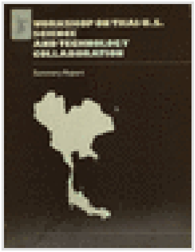

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WORKSHOP ON THAI-U.S. SCIENCE AND TECHNOLOGY COLLABORATION

Summary Report

Bangkok, Thailand
June 4-9, 1984

Jointly sponsored by

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and

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This report has been reviewed by a group other than the authors according to the procedures approved by a Report Review Committee consisting of members of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

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This summary report has been prepared by the Board on Science and Technology for International Development, Office of International Affairs, National Research Council, for the Mission to Thailand, U.S. Agency for International Development, under an amendment to Grant No. DAN-5538-G-00-1023-00.

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PREFACE

The continuing economic growth of Thailand is leading to increasing demands on science and technology. Future development will depend heavily on the ability of Thailand to use science and technology effectively, to eliminate constraints to development, and to make the best use of its natural resources. These tasks call for steps to strengthen the science and technology framework within the country and focus it on resolving specific problems, broaden the scope of human activities, raise the quality of Thailand's human resources, strengthen existing institutions, and link the public and private sectors.

Thailand can no longer afford to ignore the potential for using science and technology for national development. The Fifth Development Plan formally recognized this potential, and made the following relevant points:

- Science and technology to increase production or processing efficiency and develop new areas are still limited.
- The modifications of or improvements in imported technologies or technology developments are slow.
- The Thailand Institute of Scientific and Technological Research (TISTR) must be reorganized and strengthened. Its quality control capability must be sharply enhanced.
- An Energy Conservation Center should be created.
- An efficient Institute of Materials Science and Metallurgical Engineering should be established, and mineral handling technologies should be developed or expanded.
- Local engineering services should be improved.
- Science and technology information systems should be recast.
- Scientific and technological cooperation should be promoted with foreign countries.

- o The general public should be made aware of the importance of science and technology.

To fulfill these goals, however, a specific strategy is needed to (1) direct scientific and technological talents toward the elimination of constraints hindering development, (2) encourage science and technology-based businesses, and (3) raise the awareness and understanding of the Thai people.

The need for such a strategy is particularly vital at this point because Thailand is in a transitional period where it must choose between industrial progress and stagnation. In this regard, employment levels must be raised, incomes increased, and industrial production strengthened for the export market through development and quality control. Thailand's current political environment--internal as well as external--is favorable to the application of science and technology. This is reflected in the establishment of the Ministry of Science, Technology, and Energy (MOSTE), as well as in the inclusion of science and technology as a factor in the Fifth Development Plan, and the anticipated expansion of the role of science and technology in the next development plan.

PURPOSE AND ORGANIZATION OF THE WORKSHOP

Looking toward this anticipated expansion, and realizing the need to intensify the collaboration among the Thai-U.S. scientific and official communities, the Thai government asked the U.S. government to join with it in a bilateral science agreement, which was signed in Washington, D.C. on April 13, 1984, during the official visit of Prime Minister Prem Tinsulanonda. One of the major purposes of the Thai-U.S. science and technology program called for under the agreement is to maximize the contributions science and technology can make to the development of a broad-based economy in Thailand.

As a first step, and at the request of the U.S. Agency for International Development (USAID), a workshop was organized by Thailand's Ministry of Science, Technology, and Energy and the U.S. National Research Council (NRC) to provide input to the development of a "Strategy for the U.S.-Thai Program in Science and Technology for Development." The report of this workshop, held June 4-9, 1984 in Bangkok, follows (see Appendices A and B for the workshop agenda and list of participants, respectively).

At the opening plenary session, participants were welcomed to Thailand by His Excellency Damrong Lathapipat, Minister of Science, Technology, and Energy, and Mr. Robert Halligan, Director of the USAID Mission to Thailand (see Appendix C). Minister Damrong told workshop participants that it is now time for Thailand to reconsider its development efforts and incorporate science and technology into a meaningful role in the country's development. These statements were reemphasized in remarks made by Dr. Snoh Unakul, Secretary-General of the Office of the National Economic and Social Development Board (see Appendix C).

After The Honorable John Gunther Dean, U.S. Ambassador to Thailand, addressed the audience on the historical importance of Thai-U.S. relations and comments made by Permanent Secretary Sanga Sabhasri on the relationship between the Thai-U.S. scientific communities, (Appendix C), Ernest J. Briskey, Science and Technology Advisor to the U.S. Ambassador and Director of USAID's Office of Science and Technology in Thailand, presented a possible conceptual framework for Thai-U.S. cooperation in science and technology (see Appendix D). This framework, derived from numerous conferences, studies, and discussions with Thai leaders in science and technology from universities, government, and industry was presented as a draft.

An analysis revealed three areas for emphasis: (1) Bioscience and biotechnology; (2) Metallurgy and materials technology and; (3) Applied computer and electronic technologies. Subsequently, participants were divided into three groups corresponding to these areas, and were asked to provide input for a coherent, concise strategy document. They were also asked to focus specifically on the following components in their working group discussions and during their visits to the various universities and industries:

- Research and development
- Quality control
- Human resource development
- Strengthening support activities.

In this connection, at the plenary session Thai participants in the discussions summarized a number of papers commissioned by USAID to serve as background information for workshop participants (see Appendix E for a list of these papers).

On the second day of the workshop, participants visited TISTR and some of the major universities in the Bangkok area where research and training applicable to these three areas are in progress. On the third day, they visited several industries and were received at Government House by Prime Minister Prem. On the last day of the joint meetings, participants met in small working group sessions to review general observations and conclusions in each specific area. Subsequently, a plenary session open to a large number of senior individuals from government, academia, and the private sector was convened.

Following the workshop, U.S. panelists met with Ambassador Dean to brief him on the findings of the workshop. A meeting with Minister Damrong and other Thai officials on the findings and recommendations of the groups was also held.

Detailed recommendations and conclusions are contained in the individual sector reports that follow. Additional comments and observations regarding the role of scientific infrastructure and its needs are included in the final chapter of this report. It should be noted that these are only suggested guidelines for consideration of the Ministry and U.S. Agency for International Development.

This represents a continuation of the U.S. National Research Council's involvement with the scientific community of Thailand. In 1970, the NRC participated in a Seminar on Protein Food Promotion in

Thailand. This was followed by a Workshop on Science Policy and Planning in Thailand in 1972 in cooperation with the National Research Council in Thailand. Since that time, several visits were made to Thailand by NRC representatives and staff, as well as visits to the U.S. by members of the Thai scientific community.

This workshop report was prepared by Michael Dow and Rose Bannigan of the Board on Science and Technology for International Development (BOSTID) staff, using papers written by Thai and U.S. participants. The reports have been edited to eliminate duplication, but they accurately reflect the discussions and early preparations. The final draft was reviewed and approved by the U.S. participants and the Thai steering committee. F. R. Ruskin and Sabra Bissette Ledent edited the report.

ACKNOWLEDGMENTS

These panel discussions were organized and sponsored by the Thai Ministry of Science, Technology, and Energy and the U.S. National Research Council.

The participants wish to acknowledge the generous support of the U.S. Embassy and U.S. Agency for International Development Mission, Thailand, and express their appreciation to The Honorable John Gunther Dean, U.S. Ambassador to Thailand, for his encouragement and support. U.S. and Thai panelists also wish to thank Mr. Robert Halligan, Director of the U.S. Agency for International Development (USAID) Mission to Bangkok, for the outstanding leadership he provided to the panel. They would particularly like to thank Dr. Ernest J. Briskey, Science and Technology Advisor to the U.S. Ambassador and Director of USAID's Office of Science and Technology in Thailand, and his colleagues--Dr. Jaroon Kumnuanta, Scientific Affairs Specialist; Mr. Willy Baum, Project Development Officer; and Mrs. Wannee Vardhanabhuti, Secretary--for their valuable assistance. They also recognize the valuable contribution of the members of the Thailand Science and Technology Program Advisory Council (TSTPAC) and other Thai leaders in science and technology in preparing the background documentation.

The panelists also wish to acknowledge the contribution of His Excellency Damrong Lathapipat, Minister of Science, Technology, and Energy, and his staff, and particularly Dr. Sanga Sabhasri, Permanent Secretary, who handled all arrangements for the plenary sessions of the workshop.

Message to the Scientific Community of Thailand on the Occasion of the Workshop on Thai-U.S. Science and Technology Collaboration

As you begin your consideration of the impact that science and technology can have on the future of Thailand, this message to you demonstrates one of the uses of technology for direct communication.* Your government's decision to strengthen the capacity of Thailand's scientific and technological agencies and to use these capacities to contribute to the solution of national development problems shows a wide vision of the possibilities.

The willingness of the U.S. panel members to offer their expertise in the vital areas of biotechnology and food technology, mining and metallurgy, computer sciences, and science policy emphasizes the collegial nature of the scientific and technical communities around the world. Your meetings and deliberations over the next week, under the able chairmenship of Dr. Sanga Sabhasri and Dr. Franklin A. Long, will create a climate of cooperation, and the free exchange of information will help to strengthen the ties between the scientific communities of our two countries. We all know the value of personal interaction from our own experience. I valued the opportunity to discuss science and technology in Thailand's development when Minister Damrong Lathapipat and his colleagues from the scientific and official communities visited the National Academy of Sciences in April 1984, and am especially pleased that more of you are now able to share your expertise in a joint project of such great importance.

Walter A. Rosenblith
Foreign Secretary
National Academy of Sciences
Washington, D.C.

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*This message was transmitted from Washington, D.C. to Bangkok via a teleconferencing device.

SUMMARY OF DISCUSSIONS AND RECOMMENDATIONS

Workshop participants concurred in and adopted the elements of the conceptual framework for the science and technology program, presented in draft form by Dr. Briskey, as the basis for their report. This framework is based on extensive input from Thai science and technology leaders in the private sector, universities, and government. The conclusions and recommendations of the U.S. participants represent additions or embellishments to this conceptual framework.

BIOSCIENCE AND BIOTECHNOLOGY

Bioscience and biotechnology will have an important impact on Thai industry in the areas of agriculture, health care and pharmaceuticals, chemicals, and biomass conversion. This working group was divided into two subgroups: (1) the agriculture and agro-industry sector, and (2) the biomedical sector. The biotechnologies relevant to these sectors include tissue culture, clonal propagation, somaclonal genetic variation, protoplast fusion technology, recombinant DNA and embryo transplant, and genetic manipulation.

Agriculture and Agro-industry Sector

o The National Center for Genetic Engineering and Biotechnology (NCGEB), created by the Ministry of Science, Technology, and Energy, should be made operational and provided with a core staff. Procedures must be established for connecting this center with other bodies responsible for strategic planning of both short- and long-term goals. Internal procedures are needed for project implementation and evaluation management. As a first step, the task force sponsored by the U.S. Agency for International Development (USAID), which will visit Thailand in late July to work with the Thais on organization, project design, and program for the NCGEB, could include one member who will address these problems.

o The Center should concentrate at least initially, on a limited number of clearly defined priority areas, selected (with suitable socioeconomic input) to maximize national impact. These areas should be identified by the Thai government as of priority importance. Examples might include finding alternative uses of cassava or sugarcane, solving the aflatoxin problem in corn and peanuts, eliminating a serious fish viral disease problem, and increasing milk yields. It is suggested that one program could be in the renewable resource area, one in the health area (considered separately under the biomedical sector), and one in the food and agriculture-related area. The final selection of priorities, however, must rest with Thai officials.

o A competitive grants program should be established for five years in the areas chosen above. This program would be open to individual researchers in both university and government laboratories, and proposals would undergo peer review--possibly by a team of U.S. and Thai scientists (modeled on the U.S. Department of Agriculture's system). This program would be above and beyond designated funds for coordinated research efforts in these areas.

o A one-time equipment program of $5 million should be arranged to give block grants to universities having biotechnology programs or "pockets of excellence" in the biotechnology area. While equipment supplies are generally adequate, additional instruments for research purposes and equipment for teaching laboratory courses are needed to update capabilities in the quickly changing biotechnology field.

o Several areas of basic research important to Thailand require strengthening. These include:

- -- Tissue culture clonal propagation techniques
- -- Protoplast fusion technology
- -- Recombinant DNA technology
- -- Embryo transplant techniques
- -- Plant pest and disease control and research methodology
- -- Fish and animal viral disease methodologies
- -- Biotechnological process and bioengineering implementation.

The above areas were identified as current needs, but others may be identified in the course of developing the program.

o The Center should accelerate the process of curriculum development, particularly in the important field of bioengineering. Part of the proposed symposium on biotechnology cosponsored by the Center and the U.S. National Research Council to be held in Thailand in early 1985 should focus on this area.

o Selected Thai scientists should be provided financial support to attend major biotechnology symposia and, en route, to visit U.S. biotechnology centers in universities, research institutes, or private industries.

Biomedical Sector

o Comprehensive planning for a national vaccine development program for Thailand is recommended. Vaccine development goals are expressed as a component of the basic immunizations of children and women within the context of primary health care. National immunization programs concentrate on delivering the basic World Health Organization (WHO) program to which measles and polio are being added. Because of the high disease rates in Thailand, rabies is the only vaccine that has been added to this rudimentary list as a national policy. Although the Government Pharmaceutical Organization (GPO) manufactures most of the basic childhood vaccines used in the routine national immunization programs, these and post exposure rabies vaccines are the only ones produced locally. Basic bioscience research should be supported to lay the groundwork for in-country vaccine production for dengue, malaria, respiratory diseases, and Japanese encephalitis.

o Support should be provided for the development of vaccine and immunodiagnostic production, primarily within Mahidol University's Center for Vaccine Development and at the Pasteur Institute.

o An effort should be made to facilitate collaboration with private firms or to expand, modify, and put the GPO on a profitable basis supplying vaccines both domestically and regionally. The vaccine development center at the Salaya campus of Mahidol University will be a major resource. At this time there are no specific offers from biological products industries to locate in the "industrial park" area of the campus, thus serious attempts should be made to help the university market this concept within the private sector. In other words, the private sector firms or the GPO must be sold on the opportunities to have the commercial sector provide the engine to drive the application of science and technology to development problems.

o Incentives should be provided to bring professionals into research. These could include:

- -- Scientific development awards for new investigators.
- -- A competitive career development award to support young investigators full time in research for a five-year period. Such an award would provide both the prestige to the sector and adequate funds to launch research careers.
- -- A competitive research grants program to permit the same focus on biomedical research, supplementing designated research funds.

o A training program should be initiated to improve facilities at the Department of Medical Sciences, Ministry of Public Health (MOPH), and thereby assure adequate quality control of any future vaccine and biologicals production. Development of quality control procedures are important when establishing a vaccine or biological product industry. Thus concurrent development of this important ancillary service must be considered in the plan to promote a vaccine development industry.

o A biological resource center will be an important component of a vaccine research and production industry in Thailand. At this time there is excellent collaboration among Thai scientists and between Thais and their foreign colleagues in the exchange of research reagents. However, requirements for large volumes of biologic standards for vaccine potency, etc., will outstrip the ability of individual scientists to supply them.

o While the quality of the training and the trained human resources in this biomedical area are high, certain training needs exist:

-- Technical persons who are trained in production issues.
-- Upgrading the staff to cope with future significant increases in the number or types of biologicals for quality control. This upgrading should be carried out not by formal training but by short-term professional training in a specialized technique that will be required for a particular biological product.
-- Computer expertise in molecular genetics to bolster capabilities in sequencing studies.

o Ongoing consultation should be provided in specific areas of vaccine development such as computerization, recombinant DNA technology, production, marketing, and quality control.

o A Documentation Center for the Life Sciences should be established at Mahidol University, followed by computer linkages to appropriate data bases.

METALLURGY AND MATERIALS TECHNOLOGY

Although the contribution of the mineral industry and the associated materials industries to the gross national product is relatively small, it is expected to increase substantially as the country makes the planned transition from an agricultural to an agricultural-industrial economy. The following major steps should be taken to prepare the country for this transition.

o Upgrade teaching laboratories, research laboratories, and infrastructure facilities for improving the training and increasing the output of materials scientists, technologists, and engineers at the undergraduate and graduate levels. Current teaching laboratories are inadequate to provide the necessary training. Consequently, B.S. graduates in metallurgy, ceramics, and other fields of materials technology enter industry with insufficient "hands-on" training in the practice of scientific and engineering skills. Financial support should be provided to:

-- Upgrade teaching laboratories
-- Provide adequate research facilities
-- Improve the faculty's capability.

o To improve the faculty capability, support development through research, scholarly interactions, and collaboration. University faculty lack opportunities to achieve their full research and scholarly potential because of inadequate resources. This could be assisted by

-- Support for research projects
-- Supplemental support for sabbatical research at leading universities abroad
-- Travel grants to major conferences within and out of the country and sponsorship of appropriate conferences and workshops in-country.

o Provide a postdoctoral fellowship fund for a "science and technology corps" of U.S. materials scientists or engineers to support collaborative research at a leading Thai university, institution, or industry for 2-year periods.

o Support a clearinghouse function through the U.S. National Research Council (NRC) National Materials Advisory Board to acquaint Thai researchers in materials science and engineering with their U.S. counterparts in universities and government and industry laboratories. In addition, establish a Thai Materials Study Board, under the Ministry of Science, Technology, and Energy (MOSTE), with representation from government, industry, and universities.

o Improve the training of Thai university students in practical engineering skills. These students generally have little or no familiarity with industry, industrial production methods, or managerial techniques (production control, product design, quality control, manufacturing methods engineering, and personnel management) before entering industry.

o Improve the methodology and testing services that support quality control programs in industry and improve the quality of government services in materials processing qualification and optimization. One of the most essential components, which is still lacking in existing industries, is the capability to carry out reliable and reproducible materials testing. This handicap places the local industrial products at a serious disadvantage when compared with similar products from more advanced countries. This could be assisted by improving the facilities and capabilities of the Thailand Institute of Scientific and Technological Research (TISTR) for conducting standard materials testing and analysis in accordance with material and International Organization for Standardization (ISO) standards and American Society for Testing and Materials (ASTM) recommended testing methods. In addition, provide technical assistance to the Department of Science Services (DSS), MOSTE, for having national reference standards and equipment calibrated by the U.S. National Bureau of Standards.

o Provide financial support for testing and analytical facilities in the Division of Research, DSS, MOSTE, so that it can offer government services to industry and universities.

o Provide financial support for upgrading the capabilities of the Metallurgy Division, Department of Mineral Resources, Ministry of Industry, for measuring process yields, mass and energy balances, reaction kinetics, and product characterization for hydrometallurgical, pyrometallurgical, and electrometallurgical processes.

o Establish professional societies in materials science and technology and link them with the leading U.S. professional societies. There are no well-established materials professional societies in Thailand, and, thus limited opportunities exist for gaining access to U.S. professional journals, establishing Thai professional journals, providing technical training programs, sponsoring technical conferences, and giving recognition and awards for outstanding professional scientific and technical achievement.

o Improve direct and timely access of the Thai government document center to U.S. information and data bases that serve materials science and technology communities. Furthermore, support the establishment of an information computer center within the Division of Scientific and Technological Information. This center should be linked to GTE Telenet for network access to information services provided by the U.S. National Technical Information Service (NTIS), DIALOG, ASM Metadex abstracts, and other key U.S. information analysis centers and computer data bases, including the U.S. Patent Office.

o Develop future materials industries in rural areas. Important development programs at the DSS and TISTR will serve the need to decentralize industries away from the Bangkok area and support essential social needs in rural villages and regional cities. To accomplish this, support demonstration projects and industrial workshops that will facilitate the transfer of materials technologies at an advanced stage of development based on indigenous raw materials. In addition, support industry-university coupling projects with universities and government laboratories to facilitate the transfer of processing capability by means of three-for-one matching grants through the stage of demonstrated commercial feasibility.

o Improve capabilities for assessing industrial requirements, indexing technical capabilities, identifying essential technologies, and developing integrated action plans for acquiring critical technical resources--know-how, capital, technical talent, training, and R&D.

o Create a coordinated metallurgy and materials technology program at Chulalongkorn University that bridges the Materials Science Department in the Faculty of Science and the Department of Metallurgy in the Faculty of Engineering and later the same approach should be established at other institutions, such as King Mongkut's Institute of Technology or Khon Kaen.

o Enhance the Ceramics Research and Development Centers at the DSS and at Chulalongkorn University and other appropriate institutions by providing financial assistance to acquire equipment for high-temperature and controlled-atmosphere firing and hot pressing as well as to support technical exchanges with experts in other countries.

APPLIED COMPUTER AND ELECTRONICS TECHNOLOGIES

The computer revolution has arrived in Thailand. The nation already has roughly 8,000 computers, ranging from home computers to large commercial installations, and the demand is increasing. Operators, software developers, and systems designers are in high demand. New small industries are springing up. An increase in computer usage can be predicted with certainty because computers perform functions useful to society; however, the rate at which this usage expands is greatly influenced by economic, social, and political factors. In particular, technological change can be either facilitated or impeded by governments--either through direct support, or, more frequently, through the creation of an environment of economic incentives or disincentives for new technological development.

o A firm base of Thai technologists in computer technology should be built. This is best accomplished by developing the leading universities in conjunction with a clear national policy on the role computers should play. This policy should include:

- -- Clearly defined primary fields of application (for example, census and statistical data and government support services such as weather information, metrology, or agricultural assistance)
- -- Tax or other appropriate incentives
- -- An effective support staff in MOSTE, which coordinates university, industry, and other government agency inputs to computer application and policy.

o A sizable grant should be provided to maintain the program at King Mongkut Institute of Technology (KMIT) and to ensure the development and continuation of a "critical cell." Others should be started on a regional basis. The level of support could respond to a detailed plan from the institute, which should specify the broad areas of support. These might include:

- -- Support for graduate students
- -- Research funds, including supplemental salaries for faculty, equipment for teaching and research, and library needs
- -- Funds to enable faculty travel to conferences and for short-term visits by experts from U.S. universities and corporations.

o Funding should be sought for outreach to personnel in Thai industry and government, and local industry should be encouraged to support at least a part of the activity with a matching grant program.

o A jointly chaired Thai-U.S. program advisory committee should be formed and should include members from both industry and academia. This committee could meet annually to analyze progress and to suggest new directions for these outreach programs.

o A focal point in the Thai government for learning about standards adopted and being developed in the United States and Europe should be immediately identified. These standards cover such topics as a digital representation of the Thai language, local networking, and high- and low-level protocols. For Thailand, the early adoption of standards already based on international consensus and supported by major manufacturers in the United States, Europe, and Japan could ease the way for both orderly development of computer applications and emergence of a computer industry with access to world markets.

o On-line access to scientific and technical documentation should be facilitated.

o A statistical snapshot of Thai activities, especially in the use of microcomputers, should be obtained and used to create computer-based systems for management functions of the Thai government.

o A national measurement laboratory for science and engineering should be established.

o The National Institute for Development Administration (NIDA) should receive support to establish an Information Systems Education Center. This center would train government officials and others in the use of computer technology to complement the partnership equipment support now planned by IBM.

THE ROLE OF SCIENTIFIC INFRASTRUCTURE AND NEEDS

Government implementation of the aims of the development plan will require a coordinated approach to making science and technology more effective in solving development problems. This will involve management of science and technology, including the formulation of appropriate national policies and the use of modern program, and project planning and management methodologies.

o A national science policy body should be established at the highest level to assist the central government in analyzing, promulgating, and assessing science policies. The functions of such a group would include:

-- Advising on existing science policies and making recommendations on new policies or on the elimination of older ones
-- Commissioning studies on science policies and assessing technologies--old, new, and proposed.

Since policies for science and technology will usually have a direct impact on Thai industry, industrialists or representatives from the private sector should be included as members.

o Appropriate levels of policymaking, with concentration in the Ministry of Science, Technology, and Energy, should be established at the program level as well as the institution level. This will ensure that appropriate linkages are made in carrying out science and technology policies and will provide a framework for effective working relationships.

o The provision of training on program and project management methodologies such as those used widely in the United States will enable the Thais to use science and technology to solve key development problems. These methodologies are used at all levels of program and project management and usually include objectives, manpower and organization, facilities available, time schedules and milestones and budgets, project monitoring, and program/project evaluation. Long-term U.S. advisors should be provided to work on an overall basis, as well as with existing activities (biotechnology and TISTR) and emerging areas (metallurgy and materials technology and applied computer and electronics technologies).

Thailand Institute for Scientific and Technological Research (TISTR)

U.S. participants in this workshop were asked specifically to address the role that TISTR should play within the science and technology structure. While time did not permit any in-depth study, they concluded, based on the information supplied to them, that TISTR has too many functions within its current framework, and therefore duplicates to a great extent the work being done at other laboratories, especially at the universities. Moreover, at its presentation TISTR has no room for physical expansion. TISTR should have its own well-defined role under the Ministry to permit it to serve both industry and the government.

o TISTR could serve as a not-for-profit research institute, and should therefore continue to provide contract services for entrepreneurs, industries, and government where these clients demonstrate need for such services. In this context, it is important to recognize that government agencies can be a major, or in some cases the dominant, client without having more rights than any other client, or being involved in any way in the policy structure of the enterprise.

In fact, it is often this freedom of action in an enterprise that gives the private sector confidence that their interests will be protected. These types of enterprises serve essentially as a halfway house between the science and technology community and the private sector and thrive in their success in transferring technology and reducing it to practice. If TISTR were deputized and permitted to establish sound administrative, legal, and technical management instruments and practices that are well recognized by the private sector but well able to serve government in a client relationship, it will serve as an essential element in industrial development.

- Other roles appropriate for an institution such as TISTR are:
  - -- Providing testing and quality control services. To do this more effectively, TISTR must upgrade its capability, including equipment and technical individuals and knowledge of Industry Standard Specifications (ISS).
  - -- Helping fill the "scale-up gap" between scientific research and effective implementation of the results of that research. This gap appears to involve determination of technological and economic feasibilities. It must be filled if science and technology are to be used effectively to solve economic and social development problems.
  - -- Serving as a training center for industry, academia, and the government on program and project management methodologies such as those used widely in the United States.

U.S. participants recognized that TISTR requires continuing technical assistance to better accomplish its mission. This will include resident or visiting experts who could assist TISTR with its defined roles.

Science and Technology Corps for Development

It is proposed that a "science corps" work in selected Thai universities or government or private research institutions on problems that hinder development in priority areas. This concept seems especially appealing, and several panelists currently involved in graduate teaching felt that special privileges should be given to this science corps to attract talented, appropriately trained individuals suitable for their task. These include:

- Honorary involvement of Fulbright and Kennedy Foundations as well as the National Academy of Sciences.

- Funds to permit them to attend at least one professional meeting each year in the United States and thus keep current with the state of the art of their profession.

- A position title, such as assistant or associate professor, that gives them stature within the Thai scientific community and helps make them more effective.

- Continued association with their home university department to permit oversight of research in Thailand by a senior professor or an NAS team.

A significant effort should be mounted to establish this science corps or a similar corps with comparable objectives as an effective model that might subsequently be replicated elsewhere.

WORKING GROUP REPORTS

BIOSCIENCE AND BIOTECHNOLOGY
Agriculture and Agro-industry Sector
Biomedical Sector

METALLURGY AND MATERIALS TECHNOLOGY

APPLIED COMPUTER AND ELECTRONIC TECHNOLOGIES

BIOSCIENCE AND BIOTECHNOLOGY

INTRODUCTION

Recent research in cell biology, molecular genetics, recombinant DNA, and related fields appears to be laying the groundwork for potentially commercial technological developments. The research areas range from those at the basic end of the spectrum, requiring very complex and expensive laboratory techniques and equipment, to those that are within the capacity of modestly equipped laboratories. The relevant biotechnologies merit further explanation.

Tissue culture involves growing cells in a test-tube environment on a nutrient medium. Breeding lines can be selected from plants regenerated from genetically modified cells grown in test tubes, resulting in plants resistant to pesticides or herbicides, cereals that fix nitrogen, anti-leaking genes that improve nitrogen fixation, and crops with increased photosynthetic efficiency, salt tolerance, disease resistance, and improved horticultural traits. Agro-biotechnology techniques might also be applied to cellulose-eating yeast and bacteria, improved commercial yeast strains, and fermentation technology to enhance the synthesis of food ingredients such as casein, antioxidants, antimicrobial agents, amino acids, pesticides, growth stimulants, and growth regulators.

In clonal propagation, tissue culture is used for the high-frequency production of plants. This technique allows the efficient cloning of plants difficult to propagate using conventional horticulture technology, as well as the efficient generation of unique breeding lines for development of new varieties. It is particularly relevant to the production of elite hybrids. In this regard, somaclonal genetic variation--the variability found in plants regenerated from tissue culture--also provides an opportunity for the rapid development of new breeding lines.

Protoplast fusion involves the enzymatic digestion of cell walls which renders cells more receptive to chemical and physical manipulation. This is the most direct method of introducing genetic variability. A unique mixture of nuclear and cytoplasmic genes is obtained, which may segregate or recombine, resulting in a wide range of genetic combinations that are not possible using conventional hybridization. In a number of plant species, protoplasts can be regenerated into complete plants. When protoplasts are genetically altered, therefore, completely new crop varieties can be produced. The most useful combinations could be isolated and incorporated into a breeding program.

Gene transfer via recombinant DNA. Recombinant DNA is a technology associated with the transfer of genes between organisms. Fragments of DNA are isolated from one organism, attached to a plasmid, and transferred to a second organism. Application of recombinant DNA technology offers the ability to transfer genes that control photosynthetic efficiency, photorespiration, transpiration, and nitrogen fixation, as well as those that regulate drought resistance, cold tolerance, salt tolerance, and efficient nutrient utilization, thereby permitting plant cells to grow in adverse climates. Techniques for the use of recombinant DNA to modify crop plants genetically are similar to those originally developed for use with bacteria. Gene transfer is accomplished by first identifying and then isolating the gene desired for introduction into a crop plant. This gene is separated from the donor chromosome using restriction enzymes to fragment the donor DNA. The fragment containing the desired gene must then be recombined with a plasmid capable of entering the host plant cell. Upon entry, the plasmid containing the new DNA must undergo replication and gene expression to complete the introduction of a new gene product into a crop plant. The most frequently used plasmid in agro-biotechnology (small circular DNA) for transfer of DNA to higher plants is the Ti-plasmid, which occurs naturally in the soil bacterium *Agrobacterium tumefaciens*.

Embryo transplant and related genetic manipulations permit the introduction of desired genetic characteristics into elite herds of animals with a certainty and effectiveness that can accomplish in one year, on average, what would take many years by conventional breeding programs. Ova can be withdrawn from elite dams, stored, and artificially fertilized with semen from elite sires. The growing embryos can then be surgically divided into multiple siblings identical in genetic character, to produce small herds of identical animals--impossible to accomplish by other means and of enormous significance in experimental programs. Furthermore, the gene-linked characteristics can be identified in the ova or semen before the embryo is fertilized by the monoclonal antibody labelling technique. It is thus possible with the new technologies to institute a genetic improvement program for cattle or water buffalo that could not have been contemplated before because of the high costs.

Biotechnology is defined here as the application of scientific and engineering principles in the form of biological agents to the processing of materials. It promises to have a vital impact on Thailand's industry in the areas of agriculture, health care (including diagnostic techniques and pharmaceuticals), chemicals, and biomass conversion. Thailand is actively interested in developing bioscience and biotechnology primarily because:

- Thailand is a fertile country with a vast pool of as yet underutilized natural bioresources that can be developed into useful value-added products

- For a country of its size and population, Thailand has a relatively large number of qualified personnel in the areas of basic life sciences, health, food, and agriculture

- Genetic engineering and biotechnology require a relatively low capital input compared with other areas of technology and are therefore suitable for transfer to and further development in Thailand.

Significant progress has already been achieved with results that can be translated into major improvements in agricultural and industrial productivity and health. However, steps must still be taken to enhance plant yields, final disease-resistant varieties, control mycotoxin contamination, improve milk yields, and prevent fish and animal diseases.

From an historical perspective the development of biotechnology in Thailand has arisen naturally from the growth of both the supply and demand sides of the technology. On the supply side, the last two decades, in particular, have witnessed a remarkable growth and maturity of basic life sciences. This is linked to the emergence of a critical mass of scientists trained in developed countries and the establishment of research-based graduate schools. The graduate schools have been responsible for the presence, for the first time, of a substantial indigenous research capability.

On the demand side, problems in health, agriculture, and rapidly expanding agro-industry have made it necessary to utilize biotechnology at various levels of complexity. The urgency of the situation does not allow time for the slow process of conventional breeding, nor is it possible to solve these complex problems by conventional research alone. For example, Thailand has reached the limits of its ability to exploit available arable land and must significantly increase the yields of the existing land area. Application of additional fertilizer and improved water management will increase yields in the more favored resource locations such as the Central Plains, but improved yields in other parts of the country, particularly in the northeast, will require the contributions that applied biotechnology research may make in the future to improve crop characteristics (e.g., virus-free potatoes or mycotoxin-free maize).

The application of biotechnological techniques will also contribute to the better utilization of cassava, a major resource in Thailand. Likewise, maize genotypes that are resistant to kernel rots caused by *Aspergillus flavus* and *A. parasiticus*, must be identified as well as the genetic factors that inhibit the biosynthesis of aflatoxins.

The lack of adequate linkages between the supply side, largely located in the university sector, and the demand side, mainly located in the private and government sectors must be remedied if national efforts to develop the biosciences and biotechnology are to be effectively utilized for development. These linkages will be extensively addressed under the Thai-U.S. science and technology program, the advisory group on biotechnology (within the National Research Council), the upcoming bioscience and biotechnology symposium to be held in early 1985 in Bangkok.

Current Status of Biotechnology in Thailand

The present status of biotechnology in Thailand was determined through visits to Kasetsart, Mahidol, and Chulalongkorn universities; through conferences with Dr. Ernest J. Briskey, staff at the Thailand Institute of Scientific and Technological Research (TISTR), and a biotechnology working group; and through presentations and discussions at the workshop itself. Time limitations prevented visits to other universities, particularly outside of Bangkok. U.S. participants also benefited from extensive summaries of the status and potential of biotechnology in Thailand. Visits and conversations with Minister of Science, Technology, and Energy Damrong Lathapipat, Permanent Secretary Sanga Sabhasri, the Minister of Public Health, and the Prime Minister provided further valuable insights into the state of biotechnology in Thailand. Thus this working group's observations are presented in the context of case studies that reveal a picture of the structure of biotechnology emerging in Thailand.

The three universities visited can perhaps be classified into three categories: (1) agricultural biotechnology (Kasetsart); (2) medical biotechnology (Mahidol); and (3) food and engineering biotechnology (Chulalongkorn). All three universities, of course, have programs in the other areas, mainly in solid science, although, unfortunately, they are grossly lacking in operating funds. The engineering and technology aspects (i.e., process scale-up and economics, fermenter design, and process integration for industrial applications) are not as well developed. The strongest engineering program is at Chulalongkorn, with other pockets of excellence (in technology) existing at Kasetsart (food technology) and Mahidol (instrumentation technology).

The Thai government has a firm national commitment and explicit policy for science and technology for development in which research and development form an integral part. The Fifth Development Plan, which has one chapter dealing with this topic, cites biotechnology as holding special importance for future economic and social development. As a result, a Thai National Center for Genetic Engineering and Biotechnology (NCGEB) was recently established by the Thai government. This center is conceived as a national program or a "center without walls" to coordinate and facilitate communication among the numerous disciplines required for the practice and agricultural and industrial implementation of biotechnology in Thailand. For all practical purposes, this center will function as a national program for bioscience and biotechnology, which should be helpful in facilitating cooperation among the universities, industry, and government (including TISTR). Thailand specifically asked for assistance with the development of this center on the occasion of the recent signing of the Thai-U.S. science and technology agreement.

When planning the program of the NCGEB, Thai officials identified 12 areas that fall broadly into the category of biotechnology as major areas for investigation and development. These include:

1 Plant and tissue culture
2 Rhizobia, mycorrhizal fungi, and organic fertilizers

3 Bacterial larvicides
4 Production of selected enzymes
5 Starch (cassava and corn) conversion
6 Biofuel production (starch, cellulose, and biomass conversion)
7 Development of natural rubber
8 Nutritional biochemicals
9 Improvement of small- and medium-scale bio-industry
10 Industrial waste utilization
11 Development and design of pilot plants
12 Molecular biology (genetic engineering).

Two additional areas are also being developed by other organizations: (1) human and animal health products, and (2) biochemical and food engineering. Plant breeding and biomass production, which are included in the conceptual framework of the biotechnology program, are also addressed in existing programs.

In his opening presentation (see Appendix C) and during later discussions, Dr. Snoh Unakul stressed several problems as of priority concern to the Thai government, which could be addressed by applying biotechnology:

- Utilization of sugarcane and cassava
- Aflatoxin problems with corn
- Fish viral disease
- Enhanced agricultural yields, especially soybean.

Of course, the field of biotechnology is quite broad and multidisciplinary by definition. Consequently, much thought must be given to the management of such a biotechnology program (in any country) so that existing talent can be utilized effectively to solve problems of high national priority.

As the applications of biotechnology expand to food processing, pharmaceutical and biochemical production, and agriculture, biotechnology specialists will be required, particularly those with an engineering or applied science background. Although the three universities visited are already offering programs in this field, curricula need to be upgraded. Kasetsart has developed a limited biotechnology curriculum that emphasizes agriculture and food technology. Mahidol recently developed a curriculum oriented toward pharmaceutical and vaccine production, with certain chemical engineering courses taught by professors from other universities. Chulalongkorn has established a biotechnology institute that will emphasize food science and technology as well as applied microbiology. In all three cases, technologists and engineers will require support to participate in these curricula.

Instruments for research purposes and equipment for teaching laboratory courses are needed to update capabilities in the quickly changing biotechnology field. In particular, equipment for both research and teaching in analytical and process-scale liquid chromatography, rapid enzyme-based analytical systems (such as a glucose analyzer), and separations (such as membrane separation) would help strengthen the capabilities of the universities visited.

A distinction between small-scale pilot-plant equipment and a pilot plant itself would also be helpful. In many cases, a continuous or production pilot plant is best constructed by industry. Fundamental and applied research on individual unit operations (e.g., fermentation, separations, size reduction, sterilization, cooking, extrusion, mixing, and extraction) are needed in a university or government laboratory. Fundamental research on an individual step can be carried out on a scale large enough to obtain reliable scale-up correlations, but small enough to minimize labor and other operational costs. These kinds of units are designed to be flexible in their uses and heavily instrumented for research purposes. In this way, the data obtained can be used by industry to build a production pilot plant incorporating a number of unit operations.

This approach may deserve more attention as capabilities in the engineering of biotechnology processes develop in Thailand. Likewise, capabilities in the food science area should be strengthened in support of the potential development of a food processing industry. Programs are not yet in place to work on problems related to extruded, fermented, emulsified, frozen, dehydrated, or thermally processed food. These programs are needed to lay the foundation for biotechnological and processing enhancement. Research on cassava utilization must also be given major emphasis.

* * *

The draft conceptual framework presented by Dr. Briskey at the opening of this workshop (see Appendix D) was accepted and approved by the panel as a framework to be used for the development of a national bioscience and biotechnology program. This program will focus on eliminating problems or creating opportunities so that biotechnologically-based industries can be developed. Because the term biotechnology is so broad, the framework presented by Dr. Briskey was divided into the areas of bioscience and biotechnology. Within this concept, bioscience should be used when appropriate to solve problems.

This framework and other documents examined during the workshop clearly show that much thought and planning is in progress in Thailand, and that concrete achievements have already been made in developing an infrastructure in bioscience and biotechnology. Present researchers, however, seem to need the national goals, a focus, and project that will result in a concerted effort. Since many problems can be addressed by biotechnology, and it encompasses many disciplines, it is tempting to attempt to do too much or to address too many areas, thus diluting resources (and hence impacts). It was for these reasons that the U.S. participants recommended a focus on the most urgent problems identified by Thai officials and science and technology leaders in the private sector, universities, and government.

This working group elected to split into two subgroups and address separately the agriculture and the agro-industry sector and the biomedical sector. These sections follow.

AGRICULTURE AND AGRO-INDUSTRY SECTOR

Certain aspects of biotechnology in Thailand are already quite applied in character, but much work is still needed in tissue culture, clonal propagation, and embryo transplant techniques. While there is impetus to make a transition from research to industrial development, little information is available on some of the market forces, both domestic and foreign, that have an impact on the development of technologies in several major areas of particular interest to Thailand.

One example is the production of alcohol from cassava or the conversion of starch to fermentable carbohydrates. Cassava is a major crop (approximately 20 million tons per year) that is mainly produced in the low-income areas of northeast Thailand. Exports to Europe have recently been severely curtailed, thus alternative uses must be found. Salient factors that must be considered include the need for subsidies for alcohol production in such countries as Brazil, the Philippines, and the United States; the potential of ethanol for use as an octane booster in unleaded auto fuel in Thailand if the required use of lead-free gasoline became a national environmental policy; the low price of sugar in international markets, which must be accounted for in pricing carbohydrates obtained from starches; and the mix of value-added products that can be obtained from a renewable resource as well as the need to market these products appropriately with, at least, low profit margins.

Given the present state of biological knowledge on the conversion of cassava to alcohol and the other competitive forces, it appears that large-scale alcohol production may not be feasible without additional research to bring about a biological enhancement sufficient to reduce costs. It was made clear to the U.S. participants that work on cassava utilization, as well as on alternatives to cassava in the first place, is being given high priority by the government for the bioscience and biotechnology program. Research and development activities will continue to improve the technical feasibility of alcohol production and thereby could reduce costs. Feasibility studies can be conducted on the various alternatives during the preparation of the project paper.

The stringent pricing and low profit margin for alcohols is offset by social and other factors in Thailand, including the need to improve conditions on the farm to keep farmers from moving to the cities; the reduced demand for cassava by EEC (European Economic Community) countries and hence lower prices for this important crop; and the desire to develop value-added products from crops currently grown in Thailand. These factors combined with the tremendously fast rate of change of biotechnology, suggest that priorities and targets should be set for the development of biological and biotechnological research on cassava utilization (such as single-cell protein production for animal feed) as well as for other areas important to the economic and social development of Thailand. The latter might include efforts related to tissue culture of new and alternative crops, crop diseases, and embryo transplants. Bioscience efforts might include fish and animal viral diseases and pest control techniques.

Two supporting efforts also require attention. First, an infrastructure must be developed that will permit growth of R&D programs at various universities, while at the same time allowing resources to flow to "pockets of excellence" in universities that do not have large programs in biotechnology. This might be achieved through a competitive grants program. Second, the needed curricula must be initiated to educate the technologists and engineers required for the industry to develop. While the education of scientists is relatively good at the present, there appears to be a shortage of engineers. This weakness has already been recognized at the universities visited and is resulting in the development of relevant curricula. However, strong support is now needed in this area and should be included in the science and technology program.

Biotechnology Goals

The policy board of the Thai National Center for Genetic Engineering and Biotechnology has identified 12 major areas (listed above) that will receive program attention over the next five years.

1. Plant cell and tissue culture. Several laboratories are currently capable of culturing cells and tissues more or less on a bench scale. However, the variety of species involved appears to be somewhat limited (strawberries, sugarcane for virus-free stock, etc.), and the capability for large-scale clonal propagation of plantlets for major use in agriculture or reforestation, for example, has not yet been achieved.

2. Rhizobia, mycorrhizal fungi, and organic fertilizers. Significant capabilities have been achieved in this area. Commercial-scale production of rhizobial inoculant has already been attained by the Ministry of Agriculture, with the cooperation of the NifTAL program supported by the U.S. Agency for International Development (USAID), and this area is receiving short-term limited support from a National Research Council committee (Committee on Research Grants, Board on Science and Technology for International Development).

3. Bacterial larvicides. Mahidol University has already produced *Bacillus thuringensis* and *B. sphaericus* preparations for use in controlling major insect pest larvae in Thailand. This area should be relabelled "biopesticides" to include viruses, fungi, nematodes, and insects in the context of biological control. Support is needed to expand the ability to produce a range of commercial products.

4. Production of selected enzymes. Chulalongkorn University has produced glucose isomerase, and Kasetsart University has produced various amylases and proteases. These have not yet been scaled up for routine production, however.

5. Starch (cassava and corn) conversion. Both TISTR and the King Mongkut Institute of Technology (KMIT) have operated pilot plants for production of alcohol from cassava. Production of single-cell protein (SCP) from cassava for animal feed has been carried out by both Kasetsart and Mahidol universities, but it must be scaled up to the pilot plant level for a feasibility study (currently being supported by USAID and Appropriate Technology International).

6. Biofuel production (starch, cellulose, and biomass conversion). The cassava program has been mentioned, and KMIT has achieved biogas production from pineapple waste.

7. Development of natural rubber. There was no opportunity to discuss this topic; however, clonal propagation may be suitable for producing large numbers of high-quality plantlets for industrial plantations.

8. Nutritional biochemicals. Lysine is already being produced on a bench scale, and there are large plants for producing metabolites such as citric acid. This is clearly an important area for future efforts, both to support food industry supplementation programs and for producing value-added products.

The four additional topics--improvement of small- and medium-scale bio-industry; industrial waste utilization, development and design of pilot plants, and molecular biology (genetic engineering)--are dealt with elsewhere in the report.

Conclusions

Based on an examination of the above information, the group concluded that the goals of the new biotechnology center are consistent with the current general capabilities of the Thai scientific community, specifically:

- Basic components--staff, facilities, and academic program--are essentially in place; however, there are areas that require strengthening (noted above). Specifically, there is a major need for monetary support of focused research.

- All phases of biotechnology--research, product development, process scale-up, and design--are represented.

- Most of the academic disciplines required are in fact more or less present.

- The basic level of expertise required (with certain exceptions noted below) has been attained.

While these points reflect the current level of competence in the Thai community for development of a biotechnology program, a continuing need exists for the provision of operating expenses at the various universities or institutes where achievements in biosciences and biotechnology can take place.

Another immediate need is to establish functions for strategic planning and project management within the NCGEB or the Ministry of Science, Technology, and Energy (MOSTE). With regard to planning, it is not clear that the NCGEB project goals have been optimized to achieve the four key economic and social goals of the Thai government. An economic evaluation of each project needs to be effected, or, if it has been effected, needs to be documented and publicized. In addition, since biotechnology is, by definition, multidisciplinary, each discipline must be made aware of its role in the overall plan. The goals must be clear; their relation to the national goals must be quantified; and a strategy statement showing who does what, in what time frame, and why, must be developed. In short, the national biotechnology program needs to be focused and the projects organized.

Moreover, for the effort to remain on target, the individual project goals need to be managed as coordinated programs. The NCGEB should exercise supervisory review of the programs, assuring that timetables, budgets (project accounting), and objectives are met, and that the overall plan is modified, as required, as the work progresses or government policy is altered.

The 12 project goals of the NCGEB, for example, logically fall into five groupings:

1 Agriculture (food production)
2 Food processing
3 Health
4 Biochemicals
5 Biofuels.

Since these groupings inherently require different levels of government, industry, and academic involvement, they should be handled separately from their inception. The social and economic justification for new vaccines for serious health problems is self-evident, for example, while the economic justification for bioproduction of a consumer or industrial product must be documented.

Although the Thai academic community is ready to begin biotechnology R&D if funds were available, certain Thai-U.S. collaborative steps could be taken to facilitate progress. These include:

- Visiting professor exchange
- Selected grants for equipment and staff
- Matching fund research grants open to competitive bidding.

"Critical cells" do in fact exist to a certain extent, but lack support for many of the aspects of biotechnology contemplated. These should be strengthened and coordinated to enhance the multi-university biotechnology effort at several locations.

Interaction with industry also needs to be strengthened, and a matching research grants program is recommended. In addition, to encourage small, rural industry development, a program of goverment incentives will probably be needed.

Recommendations

Based on these conclusions, the following steps are recommended:

o The NCGEB, which has already been established, should be made operational and provided with a core staff. Procedures must be established for connecting this center with other bodies responsible for strategic planning of both short- and long-term goals. Internal procedures are needed for project implementation and evaluation management. This will be facilitated by the visit of the proposed advisory group on biotechnology, to be arranged by the National Research Council and scheduled for late July 1984.

o Among its 12 proposed program areas, the Center should concentrate at least initially, on a limited number of clearly defined priority areas selected (with suitable socioeconomic input) to maximize national impact (economic and social "payoff") and to eliminate constraints to development. It is suggested one program could be in the renewable resource area, one in the health area (considered separately under the biomedical sector), and one in the food and agriculture-related area. The final selection of priorities, however, must rest with Thai officials.

o A competitive grants program should be established at a significant funding level for five years in the areas chosen above. This program would be open to individual researchers in both university and government laboratories, and proposals would undergo peer review--possibly by a team of U.S. and Thai scientists (modelled on the U.S. Department of Agriculture's system). This program would be above and beyond designated funds for coordinated research projects in these areas.

o A one-time equipment program of $5 million should be arranged to give block grants to universities having biotechnology programs or "pockets of excellence" in the biotechnology area.

o In addition to the three key areas selected, several additional areas of basic research important to Thailand require strengthening. These include:

-- Tissue culture clonal propagation techniques
-- Protoplast fusion technology
-- Recombinant DNA technology
-- Embryo transplant techniques
-- Mycotoxin research methodology
-- Fish and animal viral disease methodology.

The above areas were identified as current needs, but others may be identified as the program progresses.

o The Center should accelerate the process of curricula development for educating biotechnologists. In this regard, the proposed visit by the advisory group from the National Research Council and the symposium on biotechnology to be held in Thailand in early 1985 will be useful, as they will allow the visits of senior biotechnology "educators." In addition, appropriate Thai scientists should receive financial support to attend major biotechnology symposia and to visit U.S. biotechnology centers in universities, research centers, and industries.

o Where necessary, operating funds to cover normal functioning costs should be provided to these critical cells so they may continue their concentration on biotechnology efforts.

BIOMEDICAL SECTOR

For the biomedical sector, significant opportunities exist today in Thailand. The application of powerful modern technologies to the biomedical field could accelerate development of the health sector, advance national development, and put Thailand in a strong competitive position in the Southeast Asia commercial market.

The health sector is vigorous, especially in clinical medicine which is developed to the level of Western Europe. The research base, which also has many components, is centered in medical colleges, although units of the Ministry of Public Health (MOPH), the Armed Forces, and the Red Cross also possess specific capabilities that would be an asset to a science and technology network. However, despite the fact that both the research and application ends of the sectoral spectrum are firmly anchored, there are weak or missing segments in the middle. For example, most of the advanced technology is imported, even though Thai scientists are capable of and interested in developing biomedical technologies to meet the rising demand. Thai biotechnology research initiatives have not been expressed commercially, even though the research community fully understands and supports the crucial role of the private sector in promoting the biomedical research component of economic development. The science and technology effort examined here could effectively bridge the gap between potential and application in the biomedical field.

This report on the biomedical sector focuses on opportunities in vaccine development and in closely related areas, such as immunodiagnostics and genetic engineering. Commercial prospects appear to be brightest in these areas, and Thai scientists have already expressed interest in these opportunities.

The veterinary science aspect of vaccine development is not covered by this sector. No site visit was made to the livestock research center, and no assessment was made of the production or application end of the livestock sector spectrum. Because development of human and livestock vaccines requires the same basic scientific skills and commercial production elements, this report may be applicable to the science and technology aspects of the livestock vaccine program as well.

Research and Development

Vaccines of importance in Southeast Asia include those for Japanese encephalitis, a major killing disease in North Thailand; dengue hemorrhagic fever, a problem throughout Southeast Asia; malaria and the serious problem of drug-resistant malaria; hepatitis B, a virus carried by 10 percent of Thais and associated with a high incidence of liver cell cancer; and rabies, a pronounced Thai problem, the imported vaccine for which costs US$250 per treatment. Some of these vaccines are of little interest to international commercial concerns, while others are of universal interest. All these vaccines represent commercial prospects for the region.

The relatively strong biomedical research base in Thailand, supported by excellent clinical programs, forms the nucleus of a vaccine development "critical cell." This cell is not concentrated physically in any one department or university, but member scientists are located primarily in the universities, although some work in the MOPH and the Armed Forces. Many scientists have already begun to collaborate, and at Mahidol University six programs, or centers without walls, have been established to maximize areas of strength across classic disciplines and faculties. Two centers at Mahidol--the Center for Vaccine Development and the Center for Molecular Genetics and Genetic Engineering--are of potential interest to the new science and technology effort. Thus in one of the premier research institutions, experience already exists with the first necessary step toward a problem-solving approach and away from a disciplinary focus. University scientists can be expected to participate effectively in the research program of the new NCGEB.

Microbiologists and immunologists are the foundation of the biomedical research cell. At Mahidol University alone there are 300 microbiologists with bachelor's or graduate degrees.

Current Activities

State-of-the-Art. With regard to the state-of-the-art in vaccine development, scientists at leading universities, at the Department of Medical Sciences of MOPH, and at the Red Cross have demonstrated the capability to produce prototype vaccines, many of which are in the early stages of testing. Credible genetic engineering capability exists within the university community, and an additional person is being trained in recombinant DNA technology. Several more will probably be needed. A genetically engineered cholera vaccine developed in the Faculty of Tropical Medicine at Mahidol University will be among the first to be tested in its new Vaccine Trial Center. USAID is currently negotiating a grant with the university to provide partial support to establish the facility, which will be a national and regional resource in vaccine development. The capability also exists to attenuate the virulence of pathogenic viruses through multiple passages in tissue culture and to produce in tissue culture adequate quantities of many viruses to serve as substrate for vaccine.

Hybridoma technology has been used to produce monoclonal antibodies to malaria parasite antigens. These monoclonals are being applied to development of immunodiagnostic techniques, but very little interest has been expressed in pursuing a commercially viable product. Scientists in the Faculty of Tropical Medicine undertaking this research are collaborating actively with leading investigators in the malaria vaccine development network funded by USAID. There is considerable commercial interest in a polyvalent malaria vaccine, and one can anticipate Thailand becoming a producer as well as a market for the product.

Among the vaccines under development in Thailand, a prototype dengue vaccine has been produced by Professor Natth Bhamarapravati (Mahidol University) through serial passage of one of the four serotypes in tissue culture. The attenuated virus vaccine is ready for initial human safety and immunogenicity trials. If this product is efficacious, it will have a considerable export market and can possibly be produced commercially in Thailand.

The interest in and capability to produce a Japanese encephalitis vaccine also exist. The director of the Department of Medical Science of the MOPH is a collaborator in the forthcoming field trials of two vaccines produced in Japan, and there is every expectation that this virologist is capable of producing a competitive product that will be in considerable demand in northern Thailand, where Japanese encephalitis is the leading cause of infectious disease mortality among children. There is also a potential export market in the region for a quality vaccine, and there is no reason that the vaccine could not be produced in Thailand.

Overall, vaccine development goals in Thailand are expressed as a component of the basic immunization program for children and women within the context of primary health care. At best, the conceptualization of approaches to technical problems appears limited only by the state of the art and professional interest in a particular problem. However, comprehensive planning for a national vaccine development program is almost nonexistent. National immunization programs concentrate on delivering the basic World Health Organization (WHO) program to which measles and polio are being added. Because of its extremely high disease rate in Thailand, post exposure immunization for rabies is the only vaccine that has been added to this rudimentary list as a national policy. Although the Government Pharmaceutical Organization (GPO) manufactures most of the basic childhood vaccines used in the routine national immunization programs, these and rabies vaccine are the only vaccines produced locally. Basic bioscience research should be supported to lay the groundwork for in-country vaccine production for dengue, malaria, Japanese encephalitis, and respiratory diseases.

Mahidol University officials have planned an "industrial park," but at this time there are no specific offers from biological products industries to locate these. Serious attempts should be made to help the university market this concept within the private sector. Land adjacent to the Center for Vaccine Development and laboratory animal production facilities could be made available for private corporations for production or pilot facilities. Other than the MOPH planning exercises for the GPO, which appear to be limited to attempts to boost production of routine childhood vaccines, the Mahidol plans are the only approximation of a national vaccine development plan encountered during the U.S. team visit.

The plans to meet the goals are, like the goals themselves, almost nonexistent. It is entirely appropriate for goals in this subsector to be articulated as part of a more comprehensive national process of setting goals for science and technology involving the health and academic groups. Strengthening the vaccine development center, vaccine-related activities of the National Center for Genetic Engineering and Biotechnology, and professional manpower in the basic life sciences appear to be priority items in any goals for vaccine development. Consequently, help in planning goals and coordination should be provided on a long-term basis.

Thailand has the greatest wealth of talent in microbiology and immunology in Southeast Asia. The climate for public and private cooperation is excellent. With proper consultation and support, immunodiagnostic and vaccine production should be possible in Thailand. The talented manpower available needs few additions for development. The private sector firms or the GPO need to be persuaded that opportunities exist for the commercial sector to provide the impetus for the application of science and technology to development problems. This sector must be apprised of the export potential for high-quality vaccines and other biologicals that are technically within the grasp of the Thai biomedical sector.

Training in Place. This is strong in nearly all critical areas. According to officials at the GPO, the availability of M.Sc.-level technical manpower, required to staff vaccine production plants, must be increased. Apparently, no significant restructuring of the technical education is required other than to strengthen education in the industry-oriented skills. Support should be given for project work, from a bioscientific as well as a biotechnological approach.

Facilities. These are adequate at the basic research level. Instrumentation is modern, and laboratories can accommodate the research required for vaccine and immunodiagnostic development. Facilities are scattered among the academic and government institutions. There is no concentration in any one location other than the GPO, the major vaccine production unit in the country.

Among the ancillary facilities, the new laboratory animal facility at Mahidol University's Salaya campus produces standard strains of laboratory rats and mice. This underutilized physical plant could accommodate other species, including primates, if there is a demand. Most laboratory animal requirements are met by facilities within each institution. Both the Armed Forces and the Division of Medical Sciences, MOPH, have extensive facilities. Radioisotope facilities do not appear to be a limiting factor in research that would be a central part of vaccine development.

Among the plans for new facilities, many components of the Department of Medical Sciences, MOPH, will soon move to a large campus near the airport, including the laboratory animal facilities. This move will allow them to maintain a herd of goats and other animals required to support an immunologic reference center. And, as already mentioned, the Vaccine Trial Center at the Faculty of Tropical Medicine, Mahidol University, will be established within the next few months.

Quality Control

The regulation of vaccines and biologicals in Thailand is divided between two units of the MOPH, the Food and Drug Administration (FDA) and the Department of Medical Sciences. The FDA is concerned almost exclusively with legal aspects, while the Department of Medical Sciences is concerned with the laboratory testing, licensing, and quality control aspects of both imported and locally produced drugs and biologicals. According to Department Director Dr. Nadhirat, the group is experienced in drug testing, but relatively inexperienced in biologicals. Because the local production of biologicals is small, there are no plans to increase technical capabilities for them. Significant increases in the numbers and types of biologicals for quality control in the future would require upgrading staff and possibly adding equipment and facilities. Upgrading of staff would not take the form of formal graduate training. Rather, it would consist of short-term professional training in the specialized techniques required for a particular biological product.

Laws and procedures exist to govern the licensing and quality control of vaccine production. The Department of Medical Sciences routinely tests the vaccines produced by both GPO and the Red Cross. The rabies vaccine used in Thailand has an unacceptably high adverse reaction rate, which has never been reported by the FDA or the Department, but no attempt was made during our visit to explore the details of the technical issues. Efforts are being made at Chulalongkorn University to study the nature and mechanisms of vaccine complications. Efforts also are being made in the Department of Medical Sciences to develop a tissue culture rabies vaccine which if tested properly could be a viable export item in the region.

If new vaccines are produced in Thailand, the Department of Medical Sciences staff will have to receive appropriate training, and additional equipment may have to be obtained to assure adequate quality control. This is particularly true if vaccines and immundiagnostics are to be sold for export. Officials of the Department agreed that the quality of any vaccines developed by scientists at the Department would be controlled by other institutes to avoid any conflict of interest. However, Dr. Nadhirat said her interest was in developing the vaccine, not in its production.

Development of quality control procedures may limit the process of establishing a vaccine or biological product industry. Thus, concurrent development of this important ancillary service must be considered in plans to promote a vaccine development industry.

A biological resource center will be an important component of a vaccine research and production industry in Thailand. At this time there is excellent collaboration among Thai scientists and between Thais and their foreign colleagues in the exchange of research reagents. However, requirements for large volumes of biologic standards for vaccine potency, etc., will outstrip the ability of individual scientists to supply them.

Human Resource Development

The supply of well-trained technical manpower is adequate, largely because of the attraction of the clinical sciences. Medical colleges attract top students, many of whom are attracted to medical research where their interest is supported by their clinical work. There is, however, no equivalent "second job" for Ph.D.s in the life sciences, thus limiting interest in the basic sciences. A viable biomedical industry in a vigorous private sector to provide career opportunities would sustain this sector.

The quality of the training is high. Top priorities should include enlarging and strengthening life science graduate studies, increasing the number of Ph.D.s, and providing advanced postdoctoral training of M.D.s in biomedical sciences in areas that are understaffed and underdeveloped. While the biomedical sector as a whole is strong, specific areas can be identified that require strengthening. For example, technical persons trained in production issues are needed as well as computer expertise in molecular genetics to bolster capabilities in sequencing studies.

Strengthening Support Activities

To strengthen this sector, the following activities are suggested:

o A competitive career development award to support young investigators full time in research for a five-year period would provide both prestige to the sector and adequate funds to launch research careers. Such a national award would allow future directions to be shaped through the specific field.

o A competitive research grants program would accomplish many of the same goals.

o A Documentation Center for the Life Sciences should be established at Mahidol University, followed by computer linkages to appropriate data bases via satellite. Libraries are a relatively under-developed component of the academic setting.

Summary of Recommendations

It is recommended that steps be taken to:

- Support the development of vaccine and immunodiagnostic production. This would be primarily within the Mahidol Center for Vaccine Development and at the Pasteur Institute. Support is also needed for bioscientific research on dengue, malaria, Japanese encephalitis, respiratory diseases, and rabies, while waiting for control by vaccine.

- Facilitate collaboration with private firms or expand, modify, and put on a profit footing the GPO for domestic and regional supply of vaccines.

- Institute a training program and improve facilities at the Department of Medical Sciences, MOPH, to assure adequate quality control of any future vaccine and biological production.

- Provide ongoing consultation in specific areas of vaccine development such as computerization, recombinant DNA technology, production, marketing, and quality control.

- Establish a Documentation Center for the Life Sciences at Mahidol University.

METALLURGY AND MATERIALS TECHNOLOGY

INTRODUCTION

At present, more than 30 minerals are being mined and utilized in Thailand. The mineral industry consists of relatively small-scale mining of tin, tungsten, antimony, manganese, iron ore, and lead and of industrial minerals such as gypsum, fluorite, and marl. Of the metal ores and concentrates, only tin is smelted in Thailand, but a zinc roasting-electromining plant is nearing completion. The ceramic industry in Thailand is an important one and produces products ranging from consumer goods to insulators.

Although Thailand possesses rich deposits of mineral resources that could be well developed for a metallurgy industry, it exports its raw mineral ores at rather low and inconsistent prices, and imports a large amount of processed zinc and lead for the local industries. Thus, improved technology is essential to better utilize Thailand's mineral resources.

The modern metal-processing industry in Thailand started nearly 40 years ago with foundry casting of iron and steel and the rolling of reinforcing steel. At present, steel making is limited to electric furnace melting of scrap iron, and a large part of the country's steel needs are imported. There have been studies of integrated steel production based on direct reduction, but the future of such plans will most likely depend on the discovery of new mineral deposits.

Although the contribution of the mineral industry and the associated materials industries to the gross national product is relatively small, it is expected to increase substantially as the country makes the planned transition from an agricultural to an agricultural-industrial economy.

It is quite likely that the growth of the mineral industry in Thailand will be aided by the discovery of new mineral deposits as new exploration techniques, such as remote sensing, are introduced. Conventional exploration techniques, which rely principally on surface indications, have been impeded by forest and soil cover and the weathering of rocks due to the tropical climate.

In addition to economic conditions and ore reserves, the rate of growth of the mineral industry will depend largely on the availability of a technological infrastructure that can nourish the development and implementation of new industrial projects.

To understand the current state of this infrastructure, the U.S. team visited the principal research organizations in metallurgy and materials technology in the Bangkok area. These included the science and engineering faculties of Chulalongkorn University, the Department of Mineral Resources of the Ministry of Industry, the Department of Science Services of the Ministry of Science, Technology, and Energy, and the Thailand Institute of Scientific and Technological Research (TISTR).

The project team also reviewed a large number of technical documents submitted by the above organizations, USAID staff, and NRC staff, and met with government, university, and industry personnel. In addition, a meeting attended by technical and industry representatives provided an opportunity for open discussion on the problems of the mineral and materials industries in Thailand.

ANALYSIS OF THE PRESENT SITUATION

The following general comments can be made in light of the necessarily brief but very intensive study of the metallurgy and materials science and technology in Thailand.

<u>Building a Technical Infrastructure</u>. The lack of an adequate technical infrastructure in some areas is impeding the development and implementation of industries for treating indigenous raw materials and for reducing reliance on imported metals and industrial minerals. A case in point is the development of a hydrometallurgical process for treating monazite and reducing imports of cerium oxide.

The infrastructure can be enhanced in the short term by increasing the exposure of Thai engineers and scientists to the up-to-date technology in their fields, by initiating graduate research programs at the foremost universities, and by upgrading the existing technical groups in the areas of metallurgy and materials technology.

<u>Linkage of Available Technical Resources</u>. The technical resources in the areas of metal extraction, fabrication, and materials technology are highly fragmented, and inadequate communication and interaction exist between the various R&D groups in universities, government agencies, and industry. There is also, in most cases, an inadequate interface with technical components in other countries. Improvements in this area will ensure up-to-date knowledge of the state of technology relevant to the Thai mineral and materials industries.

<u>Human Resources</u>. Thai engineers and scientists, both at the university level and in other organizations, are well educated, intelligent, and eager to advance the technology of their country. On the other hand, there is a strong tendency to act independently rather than share problems and resources with others outside their sphere of interest. This may be due to a natural politeness and reluctance to "burden"

others. For instance, one industrialist complained that university faculty would not take the time to visit and become acquainted with his plant, while the professors in question said that according to Thai custom, it would be totally inappropriate to "invite themselves" to that plant without being invited by the management.

Facilities. Facilities for research and development range from "state of the art," such as the Instrument Center of Chulalongkorn University, to "bare minimum." In many cases, there are no mechanisms for allowing researchers of one group to use the facilities of another. There is a special need for larger equipment at the university, to increase the exposure of students to industrial technology, and at some of the government development laboratories, to increase their effectiveness in testing or promoting new products.

Government Support and Coordination. The Royal Thai government needs to formulate a long-range plan for technological development related to metallurgy and materials technology and to nurture cooperation among the country's various technological components.

RECOMMENDATIONS

In consideration of the above factors, this working group believes that the best placement of funds and other assistance will be in the specific areas described below. These actions take into account both needs and the available strengths and resources.

- Create a metallurgy and materials technology program at Chulalongkorn University. A bridge should be created between the Materials Science Department (Faculty of Science) and Metallurgy (Faculty of Engineering) by forming a "center of excellence" or program that includes professors of both departments. Both departments are currently engaged in corrosion studies, and this should be the first area of cooperative research, with emphasis on the principal corrosion problems being experienced now in Thai industry. The center would encourage the development of graduate research programs in both departments. Some other specific research areas, selected by the project team from a number of projects discussed with the faculty, are:

  - Development of a hydrometallurgy section through interface with a U.S. university currently engaged in hydrometallurgical research, further training of current faculty members, and equipping of a basic training laboratory.
  - Enhancement of the pyrometallurgy section through interface with a U.S. university and the acquisition of additional pyrometallurgical equipment.

-- Enhancement of welding research and testing at Chulalongkorn University by means of technical exchanges with U.S. experts and the acquisition of testing equipment.
-- Initiation of a program for research and development of tin metal applications, with emphasis on applications in developing nations.
-- Development of temperature-resistant and wear-resistant materials.
-- Development of advanced kiln design and fast-firing techniques.

The new metallurgy and materials technology program should cooperate closely with the Department of Mineral Resources, with the Ceramics Research and Development Center (MOSTE), KMIT, and with other institutions or government agencies serving the mineral and ceramic industries. Indeed, such collaboration already exists between the Materials Science Department of Chulalongkorn University and the Ceramics Research and Development Center.

o <u>Enhance the capability of the Ceramics Research and Development Center</u>. This group is conducting very useful work in developing and promoting new ceramic products. It should be provided with financial assistance to acquire equipment for high-temperature and controlled-atmosphere firing and for hot pressing. There are also needs for improved process control and for analysis and technical exchange with experts in other countries.

One condition for such assistance should be close collaboration with the Materials Science Group at Chulalongkorn University and other established critical cells to avoid unnecessary duplication of effort and to keep university researchers informed of industry needs.

o <u>Encourage the formation of the Metallurgical and Materials Society of Thailand</u>. Probably no measure will do more to enhance professionalism and technical interaction within the country than the formation of an active professional society that brings industrial, government, and university technologists together. Apparently, an attempt was made a few years ago to bring "metallurgists" together but was abandoned because of their small number. It is believed that a Metallurgical and Materials Society is viable at this time if it is not based on narrow educational background but opens its doors to all chemical, physical, and engineering technologists who are associated in some way with the mineral and materials industries of Thailand. At the outset of the formation of such a society, linkages should be provided with the corresponding U.S. societies.

It is interesting to note that a highly developed country like Canada created such a society as recently as 1962, and Chile followed suit 17 years later, in 1979.

o Develop a plan for a metallurgy and materials technology program with the following components.*

Human Resource Development.

Objective 1. (Priority A). Upgrade teaching laboratories, research laboratories, and infrastructure facilities for improving the training and increasing the output of materials scientists, technologists, and engineers at the undergraduate and graduate levels.

Teaching laboratories at major universities are inadequate to provide the training necessary to apply fundamental principles. Consequently, B.S. graduates in metallurgy, ceramics, and other fields of materials science and technology enter industry with inadequate "hands-on" training in the practice of scientific and engineering skills. Moreover, there are no university research facilities adequate for M.S. and Ph.D. degree programs or to encourage world class research by the faculty. Fields of materials science, technology, and engineering--such as extractive metallurgy, materials characterization, materials synthesis, amorphous materials, welding and joining, erosion and corrosion, metalworking, surface modification, deformation and fracture, polymers and electronics, refractory and abrasive materials, and high-temperature structural and functional ceramics--are seriously lacking in even the highest level Thai universities for want of equipment.

To achieve this objective, the following strategy is recommended. Give financial support to a leading university that has curricula in metallurgy, ceramics, materials science and technology, and strength of materials to:

-- Upgrade teaching laboratories to an acceptable standard with the aim of improving the quality and practical training of undergraduate and graduate students.

-- In the area designated above, provide adequate research facilities that are most appropriate to the competence and needs of Thailand.

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*The objectives and strategies listed under this recommendation were rated as follows.

Priority A is oriented to immediate critical needs. Funding should be used for high-leverage, objective-oriented activities, with the close participation of USAID to review and measure progress. Funding support should be leveraged by Thai government financial support. Priority B is oriented to important existing and future needs. It is necessary to proceed with maximum discretion and flexibility to seek optimal channels and methods for support. Priority C is oriented to existing and future opportunities. Total discretion should be given to the Thai government, industry, and universities to optimize opportunities.

-- Improve the faculty's capability to provide engineering consultancy, research and materials analysis, and testing to industry and government agencies.

Objective 2. Support faculty development through research, scholarly interactions, and collaboration.

University faculty lack opportunities to achieve their full research and scholarly potential because of inadequate resources for undertaking research, maintaining awareness of advances in their fields, and collaborating with leading scientists and engineers in other countries.

To achieve this objective, the following strategies are recommended:

-- (Priority B) Provide financial support for faculty assistantship grants to be awarded by the Science Society of Thailand. These can be used for: start-up support for research projects; supplemental support for sabbatical research at leading universities abroad; travel grants to major conferences within and out of country; and sponsorship of noteworthy conferences and workshops.

-- (Priority C) Provide a science and technology corps to support collaborative research for two years at a leading Thai university by American materials scientists, technologists, or engineers.

-- (Priority B) Support a clearinghouse function through the National Materials Advisory Board of the U.S. National Research Council to acquaint Thai researchers in materials science, technology, and engineering with their U.S. counterparts in universities and government and industry labs.

Objective 3. Improve the training of Thai university students in practical engineering skills.

These university students generally have little or no familiarity with industry, industrial production methods, or managerial technologies (production control, product design, quality control, manufacturing methods engineering, and personnel management) before entering industry. Hence, Thai industry feels cheated by the system of higher education.

To achieve this objective, the following strategy (Priority A) is recommended: provide literature, case study materials, and instructional materials on U.S. university curricula, industry intern programs, and cooperative programs to prepare materials engineer graduates for industry careers.

Quality Control Program

Objective. Improve the methodology and testing services that support quality control programs in industry as well as the quality of government services in materials processing qualification and optimization.

One of the most essential components, which is still lacking in existing industries, is the capability to carry out reliable and reproducible materials testing. Thai industries need to know the properties of manufactured products and the sources of error in processing and manufacturing these products and in nonconformance to specifications. There is, however, hardly a laboratory that possesses or can provide standard testing facilities and testing procedures. This handicap places the local industrial products at a serious disadvantage when compared with similar products from more advanced countries.

To achieve this objective, the following strategies are recommended:

-- (Priority A) Improve the facilities and capabilities of the Thailand Institute of Scientific and Technological Research for conducting standard materials testing and analysis in accordance with material and International Standards Organization (ISO) and American Society for Testing and Materials (ASTM) recommended testing methods. Provide a complete set of ASTM standards and testing methods publications on an annual basis and facilitate communications and interaction with key ASTM standards committees.

-- (Priority A) Provide technical assistance to the Department of Science Services, MOSTE, for having national reference standards and equipment calibrated by the U.S. National Bureau of Standards (NBS). Furthermore, identify standard reference materials and measurement assurance programs that can be provided by the NBS and that will support critical quality assurance programs in industry.

-- (Priority A) Provide financial support for testing and analytical facilities in the Division of Research, Department of Science Services, MOSTE, so that it can serve industry and universities. Badly needed equipment includes: (1) furnaces for firing ceramics at temperature above 1200°C; (2) physical analysis instrumentation for measuring surface area of powder; thermal coefficient of expansion; thermal conductivity; size, shape distribution, and connectedness of porosity, thermodynamic properties; dielectric properties; (3) x-ray diffraction and ceramography equipment; (4) mechanical testing equipment for measuring rupture modulus, hardness, and thermal shock resistance; and (5) equipment for chemical analysis (microanalysis).

-- (Priority A) Provide financial support for upgrading the capabilities of the Metallurgy Division, Department of Mineral Resources, Ministry of Industry, for measuring process yields, mass and energy balances, reaction kinetics, and product characterization for hydrometallurgical, pyrometallurgical, and electrometallurgical processes.

Information Resources and Professional Societies

Objective 1. Establish professional societies in materials science and technology and link them with leading U.S. professional societies.

There are no well-established materials professional societies in Thailand and thus limited opportunities exist for gaining access to U.S. professional journals, establishing Thai professional journals, providing technical training programs, sponsoring technical conferences, and giving recognition and awards for outstanding professional scientific and technical achievement.

To achieve this objective, the following strategies are recommended:

-- (Priority A) Establish industrial affiliate memberships through the association of Thailand industries with the following U.S. professional societies: American Society for Metals, American Ceramic Society, American Society for Testing and Materials, American Nuclear Society, American Society for Mechanical Engineers, Society for International Engineers, and Society for Manufacturing Engineers.

-- (Priority A) Negotiate and subsidize group subscription rates to professional society journals and proceedings for key university libraries and for the documentation center at the Department of Science Services (Division of Scientific and Technological Information) and the TISTR.

Objective 2. Improve direct and timely access of the Thailand Government Document Center to U.S. information and data bases that serve materials science and technology communities.

Access by the Thai materials science and technology communities to key information and data bases is severely limited. Thus no cost-effective way exists to stay current of state-of-the-art information or research-in-progress bibliographic indexes.

To achieve this objective, the following strategies are recommended:

-- (Priority B) Support the membership of the Association of Thailand Industries in the Battelle Technical Information Program (BTIP) and provide sustaining funds for specific information sought and technical information services provided by the Battelle staff.

-- (Priority B) Support the establishment of an information computer center (microprocessor, modern disk storage, printer) at the Division of Scientific and Technological Information. This center should be linked to GTE Telenet for network access to information services provided by the U.S. National Technical Information Service (NTIS), DIALOG, ASM Metadex abstracts, U.S. Patent Office Computer Data Services, and other key U.S. information analysis centers and computer data bases (including the MBS-ASM phone diagram computer system).

Critical Development Cells

Objective 1. Develop materials industries in rural areas.

Important development programs at the Department of Science Services and the TISTR will serve the need to decentralize industries away from the Bangkok area and support essential social needs in rural villages and regional cities.

To achieve this objective, the following strategies are recommended:

-- (Priority A) Support demonstration projects and industrial workshops to facilitate the transfer of materials technologies at an advanced stage of development based on indigenous raw materials. Priorities include: (1) the use of dolomite for basic refractions, building materials, paint and cement, fertilizer, and water effluent treatment; (2) the use of agricultural waste to produce house building materials, insulation, fuel briquettes, and activated charcoal; (3) the use of natural clays for sanitary ceramics, cookware, flatware, and building tiles; and (4) the recovery of valuable metals and minerals from electrolytic wastes, tailings, metal removal turnings, scrap, and other forms of industrial wastes.

-- (Priority A) Support industry-university coupling projects with universities and government laboratories to facilitate the transfer of processing capability by means of three-for-one matching grants through the stage of demonstrated commercial feasibility.

Objective 2. Improve capabilities for assessing industrial requirements, indexing technical capabilities, identifying essential technologies, and developing integrated action plans for acquiring critical technical resources--expertise, capital, technical talent, training, and R&D.

Understanding of the present status of industries in this area and of their needs for further improvement is urgently required so that technological development programs can be tailored to match available capabilities in universities, government laboratories, and TISTR with various industry requirements. Examples of these industries, to name only a few, include the foundry industry, the machine tool industry, and the automotive industry where metal shaping, heat treatment, and welding and jointing are used. There is a need to identify high linkage materials technologies that will improve the efficiency of production, raise the standard of quality, lower production costs, and provide technical competitive edges against foreign competitors.

It is also necessary to identify "must-have" technologies for industries to be developed in the future. The establishment of basic "upstream" materials industries (for example, steel, glass products, ceramics, nonferrous alloys) will offset imports needed to contribute to the healthy growth of "downstream" industries. Establishment of these basic industries requires market analyses, technology resource planning, and long-term economic development planning, as well as the formulation of plans, priorities, and national policies.

To achieve these objectives, it is recommended (Priority A) that a materials study board be established under MOSTE with representation from government, industry, and academia. Planning grants should be provided to:

-- Assess technological requirements in existing and emerging industries.

-- Set capabilities within the national importance for addressing these requirements.

-- Identify gaps and shortfalls in "must-have" technologies.

-- Hold state-of-the-art seminars and workshops to build awareness and exchange ideas and know-how on available technologies.

-- Develop integrated plans of action for acquiring available technologies, promoting technological readiness in industry, and supporting highly visible developments in university and government laboratories with maximum industry support and participation.

-- Establish close ties with the Association of Thai Industries.

APPLIED COMPUTER AND ELECTRONIC TECHNOLOGIES

Electronics, integrated circuits, and computers compose an exciting and rapidly growing field of study and of commercial development which shows no signs of abating as new technologies and applications emerge. The field known generically as computer science and technology covers a wide spectrum of activities, from abstract theory to practical application. Also included in this spectrum are computer science, computer engineering, computer application, information science, information technology, telecommunications, electronics and aspects of electrical engineering, system theory, materials science, optical engineering, and physics. The applied science and engineering elements are concerned with design systems and components, computer development, software, control mechanisms, and computer applications. All these fields lead directly into new industries.

The microcomputer and microprocessor have dimensions and power requirements that make them applicable to almost any human activity. They can be tailored to a specific purpose or configured to perform a number of functions depending on the needs of the operator. Consequently, most sectors of modern society are considering how to perform traditional functions more efficiently using a computer or how to perform functions formerly considered impossible.

An increase in computer usage can be predicted with certainty because computers perform functions useful to society; however, the rate at which this usage expands is greatly influenced by economic, social, and political factors. In particular, technological change can be facilitated or impeded by governments--either through direct support or, more frequently, through the creation of an environment of economic incentives or disincentives for new technological development.

The computer revolution has arrived in Thailand. The nation already has roughly 8,000 computers, ranging from home computers to large commercial installations, and the demand is increasing. Operators, software developers, and systems designers are in demand. New small industries are springing up.

Not surprisingly, educational programs to prepare people for the various networks are also growing rapidly. These range from short courses in computer programming to Ph.D. programs in the relevant fields of science and engineering. Here, too, growth is rapid.

The major university program in the applied science and engineering aspects is at the Ladgrabang Computer Institute, King Mongkut Institute of Technology. Of the 2,800 students at the Institute, 1,250 are in engineering, with strong emphasis on electrical engineering, especially in areas relating to computers. This institute offers engineering degrees of technician diploma and bachelor's, master's, and doctoral. Roughly 300 students graduate each year. Demand for these students is high, and the institute is committed to increase its enrollment to 5,000 in the next four years.

The National Institute for Development Administration (NIDA) is a graduate school founded 18 years ago by grants from USAID and the Ford Foundation. Its 140 faculty members, 50 percent of whom hold Ph.D. degrees, offer master's degree programs to 1,000 students in public and business administration, economic development, and applied statistics. The latter area contains a small but growing computer applications group, which graduates 15-20 students per year. In June 1984, this group plans to sign a five-year cooperative program with IBM in which that company will donate a $2-million 3031-based installation, and the school will provide facilities (about 20,000 ft^2) and faculty to train Thai government administrators in computer-based management techniques.

CURRENT STATUS OF COMPUTER TECHNOLOGY IN THAILAND

While less than 1,000 Thais are involved in computer technology, the universities and some 40 fledgling computer companies have acquired, assembled, and are programming and using microprocessors for such applications as accounting, banking, farming, hotel management, and inventory control. Although one company, Thavorn, is reportedly assembling 100 Apple-look-alike microcomputers per month, most Thai manufacturing activity is undertaken by multinationals who enjoy Thailand's relative stability; minimal bureaucracy; a steady and secure supply of water, gas, and electricity; and a large pool of low-cost, appropriately skilled labor. U.S. computer assemblers include Signetics, National Semi-conductor, Data General, Honeywell, and AMP. The Japanese are a significant presence in consumer product manufacturing including Matsushita, Hitachi, and Toshiba.

Software development now involves some uniquely Thai applications, such as Thai language word processing and Input/Output. Larger computer systems, primarily for accounting, have been applied over the past 20 years in banks and large industrial organizations and are not likely to become a near-term source of Thai-created technology.

Thailand's university faculty is largely foreign educated and, although knowledgeable of the state of the art beyond Thailand's ability to assimilate it, appears to be appropriately interested in practical application rather than research. Current plans call for a substantial expansion in the number of students who can be accommodated in computer and related curricula. These include control engineering applications and uses of microprocessors, which have already produced innovations, such as a small-scale hydroelectric plant, that are important to Thailand's agricultural base.

In the next few months, all the rectors of Thai universities will gather to examine the Thai system and its relevance to the emerging science and technology world. Consideration will be given to university structure and costs. The Thai university system evolved from a model that assumed that its graduates would be primarily employed in the public sector; 97 percent of tuition is borne by the government, even for middle-class students. These factors are relevant to computer education, since KMIT's figures of 10,000 applicants and only 300 admitted appear to represent a critical lack of appropriate university facilities. In addition to a substantial expansion and possible restructuring of universities, Thailand plans to develop computer literacy training programs for government and industrial managers. Both plans are responsive to critical needs and should be ranked high as appropriate initial activities.

FUTURE NEEDS AND SOLUTIONS

Properly applied, computer technology can make a significant contribution to the development of Thailand as a middle-income country. To avoid misapplication, patience must be used to build a firm base of Thai technologists. This is best accomplished by developing the leading universities in conjunction with a clear national policy on the role computers should play. The fruits of this policy should include:

- Clearly defined primary fields of application (for example, census and statistical data and government-support services such as weather information, metrology, or agricultural assistance).

- Tax or other appropriate incentives.

- An effective support group (for example, a small 20-person contingent) in the Ministry of Science, Technology, and Energy, which coordinates university, industry, and other government agency inputs to computer applications and policy.

As the leading producer of computer engineering graduates, KMIT is a likely candidate for orderly and sizable development. Its current activities include basic digital logic (using in-house fabricated instruments), instrumentation, computer programming (in part on computers assembled in-house), pattern recognition and image processing, and fabrication facilities for solar cells and PIN diodes (using 10-micron geometry and manual step-and-repeat photolithography). All but the fabrication facilities deal with practical knowledge, which is finding immediate application in Thai society. (For example, one student recently sold a Thai word processing package for $5,000 to a Thai company).

KMIT staff have been commissioned by the Ministry of Education to prepare 11 textbooks in Thai dealing with: (1) Introduction to

Computers, (2) BASIC, (3) Operating Systems, (4) Computer Languages, (5) Data Structures, (6) Systems Analysis, (7) Office Automation, (8) COBOL, (9) File Design, (10) Computer Application in Accounting, and (11) Computer Application in Marketing. Preparation of so many texts at once is, to say the least, quite ambitious.

Selection of enhancement activities should, in the opinion of the Thais, be based on two criteria: (1) they are in the long-term interest of Thailand, and (2) will they yield capabilities that can lead to Thai products of interest outside of Thailand. From the U.S. and Thai points of view, an activity is optimal if it satisfies either of these points and produces a situation leading to a symbiotic relationship between a Thai and a U.S. organization. Candidate areas include: (1) unique Thai devices (for example, printers, OCRs, Thai word processing, Thai speech I(O)--market for U.S. vendors); and (2) Thai software (lower-cost supply for U.S. vendors).

Even though the electronics and computer program at KMIT seems the largest and most advanced university program in Thailand, there are others. Assuming an initial grant to KMIT, it would probably be wise to study the other university programs with the expectation that other, perhaps smaller, grants could be made as well. Some support could even be given to universities that are new to the field, such as the projected new program at Thammasat University.

The program at KMIT is large enough that a sizable grant covering a period of several years seems a desirable approach. This could ensure the development and continuation of a "critical cell." The level of support could respond to a detailed plan from the institute, which should specify the broad areas of support but, at the same time, allow for considerable flexibility. Such support should cover direct costs (i.e., the university could be expected to cover indirect costs). Major areas for support might include:

- Graduate student study
- Research, including supplemental salaries for faculty
- Equipment for teaching and research
- Library needs
- Provision for some faculty travel to conferences.

The explicit inclusion of some funds for the travel and expenses of short-term visits by experts from U.S. universities or corporations would also be helpful. Funding for outreach programs to people in Thai industry and government should be considered as well. Local industry should be encouraged to support the program, possibly through a matching grant program.

Management of the effort should be, as much as possible, in the hands of the faculty, who may wish to emulate, for example, the famous material research laboratories in the United States. Provision should also be made for a jointly chaired Thai-U.S. program advisory committee, with members from both industry and academia. This committee could meet annually to analyze progress and suggest new directions for the program.

A six-year support program with average annual funding of $250,000 per year might be a reasonable first estimate. However, the funding level could vary considerably--e.g., smaller during the initial and terminal years and larger in middle years, especially if equipment is purchased. Funding to other university programs, if contemplated, could follow quite different paths, depending on need. Thus a new effort, such as that proposed by Thammasat University, might obtain a one-time block grant for equipment and library needs, whereas other programs might require grants over several years. Overall, it is important to obtain firm assurances from the Ministry of University Affairs that programs will continue at the expanded level once U.S. support ends.

As described earlier, NIDA, in cooperation with IBM, plans to establish an information systems education center to train government officials and others in the use of computer technology. NIDA has asked USAID to fund up to $1 million per year for five years of enhancement activities. Since this activity directly contributes to building infrastructure and complements the KMIT activity, at least $100,000 a year should be considered as a supplementary activity in addition to the $1 million.

COMPUTER STANDARDS

Historically, standards have been adopted following the development of new products, but the rapid changes in the computer industry over the past decade have led to setting standards at the cutting edge of the implementation of the state of the art. In developing its computer industry, Thailand can thus make use of lessons learned in the United States, Europe, and Japan. One such lesson is to pay early attention to interoperability and interchange standards, including (1) fairly technical magnetic standard reference materials, (2) protocols, and (3) interface standards:

1 Since the sense head to flexible magnetic material interface is not analytically describable, the industry has come to rely on internationally available reference materials for production of magnetic storage components and for calibration of the sense amplifiers used in reading. This permits the interchange of magnetic tape and flexible disks among computers of various makes.

2 Since Thailand is entering the computer revolution in the middle of the emergence of practical global heterogeneous networks (networks whose nodes are of various makes), it should at once become cognizant of international protocols that permit such networks to function effectively. A focal point within the Thai government for learning about the standards being adopted and developed in the United States and Europe should be identified immediately. These standards might include such topics as a digital representation of the Thai language, local

networking, and high- and low-level protocols. Groups that should be consulted include the IEEE Computer Society, American National Standards Institute, International Organization for Standardization, International Electrotechnical Committee, and the Consultative Committee for Telephone and Telegraph.

For Thailand the early adoption of standards already based on international consensus and supported by major manufacturers in the United States, Europe, and Japan could ease the way for both orderly development of computer applications and emergence of a computer industry within access to world markets.

3 Interface standards describe mechanical, electrical, functional, and operational characteristics of computer and electronic equipment. Although the Western world has experience, more disagreement than agreement exists on appropriate interface standards. Nevertheless, a number have emerged and persisted. These should be examined and possibly adopted by Thailand to promote orderly development.

If it is important that the computer industry of Thailand accept internal standards and consistent methodologies in order to link up to international networks as well as international standards, it should form a government-industry board to analyze these needs, to develop a consensus on the ways in which to proceed, and eventually to promulgate the adopted Thai standards and procedures. Such a board might reasonably be established and supported by MOSTE.

RECOMMENDATIONS

To achieve the goals described above, it is recommended that steps be taken to:

o Create a joint (and jointly chaired) Thai-U.S. advisory committee to the Minister of Science, Technology, and Energy. A small committee (e.g., five members from each side) should suffice. This successful approach was used in South Korea under Minister Choi. The committee could advise on new programs, changing priorities, university-industry relations, etc. Although the Minister's office would set the agenda, the structure should be flexible enough to permit the committee itself to propose suggestions.

o Establish a National Science Foundation (NSF) for Thailand within the Thai NRC. NSF would serve as a research support agency for scientists, engineers, and health specialists in universities, and would give industry grants on the basis of proposals for basic and applied research and for research equipment submitted by individual scholars or groups of scholars. This foundation could be modeled after the U.S. National Science Foundation or perhaps the Korean Science and Engineering Foundation of South Korea. Or it may be more feasible for the Thai government to strengthen and provide additional funds for the Thai National Research Council, since it fulfills many of the functions of the proposed science foundation.

o Develop a participatory "hands-on" Museum for Science and Technology in Bangkok, modeled after the world-famous museum developed by Frank Oppenheimer in San Francisco. Every display in this museum permits manipulation and experimentation by the observer (i.e., the individual "does" the experiment or demonstration). Several other nations have developed museums of this type, and they seem universally popular with young students.

o Support the establishment of a science and technology journal for Thailand and active participation in journals and regional activities of established international professional societies such as the IEEE Computer Society.

o Provide yearly honorary or possibly cash awards for young scientists and engineers for innovation. IBM already has established such an award program, administered by a committee chaired by Prof. Snoh.

o Facilitate on-line access to scientific and technical documentation.

o Obtain a statistical snapshot of Thai activities, especially in the use of microcomputers, and use this study to create computer-based systems for management functions of the Thai government. This could build on the information systems education center at NIDA and be modeled on the U.S. and European department of commerce functions.

o Establish a national measurement laboratory for science and engineering.

o Provide operational support for the partnership that has developed between NIDA and IBM, which provided substantial equipment.

THE ROLE OF SCIENTIFIC INFRASTRUCTURE AND NEEDS

INTRODUCTION

The conceptual framework presented by Dr. Ernest J. Briskey contained the request that U.S. participants consider the total framework in which an expanded science and technology activity could play a role in national development. In response, the U.S. team recommended that both the Thai government and USAID consider the following needs and focuses:

- Policymaking and implementation mechanisms
- Effect of policy decisions on selecting project priorities
- Approach to project design
- Program and project management methodologies
- Role of government research institutes in national science and technology programs.

More specifically, the U.S. team suggested that, among the numerous variables involved in a national science and technology program, emphasis should be placed on:

- The management of science and technology, including the development and implementation of appropriate national policies and the use of modern program and project planning and management methodologies.

- Filling the "scale-up" gap between scientific research and the expected utilization of such research by public or private sector organizations.

- Providing the reliable and internationally acceptable standards, testing, and quality control services upon which science and technology-based economic growth depends.

- Ensuring that the equipment and instrumentation available to research groups, quality control and testing institutes, and industry are of the quality necessary for effective research, scale-up endeavors, quality control, and production.

POLICYMAKING AND IMPLEMENTATION MECHANISMS

A national science policy is the usual abbreviation for the important activity of devising, promulgating, and monitoring national policies for science and technology. The impact of these policies is widespread on industry, agriculture, research facilities, and universities. It follows therefore that many groups and agencies contribute to science policy and are affected by it. Science policy is also linked to important costs--for research, for education of scientists and engineers, for technology importation--and to many benefits: new industries, improved agriculture, and better transportation and communication.

Science policy does not stand alone. It is closely linked to economic policy, educational policy, and political objectives. Because of the last link especially, it is almost unavoidable that national governments, which make many science policies, are concerned with the impacts of their science policies and those of others on their society. Some coordination of science policies is of central importance, the objectives being consistency, compatibility, and congruence.

These several aspects make a good case for a national policy body--for example, a National Council of Science and Technology Advisors, chaired by the Prime Minister--to assist in analyzing, promulgating, and assessing science policies. A special National Board for Science and Technology Policy might also be developed to serve this "council" and to interact directly with the Ministry of Science, Technology, and Energy.

The functions of such a board can be manifold: giving advice on existing science policies, making recommendations on new policies or on elimination of older ones, and commissioning studies on science policies and assessing technologies--old, new, or proposed.

Since policies for science and technology will usually have a direct impact on Thai industry, it is important to include industrialists or representatives from the private sector on this board of perhaps, 10-12 persons. Members will likely be appointed by an individual at the highest level of government and with fixed but staggered terms of appointment, perhaps five years, to give continuity and experience to the board. An appropriate chairman should be elected or appointed, and a small staff employed to prepare studies and reports. This group should work directly with the Thailand Development Research Institute.

Policy determination at the program level should include all ministries, university and research institutes, and private sector organizations involved in achieving program goals established at the national level. Project goals should be established at the program level.

Policy determination at the project level should include all the ministries, ministerial components, research institutes, universities, and private sector organizations involved in achieving project goals established at the program level. Institutional goals should be established at the project level.

Institutional-level policymaking should include all the departments or other components within an institution (public, private, or university sector) which are involved in achieving the goals set at the project level. Individual goals are established at the institutional level.

Policy determination at the individual level should include all the persons involved in achieving tasks or goals established for them at the institutional level.

While Thailand has many policy and coordinating organizations, it appears that usually such organizations do not have accepted jurisdiction over all the component organizations and individuals whose cooperation would be required to achieve the goals established at any given level. These policymaking and implementation organizational problems appear to the U.S. team to be at the heart of the "linkage constraints" that keep the Thai science and technology community from working together more effectively.

EFFECT OF POLICY DECISIONS ON SELECTING PROJECT PRIORITIES

A closely related observation by the U.S. team pertains to the importance of policy decisions in selecting priority projects within established programs. This observation was made chiefly in the context of the bioscience and biotechnology program, but applies to the other program areas as well.

The earlier Thai national science and technology workshops have designated a priority bioscience and biotechnology program area in which science and technology should help solve development goals. The U.S. team saw no reason to question this decision, however, bioscience and biotechnology constitute a very large field, in which a substantial number of projects are currently being and will be pursued. To avoid dispersion of efforts and to stay within available resource limitations, a limited number of projects must be given priority.

In practice, there are three ways to select priority projects:

1 By their relative importance to achieving national or program goals (e.g., national security, control of epidemic disease, etc.) cost considerations are a secondary factor

2 By the relative cost-effectiveness of the competing projects

3. By the political influence of the project sponsor.

Selecting projects on the basis of the political influence of the project sponsor is neither a choice mechanism subject to program/project management methodologies, nor an appropriate subject for comment by those outside the political system. Thus project selection using program/project management methodologies must be based on policy decisions involving the evaluation of noneconomic factors or the determination of project priorities on a cost-benefit basis. The final results of the project should consequently be judged accordingly. The determination of project priorities on a cost-benefit basis, however, depends, in turn, on policy decisions made on a noneconomic basis, since the key elements of the cost calculations (prices allowed, labor and material costs, regulatory costs, taxes, or subsidies) are usually influenced significantly by public policy decisions made on noneconomic bases.

The U.S. team observed that the policymaking and implementation mechanisms for making decisions regarding science and technology and involving all participants at a given level are apparently not yet in place in Thailand. The assignment of long-term advisors would likely help Thai groups work together on problems of top priority. U.S. participants also observed that the techniques for project evaluation and comparison of benefits do not appear to be well developed.

APPROACH TO PROJECT DESIGN

In considering an approach to project design, it is important to realize that answers to questions frequently depend on the way in which the question is asked and on the scope of the question. For projects designed to answer questions of importance, such as key economic and development problems, it is obviously vital to ask the right questions. Some members of the U.S. team feel that the success of a Thai program to use science and technology to solve economic and social development problems could depend on the ways in which questions are asked when the answer involves the selection of priorities and the commitment of resources.

PROGRAM AND PROJECT MANAGEMENT METHODOLOGIES

The U.S. team observed that the Thai science and technology program could benefit significantly from assistance with program and project management methodologies such as those used widely in the United States. These methodologies are used at all levels of program and project management, and usually include components on objectives, manpower and organization, facilities available, time schedules, and milestones and budget, project monitoring, and program/project evaluation. Operating support was also obviously limited and should be given positive consideration.

MANAGING SCIENCE AND TECHNOLOGY: THE ROLE OF RESEARCH INSTITUTES IN NATIONAL SCIENCE AND TECHNOLOGY PROGRAMS

During the visit, Thai science and technology leaders raised many questions regarding the appropriate roles for government research institutions in national science and technology programs. The U.S. participants feel that these roles depend on policy decisions, which differ from country to country. The answer to this question in Thailand, therefore, depends on the prior establishment of the policymaking and implementation mechanisms referred to above, and on the policy decisions made by those with authority under the mechanisms established.

Any policy on the management of technology should recognize the following axioms and experience:

- The effective transfer of technology depends on the needs of the marketplace. Very little technology is reduced to practice by technology push.

- Technology transfer is a human to human interaction between the party who needs the technology and the party who has the technology. Both parties must gain from the transaction on a "win-win" basis.

- Most technology developed at universities is "raw", and contains considerable risk and uncertainty. The most useful patents are often not the primary patent but derivative patents, which describe the art of applying, producing, or tailoring the design of the invention to satisfy market needs.

- Considerable engineering is required beyond the R&D stage to work out economic trade-offs, develop production methods, design in reliability, and prove the design by testing and analysis. These engineering tasks require considerable analysis, technical insight, and know-how based on past successes and mistakes.

Most large industrial firms have the technical talent to manage the development and application of technology in accordance with the above axioms. They also have the availability of many options through normal business channels, as well as arrangements for acquiring new technology over technological know-how by means of licensing, joint ventures, acquisitions, partial equity ownership, hiring consultants, etc. However, they too need a catalytic influence and coordination with national activities to maximize national development.

Small to medium entrepreneurial operations and small- to medium-sized start-up ventures cannot afford the quality and amount of technical talent needed to carry out technology transfer, reduce the risk of new technical concepts or ventures, and conduct much of the market testing to prove commercial feasibility in the marketplace. The not-for-profit contract research institute was established in the United States to provide these services for entrepreneurs, industries, and government as needed. In this context, it is important to recognize that government agencies can be a major, or in some cases the dominant, client for such services without having any more rights than any other client, or being involved in any way in the management or policy structure of the enterprise. In fact, it is often this freedom of action in an independent, private, not-for-profit enterprise that gives the private sector confidence that their interests will be protected.

These operations work best when the following conditions are met:

- The client owns all of the intellectual properties and rights to the technology he pays for.

- o The work is done on an "exclusive scope" basis. In other words, you cannot sell the same R&D twice to different sponsors, nor can you offer exclusive rights on technology that has already been proven and reduced to practice. This policy applies to both industrial and government sponsors.

- o All data and information concerning the technology's development will be held private and confidential and rigorously safeguarded for a period of time negotiated with the sponsor.

- o Terms and conditions are negotiated beforehand on the termination of the work and the transfer of all properties to the client as well as indemnification to the institute for termination of contract.

These types of enterprises serve essentially as a halfway house between the science and technology community and the private sector, and thrive in their success in transferring technology and reducing it to practice. In the process, they add their own innovations and exploit their own know-how to help their clients successfully meet their business goals. If the Thailand Institute of Science and Technological Research were deputized and permitted to establish sound administrative, legal, and technical management instruments and practices that are well recognized by the private sector, but well able to serve the government in a client relationship, TISTR will serve as an essential element in industrial development in Thailand.

Other roles that have usually proved particularly successful for government research institutions in both developed and developing countries and that could be appropriate for an institution such as TISTR are (1) to provide testing and quality control services, and (2) to help fill the "scale-up gap" between scientific research and the effective implementation of the results of that research.

The scale-up gap must be filled if science and technology are to solve economic and social development problems effectively. To clarify this observation, U.S. team members defined the process of scientific research to useful implementation as consisting of four phases:

1 Determination of scientific feasibility. Does the proposal violate the laws of nature?

2 Determination of technological feasibility. Can it be accomplished within current technological capabilities?

3 Determination of economic feasibility. What are the cost and market value aspects?

4 Commercial feasibility. Is there a market, and if so, how can it be profitably produced on a commercial scale?

The U.S. team observed that the capability for determining scientific feasibility appears to be well established in the leading Thai universities, while the capability for determining commerical feasibility appears to exist in the vigorous and growing Thai private sector. The scale-up gap appears to involve the two middle components, namely: determination of technological feasibility and of economic feasibility. A large part of the problem may be the confusion of roles.

Both universities and government research institutions now try to perform the work required by all four phases: scientific, technological, economic, and commercial. Both university and government research personnel complain that the Thai private sector does not seek Thai science and technology capabilities. The Thai private sector replies that the university and government science and technology personnel do not understand the needs of the private sector. While the problem was frequently described as one of linkages, a more important problem may be confusion of roles.

U.S. participants described the following method of allocating roles which has proved successful in other countries:

- Determination of scientific feasibility: role of the universities

- Determination of technological and economic feasibility. These two roles would be performed by the government research institutions with input from the universities and the private sector

- Determination of commercial feasibility: role of the private sector.

APPENDIXES

APPENDIX A

Workshop Agenda

Monday, June 4	Session I: Goals of Science & Technology Development Program
Morning	Welcome, Chairman, Session I Robert Halligan, Director, USAID/Thailand
	Opening Address: Thai Science and Technology Needs H.E. Damrong Lathapipat, Minister of Science, Technology, and Energy
	Needs for Technical Solutions to Development Problems Dr. Snoh Unakul, Secretary-General, Office of the National Economic and Social Development Board
Coffee	
	U.S. Perspectives: The Honorable John Gunther Dean, U.S. Ambassador
	Conceptual Framework for Thai-U.S. Cooperation in Science and Technology Dr. Ernest J. Briskey, Science and Technology Advisor to the U.S. Ambassador; and Director, USAID Office of Science and Technology in Thailand
Lunch	
Afternoon	Session II. Dr. Sanga Sabhasri, Chairman; Dr. Franklin A. Long, Cochairman
	Commentary on Status of Concepts for Thai-U.S. S&T Program: Role of BOSTID Panel Dr. Sanga Sabhasri, Secretary-General, Ministry of Science, Technology, and Energy
	Highlights of S&T Program Commissioned Studies:
	Constraints to Thai Development: The Role of Science and Technology Dr. Anat Arbhabhirama

Key Problems in Science and Technology: Dr. Yongyuth Yuthavong, Faculty of Science, Mahidol University

Status of Science and Technology in Thailand: Dr. Harit Sutabutr, Faculty of Science, King Mongkut Institute of Technology

Status of Computer Laboratories in Thailand and their Needs: Dr. Srisakdi Charmonman, Faculty of Engineering, KMIT

Review of Studies on Organization of TISTR: Dr. Malee Suwana-adth, Director, National Center for Genetic Engineering and Biotechnology

A Perspective on Life Sciences and Biomedical Sciences: Dr. Natth Bhamarapravati, Rector, Mahidol University

Discussion

<u>Tuesday, June 5</u>

8:30 a.m.	Visit Thailand Institute of Scientific and Technological Research (TISTR)	
11:30 a.m.	Group I	Biotechnology/Agriculture and Food Processing: Visit Kasetsart University
	Group II	Metallurgy and Materials Science and Technology: Visit Chulalongkorn University
	Group III	Computer Science and Technology: Visit King Mongkut Institute of Technology
	Group IV	Biotechnology/Biomedical: Visit Mahidol University
Noon	Lunch at host universities	
	Continue discussions at universities	
3:00 p.m.	Group I	Visit Mahidol University

<u>Wednesday, June 6</u>

8:30 a.m.	Courtesy call on Minister of Public Health	
10:00 a.m.	Group I	Visit Mekhong Alcohol Factory at Pathum Thani

	Group II	Visit Ceramics Research and Development Center; Department of Science Services (MOSTE), and Science and Technical Research Equipment Center	
	Group III	Visit Tanin and computer factories	
	Group IV	Visit Salaya Campus, Mahidol University	
2:00 p.m.	Courtesy call on Prime Minister Prem Tinsulanonda		
3:30 p.m.	Group I	Visit Chulalongkorn University	

<u>Thursday, June 7</u>

8:15 a.m.	Group II	Visit Department of Mineral Resources
	Group IV	Visit Food and Drug Administration; Computer Center, Department of Medical Sciences; Government Pharmaceutical Organization
10:00 a.m.	Groups meet for discussion and analysis	
1:00 p.m.	Plenary session: Open forum for representatives of universities, industry and government organizations. Questions and responses.	
4:00 p.m.	Draft report	

<u>Friday, June 8</u>

	Prepare report
4:00 p.m.	Brief Dr. Sangha Sabhasri on group conclusions and recommendations

<u>Saturday, June 9</u>

9:00 a.m.	Brief the Honorable John Gunther Dean on group conclusions and recommendations
10:00 a.m.	Brief H. E. Damrong Lathapipat on group conclusions and recommendations

APPENDIX B

List of Workshop Participants

UNITED STATES PARTICIPANTS

Dr. Franklin A. Long, Director, Program on Science, Technology and Society, Cornell University (CoChairman)*

Dr. Arden L. Bement, Jr., Vice President of Technical Resources, TRW, Inc.*

Dr. George Curlin, Office of Health, Bureau of Science and Technology, U.S. Agency for International Development

Dr. John Eriksson, Deputy Assistant Administrator for Research, Bureau of Science and Technology, U.S. Agency for International Development

Dr. John Gmitro, Manager of Engineering Research, Kraft Inc.*

Dr. Richard Johnson, Eisenhower Professor of Neurology and Professor of Microbiology and Neuroscience, The Johns Hopkins University*

Dr. Michael R. Ladisch, Laboratory of Renewable Resources Engineering, A. A. Potter Engineering Center, Purdue University*

Dr. Charles MacVeagh, Senior Partner, Price Waterhouse

Dr. John Riganati, Systems Component Division, National Bureau of Standards*

Professor Nickolas J. Themelis, Professor of Mineral Engineering, Henry Krumb School of Mines, Columbia University*

Dr. Michael McDonald Dow, Associate Director, Board on Science and Technology for International Development (Staff Officer)

Mrs. Rose Bannigan, Program Development Coordinator, Board on Science and Technology for International Development (Staff Officer)

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*NRC Participants

THAI PARTICIPANTS

Dr. Sanga Sabhasri, Permanent Secretary, Ministry of Science, Technology and Energy (Chairman)*

Dr. Amaret Bhumiratana, Faculty of Science, Mahidol University

Lt. Col. Amnaj Thammachinda, Secretary-General, Dental Association of Thailand

Dr. Anat Arbhabhirama, AR Group Consultant*

Mr. Anek Vidhayasirinun, President, Thai Packaging Association

Mr. Apilas Osatananda, Director-General, Department of Technical and Economic Cooperation

Dr. Aree Valyasevi, Director, Institute of Nutrition, Mahidol University

Dr. Aroon Sorathesn, Consultant, Engineering Institute of Thailand

Dr. Art-Ong Jumsai, Managing Director, Microtex Company, Ltd.

Mr. Athorn Patumasootra, Secretary-General, Office of the Atomic Energy for Peace

Dr. Bhichit Rattakul, Deputy Director, National Center for Genetic Engineering and Biotechnology, MOSTE

Mr. M. L. Chainarong Hasdintra, Thailand Central Chemical Co., Ltd.

Mr. Chalermbhand Srivikorn, Srivikorn Investment Company

Dr. Chan Chanyavanich, Scientist, Mining Technology Division, Department of Mineral Resources

Mr. Chavarat Charnvirakul, Sino-Thai Group

Mr. Cherdchai Jeeravanon, Charoenpokabhan Company

Dr. Chingchai Lohavattanakul, Charoenpokabhan Company

Dr. Chokechai Auksoranandh, M. Thai Industrial Co., Ltd.

Mr. Dee-prom Chaiwongkiat, Faculty of Science, Kasetsart University

Dr. Harit Sutabutr, Deputy Dean, Faculty of Engineering, KMIT

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*Member of the Thailand Science and Technology Program Advisory Council (TSTPAC).

Dr. Jira Hongsladaromp, Thammasat University

Dr. Kalaya Sobhonbhnich, Minister Advisor, MOSTE

Dr. Kamchad Mongkolkul, Dean, Faculty of Science, Chulalongkorn University

Dr. Kampol Adulavidhaya, Director, Research and Development Institute, Kasetsart University

Dr. Kasem Balajiva, Managing Director, Thai Tinplace Manufacturing Co.

Mr. Kittipan Karnjanapiputkul, Director, Subdivision AID, Department of Technical and Economic Cooperation

Dr. Kosol Petchsuwanna, Vice Rector, KMIT

Dr. Krissnapong Kirtikara, Dean, Faculty of Engineering, KMIT

Dr. Ladawan Chottimongkul, Thailand Institute of Scientific and Technological Research

Dr. Lek Utamasil, Head, Department of Materials Science, Faculty of Science, Chulalongkorn University

Dr. Likhit Chiravegin, Dean, Faculty of Political Science, Thammasat University

Mr. Maiti Mojadara, President, Sanyo Universal Electric Company

Dr. Malee Suwana-adth, Director, National Center for Genetic Engineering and Biotechnology, MOSTE*

Dr. Mana Rakvidhyasastra, Managing Director, Praneet Industry

Dr. Manoo Veeraburus, Vice Rector for Academic Affairs, Chulalongkorn University

Dr. Narongchai Akrasanee, Economic Advisor, The Industrial Finance Corporation of Thailand*

Dr. Natth Bhamarapravatti, Rector, Mahidol University*

Dr. Nongyao Chaiseri, Rector, Thammasat University

Dr. Pairat Tutchayapong, Chaokhuntaharn Ladkrabang Campus, KMIT

Dr. Pakorn Adulbhandhu, Siam Cement Co., Ltd.

Mr. Plengsak Prakasbhesuch, Executive Vice President, Metro Company Ltd.

Mr. Poon Kongcharoenkiat, East Asiatic Co., Ltd.

Dr. Pornchai Matangkasombut, Director, Biotechnology Program, Mahidol University

Dr. Pradish Cheosakul, Technical Advisor and Executive Director, Thai-Asahi Caustic Soda Co., Ltd.

Dr. Pramote Teerapong, Faculty of Pharmacy, Mahidol University

Prof. Pravase Wasi, Faculty of Medicine, Siriraj Hospital

Dr. Preeda Wibulsawasdi, Dean, Faculty of Energy and Materials, KMIT

Mr. Pricha Amatayakul, Advisor to Executive Committee, Science Society of Thailand

Dr. Serene Piboonniyom, Vice Rector, Salaya Campus, Mahidol University

Dr. Sermlarp Vasuwat, Rubber Expert, Ministry of Agriculture and Cooperation

Dr. Sippanandha Ketudat, Department of Physics, Chulalongkorn University*

Dr. Smith Kampenpool, Governor, TISTR

Dr. Snoh Unakul, Secretary-General, Office of the National Economic and Social Development Board

Mr. Somchet Wattanasint, Siriwiwat Company

Dr. Somsak Tamboonlertchai, Faculty of Economics, Thammasat University

Dr. Srisakdi Charmonman, Faculty of Engineering, KMIT

Dr. Sumin Smutkutt, Chairman of Genetic Breeding Branch, Agricultural Science Society of Thailand

Dr. Sunt Ruchadawong, Director, Mining Technology Division, Department of Mineral Resources

Dr. Sunt Techakumpuch, Director, IMET

Dr. Suree Bhumibhamon, Minister Advisor, MOSTE

Dr. Sutat Sriwatanapongse, Vice Rector, Kasetsart University, Kamphaengsaen Campus

Dr. Suthin Nophaket, Vice President, Thai-Scott Paper Co., Ltd.

Dr. Swasdi Skulthai, Advisor, Graduate School, Mahidol University

Dr. Tan Chongsuphajaisiddhi, Head, Department of Tropical Pediatrics, Mahidol University

Mr. Tawee Butrasunthorn, Siam Cement Company, Ltd.

Mr. Teerajit Sthirotamawong, Vice President for Internal Activities, Thai Packaging Association

Dr. Thavorn Vajarabhaya, Vice Rector, Chulalongkorn University

Dr. Thiraphan Phukaswan, Director, National Inland Fishery Institute, Department of Fisheries, Ministry of Agriculture and Cooperatives

Mr. Ueychai Viravan, President, J.S.B. Company

Mr. Udom Vidhayasirinun, Tanin Industry Company, Ltd.

Professor Varakorn Samakoses, Vice Rector for Planning, Thammasat University

Dr. Vichitvong Na Pompetch, Chairman, Krirk College

Dr. Warin Wonghanchao, Director, Institute of Social Research, Chulalongkorn University

Dr. Watana Stienswasdi, Faculty of Agriculture, Kasetsart University

Dr. Wiwat Mungkandi, Deputy Dean for Academic Affairs, Faculty of Political Science, Chulalongkorn University

USAID/THAILAND

Mr. Willy Baum, Office of Science and Technology

Dr. Ernest J. Briskey, Science and Technology Advisor to the U.S. Ambassador; and Director, Office of Science and Technology

Mr. John Foti, Director, Office of Agriculture and Rural Development

Mr. Robert Halligan, Mission Director

Dr. Richard Hopkins, Division of Human Resources

Dr. Jaroon Kamnuanta, Scientific Affairs Specialist, Office of Science and Technology

Ms. Carol Peasley, Deputy Mission Director

Mr. E. Ploch, Program Officer

Mr. Terrance Tiffany, Office of Health and Human Population

Mrs. Wannee Vardhanabhuti, Office of Science and Technology

APPENDIX C

Opening Remarks

Robert Halligan
Director,
U.S. Agency for International Development
Thailand

Thailand is one of the most unusual countries in which USAID is currently working, and from a variety of perspectives. First, it is one of the fifth or sixth largest food-exporting countries in the world and the only one outside the developed world. It now has a population growth rate of between 1.8 and 1.9 percent that is steadily declining, giving it one of the most successful family planning programs anywhere in history. Thailand has a literacy rate of 86 percent, one of the highest in the world, and a life expectancy rate of approximately 63 years. It also has a very dynamic private sector, which is self-evident if we just look around the city of Bangkok and the traffic we are constantly faced with.

Another very important component of Thailand is the participation of women. Women are actively involved in the parliament, in the government, in the private sector, and in the academic world, which is also somewhat unusual in many of the countries in which USAID works.

What has been USAID's role in the past? I will not dwell extensively on what we have done in working with our Thai colleagues, but there have been three very significant achievements. Going back over three decades you could almost single out decade by decade the achievements that have been made. First, and most significant I suspect, is human resources. More than 12,000 Thais have been trained under USAID auspices over the last 30 years. This is insignificant in comparison to the over 100,000 Thais who have received training in the United States, mostly self-financed. But of these 12,000, some are sitting in this room today and many occupy very senior positions in academia, the private sector, and government.

Second, in the 1960s USAID was the leader, if you will, and the catalyst for the development of northeast Thailand. The rural road network that was established opened up the Northeast for increased agricultural production.

Finally, the third significant achievement is that beginning in 1970, we began a family planning program with our Thai colleagues that is the most successful in the world. However, we cannot really dwell on the past, and we have to look at the future. That is what USAID tries to do in these countries.

When looking at the future we realize that Thailand must look both in and out. Thailand needs growth with equity, and much of that growth must occur outside of the metropolitan Bangkok area. Thailand needs to find productive employment for a growing and increasingly educated labor force. According to recent estimates, by 1990 there will be 1.2 million new entrants into the Thai labor market. Thailand must modernize its agriculture and at the same time increase the share of gross domestic product of the manufacturing sector. Thailand also needs to export, export, and export. In reviewing the patterns of growth in more advanced countries, it is evident that in those countries there is a strong, mutually supporting relationship between the public and private sectors and universities and the sustained application of science and technology.

Last year something fairly significant occurred in USAID: we began to make science grants through the Office of the Science Advisor and through the BOSTID (Board on Science and Technology for International Development) program at the U.S. National Research Council. These science grants provided Thai researchers with resources to carry out their own research. It then dawned on some of us that the brain drain has stopped and that we no longer need to send lots of people to the United States; the human resource capability already exists in this country. We also realized that we can provide some limited resources to free up researchers' time to conduct research relevant to the needs of Thailand based in Thailand. It was only after we began to examine this seriously that we realized that there is a trinity of sorts between the universities, the government sector, and the private sector.

As a result of our examination we recruited Dr. Ernest J. Briskey, an eminent scientist, professor, and an individual with extensive private sector experience. After Dr. Briskey's arrival we formed a very distinguished advisory council, TSTPAC, which brings together the private sector, public sector, and academic community to advise us on the shape and direction of a potential science and technology program.

Why are we here and why did we ask you to join and work with us? USAID needs to develop a strategy for the sustained application of science and technology, bearing in mind, and I must underline this, the need for equitable growth and employment opportunity. This is essential for a strong and future-oriented Thailand. We are asking you to examine the institutional base, the human resource base, and the policy environment which together will enhance science and technology application.

We in USAID recognize that we cannot do this job; it must be undertaken by the people attending this workshop and, it must be done by Thailand. But just as we provided in the 1960s and 1970s the catalyst for road-building and family planning programs, we hope that the 1980s will show that we were the catalyst for a sustained growth-oriented science and technology community in Thailand. Time is short and the task is large. With that I would like to ask Minister Damrong for his comments.

Thai Science and Technology Needs

Damrong Lathapipat
Ministry of Science, Technology, and Energy
Royal Government of Thailand

On behalf of the Thai government and the Ministry of Science, Technology and Energy, I would like to welcome you to the first science and technology program development workshop. In particular, I wish to welcome to Bangkok, Thailand, the American science delegation who arrived yesterday after traveling halfway around the world and, not yet recovered from jet lag, are beginning their work this morning. We admire your effort and spirit of cooperation.

This workshop is organized with the help of the U.S. National Research Council in response to the Thai-U.S. Agreement on Cooperation in Science and Technology for Development, which was signed in Washington on April 13, 1984, during Prime Minister Prem Tinsulanonda's visit. Its purpose is to assess the state of science and technology in Thailand and to propose specific policy guidelines for cooperation in this area to the American government and Congress.

The importance of science and technology is self-evident. Improvement in the quality of life has been achieved largely through science and technology. It is the developed countries, originators of modern technologies, which have set the pace and comparative quality of life standard for the less-developed nations. The latter have attempted to do this principally by importing technology-based products, but the result is modernity without modernization. We need to revolutionize our thinking about development. The transformation of our society must depend more on home-based technologies than imported modernities. This is a process whereby we can liberate ourselves.

This observation reminds me of Rousseau's seemingly immortal words: "Man is born free, but everywhere he is in chains." Let me venture to say instead: "Man is born in chains, but everywhere he is struggling to be free."

During the past two decades, Thailand has witnessed a vigorous effort of accelerated development. But long years of intensified effort have yielded only an illusion of national development. With the growth of big cities, the multiplication of communication networks, and many other indicators of material progress, Thailand has the appearance of a modernized society. But with a great number of the population remaining in absolute poverty, we must say that it has simply achieved modernity without modernization. This situation is possible because we have mainly imported those modernities--mostly the fruit of technological advancement--without any appreciable effort to lay the groundwork for technological development on our own soil. Needless to say, importation of modernities cannot be allowed to go on endlessly. Sooner or later the purchasing power will be exhausted. Thailand, I believe, is approaching that point, and, therefore, it is time that we reconsider our development strategy. Science and technology will now have to play a key role in our development effort. Before I spell out more precisely how we conceive such a role, let me briefly review Thailand's current problems--those that I believe need technical solutions.

First and foremost is mass poverty--in the rural as well as the urban areas. As I have said, after long years of intensified development effort, a vast majority of the Thai people remain poor, with a great number of them in absolute poverty. Thus our current development plan gives high priority to rural development.

Our second major problem is that of balance of trade and payments. Basically, development and modernization are attempts to improve the people's quality of life. As we all know, modernization is technology based. Thailand's modernization drive, like that of many other developing countries, has been dependent externally for its technological needs. Through long years of modernization effort, we have made no serious attempt to lay down the basis for our own science and technology development. Inevitably, our balance of trade and payments has worsened, and continues to get worse.

The third problem is related to population growth. The impact of our family planning campaign has already been felt, and we are achieving a lower growth rate. However, the population is increasing. The economy must therefore grow to absorb the increase in population and the work force. We will soon experience, or perhaps are already experiencing, acute structural unemployment, a situation resulting from unmatched economic and population growth.

The fourth problem involves our defense needs. A modern army must be science based, but rapid progress in military technology has led to a rapid increase in sophistication, and prices, of the military hardware. Our current military expenditure is already growing painfully high and increasingly becoming a major problem for our balance of payments. There will be a point where standard military equipment will be beyond our reach.

Science and technology are apparently fundamental to the solution of these problems. We have, in the past, attached insufficient importance to science and technology and thus lacked a vision of their role in national development. Inasmuch as development and modernization are based on science and technology, we can neglect them only at our own peril. Let me say briefly, therefore, how I see their role in solving the basic problems of our nation.

First, the problem of mass poverty is fundamentally one of improving the people's productivity--enabling them to gain higher values for the goods and services they produce. The most effective way to do this, I believe, is to intensify the application of science and technology. Science and technology improves the quality of the goods and services, and improvement in quality will mean higher values.

The role of science and technology in easing the balance of trade and payments is even more obvious. We can improve our balances only by buying less from abroad and producing more high-technology products essential to modernization. High-technology products must at the same time be export oriented. To be competitive at home as well as abroad, the products must meet world standards. Newly industrializing countries, such as Korea and Singapore, have surpassed Thailand in this respect because they opted for high-technology manufacturing some 10 years or more before us. Therefore, we cannot afford to lose any more time.

Science and technology are also fundamental to economic growth. Advances in science and technology are an incentive to investment. Technology is a prerequisite for investment, which, growth theorists say, is a prerequisite for growth, which, in turn, is the basis for development and modernization. To ease the population and unemployment problems, we cannot but encourage science and technology-based investment that will stimulate growth.

Lastly, as advancement in defense technology seems to know no bounds, it is time we started developing our own military science and technology development program. The "guns or butter" dilemma is likely to persist even in the wealthiest nations. But the more we reduce our payments deficit by reducing military imports, the less painful the dilemma becomes.

The foregoing is how I see Thailand's problems and the positive role of science and technology in solving them. Technology, in this light, is a key factor. Unfortunately, it has sometimes been overlooked. Most theorists speak of inputs and outputs without mentioning the process in between. If labor is part of the input, do not forget that labor without technology is meaningless. And here again I challenge Karl Marx. For this reason, technology in most cases is invisible, so much so that one scholar has referred to it as the "black box."

I will not go into the detail of how to conceive implementation programs. That I will leave to our friends and colleagues here. In saying this, I am not suggesting that this workshop figure out for us the ways and means of solving the whole national development problem through science and technology. The Ministry of Science, Technology, and Energy, let me assure you, has already explored and found some of these solutions, and we have in some measure launched our science and technology for development program. We will certainly do our part but this is not all we want. We need insight, advice, as well as cooperation from friends and colleagues, such as you are in this room today. We do regard you as "friends in need."

Needs for Technical Solutions to Development Problems

Snoh Unakul
Secretary-General,
Office of the National Economic and Social Development Board,
Royal Government of Thailand

I am pleased to be invited this morning to participate in this very important meeting. The Minister stated in his remarks that for the first time in our history science and technology have been recognized officially as one of our top national priorities. But, it is not enough to have policies written in chapter 8 of the fifth development plan and have remain only a paper document. Since the publication of the fifth plan two and one-half years ago, we have been trying to translate this paper plan into an action plan.

Quite a number of steps have been taken in the last two and one-half years leading to the signing of the agreement on scientific and technological cooperation between the U.S. Government and the Thai Government, in Washington, D.C., this past April. We are glad that the U.S. Government has been able to send such a high powered team so soon after that signing ceremony, to be with us this morning. Certainly, we would not wish to lose this opportunity to build further on the path that we have taken during the past two and one-half years. In fact, we are hoping that, starting this morning, we can quicken this process. On our part, we would like to discharge our function by being your unpaid informers, trying to let you know about our ways of thinking and our ways of working. We hope that this information will be helpful to you throughout your visit.

My assigned task is to discuss the needs for applying technical solutions to development problems. The subject is not my own choice since it presents me with a certain problem of interpretation as to how I should handle this particular subject.

First of all, let me try to divide development problems into macro and micro levels. I will be very brief on the macro level and very blunt. On this level, our major development objective is achieving better quality, greater efficiency, and productivity in the Thai economy and in the Thai society. I would like to ask you directly--How can you help? How can you as a team, through the U.S. government, help us initiate, support, and nurture our national campaign to produce and deliver a greater volume and higher quality goods and services at a lower cost.

The reason we must place more emphasis on quality rather than quantity now than we have ever done in the past is simply that if you take a look at our economic history, or at the history of our economic development, particularly over the last 20 years or during the last four five-year plans, you will find that the major emphasis, or our development strategy, was to provide development services and development facilities for the whole population and in the entire area of the Kingdom of Thailand. The strategy, therefore, is really to bring the Kingdom together and to unite our people into one single national entity. We have done that over the last 20-30 years, and I would like to submit that this process of nation-building has more or less been completed. We have now reached the second stage of our national development. The need now is to emphasize quality to replace the horizontal expansion of development activities by the deepening of our development efforts with more emphasis on quality, efficiency, and productivity.

Perhaps it might be clearer if I illustrate my macro point by discussing cases at the micro and sectoral level. First, our basic development strategy during the last 20 years was to provide the so-called holy trinity of physical infrastructure facilities--namely, roads, electricity, and water--over as much of the country as possible. In fact, by the end of this fifth plan, just over two short years from now, a national highway system will be linking all the provincial capital centers. Rural roads will connect practically every village in the country. Electricity will be available to 93 percent of the 50,000 villages in the whole country. There are a lot of complaints about water, but in fact the government has installed more than 100,000 water projects, some large but, of course, most small all over the country.

PHYSICAL INFRASTRUCTURE TECHNOLOGIES

There are still gaps in various locations. The main problem is no longer the lack of coverage but the quality of these services. Thus we first need physical infrastructure technologies. However, this can no longer be our main priority since most of our development funds in the past have been channelled to support the construction of physical infrastructure facilities. Our strategy will be to shift from the traditional expansion of these facilities.

I would like to emphasize three areas that need improvement. First, we need to improve the existing facilities of the holy trinity. Coverage alone is certainly not enough, and, in fact, can become a burden. Bottlenecks have developed in various roads networks; therefore we need better roads. In fact, we are now going to expressway systems. We do not need a larger electrical power supply, but we must be able to rely on the current electrical supply. We cannot build a technological society with occasional power outages. Computers would be damaged with power phases that go on and off as they do now. The emphasis therefore will be on improving the reliability both of the Metropolitan Electricity Authority and, in particular, of the Provincial Electricity Authority. We also need clean, potable water, not merely more wells or more water projects. Studies have revealed very frightening data on the water quality, but will not go into more detail. So that is the first priority: to improve the things that we have already done or that we should do better.

Second, we should be doing things that we have not done to the extent we should, that is, not only to improve the road system but the transport network and telecommunication system as well. We need to lower transport costs and provide instantaneous local as well as international contact. A technological society cannot be built without a total transport network and telecommunication facilities. We lack an efficient transport network--and I emphasize "network"--that links the highways, which will continue to be the predominant means of transport, to other modes of transport (e.g., waterways, ports, railways) and to silos, grain elevators, and various other kinds of handling equipment. Thailand has suffered deeply from high transport costs which have kept it from gaining 200-300 percent profit margin, not all necessarily profit but also waste margin that we had to pay to move goods, particularly bulky, cheap agricultural products, from farms to consumers. The 200-300 percent margin can be tapped with an improved transport network. Telecommunications and telephones are currently the most critical bottleneck that prevent Thailand from moving from an economically traditional society to a technological society. Thus in the fifth plan, we have allocated the largest amount of development funds for telephones and telecommunications. We hope that within the next two years at least the instantaneous contact with the world network will be completed. In fact, within the year, an SPC program will be completed. It is more difficult to address the internal telephone network, but steps are being taken to improve the situation.

The third area that needs improvements in terms of infrastructure technology is urban problems. Thailand is now fast becoming an urbanized society. Though we still have large rural areas, the degree of urbanization is moving much faster, and we are now facing urban problems. We will need to invest many of our scarce resources to correct urban problems and this will present many problems because these are very costly problems. The more you solve them, the more you drain resources away from the countryside to support urban populations, who have the real political power and influence.

I don't think we can completely avoid spending resources on this, but we hope to spend resources wisely. This can only be done through better management of the urban system: Bangkok traffic, Bangkok floods, water supply, drainage, telephones, environmental pollution. These all cost money, and we need technologies that can improve our productivity and efficiency and, at the same time, lower our costs. I must always emphasize the cost problem.

RESOURCES MANAGEMENT TECHNOLOGY

The second area of technological requirement is resources management technology. We have used the development strategy of expansion over all areas of the country for basic infrastructure facilities, and these, of course, have benefited us a great deal. Otherwise, we would not have this kind of environment after 30 years. At the same time, however, this development process has been costly. The greatest cost has been our rich, or once rich, heritage of natural resources. We have over-exploited and wasted our natural resources. In terms of major natural resources, land resources have been the key to the livelihood of most of our people. The problem now is that we have been cutting down the forests. There used to be tropical forests, but no longer. Of course, these problems need technical solutions by using resource management technology. We no longer can ruthlessly exploit our land.

We have always thought that water is a gift from God for Thailand and free. Now, however, water has become scarce and people are quarreling over it. The problem is more the management of water resources among competing claims. Dr. Anat is our water expert. I don't think that we need very much new technology, just the resources and perseverance to support this effort.

We are now moving from the traditional low-lying paddy land into higher, more marginal lands, where we have run into problems with fertility--soil erosion in the North, soil salinity in the Northeast, and peat soil in the South. Do we know enough about these soils, being lowland people for centuries? I have been participating in some Royal projects that are trying to overcome these poor soil conditions. We have tried to find technologists in this country who know about peat soil, but, unfortunately, I don't think we have as many as we would like to have. But soil science and soil technology are fundamental to the livelihood of a great number of people.

As for forests, Thailand is really a wood culture, but we do not have wood technology. We may have nice wood-carving technology but not the modern wood technology.

We have just discovered oil and gas, and we are determined not to waste these resources as some other countries have done. We are much happier since we have come to terms with some of the more important multinational companies operating here. Our agreement with the Union Oil Company is very, very important as a milestone, and from now on, we will move with other multinational companies. We hope that we will not need to spend as much time and perhaps have better results.

With regard to minerals, we are now suffering from too much reliance on tin. The price of tin has tumbled in the world market, and this has given rise to the problem of balancing our trade deficit. Although we have no alternatives to tin, we have other minerals. We have now started an airborne geophysical survey with the help of the Asian Development Bank and Canada. It is hoped that the data unearthed from this geophysical survey, being done by fixed-wing aircraft and helicopter, as well as data from chemical survey and ground tests, will give rise to a wealth of information that we can use in planning more rational development of our mineral resources. I notice that Professor Themelis is from the Columbia University School of Mines. I would like to take the opportunity to bring this to his attention.

AGRO-INDUSTRIAL TECHNOLOGIES

The third area for technological solutions to our problems is agro-industry. We have wasted our resources and have come to the end of our land frontier. Two major problems face us: (1) the need to improve agricultural productivity on existing land, and (2) the need for modern technology to enable Thailand to achieve industrialized country status within the decade of the 1990s. Each requires elaboration.

Regarding agricultural productivity, which involves food science and food technology, Thailand faces a problem--we have developed through agricultural diversification. We no longer produce rice as a model agricultural crop, although some American leaders still feel that we only have rice to sell. We have diversified our agricultural production pattern by producing a great number of similar important crops--corn, sorghum, tapioca, sugarcane, and a variety of beans. We also have grown tree and fruit crops, rubber, and oil palm. Agricultural diversification is a very unique experience here in Thailand. Yet we come to a point in our economic history when some of the crops upon which we have been so dependent face very serious market constraints. Two very important crops are suffering from severe market constraints: sugarcane and cassava. Americans have stopped eating sugar. Also the U.S. health food industry has become a fast-growing industry and has led the world to reduce sugar consumption at the same time that the European Economic Community (EEC) has seen fit to subsidize sugar exports at our expense.

Worse still, we are now suffering from EEC restrictions on our tapioca exports. The quota will be reduced to 4.5 million tons this year, our production will be 8 million tons, and we still have 2 million tons in stock. We will soon have tremendous surplus problems. We will try to solve these problems through a revised marketing strategy to diversify our market elsewhere other than the EEC. But the economics always dictate how much one can do. Of course, one can subsidize crop production the way the Americans do with their agricultural surplus, but we are a poor country. There is a certain limit to the amount of market diversification possible, but we are going full speed to diversify our market through an export system, not through subsidies but through other means. At the same time, we have to recognize the reality of the situation. We need to do two things: (1) diversify out of tapioca, which is easier said than done, until the price is down below 50 satangs per kilo which will cause a lot of hardship; and (2) try to use technology to utilize tapioca surplus for other productive uses. TISTR is now experimenting on the utilization of tapioca for alcohol fermentation processes, but energy prices are not rising as fast as we thought. I don't know how soon Dr. Smith can come up with a rescue operation with his alcohol project. We are now trying to promote, through our Board of Investments, modified starch investments, but I feel that we need technological assistance to look for better uses of the tapioca product, keeping in mind of course the economics of this effort.

Apart from dealing with the problem of crops, we have to look for opportunities to utilize the promising crops such as corn. After many years, Thailand is now adopting hybrid corn, and with a great deal of benefits to our corn production. We are now producing 4 million tons. There is no question that we should be able to increase corn production to 8-10 million tons in a very short time, but have a problem with alfatoxin. I would not talk about this if you were marketing men, but since you are scientists and technologists, we might as well face it: we need assistance very badly to overcome our aflatoxin problem. Of course, this is only partly a technological question and partly a question of the production, distribution, storage, and handling system. Perhaps we can introduce farm-level grain elevators or small-scale farm elevators to keep moisture below 20 percent economically, or perhaps USAID can help to reduce the interest charges of these facilities. Thus aflatoxin presents a serious problem for our increased production of 10 million tons. Imagine how many people could be employed in the rural areas producing ten million tons of corn. Of course, sorghum has proved to be a valuable alternative to tapioca. Several agro-industrial complexes have tried to help promote sorghum, but it is still too slow. We must find ways to move this project faster.

Regarding soybeans, the U.S. government, in the past at any rate, has not agreed to help Thailand improve its agricultural productivity for fear of Thai competition with American agricultural products. Can you, as technologists and scientists, deliver this message of our need in the United States and overcome congressional resistance to requests for assistance. The United States will not provide assistance for soybeans because the soybean industry in Illinois will be affected. This is a very important point. Please, if you can overcome this resistance on the part of the U.S. government, we can do a lot more together to increase our agricultural productivity.

It is paradoxical--in fact, it is almost amusing--that while the U.S. government stops USAID from providing technical assistance for agricultural productivity, the U.S. private sector has introduced hybrid corn in this country: Continental Grain, Cargill, etc. Who introduced the poultry industry here? Abaaka. Who introduced pineapple technology here? The Dole company of Hawaii. We not only have American companies, but Lever Brothers, I think from England, who introduced cloning technology for our oilpalm industry. This is a very important new development, and I would like to emphasize at this particular juncture that the Minister has emphasized that this country, this economy, is primarily private sector oriented. Most of the forces that have accomplished anything worthwhile have been in the private sector. The biggest problem we now face is how to remove the obstacles imposed by government regulations and rules that are now out of date. For this reason, the entire operation of the public-private sector corporation committee is focusing on ways in which to remove public sector obstacles to private and national development. Two things can help us improve our agricultural productivity: (1) technical assistance through official channels from the U.S. government, and (2) more American private sector involvment in our agro-industrial activities.

Regarding the possibility of Thailand becoming a newly industrialized country within the 1990s, there has been some worry about this prospect here in Thailand. Some of our people are not very fond of becoming an industrialized country. We would still like to retain our agricultural and rural environment. I am afraid that the trends are moving quickly and cannot be suppressed. National income and employment statistics indicate that structural changes are taking place here and with increasing speed. Whether we like it or not, we will become a nearly industrialized country within the decade. The question is whether we can provide the technical solutions needed to enable Thailand to really become a balanced newly industrialized country. I stress the word "balanced" because we are not aiming to become a newly industrialized country like Korea which is very industry oriented, or like Hong Kong or Singapore which are simply island cities. Taiwan is one of the countries that has a more balanced industrial and agricultural structure. I believe that if we do it right, we have the potential of becoming an even more balanced newly industrialized country than Taiwan. I am not talking about Taiwan in terms of politics, I am talking in terms of economics.

We have talked a lot about agro-industrial possibilities already. You might be surprised to learn that the consumer goods industry in Thailand is the most highly developed in Southeast Asia. Why? Because we have a sizable and fast-growing domestic market with reasonable purchasing power. We also have access to neighboring countries without declaring them. Thus Thailand is really a consumer industry center in this part of the world. We have now come to the end of the first phase of our industrialization, of merely fabricating and finishing imported parts and components. In fact, this morning at the economic cabinet meeting we started a very important session on international sourcing policy of automobile parts and equipment. I hope things turn out well. I consider this meeting more important; so I came here to inform you of all the things we have been thinking about. The present technological requirements which, of course, would be carried out by the private sector, need proper policy decisions on the part of the government. With a wise government policy we can accomplish a lot. At the same time, however, the government, just like in agro-industries at agricultural level, is in a position to provide some basic infrastructure facilities for technological development here in this country.

In agricultural productivity and agro-industries, we hope that our biotechnology center will be helpful in many ways, not only in terms of genetic engineering which might perhaps come a little bit later. In terms of parts and equipment in strengthening our industrial structure, we need engineering industries, and in the engineering industries we need basic metal technology. Thus in the fifth development plan, we have supported the mineral science and technology initiative with a metal technology center.

Apart from basic metals, we certainly must look for more diversified fields. I'm glad to report that, after many years of stagnation in the electronic industries here as compared with other countries such as the Philippines or Malaysia, the Board of Investments has supported a number of large-scale electronic industries, employing thousands and thousands of Thai workers, 80 percent of whom are women. We hope these electronic industries will lead to computer technology which would be another basic element of our new industrial structure. Thus electronics and computer technology will certainly be a very high priority.

Last, of course, we have discovered oil and gas. We are developing our petrochemical industries and chemical fertilizer complex. Because we are developing plastic products, we need petroleum technology, gas-related technology, and chemical technology. All of these have been listed in the fifth development plan, and all have been major priorities of the Ministry of Science, Technology, and Energy. The National Economic and Social Development Board is also supporting all of them very firmly and very conscientiously.

We hope that with your visit to Thailand, you will be able to support the process of translating paper phrases into real action programs. Thank you very much.

Remarks

John Gunther Dean
U.S. Ambassador to Thailand

I would first like to apologize for not having been here earlier. But I would also like to explain why I was late because it bears directly on what we are doing here today.

The United States is supporting at the Asian Institute of Technology a remote sensing program to which we have already contributed $4.5 million and will contribute another million in the next year or so. We were fortunate in that Her Royal Highness Princess Sirindhorn Somdej Phra Dhep showed an interest in this program when I was up in Chiangmai in January. She said, "I'd like to know more about remote sensing, about map making and map reading. How can remote sensing serve our nation?"

Within four days, I was back in touch with her and said, "We can arrange a special program for you. Tell us when you can do it." Although the court is in mourning, she started a training course this morning and will go three times a week for this whole month to study remote sensing at AIT.

The impact that this will have on Thailand is tremendous because she is one of the most beloved people in this country. It will have an impact particularly on young people as they see a member of the Royal Family learning about science and technology--the impact of seeing her and following her example will be truly very important.

Remote sensing is an American project on which we have worked with AIT over the years. I wanted therefore to have an American presence when Somdej Phra Dhep started her first course. This explains why I was late, but it had something to do with science and technology.

Let me now address especially my fellow countrymen. For most Americans, our relationship with Thailand really starts with the Vietnam war, and that is very wrong. I will try to set into a broader framework why you are here, why science and technology deserve attention now, what is the reason behind this, and how we got here. Now, I was a very poor science student in school, so I want to come at this from another angle, something that I do know which is foreign affairs.

American involvement in Thailand goes well back into the nineteenth century. How many of you from the U.S. National Research Council know that Thailand is the country with which we have had the longest relations in Asia? Wouldn't you have thought it was China? Or Japan?

No, the first country in Asia with which we had a relationship was Thailand. One hundred and fifty-one years ago, well before Commodore Perry ever sailed to Japan or our relationship with China was established, our involvement with Asia started here.

During the nineteenth century, the United States was not merely here but played an active role here--an educational and even a scientific role. There was a reason for this. If you look at a map of 150 years ago, all the countries in this region were under someone's protection. Only one area was free and independent, and that was Thailand, then called Siam. We were also independent. We came here and played a role in the nineteenth century in bringing education to women, in English language training, and in modernizing education. This has long been forgotten in the United States. But those of you who know your Thai history will know about it. Who was the first person to introduce anesthesia in medicine here? Dr. Bradley did this in the nineteenth century. Does anybody know who developed the first Thai typewriter? It was also an American in the nineteenth century. We were involved here, making a difference, having an impact more than 100 years ago, well before we formally exchanged ambassadors, who come and go and are very quickly forgotten. I mention this so that you will see that you fit into a long history, you who have just come from all over to join this team.

As I read the annals, I saw that many Harvard professors came here. I'm sorry they weren't science professors; they were law professors, but they were also part of this history. They came to help the King of Siam renegotiate the unequal treaties. We were the first ones to give up these unequal agreements, and it was Francis Sayer, the son-in-law of Woodrow Wilson, who convinced his father-in-law that we should relinquish this special treatment. That was in the 1920s, and it was another important landmark in our relationship. Now, I'm going to work you in.

In 1945, the Thai found themselves on the wrong side of the war. But one of my distinguished predecessors, Charles Yost, who was also quite a scholar in Greek poetry, wrote a rather important telegram in 1945 to the secretary of state in Washington. He said, "Treat the Thai as if they were neutral."

When the Thai went to Singapore, the winning countries, the victors, were very hard, to a man, on Thailand. There were demands: deliver so much rice and do it free as reparations, because Thailand was on the wrong side. There were 51 more paragraphs waiting to be imposed on Thailand as well. But, as I like to remind people, the United States said to its friends and allies, the fellow victors of the war, "Treat the Thai as if they were neutral." What happened? The rice was paid for in cash, and the 51 paragraphs, which were to be imposed on Thailand, including occupation, were published but never carried out.

Then followed a period that was very much of a honeymoon for the United States and Thailand. Thailand actually left the policy of balance which she had maintained for centuries, trying to stay out of the orbits of greater powers, and we became very friendly. One of the first technical projects that we did here was building the Friendship Highway. We brought the Corps of Engineers here and the Thai remember this. The Friendship Highway was the first long paved highway in this country. Some 30 years ago, it served as a standard. Very, very quickly, the Thai understood exactly how this work should be done. Having let us be the catalyst and set the standard; from then on the Thai built their own road network. Today, if you go and look at it, you'll see one of the best infrastructures in Asia and maybe in the entire developing world.

I would also like to remind some earlier speakers that for many years, in the 1950s, the 1960s and the early 1970s, we were in the forefront in giving large amounts of money--hundreds and hundreds of millions of dollars--to Thailand. That was at a time when $100 was really $100! We built the Friendship Highway for something less than $10 million, I believe. The whole thing would cost a fortune today. We were involved in agricultural and feeder roads in every region too, and also in security. I mention this because it is this involvement that you are here to continue and renew.

In 1975, with the events that had occurred in this part of the world, there was a cloud over the Thai-American relationship. Then, as we strengthened this relationship again after a period of about four years or so, we became progressively more important in the security field. Now it is very important to me that the United States maintain a balance--that we be involved not only in security, but also in technology, science, and economic advancement. That is terribly important because I know the funds that are available to me from the American government. I know a portion needs to go into security matters and another portion goes for modernization and progress. I feel we need to be involved in these nonsecurity fields as well so that we have a balance. We must relate with the whole of Thai society as we have done for 150 years--not with one sector only, but with all sectors. I tell my American friends who have come here that this is one of the largest diplomatic missions we have anywhere. My staff is counted in the hundreds, and we interact in every field. And at this point, I want to see us stress certain nonsecurity fields in the civilian area.

Now I would like to point out some particular things that I have seen in the area of science and technology development. Dr. Johnson, a member of your team in medicine, reminded me that we have played a major role in that field over a long period of time. The Rockefeller Foundation started its involvement here more than 60 years ago, supporting Thai medical education. Today, distinguished people in the field of medicine will tell you that in clinical practice, the Thai are on a par with the western advanced countries. Today, there is no need for outside help in the clinical field, but now research comes to the forefront. Here the Thai want help, and here we can assist. This same process has happened in civil engineering and in agriculture. Now it is the time to start a new phase of cooperation at a new level.

The United States has always played one role in this part of the world and especially in Thailand--we have been the catalyst, the sparkplug. I do not say that the United States has to be the <u>only</u> foreign country working here, quite the contrary. But I think we can lead the way in science and technology, and in fact we <u>are</u> leading the way. Since Dr. Briskey has arrived and Bob Halligan has gotten all these things started, my colleagues from other embassies, other ambassadors, have been saying "How are you doing it? We're also interested." I feel fine about that. There's no need for us to be exclusive. As a matter of fact, if we ask our Thai friends they wouldn't want it that way either. They do, though, want us to be in the forefront, to move ahead so that others will follow.

This has been the case here in the economic field. In many, many areas we have been the spark, the catalyst. It is true that the Japanese have come in and replaced us in many areas. In terms of quantity, they are very important. The Common Market has come in as well. But that is after we have gotten things going. Today, in science and technology, I want us to play that same leading role.

Fortunately, it happens that today Thailand has a minister ready to seize this project in science and technology. He has been able to make people sit up and take notice of it. This is one of his major achievements. He has made people in Thailand aware that there is a need here, and it requires action. I give him full credit for this. Then there came the director of USAID, Bob Halligan, who had the vision to say, "Let's not do things the way we have done them for the last 30 years. Let's see how we have to revise our program to work for the future, not the past." He then hired and brought out a man of stature and ability, Dr. Briskey. This has permitted us to move to the front in science and technology.

Why should we move in the field of science and technology? Why are we doing so much in Thailand? Why do I sound sometimes more like the Thai ambassador to Washington than an American ambassador to Thailand? Well, I don't want to sound like former Secretary of Defense Charlie Wilson, who said some years ago that "what was good for General Motors is good for the country." But I do believe something very close to that, that what is good for Thailand is probably also very good for the United States. I believe that and I'll try to explain why.

As you look around the globe and see countries striving to develop themselves, you see that this country probably has one of the best chances of making it, and it is doing that using a system that is similar to our own.

- The Thai enjoy many of the freedoms that we enjoy, both in the political field and in the economic field.
- The country has very little debt compared to many other countries around the world.
- The people have open minds and are ready to evaluate, adapt, and accept new ideas.

So, if we can help them to modernize here in Thailand, and do so in a way in which they maintain their own system, style, and freedoms, this is in line with our national interest as well.

Now, you know what you are here to do better than I do. What I have tried to offer is some of the background, some of the flavor of this place, some of the history of which you are now part. I hope you go back as enthusiastic as I am about the future of this country. I am enthusiastic not only because it is a rich country, rich in resources, but also because, as you will find out as you stay here, it is a country rich in people as well. They are extremely able people. They do not toot their own horn as some others do, but once you get to know them, you'll see their abilities and their vision.

We have a long history of cooperation in many areas over many years. I hope this workshop will help to define in what areas we will be working together in the years to come. Thank you.

APPENDIX D

Conceptual Framework for Thai-U.S. Cooperation in Science and Technology

Ernest J. Briskey

INTRODUCTION

Thailand has had an enviable record of socioeconomic growth over the past two decades. The gross national product has grown at approximately 7 percent per annum, while the manufacturing sector has been increasing its output by about 10 percent per year. A vibrant private sector is emerging, and in current terms, manufacturing now exceeds agriculture in its percentage contribution to the gross domestic product. Yet 70-75 percent of the country's work force still works in full or in part on farms. Although the agricultural growth rate has been an enviable 5 percent per year over this time frame, about 90 percent of this growth has been due to an increase in arable land. Thailand is now the fifth largest food-exporting nation in the world, although its trade deficits are mounting because of the substantial importation of manufactured goods. Last year, Thailand imported more than 70,000 million baht in product value above the value of its exports. Agricultural exports, last year, represented about 60 percent of all export earnings. Agriculture (raw production) was also responsible for about 21 percent of the GDP.

An effective family planning program has enabled the annual population growth rate to drop from more than 3 percent in the 1960s to less than 1.9 percent today. The incidence of poverty has also been halved during the last 20 years.

The labor force is expected to continue to increase at the rate of 3 percent per year during the remainder of this decade which means that the work force will have an annual incremental increase of 1.3 million by 1990. While current "open" unemployment statistically represents only some 2 percent of the work force, underemployment may attain 15-20 percent and seasonal unemployment some 20-25 percent. Serious unemployment and underemployment have also been registered among certain categories of the educated. The 1980s will witness new and significant problems in the job sector, which will require sustained growth in agriculture, accentuated development of nonfarm and off-farm employment opportunities, and a restructuring of sectoral priorities within higher education systems so as to enhance, rather than detract from, national development performance.

Thai leaders recognize the growing need and potential for incorporating science and technology to solve national problems so as to sustain agricultural growth, and create new science and technology-based industries. We have attempted to assemble inputs from virtually hundreds of Thais regarding their assessments of the problems limiting development and to which science and technology could contribute. These inputs relate to the scope, direction, and nature that many Thai colleagues believe should be given to the U.S.-Thai science and technology program as it is conceptualized and initiated in its final form.

PROCESS OF OBTAINING THAI INPUTS

The gathering of input has itself been a process that perhaps warrants some elaboration. At the outset, we drew heavily on the guidelines and strategies of USAID and benefited from the inspired, dynamic leadership of our own ambassador, The Honorable John Gunther Dean, who looks to us for a model program that can serve as a qualitative driving force for the industrial development of Thailand. We have also benefited from summaries of recent conference discussions in Pattaya involving about 80 scientists and technologists, as well as 500 scientists and technologists who Minister Damrong brought together for the 1st National Science Congress. We have also had some summary input from a recent seminar at the Thailand Institute of Scientific and Technological Research (TISTR).

The USAID Mission in Bangkok, under Mr. Halligan's able leadership, has also taken several positive steps toward soliciting or obtaining input. Several studies have been commissioned, the highlights of which you will receive this afternoon. These studies, led by the most qualified Thai leaders in their fields, have, in themselves, involved input from over 70 leading scientists and technologists from industry, government agencies, and universities. A two-day discussion workshop was also held with about 25 Thai leaders during the middle of May. Ad hoc user groups in medicine, engineering, and business have also had input. And, of course, this distinguished National Research Council panel, as part of this process, has come to Bangkok to talk to Thai counterparts and assist USAID in the formulation of the program. Our session today, meetings on Tuesday and Wednesday at universities and industries, and an industry/university/government forum on Thursday, involving 50-100 leaders, will give significant input to panel deliberations.

I mention this process to indicate the extent to which we want to obtain maximum input and innovation without restriction, while at the same time giving you the benefit of the input of those who have preceded you. In bringing forward a framework for program conceptualization, however, we do not want to suggest that decisions have already been made on either the Thai or American side; nothing could be further from the truth.

It is true, however, that time is of the essence. We have our own USAID deadlines for strategy development, program conceptualization, and project identification, and those deadlines occur later this month. To obtain maximum assistance from the American and Thai leaders that we have with us this week we are presenting the state of our conceptualization, as it appears to coalesce logically, on the basis of input to date. We now ask for your reaction; urge you to change what should be changed, to maximize innovations, to add and subtract; and to seek your embellishment of and direction on points with which you concur. Through this process, we hope you will be able to move more quickly into helping us develop the strategy and road map to assist this country in achieving its goal.

And so it is in that spirit that I speak to you this morning. These are not my own personal views, rather, they are summarizations to date of studies, discussions, and conferences involving many Thai and U.S. views.

PURPOSE

The major purpose of the Thai-U.S. science and technology program is to maximize the potential contributions science and technology can make to the sustained, broadly based development of Thailand. The sectors that will benefit include agriculture, forestry, fisheries, health and health products, agribusiness, metallurgy, construction materials, and computers. Since this program will be only one of the actors--and a small actor at that--within the total scheme of development, we want it to make a qualitative difference in Thai development. In this program, science and technology will be used to resolve problems, both positive and negative ones (remove obstacles and develop solutions that create opportunities). Coincidentally with the solution of problems, we want to strengthen the viability of the science and technology community, strengthen the infrastructure and strengthen the problem focus of technical people. In doing so, we will place the local science and technology communities (public and private) in a position of strength so that local and foreign investors will see them as a vehicle for developing new technology-based industries, or quickly adapting technologies transferred into this country. While developments in other countries must be viewed descriptively and not prescriptively, it is still worth noting that there has never been a developed country in the world that has been able to skip over that second need--the building of its science and technology infrastructure. The fundamental assumption on which the program is based is that there is an underutilized role for science and technology in meeting opportunities or removing obstacles to increasing investment in the sustained growth of productivity and incomes in Thailand.

A guiding principle for everything that is undertaken is the need to solve problems or create opportunities for improving productive efficiency or developing new value-added products.

SUMMARY OF OVERALL PROBLEMS

Our summary of problems, solvable in whole or in part by technology, may be categorized as those overall in nature and those of a specific development nature. From an overall standpoint, I would list these problems as:

1. Employment

The 15-59 year age group is increasing rapidly, at about 3 percent per year for the rest of this decade. The educated and uneducated underemployed (i.e., those employed for less than US$15 per month) will reach 20 percent and seasonal unemployment will reach 25 percent.

2. Use of Indigenous Science and Technology Talent

Thailand lacks a model for building on or using its indigenous science and technology talent. The people of Thailand can see the benefits that science and technology have brought forth for some of their regional neighbors, but they can also see some of the problems too. They know that one country's development is not necessarily a prescription for another's. The needs are different here than abroad, but then the opportunities are also. Notwithstanding major efforts in training overseas and in Thailand, science and technology professionals remain uncoordinated as well as unlinked to and unfocused on development problems.

3. Distribution of Income

The distribution of income among the Thai people is a limiting factor to sustained development among most of the non-Bangkok population who are virtually all in rural areas. Underemployed people do not create a viable market for anything.

4. Depletion of Natural Resources

The stocks of natural resources, neglected for centuries, are now being overexploited for the short term.

Adverse environmental effects are also emerging in the form of forest depletion, soil erosion, air and water pollution, and coastal zone mismanagement.

On these bases, we can conclude that the major issues and objectives which can be resolved by or benefit from science and technology are:

- Employment and equity
- Productivity

- o Environment
- o Resource use
- o Health

CRITERIA FOR SETTING PRIORITIES

Many specific science and technology-related problems or constraints exist. Important criteria for selection of priority areas and key problems include:

- o Relevance to development. Will the solution to the problem take advantage of existing unique or abundant natural resources? Is the solution already in a crucial stage of maturity, so that progress will be noticeable with a finite input? Will solving this problem provide badly needed linkages among the "producers" and "consumers" of science and technology, i.e., the universities, the government, and the private sector.

- o Availability of human resources and their development. The major constraint to undertaking science and technology initiatives in Thailand is the lack of sufficient qualified manpower at all levels, from technicians to postdoctorates and experienced research directors. The transfer of knowledge and expertise from abroad is an essential process in strengthening science and technology.

- o "Cutting edge" advantage and unique local character (tropical environment and long coastline, abundant supply of solar energy).

- o Possibility of international or bilateral cooperation.

- o Integration with culture and environment.

SCIENCE AND TECHNOLOGY-RELATED PROBLEMS

Science and technology-related problems can also be classified as general and specific. General problems include (1) focusing the educational system, and (2) building a capable science and technology force. The higher education system is underutilized, and, for the most part, we are told that it is exclusively discipline oriented, not problem focused. Linkages with industry are poor, and industry must therefore buy technology from abroad as it does not seek or rely on indigenous sources of science and technology talent.

Thailand needs a highly capable science and technology force if it is going to acquire knowledge and expertise and transfer or adapt technologies intelligently. Programs are needed to retain their capable scientists.

Specific science and technology problems include the following:

- Tropical production of food and industrial crops in Thailand requires increased productive efficiency, new products, and quality. Classic approaches to productivity are too slow and need the benefit of relevant biotechnology. New and alternative crops are needed for both import substitution and export, and all require quality, quality control, and efficiency.

- Animal husbandry need enhanced efficiency and improvement through such approaches as embryo transplant. The elite dairy herds that could be developed in a year would take many years to develop by conventional breeding programs. It is thus possible to institute genetic improvement and disease control programs for cattle or water buffalo which could not have been contemplated just a few years ago.

- Vaccine production and rapid diagnostic techniques can be speeded up dramatically by the adoption of biotechnology techniques.

- Integrated livestock and crop pest and disease control need to be updated and enhanced through biological control, that is, through biotechnology.

- Freshwater fish production must be expanded. Recent developments in biotechnology have made possible the production of hybrid varieties of fish and crustacea in numbers required for seeding high-producing systems. Fish diseases must also be controlled.

- Value-added processes in food and engineering industries need advanced technology. Biostorage, fermentations, and extrusions all benefit from application of biotechnology, as does the lethal processing of mesophyllic spores. The biotechnology of milk handling--the membrane separation of milk constituents from the water--has direct applicability in tropical environments.

- Energy conservation and production technologies need enhancement. Oil imports represented 4 percent of the total imports in 1970 and 33 percent in 1980. In 1970, oil imports consumed 5 percent of the export earnings, but 50 percent in 1980. Biotechnology can be used to convert biomass by recycling organic wastes and producing energy from renewable biomass sources. Both traditional and new fermentation procedures can benefit from bioengineering processes.

- Mineral and hydrocarbon resources are exported too much as raw materials. Deposits of tin, tungsten, and rare earth metals appear to be rich and in good supply here. Thailand has rich deposits of high-quality dolomite, which can be developed for use as ceramic material. Badly needed secondary materials is missing because of a lack of indigenous science and technology capability. This includes forging and casting technologies adapted to Thai raw materials.

- Electronics and information science and technology must be developed to solve local development problems and to contribute to the world market through export of selected components of hardware and software which can be produced at advantage either in labor or material costs.

ANALYSIS OF THE DONOR SITUATION

As we look at the total donor situation in Thailand, it becomes clear that the Thai-U.S. association is expected to make a qualitative difference in Thai development.

SUMMARY OF REQUESTS MADE BY GOVERNMENT AND SCIENCE AND TECHNOLOGY LEADERS

Royal Thai government and science and technology leaders have expressed their hope that the Thai-U.S. program will:

- Make a qualitative difference in the industrial development process, particularly in industry (including agribusiness and health products).

- Enrich new or improved processes.

- Support new research approaches (e.g., biotechnology applications) that will accelerate results yielded by classic approaches.

- Motivate and improve science and technology capacity.

- Bring focus to institutions most capable of resolving the priority problems.

- Institutionalize the process of working together for industry development goals.

- Improve research organizational structures.

- Create long-lasting linkages between science and technology-based organizations in the United States and Thailand.

PLANS FOR OBTAINING ADDITIONAL INPUTS

Before the project paper is finished this summer we expect to personally query about 400 additional Thai scientists and technologists regarding their views of problems and their current constraints to resolving problems. We will also interview their supervisors (research administrators) whether academia, government, or industry.

PRIORITIES BASED ON INPUT TO DATE

A culmination of all input we have to date leads to three main areas of science and technology:

1 Bioscience and biotechnology
2 Material sciences and metal and ceramic technology
3 Electronic engineering and information technology.

These areas were selected for their potential to be readily commercialized, to generate increased employment, and to enhance incomes, especially in non-Bangkok areas. We visualize that these areas will support three parallel phases of industrial development.

The first phase will focus on bioscience and biotechnology, and emphasize:

- o Sustaining food and fiber production through intensification and the availability of new technology to enhance incomes and export earning potentials.
- o Supporting food and fiber production and processing industries, thereby creating expanded employment and income distribution.
- o Expanding and improving biomass conversion, energy substitution, and resource management to create new industries and employment and reduce oil imports and foreign exchanges.
- o Improving human and animal health through vaccine and biomedical development so that human productivity can be increased and suffering reduced. This would concurrently, aid the development of a strong animal industry for domestic and human use.

The following components would then be applied to each point of emphasis:

- o Research and development
- o Quality control
- o Human resource development
- o Strengthening support activities.

Research and Development

Application of the research and development component to, for example, bioscience and biotechnology would be guided by individual industry advisory councils and would focus on "critical cells," (people, equipment, and support organized to focus multidisciplinary attention on specific target objectives). Many of these cells are already in place, and they will be coordinated by the universities, institutes, and quasi-private industries. Where inadequate or insufficient numbers of people exist, some may be added. The classic approaches will be supplemented with relevant applications of biotechnology, and focus on problems. The following program and project areas are examples of the kind of problem or opportunity that may be selected:

- Enhanced food and fiber production

    - The use of tissue culture and related technology for increasing yields and producing disease-free or disease-resistant strains of, for example, rice (yield), mung bean (disease resistance), maize (yield and disease resistance, especially against aflatoxin), sorghum, soybeans (yield and disease resistance), fruit (yield and disease resistance), fuelwood trees, and rubber trees.

    - The use of embryo transplant to increase, for example, milk yields and dairy production.

    - The use of hormonal spawning to increase fishery yields and reduce fish disease.

- Expanded biomass conversion and food fiber processing

    - Cassava utilization
    - Meat and vegetable processing (extrusion, fermented foods)
    - Biomass conversion--hydrolysis or fermentation of woody legumes, water hyacinth, and water fern
    - Compost and biogas production

o Improved human and animal health. Development of vaccines, monoclonal antibodies, and biotechnologies for use in the treatment, or prevention, or rapid diagnosis of malaria, dengue, and respiratory infections. The new biotechnology capabilities will enable the "critical cells" to support special industry-oriented programs in areas such as:

- Tissue culture to improve yields and disease resistance in certain crops.
- Embryo transplants to rapidly upgrade breeding programs to increase milk production
- Special culture preparations and improved technology for biomass conversion by fermentation on an industrial scale

-- Cloning rubber trees for higher yields
-- Bulk production of elite strains of plantlet for reforestation
-- Biotechniques to reduce the impact of fish disease, enhance water quality, and develop new products
-- Biotechnological innovations such as membrane separation for milk processing and extrusion technologies for new food and feed product development
-- Biotechnology to enhance vaccine production.

Quality Control

Each relevant problem area will also be pursued from the standpoint of quality control needs and marketing and packaging aspects. This first phase will focus on reforming and strengthening the TISTR so that it can lead the nation in development through significant contributions to quality control, processing, and packaging expertise.

Human Resource Development

To accomplish these objectives through creation or strengthening of "critical cells," human resources must be tapped and supported. The following methods are suggested:

o Short-term training will be provided to enhance methodologies, techniques, and approaches taken by "critical cells."

o A "Science and Technology Corps" project would inaugurate and test experimentally how effectively such a corps could enhance the methodology, quality, and focus of research and development efforts in the selected problem areas, and upgrade science and technology efforts generally. About 20 scientists and technologists would be selected for two-year commitments and, possibly, life-long linkages.

o Special training in computer applications will be given to the critical cells and science and technology institutions involved.

o A leading institution would be selected for upgrading the freshman and sophomore programs in science and engineering to serve as tangible evidence of the value of investments in quality education programs. A trial program would also be inaugurated to bring advanced science and technology into high school curricula for gifted children to attract them to the enhanced opportunities in science and technology education.

Strengthening Support Activities

o Professional societies. Special activity support would be provided to the Science and Technology Society and the Agricultural Society to serve as models for creating enhanced interactions between industry, universities, and government.

o Science and technology publication series. A science and technology publication series would be initiated for symposia, monographs, conferences, and textbooks.

o Science and technology documentation. A documentation center model in the "life sciences" would be initiated at a leading university.

o Computer linkages to technical data bases would be supported. We also expect to create and support "developmental critical cells" in materials science and computer science during the first phase which will parallel the biotechnology focus. Further support would be directed into these areas during phases two and three.

PROJECT ORGANIZATION

The research and development component will be headed by the Permanent Secretary of the Ministry of Science, Technology, and Energy, who will act as chairman. The Permanent Secretary of the Ministry of University Affairs will serve as cochairman.

The research and development program will include designated research funds for specific "critical cells" as well as funds to initiate the first Thai competitive research grants program. This program will be based on expert review of proposals most relevant to the development problems. A model research award system will also be initiated to recognize and retain excellence.

SUMMARY

In summary, the input we have received to date has led to the following initial conceptualization of a Thai-U.S. science and technology program:

- Support would focus on solving problems or eliminating constraints to development that can be addressed through science and technology, and, coincidentally or simultaneously, on building or strengthening the capacity of the science and technology community as a resource for development. The problems or constraints will be identified by Thais, and will not be given priority by U.S. participants.

- First priority will be given to the biosciences and biotechnology areas because the results are most needed by the agriculture and agro-industries, as well as by the energy, chemical, and medical industries. Products can be produced immediately, and industries developed the most quickly. The infrastructure is most nearly in place--people have been trained, facilities are available, markets are known, and government organizational entities have been created.

- o Emphasis will be put on "critical cells." The critical cell components must have people, equipment, supplies, and essential support, although they may not all be located at one institution. The institutions may be universities, institutes, ministry laboratories or industries. A portion of the support to critical cells will be designated funds for specific solutions, while a small amount will be set aside to encourage the establishment of a Thai science and technology grants program. An "expert review panel" process will create competition for funds, based on ideas, initiatives, and productivity.

Other components receiving emphasis include:

-- TISTR quality control and packaging programs
-- Human resource development
-- Strengthening of professional societies and documentation.

- o In phase one, "developmental critical cells" will be supported simultaneously to initiate action and stimulate development in the areas of materials science and electronic engineering. Somewhat similar, although probably not as complex, programs will be initiated in phases two and three to follow.

We realize that the total process of using science and technology to enhance industrial development involves many other factors than the ones discussed in this summary. We have not as yet addressed, for instance, the whole area of "demand factors," namely, the creation of incentives by which farmers, businesses, and all government departments involved will work together effectively to implement the new technological developments and to obtain the related goals of increased employment, better income distribution, more environmental protection, and optimum research management. We ask you to consider these points as well, although the demand questions are being addressed by other programs and by other components of this present program.

For the purposes of this workshop, we ask that you give primary attention to the supply side questions we have addressed in this paper. Specifically, we ask your assistance in the following areas:

- o The identification of the elements of a successful strategy for a Thai-U.S. science and technology program. This paper summarizes elements thus far conceptualized as a result of inputs to date. We ask you for your additions, deletions, or embellishments to these elements.

- o Combination of the resulting elements into a coherent and concise strategy document.

- o Input on how the resulting strategy document can be used to develop the project identification document for phase one and the terms of reference for the other project phases to follow.

These items can be quickly stated, but they will require very hard work to complete during the brief time of our workshop. We appreciate very much the efforts you and your Thai counterparts are providing, and we also hope very much for every success in your vitally important endeavors.

APPENDIX E

Remarks of the Workshop Chairman

Sanga Sabhasri
Permanent Secretary
Ministry of Science, Technology, and Energy
Royal Government of Thailand

It is indeed my great pleasure to join you here today as chairman of this afternoon's session. It has been exactly 11 years and 11 months since the U.S. National Research Council took part in the workshop on science planning and policy which was organized in Bangkok in 1972. The chairman of the U.S. panel was Professor Harrison Brown, former foreign secretary of the National Academy of Sciences. A panelist was Mr. John Hurley, the present BOSTID director of the Board on Science and Technology for International Development and a professional staff associate at that time. If Professor Harrison Brown were with us today, he would be tempted to write Thai Science Revisited, and I would enjoy reading it as much as I did his book, The Human Future Revisited.

Having served as a member of both the advisory panel and evaluation mission to the Resource Systems Institute of the East-West Center, I had an opportunity to work closely with Professor Brown, the Institute's director. At the meeting of the International Council of Scientific Unions in Athens, Greece, in 1978, I told Professor Brown that the seed that was sown in the Thai soil in 1972 has germinated. It is a seed of science policy. Today we are happy that Professor Franklin Long, Director of Science Policy, Cornell University, has come to see the NRC seed, which has now turned into a seedling. Let us hope that Professor Long and his American colleagues will help to accelerate the growth of the science policy seedling to reach the flowering stage. Of course, I rest assured that with the fertilizer supplied by USAID, the blossom of the tree will finally produce fruit to transform policy into not only activities such as workshops, seminars, and symposia, but also action programs and projects.

Let me quote Dr. Brown's speech made at the workshop on July 4, 1972, in Bangkok. He said, "We all know that when we look at the world from purely technological points of view, hunger and deprivation are inexcusable and we all want to apply science and technology to the task of accelerating development."

I was not aware of his words at that time because I was too junior to be invited to attend that workshop. However, during the workshop, several of the U.S. participants came to see me at Kasetsart University and discussed this matter at some length. Nevertheless, Professor Brown and I happened to have the same viewpoint.

My opportunity arose in October 14, 1973, during an upheaveal in Thailand. I wrote a letter to a member of the Drafting Committee on the Constitution, proposing that there should be an article in the Constitution proclaiming that the state should apply science and technology to the development of the country. Fortunately, my proposal was well received by the Drafting Committee and later adopted by the National Assembly. This letter is now in the Parliament's archives. If the past 10 years are counted as history and one presumes that the Constitution is the supreme law and policy of the land, you may judge for yourself that we did establish our top policy on science 10 years ago.

I would like to speak further about the 1972 seminar. It recommended four points, and one of them should be repeated here. It was recommended that the country have an effective government administrative structure capable of defining, planning, and implementing the national policy on science and technology for economic, educational, and social development. The workshop, however, did not touch on the idea of establishing this at the ministerial level.

Now it may not seem appropriate for me to mention this matter at this time since we are discussing a conceptual framework for a Thai-U.S. science and technology program. However, having read several reports, I can see that the formation and the role of the Ministry of Science, Technology, and Energy is still not clear to many people.

Let me humbly start with the fact that the idea of setting up the science ministry was not clearly stated elsewhere before 1975. Based on my experience with international associations such as UNESCO, Association for Scientific Cooperation in Asia, and the Pacific Science Association, and my observations of our neighboring countries, I felt that we must establish a science ministry in order to plan and execute our science program. Upon my return trip from Kuala Lumpur after attending the meeting on science policy sponsored by UNESCO in November 1975, I proposed to the Executive Committee of the Thai National Research Council that we must have a management system or organization, if we wanted to implement science policy and to accomplish our plans and reach our targets. In addition to the required number of scientists and supporting facilities, I also proposed that that organization have a ministry status so as to have a voice in the Cabinet and extend the role of science and technology to economic and social development with full authority as well as to gain the attention of the Prime Minister and the budget planners.

It was fortunate that through a series of two national seminars which I chaired in February 1976 and in July 1976, the idea of establishing a ministry of science and technology was well received. Finally, the NRC Executive Committee approved our proposal to form a subcommittee on science policy and planning. I then invited an expert in the field of public administration, particularly on organization and management, to chair the subcommittee while I myself served as vice-chairman. That expert was Professor Choob Karnchanaprakorn, later appointed the first Minister of Science, Technology, and Energy. The subcommittee met 20 times before submitting a report entitled, "The Administrative Reform System of Government by Introducing Science and

Technology Policy and the Establishment of a Ministry of Science and Technology" to Professor Sanya Dhamasakdi, President of the Privy Council and Chairman of the NRC Executive Committee in 1976. Finally, it was submitted to the Cabinet in March 1977 and adopted by the Parliament in March 1979.

I have given you the background of development of our Thai science policy since the meeting in 1972. The success in establishing the Ministry is not due to me alone, the names of many people in this room have been gratefully recorded in the documentation published by NRC and the ministry annual reports. I would like to make known to you our concepts of science and technology at the outset so that all of you who have come from afar to consult with us and assist us will know the background.

Now that Thailand has established a Ministry of Science, Technology, and Energy, there is no need to spend more time on the administrative structure. Thailand has an abundance of natural resources, bioresources, as well as mineral resources. Thailand has large manpower in the areas of science and technology. More than 12,000 men and women have graduated from U.S. universities with M.S. and Ph.D. degrees. They are now staff members in universities, officers in several ministries, and employees in the private sector.

From today onward, we have decided to embark on advanced technology: biotechnology, material science and technology, and electronic and computer technology. We are looking forward to cooperating with advanced nations like the United States, Japan, Canada, United Kingdom, and others. It is true that the United States is the first nation to sign a formal science and technology agreement with Thailand. This was done in Washington, D.C., in April 1984, and was witnessed by Prime Minister Prem Tinsulanonda, Minister Damrong Lathapipat, and President Ronald Reagan. Under the dynamic leadership of Minister Damrong Lathapipat; an energetic ambassador, John Gunther Dean; a farsighted man with understanding of our scientific community like Dr. Robert Halligan; and also an industriously intellectual Dr. Ernest J. Briskey, may I appeal to the United States mission led by Dr. Frank Long that there not only be activities like workshops and seminars, but also long, continuous, and active programs and projects.

APPENDIX F

List of Background Papers

- "Constraints to Thai Development: ~~The~~ Role of Science and Technology"
  Anat Arbhabhirama, Asian Institute of Technology

- "Key Problems in Science and Technology" in Thailand
  Yongyuth Yuthavong, Faculty of Science, Mahidol University

- "Status of Science and Technology in Thailand"
  Harit Sutabutr, Faculty of Engineering, King Mongkut Institute of Technology (KMIT)

- "~~Status of~~ Computer Laboratories in Thailand and their Needs"
  Srisakdi Charmonman, Faculty of Computer Engineering, KMIT

- "Review of Studies on Organization of TISTR"
  Malee Suwana-adth, Director, National Center for Genetic Engineering and Biotechnology

- "A Perspective on Life Sciences and Biomedical Sciences"
  Natth Bhamarapravati, Rector, Mahidol University

A limited number of copies are available from the Office of Science and Technology. U.S. Agency for International Development, Bangkok, Thailand.