AOP-97

AOP97

Annual Operating Plan Fiscal Year 1997

October 1996

U. S. Department of Energy
Solar Thermal Electric Program

SOLAR•THERMAL•ENERGY

Sun•Lab

Sandia National Laboratories, Albuquerque, NM
National Renewable Energy Laboratory, Golden, CO
Operated for the United States Department of Energy

FOREWORD

FY96 was a year of both major progress and some disappointments for the Solar Thermal Electric Program. On the power tower front, the construction of Solar Two was completed, startup was initiated, and the plant was dedicated in a major ceremony on June 5, 1996. While all major systems have been operated successfully and to nearly their design capabilities (including simultaneous solar energy collection, storage charging, and power generation), significant flaws in the installation of heat-trace components caused a receiver failure and an extended shut-down of the plant for reinstallation of the heat tracing during the last three months of FY96. Receiver and storage performance was excellent, however, and the failure allowed a successful demonstration of receiver tube replacement techniques. In the dish/Stirling area, Cummins Power Generation, Inc. completed the successful development and testing of its Utility-Scale Joint Venture Program (USJVP) Phase 1 25-kW dish/Stirling system (including a new, state-of-the-art 100-kW parabolic dish). Unfortunately, because of a Cummins corporate decision to refocus activities on its core diesel engine business, Cummins terminated its program late in the year. Science Applications International Corporation (SAIC) initiated Phase 2 of its USJVP effort, but progress was delayed while issues of cost share by SAIC were resolved. SAIC's engine supplier, Stirling Thermal Motors, did, however, make major progress on its Stirling engine, the STM 4-120 Generation III, increasing efficiency and extending operational time dramatically. In an important development, General Motors announced the selection of the STM engine for use in its hybrid vehicle development program, increasing support for engine development and opportunities for cost reduction. Three activities continued in the Solar Manufacturing Initiative: a major cost-shared heliostat fabrication and testing effort with SAIC, a central receiver contract with the Rocketdyne Division of Boeing North American (formerly Rockwell International Corporation) to build and test an advanced molten salt receiver panel, and a dish manufacturing development effort with McDonnell Douglas. Technology development progressed as testing identified a new material for molten salt receiver tubes, preliminary testing of an all-polymeric solar reflector yielded promising performance, and progress was made in the performance of reflux receivers for dish/Stirling systems. Finally, we continued our efforts in laboratory cooperation with the successful operation of Sun•Lab, the cooperative "virtual laboratory" arrangement between Sandia National Laboratories and the National Renewable Energy Laboratory that has totally changed the way the laboratories share programs and work together.

We expect major progress in FY97 as Solar Two begins its Test and Evaluation Phase, as SAIC fields the first of several Phase 2 25-kW systems at utility sites, and as several SAIC advanced heliostats are fabricated and deployed for testing. FY97 will also see us complete strategic and five-year program planning processes with our industry partners to chart the course for solar thermal progress into the next century. We look forward to an exciting year.

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INTRODUCTION

Solar thermal electric (STE) technologies — parabolic troughs, power towers, and dish/engine systems — convert sunlight into electricity efficiently and with minimum effect on the environment. These technologies generate high temperatures by using mirrors to concentrate the sun's energy up to 5000 times its normal intensity. This heat is then used to generate electricity for a variety of market applications, ranging from remote power needs as small as a few kilowatts up to grid-connected applications of 200 MW or more. STE can begin providing energy, as well as economic and environmental security, for us today. In the long term, these technologies will compete broadly in U.S. and international markets for electric power production.

Solar thermal electricity is the least costly solar electricity for grid-connected applications available today, and it has the potential for further, significant cost reductions. While not currently competitive for utility applications in the United States, the cost of electricity from STE can be competitive in international and domestic niche applications, where the price of energy is higher. Our goal for advanced STE technologies is costs below 5¢/kWh. At these costs, our vision for the future, 20 GW of installed STE capacity by the year 2020, is achievable.

OUR VISION

Our vision for success of the Solar Thermal Electric Program is world leadership by U.S. industry in supplying 20 GW of solar thermal electric power by 2020.

OUR MISSION

Our mission within the Department of Energy's (DOE's) Solar Thermal Electric Program is to help provide for the energy, economic, and environmental security of the United States. We will fulfill our mission through research, development, demonstration, technical support, and economic and policy analyses to help U.S. industry deploy solar thermal technologies in global, renewable energy markets.

OUR OBJECTIVES

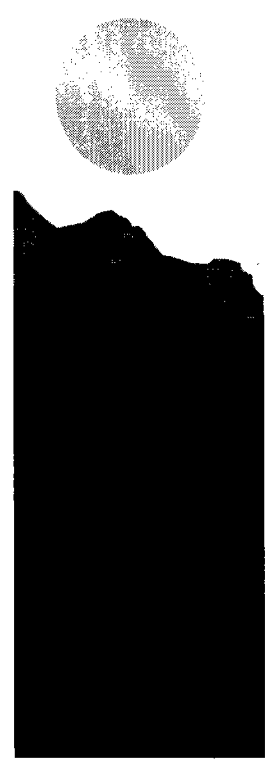
Our objectives for the Solar Thermal Electric Program are to

- Help industry bring STE technologies to near-term markets; and
- Provide the technical advances needed by industry for expansion into future markets.

OUR STRATEGIES

Our strategies for achieving these objectives, listed in descending order of importance, are to

- Support the next commercial opportunities for STE technologies;
- Demonstrate improved performance and reliability of STE components and systems;
- Reduce STE energy costs;
- Develop advanced STE systems and applications; and
- Address nontechnical barriers and champion STE power.



OUR STRUCTURE

The Solar Thermal Electric Program is structured to provide a balance of activities to exploit near-term commercialization opportunities, meet long-range performance and cost goals, and maintain a forward-looking research thrust to open new opportunities.

Program activities include the following:

- **I. Commercial Applications**
  - A. Solar Two
  - B. Dish/Engine Joint Venture Projects
  - C. Parabolic Trough Projects
  - D. SolMaT
  - E. Industry Assistance
  - F. Systems and Markets Analysis
  - G. Communications
- **II. Technology Development**
  - A. Optical Materials
  - B. Concentrator Technology
  - C. Power Tower Technology
  - D. Dish Conversion Technology
  - E. Long-Term Research and Development
  - F. Facilities Support

Management and reporting functions are detailed later in the Management and Implementation Plan.

PERFORMANCE MEASURES FOR FY97

We expect major progress in FY97 as Solar Two begins its Test and Evaluation Phase, as SAIC fields the first of several Phase 2 25-kW systems at utility sites, and as several SAIC advanced heliostats are fabricated and deployed for testing. FY97 will also see us complete strategic and five-year program planning processes with our industry partners to chart the course for solar thermal progress into the next century. We look forward to an exciting year.

As stewards of public resources and to meet the performance and quality objectives of the DOE's Office of Utility Technologies, we make the following commitments for FY97, consistent with our programmatic vision, mission, and operational strategies.

Our Commitments

Deploy four 25-kW dish/engine systems at utility and user sites in the U.S. Southwest in order to validate design and performance

We will demonstrate preproduction prototypes of SAIC's 25-kW dish/engine systems for utility applications. Commercial units will be available by 1999.

Our FY97 measures of success will be to

- Design, fabricate, and extensively test an SAIC 25-kW preproduction prototype dish/engine system.
- Install and operate three additional systems at a utility site.

Achieve full-rated 10 MW of power output at Solar Two power tower in California and demonstrate three hours of operation after sunset

We are committed to demonstrating the commercial viability of power tower systems by the successful startup of Solar Two, operating the plant over a two-year test and evaluation period, and commercializing molten salt technology by the end of the decade.

Our FY97 measures of success will be to

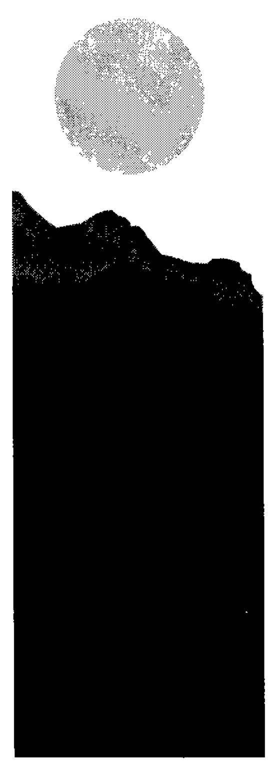
- Complete acceptance testing and begin operation of Solar Two.
- Demonstrate power production capability at 10 MW, while "charging" the molten salt for delayed generation.
- Demonstrate the dispatchable capability of molten salt by producing power for up to three hours after the sun goes down.

Construct and deploy two SolMaT Phase 2 (manufacturing evaluation) heliostats for on-sun testing

We will fabricate and test at least two faceted, stretched-membrane heliostats. These heliostats are designed to help overcome the hurdle of high costs for low production rates in early commercial applications. This type of unit will be available by 1998 to support development of the first commercial power tower.

Our FY97 measures of success will be to

- Build and test two units at the SAIC site in Golden, Colorado, and the National Solar Thermal Test Facility. (Demonstrate two additional units at Solar Two by FY98.)

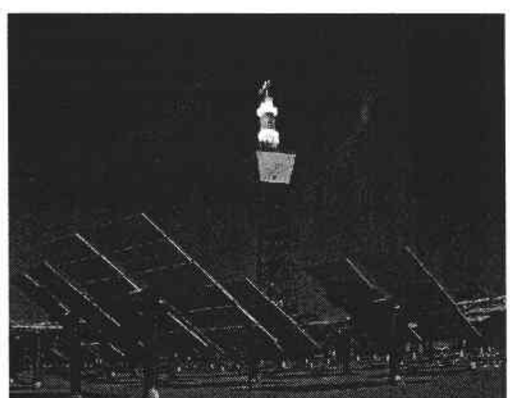


I. COMMERCIAL APPLICATIONS

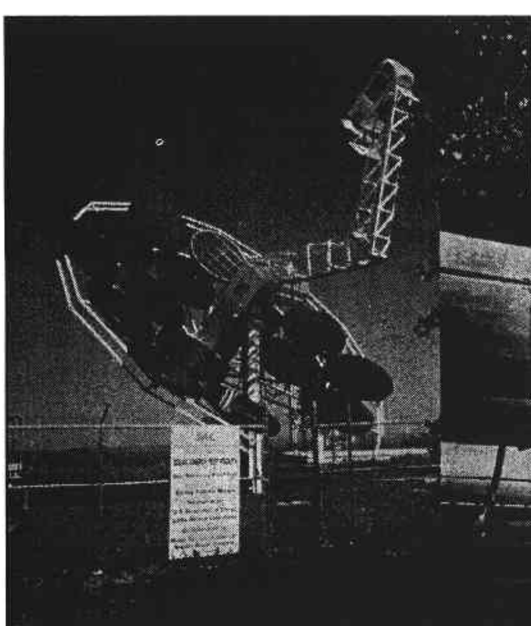
The Solar Thermal Electric Program emphasizes the development of two major categories of solar thermal technology: power towers (central receiver systems) and parabolic dish/engine systems. These two types of systems are capable of meeting the needs of the utilities for peaking and remote power applications and, eventually, for base-load capacity in the power range of a few kilowatts to hundreds of megawatts. We also support the most mature STE technology, parabolic trough systems, through the development of advanced components, systems analysis, and research and development to help reduce operation and maintenance costs of these plants.

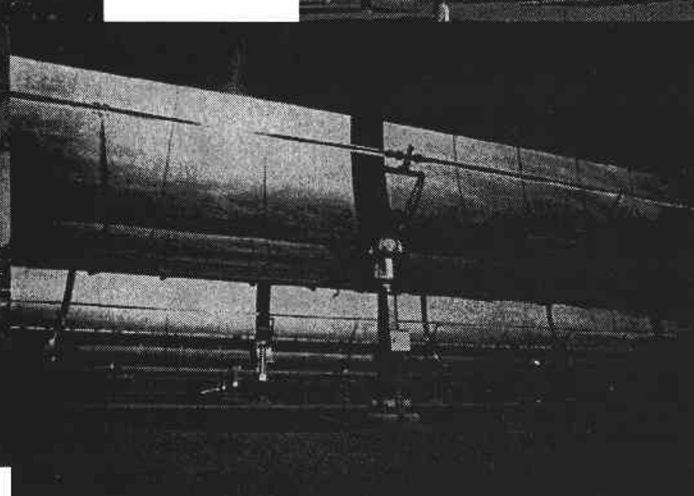
The program uses the model of DOE/industry cost-shared activities, which rely heavily on industry input to determine the program direction. These government/industry/national laboratory partnerships develop teams that are uniquely qualified to evaluate the status of development issues and to advance the technology. The partnerships combine the manufacturing, marketing, and management skills of industry with the unique capabilities of Sun•Lab, that is, the solar-specific experience base, modeling and analysis skills, experimental capabilities, and manufacturing background. Within the scope of this year's Annual Operating Plan, we will have up to eight major cost-shared, cooperative activities under way for a total value of more than $120 million. The following organizations are the private sector participants in these joint activities:

- Southern California Edison and a consortium of other utilities and industry partners (Solar Two).
- Science Applications International Corporation (dish/engine systems).
- KJC Operating Company (trough system operation and maintenance cost reduction).
- Science Applications International Corporation, Rocketdyne, and McDonnell Douglas (solar manufacturing initiative).
- A new dish/engine activity with at least one new participant.



Our Vision: large-scale solar thermal power plants





A. SOLAR TWO

Objective

The primary objective of the Solar Two Project is to validate molten-salt solar power tower technology for utility power generation to reduce technical and economic risk associated with the first commercial plants.

Rationale

One half of a million megawatts of new generating capacity will be installed worldwide in the next ten years. In the desert regions of India alone, 10,000 megawatts are needed. American companies are very interested in providing molten-salt power tower technology to meet some of these needs.

In the longer term, domestic utilities, utility commissions, governments, users, and investors want clean, renewable energy sources that can provide centralized electrical power in the western United States. Molten-salt power tower technology can provide this power usefully and cost-effectively by virtue of its capability to store thermal energy and meet peak electricity demands.

The technical feasibility of power towers has been proven. Their cost, performance, and reliability can be predicted. However, large-scale validation of the technology is still needed to overcome the perceived risk associated with the large capital investment required for construction of solar power plants.

The large-scale validation of power tower technology is being accomplished by the Solar Two Project. Solar Two is a utility/industry-led, cost-shared project to retrofit the 10-MW_e Solar One Pilot Plant with a molten-salt heat-transfer system. In 1995, the Solar Two Project replaced the Solar One water/steam receiver and oil/rock thermal storage systems with a nitrate-salt receiver, salt storage system, and steam generator. The plant went on-line for the first time in April 1996. Power production and testing is scheduled for FY97.

The cost of Solar Two ($50 million) is being shared by a consortium of utilities, industries, agencies, and the DOE. The participants and contributors include the following: *Participants:* Arizona Public Service Company, Bechtel Corporation, California Energy Commission, Electric Power Research Institute, Idaho Power Company, Los Angeles Department of Water and Power, PacifiCorp, Sacramento Municipal Utility District, Salt River Project, Southern California Edison (project manager); *Contributors:* Chilean Nitrate Corporation (New York), Nevada Power Corporation, and South Coast Air Quality Management District.

Sun•Lab efforts are needed to ensure the success of Solar Two. In FY97, Sun•Lab will continue to provide technical support to the project by (1) transferring DOE-developed solar energy technology and expertise, (2) assisting with test and evaluation to help the project meet its technical objectives, and (3) supporting project documentation efforts to guarantee that lessons learned from Solar Two will be available for future builders and operators of solar power tower plants.

FY96 Accomplishments

For Solar Two, FY96 can be characterized as a period of great success and troublesome failures. In April, the plant produced megawatts of electricity for the Southern California Edison grid for the first time. April also marked the plant's first instance of simultaneous solar energy collection, electricity production, and charging of thermal storage. Subsequently, the plant was formally dedicated on June 5. These events proved that the technology is feasible and that such plants can be operated smoothly.

Shortly after the dedication, a tube on the Solar Two receiver ruptured during operation. The rupture was caused by lack of salt flow through the tube resulting from an obstruction at the tube's intake. A careful investigation revealed that flakes of corrosion scale from the salt piping had accumulated in the receiver, restricting flow to the tubes. The excessive pipe corrosion was caused by inadequacies in the heat tracing. The problem was solved over a period of several months by redesigning and replacing essentially all of the heat trace. By the end of FY96, the startup team was gearing up to bring the plant back on-line. By this time, however, the project had experienced a major delay. Final acceptance of the plant is now anticipated in the second quarter of FY97.

FY97 Task Description

In FY97, Solar Two activities will focus on completing startup and acceptance, followed by testing and power production. Upon completion of acceptance testing, the plant will be turned over to the operation and maintenance (O&M) contractor, Energy Services, Inc., which will be responsible for implementing the Test and Evaluation (T&E) and Power Production phases of the project.

In support of these activities, Sun•Lab will be responsible for four primary tasks:

- coordinating Sun•Lab activities and on-site support
- providing T&E support
- providing technical support
- assisting with lessons-learned documentation

Task 1 – Coordination and On-Site Support

Managing Sun•Lab support in the diverse environment at Solar Two requires that we locate one staff member at the Solar Two site to provide full-time coordination of site-related activities. This individual will coordinate Sun•Lab visits to the site, help manage Sun•Lab interactions with the project team, and keep DOE current on all aspects of plant status.

Task 1 also includes in-house program management and chairing the Solar Two Technical Advisory Committee (TAC). The TAC will support the project by (1) holding quarterly meetings to review important technical issues and (2) reviewing T&E results, reports, and conclusions.

Task 2 – T&E Support

Because of the delay caused by heat-trace problems, it became necessary to restructure the T&E Plan. The new T&E Plan includes two phases:

- *Baseline Test* – a month-long period following final plant acceptance that will be used to test the plant under conditions outside of the window of normal operation. This period will be used to characterize the steam generator and electric power production systems, measure receiver efficiency, and characterize the response of the automatic control system to simulated cloud transients.
- *Power Production* – This period will be used to perform the remaining tests described in the Solar Two T&E Plan. These tests will be performed after the Baseline Test while the plant is used for routine power production. This period of simultaneous testing and power production is expected to require most of FY97 and proceed throughout FY98. During power production testing, the on-site test engineer will download data from the plant and transfer them to Sun•Lab engineers for evaluation. These engineers will make formal reports and recommendations to the project on the basis of their test results and analyses.

The T&E Plan includes four high-level evaluations in addition to the Baseline and Power Production Tests. These evaluations are designed to combine information derived from both the tests and the O&M contractor to (1) evaluate overall plant performance in comparison to prediction; (2) track maintainability, availability, and forced outages; (3) monitor and evaluate controllability and operability; and (4) monitor equipment lifetime issues. Sun•Lab will lead and perform these evaluations.

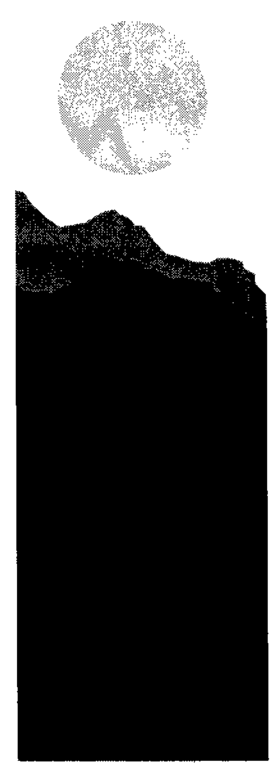
Sun•Lab will support the Baseline Test and Power Production testing by providing the following:

- test engineers to design each test, analyze test data, and report on test results
- engineers to lead and perform the evaluations
- data acquisition system support
- a full-time site test engineer

Task 3 – Technical Support

This task includes the *ad hoc* technical support that Sun•Lab will provide to assist with plant startup, checkout, testing, and operation. Sun•Lab will provide guidance on salt systems, salt chemistry, heliostats, safety, central receiver control systems, heat tracing, solar power plant modeling, and so forth.

In addition to the tasks specified above, Sun•Lab will continue to work with the DOE and industry to advance the commercialization of power tower technology. We will participate on the Solar Two Steering Committee as a nonvoting member and will contribute as members of the Commercial



Advisory Board, a group dedicated to identifying market entry opportunities for solar power tower technology.

Task 4 – Documentation

Sun•Lab will implement a small documentation activity to ensure that lessons learned from Solar Two are adequately recorded for use in future molten-salt power tower projects. A Sun•Lab engineer will interview individuals who have had and/or continue to have important roles in the project. These interviews will be recorded along with other lessons-learned documentation. Information from design, construction, and startup will be captured in FY97.

Direct Support

In addition to technical support provided by Sun•Lab, the DOE Golden Field Office will provide direct support to the Solar Two Project, which is based on a 50:50 cost share ratio between government and industry.

Major Milestones

Expected Completion	Milestone Description
May 97	Plant acceptance; initiate operations.
Jun 97	Complete baseline test/start power production.

Resources ($k)

	Sandia	NREL	DOE	Total
FTE Costs	991	210	0	**1,201**
Contracts	350	15	2,300	**2,665**
Total	**1,341**	**225**	**2,300**	**3,866**

B. DISH/ENGINE JOINT VENTURE PROJECTS

Objective

The objective of this task is to support the solar thermal industry in developing dish/engine power generation systems for remote power and utility-scale markets. The near-term objective is to build, field, and operate prototype dish/engine systems to establish performance, reliability, and cost databases.

Rationale

Solar thermal electric power systems that are based on a parabolic dish and a focal-point-mounted heat engine/generator can be economically competitive in remote, export markets by the end of the decade. Through heavy cost sharing and technical support, the DOE program offers industry the opportunity to develop the technology and enter these markets more quickly by reducing the risks.

FY96 Accomplishments

On June 28, 1996, Cummins Engine Company (CEC) announced the closure of its solar research division in Abilene, Texas. CEC, a leading worldwide designer and producer of diesel engines, indicated the decision was based on its desire to better align its resources with its core business. In late September, the assets of the CEC solar operations in Abilene, Texas, were sold to Kombassan, a Turkish holding company. Kombassan intends to ship the equipment back to Alanya, Turkey, and to commercialize the technology there.

The SAIC and Stirling Thermal Motors (STM) USJVP started again on October 21. The project had been delayed since April 30, 1996, pending the SAIC/STM team establishing the required cost share for Phase 2 of the project.

FY97 Task Description

Sandia has initiated closeout of the Dish/Stirling Joint Venture and the Utility-Scale Joint Venture contracts with the CEC. Contractual termination is by bilateral agreement. CEC has apologized to Sandia and the DOE for the discourteous way in which the closure of the contracts was initially handled. The sale of assets by CEC to a foreign company appears to be legal and not a violation of the contracts. However, it is not clear that the technology rights have been sold, as CEC's subcontractors are trying to make arrangements for future development of the dish design, the heat-pipe receiver, and the free-piston engine.

The Phase 2 objectives of the USJVP Project with the SAIC/STM team are to deploy five dish/Stirling systems for operation at utility sites. In continuing with the project, SAIC has committed to build two systems for test and evaluation immediately and the remaining three as sales are made. SAIC is currently completing negotiations with Nevada Power and Arizona Public Service for three systems, which together with two systems that SAIC has agreed to build for itself meet the Phase 2 objectives. In addition, SAIC has identified opportunities for sales to the California Energy Commission and is discussing terms with other potential users, although it is concerned about locating developmental systems at sites far removed from maintenance support.

During FY97, Sun•Lab will issue a request for quotation (RFQ) for a new dish/engine development activity. Similar to the previous joint-venture programs, this activity will have as its objective the commercialization of a dish/engine system. However, the new project, which is called the Dish/Engine Critical Components (DEC^2) Project, will differ from previous programs in that Phase 1 will focus on establishing the performance of the power conversion system, the engine, and the receiver before proceeding to integrate them into a complete system in Phase 2. In addition, the procurement will allow for power systems other than Stirling engines, will require substantial cost sharing, and will include technical support from Sun•Lab.

Major Milestones

Expected Completion	Milestone Description
Dec 96	Complete closeout of the CEC contracts.
Dec 96	Release the DEC^2 RFQ.
Jan 97	Fix concentrator geometry and structural setup. (SAIC)
Mar 97	Place contract(s) for the DEC^2 RFQ.
May 97	Complete financing package to build five systems in Phase 2 of the USJVP Project. (SAIC)
Aug 97	First Phase 2 system operational at SAIC test site.

Resources ($k)

	Sandia	NREL	DOE	Total
FTE Costs	333	39	0	**372**
Contracts	3,192	0	0	**3,192**
Total	**3,525**	**39**	**0**	**3,564**

C. PARABOLIC TROUGH PROJECTS

Objective

The objective of this task is to perform research and development to improve state-of-the-art trough technology and, if appropriate, provide assistance in developing new trough plant projects proposed within the United States and abroad.

Rationale

With 354 MW of parabolic trough power plants currently operating in Southern California, parabolic troughs represent the most mature solar thermal technology. In this task, ways to improve state-of-the-art trough technology will be identified and, if appropriate, assistance will be provided to develop new trough plant projects proposed within the United States and abroad. The state of the art is being advanced by developing new system components and reducing O&M costs. Most of the improvements in O&M are also applicable to solar power towers and large dish/Stirling power plants. Assistance to develop new power plant projects involves consulting and technology transfer activities. Assistance is given to proposed projects that may develop into significant business opportunities for U.S. industry.

FY96 Accomplishments

We developed a new selective surface that coats the receiver tubes. Initial results indicate the emissivity of the new cermet-type coating is about 40% lower than previously available coatings. This advancement significantly reduces heat losses in the solar field and is expected to lower electricity costs from trough plants by 4%.

We tested a new mirror washing apparatus. A rotating head sprays high pressure water on the mirrors. Initial results suggest that this new technique cleans the mirrors with nearly the same effectiveness as if they were scrub cleaned.

We completed a comprehensive test of wind forces on mirror panels in the solar field and of solar field wind protection scenarios. This data will allow optimization of solar operation in high winds, resulting in higher performance than previously anticipated.

An on-line performance monitoring system was installed at two of the trough plants located at Kramer Junction, California. The system allows on-line monitoring of plant heat rates and other detailed system information and provides a "what if" function that permits operators to test the effects of operating strategies prior to implementation.

We helped the World Bank develop a request for proposal (RFP) to build an Integrated Solar Combined-Cycle System (ISCCS) in Rajasthan, India. We traveled to India to work with the Indian authorities and financiers associated with this 35-MW_e trough project.

FY97 Task Description

Systems Analysis

We will perform a systems analysis that identifies the factors that are most important in reducing levelized energy costs for parabolic trough plants. This analysis will help guide future research and development activities.

Strengthened Glass Mirrors

We will develop and test a strengthened mirror panel to survive high wind incidents. Placed at the edges of the solar field, these stronger panels will significantly reduce mirror breakage and subsequent damage to other equipment caused by flying debris. We will perform in-field durability testing of the strengthened panel and will compare the panel with panels of conventional design. We will track, evaluate, and report on frequency and mechanism of failures, coincident wind conditions, and other relevant factors. Finally, we will estimate the cost/benefit ratio of strengthened mirrors compared to conventional designs.

Improved Mirror Washing Techniques

We will conduct extended performance testing on the new rotary hydroblaster mirror washing system that was identified in FY96. We will track, evaluate, and report on cleaning effectiveness, labor savings, maintenance requirements, and overall cost effectiveness compared to previous mirror washing techniques.

New Nonevacuated Receiver Tubes

The new cermet coating developed in FY96 has such a low emissivity that it may be possible to develop a receiver tube, also called a heat-collection element (HCE), that exhibits excellent performance without

necessitating a vacuum within the surrounding glass annulus. If this can be accomplished, the cost of the HCE will be cut in half. During FY97, we will build several nonevacuated HCEs and carry out extended evaluation of them compared to the previous, more expensive, evacuated design. We will track, evaluate, and report on failure modes and durability of new selective surfaces within a nonevacuated environment.

International Opportunities for Parabolic Troughs

There are two RFPs that will be issued in early 1997 by Mexico's Federal Electric Commission for constructing combined-cycle power plants near the cities of Chihuahua and Monterrey, Mexico. The objective of this task is to help potential bidders from the United States prepare an option package that includes an ISCCS based on parabolic trough technology. Success of an ISCCS project is plausible, contingent upon the availability of a $50 million grant from the World Bank's Global Environment Facility, which could be available to a project that includes an ISCCS option package.

An RFP will be issued in FY97 calling for the construction of an ISCCS in Rajasthan, India. We will help the World Bank review the technical merits of the project proposals.

Major Milestones

Expected Completion	Milestone Description
Sep 97	Document accomplishments of O&M Cost Reduction Program.
Sep 97	Complete final report on Mexican ISCCS effort.

Resources ($k)

	Sandia	NREL	DOE	Total
FTE Costs	50	40	0	**90**
Contracts	0	0	0	**0**
Total	**50**	**40**	**0**	**90**

D. SOLMAT

Objective

The objective of the SolMaT task is to develop manufacturing processes that will allow the early sales necessary for commercial demonstration of the technology and the creation of a viable U.S. STE industry.

Rationale

Solar Thermal Electric Program objectives have always been oriented toward developing technologies that could produce reliable, cost-competitive electricity with minimal environmental impacts. The program has focused primarily on technologies that could be successful in high-volume applications because high volumes imply large-market impacts and low manufacturing costs. This strategy does not address how these technologies would enter the market or lead to high-volume production. Successful early-market deployment requires that both cost goals and technical goals be met. SolMaT addresses the need for cost-effective production of solar thermal components in the near term to allow early deployments leading to large-scale production.

The SolMaT initiative addresses these issues by developing manufacturing technology and processes that enable cost-effective deployments of solar thermal systems in low-volume, early commercial applications; establishing the manufacturing basis to allow cost-effective early sales and substantially reduced costs so that higher volume sales can be achieved; reducing uncertainty in the cost and reliability of key solar components to improve financing of early commercial systems and to reduce risk of performance warranties; and promoting the development of business plans and industrial partnerships linking manufacturing scenarios to commercial sales prospects.

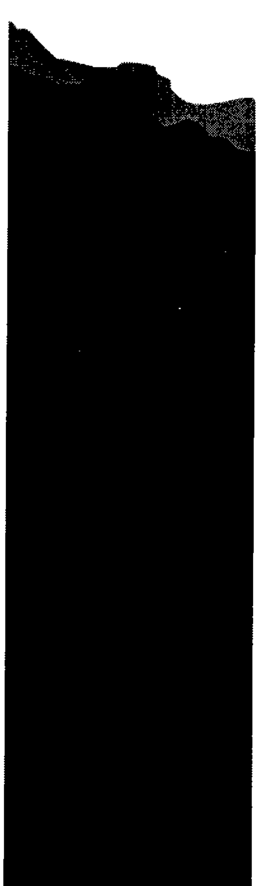
FY96 Accomplishments

In FY95, we placed three subcontracts with the primary objective of reducing the cost of near-term deployments of STE technologies. In FY96, we began to see benefits from those efforts. Phase 1 of each of these three subcontracts was completed and a fourth SolMaT effort was started. In addition to those subcontracted efforts, we continued to offer Design for Manufacturing and Assembly (DFMA) workshops to industry as a means for optimizing system and component designs for minimum cost.

During FY96, SAIC and Solar Kinetics, Inc. (SKI) developed manufacturing technologies for heliostats. Rocketdyne investigated several manufacturing and operational improvements for molten-salt central receivers. McDonnell Douglas Aerospace (MDA) started a project aimed at improving the manufacturability of dish concentrators.

SAIC completed Phase 1 of its Heliostat Manufacturing Project. Starting with its dual-module heliostat as a baseline, SAIC investigated several design modifications that could lead to significant cost reductions. The major modifications are (1) the use of 22 facets of 3-m-diameter (which amounts to a 160 m^2 total system reflective area and allows commonality with the SAIC dish/Stirling facet production and centralized facet manufacturing); (2) a low-cost facet design with a single, carbon-steel membrane and larger glass lites; and (3) alternative drive options. Detailed investigations of the structure, pedestal, foundation, and controls were also conducted. Manufacturing lines for the facets and structure were considered in detail to optimize the tooling and facility requirements for the low-volume production rates expected for near-term markets. Based on these considerations, SAIC estimates a heliostat price of \$113/m^2 (1995 dollars) for a production run of 2000 units per year. This represents a reduction of about 40% relative to the baseline dual-module heliostat. Significantly, this heliostat price is consistent with the near-term market requirements estimated by Bechtel Corporation for SAIC during the Phase 1 project. Also during FY96, SAIC began Phase 2 of its SolMaT project. In this phase, SAIC will build, install, and operate four heliostats to validate the manufacturing cost reductions developed in Phase 1. In addition to work on the four heliostats, SAIC will continue to work with its SolMaT partners, Bechtel and Rocketdyne, to develop power tower markets, business plans and arrangements, and to further develop the technology, especially in the area of drives and structures.

SKI also completed Phase 1 of its SolMaT Heliostat Manufacturing Project. Starting from the Advanced Thermal Systems (ATS) 150-m^2 heliostat, and working with its partners, ATS, Pilkington Glass, Spencer Management Associates, and Peerless-Winsmith, the following modifications were investigated and deemed worthy of incorporating into the ATS design: substitution of 4-mm single-glass mirror for glass laminate, use of less adhesive on supporting hat sections, use of nonthreaded connections on the back of the structural hat sections, elimination of the torque tube flange, elimination of pedestal taper, updates to the control technology, and making all braces the same length. SKI estimated that a *single build* of 1000 of these heliostats can be installed at a price of $\$161/m^2$ (1995 dollars). This can be compared with a price of $\$164/m^2$ (1995 dollars) for the original ATS design, which was estimated at a production rate of 2500 *per year*. This is an exceptional accomplishment because for a continuous build, it would likely translate to heliostat costs below $\$100/m^2$. Unfortunately, SKI determined that it would not be able to continue with a Phase 2 validation effort because of problems with cost share requirements for that phase and a perception that a payback in its investment would be several years away.



Rocketdyne completed Phase 1 of its SolMaT Component Manufacturing Project during FY96. The Rocketdyne project was aimed at reducing manufacturing costs associated with and improving reliability of a molten-salt central receiver. These tasks investigated headers, tube nozzles, nozzle-tube interfaces, insulation, and instrumentation and control. Rocketdyne based its work on lessons learned during design, fabrication, and operation of the Solar Two receiver and its desire to explore improvements. Results were measured in terms of cost reductions and improved availability that would accrue as a result of using the improvements over the Solar Two manufacturing methods and instrumentation. A 170-MW_e hybrid plant was used as the baseline for comparisons. Receiver manufacturing improvements would save approximately $1.3 million in capital cost. Operation and maintenance costs would be reduced by about $240,000 per year because of a more reliable control system and instrumentation. Improved plant availability of about 3% would also result from improved instrumentation. These cost reductions and improvements reduce the levelized energy cost from the solar portion of the plant by 4.4%. This is an impressive accomplishment considering that the receiver comprises less than 14% of the direct capital cost for the solar portion of the plant. In early FY97, Rocketdyne started a Phase 2 effort that will include fabrication of a complete receiver panel and installation at Solar Two. This effort is aimed at validating the Phase 1 results, giving confidence in projected receiver manufacturing and operating costs.

During FY96, a fourth SolMaT subcontract was placed. MDA began the first phase of a project aimed at reducing the cost of manufacturing dish/engine concentrators. MDA is assessing the feasibility of using composite materials in the structure of the concentrator, the facet support, and the attachment between the facet and the concentrator. Although material costs are significantly higher for the composite materials than for steel or other common structural materials, MDA believes that significant fabrication and installation cost reductions will more than offset that material cost penalty. In the first phase of the project, MDA will hand-build several of these components to better assess the manufacturing methods and costs of the items. MDA is scheduled to complete the work in mid-FY97 and, if successful, will likely propose a second phase in which a complete concentrator would be built for further validation and testing.

Four DFMA workshops were supported by SolMaT for industry partners during FY96. These included three at Cummins Power Generation, Inc. that focused on (1) Cummins' concentrator, mirror modules, and support structure; (2) the hardware that attaches the mirror assembly to its concentrator frame; and (3) on the structural element that attaches the radial trusses to the ring beam of the concentrator. The fourth workshop, attended by representatives from most solar industry partners involved with concentrator or heliostat manufacturing, was held at Peerless-Winsmith. That workshop focused not only on cost reductions for the existing Peerless-Winsmith drives but also on developing a drive specification acceptable by all current major concentrator manufacturers as a standard. The theme of DFMA workshops is a multi-disciplined design review aimed at meeting customer requirements with optimum product manufacturability and minimum cost. This approach gives our industry partners an opportunity to focus on their designs in a new way that often results in significant cost reductions, increased reliability, and improved customer acceptance.

FY97 Task Description

In FY97, we will continue a number of activities, including (1) screening studies to identify the most important manufacturing barriers impacting early commercial sales, (2) manufacturing studies of prototype components to develop and optimize the key processes for low-volume solar component manufacturing, (3) developing and demonstrating special manufacturing processes and tooling, and (4) scaling up existing prototype-level manufacturing approaches by exploiting significant deployment opportunities. These activities will be carried out primarily through cost-shared subcontracts to industry partners with consultation provided by manufacturing experts from the national laboratories. Activities are aimed solely at solar technologies ready to be commercialized, and subcontracts are awarded based on the strengths of the industrial team, the likely impacts on commercial sales, and the degree of cost sharing.

Phase 2 subcontracts with SAIC and Rocketdyne will continue through FY97. SAIC will fabricate and deploy four heliostats using manufacturing technologies developed during its Phase 1 effort. These deployments will help SAIC firm up cost estimates for heliostats and prove the in-field performance of the new design in the field. Rocketdyne will fabricate a full-scale receiver panel for installation at Solar Two and a few-tube panel for installation and testing at Sandia. These installations will help Rocketdyne determine with more certainty manufacturing cost for its receiver and prove performance of the design. MDA will complete its Phase 1 work and could move into a second phase, if warranted. During FY97, we expect to hold additional DFMA workshops for our industry partners on an as-needed basis.

Major Milestones

Expected Completion	Milestone Description
Apr 97	Fabricate the MDA concentrator structural components.
May 97	Fabricate the Rocketdyne Solar Two-sized receiver panel.
Jul 97	Install the SAIC heliostat in Golden, Colorado.

Resources ($k)

	Sandia	NREL	DOE	Total
FTE Costs	56	142	0	**198**
Contracts	1,089	240	0	**1,329**
Total	**1,145**	**382**	**0**	**1,527**

E. INDUSTRY ASSISTANCE

Objective

The objectives of the Industry Assistance task are to continue to provide timely and responsive technical support for users of STE technologies and to apply Sun•Lab's manufacturing expertise to assist STE manufacturers in reducing the cost of their products and services.

Rationale

In the past several years, the Solar Thermal Electric Program has been engaged in a number of joint venture activities with industry that are producing new STE products. These products include dish/Stirling and power tower systems. However, as these products are entering the advanced prototyping and fielding phase of development, industry's needs have shifted toward improving its products' economic and field performance. Part of this improvement is expected to result from improved manufacturing techniques and improving or modifying the design of systems/components to take advantage of these improved manufacturing techniques.

The national laboratories have a great deal of advanced manufacturing expertise that was and continues to be developed in the defense programs. Some of these capabilities include agile manufacturing, fastcasting, robotics, virtual reality modeling, and advanced welding processes and techniques. In addition, a vast array of laboratory capability exists to help improve the fielded performance of these new products, such as advanced materials technology, root-cause analysis, hardened electronics techniques, and design-for-manufacturing methodologies.

This activity enables these manufacturing capabilities to be applied on a timely and relevant basis. Manufacturer- and user-directed industrial support will be provided on a case-by-case basis to users, manufacturers, and producers of STE technologies. The program will be continually flexible in supporting the constantly changing needs of the STE community.

FY96 Accomplishments

Last year we continued to apply our manufacturing team capabilities in several areas. In one effort, we signed a Cooperative Research and Development Agreement (CRADA) with a solar product manufacturer to commercialize a new low-cost, nickel-based solar-selective absorber coating for potential parabolic trough applications. Other efforts involved performing an analysis of a spring system and linear bushings in a Stirling engine to assist the manufacturer to predict and improve performance and leading a theoretical investigation to examine a new high-temperature absorber coating for power tower applications. Another effort involved training Solar Two field personnel to operate the μScan reflectometer to measure heliostat reflectivity and supplying computer spreadsheet programs to analyze the measured data.

Sun•Lab also supports users, such as the operators of the solar electric generating systems (SEGS) in California, to improve the performance and reduce the O&M costs of their plants. We investigated the optical properties and thermal stability of a new low-thermal-emittance cermet coating that could significantly improve the solar-to-thermal conversion efficiency of the HCEs; provided computer analysis using a modified SOLERGY model to predict SEGS I's actual revenues for specific equipment changes to aid in plant upgrades; provided mirror reflectance measurement consultation support; performed an analysis of failed LS-2 HCE flange supports to determine failure modes and recommended repair solutions; and identified and prioritized, with direct SEGS I input, the technical areas of support for FY97.

During FY96, Sandia concluded collaborative research and educational outreach efforts in Mexico in the area of STE and solar heat technologies. In collaborative efforts between Sandia and the Solar Energy Laboratory of the National University of Mexico (UNAM), a series of seminars on emerging commercial STE technologies was organized for Mexican energy policy and decision makers. Eight presentations on central receiver, dish/Stirling, and trough/electric technologies were made to management and staff of federal and state agencies in Mexico City and in the sun-rich northern states of Chihuahua, Sonora, and Baja California. The full-color slide presentations were made by one of the lead researchers at the UNAM Solar Energy Laboratory.

A cooperative research program with the University of Sonora provided an opportunity for undergraduate engineering students to get first-hand experience with a solar icemaker and several solar ovens, and to explore market and manufacturing issues for these technologies. Ten students under the guidance of professors from the chemical and industrial engineering departments developed areas of exploration of the solar devices including evaluation of thermal performance, exploration of potential markets in Mexico for the devices, and economic conditions and manufacturing infrastructure for their local manufacture. The students' reports served as their undergraduate engineering degree theses.

FY97 Task Description

Technical Support

In response to requests from owners of some of the SEGS plants, Sun•Lab will provide support in the areas of both oil degradation and field alignment. We will investigate the temperature extension of the new black-nickel-based solar-selective absorber coating for parabolic trough application. Additionally, we will continue to evaluate equipment failure modes at the plants and provide technical recommendations for equipment changes and modifications.

Sun•Lab engineers will develop a formal mechanism to regularly update the STE roadmap in accordance with the strategic plan's objective of providing leadership for a forward-looking technology path for future activities.

We will continue to provide computational flow dynamics analysis to industry as needed.

Sandia will continue to collaborate with UNAM's Solar Energy Laboratory in follow-on outreach activities. The STE presentation will be updated and used as a tool to continue to inform Mexican decision makers on the status of these technologies and heighten interest in their short-term use.

Sandia, the University of Sonora, and the UNAM Solar Energy Laboratory will also conduct a joint research project exploring the diminished performance of a U.S.-made icemaker during periods of warm nighttime weather.

Sandia will continue to provide technical support to the University of Sonora's Energy Group in its solar engineering training and research activities. Several Sandia-loaned solar ovens and an icemaker will continue to be provided to them for that purpose.

Sun•Lab engineers will conduct a forum with international STE manufacturers to present Sun•Lab manufacturing capabilities and to develop a base from which to provide solutions and support for external collaborators in favorable new markets.

Sun•Lab engineers will continue to provide limited consultation to users who are trying to apply STE technology. Limited consultation is most frequently given to customers who have asked DOE Headquarters for technical assistance and are referred to Sun•Lab for action.

We will support the Soltech '97 meeting by providing technical information displays, documents, and other supporting materials, along with consultation regarding the program outline.

Manufacturing Assistance

Sun•Lab engineers, including solar and manufacturing specialists, will correspond and visit, if warranted, STE manufacturers to understand their needs and to present Sun•Lab capabilities. Using the results of these interactions, a list of technical tasks will be identified and prioritized based on customer input, Sun•Lab capabilities, and available resources. Work will address specific, high-priority tasks as they are identified. Progress and final reports will be issued for each analysis task. We will coordinate closely with the SolMaT team to ensure that these activities are nonduplicative and integrated with the SolMaT program.

FY97 OPERATIONAL PLAN

Major Milestones

Expected Completion	Milestone Description
Jan 97	Complete the first phase of oil degradation investigation at SEGS I.
Mar 97	Identify follow-on efforts for oil degradation at SEGS I.
May 97	Complete Field Alignment Training at SEGS I and II.
May 97	Identify and initiate a manufacturing support activity.
Jun 97	Present manufacturing capabilities at an international conference.
Jul 97	Complete a CRADA with a solar product manufacturer for commercial development of a new solar-absorber coating.
Aug 97	Complete an investigation of temperature extension of a new nickel-based solar-absorber coating for trough applications.

Resources ($k)

	Sandia	NREL	DOE	Total
FTE Costs	215	10	0	**225**
Contracts	70	10	0	**80**
Total	**285**	**20**	**0**	**305**

F. SYSTEMS AND MARKETS ANALYSIS

Objective

The objective of this task is to develop an improved understanding of STE technologies and their applications; to support the analysis of advanced technology concepts; to identify ways of reducing capital as well as operation and maintenance costs while increasing performance; and to identify the key issues affecting technology commercialization and market identification.

Rationale

In past years, the STE program focused a significant effort on developing technologies to penetrate the utility power market. Unfortunately, a number of factors are hindering this commercialization path for STE technologies. There is currently a glut of electric capacity in the Southwest because earlier expectations for new power requirements have not materialized. The price of electricity has dropped dramatically as a result of the deregulation of the natural gas industry and the introduction of new high-efficiency combined-cycle and cogeneration power plants. Utility deregulation has delayed the development of new power projects and seems to be moving utilities out of the power generating business. Given these factors, the domestic utility power market has a high degree of uncertainty and is likely to be a difficult market for STE technologies to penetrate in the near term. Restructuring is likely to offer new opportunities in the long term. The Systems and Markets Analysis task will focus on ways to integrate STE technologies in the new restructured power environment through support of green market development activities, such as the Corporation for Solar Technology and Renewable Resources' Nevada Solar Enterprise Zone, and through continued support of the California Energy Commission's tax equalization efforts for renewable technologies.

International power markets have been identified as the most likely opportunity for near-term STE developments. Our task will also focus on a number of issues related to development of international markets. Specific tasks will focus on continuing the development of direct normal insolation (DNI) data for international sites, a study to evaluate power tower opportunities in India, analysis of remote/village applications for dish/engine systems, and continued support to the World Bank and International Energy Agency (IEA)/SolarPACES international market development activities.

FY96 Accomplishments

Studies have shown that STE power plants would pay approximately four times as much tax over the lifetime of the plant as a comparably sized fossil fuel plant. This increased tax burden can be a significant penalty on the economic viability of STE technologies and hinder their ability to compete in an increasingly competitive marketplace. In the past, complex financial models were required to evaluate these various tax burden issues. To allow easier analysis of tax issues, the Princeton Economic Research Institute Financial Analysis Tool for Electric Energy Projects (FATE2-P) model was adapted to perform the tax equity analysis. During the year, the FATE2-P model was used to validate earlier studies by the California Energy Commission and Oak Ridge National Laboratories. The results from the new model showed good agreement with the earlier study. The new model will help simplify future efforts to evaluate tax equity opportunities.

Solar resource data is a critical need for siting new STE power plants. There is generally a lack of good quality direct normal solar resource data for most potential international markets. NREL's Resource Assessment group has been developing a new DNI mapping capability that is based on satellite cloud observation data. The original intent during FY96 was to use this technique to generate DNI maps for a promising international location. Unfortunately, the methodology was not quite ready to be implemented. However, it was soon discovered that satellite data existed to generate cloud cover maps. Because cloud cover is the major factor in determining the DNI resource, cloud cover maps provide an excellent tool for STE site evaluation. Cloud cover maps were generated for most international locations that have a good DNI potential, including Africa, Asia, Australia, and South America.

The Systems and Markets Analysis task also provides general systems analysis support for a number of STE technology activities. During FY96, this included a study to convert Solar Two to a Kokhala hybrid power tower plant, a look at using STE technologies to reduce CO_2, support for developing the Solar Thermal Electric Program strategic plan, and World Bank efforts to look at STE technologies in India and China. This task also supported the IEA SolarPACES START Mission to Egypt.

FY97 Task Description

International Markets

Given that international markets are likely to be the key opportunity for new power generation over the next 10 to 20 years, a significant part of the Systems and Markets Analysis task will focus on activities that address various aspects of international power markets. In addition to a number of more specific activities discussed later, a more generalized effort will be undertaken that focuses on developing a better understanding of international market opportunities and identifying where STE technologies fit in.

Resource Assessment

Improving our knowledge of DNI resources for potential international markets is essential to the development of international STE projects. Our activities will continue to develop better DNI data resources by generating monthly and annual DNI maps for India and at least one other international location as an extension to the cloud cover mapping activity in FY96. The DNI methodology currently only calculates the total daily DNI. We hope to be able to extend the model to obtain hourly DNI data as well.

SolarPlan for India

The Solar Two Consortium is actively pursuing the commercialization of molten-salt power tower technology beyond the completion of the Solar Two Project. On behalf of the consortium, Bechtel and Sun•Lab have initiated a collaborative set of commercialization studies called the SolarPlan. Over the past year, in-house investigations have identified India as the most likely candidate for the initial deployment of commercial-scale power towers. The proposed activities for SolarPlan during the current fiscal year will therefore focus on India and define the character, timing, and potential installed capacity of the first power tower project in the Thar Desert of Rajasthan. Project tasks include (1) evaluation of local business conditions, potential business partners, and power purchase offerings by the state of Rajasthan and private companies; (2) plant conceptual design, performance analysis, and financial analysis; and (3) preliminary evaluation of an early commercial power tower project that suits the needs of India.

Village Model for Dish/Engine Systems

It is estimated that 40% of the world's population is currently without electricity. Many of these people live in remote areas isolated from the electric power grid. In many of these areas, diesel generators are the primary source of power, but small-scale hydro, photovoltaic, and wind turbines are starting to be used as well. DOE's Wind and Photovoltaic programs have developed a model that can be used to design village power systems and optimize the size and selection of renewable and conventional technologies. This model will be adapted to include dish/engine systems and used to evaluate the opportunities that may exist. One of the primary objectives will be to better understand the design and cost requirements for dish/engine systems to enter these markets.

Distributed Value Study

Recent research indicates that there are significant added "distributed benefits" associated with locating modular generation sources within a utility's power distribution system. Distributed Utility Associates will perform a study to determine the value of these distributed benefits for utilities in the Southwest and will estimate the potential market size.

Major Milestones

Expected Completion	Milestone Description
Mar 97	Complete DNI maps for India.
Apr 97	Adapt a village model for dish/engine systems.
Jun 97	Complete the SolarPlan report for India.

Resources ($k)

	Sandia	NREL	DOE	Total
FTE Costs	93	347	0	**440**
Contracts	25	65	0	**90**
Total	**118**	**412**	**0**	**530**

G. COMMUNICATIONS

Objective

The objective of this task is to create effective communications products for the DOE's Solar Thermal Electric Program.

Rationale

Communications products and exhibit materials explain the results of work performed by Sun•Lab for DOE's Solar Thermal Electric Program and make the results of research available to program constituents. In addition, because the concept of Sun•Lab is new, these same kinds of materials are needed to define an identity for Sun•Lab as a merger of Sandia and NREL to work collaboratively on solar thermal projects for the DOE. The major projects in which Sun•Lab is involved will also be the major focus of Sun•Lab publicity.

FY96 Accomplishments

During FY96, we created an awareness of solar's potential by helping the Solar Two Consortium publicize Solar Two. We created a brochure for Solar Two in cooperation with DOE and the Solar Two Consortium and assisted the consortium with displays at the Solar Two Conference Center. We began development of a video, which will be used in an in-flight presentation for airline passengers. In addition, we helped define an identity for Sun•Lab by developing a Sun•Lab brochure and by creating a Sun•Lab display for use at Soltech '96. We supported the dish/Stirling exhibitions at the 1996 Summer Olympic Games by developing a brochure for distribution. At the member laboratory level, we provided limited support for individual laboratory communication needs.

FY97 Task Description

Our primary task in FY97 will be to provide communication products for Sun•Lab management and staff as these needs are identified during the year. We will provide support for Soltech '97, including design and implementation of graphics for a Sun•Lab booth, publications, and staffing. We will complete a video with a target audience of foreign utilities to sell the concept of power towers, based on Solar Two. We will provide a set of fact sheets for use in publicizing the program, and update our World Wide Web pages to include this information. We will publish the annual operating plan, quarterly reports, and annual summary of program activities.

Major Milestones

Expected Completion	Milestone Description
Apr 97	Provide displays and brochures for Soltech '97.
Jun 97	Complete first round of fact sheets.
Sep 97	Update the Web pages to include fact sheet information.
Sep 97	Complete video for foreign utilities.

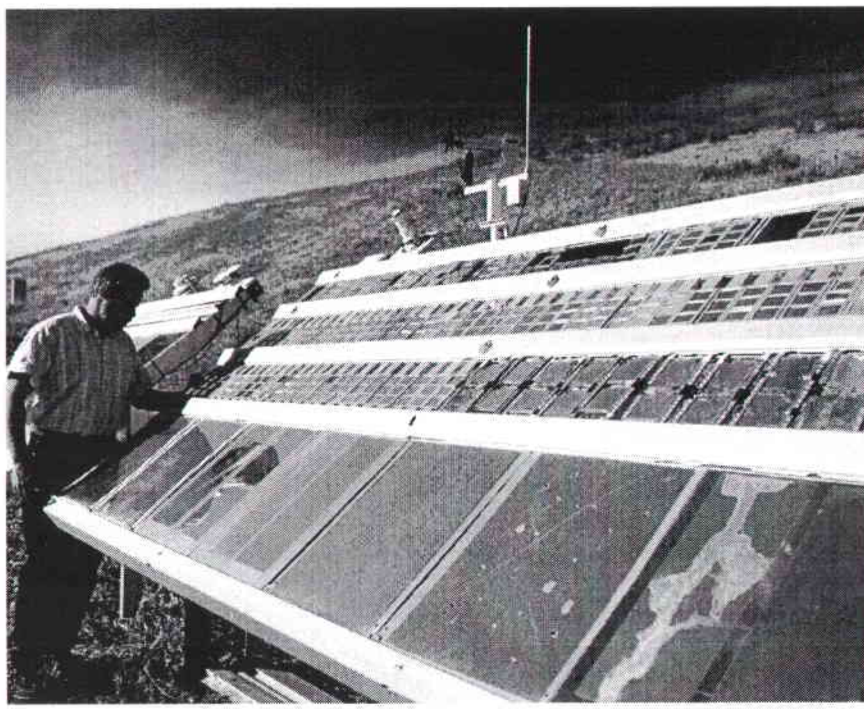
Resources ($k)

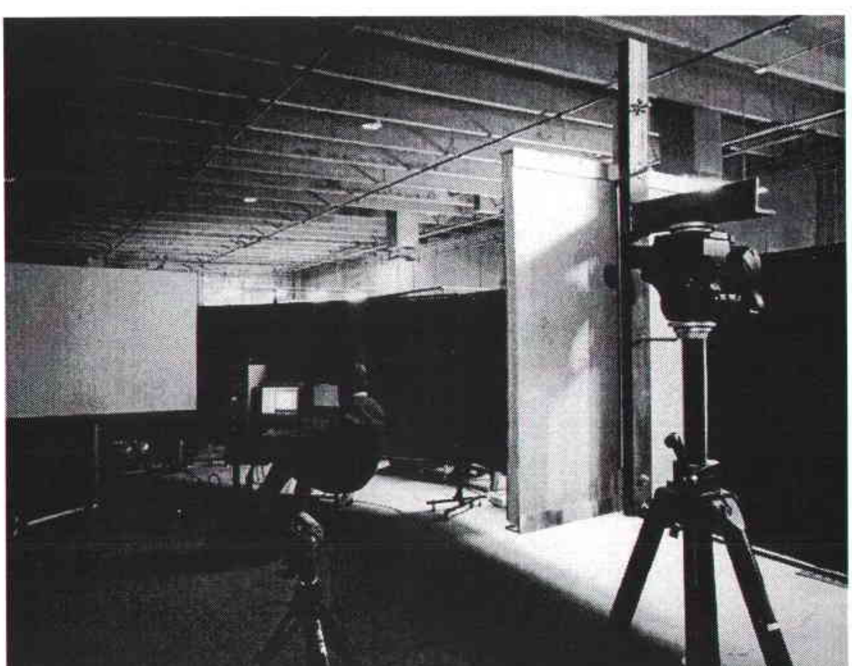
	Sandia	NREL	DOE	Total
FTE Costs	56	18	0	**74**
Contracts	71	32	0	**103**
Total	**127**	**50**	**0**	**177**

II. TECHNOLOGY DEVELOPMENT

Technology development projects support our commercialization projects by developing, in collaboration with the private sector and the international community, solar thermal plant components and subsystems that meet the cost, performance, and reliability standards needed by industry.

Sun•Lab Testing and Technology Development





A. OPTICAL MATERIALS

Objective

The objective of the Optical Materials task is to develop and test low-cost, high-performance, durable advanced optical materials for solar thermal applications.

Rationale

Low-cost, high-performance, and durable optical materials (advanced reflectors and absorbers) are necessary to achieve the cost and performance goals that are needed for commercialization of various solar thermal concentrating technologies. Uncertainties in performance, availability, and manufacturability of near- and long-term materials have been identified by the solar industry as important issues that must be resolved before end-users will accept these technologies. Industry has identified testing and development of optical materials as an appropriate area for use of Sun•Lab's core capabilities. Industrial partners routinely request support services for optical materials testing from both laboratories.

FY96 Accomplishments

Task activities during FY96 emphasized technical support for industry, continued operation of outdoor testing activities, and subcontracted and in-house development of new optical materials. During FY95, an industry panel was formed to solicit objective feedback to help clarify the optical materials task objectives and to identify current and future activities of relevance to industry. Based on the industry panel and DOE recommendations, Sun•Lab's Optical Materials Team began investigating a broader range of materials and technologies in FY96. To this end, the Optical Materials Team expanded its efforts in FY96 to further investigate thin-glass mirrors and other near-term reflector materials of more immediate interest to industry and to investigate advanced selective absorber surfaces for mid- and high-temperature applications. As described below, specific tasks included materials testing, near-term reflector materials, long-term reflector materials, outdoor testing, absorber material development, and industry support. These changes were intended to lead to a more balanced development approach offering near-term support to the Solar Thermal Electric Program.

The materials testing activity continued to support all in-house, subcontracted, and industry optical materials development and evaluation activities through accelerated exposure testing, outdoor exposure testing, optical and mechanical characterization, and analysis of materials. Key activities included progress in development of a video-based reflectometer to expedite specular reflectance measurements and continued data collection from the completed network of outdoor exposure sites.

Task staff worked with other program elements to investigate near-term reflector materials for use with solar thermal systems. Specific activities included identifying potential suppliers of thin glass, reviewing design options, and identifying test procedures that meet the current needs of the program. In addition, the team worked with the 3M Company to accelerate development of a next-generation (high-solar reflectance) all-polymeric reflector. We continued to support advanced reflector concepts, such as alumina and diamond-like protective reflector coatings and organized molecular assemblies. A critical assessment and down-selection of the benefits of these materials was carried out in FY96 as well.

In collaboration with a CRADA participant and the Solar Industrial Program, we worked toward developing and establishing the production capability for black-nickel-based, solar-selective absorber coatings for use in low- to mid-temperature applications. Specific activities included developing a more-detailed understanding of plating process parameters and assisting with the design of plating line hardware and process methods. In addition, staff began the task of establishing absorber coating specifications that address requirements for central receiver applications and began a theoretical investigation of potential candidate materials.

Industry support activities such as optical characterization, failure analysis, and materials application were continued as needed to respond to industry needs and to facilitate technology transfer. The Optical Materials Team responded regularly to requests for support from industry, including Cummins and SAIC in support of USJVP projects and Industrial Solar Technologies for development of advanced replacement facets for installation by KJC Operating Company at SEGS III through VII.

FY97 Task Description

During FY97, the core Optical Materials task activities will consist of optical characterization of advanced reflector and absorber materials, accelerated and outdoor testing of commercial and experimental reflector materials, development and evaluation of mid-temperature selective absorber materials, and support of industry/program needs.

Development of a video-based reflectometer begun in FY96 will be completed. This instrument will greatly improve the efficiency with which specular reflectance measurements are made. An existing UV-VIS-NIR spectrometer will be upgraded in terms of computer control and data acquisition, and a new spectrometer will be activated. This will increase the throughput of spectral hemispherical reflectance measurements of candidate solar optical materials.

Testing of candidate materials will be continued for both accelerated laboratory and outdoor exposure conditions. A new Atlas Weather-Ometer will be activated and laboratory facilities will be consolidated to a single location to increase efficiency and productivity. Sun•Lab's outdoor exposure test site previously located in Abilene, Texas, will be moved to a solar park in Ft. Davis, Texas. This new site will provide increased visibility of test activities as well as continuing support of industry requests for outdoor weathering to validate accelerated test results. In addition, the existing network of outdoor exposure test sites will demonstrate the effect of a wide range of outdoor environments on material performance and lifetime. Activation of additional outdoor exposure test sites by interested international collaborators under the auspices of the IEA SolarPACES program will be explored.

Activities in the mid-temperature absorber task include completion of a feasibility study and production of candidate tubes with selective absorber coatings. This work will proceed under an existing CRADA between Sandia and Energy Laboratories, Inc.

In support of industry and the Solar Thermal Electric Program, candidate foam facets will be subjected to accelerated freeze/thaw testing. An advanced vacuum deposition system will be installed and activated to allow preparation of industry-conceived and internally generated candidate reflector constructions. A matrix of candidate thin-glass/adhesive constructions will be tested in support of the USJVP.

Major Milestones

Expected Completion	Milestone Description
Feb 97	Complete interim report to SAIC on thin-glass/adhesive test results.
Jul 97	Document test results of material constructions tested.
Sep 97	Complete summary report on FY97 industry support activities.

Resources ($k)

	Sandia	NREL	DOE	Total
FTE Costs	27	597	0	**624**
Contracts	10	102	0	**112**
Total	**37**	**699**	**0**	**736**

B. CONCENTRATOR TECHNOLOGY

Objective

The objective of the Concentrator Technology task is to bring heliostat and parabolic dish solar concentrators to commercial readiness for use in STE systems.

Rationale

Heliostats and parabolic dishes provide the "fuel" for STE systems. These two types of solar concentrators comprise similar parts and use similar manufacturing processes; for example, both have an optical surface (typically glass), an optical element support structure, a two-axis drive, and a tracking/control system. Power tower and dish/engine design studies show that the cost of the solar concentrator is 40 to 50% of the cost of these two types of solar systems. The challenge that continues to face us is to reduce the cost of the concentrator while continuing to maintain the high levels of performance that are demonstrated by many of the current designs.

FY96 Accomplishments

The three tasks in this area of programmatic activity are optical tool development, industry support, and research and development (R&D) of advanced concepts. The optical tool task includes the development of specialized instrumentation and computer codes for optical analysis and concentrator evaluation. Sun•Lab provides optical analysis and measurement support to industry, which often involves using the Flux Mapper to measure dish/engine project solar concentrators and beam and heliostat characterization systems for measuring the performance of both dishes and heliostats. The concentrator R&D task is structured to develop new, innovative ideas and conceptual designs for solar concentrators that will lead to more cost-effective and/or high-performance heliostats and dishes.

Optical Tool Development

During FY96, Sun•Lab engineers at Sandia and NREL built the first prototype of a ray-trace system named Video SHOT for measuring the optical figure of merit of concentrator facets. It is a laser ray-trace device that is used to measure mirror slope at many points, to fit a surface to the slope data, and to provide focal length, root-mean-square slope error, and graphical maps of surface errors. Sandia's beam characterization system (BCS) was also duplicated at NREL, expanding the optical test support function of the laboratories.

Industry Support

Sun•Lab personnel measured the optical performance of Cummins' dishes in Abilene, Texas, and a number of optical facets provided to Sun•Lab for the Advanced Concentrator Development Program.

R&D of Advanced Concepts

There were three advanced concentrator projects funded during FY96, two for optical facet and solar concentrator development and one for development of a novel drive concept. Kansas Structural Composites, Inc. designed several types of optical facets using fiberglass honeycomb facet designs. Edtek, Inc. and Battelle's Pacific Northwest Laboratory developed a "blow-formed" method for manufacturing mirror modules. SAIC designed an advanced elevation/azimuth drive that uses a spring/worm approach. This drive will be analyzed for possible use in SAIC's advanced heliostat and dish designs.

In FY96, the capability for fabricating prototype foam facets was developed in-house at Sandia. Foam facet mirrors made with extruded polystyrene foam were found to be unsuitable because of creep degradation at high temperatures. A process for fabricating urethane foam facets (which should have much better elevated temperature creep properties) was developed and several prototypes were manufactured. Procedures for characterizing and tracking prototype foam facet manufacturing parameters and optical characteristics were also developed and implemented.

The Final Design Review for a project with Solar Kinetics, Inc. of Dallas, Texas, and AlliedSignal of Phoenix, Arizona, to evaluate the feasibility of using the single-element, stretched-membrane dish in a dish/Brayton power generator was conducted. The proposed components for the open-cycle dish/Brayton system are the turbogenerator, receiver, and dish concentrator. The turbogenerator builds on one developed by AlliedSignal for automotive applications and currently being modified for industrial applications. The design philosophy employed in this study was to use (as much as possible) off-the-shelf components, to *boot-strap* technology development with sales, and to target market entry within three years. The result of the feasibility study is that AlliedSignal has identified a dish/Brayton power generation system as a potential product in its New Product Development Program. The contract was extended into FY97 to allow AlliedSignal to explore the more detailed design of a solar receiver.

FY97 Task Description

In FY97, the three project activities, optical tool development, industry support, and advanced concentrators, will continue. Sun•Lab engineers will continue to test the Video SHOT system on advanced concentrator facets and to adapt the design for field application. We will continue to support dish and heliostat development for the joint-venture projects, Solar Two, and SolMaT programs. AlliedSignal/SKI and Advanced Concentrator Development Program projects will be completed. We will also continue to develop the foam facet for potential use on dish, heliostat, and trough collectors. In FY97, additional prototype urethane foam facets will be fabricated and evaluated. The urethane foam facet mirrors will be evaluated with the Video SHOT system and subsequently subjected to environmental testing at NREL. If subsequent Video SHOT evaluations indicate minimal degradation, edge seal approaches and engineering design tools will be developed. A methodology for measuring the slope error of a concentrator facet developed in Russia will be scaled up in an attempt to measure the slope error for an entire concentrator.

Major Milestones

Expected Completion	Milestone Description
Oct 96	Conduct an Advanced Concentrator workshop.
Nov 96	Complete the Advanced Concentrator contracts.
Dec 96	Complete the AlliedSignal/SKI contract.
Mar 97	Make a decision on the durability of urethane foam facets.
Apr 97	Complete the second-generation laboratory Video SHOT system.
Jul 97	Duplicate the second-generation laboratory Video SHOT system at NREL.
Sep 97	Develop the first-generation field-scale Video SHOT system.

Resources ($k)

	Sandia	NREL	DOE	Total
FTE Costs	741	245	0	**986**
Contracts	298	100	0	**398**
Total	**1,039**	**345**	**0**	**1,384**

C. POWER TOWER TECHNOLOGY

Objective

The objective of the Power Tower Technology task is to support industry and utilities by enhancing performance and mitigating the risks of power tower technologies through R&D.

Rationale

There are significant demands for new generating capacity in both domestic and foreign markets that can partly be met by solar thermal power tower technology. Support for research, development, and testing of advanced receivers, concepts, materials, and components is critical for reducing the risks and implementing enhancements in reliability and economics into the first commercial power tower plants. Sun♦Lab will provide the technical expertise and testing capabilities to help industry produce the first commercial plants.

FY96 Accomplishments

The power tower technology program for FY96 focused on technology development and on supporting commercialization efforts, specifically the Solar Two Project and the Rocketdyne CRADA. In FY96, we provided critical support for the startup of Solar Two and supported initiation of the Test and Evaluation Phases.

As part of our technology development, we completed testing of an impedance heating system that could be used in place of mineral-insulated heat trace and would be much more reliable. We completed experiments to quantify damage inflicted to samples of receiver tubes under various freeze/thaw sequences and we completed transient salt freezing tests to determine how far salt will flow through cold pipes.

We completed the first year of a CRADA with Rocketdyne to develop advanced power towers. We also completed corrosion experiments with advanced alloys typical of evaporator materials containing silicates to stabilize the alloys against corrosion.

We made significant progress in refurbishing the National Solar Thermal Test Facility (NSTTF) by repairing the heliostat field. We also initiated repair of the elevator lifting module used to bring large test articles to the top of the tower for high-flux testing.

FY97 Task Description

Solar Two Support

We will provide support to Solar Two for startup, operation and maintenance, and for the Test and Evaluation Phase of the project. This support will be in the form of on-site consultation, test plan development and implementation, and assistance with actual testing and analysis. We will also support the project in assessing unplanned events.

Rocketdyne CRADA

The objective of the Rocketdyne CRADA is to develop an advanced receiver that is smaller and more efficient. The second year of the CRADA is significantly scaled back from the original plan. In the scaled-back plan, we will complete isothermal and thermal mechanical fatigue tests on advanced receiver materials.

Advanced Receiver Panel Test

We will prepare for and test an advanced few-tube test panel at the NSTTF. The panel will be built by Rocketdyne under the SolMaT receiver contract. The panel material is being characterized under the CRADA. As part of this test, we will evaluate the performance of the panel, determine how well Pyromark® paint adheres to the receiver material, assess insulating materials under high-flux conditions, and evaluate other features of the panel. This test is needed to qualify the panel design for future commercial opportunities by Rocketdyne.

Facility Preparations

Last year, 140 heliostats were repaired and made reliable by replacing motors, repairing controller boards, and replacing encoders. This year we plan to continue repairing the field to get 180 heliostats working well. In addition, the process control system will be reprogrammed to reflect the changes in the system for the panel test. Computer automated design drawings of the control logic will be drawn. The entire system will be dry run prior to implementation.

The 800,000-lb. capacity Lucker lifter module, used to bring experiments to the top of the tower, will be tested. A new data acquisition system (DAS) purchased last year will be installed and programmed. The DAS will support this test and future tests. It will be programmed in LabVIEW® and will have the capability to be run from the control room.

Major Milestones

Expected Completion	Milestone Description
Apr 97	Complete installation and checkout of the new DAS.
May 97	Complete a study of slow strain rate of advanced receiver alloys for the Rocketdyne CRADA.
Jun 97	Install an advanced, few-tube test panel at NSTTF.
Sep 97	Complete planned tests on the few-tube test panel.

Resources ($k)

	Sandia	NREL	DOE	Total
FTE Costs	908	39	0	**947**
Contracts	569	3	0	**572**
Total	**1,477**	**42**	**0**	**1,519**

D. DISH CONVERSION TECHNOLOGY

Objective

The objective of this task is to develop advanced receiver and conversion technologies to improve performance, cost, reliability, and commercialization prospects of dish-electric generation systems and to address receiver and engine long-term issues projected to affect the life and marketability of the joint venture products while assisting the partners on short-term issues.

Rationale

Stirling dish-electric systems have been identified as having potential for meeting industry's long-term energy cost goals. Dish-electric systems based on Stirling engine technology were successfully demonstrated by Advanco Corporation and McDonnell Douglas Corporation and operated at high efficiency. To reach the ultimate potential for dish-electric systems, a high-efficiency, low-maintenance, and low-cost receiver is required. The current thrust is to improve the longevity and reduce the operation and maintenance costs of receivers, as well as to improve performance. The basic receiver type believed best suited for making these improvements is the reflux receiver. The reflux receiver is an optimum match for the Stirling engine's capability and requirements and can smooth the flux nonuniformities present in low-cost commercial dishes. Advanced receivers developed by the laboratories make the application of reflux receiver technology to larger systems possible. Significant issues remain concerning the lifetime of the receivers.

Laboratory expertise can significantly reduce development efforts and enhance the success of the joint venture programs in the areas of receiver and engine technologies, particularly in the areas of materials analysis, liquid metal compatibility, system modeling, and hybrid burner development.

Hybrid receivers are needed to meet the requirements of the USJVP projects and to enhance the marketability of all the dish systems. The development of hybrid receivers by the joint venture partners has lagged behind the development of the basic system functionality.

Non-Stirling conversion technologies have improved over the last decade, and the state-of-the-art technologies need to be compared to current Stirling capabilities.

FY96 Accomplishments

Activities in this area were driven primarily by the needs of our industry partners. Program goals included full-scale testing of advanced receiver wick concepts, hybrid (gas-fired) receiver development and demonstration, materials interaction studies, verification of design tools, durability testing of wick structures, heat pipe integration with a Stirling engine, Brayton engine solarization, and Stirling engine problem analysis.

In FY96, we continued the development and testing of advanced felt-wick heat-pipe receivers, concentrating, characterizing, and improving the lifetime of the technology. We tested two bench-scale devices to 1900 and 1300 hours. Upon disassembly, we investigated the durability-limiting processes occurring in the pipes. We also tested a full-scale third-generation receiver that incorporated features to address problems observed earlier. We need to continue development, primarily addressing cleanliness and wick structural stability. We are working closely with the vendor to refine the materials and manufacturing process. We have developed a simplified capsule test rig that can test up to 12 samples simultaneously, vastly improving our capability to generate long-term information. The concept was successfully tested with a single 100-hour sample capsule.

We successfully combined the STM 4-120 engine with a felt-wick heat-pipe receiver, and our testing indicated significant improvements in engine and system performance over the previous directly illuminated receiver (DIR) testing. We also redesigned the interface and coupled the engine with a Thermacore nickel-powder-wick heat-pipe receiver, which will be tested in FY97. Thermacore and STM were impressed with the results and met together at Sandia to discuss a business relationship.

We made significant progress on the design of an advanced Sun•Lab hybrid heat-pipe receiver. We evaluated many concepts, and then performed extensive analysis and design work on the selected approach. We tested a burner candidate in NREL's new emissions test facility and used the results to calibrate our design codes. We analyzed vendor samples of extended heat-transfer surfaces, evaluating the effectiveness and potential cost. We expect to build and test a bench-scale hybrid heat pipe in FY97 based on this work.

We supported Cummins' joint venture programs with receiver design and test support, resulting in a receiver tested to 96 kW_t on Cummins' dish, and a successful integrated test of the Thermacore receiver with an Aisin-Seiki Stirling engine. We also supported Cummins with fluids modeling of its Stirling engine. We supported SAIC with receiver design support.

We began collaborating with Dr. Alexander Shimkevich of the Institute for Physics and Power Engineering in Obninsk, Russia, for technical information to improve the lifetime and performance of felt/metal wicks. This initial work may lead to significant interactions with laboratories in the former Soviet Union. We also supported work at North Carolina Agricultural and Technical State University, resulting in a Master's degree for Mona Fowler on the use of artificial neural networks to model reflux receiver performance. Further collaborations are underway with Master and Ph.D. students.

FY97 Task Description

In FY97, we will continue the development of felt-wick heat-pipe receivers for application to long-term, low-cost dish/Stirling systems. The primary objectives are continued refinement of advanced heat-pipe receivers at the 75- to 100-kW_t level, development of advanced hybrid receivers, durability testing and lifetime improvements of receiver and wick materials, transfer of technology to industry, and integration support. We will also pursue advanced wick technologies that show a performance or lifetime improvement potential over current technologies. We will demonstrate a bench-scale hybrid heat-pipe receiver with low cost and high performance necessary for commercial systems. We will continue to test integrated conversion systems, including the STM/heat-pipe package and alternative conversion systems, such as Brayton. We will continue to coordinate our efforts with the joint venture partners.

We will complete testing of the STM 4-120 engine with the Thermacore heat-pipe receiver. This demonstration allows a comparison of DIR technology with heat-pipe receivers using the same engine and dish to minimize changing variables. Initial results indicate the heat pipe can improve system performance by 5 to 6%. We will closely coordinate the data analysis and reporting with both STM and Thermacore and will assist them in refining the integration of the package.

We will continue the development of advanced hybrid heat-pipe receivers. Our approach is to incorporate low-cost, high-performance features in the initial designs, rather than simply demonstrating any working system. We have down-selected to one leading candidate and will complete the design as well as fabricate and test a bench-scale device that incorporates the key features of the design. We will also continue to support Thermacore in its hybrid development effort. We will coordinate with the efforts of the systems analysis team to evaluate the market requirements for hybrid electric generation systems.

We will continue felt-wick heat-pipe development. We will concentrate our efforts on resolving long-term issues, such as corrosion and wick compaction. We will do this through bench-scale and capsule testing, and possibly with another full-scale receiver. We will work closely with the vendors to develop cleaning and manufacturing processes that improve the wick durability. We will also investigate structural changes in the wick to prevent compaction over time. We will continue our new efforts with the laboratories of the former Soviet Union to shed further light on these effects and to leverage our efforts.

We will continue to explore alternative wicks that have promise to improve durability without compromising performance. We have identified several potential areas to pursue, including specialized nickel powders, alternative felt materials, and blended felt materials and sizes. Other candidates will be screened for suitability and then tested in capsules, if appropriate. We will work closely with vendors and have them produce the test coupons, where appropriate, to minimize technical transfer delays later.

We will continue our successful support of the joint venture partners, addressing issues of immediate concern where we have appropriate expertise. We have demonstrated quick and appropriate response to problems such as receiver modeling, dish/receiver integration, receiver design, prototype test instrumentation and support, and engine problem modeling. We will continue to coordinate closely, especially in light of our ongoing integrated testing.

We will evaluate alternatives to the Stirling engine, primarily focusing on the Brayton cycle. We are currently considering engines by AlliedSignal and Northern Research and Engineering Corporation, combined with the German Aerospace Research Establishment volumetric receiver. If appropriate after evaluation, we will select an engine and test the engine on sun at Sun•Lab. We will also coordinate with the volumetric materials project to further the technology for advanced volumetric receivers necessary for the commercialization of Brayton dish systems.

Major Milestones

Expected Completion	Milestone Description
Nov 96	Complete performance mapping of the STM 4-120 engine with the Thermacore heat-pipe receiver.
Dec 96	Begin multiple materials compatibility capsule testing, which will continue for 10,000 hours.
Jun 97	Complete design of the next-generation felt-wick or advanced-wick heat-pipe receiver.
Jul 97	Complete fabrication of the prototype hybrid heat pipe.
Sep 97	Begin testing alternative conversion system on the test bed concentrator.

Resources ($k)

	Sandia	NREL	DOE	Total
FTE Costs	1,123	195	0	**1,318**
Contracts	499	25	0	**524**
Total	**1,622**	**220**	**0**	**1,842**

E. LONG-TERM RESEARCH AND DEVELOPMENT

Objective

The objective of Long-Term Research and Development is to provide advanced technologies and components for future STE systems.

Rationale

In recent years, the Solar Thermal Electric Program has focused almost exclusively on commercialization of near-term STE technologies. There was little effort aimed at new advances that could lead to major steps forward in STE technologies. Long-Term Research and Development fills in that gap by seeking the best ideas from the laboratories, academia, and industry, and by developing those ideas to the point where significant improvements in cost, performance, and reliability of STE technologies can be had.

FY96 Accomplishments

None. This is a new activity for FY97.

FY97 Task Description

This activity will have three projects for FY97: university R&D, volumetric materials, and solar hydrogen. If resources become available within the program, we may also attempt to initiate an additional project mid-year.

University R&D

This activity will help establish new long-term directions for the program. The main thrust of the activity will be a competitive procurement aimed at universities with original, promising R&D ideas. The scope will be restricted only in that solar energy must be converted to heat and then to electrical power and that the idea must fall outside the scope of existing STE technologies and program activities. A phased approach will be used in which the first phase will be proof-of-concept conducted by the university and the second phase will be aimed at moving the work from the university to the laboratories and industry, if appropriate. Use of Sun•Lab staff, facilities, and equipment will be encouraged for both phases, especially the second. During the year, we will solicit, review, and award up to two contracts.

Volumetric Materials

Volumetric receivers are essentially heat exchangers where concentrated sunlight is absorbed in a volume (rather than on a surface) and transferred to a fluid, usually air, in a manner that minimizes convective and radiative energy losses. These receivers have simple, efficient, and possibly inexpensive applications in (1) power towers, (2) dish/engines, and (3) endothermic chemical reaction processes, such as water splitting or reforming. To benefit from these advantages, new materials are needed that can withstand the severe environment characteristic of the collection of concentrated solar energy. Over recent years, significant effort has been devoted to the development of such new materials. However, absorber materials such as alumina foams and wire meshes have proved to be unreliable and prone to failure in the extreme environment of highly concentrated solar flux. With recent advances in ceramics, it is appropriate to revisit this area and identify and test new materials for use as the solar absorber. The work will be aimed at identifying new volumetric absorber materials for capturing concentrated solar energy to heat flowing air to 1000 to 1200°C and will be carried out in three tasks: (1) review literature and identify primary application; (2) identify industrial collaborators based on expertise and materials available; and (3) test select specimens in NREL's solar furnace. Based on results of these tests, a plan will be developed for follow-on work, possibly including the design and testing of a large-scale prototype volumetric receiver for an application identified in Task 1.

Solar Hydrogen Production

Hydrogen produced via solar thermal processes shows considerable long-term promise as an energy carrier and storage media for solar energy. This activity will review the most recent literature on research in this area, and conduct a first order screening evaluation for promising applications. Based on the screening analysis, recommendations on future R&D involvement will be made.

Major Milestones

Expected <u>Completion</u>	Milestone <u>Description</u>
May 97	Award university subcontracts.
Jun 97	Complete screening of the solar thermal hydrogen processes.
Sep 97	Make a decision on the usefulness of new volumetric absorber materials.

Resources ($k)

	Sandia	NREL	DOE	Total
FTE Costs	163	123	0	**286**
Contracts	446	148	0	**594**
Total	**609**	**271**	**0**	**880**

F. FACILITIES SUPPORT

Objective

The objective of Facilities Support is to operate and maintain the Sandia NSTTF and the NREL High-Flux Solar Furnace (HFSF) in support of Solar Thermal Electric Program objectives.

Rationale

The DOE's NSTTF, located at Sandia, is the major facility for testing of solar thermal components and systems in the United States. The facility is also a DOE Designated User facility. Originally constructed as the Central Receiver Test Facility in the late 1970s, its mission has been expanded to include distributed receiver technologies, line-focus and point-focus collectors, two solar furnaces, and an engine test facility. In addition, the unique capabilities of the facility have been applied to a wide variety of tests unrelated to solar energy, but using the intense heat from concentrated solar radiation or using the large-scale optical systems at the site.

The facility incorporates both permanent test capabilities, such as the power tower heliostat field and the distributed receiver test bed concentrators (TBCs) as well as experiments installed for one-time evaluation, such as the LaJet Innovative Concentrator and the large-scale water-flow test. Some of these latter types of experiments become useful for application to later programs, such as the parabolic troughs from the Modular Solar Industrial Retrofit program that were modified and used in support of the Solar Detoxification of Water experiments conducted by the Solar Industrial Program. Test apparatus installed under Work for Others (WFO) programs has also sometimes become a permanent facility asset as in the cases of the wind tunnel and the NASA-funded tracking truss used for dish-facet evaluation. Operation of the NSTTF requires a variety of staff and contract personnel to design, fabricate, test, and evaluate results.

Over time, permanent test capabilities require upgrade to maintain their capability. In addition, equipment installed for one-time tests needs to be removed when the probability of future use is outweighed by the cost of maintaining the equipment in safe condition. Environment, safety, and health (ES&H) requirements and standards must also be maintained.

The DOE's HFSF, located at NREL, was built to help meet the growing need for applied R&D in advanced materials and processes. It is a focal point for the rapid investigation and development of new industrial and high-solar flux applications that have commercial potential. The HFSF has primarily been used to support DOE's Solar Industrial Program, conducting testing on material and solar detoxification processes.

Staff expertise and the unique facilities of the NSTTF and HFSF are critical resources for testing the high-risk, high-payoff technologies being developed by the DOE and industry. They also represent resources industry can use to get high-quality, unbiased testing and evaluation. The DOE's investment in these facilities is leveraged by the WFO program and the ability to conduct nonsolar testing.

FY96 Accomplishments

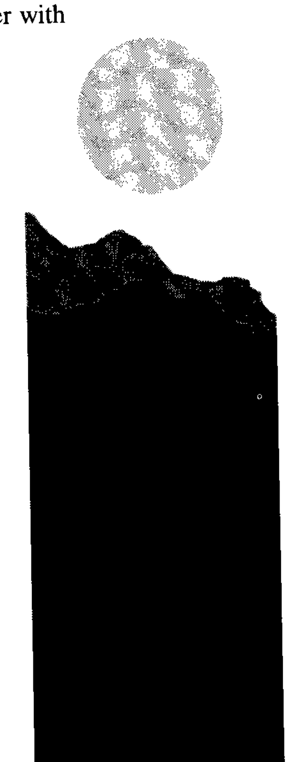
In recent years, a focus of NSTTF maintenance and upgrades has brought the facility into formal compliance with ES&H requirements. Through various inspections and audits, the facility has established a reputation for excellence in ES&H.

More recently, various facility capabilities have been upgraded. An important upgrade was that of the TBC controls. The old control system was 15 years old, and failure of the system interfered with productivity.

In FY96, we completed additional heat-pipe receiver tests on the TBC as well as further bench-scale receiver tests. We also completed the integration and initial testing of a Thermacore heat-pipe receiver with the STM 4-120 engine.

Another accomplishment was completion of testing the Industrial Solar Technologies trough. A number of tests were completed in support of the Solar Two program, including transient freezing experiments, salt corrosion effects, and impedance heater testing. Other material testing was conducted in support of the Sandia/Rocketdyne CRADA.

The lower east floor of the solar tower was renovated to allow the manufacturing and development of foam facets for testing. These facets offer the potential of low-cost reflective surfaces for dishes, heliostats, and troughs.



In addition, several test sites and supporting equipment such as the large-scale water-flow test site and the 5-MW cooling system at the tower have been disassembled and, for the most part, disposed of or reapplied to other projects.

FY97 Task Description

A major activity for FY97, as detailed in other tasks, includes designing, assembling, and testing the Rocketdyne panel at the top of the tower at the NSTTF. This test will validate the use of an advanced receiver material, the durability of the insulation associated with the panel, and the adhesion of the Pyromark® paint to the receiver material.

As detailed in other tasks, the STM engine will be tested with a Thermacore heat-pipe receiver. Bench-scale heat-pipes will be fabricated and tested to assess various wick structures. Prototype hybrid receiver heat-pipes will be designed and fabricated.

The 800,000-lb. elevating module within the tower will need to be refurbished and procedures will be written. The module will be used to support the Rocketdyne panel test.

The NREL HFSF will be maintained, quality checks will be performed on the DAS, and adjustments and calibration will be performed to keep the furnace in reliable working order.

The NSTTF's heliostat field remains operational, largely supported by the panel and in part because of reimbursable programs that have supported continued maintenance and use. However, significant maintenance of the field controls is necessary to support current tests and the upcoming panel test. Modifications are planned for the heliostats, the Bailey Net 90 Control, and the DAS.

Currently, there are two contracts for reimbursable testing. The Applied Physics Laboratory is testing a radome for the Department of Defense, and the University of Chicago is conducting night testing using the optical capabilities of the facility. If the University of Chicago testing proves viable, additional testing will be done in 1998.

Removal of a number of older, unneeded systems may be initiated as time permits.

The condition of the Power Kinetics Small Community Solar Experiment #2 Verification Module has deteriorated because of high winds. The system has to be removed because it now poses a safety risk. This system will be removed from the site once approval is obtained from the DOE to complete this action.

Major Milestones

Programmatic milestones for testing technology are addressed in each of the technology sections.

Resources ($k)

The funds shown below apply to the core site support, operation and maintenance, and general ES&H requirements of the NSTTF.

	Sandia	NREL	DOE	Total
FTE Costs	320	40	0	**360**
Contracts	449	10	0	**459**
Total	**769**	**50**	**0**	**819**

PROGRAM MANAGEMENT

The management and direction of the Solar Thermal Electric Program is structured to be responsive to national energy policy. That policy is provided by the Secretary of the Department of Energy and incorporates recommendations from the Executive Office, the Congress, national energy advisory boards, other government agencies, industry, universities, and others. Effective management of the program is essential to ensure that the overall goals of the Solar Thermal Electric Program are appropriate and are met, and that the activities leading to those goals proceed in an efficient, cost-effective manner.

Implementation of the Solar Thermal Electric Program requires careful tracking of research and development activities to ensure satisfactory progress toward the overall program's goals. Milestones and decision points have been established for each program task and are used to determine the necessity for redirecting activities in view of program priorities and available program resources.

Program Management and Organization

The DOE Office of Solar Thermal, Biomass Power, and Hydrogen Technologies reports to the Deputy Assistant Secretary for Utility Technologies. The office is responsible for managing and reporting the status and progress of the Solar Thermal Electric Program. Policy formulation, planning, resource allocation, and evaluation activities are performed by this office. DOE field laboratories and field offices have been assigned responsibility for implementing the program.

Field Laboratory Management and Organization

Specific implementation of the Solar Thermal Electric Program is assigned to two field laboratories, Sandia National Laboratories in Albuquerque, New Mexico, and the National Renewable Energy Laboratory in Golden, Colorado.

Beginning in the summer of 1995, Sandia and NREL consolidated their solar thermal management and programs into a new "virtual laboratory" called Sun•Lab. Sun•Lab provides a single point for management of the solar thermal program, including planning, budgeting, reporting, and so forth. The solar thermal staff of both laboratories now work much more closely together, providing better allocation of resources and enhanced technical teams.

Sun•Lab is responsible for implementing the technology development activities and the specific commercial applications that have been formulated to meet the objectives of the program. Activities are conducted both in-house at the laboratories and through subcontracts (often cost-shared) placed with private industry, other research organizations, and universities.

REPORTING

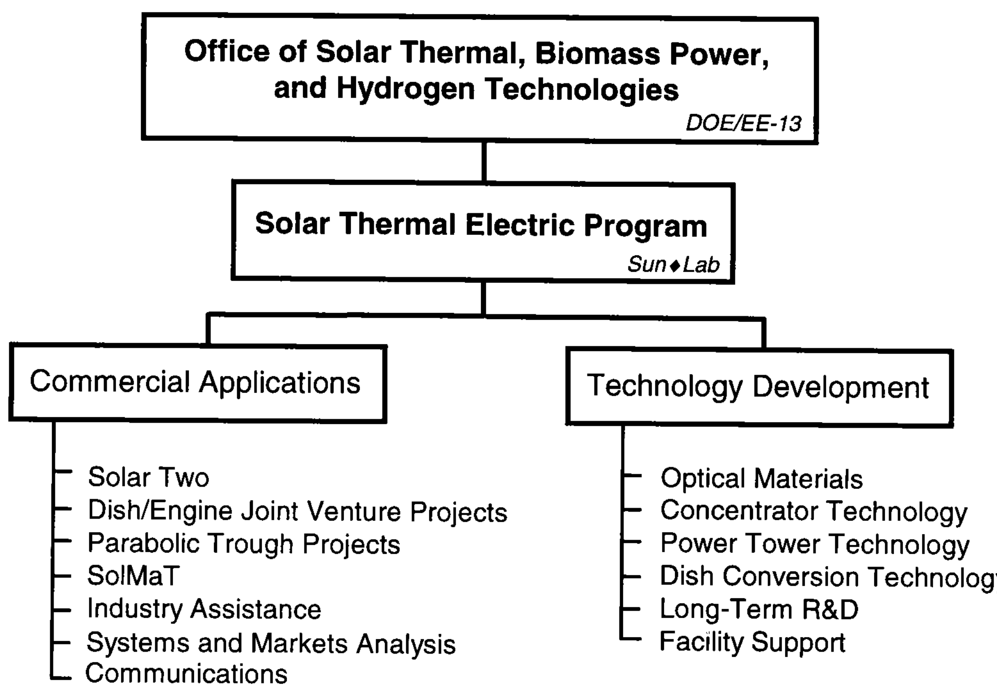
The DOE Solar Thermal Electric Program management is kept informed of program progress and management issues on a continuing basis through a variety of formal and informal means such as site visits, frequent telephone communication, weekly *Highlights*, the annual Soltech conference, quarterly reports, semi-annual program reviews and other topical meetings, and a high-level annual summary. The quarterly report is the primary formal mechanism for documentation of program progress, current planning, budget status, and other relevant management information.

TECHNOLOGY TRANSFER

The Solar Thermal Electric Program supports a number of technology-transfer-related activities to ensure the prompt, accurate, and continuous flow of significant research and technology development information to industry and other users. The primary technology transfer conduit is through commercial applications. The interactive nature of these joint industry/government activities makes frequent transfer of relevant technology an essential feature of these programs. Weekly *Highlights* provide first-level documentation of this technology transfer.

The manufacturing and technical support activity is the program element that reaches the largest segment of current and potential users/suppliers of commercial STE technology. More traditional means of technology transfer are also employed. Topical reports and publications are prepared and distributed as appropriate to document the status of the STE technologies and projects. Technical reports and papers on all aspects of the program's research and development are published and widely distributed. Technical reports are submitted to the DOE Technical Information Center at Oak Ridge, Tennessee, for entry into the national database on energy technology, and for sale by the National Technical Information Service. Sandia and NREL also make limited immediate distribution of technical reports to targeted industry, laboratory, and university representatives.

Each year, meetings and workshops are conducted to bring interested organizations, as well as researchers, scientists, engineers, and users together in technical forums to exchange technical and programmatic information. The DOE and Sun•Lab also participate in IEA/SolarPACES meetings and workshops. Industrial and end-user representatives and foreign and domestic researchers, scientists, and engineers are encouraged to visit the laboratories, solar thermal project sites, and test facilities to exchange information and ideas. Continuing academic and industry involvement through postdoctoral, sabbatical, visiting scientist, summer faculty, and student programs afford the opportunity for first-hand interactions with laboratory staff and facilities. Direct involvement in conducting significant portions of the research and development work through subcontracts to universities (including Historically Black Colleges and Universities) and industry offers a direct avenue for technology transfer and participation with the solar thermal community.



DOE/EE Solar Thermal Electric Program

FY97 Budget AOP Final 2/97	Sandia			NREL			DOE		Total		
	FTE$	Contr	**Total**	FTE$	Contr	**Total**	Org	**Total**	FTE$	Contr	**Total**
Solar Thermal Electric Total	**5155**	**7143**	**12298**	**2005**	**865**	**2870**		**7082**	**7160**	**15090**	**22250**
Technology Development (EB23-1101)	**3282**	**2271**	**5553**	**1239**	**388**	**1627**		**0**	**4521**	**2659**	**7180**
Optical Materials	27	10	37	597	102	699		0	624	112	736
Concentrators	741	298	1039	245	100	345		0	986	398	1384
Power Tower Technology	908	569	1477	39	3	42		0	947	572	1519
Dish Conversion Technology	1123	499	1622	195	25	220		0	1318	524	1842
Long Term R&D	163	446	609	123	148	271		0	286	594	880
Facility Support	320	449	769	40	10	50		0	360	459	819
Commercial Applications (EB23-1102)	**1873**	**4872**	**6745**	**766**	**477**	**1243**		**7082**	**2639**	**12431**	**15070**
Solar Two	991	350	1341	210	15	225	GO	2300	1201	2665	3866
Dish/Engine Projects	333	3192	3525	39	0	39		0	372	3192	3564
Parabolic Trough Projects	89	0	89	0	0	0		0	89	0	89
SolMat	56	1089	1145	142	240	382		0	198	1329	1527
Industry Assistance	215	70	285	10	10	20		0	225	80	305
Systems/Markets Analysis	93	25	118	347	65	412		0	440	90	530
Communications	56	71	127	18	32	50		0	74	103	177
HQ Discretionary/Taxes/Reductions	40	75	115	0	115	115	HQ	4782	40	4972	5012

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