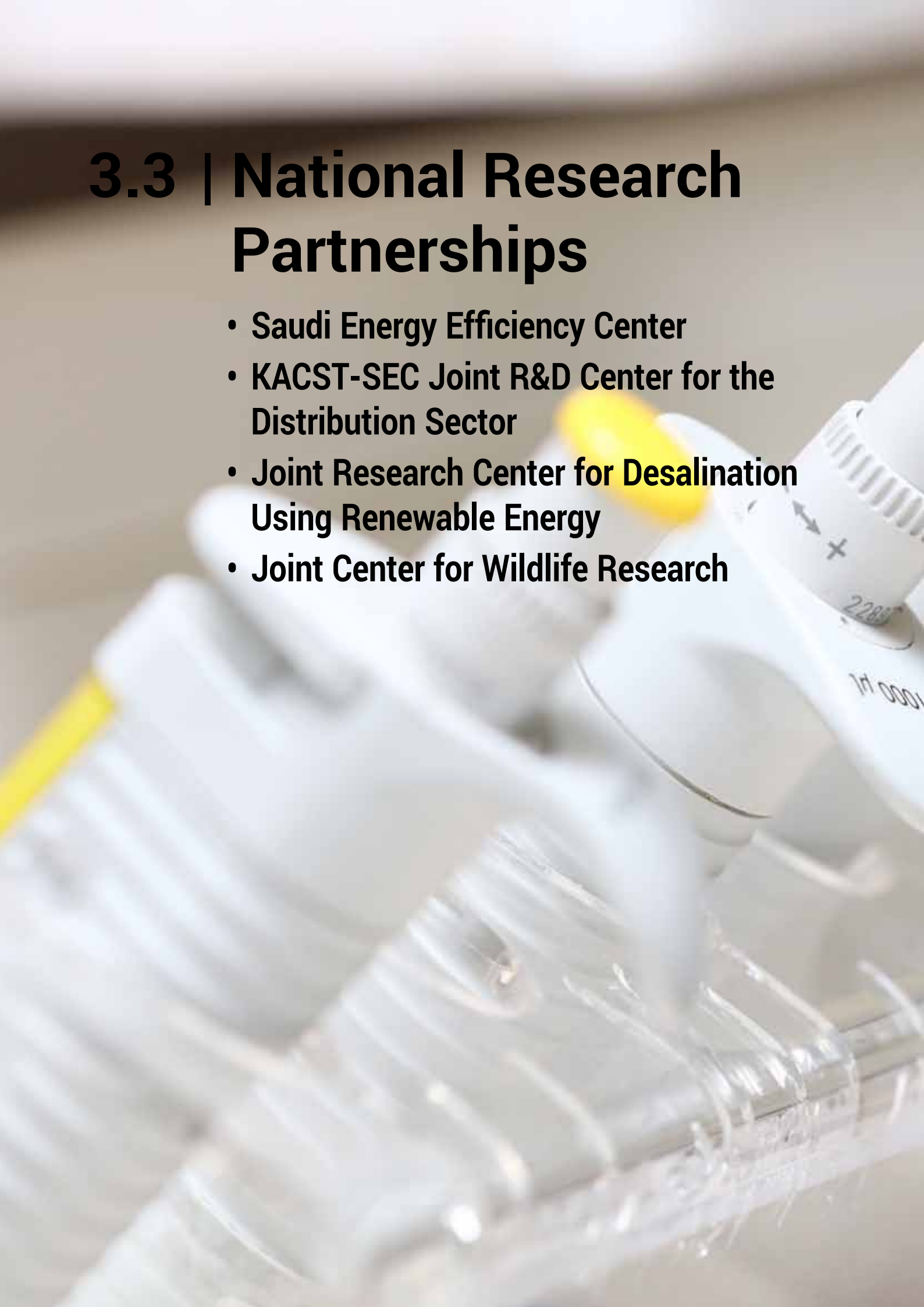
Introduction

The Decision Support Center (DSC) aims to provide innovative solutions for the defense, security and civil sectors by achieving the maximum efficiency in conducting studies and developing advanced tools for modeling, simulation and analysis, and by providing a model environment that simulates reality. The beneficiaries can conduct experiments to understand and anticipate the future, and explore options and alternative solutions in a timely manner, in order to reduce potential risks. The DSC performs the following tasks:

- Providing the infrastructure and environment to support decision-making by using the latest modeling, simulation and analysis (MS&A) technologies.
- Conducting applied research and developing technologies for decision support.
- Coordinating scientific conferences and symposiums in the fields of MS&A.
- Providing support, consultation and innovative solutions to decision-makers in Saudi Arabia.
- Developing MS&A tools for decision support systems and services.
- Conducting training workshops in the fields of decision-making support for the defense, security and civil sectors.

3.3 | National Research Partnerships

- Saudi Energy Efficiency Center
- KACST-SEC Joint R&D Center for the Distribution Sector
- Joint Research Center for Desalination Using Renewable Energy
- Joint Center for Wildlife Research



National Research Partnerships

KACST has expertise in financing, supporting and managing major research projects in coordination with national institutions and agencies to exchange knowledge in various fields in line with the requirements of development in the Kingdom

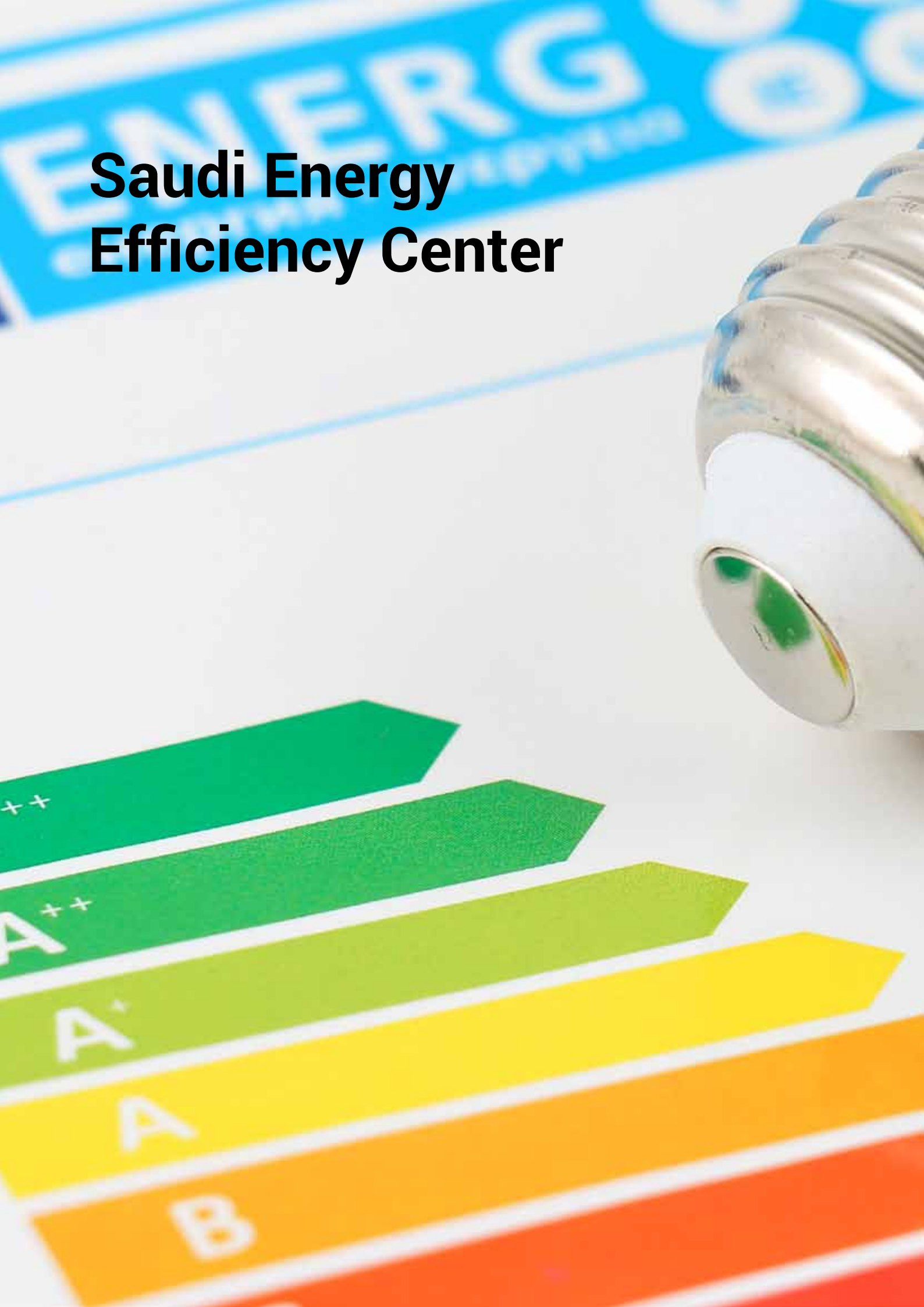
Introduction

KACST seeks to coordinate with the national institutions and agencies and exchange information and expertise. KACST is a pioneer in research, development and localization of technologies for the Kingdom's development and production sectors. KACST is cooperating with the relevant authorities to benefit from these technologies and has established several joint research centers in various fields such as energy, water and wildlife.

KACST aims to lead the efforts in scientific research in the Kingdom by providing distinguished national researchers, laboratories, and technical infrastructures. One of the main goals for the establishment of joint research centers is to build a knowledge exchange relationship based on the participation of researchers from both parties in joint research and projects, which would help reduce the costs and improve the effective usability of the of the infrastructures. It will also increase the local content, and provide researchers with practical experience in regards to difficulties facing the sectors concerned. The centers aim to:

- Raise the scientific participation of Saudi research centers in the international forums and publish research results to benefit the largest possible audience.
- Conduct high-quality research that can have a broad impact on the scientific community.
- Develop the local research skills for both parties.
- Provide a distinct environment that can help develop innovation and creativity skills and raise them to meet international standards.
- Participate in relative scientific workshops and exhibitions, to highlight the efforts made by both parties, and communicate with other sectors.

Saudi Energy Efficiency Center



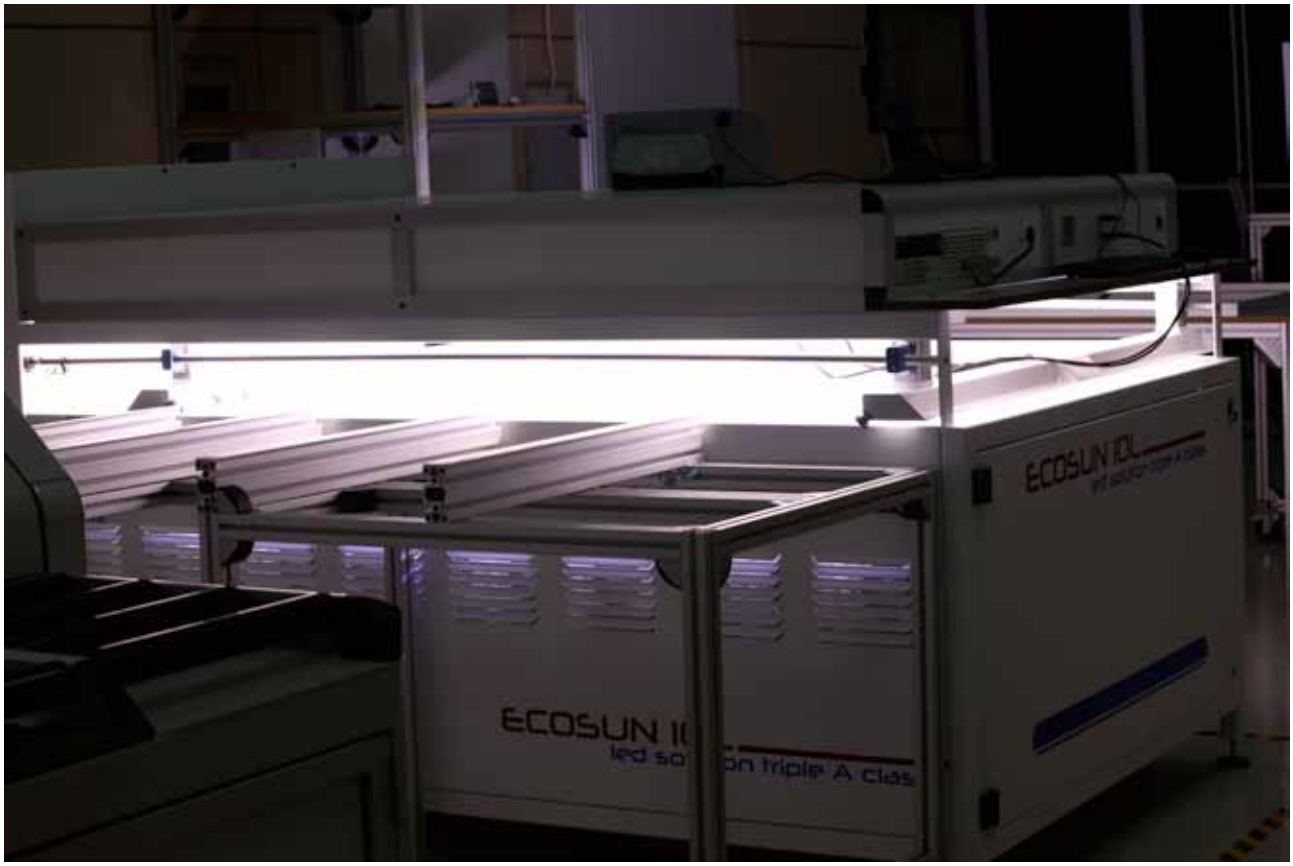
National Research Partnerships

KACST has expertise in financing, supporting and managing major research projects in coordination with national institutions and agencies to exchange knowledge in various fields in line with the requirements of development in the Kingdom

Introduction

The Saudi Energy Efficiency Center (SEEC) aims to rationalize energy efficiency, and unify efforts between governmental and non-governmental entities in this area. The center was established by the council of ministers decree No. 363, dated 24 Dhu Al-Qadah 1431H, that mandated the transfer of the (provisional) National Program for Energy Management and Rationalization at KACST to a permanent National Center. The Cabinet Decision No. 16 dated 17/1/1433 AH also approved the organization of the center as well as the addition of a number of entities to the administrative committee: Ministry of Energy, Industry and Mineral Resources, Ministry of Environment, Water and Agriculture, Ministry of Municipal and Rural Affairs, Ministry of Commerce and Investment, Ministry of Transport, Ministry of Finance, Ministry of Culture and Information, Ministry of Housing, Ministry of Economy and Planning, Saudi standards, Metrology and Quality Organization, Electricity and Cogeneration Regularity Authority, Royal Commission for Jubail and Yanbu, General Presidency of Meteorology and Environmental Protection, King Abdullah City for Atomic and Renewable Energy, Saudi Customs,The National Committee for the Clean Development Mechanism, Saudi Aramco, Saudi Basic Industries Corporation (SABIC), Saudi Electricity Company, as well as the private sector.

The main activities of the SEEC include: 1) Preparing a national program to rationalize energy efficiency and developing the necessary plans. 2) Developing policies and regulations governing energy consumption and support their application. 3) Supporting the integration of the stakeholders' efforts to improve energy efficiency and coordination among them. 4) Promoting social and public awareness of rationalization and improving energy efficiency. 5) Participating in the implementation of some pilot projects that require involvement from the center.



National Program to Rationalize and Raise Energy Efficiency

In order to achieve the most important goals of the Saudi Energy Efficiency Center, i.e., the establishment of a national energy efficiency program, the center's administrative committee approved the formation of an executive committee presided over by His Royal Highness Prince Abdulaziz bin Salman bin Abdulaziz Al Saud. The center's members represent a number of stakeholders on the administrative committee. The program involves participation from government agencies and major national companies, as well as a large number of private sector companies, in order to improve the energy efficiency in the Kingdom in places such as buildings and ground transportation. Another aim is to reduce energy consumption in various sectors including industrial fields, household electrical appliances, thermal insulation materials, lighting, vehicle fuel consumption, iron, cement and petrochemicals plants. The National Energy Efficiency Program is a comprehensive effort based on consensus and agreement among all stakeholders, both public and private. It seeks to develop and implement energy efficiency programs and initiatives, systems, and regulations. It also aims to implement funding mechanisms which will help it achieve its objectives, supported by full cooperation between relevant governmental agencies responsible for the implementation of these programs, and the full observance of and respect for the jurisdiction of the various actors. The program will benefit from international experience and expertise by looking at the results of energy efficiency programs adopted globally. The objectives of the program can be summarized as follows:

- Improving the Kingdom's energy efficiency using initiatives tailored to the local market.
- Establishing a National Energy Efficiency Program together with the necessary plans.
- Involving all stakeholders in the program creation (government, corporations and the public).
- Developing policies, systems and regulations governing energy consumption, and supporting their applications.
- Supporting the integration of the stakeholder efforts to improve energy efficiency and coordination among them.
- Promoting social and public awareness of rationalizing energy consumption and improving energy efficiency.
- Participating in the implementation of some EE pilot projects that require the input from the center.

- Achievements of the Saudi Energy Efficiency Center:

- Submitting the updated final version that consists of the following four documents to the Saudi Building Code National Committee (SBCNC) on 23/09/1437 AH.
  - Energy Conservation Code for Low Buildings (Arabic and English).
  - Energy Conservation Code for High Buildings (Arabic and English).
  - User Manual of Energy Conservation Code for High Buildings.
  - User Manual of Energy Conservation Code for Low Buildings.
- Updating the specifications of all types of small capacity air-conditioners (window /split) with manufacturers, suppliers and stakeholders from the government and the private sector.
- Preparing the energy efficiency standards for air conditioners with a capacity greater than 70 thousand thermal units, with the participation of the concerned authorities.
- Implementing the building thermal insulation mechanism.
- Conducting 16 training workshops for several regulators on the application of specifications to the targeted electrical devices.
- Collaborating with the Saudi Organization for Standardization, Metrology and Quality in the development of the "Taakd" application on smart devices. This application allows consumers to verify the information on the energy efficiency card present on the electrical devices and cars.
- Preparing reports for the first three quarters of 2016 on the commitment of car manufacturing companies on achieving the desired fuel economy standards, and sharing the reports with those companies.
- Updating the energy efficiency database with all light vehicles manufactured during the interval from 2010 to 2017.
- Conducting four workshops in January 2016 to inspectors from the Saudi Customs on how to apply the fuel economy standards on the new and used cars.
- Conducting three workshops in April 2016 to inspectors from the Ministry of Commerce and Investment on how to verify the information on the energy efficiency cards.
- Updating the electronic portal, that is dedicated to energy efficiency cards of tires, so that it meets the requirements of the governmental authorities and manufacturing companies.
- Updating the electronic portal, that is dedicated to energy efficiency cards of cars' fuel economy, so that it meets the requirements of the governmental authorities and manufacturing companies.
- Updating the energy efficiency database with all types of used cars that are imported in the interval from 2010 to 2017.
- Identifying and listing the cement, steel and petrochemical factories that are still under construction (completed), and studying the designs of those factories and developing a mechanism to improve their energy consumption (still in progress).
- Collecting the energy consummation data of the cement, steel and petrochemical factories targeted for the year 2015 (a total of 185 factories and production lines) and following up on the issuance of the final reports on the performance of their energy efficiency.
- Reviewing the initial design of 13 new production lines to ensure that they meet the energy efficiency new standards and requirements that were imposed by the center on new factories.
- Coordinating with the Electricity and Cogeneration Regulatory Authority on how to enforce government agencies to use the new cooling techniques when designing their new projects.
- Obtaining the approval from the Board of Directors of the Public Investment Fund and the Ministry of Commerce and Investment to establish the National Company for Energy Services.
- Generating licenses for the authorized power services companies.
- Completing the national directory for the inspection and verification protocol after taking into consideration the technical observations of the companies.
- Completed a field study for the targeted government buildings in cooperation with the Electricity and Cogeneration Regulatory Authority and the Saudi Electricity Company.
- Conducting three consumer awareness campaigns.
- Signing an agreement to establish a joint center for energy efficiency between KACST and King Fahd University of Petroleum and Minerals.
- Developing courses on energy efficiency for a number of colleges at five local universities.
- Conducting 11 training programs in different cities of the Kingdom.
- Conducting training for 15 local trainers on courses approved by the American Association of Energy Engineers (AEE).

KACST-SEC Joint R&D Center for the Distribution Sector

National Research Partnerships

On Thursday 14/10/1436 H corresponding to 30/07/2015, an agreement between KACST and the Saudi Electricity Co. was signed to establish the 'KACST-SEC Joint Research and Development Center for the Distribution Sector'، located at KACST

Introduction

The center aims to establish bilateral knowledge exchange between the two entities by conducting joint research and projects in the distribution sector. The focus is on the advanced research that helps in improving the operational efficiency of the sector, maximizing the utilization of the network, and creating opportunities that are more economical. The center is focused on several scopes related to the distribution sector, which are: electrical power quality, protection systems, renewable resources integration, automation, communication, control, and training. More than 35 personnel from the two entities and other collaborators, with different educational degrees (PhDs, MScs, BScs, Technicians, Administrative, and Experts) are working in the center, either full or part time, and this number is expected to increase.

The center is working on implementing several projects that can have high positive impact on the distribution sector such as: roof-top PV installations on schools and large mosques; data analytics for smart meters; distributed energy resources allocation in distribution network. These projects were designed and conducted in order to help the sector to be prepared for the promising implementation waves of renewable resources and smart meters in 2020 and 2023. The R&D efforts in such projects include detailed design processes, real time simulation tools, planning techniques, data navigation and optimization, and field work. They all enhance the R&D personnel capacity and expose them to real distribution network problems, which should be reflected eventually in advanced network solutions.

The center is participating in several local and international workshops and exhibitions, and collaborating with local and international universities and experts, which ensures the improvement and the quality of the research.

Joint Research Center for Desalination Using Renewable Energy

Seawater desalination using renewable energy is considered as one of the promising cost-effective and environment friendly solutions for water shortage in Saudi Arabia.

Introduction

A cooperation agreement was signed to implement a joint research center for desalination using renewable energy, on 26/2/1438H, between KACST and the Saline Water Conversion Corporation (SWCC). The agreement also provides the exchange of statistical information and data needed for research purposes, and cooperation to avoid duplication of efforts in the field of statistical and technical information.

The areas of cooperation in this agreement are focusing on the following topics:

- Development of highly efficient membranes for desalination and water treatment.
- Development and localization of desalination techniques using renewable energy technologies.
- Increasing the efficiency of desalination plants and improving their performance

The joint research center will be operated under a supervisory committee of the two parties with full powers, in accordance with the regulations under preparation for proposing work mechanisms. It also aims to a provide technical and administrative review of proposed research and related budgets.

The projects proposed and agreed by the parties are:

- The design and development of two desalination plants, one of which is operated by adsorption technology.
- Establishing a trihybrid desalination plant (NF-MED-RO).

The outputs of these projects can be utilized to maximize the implementation of these technologies which is expected to be cheaper than traditional existing technologies and to produce a high quality of drinking water.

Joint Center for Wildlife Research

National Research Partnerships

The Arabian Peninsula has a unique biological diversity adapted to harsh environmental conditions. Efforts have focused on developing techniques for managing wildlife in the Kingdom and finding the best ways to protect it from extinction.

Introduction

There is no coherent system for the management of wildlife in the Kingdom through which the percentage of changes resulting in protected areas and biodiversity can be measured over time. As the conservation of these ecosystems becomes a national necessity, it is only achieved through the development of field research activity in the reserve areas. Such areas are considered a natural laboratory suitable for conducting vital scientific experiments.

The center's activities are dedicated to preserve and sustain biological diversity, especially endemic species, under reserve conditions, self-renewing, disease resistance, and high genetic variation, and support the successful rehabilitation of populations that reproduce naturally in appropriate areas of their geographical spread in the Kingdom. KACST supports and promotes scientific research in the field of wildlife because of the national gains in this area that can be built on and that can accommodate future plans. This will help preserve genetic resources in light of the increasing extinction rates of endemic species in the Arabian Peninsula.

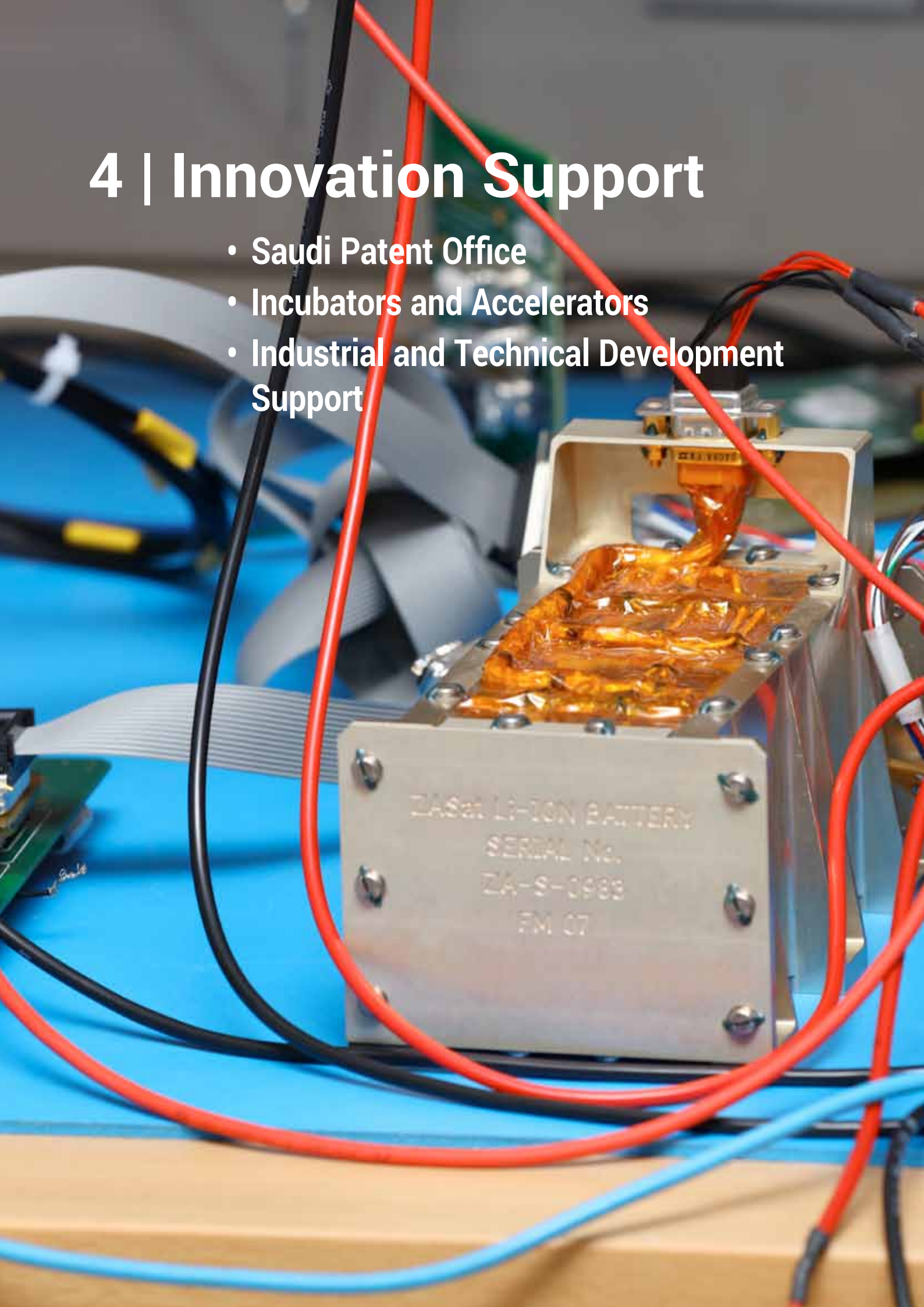
The Center is working on the transfer of research techniques in the field of wildlife research. It is also working on localization and development in coordination and cooperation with international centers of excellence and distinguished researchers in specialized disciplines in this field, assisted by qualified graduates of Saudi universities. KACST coordinates with scientific institutions, government agencies, and research centers in the Kingdom in the field of conservation and development of wildlife to prevent duplication, and to combine efforts and resources between these entities. Examples of research programs carried out by KACST include:

- Houbara Research Program.
- Development of Protected Areas.
- Marine Biodiversity Conservation in the Kingdom.

Innovation Support

4 | Innovation Support

- Saudi Patent Office
- Incubators and Accelerators
- Industrial and Technical Development Support



Innovation Support

In order to transfer the Kingdom to a Knowledge-based economy, KACST has developed a strategic plan for the development of science, technology and innovation, that serves the objectives of Vision 2030.

Introduction

Based on KACST's certainty that technology is one of the important ways to achieve the goals of growth and development that the Kingdom is focusing on in order to transform its national economy into a knowledge-based economy, KACST has developed a strategic plan for the development of science, technology and innovation associated with the 2030 vision, via several programs. These programs will enable the Kingdom to overcome the main challenges it faces, namely a weak innovation system and a lack of local technical content in key sectors, and will boost the "Grants Program for Universities and Research Centers", one of the national transformation programs (2020). Some of KACST's programs include:

- The Saudi Patent Office (SPO) which aims to provide protection for inventions, the layout-designs of integrated circuits, plant varieties and industrial designs in the Kingdom. It works on filing and examining industrial property applications, granting patents and property rights, promoting creativity levels and raising awareness among citizens.
- The Business Incubators and Accelerators which highlight the efforts of KACST to support innovation and invention through the establishment and development of technology business incubators which will accelerate and grow emerging technical businesses in KSA.
- The Industrial and Technical Development Support Program which aims to provide the accumulated technical expertise, technical infrastructure, and human resources in the technical and scientific fields as a fundamental aspect for the success of the program. The program works by providing technology development support, small and medium enterprise (SME) support, and technology consultation programs.

4.1 | Saudi Patent Office

- Patents
- Industrial Design
- Plant Varieties

Innovation Support

Saudi Patent Office

KACST's main mission, with regard to the protection of industrial property rights, is the implementation of the law of patents, layout designs of integrated circuits, plant varieties, and industrial designs, and the regulations thereof, by granting patents and registration certificates for applications satisfying the prescribed requirements.

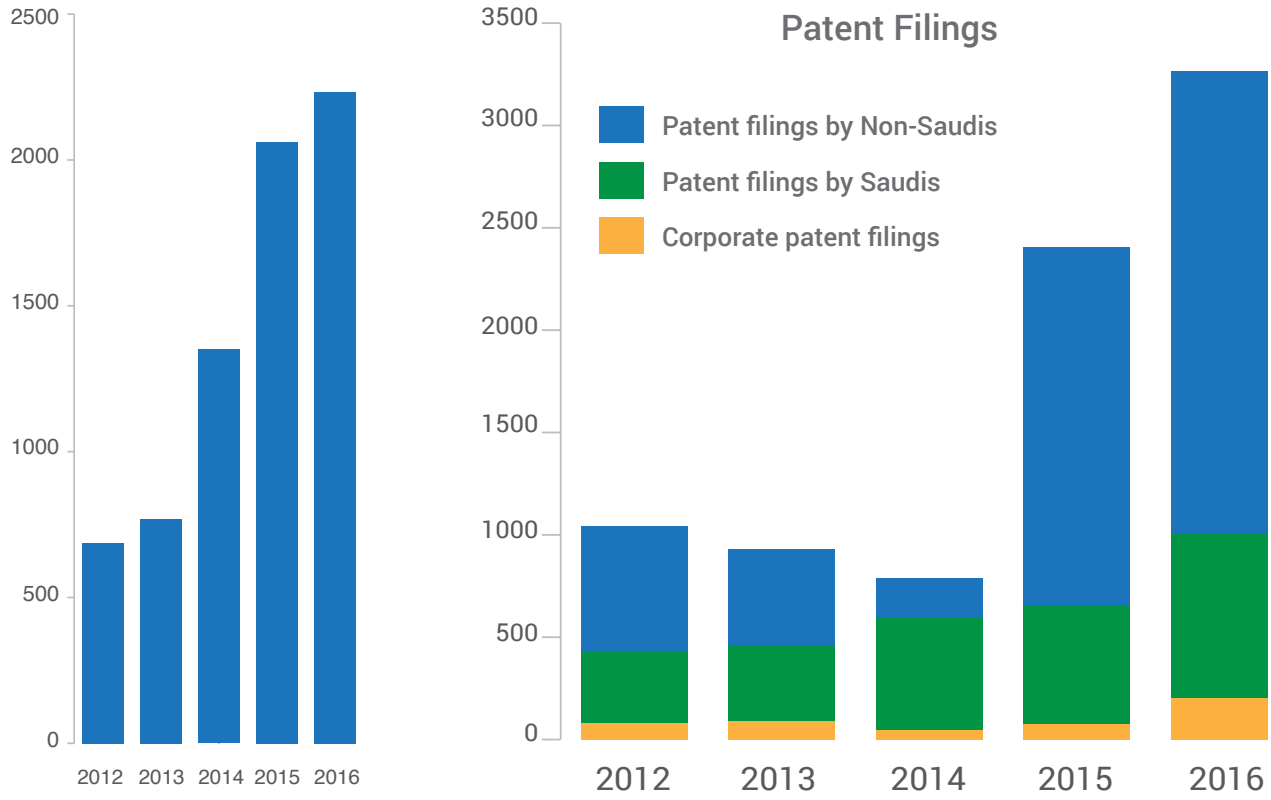
Introduction

The Saudi Patent Office (SPO) was established upon the accession of the Kingdom of Saudi Arabia to the World Intellectual Property Organization (WIPO) in 1982. Following its accession to the Paris Convention, the SPO has become the competent authority for the protection of patents, layout designs of integrated circuits, plant varieties and industrial designs.

The mission of the SPO is to grant patents and registration certificates for inventions, layout designs of integrated circuits, plant varieties and industrial designs in the Kingdom of Saudi Arabia.

The main objectives of the SPO are:

- Implementing of the law of patents, layout designs of integrated circuits, plant varieties, and industrial designs.
- Filing and examining patents, layout designs of integrated circuits, plant varieties and industrial design applications.
- Granting patents and registration certificates for inventions, layout designs of integrated circuits, plant varieties and industrial designs.
- Developing national databases for patent information, layout designs of integrated circuits, plant varieties and industrial designs information.
- Publishing patent information, layout designs of integrated circuits, plant varieties and industrial designs information.
- Raising awareness of innovation and creativity among the public.



Saudi Patent Office

Total Filings

From the establishment of the SPO in 1982 until 2016, a total of 25581 patent applications were filed, 81% of which reached final disposition.

The total number of industrial designs filed was 6932, 97% of which reached final disposition.

A total of 19 plant varieties were filed, 95% of which reached final disposition. The total number of layout designs of integrated circuits filed is 20, 50% of which reached final disposition.

Patent Filings

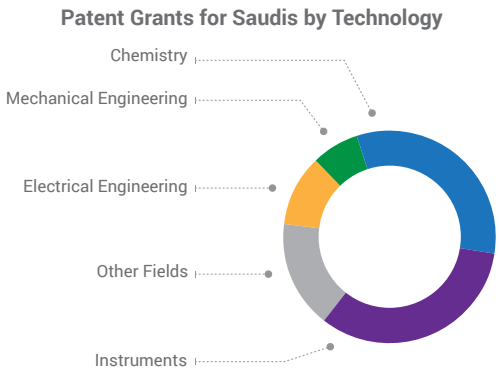
There is a noticeable 35.7% increase in the total number of applications filed in 2016 compared to 2015. This could be due to increased foreign filings through the Patent Cooperation Treaty (PCT), which gives applicants up to 30 months priority to decide where to file their patent applications.

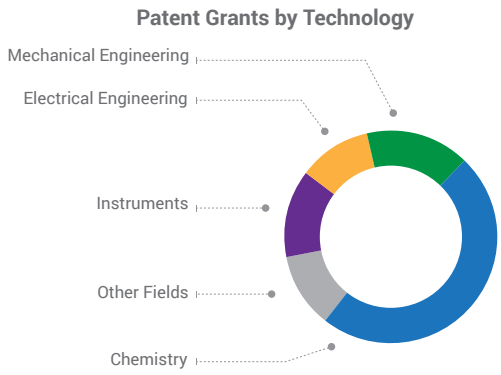
The number of patent filings by Saudis constituted 31% of total patent filings in 2016, which is a 53% increase compared to 2015. This could be due to increased awareness of the importance of patents and intellectual property rights among the individuals as a result of increased awareness raising activities held by the SPO, as well as the efforts to facilitate filing procedures by developing and optimizing the e-filing system.

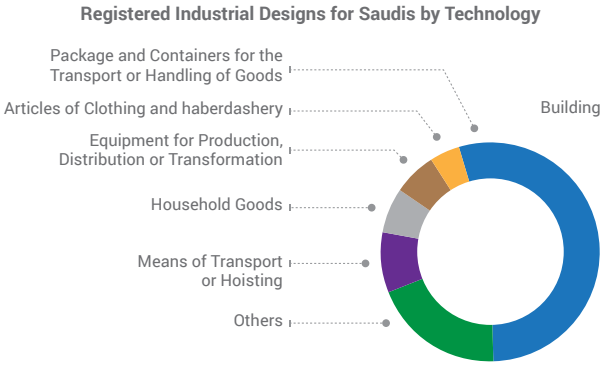
It was noticed that the number of patent filings by Saudi individuals is greater than patent filings by Saudi institutions because some Saudi universities and research institutions do not file their patent applications at the SPO.

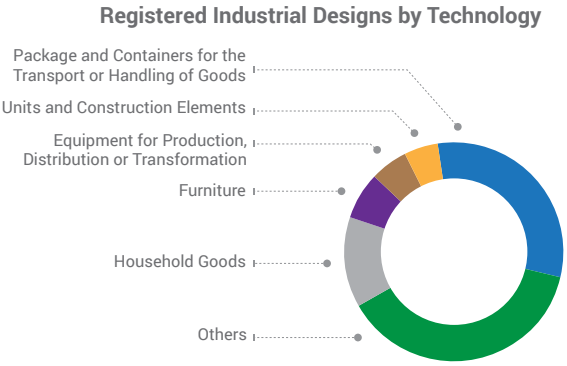
Patent Grants by Technology

In 2016, the number of patents granted was 595. Most of them were in the fields of chemistry with 289 patents, followed by mechanical engineering with 93 patents, instruments with 79 patents, electrical engineering with 67 patents, and “other fields” with 67 patents. The number of patent granted for Saudis was 111, of which 58 were for individuals and 53 for institutions, constituting 19% of the total patent grants. Most granted patents were in the fields of tools with 37 patents, followed by chemistry with 36 patents (most of them for research institutions, which is in line with total patent grants trends), “other fields” with 18 patents, electrical engineering









with 12 patents, and mechanical engineering with 8 patents.

Patent Disposition and Pendency

The total number of disposed patent applications increased by 8.2% in 2016 compared to 2015. Patent disposition in 2016 reached 2232 applications, of which 595 applications were granted a patent, 915 applications were rejected, 332 applications were lapsed, and 390 applications were examined and issued 1st substantive examination report.

Total patent pendency has decreased by 29% and reduced from 31 months to 22 months in 2016 compared to 2015. The total patent pendency in the last two years ranged from 3 months to 20 months. Pendency depends on a number of factors including the difficulty of the technical field of the invention, application backlog in the technical field, applicant response to SPO actions, and compliance of patentability requirements. In addition, the applicant has a 3-month grace period to respond to SPO actions.

Industrial Design Filings

There was a noticeable increase in the total number of filed industrial design applications in 2016 compared to 2015 (about 13.7%). This could be attributed to increased awareness raising activities by the SPO and the optimization of the filing procedures for industrial design applications.

The total number of industrial design applications filed by Saudis constituted 39.4% of total applications filed in 2016.

Most of the registered designs were in the fields of “Packages and Containers for the Transport or Handling of Goods”, with 245 designs, followed by “Means of Transport or Hoisting”, with 106 designs and “Household Goods”, with 56 designs. Most of the industrial design registrations for Saudis were in the fields of “Packages and Containers for the Transport or Handling of Goods”, with 175 designs followed by “Household Goods”, with 29 designs, “Furniture and Equipment for Production”, “Distribution or Transformation of Electricity”, with 21 designs for each field.

Cooperation with Stakeholders

Information Services Provided by SPO

Pharmaceutical Information Search Service	Prior Art Search Service
196 Pharmaceutical Information Services 30 Companies and Pharmaceutical Factories	265 Prior Art Searches

Filings and Grants of Plant varieties and Layout Design of Integrated Circuits

In 2016, no plant variety applications were filed at the SPO. This is because the concerned parties, especially the research centers at the Ministry of Environment, Water and Agriculture, as well as agriculture colleges in Saudi universities, and agriculture companies, did not apply to protect their plant varieties. The SPO, therefore, conducted an awareness program for these parties to explain the importance of breeding and protecting new plant varieties, which has an economic effect on providing food security by developing new varieties that endure climatic conditions of Saudi Arabia.

This program started with a number of presentations and discussion meetings with members of the National Agricultural Committee of the Council of Saudi Chambers, and will continue with all other concerned parties.

In 2016, the total number of layout designs of integrated circuits applications filed at SPO was 7. This number is acceptable as it is in line with the number of applications for layout designs of integrated circuits filed worldwide.

Cooperation with Stakeholders

In the report year, 121 reply notes have been prepared relating to patents and industrial designs lawsuits filed before the Committee on Patent Appeals and Litigation, upon request from the committee. KACST has also prepared 51 reply notes on the lawsuits filed before the Board of Grievances, and attended 126 sessions at the Board of Grievances.

In the report year, 299 field patent applications has been reviewed at the GCC Patent Office (batch 46). The Council of Ministers approved to mandate His Highness the President of KACST - or his deputy - to discuss with the European Patent Office the memorandum of understanding between KACST and the European Patent Office, in the field of patents.

KACST also signed a joint action plan for the years 2017-2018 with the Intellectual Property Office of the People's Republic of China (SIPO). Also in the report year, KACST reviewed the draft of the modified Patent Law. This is in addition to reviewing the Geographical Indications Law drafted by the Ministry of Trade and Investment.

In 2016, KACST welcomed the Director General of the World Intellectual Property Organization (WIPO) for a visit and discussed several aspects of cooperation.

Promotion of Intellectual Property Awareness Activities

In 2016, the SPO held a series of introductory presentations and workshops (30 presentations and workshops) on patents and the protection of intellectual property rights, in Saudi universities and other sectors as follows:

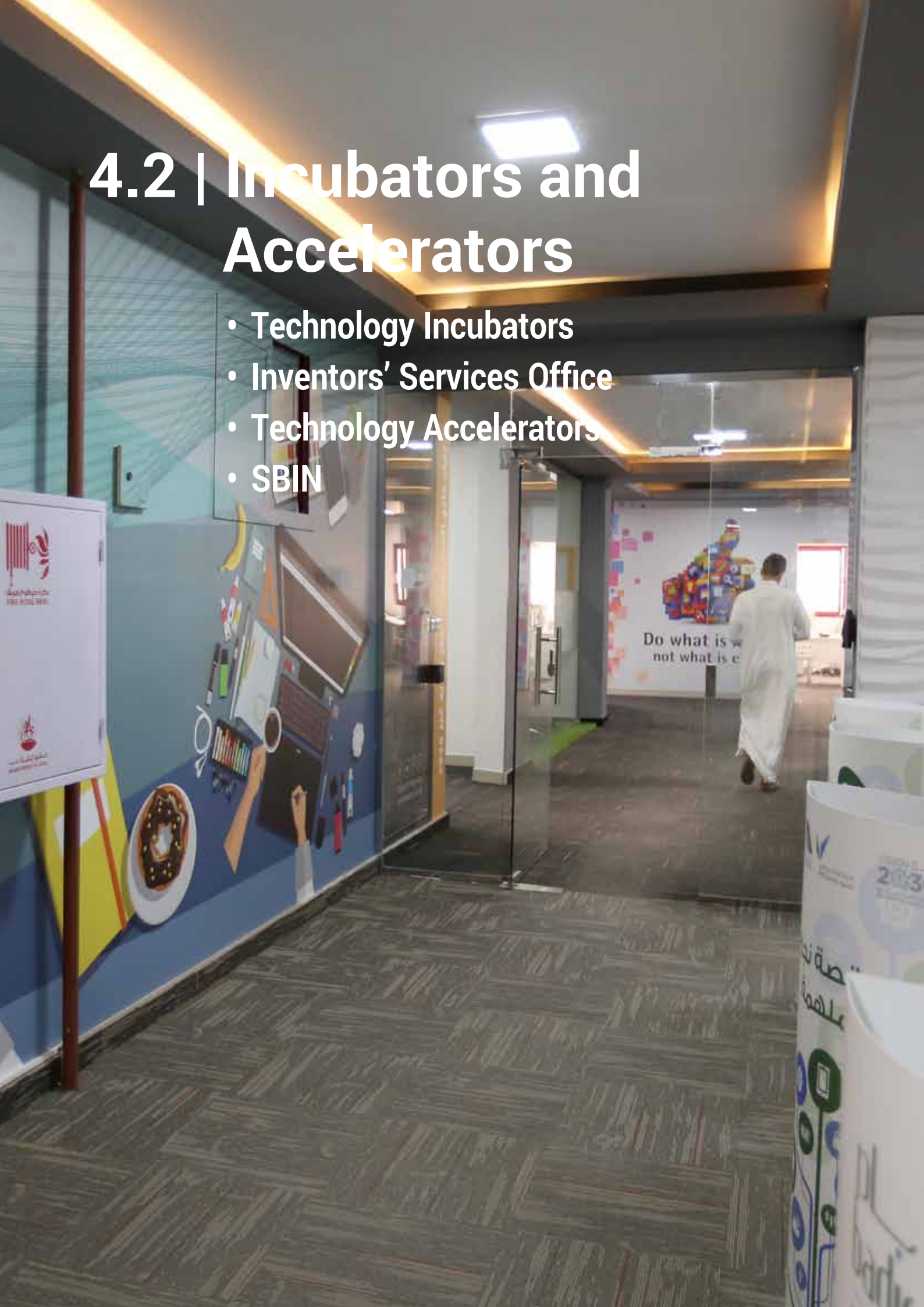
- PCT introductory presentation.
- Workshop on patent application drafting.
- Workshop on prior art search.
- Participation in 5 exhibitions regarding science, technology and innovation in a number of regions of Saudi Arabia.
- Organization of an IP day symposium in cooperation with King Abdullah University of Science and Technology (KAUST), entitled Intellectual Property: Towards A Better Economy in celebration of the world intellectual property day.
- Organization of a National Symposium on Public Health, Innovation and Trade Issues in cooperation with the World Intellectual Property Organization, the World Health Organization and the World Trade Organization.
- Organization of a workshop on PCT and the ePCT filing system in cooperation with the World Intellectual Property Organization (WIPO), targeting applicants and law firms.

Information Services Provided by SPO

- Prior Art Search Service: a free service provided to individuals to help them obtain a preliminary search report on their ideas, to decide whether or not to file a patent application. In 2016, 265 prior art searches were conducted for a number of researchers and inventors to obtain an overview of the prior art documents related to their inventions.
- Pharmaceutical Information Search Service: a service provided to pharmaceutical companies to inquire about legal status of pharmaceutical products filed at SPO, by searching published pharmaceutical information. 196 pharmaceutical information searches were conducted for 30 companies and pharmaceutical factories.

4.2 | Incubators and Accelerators

- Technology Incubators
- Inventors' Services Office
- Technology Accelerators
- SBIN



Innovation Support

Incubators and Accelerators

KACST supports the Kingdom's efforts to develop entrepreneurship in the field of technology, and provides multiple forms of support to encourage the spirit of technology innovation amongst Saudi's youth in order to strengthen the national economy.

Introduction

KACST has drawn up a strategic plan and laid out a long-term vision to develop science, technology and innovation in the Kingdom, in order to provide a blue-print for the transformation of the country's economy from one dependent on natural resources to one that is knowledge-based. As part of the National Transformation Program, KACST has a number of goals tied to those of Vision 2030. One of its key goals is to upgrade the infrastructure and tools needed to develop the local content, by creating an attractive environment for local and international investors alike, enhancing their confidence in the Saudi economy and increasing the competitiveness of the energy sector. A second goal is to establish value-added emerging technology companies to contribute to increasing the local content by supporting small and medium enterprises, encouraging entrepreneurship and developing the field of Information Technology. The third goal is to strengthen the capabilities of startup companies for them to also contribute to the local content. As part of the National Transformation Program 2020, KACST plans to increase the number of technical startups emerging from incubators with 600 additional companies that will contribute to the provision of 3600 jobs. It also plans to increase the number of emerging technology companies from universities - through the Innovative Companies Program - to 800 companies that will contribute to the provision of 4000 jobs for Saudi youth. KACST is making a major effort to promote the technology incubators industry, in support of emerging technology startups, through its BADIR incubators and accelerators program. BADIR is a national program that attracts innovators, promotes the concept of entrepreneurship and provides support and care for innovators and entrepreneurs. This is to help them transform their ideas into promising technical projects.

BADIR Program for Technology Incubators and Accelerators

BADIR program was established in 2007 under the umbrella of KACST. It is a comprehensive national program that seeks to create and develop technology business incubators, encourage the concept of technology entrepreneurship and transform technical projects and research into promising commercial products. This is done by providing a suitable environment that eliminates some of the major risks associated with any startup and allows entrepreneurs to focus on the development of their plans, with the goal of creating a knowledge-based society and economy in the Kingdom.

BADIR program has become a destination for investors looking for promising investment opportunities, given its success in creating a rich technical environment that has allowed the incubated companies to share each other's know-how and benefit from each other.

BADIR program continues to witness many achievements which helped promote an innovative and creative environment in which startups can grow, and where the capabilities of Saudi entrepreneurs can be pushed forward with the goal of transforming their ideas into promising commercial products.

Goals

BADIR program aims to contribute to the growth of the Saudi economy and to meet the needs of the community in technology sector, by supporting entrepreneurship, innovation, business incubation and development of a suitable environment for the growth of emerging ventures.

Program Services

- Business plan development and enhancement of business models.
- Workshops to develop individual entrepreneurship and business management skills.
- Legal, administrative and human resource management consultation services.
- Marketing and market research skills development.
- Assistance in obtaining access to funding.
- Ongoing mentoring and coaching support for the development and growth of startups.
- Access to work space, laboratories, workshops and offices.

BADIR ICT Incubators

The BADIR ICT Incubator was established in 2008, with the goal of supporting and developing the information technology sector in the Kingdom of Saudi Arabia. It is the first incubator to setup under the BADIR program.

Fields of Operation

- Computing and communication devices.
- Infrastructure or information technology and communications.
- Software solutions.
- Multimedia.
- Smartphone applications.

Achievements this Year

- Incubation of 26 new startups.
- Held 20 workshops to develop entrepreneurs' skills.
- Enabling 7 incubated companies to be featured in GITEX 2016 DUBAI.
- Participated in 3 major events linked to the IT field, making it possible for incubated companies to showcase their products.
- Graduated 6 successful companies:
  - Morni: An online platform for roadside assistance services.
  - Foodics: A fully comprehensive cloud computing services for restaurant management.
  - Woqood: A website and smartphone application development company.
  - Sawwerly: An online platform that connects photographers with potential customers.
  - Saudi Matches: A real time information source on soccer matches in the Saudi league and European leagues.
  - Culture Catalysts: A broad spectrum initiative that utilizes its tools to encourage, promote and recognize creative culture and helps create people achieve their goals through direct support and mentorship.

BADIR Biotechnology Incubator

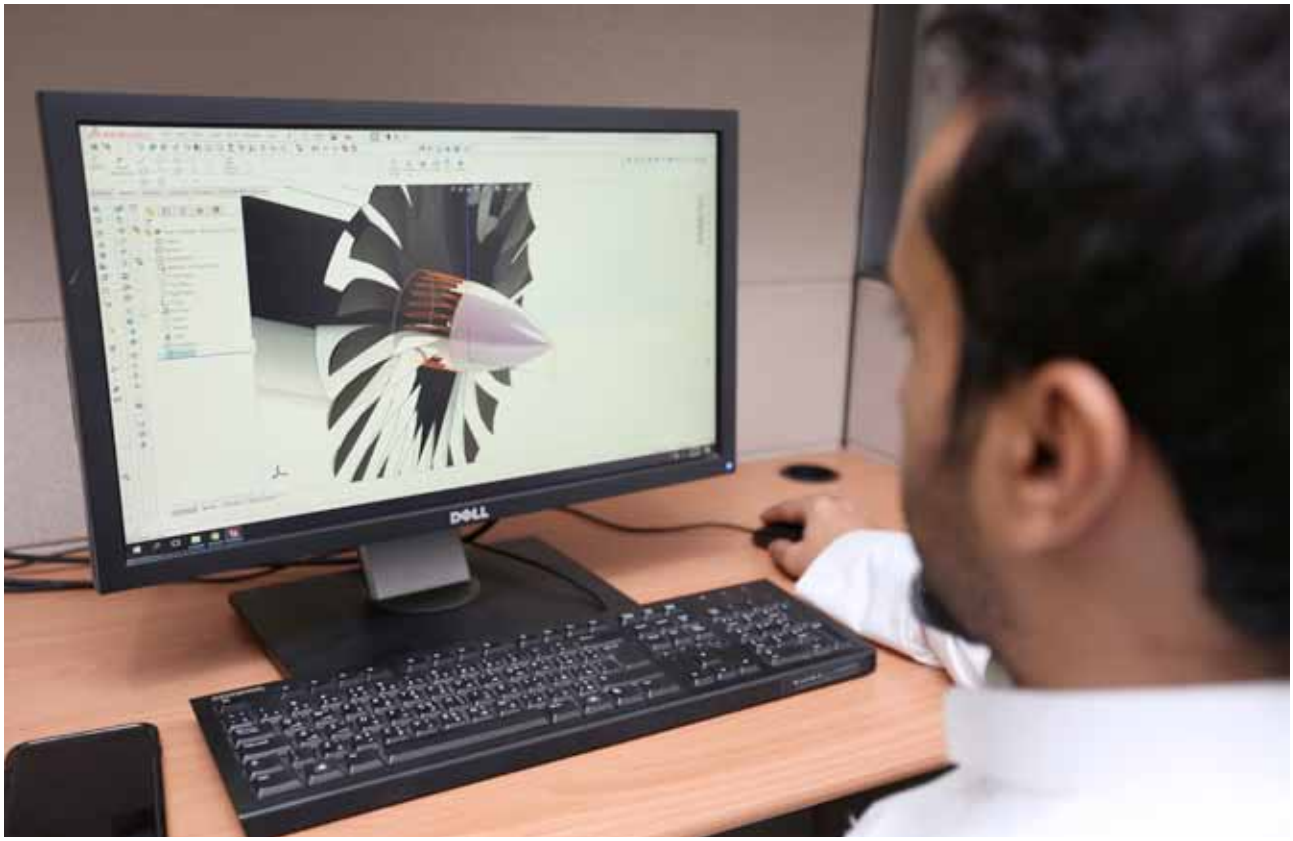
BADIR Biotechnology incubator was established in 2010 within the King Fahd Medical City complex in Riyadh. The incubator works to encourage and support the establishment and development of the biotechnology business sector, through assisting the commercialization of research projects as well as private sector biotechnology innovative products and services. Its aim is to create advanced medical services, support the localization and commercialization of biotechnology and contribute to the advancement of the health sector in the Kingdom.

Fields of Operation

- Health, medicine and pharmaceuticals.
- Environment.
- Agriculture.
- Biotechnology.

Achievements this Year

- Incubation of 7 new startups.
- Graduated 2 successful companies.
- Five companies currently incubated began to generate revenue.
- Provision of 150 new jobs from incubated companies.
- Participation in largest event catering to Biotechnology field in the Kingdom, in doing so allowing three incubated companies to be featured in the event.
- Signing MOU's with SFDA and the National Unified Procurement Company for Medical Supplies.
- Held seven workshops to develop entrepreneurs' skills.



BADIR Advanced Manufacturing Incubator

BADIR Advanced Manufacturing Incubator (AMI) was established in 2010 in Riyadh. It serves entrepreneurs and innovators in the field of engineering and advanced manufacturing, with the aim of achieving a renaissance in the advanced manufacturing industry of the Kingdom of Saudi Arabia.

Fields of Operation

- Innovation and development of advanced industrial equipment.
- Production of advanced industrial materials.
- Manufacture of new and innovative products.

Achievements this Year

- Incubation of 14 new startups.
- Held 2 workshops for the development of entrepreneurs' skills.
- Graduated one successful startup.
- Facilitated the participation of one incubated startup in GITEX 2016 DUBAI.
- Co-op training of 6 students in collaboration with the college of institute.

Inventors Services Office

The Inventors Services Office was created to provide support and consultations in the field of inventions and patenting to Saudi individuals. In addition, it has supported the development of the capabilities of inventors by organizing lectures, conferences, training courses and workshops in relevant subjects. The office has also covered financial costs associated with the patents of individual Saudi inventors which reached 2046 patents in the years 2015 and 2016.

The office has advised and corrected a total of 140 patent requests at the Saudi Patents Office by offering focused advice to patent registrants. It has also supported 6 inventions in the manufacturing and development phase, contributing to their transformation into commercial products through the "Transfer of Inventions to Market" accelerator which was launched in 2016.

Accelerators

BADIR's first accelerator was launched in 2016 with 7 companies in its first cohort. They were exposed to intensive workshops for 4 months. In addition to business development services and legal and marketing consultations, the cohort collectively received over one million Saudi riyals in seed funding. Other achievements related to the accelerator are:

- Signing of a memorandum of understanding with Abdullatif Jamil Company with the aim of setting up a new accelerator in projects relevant to the automobile industry.
- An MoU was signed with Oasis 500, the leading funding entity of entrepreneurs in the MENA region, with the aim of creating new and innovative technology startups.
- Two boot camps were held, to deliver intensive guidance and support on how startups can launch successfully. The program supported participants to devise the best business plans, models and strategies, build the right team and provided tips to help entrepreneurs succeed in transforming their innovative ideas into viable business opportunities. The boot camps received more than 400 male and female applicants, 100 of whom qualified to enter the boot camp program.

Saudi Business Incubators Network (SBIN)

BADIR established the Saudi Business Incubators Network (SBIN) in 2009 as a guiding body to help and encourage best practices in the Business Incubator Programs. SBIN's goal is to unify the efforts of developing the Saudi business incubator industry.

Angel Investors Network (SIRB)

BADIR established the Angel Investors Network (SIRB) to bridge funding gaps, and overcome the obstacles that hinder the transformation of research into technical business opportunities. SIRB has created a network of businessmen and angel investors interested in funding startups, which aims to support and fund entrepreneurs in the Kingdom of Saudi Arabia to further increase their chances of success.

BADIR Achievements

- Signing of a memorandum of understanding with the Abha Chamber of Commerce and Industry, with the goal of promoting the concept of entrepreneurship, developing an environment for innovation and technology, and supporting startups in the region via the establishment of BADIR Abha incubator in 2017.
- Signing of a memorandum of understanding with the Qassim Chamber of Commerce and Industry, with the goal of promoting the concept of entrepreneurship, developing an environment for innovation and technology and supporting startups in the region through the establishment of BADIR Qassim Incubator in 2017.
- Startup weekend Jazan was organized by BADIR in collaboration with Jazan University, Riyad Bank and Microsoft. The total number of applicants reached 755 young creative Saudi men and women, 53 of whom qualified to participate with their ideas and 15 of them were voted to compete in the final round, where "falloukah" an app designed by locals from Jazan, was the ultimate winner.
- Startup weekend Taif was organized by BADIR in collaboration with the Taif Chamber of Commerce and Industry, Taif university, Riyad Bank and Microsoft. The total number of applicants reached 505 young creative Saudi men and women, 62 of whom qualified to participate with their ideas and 15 of them were voted to compete in the final round, where "Wahidoon" was the ultimate winner. The 15 finalists were incubated at BADIR.
- BADIR program took part in GITEX Dubai 2016, allowing 7 of its incubated companies to feature their products: Morni, Foodics, Controllex, Noga, Zeez, eSIGN and Creative Arts. In Dubai, these companies were also able to sign deals with new customers and suppliers ultimately expanding their businesses.
- Seven companies incubated at BADIR were featured in the Forbes top fifty startups in the Kingdom of Saudi Arabia for the year 2016.

Future Aspirations

- Jazan University Incubator: In December 2015, during the second forum for innovation and entrepreneurship which was organized by Jazan University, a memorandum of understanding was signed between BADIR and the University aimed at cooperation in the areas of the establishment of incubators and fostering a culture of technical entrepreneurship.
- MODON Industrial Incubators: A memorandum of understanding was signed with the Saudi Industrial Property Authority, aiming to provide a framework within which the two sides can cooperate to work on establishing industrial business incubators. Planning was concluded to establish an industrial incubator in Dammam.
- Expansion: BADIR plans to increase its presence from three cities in the Kingdom to nine cities. Work is currently underway to open new incubators in Abha, Buraidah, and Dammam, as part of its first phase of expansion.
- BADIR entrepreneurship HUB: BADIR program is currently working on opening its new entrepreneurship hub which will feature low cost workspaces for startups that aren't incubated at BADIR, as well as space reserved for community events such as workshops and lectures, with the aim that this space can be a place where entrepreneurs and innovators can work together and unleash their potential.
- Mentorship Program: The mentorship program at BADIR launched in 2016 in cooperation with successful entrepreneurs who wish to give some of their time to mentor incubated company owners.
- Space Industry Incubator: A new incubator, specializing in assisting clients develop space technologies for earth-based commercial applications, will be established in cooperation with the European Space Agency.

4.3 | Industrial & Technical Development Support

- Technology Development
- Industrial and Technical Consultations
- Small and Medium Enterprises (SME) Support

Innovation Support

Industrial and Technical Development Support

KACST aims to support innovation and industry in order to enhance and develop technology; thus it has established a Technology Development Center which contributes to the localization of technology and the establishment of technical projects in the Kingdom of Saudi Arabia.

Introduction

KACST aims to boost technical and industrial innovation by providing support services throughout the lifecycle of KACST's projects. It helps determine technologies, products and patents with potential commercial value and implements strategies for further development and marketing through interaction with the private sector. The following are some of the important services provided by the Technology Development Center:

- Developing market feasibility study for each project.
- Finding opportunities for filing patents on KACST's research.
- Estimating technology maturity by assessing technology readiness levels (TRL).
- Identifying market opportunities for KACST's projects, patents and products.
- Developing marketing strategies for KACST's patents and products by supporting companies and licensing.

Technology Development

The Technology Development Center at KACST seeks to provide support services throughout the lifecycle of KACST's projects. These support services begin prior to the approval of any project submitted by researchers in KACST, through a feasibility study of the project, which focuses on the possibility of the project's success and marketability after completion.

The center also provides a service to identify and study researchers' patents. This stage is considered very important to determine the scientific outputs that can be registered as patents in order to utilize them by making a patent license or establishing startups from KACST.

One of the most important services offered is the study of TRL for KACST's projects to determine the level reached by the outputs of KACST's projects in order to know whether the project has reached an appropriate stage to commercialize its outcomes.

The center also examines the market, in order to determine the optimal way of commercializing either through patent licensing, or by establishing startups.

In addition, it connects KACST's researchers and research institutes with private sector institutions in order to transform innovative research from KACST's labs into successful and marketable products.

This process is carried out by a team of professionals in the center, with experience in science and business sectors.

There are many findings in KACST's laboratories, so once a potential patent application has been identified, a team from the center meets with the researcher to review the patent and disclose all possible applications for intellectual property protection. The team then communicates with industry partners to identify the appropriate areas in which the patent may be of great value. The end result is either patent licensing or the establishment of startups through which the research outcomes of the researcher will be commercialized, where all start-ups from KACST are in cooperation with TAQNIYA.

Industrial and Technical Consultation

In line with Saudi Arabia's Vision 2030, to be a platform and a roadmap for economic and development work in the Kingdom, KACST has adopted the Industrial and Technical Consultations Initiative, in accordance with the technical consultations in many different fields (e.g., energy, water, health, etc.) that KACST is covering. The aim is to expand the capacity of the national economy and enhance its growth, stability and competitiveness, at a much lower cost than the foreign alternative. The value of technical consultations services on average for governmental and semi-governmental entities is around 500 million riyals a year.

Initiative Objectives

This initiative aims to utilize Saudi competencies and the technical capabilities in KACST, by providing industrial and technical consultation services in various fields including energy, water, and health. KACST aims to localize technical consultation in Saudi Arabia with this idea.

The initiative was adopted by KACST because it has all the key factors of success such as accumulated technical expertise, technical infrastructure, human capabilities in technical and scientific fields, and equipment and laboratories. Accordingly, this initiative will target governmental and non-governmental entities by providing a range of technical services in return for money. It is based on a Pull System which is based on market requirements and actual need rather than the payment system based on possibility.

Initiative Services

Laboratory services include product testing, analysis and prototyping. The technical consultation services include the use of the civil force to conduct consultations and expertise in more than 12 sectors.

Initiative Success Motivators

- Lack of local content in technical consultations.
- Lack of local technical consultations in the local market.
- Non-utilization of KACST's resources in research and development.

Boosting Small and Medium-Sized Enterprises (SMEs)

The SMEs Support Initiative aims to provide a range of technical services starting from full technical upgrading of small and medium factories, in order to improve their level, qualify them to contribute to local content, and develop the quality and quantity of their products. This initiative will provide specific support services to SMEs via the following:

- The main center will provide an integrated framework and central point of support services for industrial SMEs throughout the Kingdom, as well as developing an integrated platform for SMEs services and marketing. It will also provide guidance on partnerships with interested parties to better serve industrial SMEs, as will direct industrial SMEs to appropriate stakeholders based on their needs. The main center will be a central repository of all matters related to these companies.
- Support industrial and technical training in all its stages through, technical survey, technical training opportunities identification and evaluation, project status assessment, financing, vendor selection, pre-operation installation and testing support services, and follow-up.
- Operational consulting services, through, Operational Performance Management, Compliance with best industrial practices (work flowcharts, work instructions, good manufacturing practices, etc.), optimization of supply chain, industrial design, inventory management, environmental compliance, and operational costs .
- Supporting SMEs in the areas of regulation and policy, discussing and reviewing SMEs policies at national meetings, developing technology and product policies, identifying SME needs and influencing others to take appropriate action, advocacy on behalf of SMEs, developing specific policies for SMEs, and writing SMEs policy.

Commercialization

5 | Commercialization of R&D Outputs

- Commercializing Technical Projects based on Demand
- Commercializing Technical Projects based on Supply

Commercialization of R&D Outputs

An agreement between KACST and TAQNIA has been signed to market, sell, and commercialize the products, services, assets, and intellectual properties (IPs) owned by KACST.

Introduction

The Kingdom of Saudi Arabia's economy is growing steadily, even during a period of global economic recession. Nevertheless, this growth has largely been based on oil and gas exports, a sector that has generated more than half of the Kingdom's GDP.

To diversify its economy away from oil-based dependence to a knowledge-based economy, the Kingdom has been driving a significant number of initiatives and investments in different areas directed to broaden its market, provide its youth with the necessary education and develop new sector growth. An assessment of the overall innovation value chain shows that the capabilities in the initial stages of this value chain are becoming more mature, while further downstream, commercialization and venture development, are the areas that show relevant gaps. There is a need to fill the gap in R&D commercialization and, primarily, in the venture development area.

TAQNIA commercializes R&D outputs from Saudi Arabia's research centers and universities. The Kingdom has been investing heavily in the initial stages of the innovation ecosystem or value chain. However, the development of new large companies or new technology intensive sectors was limited. TAQNIA provides a range of services to the Saudi Innovation Ecosystem on a for-profit, contractual basis. Today TAQNIA includes a number of subsidiaries that not only provide services to R&D directly but also have been established to transfer technology by creating joint ventures with global leaders within TAQNIA's six main focus sectors.

مدينة الملك عبدالعزيز
للعلوم والتقنية KACST

TAQNIA

Saudi Technology Development and Investment Company (TAQNIA)

The Saudi Technology Development and Investment Company (TAQNIA) was established in 2011 through a royal decree with a mandate to drive the accelerated diversification of Saudi Arabia's economy through knowledge-based industries, thereby creating value-adding jobs, and contributing to the development of the innovative ecosystem in Saudi Arabia.

TAQNIA creates value from technology through investments, partnerships, and commercialization to accelerate the diversification of the Saudi economy and to help create an innovative ecosystem in Saudi Arabia. TAQNIA will achieve its vision by investing in local and global technologies and actively engaging in their development and growth into economically sustainable organizations. To that end, TAQNIA has set three main objectives to achieve its potential economic effects:

- Transfer strategic technologies to the Kingdom.
- Create a balanced growth portfolio of investments.
- Develop Saudi talent to global standards.

In light of the Saudi Vision 2030 announced in 2016, TAQNIA has aligned its objectives to ensure its role in contributing to the national direction. These objectives have then been cascaded down to the department level and across TAQNIA's subsidiaries to create operational objectives that TAQNIA aims to achieve by 2020.

TAQNIA identified 6 industries to focus all its activities on. These are areas in which the Kingdom can achieve global leadership thanks to its natural resources; and areas of natural security in which it is important for the Kingdom to achieve self-reliance.

Naturally, technologies of special focus are those affecting critical sectors for Saudi Arabia that are characterized by large parts of national investment such as:

- Life and Health Sciences.
- Security & Defense Technologies.
- ICT.

That is seen as an essential sector to enable competitiveness and growth. Self-reliance in these sectors is a national objective. The other technologies of special interest are those where the Kingdom has a competitive advantage such as:

- Material Science.
- Energy & Environment.
- Water Technology.

In order to accelerate the process by which it achieves its mission, vision, and objectives, TAQNIA employed three tracks:

- TAQNIA Industries.
- TAQNIA Investments.
- TAQNIA Services.

TAQNIA's efforts will be coordinated to maximize synergies to pursue priorities and value added development. The three entities of TAQNIA play essential roles in the transformation of the R&D stream. TAQNIA Industries identify, select, and help develop the suitable candidates. TAQNIA Investments undertake two types of investment support, international and local, intended to transfer technologies to the Kingdom or support early stage start-ups. TAQNIA Services provide the full range of support services the start-up might need such as those required for business development, operations and marketing.

The Kingdom's strategic technologies are the primary focus of TAQNIA's development and investment mandate. TAQNIA's three main entities provide the full needs of commercialization of the selected technologies. TAQNIA is coordinated to maximize synergies as they seek to support the needs of the selected new enterprise as it makes the transition from R&D to a viable sustainable, economic entity.

TAQNIA's Relationship with KACST

Considering the ambitious new sector development objectives of the Kingdom of Saudi Arabia and the relative immaturity in certain stages of the R&D value chain, there is a critical need for a company like TAQNIA to play a constructive role. As technology commercialization activities are gradually being deployed by institutions like KACST, the focus for TAQNIA is to ensure the availability of services, technology assets, and investment for new ventures to develop. TAQNIA's initial role is to ensure that high potential initiatives in new R&D intensive sectors have the necessary enablers, mainly financing, to become sustainable companies. Overall effort must be focused on a limited number of sectors in which the Kingdom has relevant competencies or assets and selection of these priority sectors must be done with two objectives; either increasing country's self-sustainability or developing a competitive global player or a globally competitive hub. TAQNIA's structure must be built around the number of selected priority sectors, including a solid governance model and have concrete development objectives, to ensure investment effectiveness and provide necessary comfort to investors.

TAQNIA focuses on the more complex and financially demanding projects. TAQNIA also focuses on areas where the private sector is likely to be less motivated or hindered. Such areas include strategic technologies ventures with low financial attractiveness or a high degree of complexity. Collaboration with the private sector is expected on a variety of ventures.

Ever since its inception, TAQNIA has been adamant to always align with KACST. TAQNIA's collaboration with KACST can be classified as two types. The first type focuses on innovation or technology that has been developed or 'Pushed' by R&D centers to the market, whereas the other focuses on innovation or technology that has demand existing in the market and as such require it to be developed or 'Pulled' from R&D centers.

‘Push’ Based Projects

AN-132: The first joint Saudi Ukrainian Aircraft

TAQNIA will develop a manufacturing facility to produce the aircraft in Saudi Arabia which will serve local, regional, and international demand by taking advantage of the agreement between ANTONOV and KACST who have embarked on a journey to jointly develop, design, and upgrade one of ANTONOV’s existing aircrafts (AN-32) to its latest version: the light transport aircraft AN-132. The agreement between ANTONOV and KACST has regulated the Rights to the Intellectual Property (IP) of AN-132 as it will be equally co-owned by the two parties. This project directly delivers on the Saudi Vision 2030 objective of “localizing over 50% of military spending” as the AN-132 is planned to create a manufacturing and assembly facility in Saudi Arabia to produce the aircrafts with the aim of transferring the technology and localizing the part of related aeronautic industry. This partnership aims to transfer aircraft manufacturing know-how, develop Saudi talent, qualify local suppliers, and increase Saudi exports and the non-oil GDP for the Kingdom.

Layla IPP & PV Assembly Line: First Independent Power Plant in KSA with a Capacity of 50 MW

Another example of a technology push is that of the Water and Energy Research Institute at KACST. Their role, as a technology provider, is to establish a solar power plant in Al-Aflaj province that provides a clean, safe, and sustainable source of energy. The initiative is projected to save over 4 million barrels of high cost diesel fuel, and limit CO_2 emissions by 1.7 million tons. The Saudi Electricity Company has agreed to purchase all the power generated at a rate of 18.75 halalas per kWh. TAQNIA Energy’s role is to design, build, operate and maintain the solar plant in collaboration with the Saudi Electricity Company. This project aims to provide alternative and clean sources of energy that would ensure providing fuel for the best interest of the Kingdom’s economy and help build a future with sustainable energy. Furthermore, the project will contribute to the local content and increase knowledge-base and job creation.

GIS: Geospatial Services and Remote Sensing Technology

The Geospatial Services and Remote Sensing Technology was developed at the National Center for Remote Sensing Technologies under the Space and Aeronautics Research Institute at KACST. Applications include high accuracy targeting capabilities for defense purposes, resource mapping for agricultural use as well as for avoiding damaging flood flows before and after, for the benefit of municipal agencies. These diverse uses have allowed TAQNIA Services the opportunity to market these unique technologies to fill a need and support the Kingdom's initiatives wherever or whatever they may be; from environmental and rural affairs, to applications related to security and defense. The most relevant clients include:

- Ministry of Defense.
- Ministry of Interior (General Administration for Regional Affairs.)
- Ministry of Environment, Water and Agriculture.
- Ministry of Municipal and Rural Affairs.

AD: Saline Water Desalination and Cooling Station with Adsorption Technology

The Minister of Energy, Industry and Mineral Resources, along with the Chairman of KACST and the Governor of the Saline Water Conversion Corporation (SWCC), commissioned the Water Desalination and Cooling Pilot Unit with the Adsorption Desalination (AD) Technology. The pilot unit is the result of a collaboration among the Water and Energy Research Institute at KACST, King Abdullah University of Science and Technology (KAUST), TAQNIA's Advanced Water Technology (AWT) and the Singaporean Company, Medad Technologies. This project is considered the first applied and industrialized model utilizing the innovative technology of combining multi-effect distillation (MED) with Adsorption Technology (AD) in the world, with a production capacity of 100 m3/day. More importantly, AWT as well as KACST and Medad Technologies maintain exclusive rights in terms of marketing the technology internationally especially since many countries have shown interest in the technology and its implementation.

‘Pull’ Based Projects

SADEC: Saudi Arabian Defense Electronics Company

Saudi Arabia is one of the leading countries in terms of defense budget size, yet much of that budget is spent abroad. To support the localization efforts of the defense sector, in September 2013, Turkey and Saudi Arabia ratified an agreement to increase defense industry co-operation by improving industry capabilities for both countries. From this agreement, a joint venture between the Turkish Armed Forces Foundation (Aselsan) and TAQNIA Defense and Security Technologies (DST) was established during December 2016. TAQNIA Defense and Security Technologies will build a local facility to design, develop, test, manufacture, and sell electronic warfare, radars, and electro-optic systems for military and civil applications. Saudi Arabian Defense Electronics Company (SADEC) will operate the facility and will participate in training the 1,000 Saudi engineers and technicians this facility is expected to create. TAQNIA will leverage the Communication and Information Technology Research Institute at KACST to ensure the success of this partnership.

IXP: Saudi Internet Exchange Point

The Ministry of Communications and Information Technology has selected TAQNIA Cyber to implement and operate the Saudi Internet Exchange Point. The National Internet Exchange (IXP) is a physical infrastructure that interconnects Data Services Providers (DSP) in the country.

One of the many benefits provided by the IXP is to potentially avoid the need for data to travel to other cities and most likely other continents (to travel from one network to another) and by doing so reducing interconnection and bandwidth costs. Moreover, it will enable higher rates of data exchange (Broadband) as well as enhance quality and experience for internet users. Most importantly, it ensures the switching of all national internet traffic nationally which improves network and data security. To serve the market demand, TAQNIA Cyber will leverage the capabilities available at KACST’s Communication and Information Technology Research Institute to ensure the successful implementation of this project in Saudi Arabia.

Aero: Connectivity Services

TAQNIA Space has decided to tackle the issue of passengers being disconnected from the internet during their flights through establishing a reliable platform to enable e-mail, social networking, and live streaming at 36,000 feet for passengers connected to the TAQNIA Space Company Aero Platform. In partnership with Saudi Arabian Airlines, TAQNIA Space will begin outfitting SAUDIA'S planes in 2017 and scale it to the entire fleet until it covers both domestic and long haul flights. To ensure this project's seamless success, TAQNIA Space will leverage experts from the Communication and Information Technology Research Institute as well as the Space and Aeronautics Research Institute at KACST. Utilizing their Aero Platform, TAQNIA Space will be providing the proper bandwidth to seamlessly support Live TV, on-board voice/GSM, and broadband internet connectivity to connect passengers throughout their flights on the SAUDIA fleet. TAQNIA Space is currently discussing the potential collaboration to provide this service to other world class airlines.

Helicopter Production in the Kingdom of Saudi Arabia

In February 2016, Sikorsky, a Lockheed Martin Company, signed an agreement to establish a joint venture with TAQNIA Aeronautics that will jointly explore helicopter production opportunities in Saudi Arabia. This agreement outlines the investment required, technology specification, and skills needed to establish a multi mission utility/attack helicopter final assembly line to produce Sikorsky S-70 BLACK HAWK helicopters in Saudi Arabia. Establishing the assembly line will provide high-skilled production jobs for Saudi citizens, enable technology transfer, and increase localization of the defense sector expenditure. TAQNIA will leverage its relationship with the Space and Aeronautics Research Institute at KACST to ensure the success of this partnership, as previously done with the ANTONOV Project (AN-132), which has worked well. TAQNIA Aeronautics will market the Black Hawk aircraft to members of the Islamic Alliance as well as other local companies such as Saudi ARAMCO.

King Abdulaziz City For Science & Technology (KACST)...

مدينة الملك عبدالعزيز
للعلوم والتقنية KACST

King Abdulaziz City for Science and Technology (KACST) conducts applied scientific research, in order to serve the development of the Kingdom of Saudi Arabia, and provides scientific counsel at the national level. It has a major role in planning for science and technology in the Kingdom. It participates in the preparation of the National Plans of Science, Technology and Innovation, sets forth the required strategies for execution, and provides support to programs and projects related to scientific research. KACST also aims to develop national competencies and to recruit highly qualified specialists to help develop and control modern technology in order to serve the development of the Kingdom. Furthermore, it provides specialized scientific information services, scientific publications and the registration of patents. KACST aims to coordinate with government entities, scientific institutions and research centers in the Kingdom in applied scientific research and in the exchange of information and experiences. In addition, it develops partnerships through technological and scientific cooperation between the Kingdom and international scientific institutions.

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