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EVALUATION REPORT

PHOTOVOLTAIC DEVELOPMENT AND SUPPORT PROGRAM

(PVDSP)

February 27, 1981

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I. RECOMMENDATIONS

The conclusions and recommendations related to specific topics are presented in the relevant section of the report. However to summarize the report, the recommendations are repeated here. Based on the on-site visit to and briefing at NASA/Lewis Research Center, the discussion presented in the report and the conclusions reached by the evaluation team, it is recommended that:

- the Photovoltaic Development and Support Program (PVDSP) continue to support health delivery. New health activities should emphasize communication needs of rural health programs;

- new efforts be initiated in communications and education delivery programs;

- efforts be made to include activities in other Geographical Regions besides Africa and Latin America;

- in-country agreements be used to delineate roles and responsibilities except where a clear justification exists for another mechanism;

- for planning purposes, PVDSP operate with a two-year planning budget subject to annual funding authorization.

- DS/EY continue its principal role as funding agent and program manager of the PVDSP and as coordinator of AID's involvement with DOE and NASA concerning photovoltaics;

- as practical and appropriate, direct management of the individual subprojects be conducted by an AID officer responsible for the development program in which the photovoltaic technology will be used. This will assure that technology application concerns are properly related to the broader socio/economic development goals of AID.

- AID carefully evaluate 'life cycle' costs of energy alternatives in its development projects;

- where appropriate AID increase its use of photovoltaic technology in rural areas;

- continued attention be given to careful monitoring of field applications of the technology so as to demonstrate whether or not the technology is a cost-effective approach to providing the energy needed for the application.

II. BACKGROUND

Since 1975 A.I.D. has been encouraged by Congress to undertake innovative, imaginative programs of energy assistance to developing countries. In 1978 particular emphasis was placed on renewable energy sources and technologies. Special attention was to be given to the use of such energy systems in A.I.D.'s rural development efforts. During these years, authorizing legislation has repeatedly stressed coordination with the Department of Energy (and its predecessor agencies). Photovoltaic (PV) technology has frequently been cited by Congress as a specific technology that A.I.D. should apply in its development programs.

It was in this context that A.I.D. in 1976 initiated a project in an African village (Tangaye, Upper Volta) in which photovoltaic technology was used to pump water and grind grain. Funded jointly by USAID/Upper Volta and AID/W (TA/OST, project transferred to DS/EY upon the creation of the office), the project had several separate purposes. With regard to photovoltaic technology, its purpose was to demonstrate that the technology could provide reliable electric power in remote areas for multiple uses and that such PV systems could be operated and maintained by people w th limited technical backstopping. This effort has received much publicity and its results have been well documented (Refs 1, 2, 3). Even though it is a first-generation demonstration system, it has been operational 96 per cent of the time; although technical problems have arisen, they have been solved with a minimum of outside intervention. Experience with this initial application has demonstrated that, while technical backstopping is important, an on-site presence is not needed. Rather, necessary instructions can be sent to the application site and followed by the local personnel.

The Photovoltaic Development and Support Program (PVDSP) builds upon the experience gained in the Tangaye project. Having demonstrated that the technology can be used by local personnel, the next step is to apply the technology to cost-effective applications. The PVDSP incorporates a strategic approach to selecting the appropriate application sectors, demonstrating the use of PV technology within these sectors and identifying the opportunities for possible replication of the demonstrations.

The activities of PVDSP are meant to stimulate a greater use of photovoltaics in international development efforts. This goal reflects two themes: (1) the confidence that PV technology is the best technology for certain socio/economic development applications and (2) the desire to support the efforts of the US Government and the private sector to increase international applications of PV technology and exports of American-made products. (This point is discussed further in Section IV.) As explained in Annex C, a photovoltaic system usually includes several components: the photovoltaic modules, battery storage, control devices, support structures and miscellaneous other equipment. Much attention has

been given to the need for further research to reduce the cost of the photovoltaic module in order to make the technology cost-effective for general US applications. This work will go forward and expectations are high that technology advances will lead to reduced cost and a greater number of cost-effective applications. However, it is recognized that there are numerous cost-effective applications for the existing technology, especially in rural areas of developing countries where electric power is available only at high cost (Ref 4). The title of the Photovoltaic Development and Support Program is meant to convey that AID is financing - not technology development - but rather development of applications of existing technology to programs of socio/economic progress and the necessary technical support for those applications.

Since the goal of PVDSP is a greater use of photovoltaics in socio/economic development programs, an important element of the activities is the information that potential users will need in order to make informed decisions. This information need must be kept firmly in mind as the project demonstrations are planned and implemented and the results are promulgated. In this way the PVDSP activities will lead more directly and immediately to replication of the efforts by other development agents and agencies.

Appropriate though the technology may seem to be, program planners and managers of development efforts will not be certain of the suitability of photovoltaics to their programs until much more information has been obtained on the actual performance of the technology in actual development activities. This need to be convinced is altogether proper. Consequently, it is very important that a program of carefully monitored applications be pursued in order to provide important information related to system cost, operational performance, maintenance requirements, ability of local personnel to operate and maintain the system, availability of system components in country and possibility of replicating the system in similar applications.

Several factors that are involved in determining appropriate areas of interest are as follows: the application should involve the use of electric power for priority development programs; small amounts of electric power should be needed; the current price paid per unit of electric power should be high; an implementation agent should be easily identified; and possible replicators of the activity should be identified in advance and their information needs known.

The PID for the PVDSP was developed in December 1978 and approved in February 1979. The Project Paper was prepared in the Spring 1979. The project was designed as a five year $10 million program to be implemented by National Aeronautics and Space Administration's (NASA), Lewis Research Center, (LeRC) in coordination with the Department of Energy. Five application sectors were identified in the project paper: health delivery, education

delivery, communications, water pumping, and food processing and preservation. It was expected that the first application area would be basic health delivery. The program would be fully funded by A.I.D. and implemented for A.I.D. by NASA/LeRC. NASA/LeRC had already been identified as the principal implementor of DOE-funded applications of photovoltaics in remote areas. The use of the same implementing agent would enhance the coordination and cross-fertilization between the A.I.D. and the DOE-funded activities. In addition, as part of the larger DOE program of photovoltaic research and application development, NASA/LeRC would have access to the results of DOE-funded work being done by other agents and would be able to provide information to the DOE program on the results and lessons learned from the A.I.D.-funded efforts.

The project was approved in July 1979 with several clarifications to the original project paper. In particular, although recognizing the need for a long-term program, the project approval required that funding would be provided on a yearly basis and funding approval would be contingent upon successful evaluations of the status and progress of the project. The initial $2 million would stress applications in the rural health sector. The first management review took place in May 1980 and led to a second funding of $500,000 to continue the health sector work and begin the process of identifying opportunities in the subsequent sector (education/communications).

The first formal evaluation of the project took place on December 17, 1980. A team of A.I.D. officers visited NASA/Lewis Research Center in Cleveland to review the status of the project, tour facilities and meet NASA personnel. Of this larger group of officers, a formal evaluation team of five members had been composed in advance. The members of the evaluation team, its composition and perspective are detailed in Annex A. This report documents the findings of that evaluation team.

<u>The evaluation team concludes that</u>:

- photovoltaic technology can potentially make significant contributions to international development efforts;

- there is a need to continue the systematic field demonstrations of the technology and the acquisition of the operational information needed for informed decision making;

III. STATUS OF PROJECT ACTIVITIES

The project was initiated in August 1979 when the PASA with NASA was signed. This called for an initial level of effort of $2,000,000 and a concentration on health delivery applications. The management guidance given NASA was to examine existing AID

health programs, especially in Africa and Latin America/ Caribbean since these two Bureaus had previously identified a number of on-going programs where potential applications might be found. In addition, NASA was to consider private voluntary organizations (PVOs) active in health delivery programs in developing countries.

The project was to include two types of activities in each sector - larger applications or pilot projects and smaller applications or mini-demonstrations. In the health area, the pilot projects would be PV systems to provide general electric power to rural health clinics; the smaller activities would be demonstrations of PV-powered refrigerators for use in medical delivery programs, in particular the storage of vaccines for immunization programs ("cold chain").

From the initial review of A.I.D. programs and contacts with PVOs, potential applications were evaluated against selection criteria and a list of preferred activities was developed. Investigative field trips were initially made to Kenya, Zaire, Guyana, Peru, and Ecuador. Trips were subsequently made to Zimbabwe and Jamaica. Agreement in principle was reached for pilot projects in Kenya, Guyana and Eucador. (Later Zimbabwe was added as a result of the visit of Dr. Frank Press, the Director of the President's Office of Science and Technology Policy.)

During the course of these initial discussions, it became clear that in-country activities should be explicitly described and agreed to in country agreements. As a result, Limited Scope Grant Project Agreements were developed for each country. These agreements are signed by USAID and the appropriate host country ministry and spell out the roles and responsibilities of the several agencies involved - NASA, USAID and the appropriate host country organizations. The actual details of implementation are defined in subsequent implementation plans developed by NASA and the host country agents. Agreements have been signed with Kenya and Guyana. Draft agreements have been developed for Zimbabwe and Ecuador and signing of the final agreements is ancipated in the near future. Annex B contains a summary of the in-country work to date and a copy of a typical country agreement (Guyana).

In general, the agreements are for a four year subproject. USAID provides general liason among the parties involved in the agreement - NASA, host country governmental agency, in-country implementor and contractors. The host country agency provides the site for the application, personnel for operation of the system and logistical and administrative support. NASA provides technical services and backstopping through the life of the project (NASA personnel) and the PV system, related equipment and training of host country personnel (via contracts).

In addition to the pilot projects (general power to rural health clinics), other program activities have been undertaken. These include cataloging medical equipment suitable for PV-powered rural clinics; surveying health delivery organizations to determine equipment needs, electric power needs and costs; reviewing educational and communications programs in developing countries to identify opportunities in rural education and communications programs.

Although not funded under this project, DSB recently sponsored a National Academy of Science Workshop on Two-way Radio Communication for Primary Health Services (jointly arranged by DS/ST, DS/ED and DS/HEA). It was agreed that the use of two-way radio communication could significantly improve the delivery of rural health care; the improvements include diagnoses, treatment, logistics and supply of medicines, rotation of personnel and patient and medic morale. For these radio systems, photovoltaics was clearly identified as the preferred power source - cheaper than batteries, and more reliable than grid power when grid power was available. (Ref. 5).

The work to date has also included the use of PV-powered refrigerators in rural clinics to store medicines and vaccines. In conjunction with the Center for Disease Control (and through them, the World Health Organization), NASA/LeRC is testing several models of such refrigerators to determine which will meet the performance specifications for medical refrigerators as spelled out by the WHO. This work is related to on-going efforts of the WHO to improve the storage of vaccines needed in world-wide immunization programs. DOE funds are used to underwrite NASA's involvement with this work. Based upon successful completion of the performance tests, NASA/LeRC will procure a limited number of acceptable units for field demonstrations. The PVDSP will fund the purchase of about ten units and their subsequent field use. The DOE-funded qualification tests will assure that only models that meet WHO performance specifications will be used in AID-funded efforts.

The bulk of the PVDSP funds will be used to purchase system hardware, training and technical services from private contractors. NASA procedures require that the authorization to enter into contracts (and the required funding) be in hand before the contracting procedure is initiated (i.e., before the Request for Proposals is issued). There is a significant time lapse between the issuance of a RFP and the ultimate contract award (perhaps six months or longer). Consequently, it is important that AID plans and funds for the PVDSP be developed with this required contracting time in mind.

The existing project activities stress health delivery applications, in particular clinic power supply and single-purpose PV-powered refrigerators. The possible uses of photovoltaics in health delivery are broader than this however. Photovoltaic power

sources for two way communications in health delivery are especially attractive but these power sources would also be appropriate to operate single purpose devices like cassette players and movies or slide projectors for health education efforts. In general, the communication/education sector appears to offer many interesting and relevant opportunities to apply photovoltaic technology. Of special interest would be the use of PV power systems in the AID Rural Satellite Program (Ref. 6). The purpose of the program is to further rural development by improving telecommunications between rural and urban areas. In particular it demonstrates the effectiveness and appropriateness of using satellite communication systems and small receiving stations in rural areas to achieve this improved communications. Photovoltaic systems could easily be used to meet the power requirements of the receiving stations or to power additional transmitters and receivers needed to extend the communication link within the service area of the rural receiving station.

The evaluation team concludes that:

- the health community's interest in photovoltaics warrants continued support of this application sector;
- the programs of both PVOs and AID Missions offer important potential applications of photovoltaics;
- the AID application program offers significant benefits to other US efforts, specifically to DOE programs and to the private sector equipment manufactures;
- qualification testing of the equipment to assure that it can meet performance specifications is an important element of the program;
- the use of country-specific agreements to define roles and responsibilities of the various agencies will assure a proper understanding of the activity and the workload imposed;

It is therefore recommended that:

- the PVDSP continue to support health delivery. New health activities should emphasize communication needs of rural health programs;
- new efforts be initiated in communications and education delivery programs;
- efforts be made to include activities in other Geographical Regions besides Africa and Latin America;
- in-country agreements be used to delineate roles and responsibilities except where a clear justification exists for another mechanism;

- for planning purposes, PVDSP operate with a two-year planning budget subject to annual funding authorization.

IV. PROJECT MANAGEMENT

A. Institutional Arrangements

DS/EY is the AID Technical Office responsible for the overall management of the PVDSP. This office provides general management control over the project-funded activities of NASA/LeRC and liason with other elements of AID and outside groups, in particular NASA/Washington and DOE. The DS/EY project officer maintains contact with the responsible officer in NASA's Energy Systems Division and with the responsible officer in DOE's Photovoltaic Office. The linkage with NASA/Washington assures program coordination and proper NASA institutional oversight of the project activity. The linkage with DOE, although informal, assures proper coordination and maximum cross-fertilization of the related efforts of the two agencies.

Within AID, DS/EY has served as the focal point for the application of photovoltaics and for coordinating AID's use of the technology with the DOE program. As specific activities are developed under the PVDSP, AID management of those activities (subprojects of PVDSP) generally passes to other AID entities more closely connected to the development assistance effort in which the PV systems will be used, eg a project manager at USAID as specified in the country-specific agreements.

The PVDSP Project is implemented for DS/EY by the NASA Lewis Research Center (LeRC) in Cleveland, Ohio. LeRC has had a substantial research and technology effort in PV devices since 1963 and is the NASA Lead Center for space PV technology. LeRC's involvement in terrestrial PV systems and applications began in 1970. Since 1975, they have managed projects for the DOE (formerly ERDA) involving small-scale PV applications as part of the National PV Program and have supported AID PV activities since 1976. Recently, LeRC has been given responsibility for all international PV activities sponsored by the DOE exclusive of the so-called "bilateral agreement" projects. At present, there are a total of about 40 professionals working on PV at LeRC, several of whom are national and international experts in their field.

Terrestrial PV activities at LeRC reside within the Solar and Electro-chemistry Division of the Energy Directorate (see organization charts in Annex D). A Terrestrial PV Projects Branch has been established consisting of the Development and Support Project Office (AID), the Stand-Alone Applications Project Office (DOE), and the Photovoltaic Applications Section. A matrix management system is used to implement the AID and DOE work: project managers assigned to the respective project offices

draw upon the expertise (project engineers) from the PV Applications Section as needed. This arrangement allows close coordination of both AID and DOE PV activities and enables efficient use of technical personnel. The DOE PV Systems Test Facility at LeRC is also used to support AID PV projects on a non-interference basis. A total equivalent of 6 person-years is applied to the AID PVDSP annually by LeRC.

Day-to-day project management is performed by LeRC in accordance with approved annual operating plans with appropriate oversight by program officers. Monthly progress reports are provided for the respective programs and distributed to appropriate AID and DOE personnel.

Organization charts covering LeRC personnel and the relationships of the project and program offices are given in Annex D.

B. NASA Personnel

The PVDSP Office, managed by William J. Bifano, is staffed by three full time project managers who are responsible for medical and education/communication PV applications and country-specific applications such as Tunisia and possibly Egypt. As noted earlier, these project managers work with project engineers from the PV Applications Section. Typically, for a given project, a manager is assigned a project engineer who charges his time, as needed, to that project. It is not uncommon for project engineers to be working simultaneously on both AID and DOE projects. This results in both an efficient utilization of manpower and an effective cross-pollination of PV activities at the working level.

The qualifications and experience of the LeRC personnel assigned to AID projects are presented in Annex E.

C. Relationships of AID and DOE Projects

The full DOE program in photovoltaic technology encompasses the spectrum of activities from basic research to commercialization of existing technology. The broad program goal is to produce a technology that will find general cost-effective applications in the US. The several major contractors and agents involved with this complicated and coordinated program includes NASA/LeRC. The linkages among the principal organizations are illustrated in the chart in Annex D. As an integral part of the DOE program, LeRC provides information to the other components and has access to the results of the work of these other components. In particular, LeRC has been given the responsiblity for managing the application of PV technology to systems that are not connected to reliable electric power grids ("Stand Alone" Systems). The intent of this work is to find the largest market for the existing technology in order to accelerate the commercialization of photovoltaics.

While different in program objectives, the AID and DOE activities are similar in demonstrating the applicability of photovoltaics to a variety of users. AID is particularly interested in applying PV systems to selected socio/economic development programs where there is a priority need for electric power. DOE's interests lie - not in the type of application - but in the number of potential systems that can be manufactured and sold, that is in the commercialization of PV sytems. AID, in managing the PVDSP, specifies the application sectors, the needs and the requirements to be met by PV systems in priority international development efforts. NASA/LeRC, as technical implementator of both the AID application efforts and the DOE commercialization work, assures appropriate interaction, facilitates the transfer of information and prevents duplication of effort in the two programs.

A few examples of AID and DOE Project synergism are as follows:

The basic design of the PV system installed in Upper Volta was patterned after that used on an Arizona Indian reservation and funded by DOE. The system check out was then performed in the DOE PV Systems Test Facility prior to shipment. After nearly one year of operation, PV module failures began to occur in the Upper Volta System which were traced to a faulty design by the PV module manufacturer (Solarex Corp., Rockville, MD.). NASA/LeRC then worked with DOE's Lead Center, Jet Propulsion Center (JPL), to revise the qualification and acceptance tests for PV modules to evaluate more carefully and detect any such PV module defects. A number of revisions to the JPL test procedure have been incorporated as a result of the Upper Volta experience. DOE, as part of its technology development work, has agreed to provide replacement modules to refurbish and expand the Tangaye PV experiment. LeRC will implement the refurbishment and continue monitoring the project for DS/EY for 2 more years.

Another example of AID/DOE coordination involves the LeRC (DOE-funded) testing of PV medical vaccine refrigerators to determine which will meet requirements established to meet the needs of the AID project and other users. DOE funds are used to provide the information that potential manufacturers need to develop refrigerators which can be marketed worldwide. AID, as a user, will fund replication of these refrigerators for evaluation in the field once the units have passed the qualification and acceptance tests conducted by LeRC under the DOE project.

<u>The evaluation team concludes that</u>:

- there is positive and mutual value to the coordination between AID and DOE in the application of photovoltaic technology;

- the use of NASA/LeRC as the implementor of both programs represents an appropriate, cost-effective mechanism to enhance the results of each program;

- the continuation of the proper program guidance and management from AID will assure that the goal of the AID program is adhered to and not deleteriously admixed with the goal of the DOE program;

- NASA has developed a suitable organization for implementing the PVDSP;

- NASA/LeRC has constituted a well qualified staff of managers and engineers needed to implement the program;

- the level of effort of NASA/LeRC personnel is appropriate to the tasks involved;

- the existing arrangements within AID are appropriate. DS/EY is responsible for general program management and other AID elements (e.g. mission personnel) have responsibility for specific activities within their countries;

- NASA/LeRC personnel have shown themselves to be sensitive to socio/economic development concerns and responsive to the guidance and direction given by the AID officers with whom the personnel have worked;

- appropriate management of development issues and technology application issues should result from continued close working relationships between development officials and NASA/LeRC staff.

<u>It is therefore recommended that</u>:

- DS/EY continue its principal role as funding agent and program manager of the PVDSP and as coordinator of AID's involvement with DOE and NASA concerning photovoltaics;

- as practical and appropriate, direct management of the individual subprojects be conducted by an AID officer responsible for the development program in which the photovoltaic technology will be used. This will assure that technology application concerns are properly related to the broader socio/economic development goals of AID.

V. PHOTOVOLTAICS AND AID POLICY

In recent years in the United States much attention has been given to alternative energy technology that could reduce our dependence on imported oil. Photovoltaics has received its share of attention in this regard. Also, the technology has been frequently cited as a premier example of other concerns: a result of the space program that can meet more commonplace terrestial needs, a technology in which the U.S. currently has a global leadership position that is endangered by technical developments in other countries and a US-manufactured product with a potentially large market in LDCs. In fact the governments of several other industrialized countries that manufacture photovoltaics are already very active in demonstrations and applications of the technology in developing countries and, through these efforts, might make market advances in these areas before U.S. companies do. Interesting and important as these factors may be, AID's use of photovoltaic technology must depend upon the relevance of the technology to meet the specific goals of the foreign assistance program.

Of the many objectives, interests and elements of AID's overall policy, several are especially appropriate for a discussion of this topic. First, a negative statement is in order. AID is not a scientific or technical research agency. Since its primary task is to provide assistance to country development efforts, AID should not conduct research unless the results of that research can make an important contribution to national development and the research is not now being done or will not be done by others, especially other USG agencies under their own appropriations. AID's program emphasis is on rural development and includes a growing interest in employment generation and small industry development in rural areas. To foster rural development, AID supports rural electrification programs that lead to a productive use of electricity and measurable gains in income distribution and overall quality of rural life. While AID is especially concerned with rural development, it must consider these efforts within the context of overall national development. Regarding energy, this is particularly true and AID policy in the energy area explicitly acknowledges the need to ease the immediate energy constraints to development and the need to assist the LDCs to develop a mix of energy sources that will sustain their future economies. In carrying out its programs, AID should encourage a growing involvement of the private sector in the development of the LDCs - both the private sector within the LDCs themselves and the US private sector in LDCs. In doing this, AID should maintain its role of country assistance and should not become a particular advocate of increased US business activities in LDCs, a function properly belonging to other USG bodies.

Photovoltaics has several characteristics and qualities that make it an attractive technology for use in AID programs.

Its modular nature lends itself to either large or small applications - the size of the array and the storage system (if any) can be accurately sized to the job at hand. Photovoltaic systems can be engineered to be extremely reliable and to require limited maintenance; this is because of the absence of moving parts and the possibility of providing multiple paths in the system and hence of avoiding system failure due to the failure of single elements. The operation of the system is very simple since the system essentially runs itself - relying on a renewable resource (the sun) and natural processes to generate electricity. The electricity produced can be used for a number of applications - lighting, communications, electronics and motive power for equipment and appliances in unlimited diverse uses. Like all renewable energy technologies, a photovoltaic system has no fuel cost and consequently low operating cost. However, it has a high initial capital cost. Consequently the only way to evaluate overall cost effectiveness is to use 'life cycle' comparisons between photovoltaics and other systems. At current costs, photovoltaics is competitive with other systems for small electricity demands.

Photovoltaic technology has a proven history. The existing technology can be reliably and cost-efficiently used in many AID applications. Future changes in the technology, primarily cheaper cells and arrays, will come about due to the research and development efforts of DOE and the private sector particularly US industry which is the world leader in this field. As these improvements occur, the number of potential applications of the technology in AID programs will increase due to decreases in the cost of photovoltaic systems. An important element of cost calculations is the possibility of reducing the foreign exchange costs of PV systems by local manufacture of system components (batteries, wiring, supports), local labor in system assembly and local design of systems for replication and adaption. The foreign exchange costs of future systems are discussed in Annex F. The design of a photovoltaic system is relatively simple, requiring competence in system engineering and electrical engineering. The education and training of professionals in these areas is common both in the US and in LDCs. Existing professionals can quickly learn the state of the art. Expanding the supply of such professionals should not be difficult to do.

<u>The evaluation team concludes that</u>:

- photovoltaic technology can play a growing role in meeting rural electricity needs;

- in particular the technology can provide small amounts of power needed in AID development programs and, when properly integrated, can enhance the effectiveness of those programs;

- at the present time, photovoltaics should not be considered as a source of large amounts of power;

- photovoltaic technology meets many of the criteria for use in rural areas in LDCs - reliable, renewable, replicable and easy to maintain and operate.

- in particular photovoltaic technology is especially appropriate for those applications where the power requirement is low, the reliability of the system must be high and the availability of alternative sources of power including fuel is uncertain.

- 'life cycle' cost considerations are necessary when evaluating a potential application of photovoltaics;

- 'life cycle' cost considerations should be used when evaluating any energy alternative;

- the technology advances promised by on-going research and development will affect AID's use of photovoltaics. If costs are reduced, as promised, AID use should increase; if costs are not reduced, AID should reevaluate its interest in the technology.

If is therefore recommended that:

- AID carefully evaluate 'life cycle' costs of energy alternatives in its development projects;

- where appropriate AID increase its use of photovoltaic technology in rural areas;

- continued attention be given to careful monitoring of field applications of the technology so as to demonstrate whether or not the technology is a cost-effective approach to providing the energy needed for the application.

ANNEX A

EVALUATION TEAM

The essential character of the PVDSP is the innovative application of a little used technology to meet selected needs of international socio-economic development programs and the monitoring, evaluation and promulgation of the results of these applications. Project activities have been agreed upon in Africa and Latin America; the initial concentration area is health delivery. Future efforts are expected to emphasize countries in Asia and the Near East and applications in education and communications. Two aspects of the program are especially important - the introduction of an unfamiliar technology to the international development effort and the integration of this technology into selected development programs.

The selection of the evaluation team was based on the desire to incorporate experience in the regional areas and application sectors in which activities are already underway (Africa, Latin America; health) and in which activities are proposed (Asia, Near East; education and communication). In addition expertise was desired in engineering and system development. The biographies of the individual team members follow.

Jerome J. Bosken. (Team Leader and Project Manager). Currently Deputy Director of the Office of Energy (DS/EY), Mr. Bosken has had five years experience with developing policy and programs of energy assistance for AID. His prior experience includes strategic planning, systems management and evaluation for the Department of Defense; university teaching in the United States; cirriculum revision, teacher training and university teaching in Latin America. He has developed assistance projects and participated in technical missions in over 25 countries in Latin America, Asia and Africa.

Michael S. Gould. As engineering advisor to the Africa Bureau, Dr. Gould is responsible for ensuring the technical quality of project planning and implementation. His prior experience has included domestic and international consulting in environmental engineering, and research and development experience with Union Carbide Corporation. He has lived in West Africa and has actively been involved in the implementation of projects in five African countries.

Howard B. Keller. Mr. Keller is currently the Public Health Advisor and Health Program Analyst in the Population, Health and Nutrition Division of the Office of Technical Resources of the Asia Bureau. He has been with AID for 14 years in the field of public health. His experience includes designing, managing and

evaluating programs in malaria control, rural water supply, primary health care and family planning. He has served overseas in Ecuador, Tunisia and Pakistan and completed post graduate studies in Social Sciences and Public Health/Population.

Thomas O'Keefe. Mr. O'Keefe is presently Senior Program Analyst in the Development Technology Division of the Bureau for Development Support. Program sectors include energy, housing, science and technology, environment and information systems. As a Foreign Service Officer, he has served in the Far East and Africa. Prior to joining DSB, he was Chief, East Africa and Indian Ocean Region, Africa Bureau. Before to joining AID in 1967, Mr. O'Keefe worked as a staff economist with the U.S. Department of Labor. Private sector experience includes systems analyst for a heavy equipment manufacturing firm and inventory control specialist for a manufacturing and distribution corporation.

Robert Schenkkan. Mr. Schenkkan is currently the General Manager of the Rural Satellite Project in the Office of Education of the Bureau for Development Support. Prior to joining AID, he served as a communications consultant to AID/W and USAIDs, USICA, the World Bank and private companies. He was a Professor of Communications at the University of Texas where his principal interests were in radio, television and films. He is past President and General Manager of Southwest Public Broadcasting Corporation and former Chairman of the Board of the Public Broadcasting Service.

Fred Zobrist. Mr. Zobrist is currently the Chief Engineer of the Africa Bureau. In this regard he serves as the Bureau's senior technical expert in the field of alternative energy. Prior to joining AID, he worked as a consultant in the fields of planning, environmental assessments and engineering including undertaking studies and design of other conventional and alternative energy systems. Earlier work with the Corps of Engineers involved extensive background in the planning and design of hydropower projects.

ANNEX B

COUNTRY ACTIVITIES AND AGREEMENTS

Under project funds, NASA/LeRC personnel have visited the following countries - Kenya, Zaire, Zimbabwe, Ecuador, Guyana, Jamaica and Peru. In addition under other funds, a visit was made to Egypt.

From a US-based review of health delivery programs and projects, specific on-going activities were identified and with Mission concurrence initial investigative trips were made to determine the interest of the AID Mission, host country government and other agencies in the application of the technology to the specific activity. This was done for Kenya, Zaire, Ecuador, Guyana and Egypt. During these visits the NASA personnel met appropriate officials of the various bodies involved, explained the technology and the PVDSP project, visited potential application sites and learned more details of the on-going health delivery programs in order to ascertain if the application of photovoltaics in those program would meet project criteria. If the results of the initial trip were promising, follow-up visits were made to begin the process of collecting the engi- neering data that would be required to design the appropriate photovoltaic system and to initiate the drafting of the country agreement. Follow-up visits were made to Kenya, Ecuador and Guyana.

For Zaire, there has been no follow-up visit because of funding limitations of the project. However the Mission interest in an application there remains very high. Only one visit has been made to Jamaica, to present a general briefing on photovoltaic technology to government officials at the request of the Ministry of Energy and Mining. There was no preliminary visit to Zimbabwe. Rather, because of the interest generated by the visit of the Director of the President's Office of Science and Technology Policy, a decision was made to undertake an activity similar to what was being planned for Kenya. As a result, only the more detailed, technical visit was made.

The following tables list the dates, purposes and results of the various country visits and give the current status of the country agreements.

CHRONOLOGY OF COUNTRY VISITS

DATE 1980	COUNTRY	PURPOSE	RESULT
Feb. 24	Guyana	Initial	Follow-up recommended
Feb. 25	Ecuador	Initial	Follow-up recommended
March 3	Peru	Initial	USAID Peru will consider
March 31	Zaire	Initial	Follow-up recommended
April 15	Kenya	Initial	Follow-up recommended
June 6	Jamaica	Technical Briefing	No further action
June 8	Guyana	Obtain technical data, draft country agreement	AID/W will review draft agreement
June 16	Ecuador	Obtain technical data, visit potential sites	Country Agreement to be drafted
July 10	Kenya	Obtain technical data, support preparation of health project	Follow-up by drafting country agreement
Sept.	Kenya	Visit of Presidential Science/Technology Team, Dr. Press (Not project funded).	Agreement approved by USG and GOK
Sept	Zimbabwe	Visit of Presidential Science/Technology Team, Dr. Press (Not project funded).	Concept agreed to by GOZ and USG
Nov. 3	Ecuador	Decide system and site, prepare draft country agreement	Agreement being processed in country
Nov. 8	Zimbabwe	Prepare draft agreement	Agreement being processed in country
Nov. 16	Kenya	Obtain technical data	Implementation plan is pending.

COUNTRY	STATUS
Kenya	Country Agreement signed (September 24, 1980) Two project sites included Implementation Plan due December 31, 1980
Guyana	Country Agreement signed (November 13, 1980) Implementation Plan due March 15, 1981
Ecuador	Final Agreement pending (January 13, 1981)
Zimbabwe	Final Agreement pending (January 14, 1981)

In addition to the four countries in which projects have been approved (Kenya, Zimbabwe, Ecuador and Guyana), the AID Missions in Egypt and in Zaire have strongly urged that AID/W approve participation of these countries in the PVDSP. AID/W has indicated that these requests will be fully considered once a decision has been made on the future direction and funding of the PVDSP. Also the Asia Bureau has specifically requested to be included in future activities of the PVDSP, including the application of PV-powered refrigerators to immunization programs underway in Indonesia.

As an example of a country agreement, a copy of the Limited Scope Grant Project Agreement with Guyana is attached.

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LIMITED SCOPE GRANT PROJECT AGREEMENT

Between the United States of America, acting through
the Agency for International Development (AID)

AND
The Government of Guyana

Ministry of Economic Development and Cooperatives

(Grantee)

1. Project Title	2. AID Project Number (PASA Number)
Rural Health Photovoltaic Demonstration Project	NASA/DSB-5710-?-79

The above-named parties hereby mutually agree to carry out the Project described in this Agreement in accordance with (1) the terms of this Agreement, including any annexes attached hereto, and (2) any general agreement between the two governments regarding economic or technical cooperation.

3. Amount of AID Grant	4. Grantee Contribution to the Project	5. Project Assistance Completion Date
Not to Exceed $400,000 (est.)	in kind $Facilities and Services	December 31, 1984 (est.)

6. This Agreement consists of this title page ~~and~~ Annex A, Project Description; Annex B, Roles and Responsibilities of the Participating Parties; Annex C, Illustrative Implementation Schedule; and, a Standard Provisions Annex.

7. For the Grantee	8. For the Agency for International Development
Typed Name: H. Desmond Hoyte	Typed Name: Donor M. Lion
Signature: [signature]	Signature: [signature]
Title: Minister of Economic Development and Cooperatives	Title: Director, USAID/Guyana
Date: NOV 12 1980	Date: NOV 13 1980

AID 1330-17 (5-79) - Cover Page

9. For: Ministry of Health

Typed Name: Hamilton Green

Signature: [signature]

Title: Minister of Health, Housing and Labor

Date: 31. OCT. 1980

ANNEX A - PROJECT DESCRIPTION

Project Title: Rural Health Photovoltaic Demonstration Project

A.I.D. Project Number: PASA NASA/DSB-5710-2-79

Project Purpose:

The purpose of this project is to demonstrate and test the use of photovoltaic (PV) power systems for meeting the basic electrical requirements of Guyana's health delivery system in rural areas.

Project Description:

This project consists of: (1) the design, development, installation, and field-testing of PV systems in selected health facilities in Guyana; (2) the provision of training and education programs for appropriate host country personnel in the theory, operation, and maintenance of the systems; and (3) an assessment of the cost-effectiveness of the installed PV systems. The estimated period of performance of the project will be four (4) years from the date of the signing of this Agreement.

The United States Agency for International Development (A.I.D.) shall provide the services of the National Aeronautics and Space Administration, Lewis Research Center (NASA/LeRC) who shall assume full responsibility for the provision of technical services and goods under the project within the provisions of the PASA NASA/DSB-5710-2-79. The implementing agency for the Government of Guyana shall be the Ministry of Health (MOH). The roles and responsibilities of the participating parties are outlined in Annex B.

The exact number and location of the sites for deployment of the PV systems within Guyana shall be agreed upon by the MOH, NASA/LeRC, and A.I.D. within two months after the signing of this Agreement. An illustrative implementation schedule is included in Annex C; this schedule shall be finalized and a detailed implementation plan shall be prepared

within approximately four months after the signing of this Agreement at which time the conceptual systems design work is expected to be completed. A financial plan which summarizes cost estimates of the goods and services to be provided under the project, which is estimated to be approximately US$ 400,000, shall also be prepared at that time. Both plans shall be made a part of this Agreement in the form of a Project Implementation Letter.

ANNEX B - ROLES AND RESPONSIBILITIES OF PARTICIPATING PARTIES

Project Title: Rural Health Photovoltaic Demonstration Project

A.I.D. Project Number: PASA NASA/DSB-5710-2-79

The following parties shall assume the roles and responsibilities outlined below for implementation of this project: (1) National Aeronautics and Space Administration, Lewis Research Center (NASA/LeRC); (2) Ministry of Health (MOH); and (3) United States Agency for International Development Mission to Guyana (USAID/G).

(1) NASA/LeRC shall:

(a) Assume overall technical, financial, and administrative management responsibility for this project.

(b) Assign a Project Manager and Project Engineer from the NASA/LeRC staff to this project.

(c) In collaboration with the MOH and USAID/G, determine the number and location of sites for deployment of the PV systems within two months after the signing of this Agreement.

(d) Make arrangements for the collection of insolation data and other meteorological information in Guyana which would be required for the design of the systems.

(e) Undertake conceptual systems design.

(f) Prepare a detailed implementation plan and schedule within four months after the signing of this Agreement which shall include: a detailed description of the project and of the conceptual design of the PV systems to be deployed and delineation of the roles and responsibilities of each participating party.

(g) Prepare a financial plan within four months after the signing of this Agreement which shall include the estimated costs of all goods and services to be provided by NASA/LeRC and of the Grantee's contribution to the project; these latter costs shall be prepared by the MOH in consultation with USAID/G and NASA/LeRC.

(h) Secure the approval of the Implementation and Financial Plans by the MOH and USAID/G.

(i) Procure, in accordance with competitive procurement procedures, the services of a U.S.-based contractor to be responsible for:

(i) The design, fabrication, installation, initial operation, and field-testing of the PV systems.

(ii) The procurement from U.S. sources or where appropriate, local sources, and the shipping via U.S. carriers, where possible, of all materials, supplies, and equipment required for the fabrication and installation of the systems and their repair and maintenance during the life of the project.

(iii) Preparation of a site plan including a detailed work plan for each site selected for installation of the system.

(iv) Following installation of the PV systems, maintenance and monitoring (data acquisition, system inspection) of the systems for a specified period of time agreed upon by NASA/LeRC, during which intended users and service personnel of the system shall be trained.

(v) The training of intended users and service personnel in the operation, monitoring, and maintenance/repair of the PV systems.

(vi) Providing forms and instructions for the recording of system data including date, time of day, estimated sky-cover, weather data, system voltage, array current, etc. and monthly system inspection.

(vii) Subject to the approval of the MOH and NASA/LeRC, subcontracting with host country contractor(s), if appropriate, to perform certain elements of the work related to the project.

(j) Monitor and technically direct the work of the contractor as it relates specifically to the design, fabrication and check-out, installation, field-testing, and evaluation of the systems, and training.

(k) During the estimated four-year period of inputs to this project by A.I.D. and NASA/LeRC, provide all equipment and spare parts required for both the installation and maintenance of the systems.

(l) Make arrangements for and participate in, as appropriate, training sessions for intended users and service personnel, including the provision of operation and maintenance/repair manuals.

(m) Organize information dissemination activities which may include a conference or workshop as well as the distribution of brochures and other printed materials on the use of PV systems in general.

(n) In collaboration with the MOH and USAID/G, arrange for and participate in, as agreed upon, project evaluations which shall include inter alia, an assessment of the cost effectiveness of the systems. All details relating to the evaluation, including schedule, roles and responsibilities of participating parties and specific objectives, shall be included in the detailed implementation plan.

(o) Assume full responsibility and authority for all PV systems' materials and equipment at each site until the PV installations are completed. NASA/LeRC shall continue to provide technical assistance as required and spare parts for approximately two years after the handing-over to the GOG or dedication of the installations.

(p) Provide the MOH and USAID/G with written quarterly progress reports during the two-year pre-dedication phase and on a bi-annual basis during the two-year post-dedication phase.

(2) MOH shall:

(a) In collaboration with NASA/LeRC and USAID/G, determine the number and location of sites for the deployment of the PV systems within two months after the signing of this Agreement.

(b) Assign a Project Manager from the MOH staff to this project.

(c) Review and approve the detailed implementation plan and schedule to be submitted by NASA/LeRC within four months after this Agreement is signed.

(d) Assist the U.S. contractor with regard to receiving all materials, supplies, and equipment required for installation of the PV systems including procurement of import licenses, custom clearance at the port of entry, transportation of the goods to a storage site and temporary storage of the goods, and arranging for transportation of the goods to the project site. Costs associated with in-country storage and transportation shall be covered under the contractor's contract and shall be paid for with project funds.

(e) Make all logistical arrangements related to the contractor and local sub-contractor(s) including in-country clearances for travel, in-country transportation and accommodations, and any other local logistical/administrative services which may be required by the contractor during the life of the project. All costs for in-country travel and per diem incurred by the contractor or sub-contractors shall be covered under their contract and paid for with project funds.

(f) In collaboration with the NASA/LeRC and USAID/G, identify suitably qualified and appropriate personnel to be trained as users and service personnel in the operation, monitoring and maintenance/repair of the systems.

(g) Assist NASA/LeRC in arranging for and conducting a conference or workshop for purposes of information dissemination.

(h) In collaboration with NASA/LeRC and USAID/G, arrange for and participate in, as agreed upon, project evaluations, the details of which shall be included in the project implementation plan.

(i) Provide the necessary funds and ensure the provision of appropriate personnel to participate in project planning and coordination meetings to fulfill the responsibilities delineated.

(j) Provide the necessary funds and ensure the provision of adequately trained personnel to: (i) operate, monitor, and maintain the PV systems during the project; and (ii) service and repair the PV systems (including the procurement of spare parts) after A.I.D. and NASA/LeRC inputs to the project terminate. To carry out this responsibility, the MOH, in collaboration with NASA/LeRC and USAID/G, shall select an organization which shall be charged with the responsibility for post-installation maintenance and repairs.

(3) <u>USAID/G shall</u>:

(a) Assign a Project Manager for the Mission.

(b) In collaboration with NASA/LeRC and the MOH, determine the number and location of sites for deployment of the PV systems, approve the project implementation plan, and participate in project evaluations, the details of which shall be contained in the project implementation plan.

(c) Serve as liaison, when requested, between the parties involved in this project such as for the transmission of cabled information.

ANNEX C - ILLUSTRATIVE IMPLEMENTATION SCHEDULE

Project Title: Rural Health Photovoltaic Demonstration Project

A.I.D. Project Number: PASA NASA/DSB-5710-2-79

	Activity	Date Completed
1.	Project Agreement signed	November 15, 1980
2.	Site selection and project definition finalized	January 15, 1981
3.	Conceptual systems design finalized	March 15, 1981
4.	Detailed implementation plan and financial plan finalized	March 15, 1981
5.	Procurement of U.S.-based contractor through competitive bidding process	June 30, 1981
6.	Actual design of systems by contractor	September 30, 1981
7.	PV seminar in Guyana	To be determined
8.	Materials/supplies and equipment procurement and fabrication/check-out	February 28, 1982
9.	Site preparation	March 31, 1982
10.	Receipt of all goods in-country and installation of systems	April 30, 1982
11.	Installation completed	June 30, 1982

	Activity	Date Completed
12.	Technician training/system check-out completed	September 30, 1982
13.	Initial project evaluation	October 31, 1982
14.	Dedication	November 30, 1982
15.	Final project evaluation	December 31, 1984

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PROJECT AGREEMENT

PROAG STANDARD PROVISIONS ANNEX

A. Reference to 'this Agreement' means the original Project Agreement as modified by any revisions which have entered into effect. Reference to 'cooperating country' means the country or territory of the Grantee.

B. (1) AID will make available the amount specified in Block 3 of this Agreement, as necessary for the Project, as may be further described in Annex A.

(2) The Grantee will make available the amount specified in Block 4 of this Agreement, as necessary for the Project, as may further be described in Annex A. The Grantee will also make, or arrange to have made, additional contributions of property, services, facilities and funds required for carrying out the Project as specified in Annex A.

C. AID and the Grantee may obtain the assistance of other public and private agencies in carrying out their respective obligations under this Agreement. The two parties may agree to accept contributions of property, services, facilities and funds for purposes of this Agreement from other public and private agencies, and may agree upon the participation of any such third party in carrying out activities under this Agreement.

D. Except as otherwise specified herein or subsequently agreed by the parties, all contributions of the parties pursuant to this Agreement shall be made on or before the Project Assistance Completion Date, or amended date. A contribution of goods or services shall be considered to have been made when the services have been performed and the goods furnished as contemplated in this Agreement. Disbursement of funds may take place after final contributions have been made, but AID shall not be required to disburse funds hereunder after the expiration of nine months following the estimated Project Assistance Completion Date (Block 5 of this Agreement) or any amended Project Assistance Completion Date specified.

E. The procurement of commodities and services to be financed in whole or in part by AID may (where so required by AID procedures) be undertaken only pursuant to Project Implementation Orders (PIOs) issued by AID.

F. Unless otherwise specified in the applicable PIO or Project Implementation Letter (PIL), the procurement of commodities imported specifically for the Project and financed with the AID contribution referred to in Block 3 of this Agreement shall be subject to the provisions of AID Regulation 1.

G. Unless otherwise agreed by the parties or otherwise specified in the applicable PIO, title to all property procured through financing by AID pursuant to Block 3 of this Agreement shall be in the Grantee, or such public or private agency as it may authorize.

H. (1) Any property furnished to either party through financing by the other party pursuant to this Agreement shall, unless otherwise agreed by the party which financed the procurement, be used effectively for the purposes of the Project in accordance with this Agreement, and upon completion of the Project, will be used so as to further the objectives sought in carrying out the Project. Either party shall offer to return to the other, or to reimburse the other for, any property which it obtains through

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financing by the other party pursuant to this Agreement which is not used in accordance with the preceding sentence.

(2) Any funds provided to either party pursuant to this Agreement which are not used in accordance with this Agreement, shall be refunded to the party providing the funds.

(3) Any interest or other earnings on funds provided by AID to the Grantee under this Agreement will be returned to AID by the Grantee.

I. (1) If AID and any public or private organization furnishing commodities through AID financing for operations hereunder in the cooperating country, is, under the laws, regulations or administrative procedures of the cooperating country, liable for customs, duties and import taxes on commodities imported into the cooperating country for purposes of carrying out this Agreement, the Grantee will pay such duties and taxes unless exemption is otherwise provided by any applicable international agreement.

(2) If any personnel (other than citizens and residents of the cooperating country), whether United States Government employees, or employees of public or private organizations under contract with, or individuals under contract with AID; the Grantee or any agency authorized by the Grantee, who are present in the cooperating country to provide services which AID has agreed to furnish or finance under this Agreement, are under the laws, regulations or administrative procedures of the cooperative country, liable for income and social security taxes with respect to income which they are obligated to pay income or social security taxes to the Government of the United States of America, for property taxes on personal property intended for their own use, or for the payment of any tariff or duty upon personal or household goods brought into the cooperating country for the personal use of themselves and members of their families (not including such personal or household goods as may be sold by any such personnel in the cooperating country) or if any firm, not normally resident in the cooperating country, is liable for income, receipts, or other taxes on work financed by AID hereunder, the grantee will pay such taxes, tariff, or duty unless exemption is otherwise provided by any applicable international agreement.

J. If funds provided by AID are introduced into the cooperating country by AID or any public or private agency for purposes of carrying out obligations of AID hereunder, the Grantee will make such arrangements as may be necessary so that such funds shall be convertible into currency of the cooperating country at the highest rate which, at the time the conversion is made, is not unlawful in the cooperating country.

K. AID shall expend funds and carry on operations pursuant to this Agreement only in accordance with the applicable laws and regulations of the United States Government.

L. The two parties shall have the right at any time to observe operations carried out under this Agreement. Either party during the term of the Project and for three years after the completion of the Project shall further have the right (1) to examine any property procured through financing by that party under this Agreement, wherever such property is located, and (2) to inspect and audit any records and accounts with respect to funds provided by, or any properties and contract services procured through financing by, that party under this Agreement, wherever such records may be located and maintained. Each party, in arranging for any disposition of any property procured through financing by the other party under this Agreement, shall assure that the rights of examination, inspection and audit described in the preceding sentence are reserved to the party which did the financing.

M. AID and the Grantee shall each furnish the other with such information as may be needed to determine the nature and scope of operations under this Agreement and to evaluate the effectiveness of such operations.

N. The present Agreement shall enter into force when signed. Either party may terminate this Agreement by giving the other party thirty (30) days written notice of intention to terminate it. Termination of this Agreement shall terminate any obligations of the two parties to make contributions pursuant to Blocks 3 and 4 of this Agreement, except for payments which they are committed to make pursuant to noncancellable commitments entered into with third parties prior to the termination of the Agreement. It is expressly understood that the obligations under paragraph H relating to the use of property or funds shall remain in force after such termination. In addition, upon such termination AID may, at AID's expense, direct that title to goods financed under the Grant be transferred to AID if the goods are from a source outside the Grantee's country, are in a deliverable state and have not been offloaded in ports of entry of the Grantee's country.

O. To assist in the implementation of the Project, AID, from time to time, may issue PILs that will furnish additional information about matters stated in this Agreement. The parties may also use jointly agreed-upon PILs to confirm and record their mutual understanding on aspects of the implementation of this Agreement.

P. The Grantee agrees, upon request, to execute an assignment to AID of any cause of action which may accrue to the Grantee in connection with or arising out of the contractual performance or breach of performance by a party to a direct U.S. Dollar contract with AID financed in whole or in part out of funds granted by AID under this Agreement.

ANNEX C

TECHNICAL CONSIDERATIONS OF PHOTOVOLTAICS

Although the physical phenomenon of photovoltaics (PV) was discovered in 1839, the application of this knowledge and the development of PV systems for generating electricity from the sun (solar cells) were not systematically pursued until the advent of the space programs. Since 1958, when solar cells were first used to provide electric power on the earliest U.S. satellites, PV systems have been used on nearly every spacecraft flown by the U.S. and other countries. As space technology, photovoltaics are well known, proven and accepted as the technology of choice for many missions.

For terrestial applications, PV systems have not been so widely accepted. Several factors account for this, principally cost. The initial space applications placed a premium on performance. Since the electric power system was but a small part of the full satellite system, its cost was not nearly so important as the performance, reliability and appropriateness for the mission. Since PV systems satisfied the last three criteria, the high cost of the technology was justifiable. Also, the "one-of-a-kind" approach used in space systems means that mass production of components specifically for space use has not been necessary. As a result, cost-cutting practices in common use in more commercial sectors were not initially established for PV systems and components.

Terrestial applications of PV systems began as early as 1959 with their use in rural telephone systems in the U.S. A.I.D. funded the construction and testing of a PV-powered fishing boat in 1962. These and other experimental efforts provided important initial information about terrestial use of the technology. In 1970 NASA/LeRC began to install PV systems for U.S. agencies such as the Forest Service and the Coast Guard. This work was increased when the "oil crisis" of 1973 focused the world's attention on the need to find alternatives to oil and funding for terrestial applications of photovoltaics was provided by a series of Federal agencies as they sequentially assumed the leaderships in energy technology development - NSF, ERDA and DOE.

A photovoltaic system works as follows: Light strikes a PV cell and produces electric charges that are free to flow in an electric circuit. This electric current can be used immediately or stored for later use. A typical photovoltaic system includes the PV cells wired and packaged as modules, the structure to support the modules, switches and other electric current control devices, wiring, a battery to store electricity for later use (if desired) and other equipment. A system is designed to meet a specific requirement and can include any number of modules and

batteries. The modular nature of the technology is a prime attribute - the number of modules can be matched to the amount of electric power required, the capacity of the battery storage can be matched to the time profile of the electricity demand.

Cost

There are numerous materials which exhibit the photovoltaic effect. Commercially available PV modules all use the same material, silicon, which was initially developed for the space program. As figure C-1 indicates, the cost of these modules has been continually decreasing as production levels have increased. Current PV module prices range $10 to $15 per peak watt. Continued cost reductions are expected: they will be due to greater use of automated production techniques and to future use of materials other than silicon as these materials and processes are further developed.

At the current cost level, the PV module represents about 40% to 50% of the total system cost, the remaining being termed the balance of system (BOS). As additional system expeience is accrued, it is expected that some of the components of BOS cost such as design engineering can be virtually eliminated through system replication. Furthermore, design improvements, reduced PV module cost and greater use should lead to lower costs of storage batteries, structures and assembly. To illustrate this, the DOE program, currently operating with a $150 million annual budget, projects a module price of about $0.70/peak watt and a system price of $1.60 - $2.60/peak watt by 1986 (in 1980 dollars).

A most important factor in considering photovoltaic costs is that the technology, like all solar technologies, requires no fuel input and, therefore, has very low operating costs. However the initial capital costs are high. The only valid way to calculate energy costs for photovoltaics is to employ life-cycle costing techniques which consider initial capital costs and operations and maintenance costs for the life of the system. Using such techniques, an analysis of the cost of energy derived from PV systems at remote sites indicates cost-competitiveness relative to small diesel generators, based on today's PV module prices, for cases where the price of diesel fuel delivered is $3/gallon. The results are presented in Figure C-2 which compares the unit cost of electricity generated by PV systems and diesel generators. Assumptions are noted in the legend.

The results indicate that for applications having an annual electrical demand of 6,000 kWh or less, the energy cost for a photovoltaic system is less than for a small diesel/electric system. Points of reference for annual electric demand are the

Schuchuli Village Project, 6,000 kWh/yr. and the Tangaye Village Project, 3,000 kWh/yr. Within the range of annual energy use up to 6,000 kWh lie many important applications of immediate relevance to development in rural areas of Third World countries. Furthermore, over the next several years it may be anticipated that photovoltaic system costs will continue to drop steadily. Thus within a decade it is likely that photovoltaics will become the least expensive and most reliable source of many decentralized electric power applications in the developing world.

Reliability

The reliability of a system must be taken into account when determining its appropriateness. When compared to other technologies, PV systems offer a potentially much greater reliability due to the intrinsic modular nature of PV technology. With proper system design, the failure due to a single system element can be minimized by assuring that there are several elements that operate in parallel to maintain system performance in the event of a component failure. Thus even though individual modules might fail, the system can still function. In contrast, primarily mechanical systems (such as a gasoline engine) are critically dependent on numerous components (such as a carborator), the failure of any one of which will prevent the operation of the system.

The reliability of PV systems for space uses has been proven by the results of the twenty year space program. For terrestial applications, NASA/LeRC has the greatest experience with twenty system installations in the U.S. and overseas since 1976. Operational experience to date with these systems, that on the average have been operating for three years with no obvious limit on the total life of system, indicates the following concerning reliability.

Modules - of a total of 2,000 modules installed, approximately 1,700 modules (consisting of units from three different U.S. manufacturers) evidenced less than 1% failures. The remaining 300 modules (consisting of one manufacturers's units of a single model type) exhibited 20% failures within the first 18 months of operation. Failure of these latter modules resulted from fatigue cracking of the cell electrical interconnections induced by thermal stress, apparently due to an inappropriate choice of module substrate material. It may be noted that for the two PV systems (the Schuchuli and Tangaye, Upper Volta, Village Power Systems), which contained these 300 design deficient modules, there was no abrupt interruption of power. The systems continued to operate as module failures accumulated over an 18-month period, howbeit with a progressively diminished overall energy output. Full system operational output was restored by replacement of failed modules. Further details of the Upper Volta experience are given below.

Other components - The majority of the systems deployed did not exhibit any component problems. Minor, readily remedied component malfunctions or design problems (e.g., voltage regulator, refrigerator compressor motor) were experienced with seven of the systems.

Power system reliability is strongly dependent on system design and the proper selection and assembly of the components, i.e., modules, batteries, controls, regulators, structure and wiring. In general operating experience from the variety of geographically dispersed applications indicates excellent system reliability. Outage rates for photovoltaic systems are generally lower than for U.S. central station electric utility power considerably lower than for electric utility power in many developing countries.

NASA/LeRC Experience

The Lewis Research Center has been NASA's Lead Center for space photovoltaic technology since the early 1960's. Beginning in early 1970, LeRC, as part of NASA's policy to apply space technology to other needs, began designing, building and deploying small terrestrial PV systems for the U.S. Forest Service, Coast Guard and other agencies. In early 1976, LeRC installed two systems in India as part of the Satellite Instructional Television Experiment, a collaborative USG-India project involving transmitting educational TV programs using the ATS-6 satellite. However, until the mid-70's, nearly all PV arrays commercially produced in the U.S. were used for space applications. At about that time, a national terrestrial PV program was initiated, funded first by the National Science Foundation and then the Energy Research and Development Administration which became the DOE. LeRC was intially assigned the Tests and Applications Project involving technology development and domestic market development of PV stand-alone (no backup power) systems. Sine the terrestrial PV industry was in its infancy at that time, DOE employed a series of "block buys" of PV modules to stimulate production and thereby decrease cost. LeRC used some of these modules for demonstration projects. Again, because of limited industrial capability to develop PV systems at the time, LeRC employed in-house personnel and local contractors in designing, fabricating, testing and installing PV systems for a variety of potential users, mostly governmental agencies, in the U.S. Much of the design work developed at LeRC during this period has been or is being transferred to the emerging PV systems industry. A brief summary of the LeRC experience with DOE and AID PV systems to date is given below.

Under the DOE Project, LeRC has deployed some 20 systems mostly single function experiments such as communication or refrigeration, ranging from Hawaii to Maine and from Alaska to the

Florida Keys. The most significant experiment to date, however, is the world's first village PV power system in the Papago Indian Village of Schuchuli, Arizona. This 3.5 kW peak, 120 volt DC system, which became operational on December 16, 1978, provides the 95 villagers with electrical power for potable water pumping (for domestic use and livestock), lights in the homes and community buildings, family refrigerators, a communal washing machine and a sewing machine. The system to date has performed continuously except for several brief outages caused by control system malfunctions which have been subsequently corrected. Another significant multi-function experiment deployed by LeRC involves two fire look-out towers in northern California operated by the U.S. Forest Service. The 294 watt peak PV systems at these sites each power a water pump, refrigerator, lights and a 2-way radio. Both systems have been operating satisfactorily since they became operational in October 1976.

Under U.S. AID sponsorship, a PV system powering a grain mill and a water pump was installed, under LeRC management, in the West Africa village of Tangaye, Upper Volta and became operational on March 1, 1979. The 1.8kWp, 120V DC system supplies DC electrical power to a grain grinder and a water pump. A cooperative has been formed by the villagers of Tangaye to manage the mill. About 60 village families invested in the enterprise. Charges for milling are set by the cooperative and are competitive with commercial mills in the region. Proceeds from membership and milling are used to pay two full-time millers and to accumulate funds for spare parts and repairs. Additional profits are distributed to cooperative members. The water pump provides up to 15,000 liters of water per day for domestic and stock use. The water is available to all villagers free of charge.

As of October 12, 1980, the system in Upper Volta had been operational 96 percent of the time (i.e., 567 out of 591 days). Because of mechanical problems encountered with the burr mill, installed initially, only a hammer mill was subsequently installed to replace it. As a result of the problems with the original mill, the grain mill has been operational only 89 percent of the time.

A summary of the data for water pumping and grain grinding is given in Figures C-3 and C-4. It can be seen that water consumption has followed a seasonal pattern to some degree, the maximum use occuring at the height of the dry season in March-April. The total amount of water pumped as of October 12, 1980 is 4,623,000 liters covering 3,700 hours of pumping. During a recent visit to Tangaye in December 1980, LeRC personnel were told by an elder that the villagers no longer get sick from drinking the water from the well (since the well was covered following installation of the

pump). This perception of the health advantages of pumped water is evidently recent, not noted in Dr. Robert's final evaluation study conducted in the summer of 1980 (2). The consumption of ground grain, shown in Figure C-4, indicates several peaks and valleys due to occasional mechanical problems with the burr mill and the failure of some of the PV modules that began to occur in mid to late 1980. The failure involves fatigue cracking of the metallic interconnects between the solar cells in the specific PV modules manufactured by the Solarex Corporation that were used in the project.

The operation of the village system in Tangaye has been maintained by the effective coordination among several people and organizations. NASA personnel themselves directed the initial installation of the system (February 1979) and the replacement of the grain mill (September 1979). Since that time NASA technicians did not visit the village. NASA/LeRC did however monitor the performance of the system and respond to the identification of problems by cabling instructions to personnel in USAID and through them to the village. The USAID personnel included an agricultural officer (project manager) and a Peace Corps Volunteer who had a college degree in physics. These two undertook necessary steps to maintain the system operation. The daily operation of the system was the responsibility of an Upper Volta native of a nearby village; he was principally responsible for identifying a problem and, on the basis of instructions from USAID personnel, for carrying out the specific steps needed to correct it. It should be noted that only the NASA personnel had had any experience with photovoltaic systems before the Upper Volta system was installed.

Lessons Learned From Early PV Experiments

Experience with the Schuchuli, Arizona and Tangaye, Upper Volta systems has confirmed the need for simple, low maintenance system components and load devices. For both systems, automatic controls were initially installed to limit the usage of the systems (to prevent depletion of the storage batteries under certain conditions). It was found that these timer-type controls were an unnecessary complication which, with proper education and training of the user, could be eliminated. Furthermore, electromechanical control systems for regulating charge currents, used initially for lack of other suitable commercially available controls, were also found to be troublesome in Upper Volta. (Yet a similar control in Schuchuli, Arizona has operated flawlessly for over two years.) For the Tangaye system, this unit was replaced with a more reliable solid state control. Load devices such as the original burr mill in Tangaye and custom made refrigerators for Schuchuli have also experienced occasional problems. Again this emphasizes the importance of selecting simple, reliable and yet energy-conservative

load devices for remote PV applications. It is interesting to note that field experience, especially that at Tangaye, has provided information on PV system and load device operation and maintenance that would be virtually impossible to generate via a controlled experiment in the States. It should also be pointed out that the failure of some of the PV modules due to the previously mentioned design deficiency is peculiar to the specific Solarex modules (9200J) and has not occured in other projects where different modules are or were used.

The Upper Volta project has demonstrated the need for a capability to provide technical advice and service to field systems, it has also shown that the actual steps to be taken can usually be undertaken by someone with minimal technical experience in general and familiarity with photovoltaics in particular.

Figure C-1

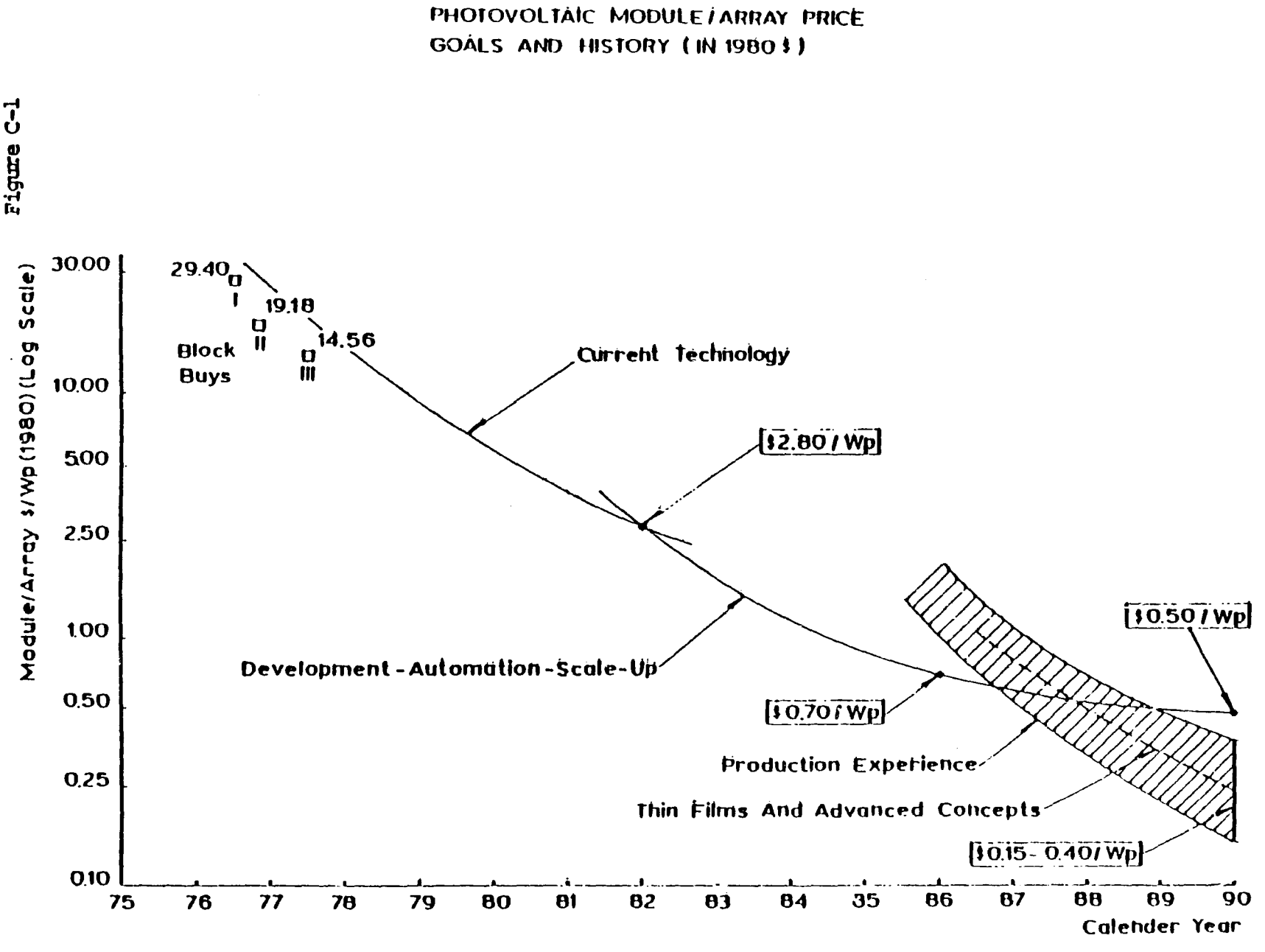


Figure C-1

Figure C-2

PHOTOVOLTAIC AND DIESEL ENERGY COST COMPARISONS

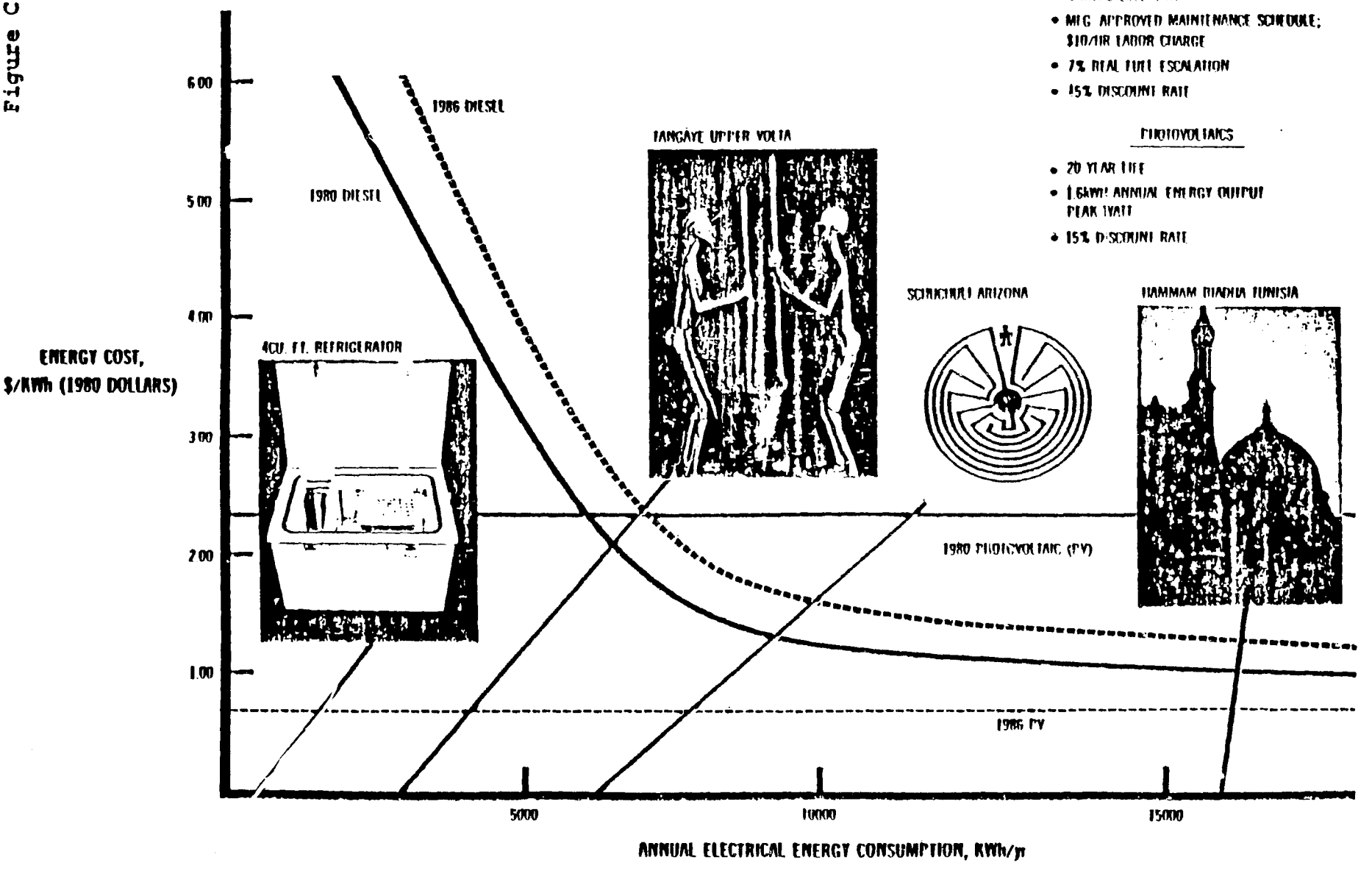
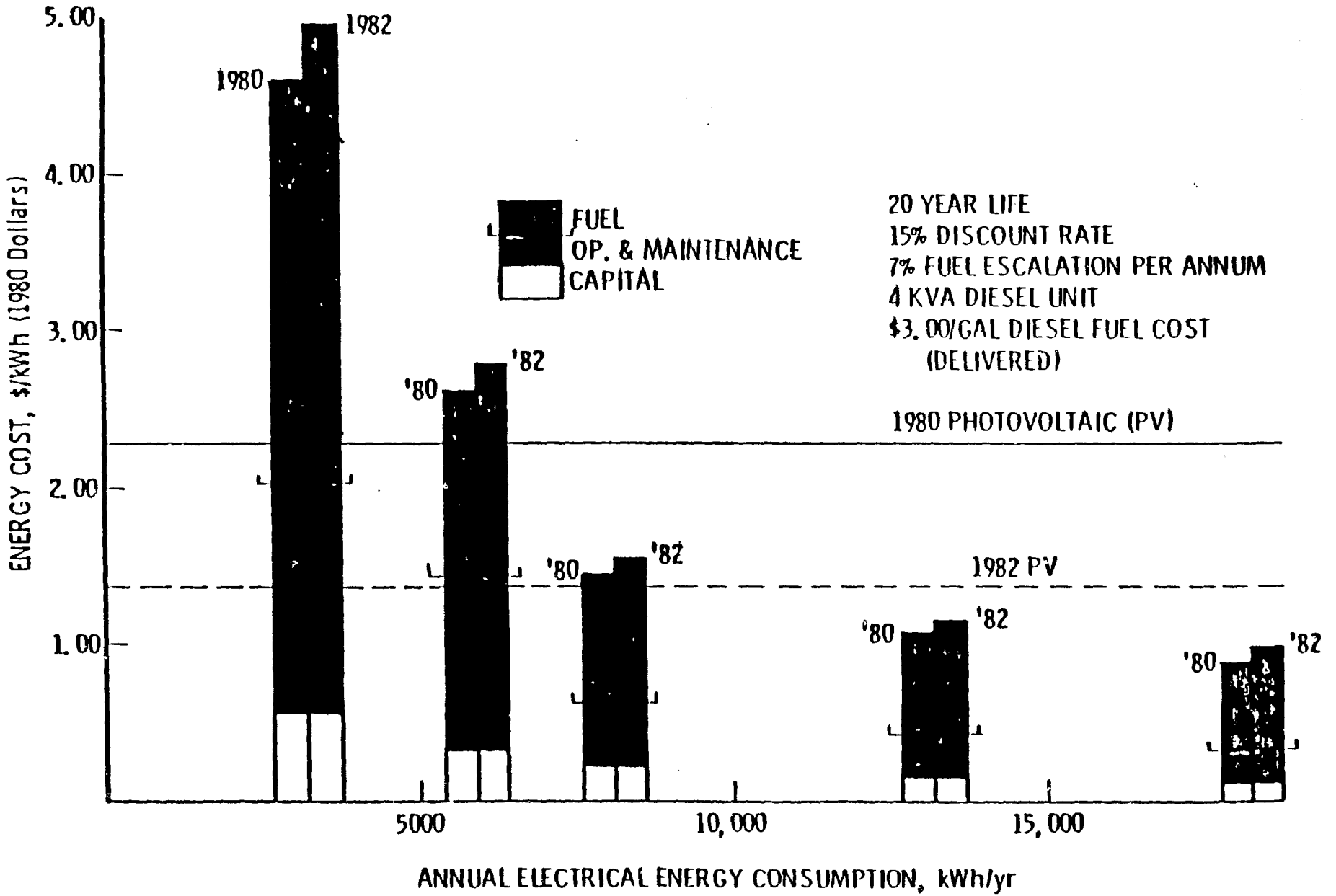


Figure C-2a

PHOTOVOLTAIC AND DIESEL ENERGY COST COMPARISONS



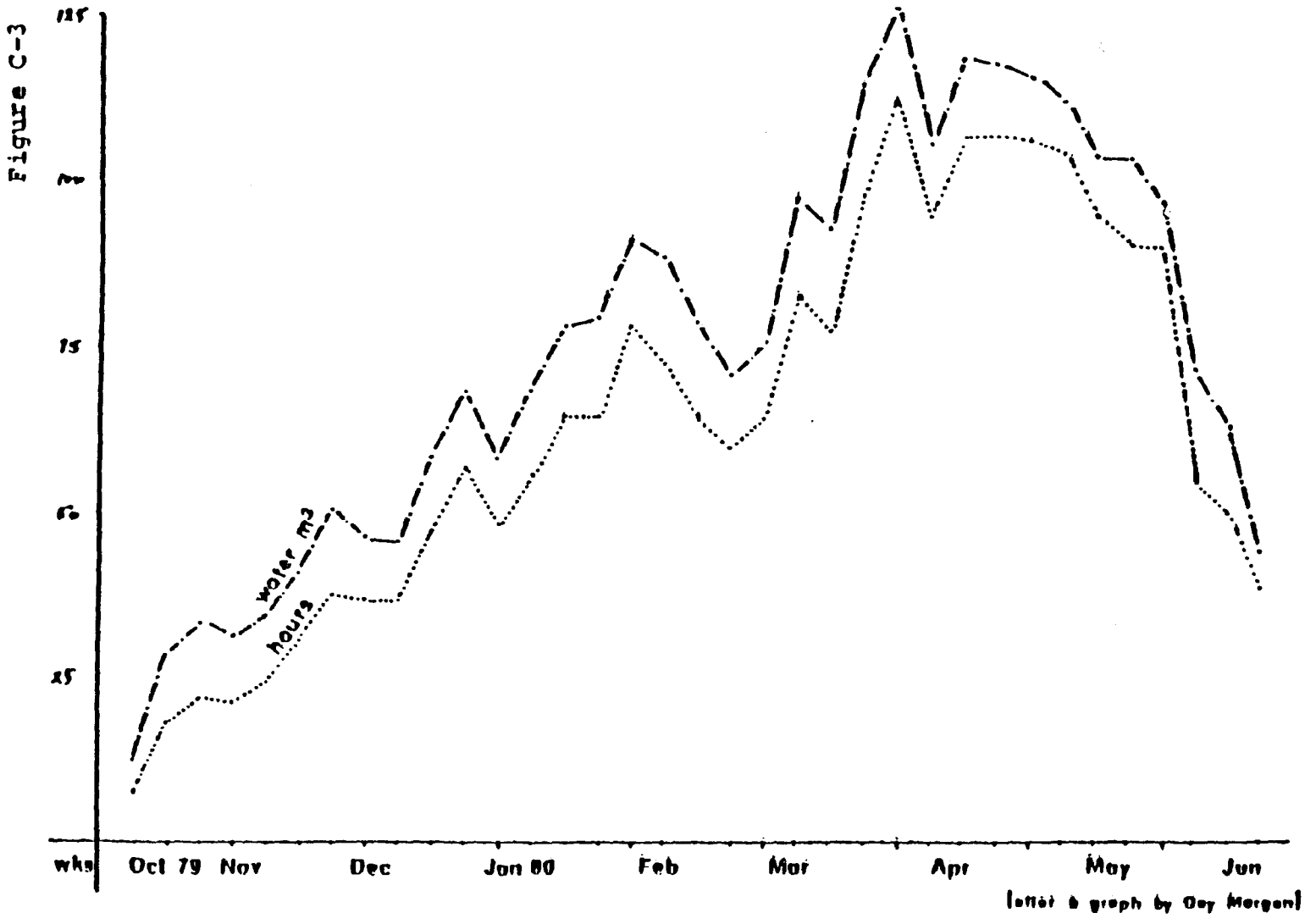


Fig. 3 - Station Water Quantities and Pump Hours

Figure C-4

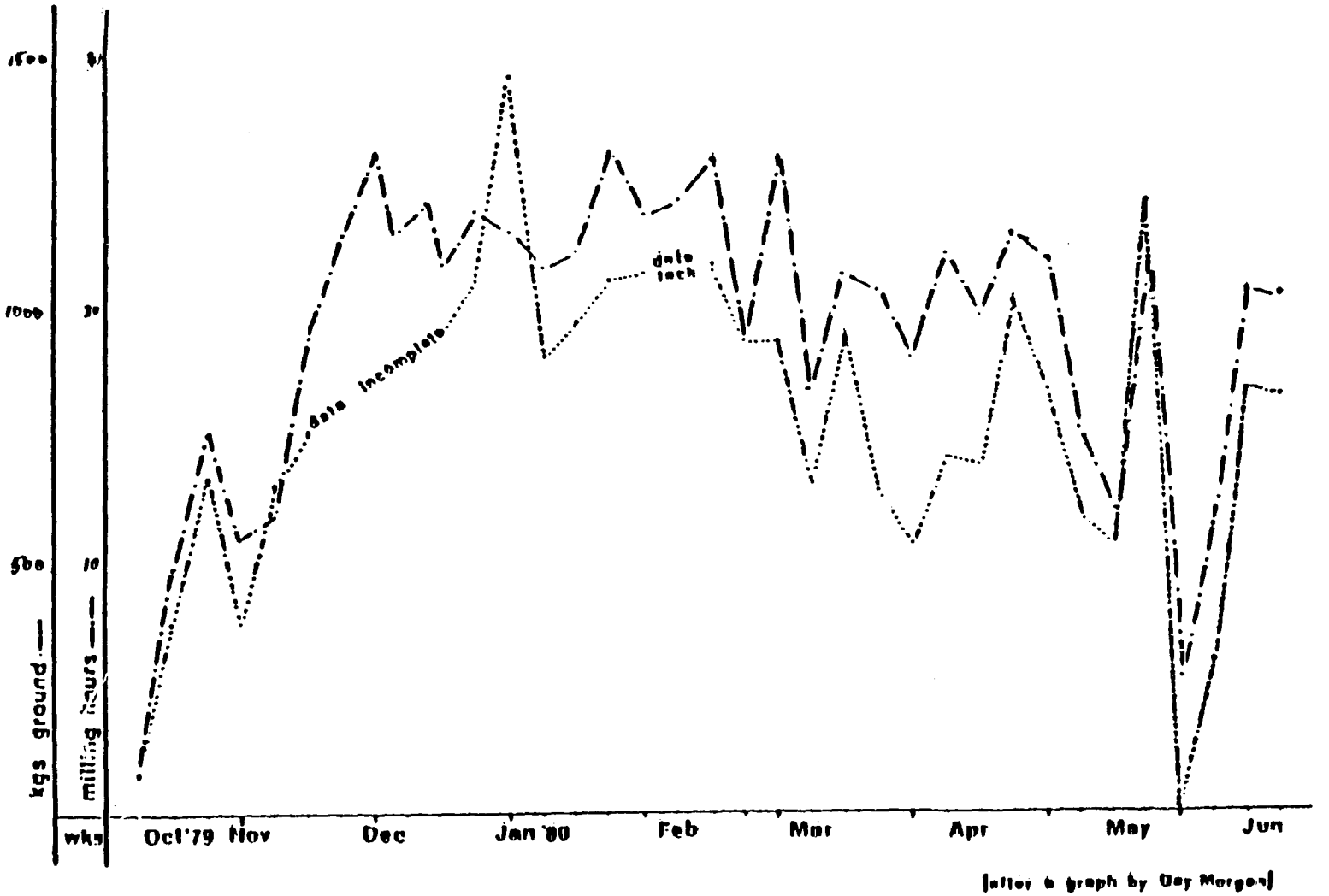


Fig. 15 – Mill Hours & Quantities

ANNEX D

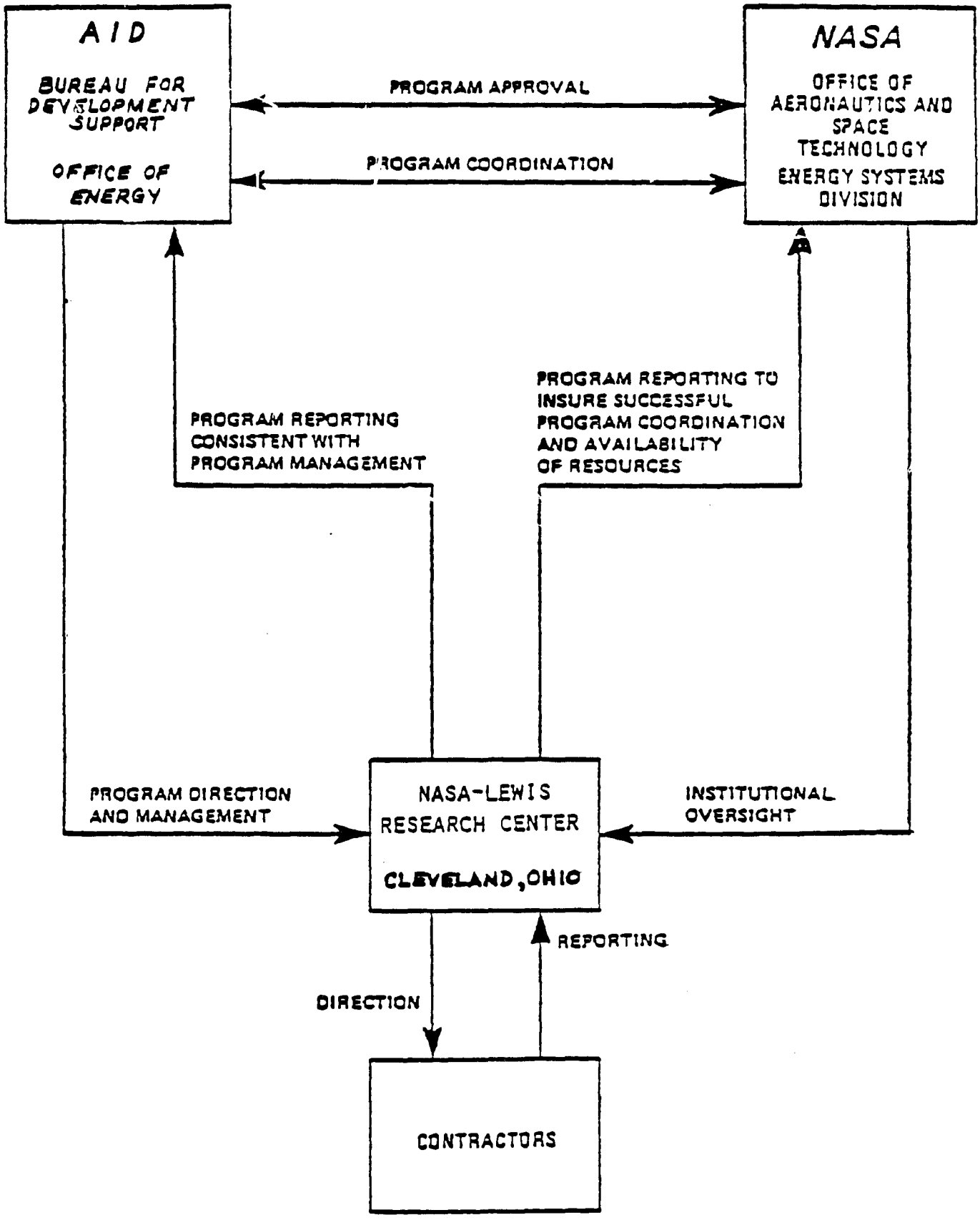
Organization Charts

NASA - AID Relationship

An organizational chart showing general and functional relationships relative to NASA's support of the AID PV Development and Support Program is shown in Figure D-1. NASA Headquarters coordinates with AID's Bureau for Program and Management Services, Office of Contract Management (SER/CM) in formalizing and periodically amending the Participating Agency Services Agreement (PASA). NASA LeRC, as project implementer, receives programmatic direction from DS/EY and issues progress and management reports to appropriate offices in AID, DOE and NASA. LeRC after securing DS/EY approval typically deals directly with AID Missions, host country governments and PVOs in developing specific projects and then contracts with industry and/or awards grants to universities for the necessary goods and services.

ANNEX D-1

TYPICAL ORGANIZATIONAL ARRANGEMENT FOR NASA SUPPORT



ANNEX D-2

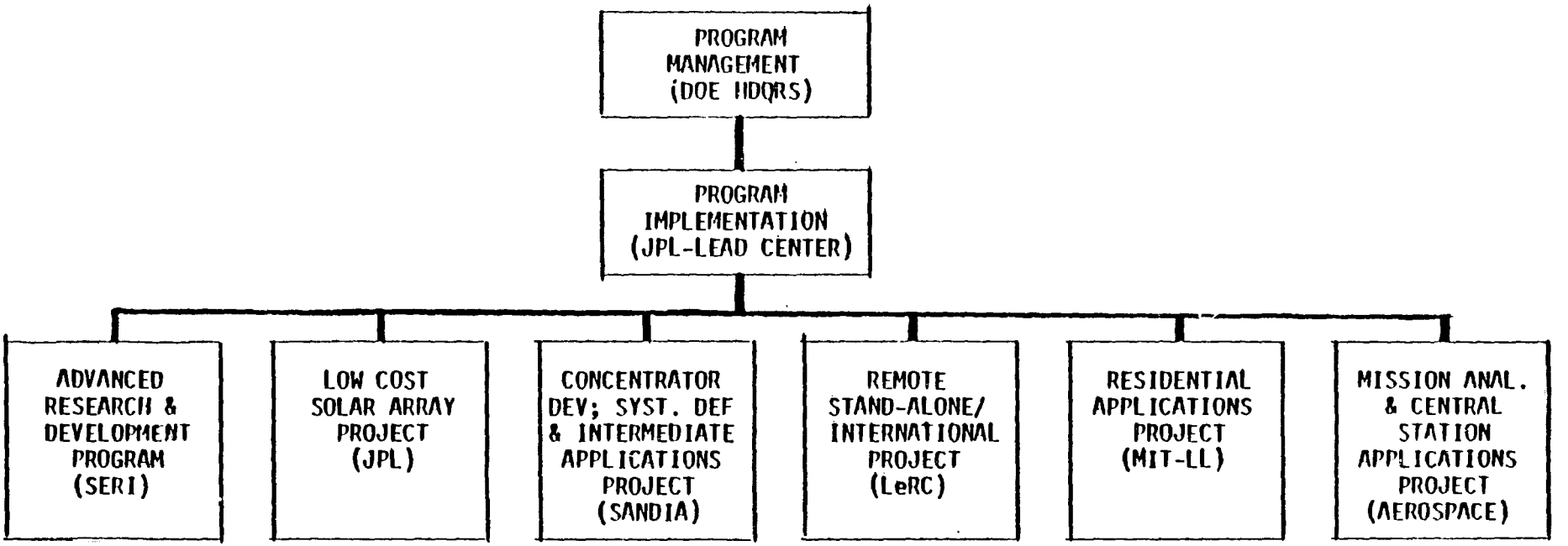
DOE National PV Program

The major organizational elements of DOE's National PV Program are shown in Figure D-2. The Jet Propulsion Laboratory (JPL) in Pasadena, operated for NASA by the University of California, serves as Lead Center for DOE. The program consists of an advanced R&D activity, a Low Cost Solar Array Project, and four Application Projects. NASA LeRC manages the Remote Stand Alone/International Applications Project.

ANNEX D-2

MAJOR PROJECT ELEMENTS AND IMPLEMENTERS

DOE NATIONAL PV PROGRAM



SERI : Solar Energy Research Laboratory
JPL : Jet Propulsion Laboratory
MIT-LL: Massachusetts Institute of Technology - Lincoln Laboratories
LeRC : Lewis Research Center

ANNEX D-3

NASA Lewis Research Center

The organization of NASA LeRC's upper level management is shown in Figure D-3. The Energy Directorate consists of three divisions which manage a variety of projects for the DOE. The PV projects managed for AID and DOE are in the Solar and Electrochemistry Division. The project level orgnaizations and personnel of the Terrestrial PV Projects Branch are given in Figure D-4

National Aeronautics and
Space Administration

Lewis Research Center
Cleveland, Ohio
44135

ORGANIZATION CHART

DIRECTOR OF ENERGY
G. Mervin Ault x.387

DEPUTY DIRECTOR
Henry O. Slone x.729

CHIEF, SOLAR & ELECTROCHEMISTRY DIVISION
Louis Rosenblum x.301

DEPUTY CHIEF
J. Stuart Fordyce x.5160

CHIEF, TERRESTRIAL PHOTOVOLTAIC PROJECTS BRANCH
Louis Rosenblum (Acting)

DEPUTY CHIEF
William J. Masica x.295

PHOTOVOLTAIC APPLICATIONS SECTION
Anthony F. Ratajczak (Head) x.6816

Ronald Cull	x.302
Richard DeLombard	x.6866
Oscar Gonzalez	x.305
James Martz	x.6866
Lawrence Thaler	x.305
Ralph Thomas	x.6866
John Toma	x.6635
John Stover	x.305
Richard Vasicek	x.6635

STAND-ALONE APPLICATIONS PROJECT OFFICE (DOE)
Edwin T. Muckley (Mgr.) x.6840

Donald Bogart	x.5255
John Bozek	x.6219
William Brainard	x.5255
Thomas Klucher	x.5255
Frank Manning	x.6360
Patricia O'Donnell	x.6945

DEVELOPMENT AND SUPPORT PROJECT OFFICE (AID)
William J. Bifano (Mgr.) x.6637

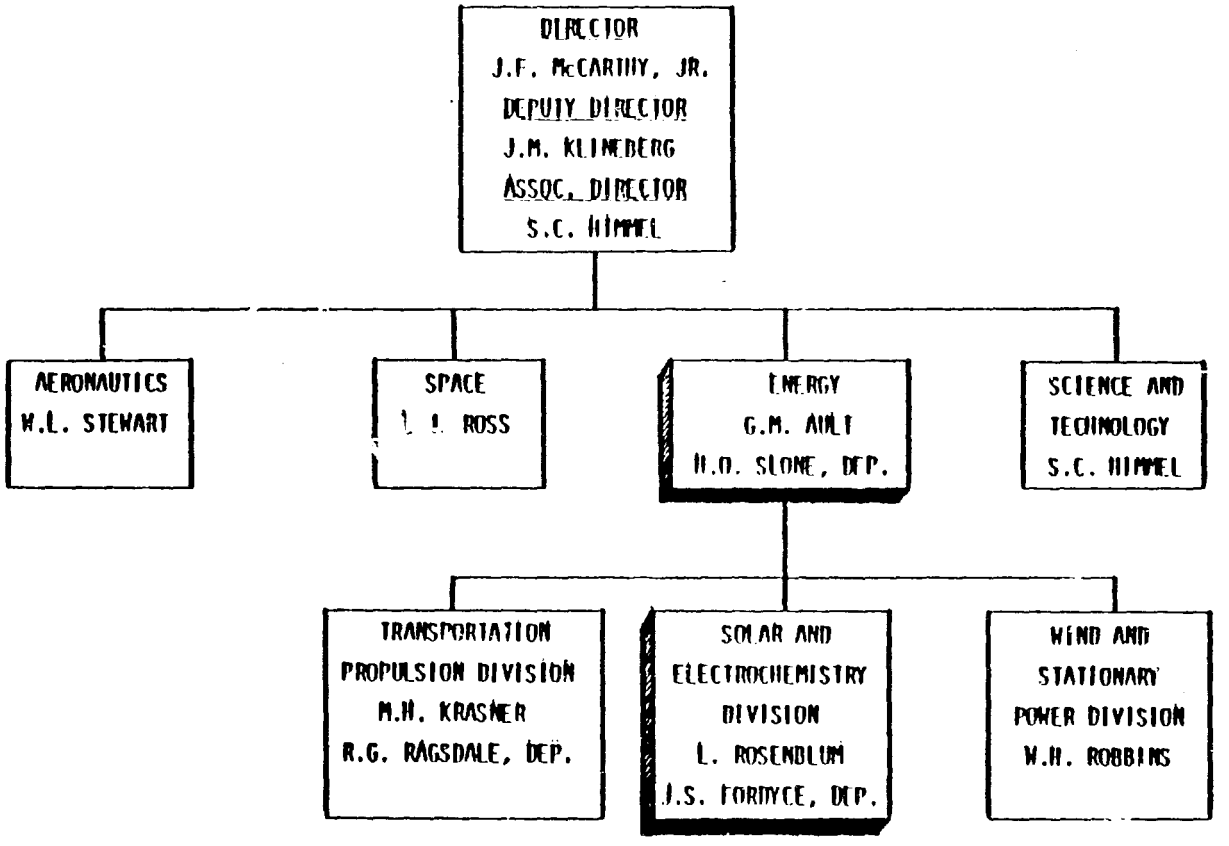
Stanley Marsik	x.6910
Larry Scudder	x.6910
Fred Simon	x.6910

Commercial Prefix: Area Code 216
433-4000 (operator will complete call)

FTS Prefix: 294 46 (if extension is less than 4 digits)

D-3

NASA LEWIS RESEARCH CENTER



ANNEX E

Profile of NASA/LeRC Staff

The Development of Support Project Office at LeRC is managed by William J. Bifano and consists of three professionals who serve as project managers. Project engineers from the PV Applications Section are assigned as needed to AID projects. Brief resumes of D&S Office personnel and project engineers currently working on AID activities are given below:

William J. Bifano, manager of the D&S Project Office, has served as project manager for both the Schuchule, Arizona and Tangaye, Upper Volta PV Projects. He has participated in TDY's to Ecuador, Peru and Kenya in support of the D&S Project. He holds a B.S. and M.S. degree in physics and has been with LeRC since 1962.

Larry Scudder assists in managing the D&S Project Office, currently serves as AID project manager for the Tunisia Renewable Energy Project, funded by the Near East Bureau, the Upper Volta PV Project, and is in the process of initiating a PV project with AID/Egypt, also to be funded by the Near East Bureau. He has participated in TDY's in Upper Volta, Tunisia, Egypt, Nigeria and Cameroon in support of AID and DOE projects. He received an A.B. degree (with honors) in 1960 and has been with LeRC since 1962. He has some familiarity with French.

Stan Marsik serves as AID project manager for PV medical applications. He previously served as project manager for the DOE PV Endurance Test project, involving the deployment of PV modules at a variety of sites in the U.S. He is fluent in both Czech and Seovak, passable in Russian and has some familiarity with German, Italian and French. He has visited Guyana, Jamaica, Zaire, Kenya and Zimbabwe in support of the D&S Project. He holds a B.S. in physics and has been with LeRC since 1965.

Fred Simon serves as AID project manager for PV education/communication applications and assists with PV medical applications. He is fluent in Spanish and has visited Ecuador and Peru in support of the D&S Project. He holds a B.S. and M.S. degree in Chemical Engineering and has been with LeRC since 1962.

Tony Ratajezak is head of the PV Applications Section. He directed implementation of both the Schuchuli and Tangaye Projects and currently supervises nine engineers responsible for both AID and DOE projects. He is also a consultant to the Solar Energy Research Institute and the United Nations in the area of PV. He holds a B.E.E. degree (electrical engineering) and has been with LeRC since 1962. He has some familiarity with French and has visited Ecuador, Egypt, Gabon, Senegal, Upper Volta, Italy and Tunisia in support of AID and DOE PV projects.

Oscar Gonzalez serves as project engineer for PV education/ communication activities and supports medical applications in Spanish speaking countries. He was a member of the site inspection team in Ecuador. He holds a B.S. degree in electrical engineering (E.E.) and has been with LeRC since 1977. A native of Puerto Rico, he is fluent in Spanish.

Dick DeLombard serves as project engineer for PV medical application projects. He was actively involved in the design and deployment of both the Schuchuli, AZ and Tangaye, U.V. systems. He has visited Upper Volta, Kenya and Zimbabwe in support of the AID project. He holds a B.S. and M.S. degree in E.E., has some familiarity with French and has been with LeRC since 1977.

Jim Martz serves as project engineer for both the Tangaye, U.V. and Tunisia Renewable Energy Projects. He holds a B.S. degree in chemical enginering and has been with LeRC since 1957. He has visited both Upper Volta and Tunisia. He has some familiarity with French.

Ron Cull serves as project manager for the PV Systems Test Facility at LeRC. He was actively involved in the design and testing of both the Schuchuli and Tangaye PV systems. He hold s a B.S. and M.S. in E.E. and is currently working on his dissertation for a Ph.D. in E.E. He is a nationally recognized expert in the design of controls and instrumentation for PV systems. He has been with LeRC since 1966.

Gay Morgan, currently working for AID/UV under contract, will be offered a position with LeRC as an AID project manager in the D&S Project Office. Ms. Morgan has also served in the Peace Corps. For the past two years she has supported the training and monitoring efforts associated with the Tangaye PV system. She holds a B.S. degree in physics from the University of Colorado, is fluent in French and can communicate in several African languages.

ANNEX F

PROGRAM BUDGET

The PV Development and Support Project represents a five-year, $9.75 million activity involving a series of non-c ntry specific demonstration projects. Such projects are planned .or each of four application categories, (viz., health, education/communication, water pumping and food processing and preservation). A budget breakdown is given below for: 1) a typical demonstration project for a given application, 2) system replication costs including projected foreign exchange costs, 3) the $2.5 million authorization for FY 79/80, and 4) the planned authorization for FY 81.

E-1 - Typical PV Demonstration Budget Breakdown

The procurement strategy being used by NASA LeRC for each AID application category involves a "mass buy" approach wherein a so-called "standard PV system" design is developed and a number of replicate systems are fabricated, shipped and installed at predetermined sites in developing countries. Those costs associated with one-time design/engineering activities are viewed as non-recurring costs, while those associated with materials, labor, shipping and travel are recurring costs which must be borne for each demonstration project. Operations costs involving such activities as monitoring of system operation and reporting are considered separately. For purposes of illustration, cost estimates associated with the PV medical applications are presented below:

PRELIMINARY CONTRACT COST ACCOUNT ESTIMATES ASSOCIATED WITH DESIGN, DEVELOPMENT, DEPLOYMENT OF A FAMILY OF EXPERIMENTAL PV SYSTEMS (END OF 1980 DOLLARS)

Baseline System: Array = 1.8 kWp (28 C); 120 VDC Battery - 350 AH (42 kWhr)
Insolation: 390 langleys/day

1. Nonrecurring costs

1.0	Design (Labor)	
1.1	Engineering (1050 hrs @ $16-20/hr)	$18.0K
1.2	Drawings (1K/dwg X 8 dwg)	8.0
1.3	Failure Modes/Effects (200 hrs @ $16/hr)	3.2
1.4	Review (120 hrs @ $16/hr)	2.0
	Subtotal	$31.2

2.0	R&QA (Labor; 100 hrs @ $10/hr)	1.0K
3.0	Fabrication (Labor; 700 hrs @ $10/hr)	7.0
4.0	Proof of Design Testing (Labor; 160 hrs @ $10/hr)	1.6
5.0	Operation/Maintenance & Training Manuals (Labor; 2.3K/manual)	8.0
6.0	Contractor's Project Management (Labor; 250 hrs @ $25/hr)	6.0
7.0	Travel	4.0
	Subtotal	58.8
	Overhead (150% - 250%)	88.2 - 147
8.0	Materials (Cost + Overhead)	1.2
	Subtotal	148 - 207
	G&A (20%)	30 - 41.4
	Subtotal	178 - 248
	Contingency (10%)	18 - 25
	Profits (10% - exclusive of contingency	18 - 25
	Total Nonrecurring	214 - 298

II. Recurring Costs

1.0	Materials	
	1.0 Array Field	
	1.1.1 Modules; 11/Wp (28 C, including 5% spare) X 1.8 kWp	$20.8
	1.1.2 Frame, Support, Wiring, Signs, Fencing	4.0
	Subtotal	24.8
	1.2 Battery (5% Spare, $150/kWhr) X 42 kWh	6.6
	1.2.1 Battery Racks	0.4

1.3	Controls & Instrumentation (Hardward & Spares)		4.0K
1.4	Loads and Spares		4.0
1.5	Enclosures (Battery, Controls, etc.)		1.0
1.6	Electrical Distribution		1.0
1.7	Packaging		2.0
		Subtotal	43.8
1.8	Overhead (15%)		6.6
		Subtotal	50.4
2.0	Labor		
2.1	Assembly of Array (Factory)		1.4
2.2	Controls & Instrumentation (Factory)		2.0
2.3	R&QA/Acceptance Testing (Factory - Field; 150 hrs. @ $10/hr		1.5
2.4	Packaging		1.0
2.5	Field Installation & Checkout (Site Preparation, Array, Battery, Loads, Enclosure, Power Distribution; 1360 hrs @ $16/hr, $10/hr, $1/hr)		10.0
2.6	Site Specific Survey (40 hrs @ $16/hr)		1.6
2.7	Training (40 hrs @ $16/hr)		0.6
2.8	Contractor's Project Management (200 hrs @ $25/hr)		5.0
		Subtotal	22.1
	Overhead (150% - 250%)		33.5 - 55.3
		Subtotal	55.6 - 77.4
3.0	Shipping		
3.1	Array		1.2
3.2	Battery		1.3
3.3	Auxiliary Hardware		0.7
		Subtotal	3.2

	Overhead (15%)	0.5K
	Subtotal	3.7
4.0	Travel	
4.1	Site Specific Survey	1.4
4.2	Field Installation/Training	10.0
	Subtotal	11.4
	Overhead (15%)	1.7
	Subtotal	13.1
	Total (1 - 4)	123 - 145
	G&A (20%)	25 - 29
	Subtotal	148 - 174
	Contingency (10%)	15 - 17
	Profits (10% - exclusive of contingency)	15 - 17
	Total Recurring Cost	178 - 208
5.0	Operations	
5.1	Monitoring/Reporting (320 hrs @ $16/hr)	5.0
5.2	Service (320 hrs @ $10/hr)	4.0
5.3	Contractor's Project Management (64 hrs @ $25/hr)	1.5
5.4	Travel	11.0
	Subtotal	21.5
	Overhead (100%)	21.5
	Subtotal	43.0
	G&A (20%)	8.6
	Subtotal	51.6
	Contingency (10%)	5.2
	Profit (10% - exclusive of contingency)	5.2
	TOTAL	$62.0

III. Total System Cost

A.	Nonrecurring Cost (Independent of number of systems)	214 - 298
C.	Recurring Cost (For each system)	178 - 208
C.	Total System Cost	$392 - 506
D.	Operations	$62 K

E-2 - System Replication Costs

Once a design has been established and verified as being suitable for a given application, replication is expected to follow. For such replications, the costs can be divided into foreign exchange (U.S supplied goods and services) and local costs (indigenous labor and materials). PV modules, electronic peripherals and, at least initially, battery storage would fall in the former category, while structure, wiring, site preparation and maintenance and service would represent local costs. Since developing country officials are quite concerned about total dependency on outside sources of energy (whether conventional or alternative renewable types), the use of local labor and materials will be encouraged so as to minimize foreign exchange costs.

The estimated replication costs for PV medical systems assuming today's PV module cost, are given below in terms of foreign exchange (FX) costs and local costs (LC):

FX	
PV Array ($11/Wp X 1800 Wp)	$20k
Balance of System (battery/electronics	17
Packaging	2
Overhead	6
Shipping	4
FX Subtotal	$49K
LC	
Frames & Supports	$ 4K
Site Survey	2
Installation/Checkout	10
Assembly	6
LC Subtotal	22
Total	$71K

Foreign exchange costs projected for the near future (i.e., by mid-1980's) when PV module prices are projected to drop to less than $3/Wp, are as follows:

FX

PV Array ($3/Wp X 1800 Wp)	$ 5.4K
Other	29
FX Subtotal	$34.4K

Assuming local manufacture of electronic components, battery storage and construction materials, well within the capability of many developing countries, FX costs could decrease further as follows:

FX

PV Array	$ 5.4K
Packaging	2.0
Overhead	2.2
Shipping	2.0
TOTAL	$11.6K

Hence, while first costs are relatively high for PV demonstration projects, future costs are projected to decrease significantly due to lower PV module costs (through increased production and technology development) and lower foreign exchange costs (as the host countries begin to assume more of the non-PV related costs, i.e., through the use of indigenous labor and materials).

E-3 - FY 79/80 PVDSP Authorization

Total commitments (actual and projected) relative to the PVDSP for the period September 1, 1979 to March 31, 1981 are given below:

ACTIVITY		TOTAL COMMITMENTS
Project Management (In-house)		$ 590K
Manpower	500	
Travel	75	
DCAS (Cont. Administration)	15	
Planning and Studies (Contracts)		62
Medical Survey	12	
Education/Comm. Definition Study	50	
Field Test Support (Contracts)		93
Catalog of Medical Equipment	43	
Load Test & Evaluation	50	

Medical Applications		1,600
Medical Systems for 5 Rural Clinics	1,450	
Medical Refrigerators	150	
Training and Information		50
Other		105
Management Support (Contract)	75	
Upper Volta (In-house)	30	
TOTAL		$2,500K

E-4 - Plans for FY 81

An estimate for the PVDSP budget breakdown for FY 81 is given below assuming funding levels of $1M and $2M. As indicated the bulk of the funding has been allocated for education/communication application projects.

ACTIVITY	$1M (FY 81)	$2M (FY 81)
Project Management		
Manpower 6 X 50K	$ 300K	$ 300K
Travel	30	
Planning & Studies		
Next Appl. Category	0	100
Field Test Support	0	50
Applications		
PV Medical-Add Zaire	150	150
Communication Satellites*	200	400
Education Applications	(1) 250	(3) 750
Training & Information	70	200
TOTAL	$1,000	$2,000

*Support of AID DS/EY Rural Satellite Project(s)

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ANNEX G

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(3) Ratajczak, A. F. and Bifano, W. J., Description of Photovoltaic Village Power System in the United States and Africa, April 1979. NASA: TM-79149.

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(5) Two-Way Radio Communications for Primary Health Services, Academy for Educational Development, July 1980.

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