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USAID Assistance For
Remote Sensing in Thailand:
An Evaluation

Resources Development Associates

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Remote Sensing in Thailand:
An Evaluation

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by

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Preface

This evaluation has been prepared by Dr. Robert Muscat, Independent Consultant and Mr. Kenneth Craib, Dr. Richard Ellefsen and Dr. Matthew Willard of Resources Development Associates, Inc.

The evaluation was conducted in Bangkok, Thailand during May 1983. The evaluation could not have been completed without the interest and assistance of numerous people both in the United States and in Thailand. Section 10.0 contains a complete list of people interviewed. In particular we would like to thank Mr. Suvit Vibulsresth and Dr. Darasri Srisaengthong who helped to arrange many of our interviews and often provided us with transportation during the evaluation. We would also like to thank Dr. Kaew Nualchawee of the Asian Institute of Technology, Dr. Basharat Ali of USAID/Bangkok and Ms. Maureen Norton of USIAD/Washington, who gave generously of their time and facilities.

PROJECT IDENTIFICATION DATA

1. Country: Thailand

2. Bilateral Project Titles: Remote Sensing Technology for Development

3. Bilateral Project Number: 493-0314

4. Program Implementation:

   a. First Project Agreement: 7/18/79
   b. Final Obligation:
   c. Final Input Delivery:

5. Program Funding:

   a. A.I.D. Bilateral Funding $290,000
   b. Other Major Donors:
   c. Host Country Counterpart Funds: $5,172,000

6. Mode of Implementation: Project Grant Agreement Between USAID/Thailand and Department of Technical and Economic Cooperation

7. Previous Evaluations and Reviews: December 1978: Eval. of predecessor project - ERTS 1, 493-11-198-180.14

8. Responsible Mission Officials:

   a. Mission Directors: Donald D. Cohen
   Robert Halligan

   b. Responsible Project Officers: R. McDonald/Vanchi, B. Ali (since 10/26/82)

9. Host Country Exchange Rates:

   a. Name of Currenty: Baht

   b. Exchange Rate at Time of Project: $1:B22.6

PROJECT IDENTIFICATION DATA

1. Country: Thailand

2. Bilateral Project Titles: Asian Remote Sensing Training Center

3. Bilateral Project Number: 498-0253

4. Program Implementation:

   a. First Project Agreement: 8/31/79
   b. Final Obligation:
   c. Final Input Delivery:

5. Program Funding:

   a. A.I.D. Bilateral Funding $5.6 million
   b. Other Major Donors: .5 million
   c. Host Country Counterpart Funds: 1.835 million

6. Mode of Implementation: Project Grant Agreement Between USAID/Thailand and Department of Technical and Economic Cooperation

7. Previous Evaluations and Reviews:

8. Responsible Mission Officials:

   a. Mission Directors: Donald D. Cohen
   Robert Halligan

   b. Responsible Project Officers: R. McDonald/Mintara, B. Ali (since 10/26/82)

9. Host Country Exchange Rates:

   a. Name of Currenty: Baht

   b. Exchange Rate at Time of Project: $1:B22.6

GLOSSARY

MSS or	Multispectral Scanner. - A "remote sensing" device capable of recording reflected or entitled energy at multiple frequencies or in several bands of the electromagnetic spectrum. The Landsat series of Satellites includes an MSS system as one of the primary remote sensing systems on board.
TM or	Thematic Mapper - Similar in concept to an MSS system, but capable of recording data at much higher spatial resolution levels.
Resolution	The relative ability to distinguish fine detail.
X-Band	The radar frequency band 5.0 to 12.0 GHE, or 6.0 to 2.5 cm wave length; frequency band at which Thematic Mapper data is transmitted to earth from space.
S-Band	The radar frequency band 1.5 to 5.0 GHE, or 20 to 6.0 cm wave length; frequency band at which MSS data is transmitted to earth from space.
"BW" or "Pan"	Commonly used abbreviation for "black and white" panchromatic film or photography.
BWIR	Commonly used abbreviation for "black and white infrared" film or photography.

CCT — Computer Compatible Tape. Data received at Landsat ground receiving station is initially recorded as a "High Density Data Tape". This tape is then processed to correct certain geometric distributions and to facilite subsequent computer analysis of the data. The result of this correction and processing is a "Computer Compatible Tape," or CCT.

Diazochrome — A relatively inexpensive method of forming color composite transparencies from Landsat image data.

SPOT — Systeme Probatoire de I'Observation de la Terre, French earth resources satellite, presently scheduled for launch in 1984.

Line Start — Malfunction in Landsat 3 data.

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1.0 EXECUTIVE SUMMARY

1.1 Problem and Overview

AID's three remote sensing projects in Thailand were designed to help develop Thai and regional capability to receive, process, interpret and apply remotely sensed satellite data. Landsat data can help identify and map a wide variety of geographic and natural resource conditions -- forestry, soil, water, agricultural land use, urbanization, etc. Remote sensing data thus was not seen as a response to a specific development problem; rather it was seen as a tool that could provide information (a) otherwise not available (or obtainable only at unacceptably high cost), (b) on a recurrent basis, more frequently than alternative data sources, (c) applicable to problem-solving across the board.

1.2 Nature of U.S. Assistance

Thailand began acquiring Landsat imagery in 1972, soon after launch. Thai scientists were trained in the U.S. with funding from AID and other sources. In 1978 the RTG decided to build a station near Bangkok for direct reception from Landsat and meteorological satellites. The station began operations in late 1981. Under the Earth Resources Technology Satellite project (1972-1979), AID (among other donors) provided technical assistance and equipment to the RTG agency responsible for remote sensing, the National Research Council (NRC). Funding totalled $261,000. In the follow-on project (1979-82), Remote Sensing Technology for Development (RSTD), AID provided an additional $290,000 for further training and equipment. Project purpose was to "establish the capability within the RTG to meet line agencies' and policy makers' needs for timely and relevant remote sensing data for effective resource management."

While the RSTD project was being planned, AID also initiated a third project, to develop a regional Center for Asian Remote Sensing Training. Authorized in 1979, ARRSTC was also seen as contributing broadly to natural resources management in the ESCAP region. At $5.6 million, the AID role in the conception and creation of the ARRSTC was very great compared with the relatively small AID role in development of RTG remote sensing capability. On the other hand, the role of U.S. institutions altogether (NASA, U.S. universities, AID) in the transfer of remote sensing technology to Thailand was very much larger than any other country's role. In addition, the U.S. private sector made a significant contribution in the form of computing equipment donated (in effect) by IBM to the regional computing center at the Asian Institute of Technology, which services the computer teaching of the ARRSTC, a unit within the Institute. The AID project finances five resident professors (on individual personal services contracts), equipment and scholarships. The center is designed primarily to provide training in visual and digital techniques for analyzing Landsat data, but also is supposed to offer outreach services (e.g. information updates, research assistance) for technicians and scientists in the region using Landsat data.

1.3 Purpose of Evaluation

This evaluation focuses on the operations of the RTG remote sensing "network", i.e., the production and delivery of Landsat data by NRC and its use by RTG agencies. In the case of the regional center, the evaluation is a "mid-course" look since the project was delayed in implementation; only two classes have graduated thus far and the outreach services have barely begun. In addition, the evaluation did not include any travel to ESCAP countries to follow impact of the training on user agencies. For the NRC project, a previous evaluation was performed in 1978 to determine whether and how the RSTD project should proceed as follow-on to the earlier ERTS project. The present evaluation was done by a four-man team, based on extensive interviews during a month in Thailand. The evaluations were not intended as detailed internal "audit" type examinations of implementation experience. Rather they focused on substance, on application of the technology, and included an effort to draw general conclusions for AID regarding technology transfer, not just with respect to remote sensing.

1.4 Findings

With respect to the NRC receiving station and the data production and outreach functions of the NRC remote sensing unit, the evaluation found RTG operation technically sophisticated, but suffering from production backlogs about which the team made some suggestions for management and equipment. The team also noted the equipment and other problems posed for the RTG by the uncertainties facing future U.S. actions with respect to Landsat or similar satellites.

Many RTG user agencies lack simple analysis equipment which would enable them to analyze remote sensing data more fully. Lack of this equipment has slowed the rate of adoption of this technology. In addition, interactive digital analysis equipment of appropriate type and quality is not readily available to the majority of RTG user agencies, limiting the detail that can be extracted from the data.

The principal RTG objective has been to obtain data useful for crop measurement and forecasting. This objective has not been realized, partly due to cloud cover, partly to need for further research and technical development (e.g. application of area frame sampling techniques). Some other potential applications also appear under-researched. Overall, remote sensing technology is being effectively utilized in Thailand for resources assessment, evaluation and planning purposes. The evaluation reviewed user agency applications in some detail. USAID projects over the years have played an important facilitating role in this transfer process.

The educational program at ARRSTC is sound conceptually, but does not adequately address the problem of differential student preparation, background and interest; is not yet an integral part of the academic program at AIT; and is hampered by organization as a single large class.

The IBM software (DIMAPS) on the IBM 370/3031 at AIT is not acceptable for meeting the center's objective of teaching digital analysis at a sophisticated enough level. The program is "user friendly" but has inadequate resolving power. The adoption of digital analysis in the region will be set back by continuation of the use of the IBM program. Another limitation on the training program is the difficulty of getting suitable aerial photography and maps at appropriate scale for training aids on sites in Thailand.

The AID remote sensing projects for Thailand have been "technology-driven", in the sense that the design and evaluation efforts did not explore with enough depth the technology management and user diffusion requirements. Problems in these aspects that have been unresolved for a few years might have been usefully addressed by the AID activities if they had been probed more deeply in the design and evaluation stages.

1.5 Project Design and Policy Implications

The projects assisting the NRC provided most of the planned inputs and contributed, as expected, to the increasing capability of NRC to meets its data acquisition and production, and training, objectives. As indicated above, the short-falls were in the nature of omissions and opportunities AID might have taken (a) to help overcome NRC production problems that have not been overcome as assumed, and (b) to provide the relatively modest additional inputs the user agencies (not included in the AID projects' scope) need to exploit the Landsat data to the full extent that would justify the considerable investment the RTG has already made in Landsat data acquisition. In the case of the regional training center, similarly, and where the AID role has been very substantial, a greater AID role in the development of the software might have obviated the need at this time, mid-way in the project life, for ARRSTC to correct this deficiency. In both cases, the problems cited are recognized by the institutions involved, and are likely to be addressed if resources are not a severe constraint. The evaluation drew some specific recommendations for possible future AID role with respect to these projects (and for remote sensing and "high" technology transfer) outlined below. Insofar as project design is concerned, we conclude that closer adherence to the standard requirements of the AID project analysis sequence, with particularly close attention to the "assumptions" part of the logframe analysis, which in these cases harbored what has turned out to be the problems of these activities (not all included in this executive summary), would have forced more attention to these problems and perhaps changed the mix of activities under the projects or some aspects of their implementation. The AID mission's inability to allocate enough staff oversight time to the NRC projects was an unfortunate weakness of implementation In addition, USAID attention has been absorbed largely by procurement and other details of daily implementation.

1.6 Recommendations

Besides the specific recommendations to NRC and ARRSTC, addressing the problems cited above, the evaluation recommends USAID continue to play a role in remote sensing. The U.S. remains the leading country in this technology; Thai linkages with U.S. scientists will remain vital for maintaining the momentum of adoption of the technology; assistance in the science management aspects of the diffusion process could yield important benefits to Thailand for relatively small U.S. inputs; as a mission with a long history in Thai development, USAID can provide the "good offices" function of the outside advisor on the management and agency linkage problems. Any additional assistance should address user agency needs.

Some guidelines for projects assisting the transfer of new, rapidly changing "high" technologies are suggested: (a) allow more flexibility for "mid-course corrections" during implementation; (b) be sure logframe "assumptions" are examined vigorously; (c) plan for close mission attention to institutional and management aspects; (d) examine how AID might help countries minimize costs entailed by short-time lapses between equipment "generations"; (e) be sure complementary and topping-off equipment needs of all agencies in the network of the technology are addressed.

2.0 MAJOR CONCLUSIONS AND RECOMMENDATIONS

1. Conclusion:

At present, the Thia ground receiving station is capable of receiving Landsat 4 Multi-Spectral Scanner data. It is not capable of receiving either Thematic Mapper data or SPOT data. Landsat data may not be available beyond the design life of Landsat D'. This would mean that unless a private sector company or another country launched a satellite comparable to Landsat, the Thai ground receiving station would become unusable without software upgrades necessary to process other types of satellite data.

Decisions regarding future remote sensing satellite systems will become more complex as the quantity of data being generated in space increases many fold and as several countries launch remote sensing satellites.

Recommendation:

The RTG should evaluate the impact of these changes on their plans for continued operation of their satellite ground station.

2. Conclusion:

Equipment problems, lack of sufficiently trained technicians and a commendable effort to maintain quality control have all plagued the NRC production and dissemination process. In particular, the Optronics Film Writer (which transfers digital data into film products) is a bottleneck. Certain products desired by users are not presently available from NRC. A particularly sought after and useful form of data would be the 1:250,000 color composites.

Recommendation:

NRC is considering going to two shifts--working the Optronics Film Writer 16 rather than 8 hours a day. The evaluation team encourages this as a possible solution but notes that doing so will require more trained personnel and a ready supply of spare parts for the Optronics. Another possible solution would be to procure a second Optronics and run it in parallel with the one now in place. A third solution would be to buy a more advanced, faster system, such as a laser writer. Some consideration should be given to employing an independent analyst (for 2 - 3 months) to examine NRC's production and distribution process and to prescribe equipment purchases (or modifications). Management and personnel requirements should also be studied and appropriate recommendations made to increase efficiencies.

3. Conclusion:

Many RTG users lack simple analysis equipment which would enable them to analyze remote sensing data more fully. Lack of this equipment has slowed the rate of adoption and effective transfer of this technology.

Recommendation:

The RTG should acquire simple visual analysis equipment that user agencies need to round out their interpretation capabilities. This equipment could include such items as stereomicroscopes, Zoom Transfer Scopes, reflecting projectors, and "hard copy output" peripherals for existing electro-optical image analysis equipment.

4. Conclusion:

Interactive digital analysis equipment of an appropriate type and quality is not readily available to the majority of the RTG user and potential user agencies. Lack of this equipment has slowed the rate of adoption and effective transfer of this technology, and limits the detail that may be extracted from these data.

Recommendation:

The RTG should consider establishment of a centrally located and readily accessible digital analysis center for operational use by user agencies. Such a center could be built around a dedicated mini-computer digital analysis system. Shared usage would serve needs of a number of agencies for awhile (until individual agencies reached the threshold for their own systems). Investment costs would be staged and growth incremental. Cost savings should be realized.

5. Conclusion:

At this stage in the development of applications of remote sensing data in Thailand, research serves two functions: to define and refine the potential uses of remotely sensed data under Thai conditions, and to help solve knowledge problems in subject matter applications where the techniques of application have been worked out and found satisfactory. The NRC research budget has been allocated by the research committee based on reviews of proposals put to the committee by Thai researchers.

Recommendation:

With several potentially important applications of Landsat still not demonstrated (in) for conditions in Thailand, the committee should consider setting aside some of the research budget for subjects that deserve priority in an effort to develop the full range of this potential. Crop measurement and forecasting is an obvious first priority. Other subjects for which Landsat data may prove useful, but which appear under-researched thus far include (a) more detailed mapping of forest condition, including species differentiation; (b) coastal monitoring; (c) monitoring of change in urban sprawl and its encroachment on agricultural land; (d) urban hydrology; and (e) salt water intrusion in the Chao Phya delta.

6. Conclusion:

A principal objective of and justification for remote sensing in Thailand, agricultural crop production, measurement, and forecasting, has not been realized. This area continues to be of major importance to Thailand. The current "area frame sampling" program will attempt to use remote sensing technology in a supporting role.

Recommendation:

Remote sensing research and demonstration testing in agricultural applications should be encouraged and expanded.

7. Conclusion:

Although the RTG and NRC have made commendable efforts to organize and train to promote remote sensing diffusion, technology adoption remains uneven. In addition, NRC has been overloaded with tasks and has had difficulty carrying out its primary data acquisition/production/distribution function.

Recommendation:

NRC should concentrate on its first priority: the data acquisition/production/distribution function. USAID should consider providing assistance to NRC in production planning, quality control, and user assistance support service.

8. Conclusion:

NRC appears to be subsidizing the sale of Landsat data throughout the region.

Recommendation:

NRC should carry out a proper cost accounting of its products to get a clear picture of its cost and subsidy position.

9. Conclusion:

Remote sensing technology is being effectively utilized in Thailand for resources assessment, evaluation, and planning purposes. The technology is being adopted and assimilated into the country resource information system. Its use has increased steadily in the last 11 years and is expected to continue increasing in the future. USAID has played an important facilitating role in this technology transfer process.

Recommendation:

For reasons outlined in Section 9.0 of this report, USAID should continue to play a role in remote sensing in Thailand and in the Asian region.

10. Conclusion:

The general educational and training program at ARRSTC, while conceptually sound, does not adequately address the problem of differential student preparation, background and interest; is not, as yet, an integral part of the academic program at AIT; and is hampered by its organization as a single large class.

Recommendation:

Change the fundamental structure of the program from a single training course to a program of comprehensive, related courses. Accruing would be greater flexibility, smaller class size, the offering of courses at appropriate experience levels for a wide variety of students, as well as offering specialized courses in specific discipline application topics. This structure could be employed by develop the offering of an appropriate degree or diploma program.

11. Conclusion:

A need for high quality education in remote sensing has existed in the Asian region and will continue to exist for an indefinitly. The ARRSTC program can fill this need. The start of the ARRSTC program was substantially delayed due to problems in procuring equipment and obtaining adequate technical assistance; the program is presently behind schedule.

Recommendation:

USAID should consider an extension of the project completion date to compensate for time lost in procurement delays.

12. Conclusion:

The existing IBM software package (DIMAPS) on the IBM 370/3031 at AIT is not acceptable for meeting the center's objective of teaching digital analysis at a sophisticated level. The program is "user friendly" but has inadequate resolving power. The adoption of digital analysis in the region will be set back by continuation of the use of the IBM program.

Recommendation:

AIT should take positive action to alleviate the situation, such as choosing one of the following courses of actions: (1) modify and upgrade the existing DIMAPS program to include necessary analysis routines and approaches; (2) add visual peripherals and interaction hardware/software to the RECOG-X package and have it serve as the primary system; (3) replace both DIMAPS and RECOG-X with a system (such as EDITOR or LARSYS) that already incorporates user interaction features with high powered processing; (4) replace the existing IBM system with a mini-computer system dedicated to remote sensing digital analysis (the present IBM system would continue to serve other AIT users).

13. Conclusion:

The assumption that aerial photography and maps at appropriate scale would be readily available to ARRSTC to support training exercises was incorrect. Even when aerial photography is available, it is often so out of date that it serves poorly as a training aid.

Recommendation:

ARRSTC should define its requirements for ground truth sites in Thailand and NRC should continue its effort to coordinate and arrange for the release of these data to ARRSTC as soon as possible. NRC should consider using a light aircraft, modified for small-format (e.g., 35 mm or 70 mm) photography to support applied research and training efforts in remote sensing technology.

14. Conclusion:

Previous evaluations and project design efforts involving remote sensing technology have been "technology-driven." The fact that a technology is "high" should not by itself be an excuse for treating the analysis of project input needs differently from those of more "ordinary" projects.

Recommendation:

In the case of new, high technologies, it is extremely important that USAID adhere to project design and evaluation formats and procedures.

SUMMARY CONCLUSION

The experience of these projects suggests some guidelines for AID projects assisting the transfer of new, rapidly changing "high" technologies: (a) allow greater flexibility for "mid-course corrections" during project implementation; (b) be sure logframe "assumptions" are examined vigorously; (c) plan for close USAID attention to institutional and management aspects; (d) examine how AID might help countries minimize costs entailed by short time lapse between equipment "generations"; (e) be sure complementary and topping-off equipment needs of all agencies in the network of the technology are addressed.

3.0 PROJECT CONTEXT

AID's remote sensing projects in Thailand were designed to help develop Thai and regional capability to receive, process, interpret and apply remotely sensed satellite data. Since remotely sensed data can be used to determine and map a wide variety of geographic and natural resource conditions - forestry, soil, water, agriculture land use, urbanization, etc., the satellites are a widely applicable data source. Thus development of remote sensing capability was not seen by the US or the countries of the region as a response to any particular development problem as is the more usual situation when (say) agriculture production or other technologies are proposed for transfer and for external assistance. Instead remote sensing was seen as a powerful new data tool that could provide information (a) otherwise not available (or obtainable only at unacceptably high cost), (b) on a recurrent basis with a much higher frequency than alternative data sources, (c) applicable to problem-solving across the board.

As a new source of data input into development planning, project planning, disaster monitoring and economic policy formulation, the justification for investment in remote sensing capability was the same in principle as that for all other sources of the data streams feeding into development planning. While the project papers gave examples of specific potential and actual uses, these were illustrative in fact since (a) some turned out to be infeasible, (b) others will develop or become more powerful as the technology improves (e.g. with the higher resolution planned for the French SPOT satellite due for 1984 launch), and (c) actual use would depend on decisions by user agencies other than the data generating and training units assisted by these projects. In addition, absent any effort to quantity benefits that might flow from specific uses, the project papers did not attempt to tie remote sensing capability to any subset of uses that would entail by themselves benefits sufficient to demonstrate the economics of this particular data source compared with alternatives, or compared with the cost of obtaining the remote sensing data.

In short, these projects involved a transfer of technology which had to be diffused outward to users, the applications of which had to be tested and demonstrated, the reverse of the normal sequence embodied in AID's project conceptualizing process in which the designers are assumed to start with some (preferably sharply defined) problem(s) and work backward through the factors determining the conditions to be addressed, to the data requirements for their measurement and monitoring.

The use of aerial photography in mapping in Thailand goes back 30 years at the Royal Thai Survey. In 1971 the RTG recognized that satellite imagery could be a data source for a variety of agricultural, forestry, land-area mapping, geological and hydrological, oceanographic and environmental uses, and decided to join the NASA remote sensing programs. An inter-ministerial National Remote Sensing Coordinating Committee was appointed, and soon after launch, Thailand began to acquire Landsat-1 imagery (Nov. 1972) from the U.S. With funding from AID and other sources, seminars and training programs were initiated from the start. Thai scientists received training in the US, some in basic orientation courses at the EROS Data Center in Sioux Falls S.D., others in more intensive study at Purdue University IN. Quite naturally, given the leading role played by the US in the 1970's in the development of satellite remote sensing, the Thai and other East Asian scientists and technicians drawn into remote sensing developed a network of professional and collegial relationships closely tied in with the US institutions and scientific community involved in this rapidly emerging technology. By 1978 the RTG had decided to build a station near Bangkok for direct reception of data from Landsat and meterological satellites. The station began operation in late 1982.

During this whole period, Thai scientists were carrying out a variety of research projects testing out the interpretation and application of remote sensing data (obtained from NASA until the recent start-up of the thai receiving station). While the ground was being laid for wider familiarity with the analysis of remote sensing data, and some significant applications to development planning were obtained (as described below), widespread and systematic use was not (and probably could not have been) achieved.

As noted, the relationships between Thai and US institutions and professionals were critical for this entire phase of Thailand's experience in acquiring capability in this technology. Other donors also made valuable contributions (ESCAP, UNDP/FAO, Australia, France, Ford Foundation), and Canadian aid is now emerging as the major external source for the further development of NRC capability.

Beginning in 1972, AID has assisted the NRC and individual Thai investigators under three projects. A number of Thai research projects into potential applications were funded under the centrally-funded Small Grants Project. This project was designed to introduce and stimulate interest in remote sensing applications and provided significant seed money for the handful of Thai researchers who were in position to undertake this work.

Under the Earth Resources Technology Satellite (ERTS) project (1972-79), AID provided technical assistance and some equipment to NRC. Ten Thais received training in the US. Seventy-one were trained in Thailand in two 6-week courses for personnel from user agencies. Several pieces of equipment were obtained to provide imagery production and reading capacity. Total funding in this project was $261,000.

In 1977 the RTG proposed that the ERTS project be extended another two years to help further strengthen NRC. In the process of deciding its response, AID conducted an evaluation of the project in 1978 (reproduced in the RSTD Project Paper, May 1979). The evaluation concluded that the project had met its objectives and that the proposed follow-on project should be "favorably considered".

The follow-on RSTD project obligated $290,000 in 1979, about half for additional training and half for photographic and analytic equipment. As summarized in the Logical Framework, the broad objective was to "optimize effective utilization and conservation of natural resources in rural Thailand for the benefit of the rural population". The specific project purpose was to "establish the capability within the RTG to meet line agencies' and policy makers' needs for timely and relevant remote sensing data for effective rural resource management". The outputs of the project were to be trained staff and functioning equipment, and "linkages established between line agencies and NRC". AID disbursement was projected to end in 1982. Since the project was associated with the next major step in Thailand's development of remote sensing capability, the construction of the receiving station, the RTG contribution to the project (shown as including the estimated $4 million cost of the station) was over $5 million, or 18 times the AID contribution.

At the same time as AID was preparing this third activity, it was also developing a regional project for an Asian Remote Sensing Training Center. Authorized in 1979, the ARRSTC project was also seen as contributing very broadly to natural resources management in the region. AID played a much greater role in the initiation of the Regioned Training Center than in the development of the Thai facility, where early RTG interest in having a regional receiving station resulted in the decision to build its won station with Thai funds. The idea for the Center was developed in AID/W and was adopted by AId after a team visited some countries of the region in August and September 1978, to explain the proposed project and assess government interest. The team found "varying but generally keen interest", sufficient to warrant proceeding.

This project was designed to develop an internationally recognized center with "an ongoing program fully supported by the region's countries and institutions, and an output that is satisfactorily utilized throughout the region". The Center would be located at, and be an organizational entity of, the regional Asian Institute of Technology (AIT). In Phase I over the first three years, the Center would develop the capacity to provide short-course training to user agency personnel and to offer support services to user agencies through "problem solving, research and outreach". Phase II was expected to start in FY 82 and differed from Phase I in having greater emphasis on program implementation then start-up activities, with the added feature of possibly developing a master's degree program. A mid-course evaluation was planned before final commitment to proceed with Phase II.

Total cost of the project through FY85 was planned at $12.6 million of which ESCAP was to contribute $0.5 million for scholarships, AID $4.7 million for operational costs, commodities and computer maintenance, and AID $5.6 million. The RTG contribution was shown at $1.8 million of which $1.3 million, one-third the cost of the receiving station, was attributed to the project since the ARRSTC would be a major user for the station and was supposed to receive NRC data at no cost. Under the actual agreement between NRC and AID, NRC is to provide data at a price covering cost. AID funds were allocated mainly for long-term consultants (5 members of the teaching staff) and equipment, including visual analysis hardware, analog equipment, and computer peripherals.

An unusual feature of the ARRSTC project was a contribution from the US private sector in the form of a long-term loan to AIT of computer equipment by the IBM Corporation. While this loan to the AIT Regional Computer Center (along with an expert seconded by IBM as RCC director) preceded the establishment of ARRSTC, the heavy reliance of ARRSTC on the computing center (and the considerable portion of computing time that ARRSTC would require) meant that the role of the computer center was critical to the operations of the training center. The IBM equipment was valued at $5 million.

The outputs foreseen in the ARRSTC logframe included the training of 200 or more technicians and conduct of at least two regional seminars per year, in addition to the establishment of the processing facilities and archives. Outreach services were also important planned outputs (although not included in the logframe). The ultimate purpose of the project of course was to see its graduates in responsible positions in user agencies of governments of the region, integrating the analysis of satellite remote sensing data into the planning processes of their countries.

This evaluation is not expected to examine in any depth the extent to which the AIT project is contributing to diffusion of this technology in the region. Such an examination would require much time and travel to each of the countries. In any case, it would be premature to attempt more than a "monitoring" look at end results since only two classes have graduated thus far and the outreach services have barely begun. We have attempted to get a feel for the problems facing diffusion outside Thailand, but have naturally concentrated on the user issues within Thailand.

4.0 SPATIAL RESOURCE INFORMATION SYSTEMS AND PROCESSES

A review of the characteristics of a successful system of acquiring, analyzing, and using spatial information gathered by remote sensing means can provide a useful point of reference against which to measure the evolution, situation, and future development of remote sensing activities in Thailand. The review is essentially that of the situation in the United States; other developed nations operate in much the same way.

Emphasis throughout is placed on the use of remote sensing to provide information on the spatial aspects of problems, e.g. deforestation, surface water usage, or urban sprawl. Accordingly, the tools and techniques are discussed relative to their ability to provide that spatial information rather than to emphasize their "space-age" hardware characteristics. Remote sensing is nothing more than a suite of tools and techniques producing spatial information that can augment or replace (in some instances) spatial data acquired in other ways. A large number of organizations -- mostly governmental, some private sector -- charged with the responsibility of developing, maintaining and reporting spatial information -- e.g. area of crops, forest -- can employ remotely sensed spatial data.

Therefore, the significant question to raise regarding the value of remote sensing is <u>not</u> what the impact of remote sensing technology has been on improving difficult resource management problems but rather how well remotely sensed data has aided the gathering and use of spatial information. Have agencies realized savings from the use of remotely sensed data (over conventional) or have, perhaps, these data provided some information that non-synoptic systems (especially those not able to invoke modern tools of analysis) cannot deliver.

The emphasis on potential utility in providing spatial information was seen in the United States at the beginning of the program when, prior to the launch of the original Landsat (ERTS-1), extensive discussions were held with potential users of the data (including Thai scientists). Their needs were then incorporated into the process of making decisions on the configuration and design of the satellite. These specified needs were blended with then limitations in hardware selection and with political decisions to be considered in opening the skies to earth surveillance of all the world's countries for the first time. The agreed upon resulting package was the now familiar one: the Return Beam Vidicon system, whose usage was limited by technical problems; and the Multi Spectral Scanner Subsystem (MSS) that has become the core of the Landsat system (through four separate replications of the Landsat satellite series.)

Other components of the system of equal significance to the type of data specified by the users concerned the nature of the satellite itself, its data gathering equipment, sustaining systems, data recording and transmission systems, and the timing and the routing of the satellite itself. While the totally U.S.-developed and operated system has certain shortfalls, as judged by current standards, the system has produced a steady stream of data, from July of 1972 through the present, that have been widely used by nations everywhere. Only recently have major changes in the total system package been introduced (as with the case of the Thematic Mapper system aboard Landsat 4) or other satellites been planned; the French and Japanese are scheduled to launch earth observation and resource data gathering satellites sometime within the next few years.

Because the parameters of the data were the result of compromises and are not tailored for specific countries or for greatly differing environments within a single country (e.g. forests versus urban areas), users have been required to manipulate and modify their requirements to match the data available. Awareness of this fact is necessary in evaluating the success of remote sensing in Thailand and other tropical countries, as well as in varying environments in any country.

An early detected weakness in what proved to be a remarkably reliable system (the first satellite was given a nominal lifespan of one year but continued to transmit vital data for several), was the capturing of data by tape recorder while the satellite was beyond reach of tracking/receiving stations in the United States. A straightforward solution to this problem was the establishing of tracking/receiving stations at various points in the world. Among these was Thailand. A more sophisticated system for achieving the same end has been the development of a system of two satellites permanently parked in stationary, geosynchronous orbits that would receive data from Landsat and transmit it to a single U.S. station at White Sands Missile Range, New Mexico. The first of these Tracking Data and Relay Stations, TDRS East, was placed into a faulty orbit by Space Shuttle in April, 1983. Ground experts are hoping to nudge the station into its designed orbit. Previous plans have called for the launching of TDRS West in June of 1983. The need for many of the ground receiving stations to acquire data would be somewhat obviated.

Thus Thailand, with its tracking/receiving station, today has both the advantages and responsibilities that accompany the stewardship of such a station. An apparent advantage is the immediate access to data it receives -- and even the exciting possibility of eventually processing the data in "real time". The disadvantage though is the burden of responsibility of providing data both to the United States and to Asian countries within coverage of the tracking station.

4.1 Data Dissemination

Ranking in equal importance to data acquisition is data dissemination. While maintaining a constant flow of a product is essential to any production function, be it a manufacturing establishment or a service facility, a Landsat data facility must have the capability to deliver data very quickly if it is to meet the challenges and opportunities made possible by the Landsat system. A complex system of support services is required to meet these ends. Equipment needs are high, methods must be regorous, and all the necessities for handling large volumes of data must be present. The Earth Resources Observation System at Sioux Falls, South Dakota operated by the U.S. Geological Survey, and aided by private contractors, is such a facility.

In addition to the ability to respond quickly to data orders placed by users, a system must exist that provides users with an ordering service. Complex ones provide a visual image copy (usually on computer controlled retrieval systems) of the desired location. The customer can make initial determinations of the suitability of an image (considering cloud cover, clarity, and spatial coverage). An even more sophisticated level of consumer service is where resource specialists in the user center can discuss the nature of the problem to be studied and prescribe the type of data required, for example, a single band, combinations, black & white, or color images at varying scales, as well as the configuration of Computer Compatible Tapes (CCT's) if the user is considering digital analysis.

4.2 Technology Transfer

4.2.1 Awareness and Introduction to Remote Sensing Principles

Remote sensing is a broad term and comprises all forms of observing and measuring of phenomena from afar (on the ground, under the sea, and in the atmosphere). A principal component of remote sensing is the interpretation of aerial photography, a skill that was introduced in the early 1900's and was vastly expanded by the end of the World War II. The term remote sensing should not be applied solely to data gathered by satellite. By this definition, a small cadre of users has been involved in remote sensing for a long time. The quantum jump forward in obtaining synoptic coverage of much of the earth's surface -- justifiably excited the public imagination and opened enormously broad possibilities for repetitive, observation of the earth's surface.

To make maximal use of these new data, promoters of the system -- largely NASA -- entered upon a major world effort to publicize the system and demonstrate a wide variety of possible applications. Activities designed to meet this end consisted of presentations of workshops, sponsoring of conferences, and cooperative experiments with numerous countries. Progress reports and research findings were presented at international symposia.

The ideal situation of having individual countries join NASA in its spreading of awareness of remote sensing was attained when several countries (including Thailand) initiated their own programs, often with US funding.

4.2.2 Training and Education

A distinction should be made between training and education. The former should refer to just the learning of the techniques required to use remote sensing data by persons already involved in the analyzing and manipulation of spatial data in their daily work. Education for making wise management decisions) takes the process a step further. In addition to having attained technical abilities, the person should be knowledgeable enough in the entire field of remote sensing to be able to make decisions and choices over which techniques are to be used, which data will provide the required answers and the degree of supporting equipment, personnel, and field activities required. These persons need to be educated to the point where they can make the decisions that are the most practical and help to solve problems in the most cost-effective way.

To meet training and education goals appropriate institutions must be established. Training can, and has been, achieved through the device of bringing members of a particular discipline together to centers of either education or research. At these institutions, individuals are given rigorous short courses supported by "hands on" sessions with the appropriate equipment and self-taught tutorials (using a variety of audio and visual training techniques). Education, the broader approach, requires the full integration of remote sensing technology into a program of study within a particular discipline working toward an academic degree. Such programs can and should encompass several academic terms with the remote sensing component of the degree achieving a level of a minor emphasis within a program. Many universities having well developed remote sensing teaching and experimental laboratory facilities conduct such programs. A good example is the Laboratory for Applications of Remote Sensing at Purdue University.

4.3 Relationship of Remotely Sensed Data to Solution of Spatial Problems

The making of maximal use of remotely sensed data requires first the full understanding of the role played by any spatial data, regardless of how acquired (either ground collected or obtained by remote sensing). Virtually all problems of managing resources or acquiring more knowledge about the character of the earth's surface or its man-made occupance have a spatial component. The need almost always exists to know the spatial distribution of a phenomenon partly to assess any problems associated with location and necessary dynamic interaction (for instance, transportation of a product) and partly to be able to quantify total amount. The person or agency responsible for measuring a phenomenon should therefore explore the possibility of using remotely sensed data to support, or even replace, traditional means of gathering spatial data. A simple example is the determination of the extent and quality of a forest. By traditional means, ground estimates are made of the volume of timber. These estimates have been sharpened through experience and, on the whole, are reliable. Clearly, though, they require frequent, lengthy surveys on foot, often in areas that are topographically rough and located at great distances from logistical support. By some means of remote sensing -- aerial photo interpretation either used alone or in consort with interpretation of satellite data, either visual or digital -- the area of forest under study can be analyzed and estimates of the timber cover made.

Having made the decision to employ remotely sensed data, an analyst must then select from a variety of data sets available. Making the decision requires the consideration of all the pertinent factors before selecting. These may be grouped under the headings of: availability of remotely sensed data; cost of acquiring it; equipment to make maximal use of it; and possession of the requisite skills to analyze the data and to interject it into the project at hand. At this critical point, care should be taken to avoid the selection of data set only because it was the only one readily available or the only one the analyst had the skill to use. Where data are scarce -- as is often the case in developing nations -- the temptation often surfaces to use data that is poor in quality or taken at an inappropriate date. In an ideal situation where the analyst has elected to use Landsat digital data processsed by computer, there should be an opportunity to order supporting aerial photography and collected ground truth data that is contemporaneous with the over flight of the satellite.

4.4 Placing Remotely Sensed Data Into a Spatial Information System

Regardless of the source of spatial data, be it ground collected or remotely sensed, its value as a support to problem solution can be realized only when placed into a spatial information system. These spatial information systems can be simply a map on which officials can see relationships or the information can be put into digital address format and incorporated into a Geographic Based Information System (GIS).

Commonly, information taken through interpretation of aerial photography, or satellite visual imagery is transferred to maps manually by noting the location of the information phenomenon, finding that same location on a map and drawing in a polygon. More elaborate systems use some sort of optical transfer device.

More advanced systems, especially those using computers to process satellite digital data, can make map products through manipulation of various "hard copy" devices. In these, the digital data can be given precise geographic addresses and registered to map coordinates. As a further enhancement, map point and line data can be superimposed.

Once the information is placed into map form, the vital step of making areal measurements is undertaken. This provides the areal dimension of the phenomenon in addition to its location. by superimposing the boundaries of areal administrative unites -- a province, government reservation, etc. -- the further step can be taken of aggregating the area of the item of interest. Tables can then be derived of all spatial data reported by administrative area.

4.5 Integrating Spatial Data Results Into Line Operations

Accurate, timely, and synoptic data sets, derived from remote sensing sources in this case, should serve as vital information to help policy planners reach decisions on courses of action. Examples are many. A dominant one in tropical countries is measurement of the amount and location of deforestation. Awareness of the spatial aspect of the problem can bear on such decisions as whether or not to penetrate a given area with a new road, to build a dam, to encourage settlement, or to impose restrictive legislation.

In summation, the collection of spatial information and its presentation in both map and tabular form in a form of value to decision makers can be greatly facilitiated through the use of remote sensing. Ground collection of data, has disadvantages that makes it unsuitable to meet the demands of managing such resources as tropical forests, whose situation has taken on crises proportions. Ground collection is slow, costly in terms of labor, and is often inaccruate as it must depend on the vagaries of personal observations. Remote sensing as a data collection and analysis tool has the advantages of the synoptic view from the atmosphere (in aircraft) or beyond (from satellites). Data gathering can be rapid and, in the case of Landsat, frequent. Analysis and classification means can be done with the assistance of computers and sophisticated optical equipment. Finally, computer-aided means are available to convert these spatial data into geographic based information systems that have the flexibility and power to be manipulated and integrated into the broadest aspects of resource planning.

5.0 REMOTE SENSING IN THAILAND

This section of the report develops an overview of the entire remote sensing process in Thailand, from data acquisition through to the utilization of resource information by decision makers. It is divided into six parts.

1. Data Acquisition
2. Data Preparation
3. User Awareness
4. Remote Sensing Education
5. Data Analysis and the User Community
6. Summary and conclusions

The discussion of these six areas in Thailand is put into the context of the idealized system and process: described in Section 4.0. By weighing the progress Thailand has made in the area of remote sensing against this base line or idealized system, the team will be able to draw findings and make recommendations about the future direction of, and the role of USAID and other donor agencies in, remote sensing in Thailand.

Thailand's National Remote Sensing Program is located in the National Research Council in the Ministry of Science, Technology and Energy. The Program consists of six divisions including general services, research coordination and follow-up, data analysis, technical and maintenance, user services, and the ground receiving station. The program is overseen by a National Remote Sensing Coordinating Committee representing a wide range of government departments and offices. The committee has six subcommittees covering a range of operational and discipline oriented topics. An organizational chart for the National Remote Sensing Program in Thailand is presented in Annex I.

5.1 Data Acquisition

5.1.1 Satellite Data

NRC has collected a substantial archive of Landsat data covering Thailand from the years 1972 - 1982. These data have been obtained through the EROS Data Center and are now being obtained directly from the satellite at Thailand's ground receiving station. After 1979 the data are only intermittently available due to several technical problems. First, in 1980, and before the Thai ground station was operations, the tape recorders on Landsats 2 and 3 became unusable and no data over Thailand were collected. Second, once the ground station was operational, data were collected from Landsat 2 for only a few months (between November 1981 and February 1982) before Landsat 2 was terminated. Landsat 3 developed a "line-stop" problem which mars MSS data, and has now been turned off as well. No data are available from Landsat 4 for users as yet. These problems have limited the availability of good quality data since 1979.

The Thai receiving station is unable to receive Landsat Thematic Mapper data which was supposed to be available beginning in the mid 1980's. Also, the station is not capable of receiving SPOT data, expected to become available in 1985. The capability to receive these new data requires both new hardware and software as both Thematic Mapper and SPOT data are transmitted on an X-band downlink and the station is currently equipped with only an S-band downlink. The software problem affects the ability of the station to process Landsat 4 Multi-Spectral Scanner (MSS) data, as well as its ability to process these new types of data. Software is needed to enable the station to correct the data both geometrically and radiometrically so that they can be formatted for users. Under a grant from the Canadian Government the software for processing Landsat 4 MSS data will be procured; however, this system upgrade will not provide the capability to process Thematic Mapper or SPOT data. The specifications for this upgrade are being written to allow future upgrades if so desired. This matter is of some concern because the future of the U.S satellite program, and hence the future availability of the MSS data, is unclear.

Thailand is also able to acquire satellite data from the United States Earth Resources Observation System Data Center (EROS Data Center or EDC). The EDC maintains a complete archive of all Landsat data taken since the beginning of the program and any available historical data which are desired can be bought from EROS, although the price of the data is increasing substantially.

In sum, the greatest problems for the acquisition of satellite data by the ground receiving station are the need to upgrade the station to receive data from future satellites, and the future availability of MSS data from US satellite systems. At the same time, the cost of buying the data from EROS is increasing so that the acquisition of historical data from EROS is becoming expensive.

5.1.2 Aerial Photography

It is important at this juncture to note another key source of remote sensing data in Thailand: aerial photography.

The Survey Department has 1:50,000 scale maps and complete air photo coverage of the entire country. The Survey

Department has two RC-10 cameras, an RC-8, and two Zeiss RMK 15/23 cameras. Aircraft for flying the photo missions consist of: two Beech Queen Air, one King Air (c-90) and one Turbo Commander. Aircraft were operated by the Survey Department until this year, when they were all tranferred to the Thai Air Force, who now operates them for the Survey Department. In addition to flying black-and-white photo missions, they have flown a 4-band multispectral camera, and will fly color photography this year for the first time.

The Survey Department can make 40 X 40 BW prints, can print Landsat visual images at 1:250,000 scale, and will be able to print 30 X 30 inch color later this year. They have produced an "Atlas of Thailand" which consists of a series of 54 thematic maps, with about 45 now available. These thematic maps cover the years 1951 - 1974 at scales of 1:2,500,000 and 1:4,000,000. The Atlas is openly available for purchase at the Survey Department at a cost of about $1 per sheet.

5.2 Data Preparation and Dissemination

The National Research Council's Remote Sensing Program is responsible for the dissemination of data to user agencies throughout Thailand and Southeast Asia. Under an agreement with the national Oceanic and Atmospheric Administration (NOAA -- which has taken over operation of the Landsat system from NASA), NOAA will not provide newly acquired data to users within the range of Thailand's receiving station. Thailand, however, may have to "compete" with other ground stations in the region (those of Bangladesh and Japan) whose coverage overlaps that of its station.

NRC initially planned to provide a variety of data types, including:

1. Black and White Imagery

   a. 1:500,000
   b. 1:250,00
   c. 1:1,000,000

2. Mosaic of Entire Country

   a. 1:2,000,000
   b. 1:1,000,000
   c. 1:500,000

3. Diazochrome

4. Slide

5. CCT

6. Film Positive

   a. 9", 8" X 12", 12" X 24"
   b. 1:500,000
   c. 1:250,000
   d. 1:125,000
   e. 1:1,000,000
   f. 240 mm

7. Film Negatives

   a. 9"
   b. 70mm
   c. 1:1,000,000
   d. 1:336,900

Due to technical difficulties and economic considerations, NRC is now able to offer only the following products:

1. Black and White

   a. 9" positive and negative film @ 1:1,000.00
   b. 9" paper at 1:1,000,000
   c. 20" paper @ 1:500,000
   d. 36" paper @ 1:250,000

2. False Color Composites

   a. 9" positive film and paper @ 1:1,000,000
   b. 20" paper @ 1:500,000

3. Computer Compatible Tapes

The preparation of data by the NRC for distribution to users has encountered several difficulties. The equipment which produces these data for users does not seem to be working to its full capability. For instance, users report that film negatives, diapositives and CCT's can be difficult to obtain, and that 1:250,000 color prints and 1:250,000 diazochromes are also not readily available. The data are also not always produced in a timely fashion. Users have waited up to one month to get older data and getting newer data (post 78-79) seems to be very difficult. The difficulty in obtaining newer data, post 1979, is due in large part to the fact that the data simply do not exist or are marred by the "line-stop" problem that has plagued Landsat 3. This is not an NRC problem and is not something NRC can remedy. At the same time, NRC like any other user, has to wait for data obtained from EROS who has also faced many delays in responding quickly to data requests.

The slow turnaround time in preparing data products for users, however, also has equipment and manpower components. The data preparation facility is dependent in large part upon the Optronics Film Writer which is used to create film products out of digital data. Every time an order is placed for a particular Landsat scene for which no previous request had been made, NRC must remount the digital tape and use the Optronics to create a film product. Hence data which are ordered out of the archives can take quite a while to produce. Requests for data already processed can be turned around in a much quicker time. The above problems in filling of data orders, if rectified, would resolve many user complaints.

The Optronics is run manually and is subject to breakdown and human error. At present, NRC Optronics equipment can process about 10 scenes a day (forty negatives as each Landsat scene contains four spectral bands and consists of four negatives). This particular piece of equipment seems to be a key component of the data production bottleneck at NRC. There is also a problem in that NRC personnel are relatively new to the satellite data production process. The quality control officer at NRC has often had to reject data products to maintain quality during a period in which NRC personnel are becoming familiar with the production process. This, of course, adds to the backlog and slows down the pace of delivery. The problem of inexperience is being solved over time.

The magnitude of the production and distribution problem is indicated by the fact that there is currently a backlog on processing orders of about 300 scenes. The NRC estimates that at current ordering and production rates this backlog could be cleared up in a matter of a few months. However, some users have complained that data takes from two months to over a year to get. This causes them to lose enthusiasm and discourages them from using Landsat digital data in any more than an experimental mode.

Users have also been unable to obtain certain color composites; keeping perishable photographic paper to produce 1:250,000 scale color composites on hand for a few possible user orders is not economically feasible for NRC.

Some of NRC's problems would be alleviated if users were more sophisticated in their requests for data. They often fail to specify precisely the location of areas of interest, time, and date. The users have also often requested all possible data for a test area when one or two well-selected scenes would have sufficed. Asking for all the data of a certain region for a given period of time is not an appropriate way of ordering data -- and here some user training and awareness is essential to the effective data production process.

There are several possible solutions to the processing of data for distribution at NRC. These include buying a new laser writer which would cost in the neighborhood of $1 million. A second solution would be the purchase of a second Optronics Filmwriter to back up the current system and perhaps to be run simultaneously. This would cost in the neighborhood of $250,000. There is also the possibility of running double shifts on the current Optronics (this seems to be the current plan) but this requires a fairly complete in-house set of spare parts. A complete set of spare parts could cost from $25,000 to $50,000.

While any of these solutions would help solve the data production problem, a staffing problem remains. NRC must have a sufficient number of qualified personnel to operate and maintain its equipment. However, the pay scale which NRC must use is unattractive to the skilled technicians and engineers needed. In general, a university graduate begins work at a pay of $100/month, about 25% of what he would make working in the private sector. Someone with a Ph.D. from overseas begins at a salary of about $200/month.

The problems of data production and delivery at NRC can therefore be traced to a number of factors. First, not very much good quality data have been available since 1979. Second, the data preparation process at NRC has been slowed by equipment problems, lack of experienced personnel, and efforts to maintain strict quality control. In particular, the Optronics Film Writer seems to be creating a bottleneck that produces a backlog of orders leading to delays in filling user data orders. Timely delivery of high-quality data is crucial to the success of the program. without it the transfer of remote sensing technology will not take place in an effective manner.

5.3 User Awareness

User awareness is another key area in preparing data for dissemination. An introductory course which familiarizes users with remote sensing data is essential. This is discussed below.

In an effort to facilitate the dissemination of data, NRC has set up a manually operated browse file for users who want to examine what data are available for a particular region of the country. This look-up system is now being installed on a word processing system to assist initial search efforts. Once the data have been identified, the users go to the hard copy "library" and examine nine-inch black-and-white prints logged in loose leaf notebooks. This is an acceptable system for enabling users to determine data availability and quality.

The provision of data by NRC to its users has steadily increased during the period 1979-1982. In general, the main users of data have been Thai government agencies. Use has increased from 3,588 scenes in 1979 to 4,191 scenes in 1980, 5,767 in 1981, and 3,470 for the first nine months of 1982. The minimal use of Landsat digital data in the region is reflected by the low number of CCT scenes ordered from NRC (28 CCT scenes were delivered in 1979, 33 in 1981, and 18 for the first 9 months of 1982. The following tables produced from annual reports of NRC to the Data Distribution Working Group

Meetings held by NASA summarize the users and the type of data ordered. Another table of data translated from an NRC Annual Report for FY 82 gives a slightly different picture of the amount of data being provided. It suggests that during FY 82 10,852 scenes were provided by NRC to users (including to the NRC itself). Of these, over 96% were provided to Thai government agencies. This table is also reproduced below.

ANNUAL DISTRIBUTION OF DATA
DATA DISTRIBUTION WORKING GROUP

	CY 1979	CY 1980	CY 1981	CY 1982
B/W PRINTS:				
9"	1002	1254	3175	1377
3x5"	0	749	0	0
24"	910	697	1140	677
36"	878	945	676	651
B/W Film:				
2.2"	0	62	0	0
9"	0	21	282	311
24"	0	35	172	0
Color Prints:				
9"	0	24	1	203
24"	0	0	0	8
36"	0	0	0	1
FCC Trans:				
9:	620	663	517	232
Mosaic:				
1:5 mill	54	119	16	10
1:4 mill	3	2	19	6
1:3 mill	0	3	3	32
1:1 mill	3	31	10	10
Mosaic, NE:				
1:2 mill	4	5	0	0
1:1 mill	2	2	5	1
1:500K	4	3	3	0
Color Pos Film:				
35mm	0	6	0	0
CCT:	28	33	53	18
TOTAL:	3526	4688	6141	4044

DATA DISTRIBUTION BY USERS

	CY 1979	CY 1980	CY 1981	CY 1982
Government	3588	4191	6088	3470
State Enterprises	19	306	58	34
Inter. Organizations	64	54	169	11
Private Sector	10	104	94	6
TOTAL	3681	4655	6088	3521

DATA SERVICE FOR FY 1982

ORGANIZATION	NUMBER OF IMAGES
Office of the Prime Minister	60
Ministry of Defense	173
Ministry of Agriculture:	
Royal Irrigation Department	40
Royal Forestry Department	672
Department of Land Development	136
Department of Agriculture	13
Department of Ag. Extension	4
Office of Ag. Economics	37
Other	14
Ministry of Communication	113
Ministry of Interior:	35
Ministry of Science, Technology and Energy	
National Research Council	7659
National Environmental Board	46
Other	3
Ministry of Education	175
Ministry of Industry	378
Office of University Affairs	
Chulalongkorn University	227
Kasetsart University	138
Ramkhamhaeng University	180
Prince of Songkhla University	106
Srinakharinwirot University	143
Other	108
State Enterprises	121
International Organizations:	
AIT	8
Mekong Committee	8
Bangladesh Embassy	56
FAO	37
Other	104
Private Enterprise	36
TOTAL	10852

5.4 Technology Utilization

5.4.1 Introduction to Remote Sensing Principles

To increase user awareness and provide an introduction to remote sensing principles, NRC has conducted annual introductory and computer analysis training programs. These courses familiarize the trainees with the use of satellite data for resources planning and management. The introductory course is a good first exposure to remote sensing. Annex II contains an outline of course topics. The course has brought remote sensing to the attention of many potential users who have then gone on for more advanced training elsewhere.

This type of awareness and introduction to remote sensing techniques is a key part of the remote sensing technology transfer process. However, it should not be confused with the in-depth training and remote sensing education which is essential to effective transfer, use and analysis of remote sensing data by user agencies.

5.4.2 Training and Education

There are a number of training and education activities going on in Thailand. In addition to NRC's courses there are: the Asian Institute of Technology's Asian Regional Remote Sensing Training Center (ARRSTC) program; the remote sensing training courses within the Department of Forestry at Kasetsart University (under Dr. Sathit); several courses in photogrammetry and remote sensing at Chulalongkorn University (in the Survey Engineering Department).

The ARRSTC training is a USAID-funded project for people from ESCAP countries and not solely for the remote sensing users of Thailand. The program is designed to train students in both visual interpretation and computer/digital analysis of remote sensing data. A thorough description and analysis of this program is contained in section 7.0 of this study.

The courses offered at the Faculty of Forestry at Kasetsart University include Principles of Remote Sensing, Passive Remote Sensing, Active Remote Sensing, Automatic Analysis of Remote Sensing, and Advanced Remote Sensing. While we were not able to get detailed description of the content of each of these courses, they seem to emphasize the visual and manual interpretation of aerial photographs and satellite data. These courses train foresters in the use of remote sensing techniques, in conjunction with ground truth, for the mapping of forest lands. Students coming out of these courses do not have a capability in computer/digital analysis of satellite imagery. The Department of Survey Engineering at Chulalongkorn University offers three courses: one course in aerial photo-interpretation plus a beginning and an advanced course in remote sensing.

The training courses offered by the NRC include a four-week introduction to remote sensing and the use of satellite data for resources analysis and a shorter two-week course which is an introduction to computer/digital analysis of satellite data. As evident from the outline of the course provided by NRC and contained in this report, the introductory course serves a valuable awareness and introductory function. However, most of the individuals who found the course to be useful were those who were already trained in the basic tools of photo-interpretation and visual analysis and saw this course as an introduction to a new data source. These people were then able to use their traditional map-reading and map-making techniques on this new imagery. Those who came to the course to learn basic photo-interpretation techniques were less able to transfer the use of satellite imagery to their departments. This course seems then to be very effective at introducing those who are familiar with remote sensing techniques to a new source of resource information. The course is less useful as remote sensing education.

The introduction to computer analysis course taught at the NRC is designed to expose users to the digital analysis of this new information source. On the basis of our interviews it was found that the computer analysis course was not particularly useful in transferring the technology of computer analysis to users. This is true for several reasons. First, most of the students are not sufficiently trained to learn this new analysis technique. Second, this course, like the basic course, serves primarily to introduce the users to a new technique and not to train them to be able to use this technique in an operational fashion. Finally, and most critically to the operational use of digital/computer analysis, there are very limited computer facilities which are available to the users once the course is completed. This problem of appropriate digital analysis facilities will be discussed in detail in the section below on data analysis.

5.5 Data analysis and the User Community

The key to the successful application of remote sensing data is its transformation into resource information and its subsequent use by resource managers and user agencies. The team interviewed many users on the extent to which they are applying the technology.

5.5.1 Royal Forestry Department

The Royal Forestry Department, Forest Mapping and Remote Sensing Subdivision is a major user of Landsat data and provides an example where these data and their analysis led directly to an increased awareness of a severe resource problem and prompted a policy change in the Thai Government.

There are 36 people in the remote sensing subdivision. Twenty of these are involved directly in remote sensing, ten work with aerial photography and ten with satellite data. These foresters have received training in the U.S., Canada, at ITC in the Netherlands, and also at NRC and AIT. It is useful to note that they are foresters first -- who have picked up remote sensing data analysis as a tool.

The subdivision has a strong capability in visual and manual interpretation of aerial photography and satellite imagery, developed through the training sources noted above. They are hoping that the AIT course will strengthen their capabilities in computer analysis.

The Forestry Department's use of Landsat data is limited, however, by the extent to which these data are made available -- it takes anywhere from 2 - 5 months for the department to get Landsat data and up to two years to get new aerial photography flight lines flown. Their use of satellite imagery is also limited by their analysis capabilities. At present, the Department relies on visual interpretation of satellite data as they can do it quickly and are able to produce something which is recognizable and accepted by the ministers. Their equipment consists primarily of simple light tables, mirror stereoscopes, and a few reflecting projectors. They would like to add a color additive viewer, stereo microscopes and a Zoom Transfer Scope.

They understand that more detailed information is available through digital analysis, but at this point prefer to use the computer for research work rather than for operational analysis. This is a key step in the technology transfer process as this sort of experimental use is the only way to introduce computer analysis into a standing resource information operation.

The Royal Forestry Department has made a good deal of use of Landsat in its operational mission. They use Landsat data in their three primary tasks: monitoring deforestation; locating possible areas for reforestation; and for forest protection.

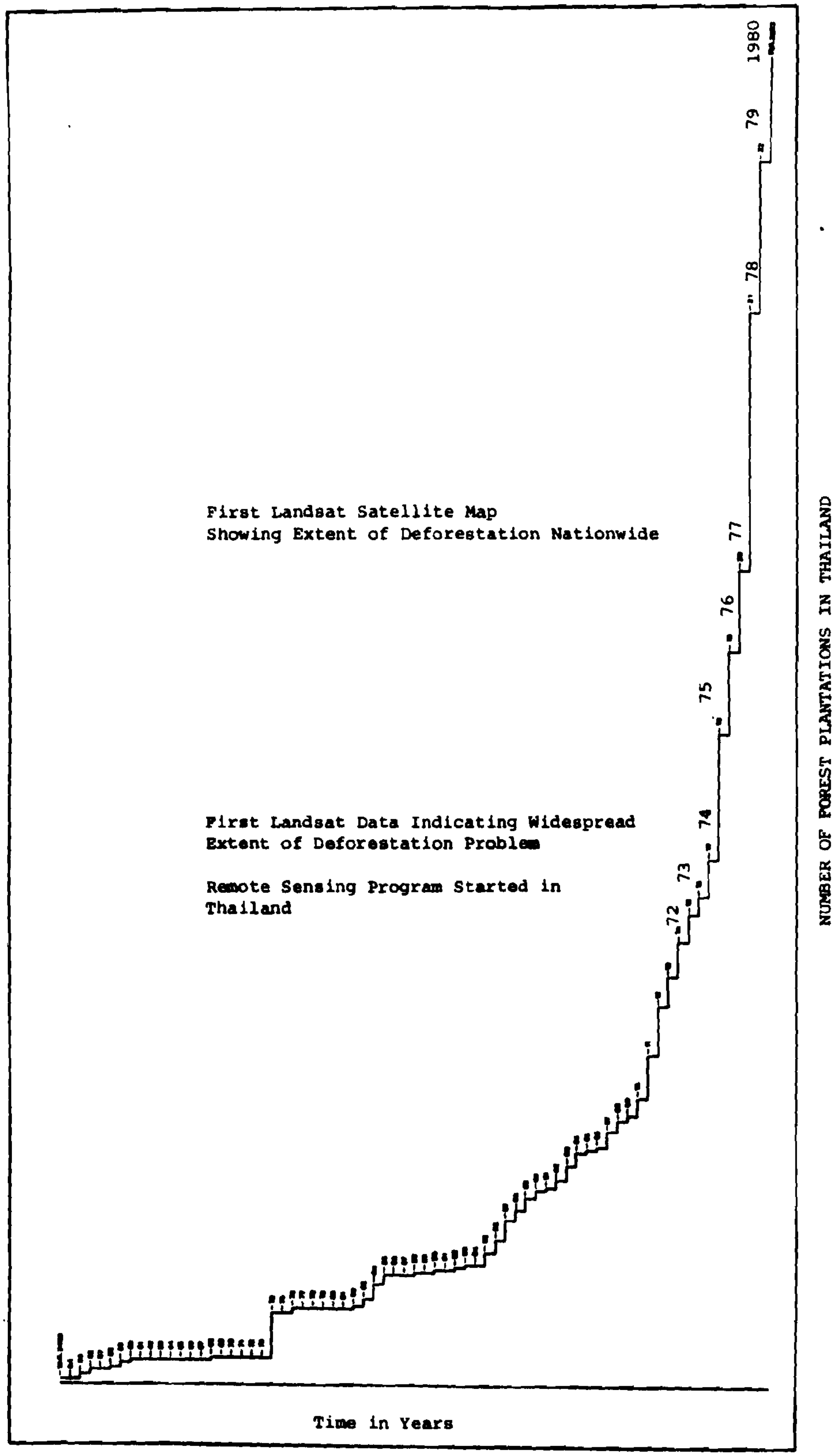
The Department has compiled data on the status of deforestation nationwide as of 1973, 1976, 1979 and 1982. This was achieved almost entirely using Landsat visual images (scale 1:250,000) supplemented by some photo interpretation and field spot checks; difficulty is experienced in getting timely air photos.

In August, 1981, the Prime Minister's Office requested a report on the status of forest lands and deforestation throughout Thailand. The Forest Department prepared this report using Landsat data. Since then, the Prime Minister has required reports every three months on the problem of deforestation in different parts of the country. The Prime Minister's staff then makes recommendations to the Ministry of Agriculture and Cooperatives regarding planned agricultural development projects designed to keep people out of "forest" lands and direct them into areas already "deforested."

Landsat data are also used to select priority areas for reforestation. The Silviculture Division is responsible for replanting. They have over 100 nurseries in Thailand (mostly in teak). Each year, 500,000 rai are replanted. In 1981, there were 3,875 Km^2 in new forest plantations. The following table shows the timing of the first use of Landsat in 1973 and the first full study which was produced in 1977. It appears that Landsat data enabled the Forestry Department to illustrate dramatically the deforestation problem: a policy to increase reforestation was implemented.

In another area the Fire Control Division of the Forest Department plans to use Landsat data to monitor areas of shifting cultivation. Most forest fires in Thailand result from slash-and-burn clearing. The Fire Control Division is using Landsat data to identify areas of potential spread of slash-and-burn. The Division intends to patrol these areas by helicopter. While helicopters have been used for the last 4 - 5 years for observation of illegal cutting, use of Landsat data to plan their observation paths will be new.

The deforestation problem in Thailand is severe. Each year an average of 4,650 sq. km. of forest land is cut over while only 800 sq. km. are reforested for a net loss of over 3,800 sq. km. each year. At this rate of deforestation, all the present forest cover of 165,000 sq. km. will be gone by the year 2026.



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The Forest Department has done a good job of using Landsat data for monitoring and highlighting the problem and integrating it into decision-making processes. Their analysis capability would be greatly enhanced if they were able to utilize computer/digital analysis.

5.5.2 Faculty of Forestry, Kasetsart University

The Faculty of Forestry at Kasetsart University is currently involved in a project related to the mapping of Thailand's forests and watersheds in conjunction with the Royal Thai Survey Department and the Royal Thai Forestry Department. This project will utilize Landsat visual imagery in conjunction with aerial photography and ground truth.

The Faculty has strong capabilities in visual interpretation of remote sensing imagery. They are well grounded in photo-interpretation and cartographic techniques. They can do image analysis on an I2S color additive viewer but Landsat data suitable for this viewer are not currently available. They do not have computer/digital analysis capability.

The Remote Sensing Lab at the Faculty contains the following equipment:

I2S Color Additive Viewer with projection screen
Zoom Transfer Scope, Vertical
Electronic Pneumonics Planimeter
Reflecting projector
Stereoscopes
Diazo
Five Sketchmasters
Stereo Plotter
Light Tables
Basic Cartographic Equipment

The development of this capability rests largely with the Faculty of Forestry staff and particularly Dr. Sathit. This department offers several courses in remote sensing (described briefly above) and what amounts to a remote sensing minor within a graduate program leading to a MS in forestry and watershed management. Some of these students have also taken the NRC training courses. If budget allows, the Faculty would like to send several of its students to ARRSTC for computer/digital analysis training.

The Faculty has participated in several studies using digital analysis. One study, entitled "Forest Land Assessment of Khob Kaen and Mahasarakat Provinces" showed the use of Landsat in demonstrating the deforestation problem in Northeast Thailand. However, the Faculty feels that without a digital analysis facility at the University to extract the maximum information possible from Landsat data, technology transfer has been slowed. This capability is not available from NRC as the image analysis systems there are not available most of the time.

At Kasetsart University there are many potential and actual users of remote sensing data including the Departments of Forestry and Watershed Management, Agriculture, Geology, Soils Science, Geography, Civil Engineering, Irrigation, Fisheries and Agricultural Economics. Of these the Forestry Department is currently the most sophisticated user.

The team also talked to the Faculty of Agriculture who have used Landsat to study the impact of mining on mangrove resources and to aid in soils mapping in Thailand's southeast coast. These studies were funded by NRC. This faculty experienced no problem getting data from NRC (they ordered pre-1979 data) but had not done any digital analysis. In most cases where NRC funds research work utilizing computer analysis, they send the researchers to Chulalongkorn University to use the IBM 370/145. The computer center at Chulalongkorn appears to be willing to cooperate with RTG agency users. They see support of Landsat digital processing as a useful and productive activity. In sum, no production computer analysis capability exists at Kasetsart and hence a key ingredient for effective training in and use of Landsat data is missing.

5.5.3 Office of Agricultural Economics

The Office of Agricultural Economics is a minor user, at present, of satellite remote sensing data. However, they are using Landsat data in the design of their current Area Frame Sampling Program. In this program, Landsat data will be used to sharpen the stratified sample. This sampling base will be a considerable improvement over that derived previously from out-of-date aerial photographs. (The last country-wide aerial photo coverage is nearly ten years old.)

NRC seems to have played a small role in the training and development of remote sensing capabilities at the OAE. There are two members of the Remote Sensing Section currently receiving training -- one at AIT in computer applications (not at the ARRSTC) and one at Kasetsart University in agricultural economics. One staff member has taken the AIT remote sensing training course but she is not performing any digital analysis.

The OAE does have a computer analysis facility. This consists of an untested version of RECOG-X on their Univac computer. This program should be an effective analysis tool. They have produced a very good research study entitled "Area Sampling Frame Construction and Applications of Remote Sensing For Rice." This study compared the accuracy of digital classification and visual interpretation of Landsat imagery and data for the delineation and measurement of paddy fields in Ayudthya. The study concluded that computer analysis produced a more discrete classification than was possible with visual Landsat means; aggregated totals (the more discrete computer classification classes had to be grouped into the more general classes derived from aerial photo interpretation). It also made some general conclusions about the use of satellite remote sensing for crop forecasting:

1. Rice fields may be too small to be picked up by Landsat
2. Cloud cover prevents data acquisition
3. Some errors in classification are caused by the mismatch between rice field boundaries and the edges of pixels.
4. Data are not available quickly enough to enable the use of satellite data to monitor crop growth.

While they are not currently using Landsat in any operational sense, their use of satellite data will likely increase as data from Landsat 4 becomes available.

The RTG has made a strong commitment to the development of an area sampling frame program for collecting agricultural data. The RTG uses the data produced by the OAE to make policy decisions regarding agricultural prices and exports, and other agricultural policy decisions. To the extent that Landsat data are used to improve the data and statistical system of the OAE, and to the extent that the data and information of the OAE are used by RTG decision makers, Landsat data will support policy formulation.

It is important to note that the use of satellites to help predict crop production and crop yield produced the original impetus and justification for much of the developing world's (including Thailand) adoption of Landsat technology. Unfortunately, the application of satellite data to crop forecasting has been problematic, and has not lived up to the expectations generated at the outset of the Landsat program.

Early on in Thailand's Landsat program a study pointed out the difficulties of using Landsat to forecast crop acreage (see Hildebrend, 1979). This study seems to have been largely ignored in the remote sensing project papers prepared since the beginning of the program in Thailand. This study, and others such as the one done by the OAE, have pointed out that the crop fields are often too small to be picked up with Landsat data, and that intercropping and multiple cropping practices make it difficult to use satellite data for forecasting. Finally, the problem is particularly pronounced in tropical countries where cloud cover during the rainy season makes it nearly impossible to collect data for critical periods during the growing season.

Still another difficulty with using Landsat data to predict crop production is the fact that Landsat, even if it could be used to determine crop area (number of acres in cultivation of a certain type of crop) cannot produce data on yield per acre. Crop yield models require extensive ground truth, data on weather conditions as well as fertilizers used, and general crop condition and agronomic information. Crop yield models are not easily developed and any use of Landsat data to help in crop forecasting must take into account the need for research into crop yield modelling as well as projections of acreage under production.

It is essential, however, to remember that future satellite data are likely to be an important source of data for crop forecasting efforts. In the near future satellites gathering data at finer resolution levels than at present will become available permitting the difficulty of picking up small fields to be overcome. Satellite carried radar sensors will overcome the problem of cloud cover (radar penetrates cloud cover). Finally, as computer analysis techniques are adopted, satellite data will become more intensively utilized. The development of digital analysis capability will be essential for the successful use of satellite data for crop forecasting in the future, and for the realization of the major potential of the Landsat program.

5.5.4 Department of Agriculture -- Soils Science Division

The Soil Science Division of the Department of Agriculture began using Landsat data in 1973. The Soil and Water Reserch Branch orders about 150 black-and-white Landsat prints per year at a scale of 1:250,000 and sixty to seventh Diazo color composites at a scale of 1:100,000. The Division has strong capability in the visual and manual interpretation of remote sensing imagery. They have three people working in remote sensing with backgrounds in soil survey. In addition, eight to ten MS degree theses have been written which apply remote sensing to soils survey analysis in Thailand; most of these have been done at Mahidol University.

The Division's first remote sensing project, started in 1976, mapped rubber growing areas in Thailand on two test sites. This project demonstrated the ability to map "old rubber, young rubber, field crops, tropical forest," and similar items at 1:250,000 scale. After feasibility was demonstrated, the Rubber Research Institute and the EEC provided financial support to map rubber-producing areas throughout Thailand. The digital analysis in this project was performed at AIT, before the ARRSTC project got underway. These data are now used to help predict rubber production in Thailand. Indonesia and Malaysia are said to have adopted this same technique.

The second project was to map soil moisture and soil classes in the Central Plain area. These data are used primarily for planning cropping systems. Agricultural Extension Service personnel have also used these data to advise farmers regarding where and when to plant. However, the use of these data is not widespread in the Extension Service as only people who have attended the Agricultural Extension Service training program (about 10 - 15 people) have actually used the data. Hopefully, there will be future training to educate more Extension Service personnel in this technique.

A third project evaluated soil erosion problems in Thailand near the Pitsanuloke-Lomask Highway and in the Phumipol Dam region. This project, completed in 1982, identified several areas of class IV ("very severe") erosion. Some of these areas have lost ten tons per rai of topsoil per year, or over 20 cm of soil on steep slopes. This situation has been brought to the attention of several agencies (Forestry, Land Development, etc.). One result of this activity is a bill now before Parliament to prohibit agriculture on steep slopes (greater than 45%).

The Soils Science Division would like to perform more digital analysis of Landsat data but does not have a facility. When the AIT computer was "free of charge," it was used regularly. Now, however, when it costs 2,000 Baht per hour of computing time, the Division can no longer afford to use it. Interestingly, while many users seem to think obtaining budgeted funds to buy Landsat visual products will be fairly easy, they feel that getting money for computer time would be difficult. A worthwhile task would be examining the cost-effectiveness of performing digital analysis. The cost of one hour of CPU time may seem to be a lot but much can be accomplished in that hour.

5.5.5 Department of Mineral Resources, Geological Survey Division

The Geological Survey Division has used Landsat data to help produce geological and lineament maps. They have found that satellite data are better than aerial photography for detecting circular features and large structural patterns. They believe that they have made some mineral discoveries along fracture patterns discovered using Landsat, including one major folite discovery in Western Thailand. They intend to use Landsat data in the future but they have had trouble obtaining the data in a timely fashion.

The Division has strong photo-geologic interpretation capabilities for analyzing remote sensing data. They are schooled primarily in visual/manual, using steroscopes, a stereo microscope, and a color additive viewer. The primary mode used in the interpretation of Landsat is visual analysis using a simple magnifying glass. The Division has sent all ten of its geologists to the NRC introductory course and several to AIT. The Division has recently found it difficult to obtain data of good quality and in a timely fashion.

Except for a few examples of data used to map geologic features and lineaments, the division has not integrated the use of Landsat data into their planning and analysis. In fact, most of their imagery is from 1972 and 1973. They have several upcoming projects for which satellite data would be used if they were readily available. These include a study of the impact of tin-dredging on Thailand's coast and a study on underground water in the Northeast. In the latter project they believe that Landsat could be used effectively in conjunction with aerial photography and ground truth.

5.5.6 Royal Irrigation Department, Hydrology Division

The Hydrology Division uses Landsat in three major areas. These include measuring the area of flooded lands, reservoirs, and sedimentation in reservoirs.

The Division has sent several of its people to the NRC courses and believes that they are useful for familiarization. Currently two members of the staff are training at AIT. Upon completion of the course, they will be in a position to employ digital analysis in departmental studies. When they complete training they will try to use the IBM at Chulalongkorn University instead of the computer at AIT which they consider too expensive. The computer facilities at NRC are not being considered as they are neither intended for users for production data analysis nor are they sophisticated enough for intensive work. A key problem in this area is the fact that there is no hard copy facility at NRC for producing paper copies of digital classifications. This makes it nearly impossible for users to integrate digital analysis into spatial information systems.

The Hydrology Division has a special problem with the use of computer/digital analysis pertaining to its particular subject area. The reservoirs they need to map are of such irregular shape that using computer classification to obtain area estimates encounters a boundary fit problem. Another problem is the fact that very little satellite imagery can currently be collected for flood monitoring due to the frequent and heavy cloud cover in the rainy season.

5.5.7 Land Development Department, Land Use Planning Section

The Land-Use Planning Section is a strong user of Landsat data and imagery. They have performed digital analysis in an experimental mode to attempt determination of how digital analysis compares to traditional visual analysis of aerial photography. They are also using visual/manual interpretation of Landsat data in an operational mode to make 1:500,000 reconaissance level land-use maps.

The Division has experienced little trouble getting Landsat data from NRC. They do have a fairly complete set of Landsat data dating from 1972 and have black-and-white prints up through 1982. These NRC-supplied prints, of fairly good quality, are being used for visual analysis. The Department has had more trouble getting recent aerial photography. There is a one to two year delay in requesting new flight lines, flown by the Royal Thai Survey. This is important because effective visual analysis of Landsat imagery is made more difficult without the support of aerial photography.

The Planning Section does most of its own training as there is no land-use/soils mapping program at any of the universities. They hire people who know the discipline and then train them at the Land-Use Division in photo-interpretation and visual analysis. Five of the people in this division have gone to the NRC basic training course. Two people have gone to AIT for training, one of whom has studied at LARS/Purdue for two years. Computer analysis training was deemed to be quite useful; the course they attended at AIT (the first one taught) devoted an insufficient amount of time devoted to the subject. (see Section 7.0). The Department expressed an interest in conducting more digital analysis of Landsat data. The computer-aided analysis training offered by AIT would constitute a strong plus in this area if the Department had access to a facility at which to perform production digital analysis. For instance, the Division used the computer facility at AIT (before the ARRSTC program began) to develop a land-use map using Landsat imagery. A supervised classification was done using the RECOG-X program. The results showed that digital classification of Landsat images produces a map with more discrete classes than a map made using visual analysis of aerial photography.

Another study, using the computer facility at Chulalongkorn University, compared land area measured using traditional air photo-interpretation means to digital analysis of Landsat data. The promising results of this project suggest that satellite data can be used effectively to develop land-use maps.

In general, Landsat data used reconnaisance level mapping at a scale of 1:500,000, has been integrated into the information flow at the Land Development Department. For decision-makers these data are too coarse to allow the detailed interpretation that is needed for land use planning. The Land-Use Section believes that digital analysis could be used to produce information more directly relevant to decision-makers.

5.5.8 National Environmental Board

The National Environmental Board is a potential user of satellite data, but has also expressed difficulties getting data from NRC. The Environmental Remote Sensing Section now has fifteen degreed professionals, most of whom are geographers. All have been to the NRC training course and found it a useful introduction. One staff member is currently training at AIT. They have an ISI VP-8 image analyzer and a Zoom Transfer Scope. They are now working on several projects for which they would use Landsat data if it were readily available.

One of these projects, near Phuket in southwestern Thailand, is studying the effects of sedimentation from tin mining on a resort beach nearby. The analysis project, started three years ago, must be completed within one more year. They have done extensive field (water) sampling and analysis. Satellite data if available would be extremely useful for the analysis, and might have a tangible impact upon the decisions made regarding this problem.

The second project, in the Nam Choen dam area, examines the environmental impact of dams on forest areas. There is some disagreement about whether the reservoir area is still covered with virgin forest or whether it has been cut over and ruined, and therefore whether the dam will further destroy the forest. Photography in this area is about two years old. They have some satellite data but they are about one year old. Current information is required. Satellite data would be particularly useful in this project, if used in conjunction with aerial photography, as they cannot get to the field sites on the ground due to "terrorists" in the area.

Urban sprawl is a major problem, and the monitoring of it around Bangkok is an important potential application of satellite imagery. At present, satellite data do not have enough resolution to be used effectively to monitor this problem. Digital analysis of satellite imagery, however, has been demonstrated elsewhere to be effective. Especially useful would be Thematic Mapper (with its 30m resolution) or SPOT data (with its 10m and 20m resolutuion).

The Board is aware that digital analysis of satellite data would be useful. However, they have not yet been involved in any digital analysis of Landsat data because of the inaccessibility of computer facilities. They are considering purchasing a digital analysis system of their own (estimated cost $200,000).

5.5.9 National Statistical Office

The National Statistical Office is not a current user of satellite remote sensing data, although they did use the data to help set up the census area frame sampling program. This office has sent some of its people to the NRC training course, primarily for familiarization and appreciation and felt that the courses served that function very well.

5.5.10 Shell Company of Thailand, Ltd.

Shell became a major buyer of Landsat data from NRC in 1982. They bought sixteen CCT's and negative film products to aid in their exploration for tin in Thailand. They feel that the cost of these data is very small compared to overall exploration costs. They will want to get TM and/or SPOT data as soon as it is available because while they can get aerial photos of some areas, it is difficult in others.

Shell has not utilized the training courses at NRC or AIT although they would be interested in utilizing the user assistance center at NRC.

Shell is not likely to buy much more data from NRC in the near future because they were able to get relatively cloud free coverage by buying the 16 CCT's. They have sent the tapes and film products to The Hague for preparation of further data products which will then be used for structural analysis. If the data proves useful they will be integrated with the information gleaned from field crews and whatever aerial photography can be obtained.

5.5.11 Mekong Committee

The Mekong Committee collects and analyzes data, seeks funding from donor countries, and manages projects within the Mekong basin. The staff is currently trying to assemble Landsat data for Thailand, Laos, Cambodia and Vietnam. They have some photography, but aerial photography is difficult to get in some areas. They have conducted visual analysis of Landsat data, and plan to do digital analysis. Their physical area of interest is large, and they use Landsat as an alternative to aerial photos. The Committee has purchased about 1,000 Landsat images since 1972, or about 50 scenes per year.

They have just completed a reconnaissance-level "dam site selection" study in Laos. Using Landsat data, a consulting geologist from Hong Kong was able, in only ten days of study, to identify areas with potentially high construction problems. The staff would like to do more digital analysis but has had trouble finding a suitable facility. They have not used NRC's analysis system because they were advised that there would be a long wait. They are presently planning to purchase a "Vax 11730" computer system, but about $150,000 (including some maintenance).

5.5.12 USAID Projects Using Remote Sensing Data

Two USAID projects have made use of Landsat data. In the case of the Lam Nam Oon irrigation project, a member of the resident engineering staff is attending the current NRC course to learn how to read the imagery. Although this project is small compared with the scale of Thai irrigation works in the Central Plain, it has attracted attention among policy-makers in Bangkok because of its Northeast location and its disappointing record in terms of actual area irrigated and cultivated by farmers during the dry season for the past several years. The question of how much land was actually being cultivated was hotly debated each year, with widely differing "eye-ball" estimates made by different project personnel and AID advisors, giving different impressions as to progress being made in achievement of project objectives. Remote Sensing data should help project staff settle this question and locate the precise areas of spread of cultivation.

In another project, Northeast Rainfed Agriculture Development, designed to help develop mixed farming solutions to the problems of agriculture production in the largely rain dependent Northeast, the contractor, the University of Kentucky, is attempting to use Landsat imagery. The project will be working in about 100 vilages with a population of about 9,700 farm families.

In both of these cases, the application of remote sensing data to problem-solving at the level of modest sized projects represents examples of how the technology can be used at the activity level to benefit specific rural communities.

Thailand has made very good use of Landsat data in forestry, land-use planning, water resources management, cartography, and mineral resources exploration. Satellite data have been used less extensively in agricultural production forecasting, demography, environmental protection, marine resources and coastal zone monitoring and disaster warning and assessment. In general, Landsat data have been used as one would expect -- in a reconnaissance-level mode and as a supplement to other data sources.

The team has not attempted to quantify the benefits Thailand has already derived from the usage and decision effects described above, but they are without question greater than the relatively small cost of the training, data acquisition and data analysis equipment the users have needed to carry out the analysis. The continuing flow of information from the uses already underway into the decision processes already absorbing this information, plus the new uses and techniques that are yet to be worked out (and possible use areas yet to be initiated or recognized), are likely to yield high returns on the margin for the investments of past years, and continue to be an important source of information for Thai development planning in the future.

5.5.13 Costs and Fees

Although NRC has not done a proper cost study on its products, it is clear that the products are being sold at subsidized prices, even at the recently increased schedule. NRC continues to charge the lower former fee schedule for sales of old data. In 1982 about 40% of the fee earnings came from sales to RTG users, 30% to other governments or agencies and corporations.

Whether NRC sells at a subsidy or at full cost may affect user agency demand and therefore total production and cost to the RTG as a whole (although how that cost is distributed between NRC or RTG user budgets is otherwise unimportant). Sales to the private sector in Thailand could earn a modest net revenue if properly priced, but such sales thus far have been limited to a single purchaser. It is difficult to foresee significant private sector sales. There are few corporations in Thailand with need for large-area ground data.

The Thai Budget Bureau has yet to raise the issue of cost recovery. But there is no reason Thailand should subsidize sales of NRC products to non-governmental buyers, especially if sales to buyers outside Thailand are entailing a net foreign exchange loss and NRC prices remain below those of the US. On the assumption that the whole technology has a substantial future in the region, NRC sales should continue to grow to the point where the subsidy versus cost-recovery issue becomes big enough to attract Budget Bureau attention and warrant more systematic study. (NRC estimates the sudsidy or "loss" in 1982 at over $500,000.) At this stage, it would be useful for the NRC to carry out a proper cost accounting of its products, including both marginal and fixed costs. With a clear picture of its cost and subsidy position, NRC would be better able to see how much of a fee increase whould be needed to cover its product costs, and where such increases would put its fees in relation to EROS fees for the same products.

The fee question must also be put into the perspective, at this early stage in the technology diffusion process, of the effect of a cost increase on the willingness of still uncertain users to buy the products. In fact RTG users, both the technical and administrative levels, are well enough along in the absorption of the technology so that present fee levels are not a significant factor in its diffusion.

For some agencies the level of data usage (number of products bought from NRC) is low and the increased costs will amount to very small fractions of their budgets. The cost increases appear to be trivial factors. For the more active users, the imposition of higher fees has caught them by surprise in the middle of a fiscal year. If there is any impact on willingness to buy imagery or CCTs, or on the number of products bought, it will emerge in the fiscal year beginning in October 1983. However, no users interviewed raised the fee question before the team did, and none saw the fees as a significant issue or a deterrent to reaching a desired level of acquisition. Whether there is any effect or not will depend on the severity of overall budget pressure in the next year or two as Thailand faces a difficult short-term fiscal outlook. The RTG Budget Bureau reviews of line-item requests by user agencies are said to be thorough enough to ensure that specific applications were indeed being planned, but not obstructive. In any event, user agencies then have enough flexibility after receiving budget authority to make line-item adjustments.

The general picture that emerges from this review is that Thailand has made substantial strides in the area of satellite remote sensing and analysis. However, at each step of the process -- from data acquisition to data preparation to training and data analysis, and finally to the integration of Landsat data analysis into decision-making -- more needs to be done. The technology contains much information that Thailand is not yet extracting from it.

5.6 Findings And Recommendations

Data Acquisition

Findings: At present, the ground receiving station is capable of receiving Landsat 4 Multi-Spectral Scanner data. It is not capable of receiving either thematic mapper data or SPOT data. Landsat data may not be available beyond the design life of Landsat D'. This would mean that unless a private sector company or another country launched a satellite comparable to Landsat, the Thai ground receiving station would become useless without software upgrades necessary to process other types of satellite data.

Decisions regarding future remote sensing satellite systems will become more complex as the quantity of data being generated in space increases manyfold and as several countries launch remote sensing satellites.

Recommendation: As decision-making processes regarding satellite remote sensing programs become more complex, consideration should be given to how best to develop the capability to make these complex decisions. An independent assessment may be required.

Data Preparation and Dissemination

Finding: NRC currently has too many tasks, given its current staffing level and budget, to perform effectively its primary function: data preparation and dissemination.

Finding: NRC is currently unable to process Landsat 4 MSS data but is dealing with this problem through a grant from the Canadian Government. If and when Thailand begins to receive data from other satellites a further modification in processing software may be necessary.

Finding: Some users have difficulty obtaining satellite data from NRC, both in terms of product availability and in speed of delivery. There has also been difficulty obtaining aerial photography from the Royal Thai Survey Department; it can take up to two years to get new flight lines flown.

Finding: Equipment problems, lack of sufficiently trained technicians and a commendable effort to maintain quality control have all plagued the NRC production and dissemination process. In particular, the Optronics Film Writer (which transfers digital data into film products) is a bottleneck. Certain products desired by users are not presently available from NRC. A particularly sought after and useful form of data would be the 1:250,000 color composites.

Recommendation: NRC is considering going to two shifts -- working the Optronics Film Writer sixteen rather than eight hours a day. The evaluation team encourages such a solution but notes that doing so will require more trained personnel and a ready supply of spare parts for the Optronics. Another possible solution would be to procure a second Optronics and run it in parallel with the one now in place. A third solution would be to buy a more advanced, faster system, such as a laser writer.

Some consideration should be given to employing an independent analyst (for 2 - 3 months) to examine NRC's production and distribution process and to prescribe equipment purchases (or modifications). Management and personnel requirements should also be studied and appropriate recommendations made to increase efficiencies.

Recommendation: The same independent analyst could review the manpower and equipment needs of the user agencies so that decisions can be made regarding the rational use of equipment and the possible procurement of additional visual and computer analysis equipment.

Recommendation: NRC should focus its activities on the production and distribution of data, even if it means cutting back its activities in some other areas.

User Awareness and Assistance

Finding: The two current NRC courses are most useful as introductions to remote sensing and for creating an "awareness" of remote sensing technology.

Finding: NRC has developed an efficient browse file by which users can determine data availability, quality, and suitability.

Finding: User training and remote sensing education should be encouraged so that the users themselves can better determine the type of data required for a particular application. User services are not used as intensively as they should.

Recommendation: NRC training courses should be continued. Consideration should be given to limiting them solely to familiarization and introduction to digital processing.

Recommendation: Consideration should be given to reducing the length of these courses.

Training And Education

Finding: The training program at NRC serves as an introduction and awareness course -- not as a training and education course.

Finding: Training in remote sensing available at the Faculty of Forestry is good in manual/visual remote sensing analysis but not in digital/computer analysis.

Finding: the training program at AIT is in an evolutionary stage. The course currently underway is the first (of three) able to approach fulfilling program design; geographic information systems equipment, for instance, is still being installed. Digital processing is now given greater emphasis than visual image interpretation as was intended.

Recommendation: The training and education of Thais in remote sensing should be conducted at the University and/or at AIT. NRC should not be expected to provide remote sensing training and education as defined in Section 4.0 of this study.

Research Coordination

Finding: At this stage in the development of applications of remote sensing data in Thailand, research serves two functions: to define and refine the potential uses of remotely sensed data under Thai conditions, and to help solve knowledge problems in subject-matter applications where the techniques of application have been worked out and found satisfactory. The NRC research budget has been allocated by the research committee based on reviews of proposals put to the committee by Thai researchers.

Recommendation: With several potentially important applications of Landsat still not demonstrated for conditions in Thailand, the committee should consider setting aside some of the research budget for subjects that deserve priority in an effort to develop the full range of this potential. Crop measurement and forecasting is an obvious first priority. Other subjects for which Landsat data may prove useful, but which appear under-research thus far include (a) more detailed mapping of forest condition, including species differentiation; (b) coastal monitoring; (c) monitoring of change in urban sprawl and its encroachment of agricultural land; (d) urban hydrology; and (e) saltwater intrusion in the Chao Phya delta.

Data Analysis

Finding: Thailand has developed a fairly strong, however somewhat uneven, capability in visual/manual analysis of remote sensing data. Thailand has made only limited use of satellite digital data because most user agencies lack the requisite computer facilities and the necessary experience.

Finding: There is currently no device at NRC to generate hard copy output of any digital analysis it performs.

Finding: The computer image analysis capability at NRC is insufficient to serve as a production computer analysis facility for Thailand's line agencies. Such a facility is essential to deriving maximum benefit from satellite data.

Finding: The computer facility for remote sensing at AIT cannot serve as a production computer analysis facility for the RTG on any significant scale.

Recommendation: The Thai Government should consider the procurement of sufficient visual/manual analysis equipment so that the agencies who are using remote sensing in an operational mode can produce analysis. In some departments, equipment lies around unused, while in others where it is needed a great deal, there is none. The equiping of user agencies is not only a technical/equipment problem, but also a management/institutional problem. As suggested above some consideration should be given to doing an independent assessment of equipment and management needs within the Thai Government.

Recommendation: The RTG should set up a production level computer analysis facility dedicated to the analysis of satellite data. This facility should probably consist of a fairly sophisticated mini-computer, something as powerful as ESL's IDIMS system. Consideration should be given to hiring an outside consultant to spend some time with user agencies in order to determine the best computer facility and institutional arrangements.

Recommendation: The evaluation team believes, upon first examination, that any such facility ought to be located within NRC, but should be dedicated solely to computer processing by line agencies. This new facility will require additional personnel and equipment.

6.0 THE USAID NATIONAL RESEARCH COUNCIL REMOTE SENSING PROJECT

6.1 Introduction

Section 3.0 discusses Remote Sensing in Thailand in the context of the overall remote sensing process. This process consists of the movement of satellite data from data acquisition through data preparation and distribution to user agencies which generate resource information from the data, and then to decision makers who make use of resource information. Following that, one would hope that these decisions, based on improved information, would lead to "better outcomes" than would otherwise have occured.

The team generally feels that the development of remote sensing capabilities in Thailand has been quite good, and that USAID and other outside donor aid programs have had a positive impact. In this section we review USAID programs as they have affected each of the parts of the remote sensing process, and show how some of the problems which the Thais now face could have been more adequately addressed.

6.2 Issues

An evaluation of this particular USAID program must recognize the fact that USAID's contribution is a relatively small part of the investment which has been made by the RTG. This investment is over $10 million at the present time while the entire USAID commitment is on the order of $500,000.

In a general sense the RSTD project was successful. Equipment was procured and is now in place at the NRC facility. Training has occurred although there was some difficulty in finding personnel qualified for training in the United States at a graduate level.

However, the program must be viewed more critically when put in the context of the overall remote sensing process in Thailand. In other words, one should ask what effect this program had on Thailand's overall remote sensing capability. In particular one must also evaluate this program on the basis of whether or not is was designed to deal with the problems of Thailand's remote sensing program, whether its management helped or hindered the project, and whether or not the project led to greater utilization of remote sensing data by user agencies.

In the area of data preparation the USAID project was designed to help the Thais produce better quality photographic products. The Project Paper noted the need to upgrade the processing and handling capability at NRC in the expectation that the demand for data was likely to increase substantially. Funding was also provided for training of personnel to run the new photographic equipment necessary to enable the center to produce user products. The USAID project has certainly accomplished these goals, enabling the NRC to produce better photographic products and data for users.

The USAID project, however, did not address what has appeared to this evaluation team as a major bottleneck in the preparation of data by NRC. This is the fact that the manually operated Optronics Film Writer is slow and inefficient. This makes it difficult for the NRC to keep up with the data demand. This could not have been forseen by USAID as a problem at NRC because information collected by a previous evaluation team on the amount of data requested by line agencies and the number of requests filled showed that no data preparation and dissemination problem existed.

The Project Paper also does not contain an analysis of the flow of data through the NRC processing center. Given a projection of rising data demand and the then current capabilities of the processing facility, an evaluation of the capability of the production equipment might have shown that the production of film products from digital tapes would slow down the data preparation process and the ability of NRC to product data for its users.

In this case, the USAID program was only partially successful. It helped to solve one problem, that of providing the equipment to produce color and photographic products (which were needed partly due to changes in the design of the US satellite) but it failed to address the problem which would arise, and did arise, as data demand increased.

The project training component included money for staff of the NRC to be trained to operate the NRC equipment. While this training was essential, the project took an implicity narrow view of what was needed to transfer the technology to user agencies. For this transfer to take place, training must occur in a number of areas besides NRC production: analysts who can interface with users to help them to be able to use remote sensing analysis equipment; line agency technicians who will use the data; senior science administrators in the area of technology management. The USAID program helped to train technicians, but did not address any of these other types of training needs.

The project did not address problems of data analysis and interpretation. It is here, at the user level, that the real payoff comes from remote sensing data. Many Thai agencies do not have the proper equipment to make full use of satellite remote sensing data.

This is true both in the visual analysis of Landsat data where some users do not have sufficient equipment to effectively perform visual/manual analysis of satellite (or aerial) data and also in the area of digital analysis. Without a capability for production level digital analysis, the use of satellite data to maximum advantage can never be accomplished. Nothing in the USAID project was directed at building the users capability to analyze data -- either in visual techniques or in digital techniques.

The difficulty in designing a technology transfer project should not be minimized, and the team does not mean to do so. It is also not the intention of the team to suggest that USAID should have allocated funding for all of the problems encountered by the Thais in the utilization of satellite remote sensing. In fact, the limited amount of USAID funding which was allocated for the project was spent in needed areas. However, when dealing with remote sensing it is essential to realize that the technology transfer process has many components, none of which can be neglected without the possibility of the overall process failing.

In sum, the project addressed equipment needs only at NRC and did not consider the question of the corresponding equipment needs of the users, which are no less important. The project did not address the management issues, perhaps because the evaluation on which it was based appears to have misread the situation in some respects (e.g. the product production and delivery situation). Third and perhaps most important was the limited nature of mission involvement. For a good portion of the implementation period of the NRC project, the project manager was detached for other duties. The time he could allocate to the project and the time of the other USAID officer assigned to the project were apparently completely absorbed by paperwork and implementation problems regarding procurement and participant training.

6.3 Coordination Between NRC, USAID and Other Non-RTG Agencies

As can be seen in the organization chart in Annex I, the RTG brought together all interested agencies when the remote sensing coordinating arrangements were originally made. The three non-RTG agencies involved in remote sensing -- AIT, USAID and ESCAP -- link to this structure through their individual relationships with NRC. The team believes that the coordination arrangements between NRC and the non-RTG agencies should be reviewed immediately with a view to improving communication regarding forward planning and ensuring that possible missed opportunities are in fact recognized. The issues raised in this evaluation include several where NRC could obtain useful inputs from some donor. The major Canadian contribution to NRC staff and equipment capability now being planned in detail will affect some of these question, e.g. the relationships between AIT training curriculum and the training needs and activities of NRC, but there appears to have been little communication among the parties involved. The ESCAP regional remote sensing coordinating unit is undertaking a comprehensive review of the status in the region which will put the head of the unit (Mr. Heng Thung who also happens to have been one of the original US team that appraised regional interest in the training center idea before the project was initiated) in position to provide information and perspective about other countries' needs and plans not otherwise obtainable in Bangkok. When the French SPOT satellite is operational, France will become another important participant, possibly a donor. Australia has been interested in the past, and Japan is also planning a satellite. The FRG has a program of training in remote sensing (not active in Thailand), and some Thais have attended photogrammetry training in Holland at ITC.

A minimum step toward improved coordination would bring together AIT, CIDA, USAID and ESCAP. Consideration should be given to the possibility of inviting some of the other countries, especially where there is an active aid program that could include some activity in remote sensing even if there is none at present. A wider grouping would make particular sense if the National Coordinating Committee were to develop a systematic plan for staged topping-off and upgrading of both NRC and user agency equipment, and if the training requirements were clarified after taking account of NRC and AIT programs.

6.4 Findings and Recommendations

Finding: The RSTD project was a technical success in that equipment was procured and installed and some training occured. However, the project did not address some important problems in NRC data preparation and distribution. The project also did not address some critical problems in the use of remote sensing data.

Finding: The evaluation team found that the previous evaluation considered some components but did not consider the entire remote sensing process in Thailand. As a consequence the subsequent program design did not address some important problem areas.

Recommendation: USAID should adhere fully to its normal design and evaluation procedures on projects of this type. Had those procedures been followed the issues regarding technology transfer to end users would have been addressed, and the RSTS project might have been designed differently.

Recommendation: The team believes that the coordination arrangements between NRC and the non-RTG agencies should be reviewed immediately with a view to improving communication regarding forward planning and ensuring that possible missed opportunities are in fact recognized.

7.0 THE ASIAN REGIONAL REMOTE SENSING TRAINING CENTER

7.1 Introduction

Operations of the Asian Regional Remote Sensing Training Center (ARRSTC) are being examined here at about the half-way point of a designed six-year project. The project was designed to consist of two phases. The first phase, completed in 1982, consisted of the development of facilities, the acquiring and storage of data, purchase of equipment, and an unspecified amount of training, problem solving, research, and outreach. Phase II, a second three-year period, has approximately two and one-third years left. The dominating component of this second phase, the training program, will be examined in detail in this section. Research and outreach, barely underway, will be given an appropriate amount of discussion.

As a guide to consideration and evaluation of the program, the original goals and purposes are worth reviewing. The July Project Paper stated that the purpose was "to establish an Asian Remote Sensing Training Center with the capability to: (1) provide training to ESCAP technicians, (2) demonstrate the usefulness of remote sensing in development planning, as well as resource management, and (3) assist in planning, as requested by Asian user agencies, with a view toward the Center's becoming an integral part of the Asian Institute of Technology." The paper further stated that "the project will provide: (a) data bank and outreach facilities to give Asian decision-makers the most sophisticated and current data available to regulate their resource anu land-use procedures, and (b) a facility to train Asian technicians who will be capable of developing resource and environmental utilization plans based on sound, current, regional data obtained from U.S. space vehicles."

7.2 Description of the Training Program

Description of the program is subdivided into an account of: (1) facilities and equipment, (2) staff, and (3) curriculum. Findings and recomendations follow.

7.2.1 Facilities and Equipment

The Center, housed at the Asian Institute of Technology, has modern, air-conditioned classrooms, laboratories, offices, and computer facilities. Equipment consists of shared time on the IBM 3031 (actually a 370 console and a 3031 Central Processing Unit (CPU), and a variety of instruments to serve the process of visual image interpretation and the establishing of a geographic based information system. Without listing an item-by-item inventory, the equipment consists of:

Zoom Transfer Scope

Color Additive Viewer

Stereo Plotter

Electronic Planimeter

Digitizer

Variable Image Size Electrostic Plotter

Geographic Information System Peripherals

Color CRT interactive devices

Lighted tracing tables

Drafting machines and kindered equipment

Mirror Stereoscopes

B. Staff

The staff consists of five American experts in remote sensing working under the direction of Associate Professor Kaew Nualchawee, Ph.D. The five are:

Dr. Buddy Atwell, Associate Director

Dr. Gary Johnson

Dr. Larry Fox

Dr. Bill Hodson

Dr. Aulis Lind

7.2.2 Staff

Teaching. The primary responsibility of staff members so far has been the conducting of the training course. The schedule for training (see the schedule for the May-August, 1983 term in Attachments) illustrates how teaching responsibilities are divided. Each faculty member conducts the segment of the course lying within his/her area of specialization. Within the constraints of physical space and in accordance with the design of the curriculum, educational goals are best served by dividing the day into morning and afternoon sections. In general classroom situations, a professor will direct the students for an entire session. In special situations, especially in the conduct of field visits, the entire staff is involved. Analysis of the schedule (see Annex III) reveals that each faculty member is responsible for about nine contact classroom hours per week, on the average; the figure is in keeping with customary university scheduling.

Supporting Activities. Time not spent in the classroom and not devoted to the development of research proposals or the conduction of research is spent in a variety of ways supporting the educational mission. First, a considerable amount of adjustment in the curriculum has taken place during this first year of operation. This has been necessary partly because of the need to adjust the course to serve the current large class (31 students); -- seven students constituted the first class and nine the second. Also requiring a great deal of outside time has been the developing of the digital processing phase of the course. Effort has had to be directed toward developing or modifying the required computer software, preparing exercises that could be used in conjunction with the computing equipment, and in installing and "shaking down" newly-delivered equipment to handle geographic based information systems.

Time is also routinely spent on advising and directing students on a personal basis. This is an expected situation considering that students speaking a variety of tongues are being instructed in English. Personal contact and demonstration of techniques, especially on sophisticted equipment, is vital to the success of the project. This alone may well justify the low student/faculty ratio (six to one this term).

The faculty has also been engaged in initiating research projects. So far these activities have taken the form of supervising student projects within the program and in conceiving ideas for development of research proposals.

Another ongoing task for all of the faculty is the establishment of contacts within Thai government agencies employing remote sensing to support their research or management activities.

7.2.3 Curriculum

The training course, as designed from its inception, is comprehensive in its scope and yet, thanks to the eight hour a day, fourteen week period devoted to it, is extremely detailed. Indeed, the course is probably the only one given in the world that provides the time to go into a fine level of detail in virtually every known technique in the field of remote sensing. Other courses, commonly, will either cover only a specialized part of the field or offer a highly generalized overview. The length of time available in the course also provides for regular and fully integrated laboratory and field experience to support the teaching of theory and techniques. The course, as so offered therefore approaches the ideal mentioned in a previous section to education rather than training. The depth of experience gained in the course should make the graduates aware of the advantages and disadvantages of varying analyses systems so that he/she can make vital management decisions on remote sensing use upon return to their regular positions.

The course has grown and improved through the three terms of its existence (this third course will be completed in August, 1983). The first offering commenced only a short time after the arrival of all of the teaching staff in Thailand. With such limited time available for preparation and with requisite programming not available on the computer to allow practical application of the digital component of the course, the curriculum of the first term (and the second) was restricted to teaching of techniques in aerial photo-interpretation and analysis of visual satellite images, and lectures and demonstrations on the theory of digital analysis and geographic based information systems.

Because of insufficient time to advertise the first course adequatelym the class's composition consisted of only seven Thais. The second course consisted of seven more Thai students plus two Indians. By the time of the third course, the present one, the availability of the course was well enough known that a total of forty applied and of that, thirty-one students finally were accepted. The composition of the class is truly international and meets much more closely the conceived regional participation. The class consists of:

18 students from Thailand

3 students from Indonesia

2 students from Nepal

1 student from the Republic of China

1 student from the Philippines

1 student from Korea

1 student from Viet Nam

1 student from pakistan

Twenty of these students are supported by USAID/AIT, one by the Royal Thai Air Force, three by the Ford Foundation, three by ESCAP/USAID, and two by ESCAP.

<u>Structure of the Curriculm</u>

The curriculum was designed to cover, in a comprehensive fashion, virtually all aspects of the field of remote sensing. The course is structured to provide to its participants, an education in the field, one that is broad enough to grow into leadership positions in their respective countries in the remote sensing activities of their home agencies. The training in techniques is supported by lectures on theory. Sufficient time is allowed for application of lessons learned to excercises that are examples of "real-world" resource problems. The following is an abbreviated listing of the curriculum (the full curriculum outline is included in Annex IV).

I. Fundamentals of Remote Sensing

Definition and Purpose of Remote Sensing

Electromagnetic Radiation

Instrumentation for Remote Sensing

Fundamental Characteristics of Image Data

II. Field Investigations to Support Remote Sensor Data

Scope and Purpose

Field Approaches

Field Study in Remote Sensing Applications

Field Studies Relating to Thermal and Microwave Remote Sensing

III. Visual Analysis of Remote Sensor Data

Philosophy and Techniques of Image Interpretation

Photographic Sensors

Photo Measurements

Applications of Visual Interpretation

IV. Radar Remote Sensing

Principles

The Synthetic Aperture Radar System

Interpretation of Radar Imagery

Applications of Radar Remote Sensing Data

V. Computer Analysis of Remotely Sensed Data

Fundamentals of Image Enhancement

Fundamentals of Pattern Recognition

Applying the Quantitive Approach

VI. Computerized Geographic Information Systems

Important Characteristics of Geographic Information Systems

Methods Used to Digitize Data

Basic Storage and Map Concepts

Basic Analysis

Application of GIS Technology to Site a New Town

GIS Analysis Models

The degree of emphasis given each component of the course reflects the complexity of the material, the background of the participants, and the judgment of the staff in determining the vital elements of remote sensing both at its present level of development in the participating countries, and its anticipated usage in the future. While some segments of the course are interwoven with others throughout the term -- causing the time devoted to each becomes difficult to assess -- an approximation of time spent on each item is as follows:

- Five weeks on the visual imagery, how it is acquired, analysis and application;
- seven weeks on computer processing of Landsat digital imagery;
- about two weeks on radar and geographic based information systems.

The latter item reflects "plan" more than "reality" as the geographic based information system equipment is now in the process of being installed during the course of investigations conducted by this review team. The stated plan is to integtate the GIS work with digital analysis. This is a valid approach considering that data derived from computer processing are vital information inputs to a spatial information system.

A description of some of the details of the curriculum, shown in broad outline form above, will demonstrate the comprehensive and intensive nature of the course. The following are examples (using headings from the outline above):

Visual Interpretation: All of the usual techniques are taught for analysis of visual imagery (both aerial photography and satellite images). Acquisition of these skills is vital both to program graduates from the countries (or some agencies within generally more advanced countries) lacking digital analysis capabilities, and those who will use visual imagery in support of digital analysis.

Field Investigations. Full awareness is taught of the role that remote sensed data has to play within the context of supporting information, maps, statistical data, ground field surveys, and surface ("ground") truth. This conceptual approach is vital. It effectively demonstrates that remote sensing is not to be thought of in isolation and as a single panacea but is only a component of the total spatial information system of the type needed to solve resource problems.

Photographic Sensors. The science of photography is inextricably bound with the techniques and tools of remote sensing. A common omission in remote sensing training is the development of an understanding of photographic theory and how that knowledge can be applied to selection of methods for the acquisition of remote sensed information.

Radar Remote Sensing. An awareness of radar remote sensing -- and its possible application in often cloud-covered tropical areas -- is properly included in the course. This type of awareness is a valuable component of the education (as opposed to the training) of the participants and could serve them well in the future when radar imagery could be more readily available.

Pattern Recognition. Pattern recognition theory is an extremely complex body of knowledge but a vital one lying at the heart of development of true understanding of the principles of remote sensing. Classroom lectures, supported by laboratory demonstrations, are vital to the attainment of an adequate education in the field. It helps the participants to develop that all important sense of the spectral character of the landscape for it is in this that computer processing of satellite digital data is so profoundly different than the common spatial relationships understood and used in the interpretion of visual imagery. The course can make only limited inroads into this complex subject. True understanding comes only to those who have worked intensively in computer-aided processing for considerable periods of time.

Geographic Based Information Systems. Computerized, geographic based information systems hold promise of allowing full control and usage of all spatial data, both that sensed remotely and that collected in other ways. Visual spatial information systems (in the form of map overlays) have existed for a long time but are limited by the ability of the user to comprehend very many patterns interactively and results are slow and difficult to derive. Computers present a means for handling the extremely large number of data points required to achieve sufficiently fine resolution in an area of interest. The inclusion of theory and methods of developing and using a GIS -- while ahead of its time -- is, nevertheless, part of a solid body of knowledge on which the graduates can later draw.

Computer Processing of Satellite Digital Data. The most important contribution to the acquisition of knowledge of remote sensing is the intensive training in digital processing being given in this third term of teaching. Only through the use of digital processing can maximum use of data from Landsat (and other earth resources satellites -- including future French or Japanese ones) be made. This training is essential to the students who will return to their agencies, as it gives them both a practical and theoretical base which which they can enter the world of digital processing. Their knowledge is an essential ingredient in any program of acquisition of digital data handling capabilities. Many of the countries -- including Thailand -- have some digital processing facilities available now and many more will be acquired in the future, particularly as computer capabilities are expected to rise by several orders of magnitude and at lower relative cost. Some observers have questioned the appropriateness of AIT's emphasis on digital analysis as compared with course time devoted to visual analysis techniques. the team considered this problem of accommodation and concluded that visual analysis is well-covered, but that grounding in digital analysis was important even for trainees from countries not yet in position to use these techniques. Lacking this grounding would amount to a serious handicap constraining the ability of these countries to advance their techniques for full exploitation of the potentialities of remote sensing.

7.3 findings and Recommendations

Examination of all aspects of the design, organization, and functioning of the Asian Regional Remote Training Center's program was conducted through the media of interviews of staff members, interviews of RTG agency staff members who had relationships with the program, and reference to curriculum and other documents. Several clear findings resulted from these activities.

Finding One: The general program for training at ARRSTC is conceptually sound. A need has existed and will continue to exist indefinately for high-quality education (as opposed simply to training of technicians) in the remote sensing aspects of the acquisition, analysis, and application of spatial data covering a variety of problems common to nations of the region.

Recommendation. The concept of this approach to remote sensing needs to be continued. The training program is barely under way in the form in which it was designed. The team recommends that AID/W should start considering now, in 1983, the possible extension of the ARRSTC project beyond 1985. The grand design simply needs more time to bear fruit. Education programs, by nature, have long-term payoffs that are slow to be realized. Graduates of the program need time to rise to positions of influence in their home countries before any final assessments can be made.

Finding Two. The full design of the training course was not adhered to in the first two terms (from August, 1982 through April, 1983). A variety of reasons precluded the staff from following the project plan. Reasons are: (1) delays in engaging staff members and bringing them to Thailand resulted in the first term commencing only a few days after arrival in-country of some of the staff; (2) insufficient time was allowed for curriculum development (the staff drew largely from their previous experiences at having given short courses and workshops in the US but didn't have time to "tailor" their wares specifically for a local audience); (3) not all the required equipment had arrived and some that had was not yet operational; (4) the digital processing system was in a state of change because of the introduction of new computer equipment and the conversion from one set of software to another; (5) arrangements had not been made to acquire supporting visual imagery, particularly of tropical examples (Dr. Gary Johnson fortunately had the foresight to bring a fair quantity of visual examples from his technology transfer job with the EROS Data Center. Even though the examples are generally from US environments, they are serving as the only examples of certain phenomena available); (6) arrangements for administrative support for the teaching staff had not been made -- only recently has an administrative structure been established (Dr. Kaew Nualchawee is Director and Dr. Buddy Atwell is Associate Director); and (7) the relationships between teaching staff, the Asian Institute of Technology, and USAID/Thailand were not delineated clearly enough to avoid confusion on the part of the teaching staff.

Recommendation. Difficulties of a slow start for the program and its slow progress toward reaching conceptual goals should be viewed as "growing pains" and to be expected in an endeavor of this sort. Some solutions to the problems identified above have been reached; others have been well identified -- such as the shortage of visual support data. Some movement toward their solution is underway.

Finding Three. Several related problems concerning functioning of the program surfaced during the course of the investigation. Some were voiced by graduates of the program, as cricitism. The most commonly heard was that for some students, the program had the wrong degree of emphasis; some parts were too elementary (relative to their background and previous training), and some parts were too complicated and deserved more time. these kind of comments were to be expected considering the varying experience levels of the participants. Skill and education ranged all the way from advanced degrees in disciplines (with strong emphasis in remote sensing) at leading centers in the U.S., through on-the-job training in Asia in some elements of aerial photo-interpretation.

A second major concern was that the course of study was not an integral part of the academic programs at AIT (that is either interacting with a degree program or leading to a degree in remote sensing). These were expressed even though the Project Paper stated (page 9) that "the Center plans to begin by teaching only one-term (3 to 4 months duration) special courses during the first year to maximize flexibility to respond to individual requirements." The question of the remote sensing program evolving into a more traditional university education form in the near future is, however, a key question.

A third related problem, but one encountered only during this present term, is the limitation of class size to a number that would be well-matched to the complex nature of the subject. The mode of instruction being a foreign language to most of the students, adds to the problem of the limited number of sophisticated, expensive pieces of equipment. The size of the present class (30 students) is clearly too large a number to handle effectively. The attainment of the requisite skills by the students can come only by faculty members personally guiding them in analysis techniques.

Recommendation. All of the related problems stated above could be obviated by changing the fundamental structure of the program from that of a single training course to a comprehensive, traditional, University-like program of related courses. The use of such a program (a suggested design is given below) would, because of greatly expanded flexibility, permit the offering of courses of the appropriate experience level for all of the students. Those with no background could be directed into the basic courses. Those with skill in a discipline and experience in some aspects of remote sensing (e.g. aerial photo interpretation) would take courses in more sophisticated general remote sensing methods and specific applications of methodology in their disciplines. The broadening of the number of course offerings would, probably, have the effect of reducing class size. Finally, the structure envisioned here could be employed to develop the offering of a degree or diploma program. Organization of the offerings in such a way would further ensure that the program would not be taken over by some existing academic department at AIT but would remain an autonomous unit, one that would be recognized in the region in accordance with the original specified design.

The following suggested program design makes the assumption that the academic value of the present course (considering its full-time 14 week structure) is worth approximately twelve traditional credit hours (allowing for laboratory courses with their weighted values, students are engaged in classroom instruction and laboratory work for about 30 hours a week). This assumption forms the basis for suggesting offering a program of nine courses, each of which would be a traditional four-hour/week university-type course. A given student student would be expected to take three courses in a given term. Those that would come to AIT for only one term could take a "tailored" program of three courses and achieve the same total credit as exists in the present course. Some students, assuming that a desire existed and that funding were available, could take a structured series of nine courses over the period of three terms and be awarded a graduate diploma in remote sensing and/or credits toward a discipline-based Masters degree. A student could earn a nominal 36 trimester credit hours (24 semester hours). The suggested program design is as follows:

Course	First Term	Second Term	Third Term
Air Photo Interpretation	X	X	X
Satellite Visual Imagery Interpretation	X	X	X
Computer Processing of Satellite Digital Data	X	X	X
DISCIPLINE APPLICATIONS Forestry	X		
Agriculture		X	
Land-Use Planning			X
Minerals & Geology	X		
Environmental Hazards		X	
Hydrology			X
Directed Study	X	X	X
Thesis/Project	X	X	X

X = possible scheduling of course offerings

Determination would have to be made by program planners on frequency of offering of each course. A review of existing and potential demand would have to be maae. Faculty staffing would have to be planned and possible inter-relatonships with research projects by staff members would have to be programmed.

Many more research and application studies would result from adoption of this suggested program because: (1) some students would be associated with the program for up to one year and; (2) some of the students would be at advanced levels both in their disciplines and in their remote sensing application skills. A further plus would be synergism between these advanced students and faculty members.

Finding Four. The existing software packages accessible on the IBM 370/3031 are not ideally suited to a stated mission of the Center to teach digital analysis of Landsat data. Gaining an understanding of the problem requires more than just a simple examination. The reader's indulgence is requested for the follwoing necessarily technical discussion on the characteristics of the problem.

The analysis software package having the widest exposure in Thailand -- a significant number of Thai government agency remote sensors have been trained in the system -- is a program called RECOG. This program, originally a version of a once "state-of-the-art" program developed at the Laboratory for Applications of Remote Sensing (LARS) at Purdue University, had been placed on a computer at Colorado State University (this adoption was facilitated by long-term ties between LARS staff and CSU). The program was subsequently imported to Thailand by CSU Ph.D. Kaew Nualchawee. Because of necessary modification it was extended; this change was reflected adding a suffix to the name making it RECOG-X. The program was installed on the AIT IBM 370 and, in another modified version, at Chulalongkorn University where it is called CU-RECOG-X.

The program, being somewhat old-fashioned, is not very "user friendly." Instead of enjoying the benefits of modern systems (including the popular personal versions) that have CRT screen prompts, menus, and the facility for the operator to make changes before entering the command mode, commands are given through the medium of punch cards. "Jobs" are then run in a "batch" mode. This means that the first time the analyst sees the results of input effort they are in the form of line printer output. Accordingly, an analyst spends a great deal of time away from the computer terminal plotting the next step, preparing punch cards, and analyzing output from previous "runs." Interactive modes are far preferable (indeed, Purdue University has long since abandoned its earlier method and today has fully interactive systems).

The use of this non-interactive system is especially a detriment to the teaching of techniques. The student is unable to see quickly the results of varying stages of the analysis process. For instance, much of the success of the processing procedure is dependent on the ability to see graphic expressions of the degree of success of "clustering" data points of spectrally similary surface features (the most significant principle of the entire process is that of identifying "spectral signatures" of items of interest on the earth's surface that are as discrete as possible). The old-fashioned way is to analyze tables of data showing degrees of "separability" of "clusters" of data or by reviewing print-out versions of histograms.

The specific related problem at ARRSTC is that, while RECOG-X is installed and usable on the IBM 370/3031, it cannot take advange of the visual peripherals that the system features. Indeed, the IBM 370-3031, through its IBM-developed DIMAPS program concentrates its efforts in the digital enhancement for the production of visual products and not on digital analysis/classification.

While the DIMAPS program definitely has the edge over RECOG-X in ease of use through its interactive facility, the case for accuracy and detail in the <u>classification</u> of a selected area of Landsat visual data is a different story. An aside into the fundamentals of the computer processing system is relevant. The computer-aided processing of data into a useful map of surface features of interest (depending on the nature of the inquiry) consists of two basic steps. The first (once preliminaries of registration to known points on the earth's surface have been accomplished) is to extract a signature that is close to being unique as possible for a particular item of interest (e.g. a particular crop, a condition of the forest, a land-use, etc.). This is achieved through the process of "clustering" energy reflectance values for the four bands of the electromagnetic light spectrum; each of the four bands on Landsat, as recorded by the multispectral scanner, has a discrete number along a gray scale continuum for each and every picture element (pixel) of which the scene is composed. The discriminating of these clusters of like values is traditionally done in one of two ways or a combination of the two. One is the "supervised" method in which the analyst demarcates areas on the visual image that he/she views as being spectrally homogeneous and representing some feature of interest. These values (in the form of "training fields") are then given to the computer which then places all such areas encountered on the image in that pre-determined class. The opposite of this technique is the "unsupervised" approach in which a sampling of the data is examined and subjected to clustering algorithms. The resulting clusters are then examined, vis-a-vis the real world, to see what, in fact, they represent. Classes are thus derived. A third option, the preferred on, is the combination of the two. In this method, likely areas (training fields) are first delimited and then the unsupervised clustering algorithm is set to work on the values within these fields.

Clustering results are thus controlled to a much finer degree than is possible with random sampling of the data. The values are then examined statistically to determine the "tightness" or the clusters; modification, re-clustering, and several other steps can be taken to improve the discreteness of the clusters.

Once the clusters are refined, the analyst can then set about to "classify" the image. Stated simplistically, the clusters form "bins" into which values from each picture element (pixel) can be placed ("classified"). The exact means is a classification algorithm. Several have been developed over the years. Some are simple, some extremely complex. RECOG-X, fortunately, has one of the best classification algorithms, the maximum likelihood classifier. Unfortunately, the DIMAPS system has one of the weakest, the parallelpiped classifier. Authorities agree that the maximum likelihood classifier yields good results and that the parallelpiped system does not make those fine distinctions in character that are essential if the analyst is to achieve the required high levels of accuracy.

The result of all of this is that ARRSTC has two significantly different systems each with its peculiar set of advantages and disadvantages. The RECOG-X system, with its good classifier, can yield good quality results in an operational mode but is harder to use and does not take advantage of the IBM's capabilities in interactive visual aids. DIMAPS, because of its attractive color TV interactive terminals, is well-designed for teaching but produces much poorer classification results (partly because it makes no provision for unsupervised clustering and partly because of its weak classifier) so that its use in resolving resource problems is limited. The system, by the way, is about on a par with the Image 100 system (that also uses supervised clustering and a parallelpiped classifier); The Philippines bought one several years ago.

The consequences of continuing the present situation could be extremely damaging to the training program in several ways. First, and most important, students learning digital processing using DIMAPS will gain the impression that the results have such a low level of accuracy that they are unusable in the solution of resource problems. They will probably feel that the system is colorful, even fun to use, but produces results that are not as useful as those gained from interpretation of visual images. Upon returning home, having this attitude, they will favor visual means of analysis. If they are in expected positions of authority, they could prescribe the use of visual data only. The cause of digital processing, with all its inherent opportunities, will be set back in Asia for years to come. A second disadvantage of using IBM's DIMAPS processing system is that there are but two or three of these systems anywhere in the world. Any machine processing ARRTSC graduates would do, would probably be on some other classification system. A further problem with the DIMAPS is its lack of ability in the pre-processing of Landsat data. Without this feature, such data manipulation as geometric correction of Landsat scenes and the registering of two images of different dates cannot be achieved.

One other software package available at AIT requires passing mention. This package, ERMIN II, has many of the desired features but cannot easily be used on the machine because it requires two operating systems.

<u>Recommendations</u>. Considering that the choice of the best computer program is the lynchpin to success of the digital training effort, some positive action must be taken to rectify the existing situation. Several options are possible, each with advantages and disadvantages. The first would be the hiring of programmers to add the very important unsupervised clustering and the maximum likelihood classifier to the existing DIMAPS program. These additions would result in a combination of the best of both DIMAPS and RECOG-X. The magnitude of the tasks -- manpower and time -- are not known but the presumption is made that the job would require at least two full-time programmers working at AIT a considerable period of time, say one year, to complete the job. A second option would be the addition of visual peripherals to the RECOG-X system. This would probably be more difficult than the first option. A third option would be to purchase a "state-of-the-art" mini-computer system dedicated to remote sensing digital analysis and install it at AIT. A machine/peripheral system would have to be selected that included the desired elements -- high powered processing, and interactive capability to facilitate teaching. One advantage of this approach to the problem is that ARRTC would not be dependent on AIT's main frame, a machine whose use by other departments on the campus will probably increase in the future. A further advantage would be compatibility with (providing the same system was selected) any remote sensing dedicated computer that the RTG may acquire in the future. A final option, and an unacceptable one, is the continuation of the present system in which teaching of principles of digital processing can be done through the interactive DIMAPS but serious project work would be done through use of the

obsolete RECOGO-X. This option, while barely satisfactory at the moment, would not fulfill the broad design and goals of the whole remote sensing technology transfer project.

Finding Five. The ARRSTC has not yet fulfilled the other two of the originally stated three purposes (Project Paper, page 2), namely: "demonstrate the usefulness of remote sensing in development planning, as well as resource management, and assist in planning, as requested by Asian user agencies, with a view toward the Center's becoming an integral part of the Asian Institute of Technology". While these charges are a little ambiguous, the obvious thrust is that research and application projects will be conducted by ARRSTC personnel. One experiment is known to have been conducted by a Purdue-trained researcher from the Lnad Development Agency several years ago (long before the present teaching staff came aboard). The results were excellent, provided useful, accurate data. More along the line of the anticipated is the recently awarded projected (NESDB to AIT) to conduct a digital analysis study of irrigation tanks in northeast Thailand. This project, with Dr. Buddy Atwell as principal investigator, will use all possible analysis means at the Center to map and measure surface area of these tanks (from which volume can be inferred). How well the available processing packages will be able to perform the specified project tasks remains to be seen.

Recommendation. Accepting that the task of conducting research projects is a responsibility and desirable obligation of the Center, the team recommends that more of such projects be initiated. Ideally, these should be conducted by students from countries in the region using problems from their countries. To do so will require the bringing of peripheral information to the Center, such as aerial photography, maps, and ground truth. This mode of operation follows the common practice at US training centers.

A more specific recommendation is that producing digital analysis of high-quality for the region requires resolving the computer programming problem stated in the previous section. Guaranteeing high quality analysis is essential to the advance of remote sensing as a problem-solver in the region.

8.0 TECHNOLOGY TRANSFER

8.1 Impetus and RTG Interest

The impetus for the initiation of satellite remote sensing programs came from scientists at the National Research Council. High level political support was gained under the expectation that Landsat data would provide Thailand with crop production information. Whatever political and other factors may have contributed to the strength of Thailand's interest in remote sensing technology, the subject is now firmly in the hands of technicians in many RTG departments, and well-enough regarded by RTG budget and planning authorities, so that present impetus appears to derive from genuine "demand".

8.2 Role of the USG and RTG: Facilitation and Hindrance

The various ways in which the U.S. Government and RTG promoted, and hindered, the technology transfer process, are discussed throughout this report. The key contribution of the U.S. has been the training of the cadre of Thai scientists and technicians who are in the forefront of the technology in Thailand. U.S. financing of equipment has been of lesser importance, since the amounts were not large and might have been obtained from other sources or out of the RTG budget. The main "hindrance" on the U.S. side has been more in the nature of the omissions and the failure to identify problems of management and process where the RTG might have been interested in U.S. assistance.

While one can always imagine how more money would have pushed a technology diffusion process along faster, there is little evidence that RTG budget stringency has been a serious obstacle to the development of Thailand's remote sensing capacity. The RTG has made substantial outlays, and the various departments involved do not seem to have suffered any more than than average, perhaps even a bit less, budget constraint with respect to their application activity. The subject captured high-level interest from the start, including in NESDB, and was facilitated by early creation of inter-ministerial coordination.

On the negative side, a serious hindrance that may be emerging now, according to NRC, is the disparity in salary scales the RTG and the private sector offer for people trained in high-tech skills, especially computer skills, but also the photographic and other peripheral skills required for the NRC operation. The RTG may still have an edge in the prestige and research possibilities open to scientists applying remote sensing skills who are in supervisory positions in the bureaucracy. But at the technician level this edge is much more difficult to hold.

8.3 Role of the Private Sector

As noted earlier, the IBM equipment loan to the AIT Regional Computing Center was an important contribution to the regional remote sensing training center. IBM's principal gain came not from the profit of the sale of system peripherals but rather from enhanced corporate "image" and the likelihood of future sales to countries whose scientists learned remote sensing digital processing on IBM equipment. They wanted the students to "think blue."

Unfortunately, for ARRSTC, IBM'x generosity in contributing a Landsat digital processing software package (DIMAPS) has caused the problems detailed in Section Seven. The problem was created by IBM's view of its historical approach to the use of Landsat data. The company concentrated on the visual enhancement of satellite imagery (producing excellent products). Its continued attention to visual enhancement is manifested by the visually oriented, user-interactive, peripherals at ARRSTC. DIMAPS, accordingly, is well suited to visual enhancement of data but has shortcomings in its ability to perform high quality, accurate digital processing.

IBM, in its adherence to emphasizing the visual, did not give proper consideration to meeting the goals of the digital processing element of ARRSTC's training program. The issue should have been examined, during the planning stage, by a disinterested digital remote sensing expert, one with knowledge of all software package options, their relative merits, and their relationships to the stated objectives of the program.

In the case of NRC, U.S. and other corporations offering computing and processing equipment have been very active in demonstrating their wares. According to NRC, sales promotion efforts have been a more important source of information about the technology in these processes than that received from U.S. government agencies. Private sector competition appears in this situation to be a positive part of the technology transfer process, even if seen as "unprogrammed" from the viewpoint of methodical institutional development attempted by government donors.

8.4 Impact of USG Policies and Regulations

Satellite remote sensing programs in Thailand are unavoidably tied to decisions of the few countries that develop and launch satellite remote sensing systems. In particular, changes in and uncertainties about U.S. policy regarding Landsat have caused some difficulty in the transfer of the technology to, and its adoption by, Thailand.

In 1979, President Carter committed the United States to the continuity of Landsat data into the 1990's, but policy was not implemented to ensure that this commitment would be honored. On the basis of their belief that Landsat data would be available, many countries around the world have made substantial investments in satellite remote sensing technology. In 1982, US announced that the Landsat satellite series would be terminated following the end of life of Landsat D' in 1987 or 1988.

Landsats 4 and D' are also supposed to provide Thematic Mapper data to foreign ground stations. However, the capability for sending these data to ground stations has failed on Landsat 4. In addition, the United States has no current plans for making MSS data available beyond the lifetime of Landsat D'.

In the face of changing US policy regarding the future of US satellite remote sensing programs, the Thais cannot effectively plan upgrades of their own satellite remote sensing capabilities. This is particularly important with respect to the continuity of MSS data which users are now beginning to fully accept, and Thematic Mapper data which when available would provide a quantum leap in the ability of users to make effective use of satellite data.

8.5 Thailand's Adaptive Research Capacity

One measure of success of the technology transfer process is the extent to which AIT and NRC, and other RTG agencies, have developed a capacity for adaptive research in the area of remote sensing. The NRC Remote Sensing Division is charged with the responsibility to assist RTG user agencies through coordination of research, elimination or minimization of duplicative research activities, and to provide funding for adaptive research. The NRC has a budget (RTG funds) of 1,000,000 Baht for adaptive research in 1981-82. They received approximately 20 applications and are presently funding 12 projects. In 1980-81, they received 12 applications and funded 3. Clearly a capacity for research exists, it is being funded directly by the RTG, and is increasing in volume.

In a similar vein, AIT is included in the adaptive research process. Recently, the NESDB required information regarding the extent and time rate of change of surface water impounded in N.E. Thailand and requested this information from the Royal Irrigation Department. When the RID was unable to provide the information, NESDB approached the ARRSTC. This resulted in a 7,000,000 Baht 18-month contract to AIT to provide the required information. This project indicates AIT's willingness and apparent capacity to undertake such activity.

8.6 Remote Sensing and Other Technology Transfer Processes

While the team did identify areas where new RTG policies or activities were set in motion by information developed from application of remote sensing data, we did not learn of any other technology changes or new technologies being introduced into Thailand as a linkage effect from remote sensing.

8.7 Technology Transfer and Private Investment

The applications to particular projects (like the Lam Nam Oon example), or to planting time recommendations to farmers, or other activities that improve farm income potential, could all lead to the widespread but individually small investments of farm families in their own production capability that have traditionally comprised an important fraction of private investment in Thailand. The team was not in position to trace private sector effects of this type, nor did it identify specific natural resource investments. Mineral investments based on exploration guided by remotely sensed data are certain to result, assuming additional commercial deposits of tin or other minerals are in fact located. At this stage, many of the potential applications that could result in private investment impact have been proven out in their technical feasibility, but remain to be applied on a program basis.

We note elsewhere the study being done by the Environmental Board of the coastline pollution in an area along Thailand's peninsular west. In recent years private investment in the tourist industry in this area has been extensive. Failure to identify and stem this pollution could result in degradation of the area's tourist attraction and dampening of the incentive to further investment.

8.8 Use of Remote Sensing Data and Impact on Inhabitants of Rural Areas

As an information source that feeds into resource and spatial planning, remote sensing technology can have pervasive effects on the welfare of large numbers of Thais, both rural and urban, and in both the short and longer run. In the case of forestry, the greatly heightened sense of urgency that resulted from the rate of deforestation revealed by Landsat data has resulted in increased efforts to discourage slash and burn deforestation, and may cumulate over time in efforts that preserve considerable forest area that would otherwise disappear. To avoid negative effects of this on the relatively small numbers of people each year who resort to deforestation, the RTG offers a resettlement program. For the rural population as a whole however, in large areas that would undergo profound and perhaps irreversible change in watershed conditions and other environmental characteristics related to forest cover, the effects of more vigorous policy would be widely and profoundly beneficial.

If current mineral exploration efforts using remote sensing data to identify promising areas result in finds that are commercially exploited, employment and income would be created for rural inhabitants. The AID-assisted projects cited above are examples of local area applications beneficial to identifiable communities.

A number of the research projects that have explored potential applications have shown the feasibility of uses that would have direct impact, e.g. the rubber production assessment technique that would relate to Thailand's role and policies within the international rubber commodity agreement, or the soil moisture assessment that has been used by the extension department, on a limited scale thus far, to advise farmers when to transplant rice seedings. The data used by the Royal Irrigation Department to help determine water levels in irrigation reservoirs is improving the information base for water release decisions.

9.0 RECOMMENDATIONS AND GUIDELINES

9.1 Should AID Consider A Future Role in Remote Sensing in Thailand

In the face of the uncertainties discussed above surrounding satellite configurations in the 1980's, with each satellite and data signalling technology having different requirements for ground receiving and/or processing equipment, the Thais face needs for additional investment that are difficult to quantify at present. With the infusion of significant aid from CIDA, and continued RTG Budget Bureau confidence in the usefulness of the technology and professionalism of the officials involved, financial constraints do not appear to be threatening to the continuing development of remote sensing application. On the other hand, some fiscal stringency will be felt in this field as in all other areas, so that additional aid resources on the margin can play a significant role. There is no doubt that the RTG commitment to continued use of the remote sensing technology is strong.

The priority that AID may attach to future assistance in Thailand in remote sensing depends on factors beyond the evaluation team's scope, regarding the future direction of the assistance program and other areas NESDB may wish to see emphasized. Apart from this constraint, the team thinks that USAID involvement in the future development of this technology should continue for the following reasons:

1. The US remains the leading country in this technology. If comparative advantage in technologies that the US can help transfer is taken into account in determining program priorities, remote sensing

would easily be identified (in contrast to some other technologies the mission is currently working in) as a subject where deliverate transfer aid would be likely to yield the highest return for the Thais.

2. Thai linkages to US scientists will remain vital for maintaining mementum in the adoption of this technology. The AID program can play a facilitating role in this, an activity that should be seen as having high marginal payoff by capitalizing on the strong Thai-US relationships already inherent in the transfer process.

3. Technical assistance in the management of aspects of the diffusion process we have identified as falling short, could yield important benefits to the Thais for reelatively small cost and man-monts of US input.

4. The AID mission will remain an important factor in any case as it monitors and assists in the implementation of the large grant to AIT. If the recommendations we are making regarding coordination among donors and the encouragement of a systematic examination of equipment and management needs are adopted, the mission can be helpful in these matters even without further contribution to NRC or Thai agency user capabilities, through attention to rationalization of the roles and relationsyhips between AIT and NRC. Beyond that, the mission's prominent role and its knowledge base would represent another lost opportunity if the program did not pick up some of the rounding-off suggestions made here that would be logical for the US to undertake and would keep the mission directly concerned with both the training (AIT) and production (NRC) aspects.

5. Finally (as noted below) the number of senior technical

people and decision-makers who are determining the speed and effectiveness of remote sensing technology application is small and almost entirely located in Bangkok. As a resident mission with a long history of serious interest in Thai development, and generally excellent relations with the RTG, USAID can provide the "good offices" function of the outside advisor on the management and linkage problems, with the responsible officer able to know and sustain contact with all the RTG principals involved. For the mission to play this role, however, the project officer whould have to allocate more time than has been given to remote sensing, backed up by occasional involvement of mission management.

9.2 Recommendations and Technology Transfer and the AID Role

Before examining lessons for USAID's role in technology transfer in general, it will be helpful to set out certain features of the institutional arrangements, aid relationships and technology transfer that make this experience unusual compared with the ordinary run of AID project and shed some light on technology transfer assistance.

1. The technology AID is helping transfer is probably the "highest", in the sense of the term "high-tech", of all subjects in which the agency is providing technical assistance. The agency makes no pretense that the subject is direct or close to poor beneficiaries. Remote sensing is only a data source, one among many, that feeds into information and analysis systems. These systems in turn feed into sectoral and then overall development planning processes. While better data can improve the decisions that affect very large numbers

of people, the links between data and direct benefits are long and often demonstrable only in a general way, even if the benefits of improved knowledge turn out to be powerful.

2. The high-tech nature of remote sensing also gives the subject a "prestige" character that does not often apply to AID's subjects. This opens up the possibility that host government motivation to acquire the technology may involve considerations other than development merit. Of course, the prestige symbolism of space-oriented technology says nothing in itself of the merits of this data source, but should alert the agency and governments to the possibility that the transfer process is being driven by the technology rather than resulting frm the needs of the information and analysis systems it is intended to serve. This danger should also serve to heighten AID's level of attention over the more mundane aspects of the transfer process that, if deficient, could greatly limit the diffusion and benefits from an expensive superstructure.

3. The transfer process itself has been treated in a "top-down" manner. That is, the establishment of facilities for a new supply of data has assumed that the demand side, or users, will emerge quickly enough to complete the linksand validate the confidence that these data will not remain so underutilized as to become a technology in search of a function. The fact that the remote sensing facilities -- both the receiving center and NRC unit, and the regional training center -- are not integral to users (in the case of AIT, the remote sensing facility is also not integrated into AIT's subject matter divisions, but stands separately as a short course service for technical personnel), means that actual adoption and usage is not inherent in the projects but depends on outside decisions and

processes. In some cases, as described above, this two-step character has resulted (thus far) in underutilization of the data; the technology itself is "working", but it remains (for these applications) disembodied and without impact.

4. The transfer process has been unusual in another respect. Adoption in Thailand of the same technology, has been effected through two different institutions and as far as AID's role is concerned, through different bureaucratic channels. The NRC and AIt facilities are certainly quite different in their purposes. Still some overlap exists, and some problems have arisen from their location in the same country, alongside the benefits that their complementary functions generate for each other. For AID, the two projects have been of very great difference in size, have been planned and implemented with different relative roles of AID/W and the Mission in each case, and have gotten rather different levels of attention from the Mission.

5. If a technology is very new and complex, its introduction is likely to require big rather than incremental changes. If the remote sensing experience in Thailand is a typical example, such changes will include substantial advanced training; acceptance by senior people schooled only in earlier technologies; creation of new organizations (or units in pre-existing organization) tailored to perform the requisite new scientific tasks and of systems linking the new organizations to other organizations utilizing the technology; acquisition of complementary equipment or other investments in a range of organizations that need to make their own internal adjustments to adopt and internalize the technology for their own requirements.

6. Finally it is important to note that the transfer process in this subject involves a small number of people. The total professional RTG cadre directly handling remote sensing data probably numbers less than 150, of whom only a fraction are supervisory and decision-making. Put another way, although the transfer process involves several agencies of the government (in a government where the process of articulation among bureaucracies is known to be unsatisfactory), it requires a very small number of individuals to bring the products of the technology to the end point of being integrated into information systems that feed planning processes. This compares strikingly with most of AID's activities. Just to take the example of agriculture, AID's largest sector, the end point application of all the reserch, seed, fertilizer, practices, irrigation, and other facets of production on which AID institutional and other projects are working, requires acceptance and implementation by literally millions of farmer decision-makers. In the case of remote sensing USAID faces an absorptin community of a few dozens. This has implications for the RTG and for donor roles in the transfer process (see points 3 and 4 above).

It should be clear that overall the team has been facorably impressed with the development of capacity and usage found in both NRC and among user agencies. We also think the basic institutional concepts and roles are correct. At the same time there have been problems, not all of recent origin, that have slowed the pace of diffusion and caused user irritation and frustration. Some of these are general problems of RTG administration (e.g. payscale, or the inhibiting effects of poor personal relationships in some instances). Others might have been eased by appropriate U.S. (or other source) assistance. One example is the persistence of equipment needs, some relatively inexpensive, that could permit much more effective application of the technology which is now at the command of many Thais in different user agencies. There is a parallel here with the common problem of irrigation projects (in Thailand and elsewhere), in which heavy investment in storage and main channel systems yields much less than optimum results because no investment is put into the last like, the tertiary farm canals, despite the relatively modest cost of this missing element. The position of remote sensing in Thailand is not so start, but there are complementary equipment needs that should be filled to increase the benefits from the heavy up-stream investment. Another example is in technology management. Although the RTG and NRC have made commendable efforts to organize and train to promote remote sensing diffusion, adoption remains uneven. In addition, NRC has been overloaded with tasks and has had difficulties carrying out its primary data production functions. In such situations, organizations often make use of outside advisory services to reexamine their structure and management processes. Any significant contribution to speeding up NRC's product delivery capacity (NRC has identified some possibilities on its own) would have helped increase the spread of remote sensing application and reduced the irritation among some customers facing long delays.

With the benefit of hindsight, the evaluation suggests some general points about the technology transfer process, and USAID's role in particular cases:

1. <u>More Project Flexibility</u>

Whenever the technology involved is in a stage of rapid development in the technologically advanced countries, which means that both equipment and training needs are also changing rapidly, an AID project which is planned to extend over a number of years should have enough flexibility built into the implementation plan to allow for significant adjustments. The elaborate AIF project planning framework is designed to force systematic and specific planning of inputs and outputs from start to finish, and undoubtedly contributes to raising the effectiveness of the general run of project. In the case of both these projects, the rapid technical and institutional changes have outrun the ability of the project planners to foresee the needs even a very few years ahead.

2. <u>Closer Examination of "Assumptions"</u>

In longframe parlance, it is the "assumptions" on which the project is based, that have proved fragile. In some cases, closer examination would have shown some assumptions to be questionable. Others would have been stated with less certainty, which could then have led to allowing the greater flexibility suggested.

3. <u>Greater USAID Attention</u>

To make use of the greater flexibility if it had been built in, would have required much greater USAID involvement and attention to the transfer process than was the case with NRC or is the case now with AIT, even with the much higher level of funding in the later project. Of course, it is not incumbent on any donor to take broad responsibility on itself (assuming the assisted institution is interested in such a donor role) for the institutional, the linkage and other aspects of the diffusion process. With the NRC project, AID chose a limited role at a low level of funding. In the AIT project however, AID was central to the institutional development involved and is the major funding source.

It may be useful to divide the institutional and management problems we discussed into two categories, those internal to the agencies involved, and those concerning their technical and operational relationships to other agencies, i.e. the remote sensing "network". Both institutions could benefit from strengthened internal management. The comparative advantage of highly trained technical leadership almost always lies in their technical functions, not in the general management responsibilities that also rest, ultimately, in the same leadership office. Both institutions would be well served if they arranged to devolve the management responsibilities to deputies carefully chosen for that function alone. We have also suggested that consideration be given to short-term consultant assistance to NRC to advise on the production process, and to review equipment needs of NRC and user agencies.

In the case of their relationships with other agencies in the remote sensing network, we have identified problems regarding training needs, for example, that should be reviewed by some kind of standing coordinating machinery between AIT and the country clients. The point here is that AID, must less AIT and NRC, should not rely on the occasional evaluation to put such issues on the table, especially where the conditions are changing in the very early years in the process of adoption of a technology of an advanced nature. The institutional complexity is further heightened by the fact that the technology transfer process has the top-down, or disembodied in character as we suggested earlier, necessitating effective links and relationships among a large number of separate agencies, in the case of AIT in separate countries.

It is not in any way disrespectful to the individuals or agencies involved, with their advanced training and technical sophistication, to note the useful role of outside agency or advisor can play in these problems. Regardless of nationality, the outside advisor who is not a part of the bureaucratic systems or technical institutions being assisted has the flexibility and independence to play a helpful role in these kinds of problems. To some extent a USAID project officer, or science officer, could play such a role. In more technical aspects, it might be good to have standing arrangements that would give the host institution involved the capability of calling on consultant expertise for short-term review of such issues as they arise. The essential point is to ensure that the whole area of management of the technology adoption and diffusion process is somehow addressed, and that all external assistance not be limited to the technical aspects of the technology.

4. Rapid Obsolescence

The rapid obsolescence of equipment in an emerging technology presents complex problems for developing country that cannot afford costly mistakes in equipment choice and that must minimize the costs entailed by the steady flow of new generations of technology. The problem is a general one for developing country planners, but affects AID in few subject areas given the nature of most AID projects. Where it does affect AId projects however, as in this case, it would be worth AID giving the problem some thought, looking for ways in which the agency might help host country agencies minimize the costs entailed by the short time lapse between "generations" in the technologies involved. One possibility may lie in more procurement of earlier generation equipment. Even though this means that the user is entering the technology a stage below the latest capability, that stage may well represent a major enough advance over methods prior to the technology in question.

Another useful service to meet this problem, when host government agencies are buying equipment with their own funds, would be provision of independent consultant assistance to ensure that the buyers were aware of the full range of options, were assisted if necessary in comparative analysis, and were not limited to knowledge of the technologies offered by the vendors who happen to be active in the country.

5. Scan the Whole Technology

It is important that the complementary and topping-off equipment needs not be neglected when expensive technology is being installed that depends on a "full complement" of capabilities for its effective application. AID might have included some of these relatively inexpensive items in the NRC project if there had been a better sense of the entire "system" respecting the technology, and the project had not been limited, arbitrarily in a sense, to one institution within the technology comples.

6. Project Design Should Not Be Technology-Driven

The fact that a technology is "high" should not by itself be an excuse for treating the analysis of input needs differently from that of "ordinary" projects. Analysis of forward and backward linkages, and of the institutional arrangements and what will be required for their effective functioning, is precisely what the USAID project design format is intended to induce and lay out. In the case of new, high technologies it is extremely important that project design adhere to this discipline.

10.0 LIST OF PEOPLE CONTACTED

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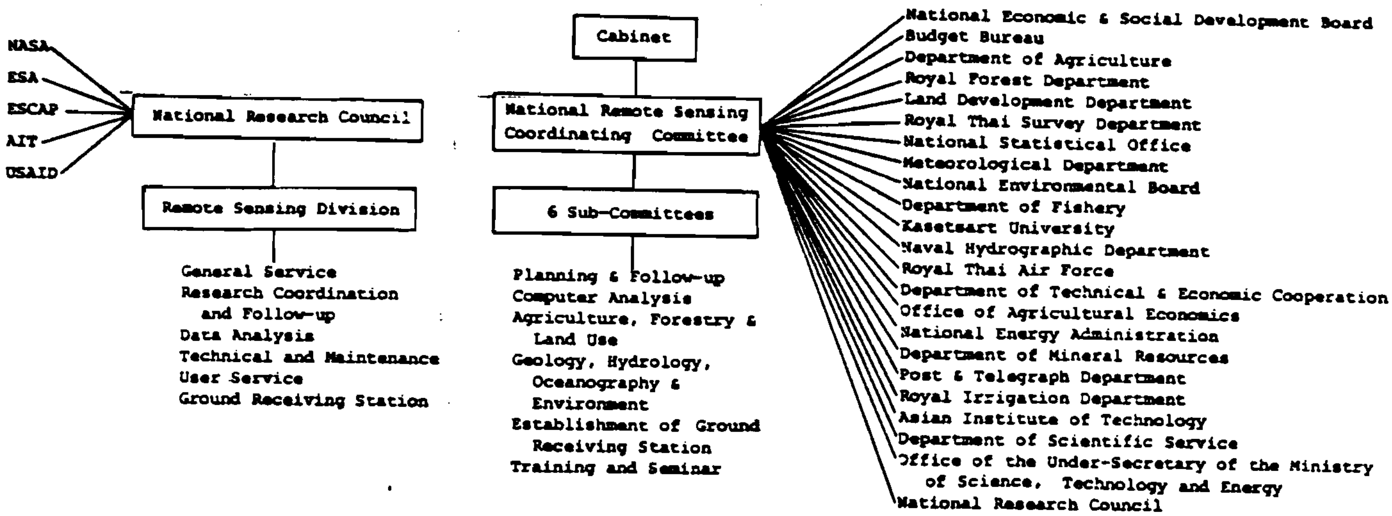
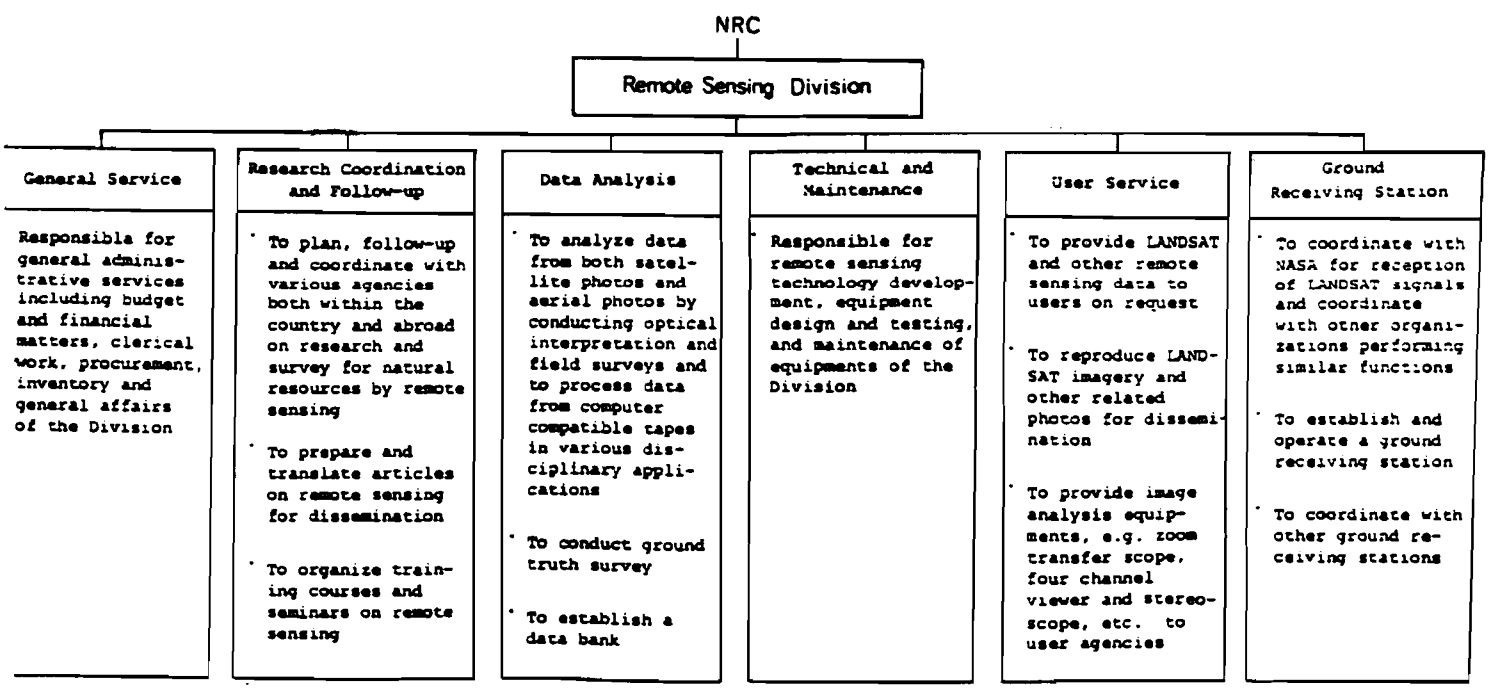
ANNEX I
National Research Council, Remote Sensing Division





ANNEX II

NRC INTRODUCTORY COURSE OUTLINE

Remote sensing

Landsat

Primary Knowledge Regarding Remote Sensing

Characteristics of Electromagnetic Radiation

Sensing System

Satellite Photography and Interpretation

Use of Data from Satellite in Agriculture

Automatic Data Processing

Use of Data from Satellite in Land Use

Use of Data from Satellite in Forestry

Use of Data from Satellite in Geology

Use of Data from Satellite in Environment Conservation

Use of Data from Satellite in Oceanography

Use of Data from Satellite in Geography

Use of Data From Satellite in Mapping

Meteorological Satellite and Ways of Application

Map Reading

Interpretation of Imagery with Diazochrome

Use of Data from Satellite in Agriculture, Forestry, Land Use, Geography and Environment Conservation

Use of Data from Satellite in Geology, Geodesy, Hydrology and Oceanography

Preparation for Survey

Land Survey in Nakhon Pathom, Ratchaburi, Kanchanaburi and Suphan Buri

Visit to the Satellite Signal Receiving Station at Lat Krabang District

Visit to the Department of Meteorology

Visit to the Asian Institute of Technology

Visit to the Royal Thai Air Force

Discussion to Summarize Outcome of the Land Survey

Discussion on Outcome of the Training and Question and Answering

Presentation of Certificates and Closing Ceremony

ANNEX III

ASIAN REGIONAL REMOTE SENSING TRAINING CENTER (ARRSTC)

MAY TERM SCHEDULE — May 2-13, 1983

WEEK NO. 1

MONDAY 2/5/83	TUESDAY 3/5/83	WEDNESDAY 4/5/83	THURSDAY 5/5/83	FRIDAY 6/5/83
AM HOLIDAY	AM 0900 - General Intro, faculty, students -Kaew Intro to curriculum -Fox Tour of facilities -Kaew	AM General Overview Remote Sensing Historical Development, Main Concepts -Johnson	AM HOLIDAY	AM Basic Principals of E-M radiation -Atwell
PM HOLIDAY	PM French Film EROS Films Slide Set Remote Sensing - What is it? -Johnson	PM Basic Characteristics of Image Data -Hodson	PM HOLIDAY	PM General Overview Remote Sensing -Johnson

WEEK NO. 2

MONDAY 9/5/83	TUESDAY 10/5/83	WEDNESDAY 11/5/83	THURSDAY 12/5/83	FRIDAY 13/5/83
AM E-M radiation -Atwell	AM Philosophy of Image Interpretation -Johnson	AM E-M radiation -Atwell	AM Integrated terrain unit mapping -Hodson	AM E-M radiation -Atwell
PM Characteristics of Image Data -Hodson	PM Image Interpretation Exercise -Johnson	PM Image Interpretation Exercise -Johnson	PM Photographic Systems -Fox	PM Integrated terrain unit mapping exercise -Hodson

REMARK:

ASIAN REGIONAL REMOTE SENSING TRAINING CENTER (ARRSTC)

MAY TERM SCHEDULE May 16-27, 1983

WEEK NO. 3

	MONDAY 16/5/83	TUESDAY 17/5/83	WEDNESDAY 18/5/83	THURSDAY 19/5/83	FRIDAY 20/5/83
AM	E-M Radiation -Atwell	Photographic Sys. -Fox	Applications of Visual Interp. -Lind	Applications of Visual Interp. Change Detection -Hodson	Photographic Sys. -Fox
PM	Case Studies, Thermal Remote Sensing -Atwell	Applications of Visual Interp. -Hodson	Photographic Systems -Fox	Photographic Systems -Fox	Philosophy of Map Classification -Lind

WEEK NO. 4

	MONDAY 23/5/83	TUESDAY 24/5/83	WEDNESDAY 25/5/83	THURSDAY 26/5/83	FRIDAY 27/5/83
AM	Phil. of Map Classification -Lind	1st Local Field Trip -Lind	Photographic Systems -Fox	HOLIDAY	Remote Sensing Instrumentation -Atwell
PM	Photographic Systems -Fox	Ground Data Collection	Satellite Remote Sensing -Johnson	HOLIDAY	Photographic Systems -Fox

REMARK:

ASIAN REGIONAL REMOTE SENSING TRAINING CENTER (ARRSTC)

MAY TERM SCHEDULE May 30 - June 10, 1983

WEEK NO. 5

MONDAY 30/5/83	TUESDAY 31/5/83	WEDNESDAY 1/6/83	THURSDAY 2/6/83	FRIDAY 3/6/83
AM Remote Sensing Instrumentation -Atwell	AM The Landsat System -Johnson	AM Field Trip to Landsat Receiving Station ↓	AM Intro. to Visual Analysis Proj. -Johnson	AM Visual Proj. Work -All Faculty
PM Photographic Sys. -Fox	PM The Landsat System -Johnson	PM On to National Research Council -Kaew -Hodson	PM Visual Analysis Proj. Work -Johnson -All Faculty	PM Visual Proj. Work -All Faculty

WEEK NO. 6

MONDAY 6/6/83	TUESDAY 7/6/83	WEDNESDAY 8/6/83	THURSDAY 9/6/83	FRIDAY 10/6/83
AM Concepts of Digital Imagery -Fox	AM Concepts of Digital Imagery -Fox	AM 2nd Local Field Trip ↓	AM Concepts of Digital Imagery -Fox	AM Visual Proj. ↕
PM Visual Proj. Work -Johnson	PM Visual Proj. Work -Johnson	PM Ground Data Collection -Lind	PM Visual Proj. Work -Johnson	PM Work -Johnson

REMARK:

ASIAN REGIONAL REMOTE SENSING TRAINING CENTER (ARRSTC)

MAY TERM SCHEDULE June 13-24, 1983

WEEK NO. 7

MONDAY 13/6/83	TUESDAY 14/6/83	WEDNESDAY 15/6/83	THURSDAY 16/6/83	FRIDAY 17/6/83
AM Concepts of Digital Imagery -Fox	AM 3rd Local Field Trip	AM Finish Vis. Proj. -Johnson	AM Digital Image Enhancement -Fox	AM Digital Image Enhancement -Fox
PM Visual Proj. Work -All Faculty	PM Ground Data Collection -Lind	PM Final Reports Visual Proj. -All Faculty	PM Intro. to DIMAPS -Hodson	PM open-catch-up

WEEK NO. 8

MONDAY 20/6/83	TUESDAY 21/6/83	WEDNESDAY 22/6/83	THURSDAY 23/6/83	FRIDAY 24/6/83
AM Pattern Recognition -Atwell	AM repeat Monday pm ½ class Group A - DIMAPS DEMO -Hodson -Fox ½ class Group B - Image Proc. Sys. Man. Ex. -Lind	AM Pattern Recognition -Atwell	AM RADAR -Lind	AM Pattern Recognition -Atwell
PM ½ class Group A - DIMAPS DEMO -Hodson -Fox ½ class GROUP B - Image Proc. Sys. Man. Exercise -Lind	PM reverse of am ½ class Group B - DIMAPS DEMO -Hodson -Fox ½ class Group A - Manual Ex. -Lind	PM repeat Tuesday pm ½ class Group B - DIMAPS DEMO -Hodson -Fox ½ class Group A - Manual Ex. -Lind	PM DIMAPS REVIEW SESSION -Hodson	PM RADAR -Lind

REMARK:

ASIAN REGIONAL REMOTE SENSING TRAINING CENTER (ARRSTC)

MAY TERM SCHEDULE June 27 - July 8, 1983

WEEK NO. 9

MONDAY 27/6/83	TUESDAY 28/6/83	WEDNESDAY 29/6/83	THURSDAY 30/6/83	FRIDAY 1/7/83
AM Pattern Recognition -Atwell	AM DIMAPS Ex. #1 Intro. 3 band Composite -Hodson	AM EARLY SESSION 8-11 Pattern Recognition -Atwell	AM DIMAPS #1 Processing 3 blocks 18 people 0800-1130 1200-1530 1600-2000	AM DIMAPS #1 Processing Ex. 0800-1130
PM RADAR -Lind	PM RADAR -Lind	PM DIMAPS #1 Processing 1200-1530 1600-2000 Teams of 3, two sta. 6 people/4 hrs | 12 12 people/8 hrs | people	PM Students to work on Manual Image Processing Exercise Additive Color Viewer -Fox	PM 1200-1530 Extra Processing Time for 12 people, those who need it

WEEK NO. 10

MONDAY 4/7/83	TUESDAY 5/7/83	WEDNESDAY 6/7/83	THURSDAY 7/7/83	FRIDAY 8/7/83
AM Instructors Review First DIMAPS Session -Hodson	AM DIMAPS Ex. #2 Multispectral Classification -Fox	AM ½ class Group B - DIMAPS MSS Class. -Hodson -Fox ½ class Group A - Canadian Man. MSS Calss. -Johnson	AM 0800-1130 DIMAPS Processing 6 people	AM 0800-1130 DIMAPS Processing 6 people All students to complete 1st 3½ hrs Session
PM RADAR -Lind	PM ½ Class Group A - DIMAPS DEMO MSS Class. -Hodson -Fox ½ Class Group B - Canadian Man. MSS Class. -Johnson	PM 1200-1530 DIMAPS Processing 6 people rest work on EROS Manual Ex.	PM 1200-1530 6 people 1600-2000 6 people	PM 1200-1530 1600-2000 12 people

REMARK:

ASIAN REGIONAL REMOTE SENSING TRAINING CENTER (ARRSTC)

MAY TERM SCHEDULE July 11-22, 1983

WEEK NO. 11

MONDAY 11/7/83	TUESDAY 12/7/83	WEDNESDAY 13/7/83	THURSDAY 14/7/83	FRIDAY 15/7/83
AM DIMAPS PROCESSING 0800-1130 6 people	AM Instructors Review Multispectral Classification -Fox	AM DIMAPS EXTRA PROCESSING FOR THOSE NEEDING IT 0800-1130	AM Micro-Computers for Image Processing -Lind	AM FIELD TRIPS TO CONFUSING AREAS 3 groups -Lind -Fox -Hodson -Johnson
PM 1200-1530 1400-2000 12 people All students to Complete 2nd 3½ hrs Session	PM Micro-Computers for Image Processing -Lind	PM 1200-1530 1400-2000 18 people Micro-Computer Demos am-pm ½ class -Lind	PM MICRO- DEMOS Small Groups Rest to Finish MSS Classification, Manual & Computer	PM ↓ ↓

WEEK NO. 12

MONDAY 18/7/83	TUESDAY 18/7/83	WEDNESDAY 20/7/83	THURSDAY 21/7/83	FRIDAY 22/7/83
AM Intro to DIMAPS Ex. #3 Contrast Stretch -Fox	AM ½ class Group B - DIMAPS DEMO Contrast Stretch -Johnson -Hodson ½ class Group A - Written Exercise -Fox	AM DIMAPS SESSIONS 0800-1130	AM Instructors Review DIMAPS #3 Contrast Stretch -Fox	AM Unsupervised Classification Lecture -Fox
PM ½ class Group A - DIMAPS DEMO Contrast Stretch -Johnson -Hodson ½ class Group B - Written Exercise -Fox	PM Computer Sessions DIMAPS 1200-1530 1600-2000 12 people	PM 1200-1530 1600-2000 18 people	PM Finish DIMAPS #3 DIMAPS 1200-1530 1600-2000 12 people Those who need	PM Case Studies Image Classification -Johnson

REMARK:

ASIAN REGIONAL REMOTE SENSING TRAINING CENTER (ARRSTC)

MAY TERM SCHEDULE July 25 - August 5, 1983

WEEK NO. 13

MONDAY 25/7/83	TUESDAY 26/7/83	WEDNESDAY 27/7/83	THURSDAY 28/7/83	FRIDAY 29/7/83
AM HOLIDAY	AM HOLIDAY	AM Intro. to DIMAPS Exercise #4 Edge Enhancement -Fox	AM ½ class Group B - DIMAPS DEMO edge enhancement -Johnson -Hodson ½ class Group A - Manual Exercise Edge Enhancement -Fox	AM DIMAPS 0800-1130
PM	PM	PM ½ class Group A - DIMAPS DEMO -Johnson -Hodson ½ class Group B - Manual Exercise edge enhancement -Fox	PM DIMAPS SESSION Ex. #4 1200-1530 1600-2000 12 people	PM 1200-1530 1600-2000 18 people Ex. #4 Complete

WEEK NO. 14

MONDAY 1/8/83	TUESDAY 2/8/83	WEDNESDAY 3/8/83	THURSDAY 4/8/83	FRIDAY 5/8/83
AM F R E	AM N C H	AM S Y	AM M P O S I	AM U M
PM DIMAPS work sessions 1200-1530 1400-2000 Finish Projects All week, ea. pm.	PM	PM	PM	PM

REMARK:

ASIAN REGIONAL REMOTE SENSING TRAINING CENTER (ARRSTC)

MAY TERM SCHEDULE August 8-12, 1983

WEEK NO. 15

MONDAY 8/8/83	TUESDAY 9/8/83	WEDNESDAY 10/8/83	THURSDAY 11/8/83	FRIDAY 12/8/83
AM Remote Sensing Proj. Implimentation How to get started -Johnson	AM GIS -Hodson	AM Options for Asia -Johnson	AM ARRSTC GRADUATION	AM HOLIDAY
PM CASE STUDIES -Fox	PM Geological Case Studies -Atwell	PM GIS -Hodson	PM	PM

WEEK NO.

MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY
AM	AM	AM	AM	AM
PM	PM	PM	PM	PM

REMARK:

ANNEX IV

ASIAN INSTITUTE OF TECHNOLOGY

Asian Regional Remote Sensing Training Center (ARRSTC)

April 29, 1983

CURRICULUM OUTLINE

I. Fundamentals of Remote Sensing

1. Definition and Purpose of Remote Sensing

   a. Information From a Distance

   b. Communication Links, Sensor to Scene

   c. General Overview of Remote Sensing

2. Electromagnetic (EM) Radiation, The Common Link

   a. EM Radiation and Radiation Sources

      1) Radiation terminology

      2) Blackbody radiation

      3) Solar radiation

      4) Earth radiation

      5) The electromagnetic spectrum

   b. Atmospheric Effects

   c. Reflectance in Remote Sensing

      1) Reflectance in general

      2) Lambertian reflectance

      3) Bi-directional reflectance

3. Instrumentation for Remote Sensing

   a Elementary Optics

   b. General Principles of Instrumentation

   c. Radiation Detectors

   d. Remote Sensing Instrumentation

e. Some Remote Sensing Systems

1) Aircraft scanners and cameras

2) Spacecraft scanners and cameras

4. Fundamental Characteristics of Image Data

a. Spatial Dimensionality

b. Multiplicity of Layers

1) Multi-spectral

2) Multi-temporal

3) Multi-variable

c. Image Analysis

II. FIELD INVESTIBATIONS TO SUPPORT REMOTE SENSOR DATA

1. Scope and Purpose

a. Orientation - Planning

b. Verification Studies (accuracy)

c. Training Site Selection

d. Supporting Studies

e. Correlation Studies

f. Sensor Specification/Design Studies

2. Field Approaches -- Combined Activities Usually Practiced

a. Documentary

1) Maps (soils, geologic, vegetation, agriculture, water resources)

2) Statistical data (i.e., census data)

3) Other inventories (e.g., historical data)

b. Role of "photointerpretation" for Satellite Remote Sensing

c. "windshield Surveys"

d. Physical Sampling, -- Surficial Materials, Vegetation-Crops

e. Multistage (i.g., low level aircraft)

f. Specifications for Mapping and Classification Keys

g. Inventory - Area, Volume Measures

h. Ground Level Photography and Observation Scheme

3. Field Study in Remote Sensing Applications

4. Field Studies Relating to Thermal and Microwave Remote Sensing

III. VISUAL ANALYSIS OF REMOTE SENSOR DATA

1. Philosophy and Techniques of Image Interpretation

a. Convergence of Evidence

b. Using The Seven Basic Elements of Image Interpretation

1) Effect of sensor type

2) Effect of scale

c. Stereoscopy

2. Photographic Sensors

a. Film Chemistry

b. Film Characteristic Curve

c. Black and White Film Types

1) Spectral sensitivity

2) Film and Filter Selection

d. Additive Color Theory

1) Additive colors: blue, green, red

2) Subtractive colors: yellow, magenta, cyan

e. Color Emulsions

1) Natural color

2) Color infrared

f. Film Resolution/Speed

3. Photo Measurements

   a. Focal Length, Flying Height, Scale

   b. Photo Distance, Ground Distance, Scale

   c. Relief Displacement

   d. Hot Spot, No-shadow Point

   e. Scale Determination

      1) From known ground distance

      2) From planimetric maps

   f. Ground distances

   g. Bearings

   h. Area Measurement

      1) Dot grids

      2) Polar planimeter

4. Applications of Visual Interpretation

   a. Recognition and Measurement of Land Cover

      1) Urban features

      2) Wetland cover types

      3) Forest cover types

      4) Grassland cover types

   b. Recognition and Measurement of Land Form

      1) Terrain analysis

      2) Soil types

   c. Mapping From Vertical Aerial Photography

      1) Problems with relief displacement

      2) Type mapping

      3) Photo to map transfer techniques, ZTS

IV. RADAR REMOTE SENSING

1. Some Principles

   a. Definition and Scope of Applications (RADAR, SLAR, SAR)

   b. Operation and Theory of SLAR

      1) Distinctive characteristics

         a) atmospheric penetrability under nearly all conditions

         b) microwave reflections require separate interpretation keys-unlike visible or IR

      2) RADAR Wavelength/frequencies commonly used

         a) K bands

         b) X band

         c) L-P bands

      3) Polarization

         a) parallel polarized

         b) cross polarized

         c) variants

      4) Spatial resolution

         a) range direction

         b) azimuth direction

         c) pulse length and antenna aperture considerations

      5) Depression angle

      6) Overview of SLAR -- real aperture system

2. The Synthetic Aperture Radar System (SAR)

   a. Operation and Use

      1) Use of doppler effect

      2) The development of SAR imagery

b. The Use of SAR in Space

1) SEASAT

2) Space shuttle

3) Future missions

3. Interpretation of Radar Imagery

a. Terrain Characteristics and Radar Returns

1) Surface geometry

a) diffuse reflectors

b) specular reflectors

c) corner reflectors

2) Electrical properties

a) dielectric constant

b) role of soil moisture

3) Role of system properties

b. the Sea and Raday Returns

1) Role of system properties

2) Surface Geometry of the sea

4. Applications of Radar Remote Sensing Data

a. Radargrammetry

b. Distortion Problems -- Relief, Scale, Layover

c. Look Direction

d. Environmental Analysis

1) Emagery use/orientation

2) Drainage overlay

3) Geologic overlay -- regional and local

4) Land cover overlay

5. Enhancement of Space Shuttle, SAR.

V. COMPUTER ANALYSIS OF REMOTELY SENSED DATA

1. Fundamentals of Image Enhancement

   a. Generating Color Composites

      1) Standard false color composite

      2) Specialized composites

         a) two band composites

         b) various color assignments

   b. Color Density Slicing

   c. Contract Stretching

      1) Linear

      2) Histogram equilization

      3) User specified stretch functions

   d. Edge Enhancement

   e. Spatial Filters

2. Fundamentals of Pattern Recognition

   a. What is a Pattern?

   b. Geometric Interpretation of Pattern Recognition

   c. Training a Pattern Classifier

   d. The Statistical Approach to Pattern Recognition

   e. Statistical Characterization of Data

   f. Discriminant Functions Based on Statistical Analysis

   g. Evaluating the Classifier

      1) Error estimation from training data

      2) Error estimation from test data

      3) Indirect estimates of classifier error

h. Statistical Separability and Feature Selection

1) Divergence

2) J-M distance

i. Feature Extraction

1) Subsets

2) Ratios

3) Linear combinations

j. Clustering: Unsupervised Analysis

k. Summary: Putting the Pieces Together

3. Applying the Quantitiative Approach

a. Key Steps in Carrying Out a Remote Sensing Project

b. Crop Identification and Area Estimation

c. Forest Cover Mapping

d. Geologic Mapping

e. Coastal Zone Mapping

f. Additional Applications as Required

VI. COMPUTERIZED GEOGRAPHIC INFORMATION SYSTEMS

1. Important Characteristics of Geographic Information

a. Uses (why overlay and aggregation would be desireable)

1) Erosion model

2) Urban expansion

3) Forestry/Agriculture

4) Difference images

b. Sources of Initial Data

1) Photointerpretation

2) Maps

3) Field

4) Imagery

c. Spatial Characteristics of These Data

1) Resolution

2) Physical size/coverage

3) Scale

4) Northing (rotation)

5) Projections

6) Compilation (interpretation methods) -- line placement

7) Shrink/stretch -- base material

d. Classification Characteristics

1) Classification terminologies

2) Basic vs interpreted classes -- advantages and problems

3) Mutually exclusive classes

e. Methods for Resolving

1) Digital

2) Manual

3) Integration of data

2. Methods Used to Digitize Data

a. Relationship to an Image

b. How Digitized Data are Stored

c. How Original Data are Edited, Terrain Unit Concept

3. Basic Storage and Map Concepts

a. X, Y, Z

b. Point, Line, Polygon (and variations)

c. Line/Sample

d. Row/Column

4. Basic Analysis

   a. Single Variable (map)

      1) Distance calculation

      2) Area calculation

      3) Searches

      4) Aggregations

      5) Reassigning values

   b. Multiple Variables

      1) Overlay and sample (Cookie-Cutter)

      2) Overlay and revalue ("modeling")

         a) additive

         b) generalized weighted overlay

         c) operational (e.g., soil loss calculations)

5. Application of GIS Technology to Site a New Town

   a. Digitize Basic Data

   b. Opportunity/Constraint Interpretations are Identified

   c. Capability/Suitability Criteria Developed for Given Goal

6. GIS Analysis Models

   a. Qualitative Models

   b. Quantitative Analysis

   c. Multiple Parameter Analysis

   d. Relation Between Model Design and Output

   e. Multispectral Bands as GIS Data Planes.