SOLAR ♦ THERMAL ♦ ELECTRIC

Quarterly Progress Report

Third Quarter, FY96

July 1996

SOLAR•THERMAL•ENERGY

Sun♦Lab

Sandia National Laboratories, Albuquerque, NM
National Renewable Energy Laboratory, Golden, CO

Operated for the United States Department of Energy

SUMMARY OF ACCOMPLISHMENTS: THIRD QUARTER FY96

Significant progress toward program goals and objectives was made during the quarter. Following are selected highlights. Details can be found in the body of the report.

Solar Two

- Solar Two produced electricity for the Southern California Edison grid.
- The plant was dedicated on June 5, 1996, at a ceremony attended by Energy Secretary Hazel O'Leary.

Dish/Engine Joint Venture Programs

- Cummins installed a dish/Stirling system on the Georgia Tech campus and site of the 1996 Olympic Games.
- Cummins initiated Phase 2 USJVP activities.

Manufacturing and Technical Support

- The modified SOLERGY code was completed and transferred to the operators of SEGS I.
- We signed a CRADA with a small business solar manufacturer to develop a new absorber coating for trough applications.
- We completed six solar thermal technology application presentations in Mexico.

SolMaT

- SAIC and SKI both completed Phase 1 of their heliostat manufacturing projects.
- Rockwell completed Phase 1 of its central receiver manufacturing project.
- SolMaT strategic planning was initiated.

Systems and Markets Analysis

- A financial model was developed to evaluate tax equity issues.
- A promising new cermet selective surface coating was tested.
- A study was completed that looked at converting Solar Two into a Kokhala plant.

Concentrator Technology

- Kansas Structural Components, Inc. fabricated and delivered composite facets for evaluation.
- SKI and AlliedSignal have completed their dish/Brayton system design.

Power Tower Technology

- Sun♦Lab continues to support startup of Solar Two through technical consultations and on-site work.
- We completed the first-year activities of the Rockwell CRADA to develop an advanced molten-salt receiver.
- The heliostat field at the NSTTF has been significantly refurbished.
- The tower module has also been repaired and will be tested next quarter. This module will allow large test articles and equipment to be brought to the top of the tower for on-sun testing.

Dish Conversion Technology

- The felt-wick heat-pipe receiver tested with the STM engine was sectioned and examined for defects. A design was developed to test the same engine and condenser with a Thermacore nickel-wick receiver.
- A Sun♦Lab technician provided two weeks of on-site support to the NREC Brayton engine development effort, gaining valuable experience while assisting the NREC team.
- A prototype long-term materials compatibility capsule was tested for 100 hours and then sectioned to verify the design. Four more capsules were readied for long-term testing.

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INTRODUCTION

A need for new electric generating capacity, a heightened awareness of the environmental impacts associated with energy generation and use, and increased attention to energy efficiency will lead to a greater demand for solar thermal electric and other alternative energy technologies in the years ahead.

To date, over 350 MW_e of solar thermal electric systems have been installed in the United States, representing over 90% of the world's installed solar capacity. This power meets the needs of over 350,000 people and annually displaces the energy equivalent of 2.3 million barrels of oil. In addition, key cooperative joint ventures representing a 50/50 cost share between the federal government and the private sector have been established for power tower, parabolic dish/engine, and parabolic trough technologies. These joint ventures, valued at more than $150 million, strengthen the partnership among industry, utilities, and users. They are some of the current steps being taken to reduce levelized energy costs from solar thermal electric plants to between 6 and 10 cents per kilowatt-hour, thus leading to direct competition with conventional technologies.

OUR VISION

Our vision for solar thermal electric technology is the large-scale acceptance and installation of U.S.-designed and U.S.-manufactured solar thermal electric systems operating worldwide by early in the next decade. We expect to realize this vision through a coordinated program of joint venture projects, technology development and validation, and market conditioning.

OUR MISSION

The mission of the Solar Thermal Electric Program is to work with current and potential manufacturers and users of solar thermal electric technology to

- develop reliable and efficient solar thermal electric systems for generation of economically competitive power that can contribute significantly to the national energy mix and thereby reduce our dependence on imported energy sources,
- increase acceptance of this technology as a candidate for cost-competitive modular power generation by utilities, industry, and other user groups, both in the United States and abroad, and
- aggressively support the development of the industrial base required for this technology to penetrate a variety of energy applications and markets, creating new jobs and business opportunities for U.S. industry.

OUR STRATEGY

The Solar Thermal Electric Program strategy is consistent with the objectives set forth by the Department of Energy (DOE) in *Solar 2000—A Collaborative Strategy.*[1] The DOE and Sun♦Lab (a cooperative activity of Sandia National Laboratories and the National Renewable Energy Laboratory) will

- increase, through cooperative ventures, industrial participation in both the planning and execution of program elements. Specifically,
  - — the Solar Two molten-salt power tower project led by Southern California Edison will provide the technical base for the first commercial power tower plants.
  - — the Cummins Power Generation, Inc. (Cummins) 7-kW_e dish/Stirling system, designed for both remote and grid-connected applications, will be operated at utility and industrial sites.
  - — Science Applications International Corporation and Cummins, operating through the Utility Scale Joint Venture Program, will field 25-kW_e dish/Stirling systems, with the last phase of this program resulting in at least one megawatt of dish/engine system capacity installed by utilities.
  - — the SolMaT initiative will continue to support development of improved manufacturing capabilities for heliostats and other components to reduce costs in near-term markets.
- utilize the analytical and experimental capabilities of the program to support and enlarge the solar thermal technology base and our user, supplier, and decision-making constituency. Specifically,

[1] *SOLAR 2000—A Collaborative Strategy*, Office of Solar Energy Conversion, United States Department of Energy, Washington, D.C., February 1992.

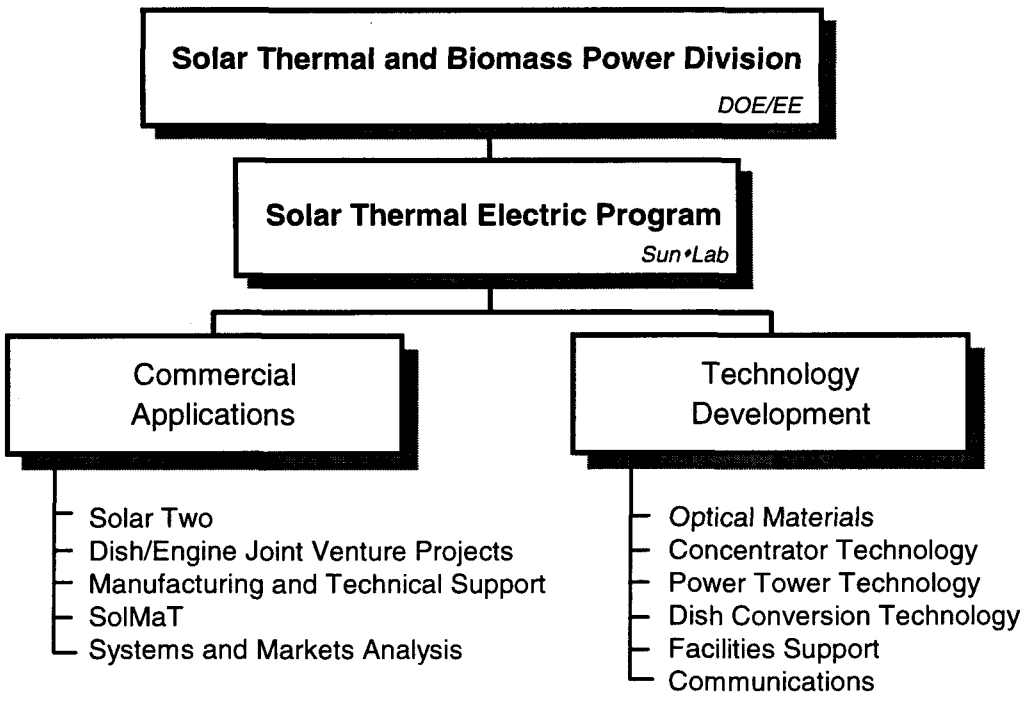
— industry/laboratory teams will extend the performance and reliability of critical system components (concentrators, receivers, optical materials, etc.) through focused research and development.

— industry and user requests for assistance will be addressed by the Solar Thermal Manufacturing and Technical Support program and other program resources.

— information exchange through conferences, road shows, and publications will be used to bring the technology to the attention of regulators, potential users, and the public.

OUR MANAGEMENT STRUCTURE

Specific implementation of the Solar Thermal Electric Technology Program is assigned to two field laboratories, Sandia National Laboratories in Albuquerque, New Mexico, and the National Renewable Energy Laboratory in Golden, Colorado. Sandia National Laboratories is the program's lead laboratory. Together, these two field laboratories are responsible for implementing the research and development plans that have been formulated to meet the objectives of the program. Activities are conducted both in-house at the laboratories and through subcontracts placed with private industry, other research organizations, and universities.



I. COMMERCIAL APPLICATIONS

The Solar Thermal Electric Program emphasizes two major categories of modular solar thermal technology: power towers (central receiver systems) and parabolic dish/engine systems. These two types of systems can satisfy utility needs for capacities ranging from a few kilowatts up to hundreds of megawatts. We also support parabolic trough system operations to help reduce operation and maintenance costs of future plants.

The program focuses on cost-shared activities led by industry. These government/industry partnerships represent teams uniquely qualified to rapidly advance the technology. The partnerships combine the manufacturing, marketing, and management skills of industry with the solar-specific experience base and analytical and experimental capabilities of Sun♦Lab. Presently, five major 50/50 cost-shared cooperative activities are underway within the program with a total value of more than $160 million. The following organizations are the private sector leaders of these joint activities:

- Southern California Edison and a consortium of other utilities and industry partners (Solar Two).
- Cummins Power Generation, Inc. and Science Applications International Corporation (dish/engine systems).
- KJC Operating Company (trough system operation and maintenance cost reduction).
- Science Applications International Corporation, Solar Kinetics, Inc. (heliostats), and Rockwell International Corporation (central receivers) (SolMaT).

A. SOLAR TWO

This goal of this project is to advance the near-term commercialization of solar power tower electricity generating facilities. The components for a power tower plant have been proven through testing and analysis. The next step in the commercialization of the technology is to design, construct, and operate a demonstration plant of a size that is large enough to reduce to acceptable levels the risks (technological and economic) of building the first commercial plant.

A consortium of U.S. utility concerns led by Southern California Edison Company (SCEC) is conducting a cooperative project with the U.S. DOE and industry to convert the 10-MW_e Solar One Central Receiver Pilot Plant to utilize molten-nitrate-salt technology. Successful design, construction, and operation of the converted plant, called Solar Two, will reduce the economic risks of building the initial commercial power tower projects and accelerate their commercial acceptance. Joining SCEC and the DOE in sponsoring this project are the following organizations: Los Angeles Department of Water and Power, Idaho Power Company, PacifiCorp, Sacramento Municipal Utility District, Arizona Public Service Company, Salt River Project, California Energy Commission, Electric Power Research Institute, South Coast Air Quality Management District, Bechtel Corporation, Rockwell International Corporation, and Nevada Power Corporation. Sandia chairs the project's Technical Advisory Committee (TAC) and supports the DOE in technically monitoring the project. The Solar Two Project converted the Solar One heat transfer system from water/steam to molten nitrate salt by replacing the water/steam receiver and oil/rock thermal storage systems with nitrate-salt receiver, thermal storage, and steam generator. The estimated cost of Solar Two, including its three-year test period, is $48.5 million. The plant is expected to be on line in early 1996.

Status

Startup and checkout of the Solar Two plant continued throughout this quarter

Accomplishments

Startup, Checkout, and Acceptance

- The plant produced grid electricity for the first time on April 4.
- We achieved a power production level of 9.9 MW_e.
- The plant was dedicated by Energy Secretary Hazel O'Leary on June 5.

Test and Evaluation

- We continued preparation and review of test procedures.
- Test 18, Corrosion and Salt Chemistry, was started.

Operations and Maintenance

- Energy Services, Inc. began operating the plant and essentially took over heliostat maintenance activities.

Programmatic

- A Steering Committee meeting was held on April 11, 1996. The committee approved an increase of the project expenditure limit to $49,030,000. Tom Williams of NREL presented an evaluation of the benefits and options for converting Solar Two to a commercial power plant.
- The TAC held its quarterly meeting on June 19. Operation and maintenance (O&M) activities and startup issues were the focus of the meeting.

Sun♦Lab Support

Sun♦Lab provided

- assistance solving a heliostat drift problem.
- assistance with a sun tracking problem.
- assistance identifying the cause of the receiver tube failure (see below).

Planned Activities for Next Quarter

- The plant will be repaired (see below).
- A cost/schedule recovery plan will be developed.

Issues

- On June 11, a single tube in a north receiver panel failed during operation. Approximately 2000 lbs. of salt was lost onto the ground. A detailed investigation by Bechtel, Rockwell, and Sun♦Lab confirmed that the tube failed because it overheated as a result of lack of cooling. Salt flow in the tube was restricted by corrosion debris from a carbon steel pipe. The source of corrosion was piping from within the plant where heat trace was improperly installed. This resulted in tremendous overheating of certain pipe sections leading to extreme internal and external corrosion. Large pieces of corrosion scale migrated through the salt system and accumulated in the receiver. The problem will be solved by (1) redoing all of the bad heat trace, (2) flushing the salt piping and receiver with a solution that dissolves corrosion scale, (3) verifying pipe integrity and replacing pipe if needed, and (4) adding strainers to the salt flow line.

This recovery plan is expected to delay the project for three months.

Major Milestones

Milestone	Planned	Actual
Plant acceptance; initiation of operations.	Feb 96 *Delayed.*	
Formal dedication of Solar Two.	Jun 96	Jun 96

Resources ($k)

	Sandia	NREL	DOE	Total
FTE Costs	603	85	0	**688**
Contracts	59	50	1,500	**1,609**
Total	**662**	**135**	**1,500**	**2,297**

B. DISH/ENGINE JOINT VENTURE PROJECTS

The objective of the dish/engine cooperative projects is to commercialize dish/engine solar thermal electric systems. The approach is to form joint ventures with industry, utilities, and other users. The Dish/Stirling Joint Venture Program (DSJVP) with Cummins Power Generation, Inc., underway since 1991, will develop a 7-kW$_e$ dish/Stirling system primarily for remote application. Two Utility Scale Joint Venture Program (USJVP) contracts with Science Applications International Corporation (SAIC) and Cummins will develop 25-kW dish/Stirling systems for utility application.

DSJVP

Status

The DSJVP team continued to work with the existing 5-kW$_e$ Clever Fellows Innovation Consortium (CFIC) Stirling engine/linear alternators. Engine/alternator output, however, is still limited to 2 to 3 kW$_e$. Problems with creep of the heat-pipe containment has also limited on-sun and test cell testing. Despite these problems, Cummins was able to install a system for demonstration at the 1996 Olympic Games. Engine design work and revised program planning were also conducted during the quarter. To eventually achieve 7 to 9 kW$_e$ net system output, Cummins made a decision to use the 25-kW$_e$ CFIC design as a starting point for a new engine design.

Accomplishments

- Cummins installed a power conversion unit on the CPG-460 solar concentrator at the SERDP Ft. Huachuca, Arizona, test site.
- Cummins installed a dish/Stirling system on the Georgia Tech campus and site of the 1996 Olympic Games.
- Cummins continued to operate dish-concentrators and calorimeters at the Texas Utilities test site in Dallas, Texas.
- Operation of the concentrators and heat-pipe receivers were suspended at the Central and South West Services, Inc. test site in Ft. Davis, Texas, and at the California State Polytechnic University (Cal Poly) test site in Pomona, California.

Planned Activities for Next Quarter

- Cummins will continue to design a free-piston Stirling engine for a 9-kW$_e$ net system.
- Cummins will demonstrate its dish/Stirling system at the 1996 Olympic Games.

SAIC/STM USJVP

Status

The objective of the USJVP is to develop 25-kW dish/Stirling systems for use in utility markets. The Energy Projects Division of SAIC in Golden, Colorado, leads a team comprising Stirling Thermal Motors (STM) of Ann Arbor, Michigan, and several utility partners. SAIC is the systems integrator and is also responsible for developing the solar concentrator and the second-generation faceted stretched-membrane dish. STM is developing the third generation of its kinematic Stirling engine for the project.

Accomplishments

- SAIC did not establish the source of its remaining Phase 2 cost share, and Sun♦Lab funds were not provided after April 30, 1996. SAIC chose not to continue development and the project has been on hold.
- Because of the status of the project, no decision was made on the heat-pipe receiver; facet production tooling was not completed; the concentrator design was not completed; and laboratory testing of the first Phase 2 power conversion system at STM was not started.

Planned Activities for Next Quarter

- We will make a decision on the heat-pipe receiver.
- SAIC will establish the remaining Phase 2 cost share.
- We will complete facet production tooling.
- We will "freeze" the concentrator design.
- We will begin laboratory testing of the first Phase 2 power conversion system at STM.

Issues

- SAIC needs to define the commitment of $1.7 million of required Phase 2 cost share before we can approve the resumption of Phase 2 activities. We are hopeful that this will occur by July or August.

Cummins USJVP

Status

Cummins Renewable Energy Corporation (CREC) initiated Phase 2 of the USJVP project on April 1. Work has begun on incremental improvements to each of the dish/Stirling subsystems. CREC has contacted STM to discuss the possibility of using its engine package with its Phase 2 system; an evaluation of the STM and Aisin-Seiki packages will be made in the next few months.

Accomplishments

- CREC initiated Phase 2 of the USJVP on April 1.
- CREC stopped testing the Aisin-Seiki engine 95-1 because of a failure in the test cell heat pipe.
- CREC continued researching various foam facet construction techniques.
- CREC initiated development of a system control and data acquisition (SCADA) control system for use in controlling a field of dish/engine systems.

Planned Activities for Next Quarter

- CREC will select the engine to be used for its Phase 2 system.
- CREC will complete its detailed, "bottoms-up" planning exercise for Phase 2.

Issues

- In May, Sandia transferred its DSJVP and USJVP contracts to CREC, a new organization that would be owned by Cummins Engine Company and a number of investors. On June 30, Cummins Engine Company suspended its solar division activities in Abilene, Texas. Continued development under our cost-shared contracts with CREC is dependent on Cummins Engine Company completing the deal with the new investors and forming CREC.

Major Milestones

Milestone	Planned	Actual
Deliver Cummins 7-kW_e system to Texas Utilities test site. *Concentrator delivered Nov 94.*	Mar 94 *Delayed until Dec 95.*	Nov 95
Deliver Cummins 7-kW_e system to Central and South West Services test site. *Concentrator delivered Nov 94.*	Apr 95 *Delayed.*	
Initiate backup NREC Brayton engine test cell testing at Cummins.	Apr 95 *Delayed.*	
Assemble first Cummins prototype 25-kW_e Stirling engine.	Sep 95 *Delayed.*	
Initiate laboratory testing of STM Generation III Stirling engine system. (SAIC)	Oct 95	Oct 95
Initiate testing of Aisin-Seiki 25-kW_e Stirling engine.	Nov 95	Dec 95
Start Phase 2 of SAIC USJVP.	Jan 96	Jan 96
Deliver Cummins 7-kW_e system to Cal Poly test site. *Concentrator delivered Dec 93.*	Feb 96 *Delayed.*	
Initiate testing of Cummins USJVP system.	Feb 96	Feb 96
Complete Phase 1 of Cummins USJVP; start Phase 2.	Apr 96	Mar 96
"Freeze" concentrator design. (SAIC)	Apr 96 *Delayed.*	
Make decision on heat-pipe receiver. (SAIC)	May 96 *Delayed.*	
Initiate testing of Cummins 7-kW_e water pump system.	Jun 96	
Test hybrid receiver on-sun. (SAIC)	Jul 96	
Down-select engine for the Cummins USJVP.	Sep 96	
Install first system at Mojave. (SAIC)	Sep 96	

Resources ($k)

	Sandia	NREL	DOE	Total
FTE Costs	277	100	0	**377**
Contracts	5,398	0	0	**5,398**
Total	**5,675**	**100**	**0**	**5,775**

C. MANUFACTURING AND TECHNICAL SUPPORT

The overall objective of the Manufacturing and Technical Support (MATS) task is threefold: (1) to provide timely and responsive technical support for users of solar thermal electric (STE) technology including domestic and selected international applications; (2) to apply Sun♦Lab's manufacturing expertise to assist solar thermal electric manufacturers in reducing the cost of their products; and (3) to initiate new activities and efforts as required by the program.

This task was initiated this year in response to program needs. In the past five years, the STE program has been engaged in a number of joint venture activities with industry that are producing new STE products. As these products are entering the prototyping and fielding phase of development, industry needs have shifted toward improving products' economic and field performance as well as reliability.

The national labs have a great deal of manufacturing and reliability improvement expertise that was developed in the defense programs. This MATS activity allows these capabilities to be applied on a timely and relevant basis. Manufacturer- and user-directed technical support will be provided on a case-by-case basis to users and manufacturers of STE technology. The MATS activity will allow the program to be continually flexible in supporting the constantly changing needs of the STE community. In addition, the MATS task will help initiate new activities as required by the STE program.

Status

During the quarter, the MATS team worked with the SolMaT team to coordinate their efforts for next year. The results of the effort helped identify what manufacturing efforts should be provided to industry and the responsibilities of the two programs. Assistance to SEGS I and II operators also continued. The modified SOLERGY code was completed and transferred to the operators. Training on the use of the code is underway. Additionally, the MATS team assisted Cummins on some of the critical issues involving engine reliability. In Mexico, presentations were made to critical audiences throughout the country. A Cooperative Research and Development Agreement (CRADA) was signed with a small business solar manufacturer to develop a new absorber coating for trough applications that is more environmentally safe than black nickel, has excellent optical properties, and costs less than other trough receiver coatings.

Accomplishments

- The SolMaT and MATS teams met for a strategic planning session for next year's program. The result was an agreement about what manufacturing assistance should be provided to industry and how to divide up the manufacturing assistance activities between the two programs. The MATS program will be responsible for small efforts that require quick response and short deadlines. The SolMaT program will handle more of the larger and long-term efforts.

- Sun♦Lab engineers at Sandia created a dynamic computer model of the 5-kW Stirling engine. The model allows researchers to precisely quantify the lateral loads on the linear bearing. It also allows the lateral loads to be analyzed visually using Sandia's virtual reality graphics system to help determine the cause of the side loading from possible sources such as the magnetic sensor located on the piston system.

- A CRADA regarding a new solar selective coating was approved this quarter. The CRADA is with Energy Laboratories, Inc. (ELI) and is intended to commercialize a new solar selective coating using both a batch and a strip-coating process. Sun♦Lab researchers have begun work on applying the new in-house coating methods developed at Sandia to the manufacturing process at ELI. The coating can be used for flat-plate or trough concentrator applications.

- Sun♦Lab engineers completed the training of Daggett Leasing Corporation engineers on the use of the modified SOLERGY code to predict SEGS plant performance. The code is now in use and is helping Daggett officials to prioritize future plant modifications. One of the results was that the oil coking problem and the field collector alignments were identified as the highest priority items to pursue. In addition, Sun♦Lab engineers worked with Daggett personnel to help develop a heat-collector element refurbishment technique using Pyromark® selective paint. This will continue to be pursued next quarter.

- In support of technology applications in Mexico, Sun♦Lab staff organized six STE technology presentations. The groups to which presentations were made include the Mexican National Commission for Energy Savings, the Sonora State Government and State Agribusiness group, the University of Sonora, Baja California Norte State officials, the National Engineering Conference, and Chihuahua government officials and businessmen. The presentations were well received and resulted in a verbal proposal to host a dish/Stirling demonstration project in Chihuahua.

Planned Activities for Next Quarter

- Sun♦Lab engineers will begin developing a modified SOLERGY code for the Harper Lake, California, SEGS facility, if Harper Lake personnel agree that it is useful to them.
- Two new efforts will be initiated with Daggett Leasing: (1) a contract will be issued to help investigate the oil coking problem, and (2) we will begin work with Kramer Junction Company on a training program for field alignment of the SEGS I and II fields.
- Under the CRADA, Sun♦Lab engineers will help implement the Sandia-developed selective coating process in ELI's manufacturing facility.
- Support to Cummins will continue in order to assist in improving the reliability of the engine.

Issues

- One of the milestones will be delayed or canceled. The milestone involves creating a modified SOLERGY code for the Harper Lake SEGS facility. The delay occurred because Harper Lake personnel indicated that their interest in the program has waned in recent months. We are continuing to work with them on the issue, but it is likely that they will not want the work done at this time. We will continue to work with them on other issues of interest.

Major Milestones

Milestone	Planned	Actual
Identify and initiate first manufacturing support activity.	Dec 95	Dec 95
Complete development of the Spanish version of the audio/ visual presentation on STE technologies.	Jan 96	Dec 95
Complete performance predictions for SEGS I and II based on recommended modifications.	Feb 96	Feb 96
Document support recommendations for all STE manufacturers.	Mar 96	Mar 96
Complete performance predictions for SEGS VIII and IX based on recommended modifications.	Apr 96 *Delayed.*	
Obtain a project proposal from key Mexican research institutions for a demonstration project.	Jun 96	Jun 96

Resources ($k)

	Sandia	NREL	DOE	Total
FTE Costs	163	0	0	**163**
Contracts	187	0	0	**187**
Total	**350**	**0**	**0**	**350**

D. SOLMAT

The objective of the solar manufacturing initiative is to develop manufacturing technology and processes that will permit cost-effective deployments of solar thermal systems in low-volume, early commercial applications; to reduce uncertainty in the cost and reliability of key solar components in order to improve financing of early commercial systems and reduce the risk of performance warranties; to promote the development of system-level business plans and industrial partnerships linking manufacturing scenarios to commercial sales prospects; and to establish the manufacturing basis for achieving the substantial cost reductions possible through higher volume production.

The Solar Thermal Manufacturing Technology (SolMaT) initiative is aimed at reducing the cost of solar thermal technologies in an environment of uncertain future sales and modest initial production volumes. In this way, SolMaT will fill a critical need for allowing solar thermal manufacturers to produce cost-effective products even before market demand will support high volume production.

Status

The SolMaT initiative presently has four subcontracts in place. SAIC of Golden, Colorado, and Solar Kinetics, Inc. (SKI) of Dallas, Texas, are both developing manufacturing technologies for heliostats in two-phase, multi-year efforts. Rockwell International Corporation (Rockwell), of Canoga Park, California, is developing improved manufacturing methods for central receivers in a nine-month effort. McDonnell Douglas Aerospace (MDA) of Huntsville, Alabama, is investigating alternate structural materials and manufacturing methods for dish/engine systems in a 12-month effort. In addition to subcontracted work, the initiative is applying capabilities of the Sandia Manufacturing Technology Center to industry's problems. Finally, SolMaT continues to sponsor Design for Manufacturing and Assembly (DFMA) workshops for our industry partners.

Accomplishments

- The Sun♦Lab SolMaT team conducted a strategic planning session on May 29, 1996. A primary objective of the session was to develop a coherent strategy that would lead to proposals for FY97 activities and to integrate SolMaT activities with other program elements. Key strategic elements identified at the meeting were a focus on near-term manufacturing issues, cost-shared collaborations with industry, technology transfer from the labs and U.S. industry in general to the solar industry, development of relationships with new manufacturing partners, a focus on international markets and how they may impact manufacturing scenarios, and DFMA workshops. In the next step, team members will use these strategic elements to make and rank recommendations on existing and new SolMaT activities.

- SAIC submitted a final report on Phase 1 of its heliostat manufacturing project. The report was reviewed and approved by Sun♦Lab staff. Starting the SAIC Phase 2 work is contingent on submitting a revised work plan and cost plan, which is imminent. SAIC is planning to compress the Phase 2 schedule from 24 months to 18 months to ensure adequate test time for its heliostats at Solar Two.

- SKI has determined that it may not be able to meet the cost-share requirements of its Phase 2 heliostat manufacturing project. The main reason for this is that the heliostat market and, therefore, recovery of the SKI investment in the cost share are too far in the future. SKI is presently working with its SolMaT partners to determine if other arrangements may be feasible.

- The Rocketdyne Division of Rockwell International Corporation completed Phase 1 of its SolMaT component manufacturing project with the delivery of a final report and presentation package. The Rockwell project consisted of four technical tasks 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. An additional task focused on a plan for a Phase 2 effort.

- MDA completed facet design specifications and drawings and placed purchase orders for production of prototype mirror facets. Bent Glass Designs of Kings of Russia, Pennsylvania, was selected to provide the prototype sagged glass facets after the original company, Eagle Convex Glass, encountered unrelated production problems at its factory. The Bent Glass Design sagged facets will be silvered by a second company, Silver Service of Chicago Heights, Illinois. The glass for the facets is being purchased from Erie Scientific of Portsmouth, New Hampshire. MDA completed a draft specification and design drawings for a manufacturable mirror facet/support structure with facet attachments and is ready to fabricate prototypes.

- The SolMaT initiative sponsored a DFMA workshop at Cummins on May 14-15, 1996, in Abilene, Texas. This workshop focused on the structural element that attaches the radial trusses to the ring beam of the Cummins dish concentrator. Attendance included staff from Cummins, WG Associates, and Texas Steel Company (both of Dallas, Texas). Hughes Electronics of El Segundo, California, facilitated the workshop. The main objective of the workshop was to determine if a casting could be used instead of a welded flange for this structural element. Material cost, fabrication, welding, and post-weld processing were seen as the main cost drivers for the baseline design.

- Pacific Northwest National Laboratories (PNL) has completed a heliostat cost normalization study. The purpose of this study was to bring to a common basis historical heliostat costs and to provide a better basis for judging progress of the SolMaT heliostat manufacturing studies. In addition, the study provides a historical heliostat price trend that is more defensible than those that have been published in the past. With regard to the present heliostat manufacturing projects, the normalization showed that heliostat prices well below $\$100/m^2$ are a real possibility now. The study also shows that the first phase of the SolMaT heliostat manufacturing projects reduced the price of heliostats by about 50%.

Planned Activities for Next Quarter

- SAIC will submit a cost plan for Phase 2 and will start the validation phase of its heliostat manufacturing project.

- We will make a final determination on whether SKI will be able to meet its cost-share obligations for Phase 2 of its heliostat manufacturing project.

- Rockwell will begin Phase 2 of its central receiver manufacturing project. In Phase 2, Rockwell will fabricate a receiver panel to demonstrate cost savings of improved manufacturing techniques, procedures, and design. It will test the panel in a central receiver environment. Phase 2 activities will be monitored by Sandia and coordinated with the current Rockwell CRADA to develop an advanced receiver.

- MDA will have the first prototype facets tested by the end of July. This surface quality testing will take place at MDA's Huntington Beach facility using its direct-insolation receiver flux mapping process. A small three-foot section of the support structure with facet attachments will be fabricated to validate the support structure manufacturing process. If successful, a full section of the center structure will be fabricated by the end of July. Testing of the complete structure will then be done to validate optical performance. A mid-term project review meeting will be scheduled within the next month to be attended by MDA and Sun♦Lab SolMaT staff.

Major Milestones

Milestone	Planned	Actual
Sponsor DFMA workshop for heliostat developer.	Mar 96	Dec 95
Complete SAIC Phase 1 heliostat work.	Apr 96	Apr 96
Complete SKI Phase 1 heliostat work.	Apr 96	Apr 96
Complete Rockwell Phase 1 central receiver work.	Jul 96	
Identify manufacturing technologies/methods for 20% cost reductions for near-term heliostat production.	Aug 96	

Resources ($k)

	Sandia	NREL	DOE	Total
FTE Costs	48	104	0	**152**
Contracts	200	879	0	**1,079**
Total	**248**	**983**	**0**	**1,231**

E. SYSTEMS AND MARKETS ANALYSIS

The objective of the systems and markets analysis task is to develop an improved understanding of solar thermal electric technologies and their applications, to support the analysis of advanced technology concepts, to identify ways to reduce capital and operation and maintenance costs and/or increase performance, and to identify the key issues affecting the commercialization of the technologies and market identification.

Status

During the quarter, a model was developed to carry out the next step in the tax equity analysis. Activities continued to support international development of STE technologies in India and Mexico. A promising new cermet selective surface coating was tested. We completed a draft report that examines the potential for converting the Solar Two project into a Kokhala plant.

Accomplishments

- Princeton Economic Research Institute (PERI), revised its cash flow model, FATE2-P (Financial Analysis Tool for Electronic Energy Projects), to perform the large-circle tax equity analysis used by Chapman in his FY95 Tax Equity Study. The PERI model was used to reproduce several of the Chapman cases. Excellent agreement was found between the FATE2-P model and the Chapman study results.

- We assessed the optical properties of a new cermet coating to be developed within the O&M Cost Reduction Program. Initial results indicate the emissivity of the new coating is about 40% lower than previously available coatings. This advancement significantly reduces heat losses in the solar field and is expected to lower the levelized energy cost from trough plants by approximately 4%.

- NREL Resource Assessment generated monthly and annual cloud-cover maps for Africa and Australia. An annual map was also generated for the northern hemisphere.

- We completed a draft report that examined potential Kokhala hybridization options at Solar Two. The report concludes that a Kokhala plant could produce electricity for about 6¢/kWh. Unfortunately this is double Southern California Edison's current projection of avoided cost at 3¢/kWh.

- We continued to provide comments to the World Bank on the Request for Proposal to build an Integrated Solar Combined-Cycle System (ISCCS) in Rajasthan, India. We attended a meeting at the World Bank to discuss these comments with the Indian authorities and the financiers associated with the project.

- We met with Indian officials at Solar Two to discuss the possibility of building a commercial-scale molten-salt power tower in Rajasthan. The officials stated they would welcome such a project and gave us a rough idea of the power purchase agreement.

- We completed a draft report that summarizes Spencer Management Associates' efforts to establish an ISCCS project in Mexico.

- We continued to help the DOE develop the strategic plan for the solar thermal program. This plan identifies the issues that need to be resolved over the next 20 years to meet the goals of the program.

Planned Activities for Next Quarter

- The tax equalization study will begin to identify which tax strategies best equalize the tax burdens between conventional fossil and renewable power technologies.

- A final interim O&M cost reduction report will be issued.

- The O&M Cost Reduction Program will begin a task to develop heat-collector elements with the new coating that was tested during the present quarter.

- A report will be generated to distribute the cloud-cover maps that have been generated for Africa, Asia, Australia, and South America.

- With Bechtel Corporation, we will begin a study to investigate the techno-economic feasibility of constructing a molten-salt power tower in Rajasthan, India.

Issues

- The tax equity study is behind schedule because of additional work that was undertaken to review a study performed by Oak Ridge National Laboratories. As a result, the draft Tax Equity Plan for Solar Thermal Electric Technologies will be delayed until the end of FY96 or early FY97.

- NREL Resource Assessment has not finished developing the methodology to be used for generating

international direct normal insolation (DNI) maps. However, cloud cover maps have been generated for all promising international regions.

Major Milestones

Milestone	Planned	Actual
Complete draft Tax Equalization Plan for solar thermal electric technologies.	Jun 96 *Delayed until Sep 96.*	
Complete DNI maps for promising international site.	Aug 96	

Resources ($k)

	Sandia	NREL	DOE	Total
FTE Costs	185	196	0	**381**
Contracts	45	0	0	**45**
Total	**230**	**196**	**0**	**426**

II. TECHNOLOGY DEVELOPMENT

Technology development projects support the commercialization activities 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.

A. OPTICAL MATERIALS

Low-cost, high-performance, and durable optical materials (reflector and absorber) are necessary to achieve the cost and performance goals needed for commercializing various solar thermal concentrating technologies. The objective of the optical materials task is to identify and develop advanced optical materials for solar-thermal applications that meet industry's commercialization needs. The optical materials team conducts basic research and analysis to better understand the fundamental properties that influence optical material performance; performs testing, characterization, and evaluation of candidate materials; and collaborates with the solar and materials industries to develop and test optical materials of near- and long-term interest.

Status

Optical materials development of advanced reflectors and absorbers has made substantial progress over the past quarter, specifically in the areas of industry collaboration. Current industry collaborations are with Energy Laboratories, Inc., SAIC, Industrial Solar Technologies (IST), and KJC Operating Company. We are working toward two new potential collaborations with Rockwell International Corporation and 3M Company, both of which will take advantage of existing or new capabilities at Sun♦Lab. Steps have been taken to boost in-house efforts, slowed down by staff cutbacks at NREL last quarter.

Accomplishments

- We held a very productive meeting with staff from 3M to discuss their corporate plans for an innovative next-generation solar reflector material. 3M has developed an innovative high-reflectance (>99%) material for nonsolar applications. We are interested in developing a collaborative arrangement with 3M to extend this material to solar applications, for example, high performance (>99% solar-weighted reflectance) and high outdoor durability.

- NREL and 3M researchers met with staff from IST to discuss quality control improvements in their current manufacturing line and potential areas for long-term improvement of ECP-305+ reflective film. Manufacturing and quality assurance improvements are of greater concern than long-term enhancements and offer greater short term benefit to 3M and IST. Staff have since recommended several improvements that may be incorporated into 3M's next run of the material.

- SAIC in McLean, Virginia, is continuing its investigation of ion-assisted alumina hardcoat coatings for protection of front surface silvered mirrors. SAIC has partnered with Sheldahl of Northfield, Minnesota, a leading web coating company that has expressed interest in developing and producing the material.

- NREL and Rockwell have agreed on a preliminary joint Statement of Work for a CRADA to develop advanced optical materials for heliostat applications. Under the CRADA, Rockwell will be responsible for procuring available reflector materials, carrying out internal development of advanced reflector materials, and developing cost and performance requirements specific to materials application. NREL will be responsible for accelerated and outdoor testing of the materials provided by Rockwell and for collaboration with Rockwell on its internal development efforts. The CRADA is expected to be signed at the beginning of next fiscal year.

- Degradation propagating from cracks and unprotected edges of thin-glass mirrors was observed in samples subjected to accelerated weathering in laboratory exposure chambers. Thin-glass samples from outdoor exposure test sites will be retrieved and analyzed in the near future to see if the accelerated test results are replicated in some of the more aggressive outdoor environments.

Planned Activities for Next Quarter

- We will install an advanced ion-assist deposition system. The system will be used initially in support of the proposed CRADA with Rockwell.

- We will finalize the CRADA for developing a black-nickel-based selective coating for low- to mid-temperature solar applications.

- Sandia staff will travel to ELI's facility to collaborate in scaling-up the solar selective coating process to an intermediate-sized continuous web process.
- We will complete negotiations on the Statement of Work for an NREL/Rockwell CRADA for advanced optical materials.
- We will recall outdoor thin-glass samples to analyze for degradation and compare results with indoor accelerated test data.
- We will begin hail testing on an SAIC dish facet in support of SAIC's USJVP contract (delayed last quarter because DOE suspended cost-share for Phase 2).

Major Milestones

Milestone	Planned	Actual
Initiate CRADA for mid-temperature selective absorber development.	Feb 96 *Delayed until May 96.*	Jul 96
Complete development of video-based reflectometer.	Feb 96	Mar 96
Document results of thin-glass survey.	Mar 96	Mar 96
Complete installation of advanced deposition system.	Jul 96	
Complete critical assessment and down-selection of materials.	Jul 96 *Delayed until Sep 96.*	
Document review of high-temperature absorber materials.	Aug 96	

Resources ($k)

	Sandia	NREL	DOE	Total
FTE Costs	130	819	0	**949**
Contracts	0	211	0	**211**
Total	**130**	**1,030**	**0**	**1,160**

B. CONCENTRATOR TECHNOLOGY

The objective of concentrator technology development is to bring heliostat and parabolic dish concentrators to commercial readiness for use in solar thermal electric systems. Concentrator technology 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. This task includes developing specialized instrumentation for optical measurement, optical materials, and concentrator evaluation techniques; providing industry support; and developing advanced concepts. As activities within this task become more developed and formalized, they generally "spin off" into their own projects within concentrator technology or another area of the Solar Thermal Electric Program.

Optical Tool Development

Status

The solar concentrator is the first component in the sequence of technologies that comprise a solar thermal electric power generation system. Because the concentrator provides the fuel for the system, it is important to know precisely how it performs. During this quarter we made advances on both the Video SHOT system and the beam characterization system (BCS), and prepared a presentation on the 2-*f* system.

Accomplishments

- We completed the Video SHOT laser scanner and video subsystems. Integration of the subsystems into the prototype is delayed until next quarter.
- The target for the BCS is currently being fabricated.

Planned Activities for Next Quarter

- We will complete the prototype Video SHOT system.
- We will assist Cummins with setting up a Video SHOT system.
- Video SHOT will be qualified in evaluating foam facets, Cummins facets, and the Kansas Structural Components, Inc. facets.
- The BCS components will be assembled into a system.

Industry Support

Status

As part of the concentrator technology task, we provide measurement and engineering in support of the dish/Stirling project and the Solar Two project and, more generally, to those requiring help designing or evaluating their concentrator design.

Accomplishments

- We provided test support for Solar Two heliostats.

Planned Activities for Next Quarter

- We will continue to provide support for dish/Stirling projects and Solar Two as needed.

Advanced Concepts

Status

Advanced concepts provide the "seeds" from which the next-generation technologies grow and mature. Under this task, we are focusing on a number of areas that have a major impact on the performance and cost of solar concentrators. We have contracts in place with Kansas Structural Inc. to provide composite facets, with Edtek, Inc. to produce a blow forming die and design an aluminum quenching subsystem, with SAIC to evaluate advanced drive concepts, and with SKI and Allied/Signal to complete a component conceptual design.

Accomplishments

- Kansas Structural fabricated and delivered several more 22-in. by 26-in. facets for extended testing and also delivered a Cummins gore facet.
- Edtek, Inc. completed the conceptual design of a forming chamber for integration with PNL's coating operation.
- Edtek, Inc. and PNL coated several small samples, which are currently being evaluated at NREL.
- Several new foam facet designs were fabricated and evaluated. One, a foamed-in-place urethane facet, shows good promise and will be used for additional evaluation.
- A finite-element model for the deflection of a foam facet under load was validated through experiment.

- The SAIC drive project selected a spring/worm wheel approach as the preferred drive concept. A number of laboratory tests have shown that this configuration is capable of carrying the types of loads required.
- SKI and AlliedSignal completed system conceptual design, component review, and commercialization plans for their dish/Brayton project. The final design review and final report will be completed next quarter.

Planned Activities for Next Quarter

- Kansas Structural will deliver a 3-m-diameter round facet for a faceted stretched-membrane dish to SAIC.
- Edtek, Inc. will fabricate a 48-in.-diameter prototype facet and also complete the cost estimates for facets formed using this process.
- We will use the Video SHOT system to test the facets manufactured by Kansas Structural.
- We will fabricate additional test bed concentrator (TBC)-like foam facets for test and evaluation.
- We will conduct the final design review for the AlliedSignal/SKI Dish Brayton Project.
- We will complete the final design report for the AlliedSignal/SKI Dish Brayton Project.

Major Milestones

Milestone	Planned	Actual
Complete support of USJVP dish test at Cummins.	Oct 95	Oct 95
Place advanced concentrator contracts.	Nov 95	Nov 95
Complete heliostat field upgrade support.	Nov 95	Nov 95
Review Video SHOT system design.	Dec 95	Dec 95
Test prototype TBC foam facets.	Mar 96	Mar 96
Complete Video SHOT prototype system.	May 96 *Delayed.*	
Complete SKI/AlliedSignal project.	Jul 96	
Test heliostat-type foam facets.	Sep 96 *Delayed.*	

Resources ($k)

	Sandia	NREL	DOE	Total
FTE Costs	850	104	0	**954**
Contracts	130	128	0	**258**
Total	**980**	**232**	**0**	**1,212**

C. POWER TOWER TECHNOLOGY

The purpose of the Power Tower Technology Development Project is to advance the development and commercialization of central receiver technologies by mitigating the risks of central receiver systems through research and development activities. We also support industry and utility concerns by conducting research on new concepts and by performing tests and analyses of components and procedures. The rationale for these activities is that there are significant demands for new generating capacity in foreign markets (estimated to be over 500 GW_e by 2002); these demands can partly be met by solar thermal central receiver technology. In addition there are significant commercial domestic renewable energy projects proposed (that is, National Solar Enterprise Zone, Sacramento Municipal Utility District (SMUD), plus possibly other small power tower projects). 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 plants. The Sun♦Lab participants will provide the technical expertise to industry for producing the first commercialization plants.

Status

This fiscal year, the main tasks in power tower technology have been the following: (1) support the Solar Two project on technical issues and with the test and evaluation phase; (2) continue developing an advanced receiver through the Rockwell CRADA; (3) refurbish the National Solar Thermal Test Facility (NSTTF) to support future receiver tests and facility projects; (4) conduct central receiver development tasks, which include impedance heating tests and molten-salt cold pipe tests; (5) conduct a study with the SMUD on combined cycle power towers; and (6) develop advanced concepts in central receivers (including testing of the International Energy Agency/Task III internal film receiver project at Plataforma Solar de Almeria, assessing (by modeling) potential low emissivity coatings, and completing experiments to measure corrosion rates of potential steam generator materials in nitrate salt).

Accomplishments

- Sun♦Lab continues to support the Solar Two project by providing technical assistance with receiver preheat and initial salt flow through the receiver.
- The first year of the Rockwell CRADA to develop an advanced power tower has been completed. A review of the first year's work was held in May. The second project year will include solar testing of tube samples or a panel. Activities in the Rockwell SolMaT project will be leveraged with the CRADA to make use of limited funding.
- The tower elevation module has been refurbished this quarter. The tower module is the large platform in the center of the NSTTF tower where test articles are built and elevated to the top. Refurbishment of this module will allow us to test large articles at the NSTTF; one such article will be a Rockwell panel. The elevation module will be tested next quarter.
- The heliostat field refurbishment has progressed well. We can reliably track 135 to 140 heliostats. The remaining 82 to 87 heliostats require much more extensive work to bring them on-line. For example, currently, there are no spare encoders available nor are there any commercial off-the-shelf replacements. We expect to have a replacement encoder source and funding requirements identified this summer and to be prepared to place an order when FY97 funds become available.
- Under contract, Service Optics Corporation of San Diego, California, is conducting a theoretical analysis of selective "pigments" for high temperature solar thermal applications. Preliminary results should be available next quarter on the potential for building a selective coating. In addition, SOLEL is interested in working with Sun♦Lab on designing a selective coating using the cermet technology.

Planned Activities for Next Quarter

- We will provide technical support to the Solar Two project.
- We will begin plan-year two activities for the Rockwell CRADA.
- We will test the tower elevation module at the NSTTF and continue heliostat field refurbishments and modifications.
- We will evaluate the potential of selective "pigments" for high temperature solar thermal applications.

Major Milestones

Milestone	Planned	Actual
Complete testing of the 500-kW_t Recepto Avandazo de Sales internal molten-salt film receiver at Plataforma Solar de Almeria.	Sep 95	Canceled
Complete corrosion testing of advanced steam generator materials for molten-salt applications.	Dec 95	Dec 95
Complete planned impedance heating tests.	Feb 96	Mar 96
Complete thermomechanical fatigue tests for Rockwell CRADA panel design.	May 96 *Delayed.*	
Complete molten-salt cold-pipe fill tests.	Jun 96	Feb 96
Complete process control upgrade for Rockwell panel test.	Jul 96	
Complete facility preparations for Rockwell panel test.	Sep 96	

Resources ($k)

	Sandia	NREL	DOE	Total
FTE Costs	685	120	0	**805**
Contracts	445	0	0	**445**
Total	**1,130**	**120**	**0**	**1,250**

D. DISH CONVERSION TECHNOLOGY

In cooperation with industry, Sun♦Lab has been engaged in a program to solarize, test, and evaluate power conversion systems that have the potential to be utilized in commercial solar-thermal electric point-focus systems. The goals of this program are to engage in projects that directly support ongoing commercialization efforts; to develop solar-thermal power-conversion systems that are candidates for commercialization; to pursue advanced development of solar-specific components; to identify and respond to solar-specific design issues; and to increase the general industry knowledge base on system integration and testing techniques. Support efforts have concentrated on Stirling engine performance improvements, Brayton system proof-of-concept, reflux receiver development and testing, and hybrid receiver development and support.

Status

We are investigating the cause of the hot spots we observed on several full-scale felt-wick receivers. We are preparing to integrate the existing Thermacore heat-pipe receiver with our STM engine for further on-sun heat pipe testing. The NREC Brayton engine was nearly ready for on-sun testing at Sandia, but a compressor failure has exhausted available funds and the program is on hold. We have progressed on the hybrid heat-pipe receiver design, and have correlated our models with laboratory results. We continue to directly support our commercial partners through design, analysis, and test support for both engines and receivers.

Accomplishments

- We cleaned and sectioned the heat-pipe receiver used on STM engine tests. We observed extensive corrosion areas and bulges on the wick structure. Results indicate that pretest cleaning procedures need to be improved.

- We performed tests on a 75-kW third-generation felt-wick receiver that uses a compressed layer of coarser felt to improve local liquid distribution. Hot spots developed on the absorber surface at vapor temperatures above 650°C. We cleaned and opened the receiver, but we observed no obvious causes of the overheating. Our plans to combine this receiver with the STM engine are on hold until the problems are resolved.

- We initiated work to interface the existing-design Thermacore heat-pipe receiver with our STM engine to further investigate performance enhancements of the heat pipe over the directly illuminated receiver.

- We provided analytical test and instrumentation support at Cummins to help determine the cause of minor hot spots on the full-scale Cummins receiver.

- We halted a long-term durability test on a bench-scale heat pipe after 1300 hours because of hot spots on the absorber surface. The wick structure appeared to be free of corrosion, but the wick was highly compacted above and below the evaporator area. Sections of the wick have been delivered to Sandia Labs in California for further examination.

- We completed 100 hours of testing at 700°C on a small felt-metal-wick heat pipe proposed for materials and cleaning studies. We cleaned and opened the device, and observed minor corrosion and a copper deposit. We completed fabrication of four additional capsules that will be used to explore various pretest cleaning procedures for long-term operation. Operation of the capsule pipes will begin early in the fourth quarter of FY96.

- We are nearly finished with preparations at Sandia for the NREC/DLR Brayton power conversion system test. Guido Domke, a German student working with DLR, spent two weeks helping NSTTF staff prepare.

- NREC continued to experience start-up problems with the Brayton engine; the most recent problem was a failure of the oil lubrication system that resulted in damage to the engine compressor. Bill Kolb provided several weeks of on-site hands-on technical support at NREC to gain experience in maintaining the engine and to improve the possibility of successful operation. Our funding for this project has been exhausted. Further work will await consideration of this project during the budgeting process for FY97.

- We completed a detailed performance and emissions map of the metal matrix burner and developed correlations of the measured data. We will use these correlations to examine design tradeoffs in the hybrid heat-pipe burner system and to calibrate our heat-transfer model.

- We completed preliminary computational fluid dynamics calculations of flow and heat transfer and finite-element thermal-stress analysis for candidate burner convection section configurations. Results for the best configurations will be coupled with the performance and emissions correlations as described above.

- We discussed the hybrid-receiver pin-fin heat exchanger concept with fabrication shops and began receiving cost estimates and fabrication samples.

- Sun♦Lab staff reviewed the Cummins second-generation hybrid heat-pipe design report. In general, staff felt that the work should continue into the fabrication phase. Cummins is responding to particular review comments prior to the start of the second phase.

- We submitted a proposal to the Sustainable Technology Energy Partnerships program to conduct metal matrix burner lifetime testing. The proposed work, a collaboration between NREL and the California Energy Commission, would focus on a critical design criteria for using these low-NOx burners in dish/Stirling systems.

- Steve Goods and Bob Bradshaw continue to analyze the Stirling Technology Company NaK capsule tests. Under Steve Good's supervision, AdTech continues elevated temperature fatigue tests on Thermacore's spherical-powder-nickel wick.

- We continued discussions with the Institute for Physics and Power Engineering of Obninsk, Russia, on the subject of applying its sodium heat-pipe technology to extend reflux-receiver-wick lifetime.

- Mona Fowler, a Master's degree candidate at North Carolina Agricultural and Technical State University (NCA&T), successfully defended her dissertation on the use of artificial neural networks to model reflux receiver performance, a work performed in collaboration with Sandians Jim Moreno and Phil Heerman, under the auspices of the DOE Science and Technology Alliance.

- Jim Moreno continues to work with Mary Murdock, a Ph.D. student in Mechanical Engineering at NCA&T, to formulate a dissertation topic on reflux-receiver transient thermal stress.

- We have completed the installation of a hydraulic cylinder on both test bed concentrators, used in the event of an elevation drive failure to prevent permanent damage to the dish.

Planned Activities for Next Quarter

- We will integrate the STM 4-120 engine heat-pipe heads with the existing Thermacore/Cummins heat-pipe design. The receiver will be fabricated and filled this quarter, and tested in the first quarter of FY97.

- We will begin long-term testing of the cleaning-procedures heat-pipe test capsules.

- We will continue test and analysis support of the Joint Venture Program engine and receiver tasks.

- We will use burner performance and emissions correlations to perform design tradeoffs for the hybrid heat pipe. Performance and manufacturing issues associated with the convection section will be resolved. We anticipate shifting the focus of this work to burner lifetime in the near future.

- We will complete our investigation of full-scale felt-wick heat-pipe hot spots and design a new version of the receiver to address any issues discovered.

- Fabrication of the Cummins/Thermacore second-generation hybrid heat pipe is on hold until the financial relationships with Cummins are resolved.

- We will continue collaborations with NCA&T, and we will review proposed dissertation research, to be performed for Sun♦Lab by a Ph.D. candidate at NCA&T, under the auspices of the DOE Science and Technology Alliance.

Issues

- NREC requires more funding to overcome difficulties experienced with compressor-stage failure.

- Cummins/Thermacore hybrid receiver work is on hold until Cummins resolves its working relationship with the solar project team.

Major Milestones

Milestone	Planned	Actual
Complete integrated testing of STM engine with a heat-pipe receiver.	Feb 96	Mar 96
Begin materials compatibility capsule tests.	Feb 96	Mar 96
Complete testing of third-generation heat-pipe receiver.	Mar 96 *Delayed until May 96.*	May 96
Complete testing of NREC Brayton system.	May 96 *Delayed indefinitely.*	

Resources ($k)

	Sandia	NREL	DOE	Total
FTE Costs	1,267	118	0	**1,385**
Contracts	820	150	0	**970**
Total	**2,087**	**268**	**0**	**2,355**

E. FACILITIES SUPPORT

The DOE's National Solar Thermal Test Facility (NSTTF) is the primary test facility for testing solar thermal components and systems in the United States. The facility is also a DOE Designated User test facility. Originally constructed as the Central Receiver Test Facility in the late 1970s, the mission of the facility has been expanded to include distributed solar thermal technologies, solar furnace testing, and engine testing for solar technologies. In addition, the unique capabilities of the NSTTF are often applied to a wide variety of tests unrelated to solar energy that require high temperature, high flux, and excellent data acquisition capabilities. The facility support activity covers the basic operation and maintenance of the NSTTF.

Status

The NSTTF continues to support all the technology development programs and many of the commercial applications projects. All facility support for those programs and projects is covered in other parts of this report. In addition to the test and evaluation support, the NSTTF staff continues to maintain an excellent record in addressing environmental, safety, and health (ES&H) requirements. A significant effort during this year is to remove old and unneeded systems and test fixtures. We are also pursuing other nonrenewable test and evaluation business opportunities to leverage the operation and maintenance cost of the facility.

Accomplishments

- We continued refurbishment of the NSTTF field. This quarter approximately 22 control boards for the heliostat-control elements (HCEs) were repaired, 36 HCEs were repaired and placed in the field, and 19 heliostat drives were replaced. We currently have 150 functional heliostats.
- We completed refurbishing the elevating module in the tower. An operating procedure is being prepared to operate the module.
- We completed installation and checkout of the new controllers for the Distributed Receiver Test Facility.
- We completed the initial "coupon tests" for Applied Physics Laboratory on our Work for Others project. This test involved three days of solar testing at the 79-m test bay. We continued to prepare the heliostat field and 79-m test bay for conducting boresite measurements on a new radome.
- We prepared a user facility proposal for the University of Chicago to use NSTTF for conducting astrophysics experiments. The University of Chicago and other universities will use the NSTTF field as a large antenna to conduct their experiments. Work will begin in August 1996.
- We removed a number of "old" experiments, including the direct absorption receiver Large Water Flow Experiment and the molten salt electric experiment 5-MW fluid coolers.

Planned Activities for Next Quarter

- We will continue to repair and modify the heliostat field.
- We will initiate the user facility testing with the University of Chicago at the 79-m test bay.
- We will continue the fabrication, installation, and testing for the Work for Others contract with Applied Physics Laboratory.
- We will continue to remove obsolete equipment and tests.

Major Milestones

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

Resources ($k)

A majority of the NSTTF's activities, including maintenance and upgrade, are funded proportionately by all users, the majority of which are associated with the Solar Thermal Electric Program. However, the funds shown below apply to the core operation of the facility.

	Sandia	NREL	DOE	Total
FTE Costs	100	0	0	**100**
Contracts	100	0	0	**100**
Total	**200**	**0**	**0**	**200**

F. COMMUNICATIONS

The objective of the Sun♦Lab Communications Team is to create effective communications products for the DOE's Solar Thermal Electric Program. These products and related exhibit materials explain the results of work performed by Sun♦Lab and make results of research available to the constituents of the program.

Status

During the third quarter of FY96, the Sun♦Lab Communications Team met two more of its milestones, continued working on the next milestones, and began planning for FY97.

Accomplishments

- The Solar Two conference center exhibit room was completed for the Solar Two dedication on June 5.
- Dish/Stirling brochures and a sign for the dish/Stirling system were completed in time for the 1996 Summer Olympic Games in Atlanta.
- A draft Sun♦Lab Word Wide Web site was established in time to carry information about the Solar Two dedication.
- The Solar Two brochure is being distributed through EREC, a national information distribution service.

Planned Activities for Next Quarter

- Jim Jones (NREL), Anne Van Arsdall (Sandia), Joe Flores (SCE), and Rick Clyne (an NREL contractor) will coordinate shooting of a video at Solar Two and developing a script for the video.
- Jones will continue to identify and target publications in which to place a major article about Solar Two.
- Jones, Van Arsdall, and Mark Mehos of NREL will continue development of a draft World Wide Web site for a development server.
- Jones and Van Arsdall will contact leaders of Sun♦Lab projects among staff members from Sun♦Lab, DOE sponsors, and industry partners to identify communications needs for FY97.

Major Milestones

Milestone	Planned	Actual
Complete Solar Two brochure (carryover from FY95 under the Technical Information Program).	Mar 96	Mar 96
Produce brochure and Soltech '96 exhibit for Sun♦Lab.	Mar 96	Mar 96
Provide support, including an informational video, for the Solar Two inauguration and visitor center.	Jun 96	Jun 96
Establish draft Sun♦Lab home pages on the Internet.	Jun 96	Jun 96
Create a brochure on dish/Stirling for the 1996 Summer Olympic Games.	Jul 96	Jun 96
Place an article about Solar Two in a national magazine.	Sep 96	
Place an in-flight Solar Two video on an airline video program.	Sep 96	
Update the Sun♦Lab home pages on the Internet.	Sep 96	

Resources ($k)

	Sandia	NREL	DOE	Total
FTE Costs	25	60	0	**85**
Contracts	15	0	0	**15**
Total	**40**	**60**	**0**	**100**

Publications

Dish/Stirling brochure, published June 1996.

Fowler, M., D. Klett, J.B. Moreno, and P.D. Heerman, SAND95-2789C, ***Using Artificial Neural Networks to Predict the Performance of a Liquid Metal Reflux Solar Receiver: Preliminary Results,*** Prepared for the Fourth Annual Historically Black Colleges and Universities/Private Sector—Energy Research and Development Technology Transfer Symposium, Greensboro, North Carolina, April 1996.

Jorgensen, G.J., H.M. Kim, and T.J. Wendelin, **"Durability Studies of Solar Reflector Materials Exposed to Environmental Stresses,"** *Durability Testing of Non-Metallic Materials, ASTM Special Technical Publication 1294,* Robert J. Herling, Ed., American Society for Testing and Materials, Philadelphia, Pennsylvania, January 1996.

Kim, H.M., G.J. Jorgensen, D.E. King, and A.W. Czanderna, **"Development of Methodology for Service Lifetime Prediction of Renewable Energy Devices,"** *Durability Testing of Non-Metallic Materials, ASTM Special Technical Publication 1294,* Robert J. Herling, Ed., American Society for Testing and Materials, Philadelphia, Pennsylvania, January 1996.

Perez, R., D. Menicucci, J. Anderson, **"Calculating Solar Radiation Received by Tubular Concentrators,"** Transactions of the American Society of Mechanical Engineers, *Journal of Solar Energy Engineering,* Vol. 117, No. 4, November 1995.

Solar Two brochure, published for SOLTECH '96, March 1996.

Stine, W.B., **"Solar Electric Applications of Stirling Engines,"** *Proceedings of the 7th International Conference on Stirling Machines, November 1995, Tokyo, Japan.*

Strachan, J.W., R.B. Diver, and C. Estrada, **"Dish/Stirling Systems: Overview of an Emerging Commercial Solar Thermal Electric Technology,"** *Proceedings of the 1995 Annual Meeting of the Mexican Solar Energy Association, October 1995.*

Sun♦Lab brochure, published for SOLTECH '96, March 1996.

Tyner, C.E., J.P. Sutherland, and W.R. Gould, Jr., **"Solar Two: A Molten Salt Power Tower Demonstration,"** *VDI Berichte 1200, Verein Deutscher Ingenieure: SolarThermische Kraftwerke II Tagung Stuttgart, 11 und 12 Oktober 1995. ISBN 3-18-091200-6.*

Publications In Progress

Adkins, D.R., C.E. Andraka, R.W. Bradshaw, S.H. Goods, J.B. Moreno, and T.A. Moss, ***Mass Transport, Corrosion, Plugging, and Their Reduction in Solar Dish/Stirling Heat Pipe Receivers,*** Prepared for Intersociety Energy Conversion Engineering Conference, August 1996, Washington, DC.

Andraka, C.E., et al., SAND94-1538, ***NaK Pool-Boiler Solar Receiver Durability Bench Test, Vol. 1: Test Design and Results,*** Sandia National Laboratories, Albuquerque, New Mexico.

Andraka, C.E., K.S. Rawlinson, T.A. Moss, D.R. Adkins, J.B. Moreno, D.R. Gallup, and P.G. Cordiero, ***Solar Heat-Pipe Testing of the Stirling Thermal Motors 4-120 Stirling Engine,*** Prepared for Intersociety Energy Conversion Engineering Conference, August 1996, Washington, DC.

Jorgensen, G., J. Pern, S. Kelley, A. Czanderna, and P. Schissel, **"Polymers for Solar Energy Devices,"** *Functional Polymers for Emerging Technologies,* American Chemical Society.

KJC Operating Company, ***O&M Cost Reduction Study,*** second interim report.

Lippke, F., ***Part-Load Behavior of SEGS Plants,*** draft report, to be published.

Lippke, F., ***Solar Two Overall Efficiency at Reduced Receiver Outlet Temperatures,*** draft report, April 14, 1995.

Moreno, J.B., et al., ***Solar Dish/Receiver Calorimetry Uncertainty Analysis,*** draft report.

Pacheco, J.E., and W.J. Kolb, **"Testing of An Impedance Heating System for Solar Power Tower Applications,"** *Proceedings of the 1996 National Heat Transfer Conference, August 3-5, 1996, Houston, Texas.*

Prairie, M.R., J.E. Pacheco, and G.J. Kolb, **"Solar Central Receiver Technology: The Solar Two Projected,"** *Proceedings of the 1996 National Heat Transfer Conference, August 3-5, 1996, Houston, Texas.*

Price, H., ***Solar Two Kokhala Analysis,*** draft report, NREL, June 1996.

Spencer Management Associates, ***Mexico ISCCS Project,*** draft report.

Meetings and Presentations

Fowler, M., D. Klett, J.B. Moreno, and P.D. Heerman, ***Using Artificial Neural Networks to Predict the Performance of a Liquid Metal Reflux Solar Receiver: Preliminary Results,*** SAND95-2789C, to be presented at the Fourth Annual Historically Black Colleges and Universities/Private Sector—Energy Research and Development Technology Transfer Symposium, April 1996, Greensboro, North Carolina.

Grossman, J.W., and R.M. Edgar, ***Transforming the Sandia 2-f Optical Performance Measurement System to Color,*** SAND96-0204C, presented at the American Society of Mechanical Engineers International Solar Energy Conference, March 31-April 3, 1996, San Antonio, Texas.

Jones, S.A, ***Annual Performance Predications for Off-Axis-Aligned LUGO Heliostats at Solar Two,*** presented at the American Society of Mechanical Engineers International Solar Energy Conference, March 31-April 3, 1996, San Antonio, Texas.

Jones, S.A, ***A Comparison of On-Axis and Off-Axis Heliostat Alignment Strategies,*** Solar 96, presented at the 1996 Annual Conference of the American Solar Energy Society, April 1996, Asheville, North Carolina.

Pacheco, J.E., and S.R. Duncan, ***Assessment of Molten-Salt Solar Central-Receiver Freeze-up and Recovery Events,*** presented at the American Society of Mechanical Engineers International Solar Energy Conference, March 31-April 3, 1996, San Antonio, Texas.

Pacheco, J.E., and W.J. Kolb, ***Testing of An Impedance Heating System for Solar Power Tower Applications,*** to be presented at the 1996 National Heat Transfer Conference, August 3-5, 1996, Houston, Texas.

Prairie, M.R., J.E. Pacheco, and G.J. Kolb, ***Solar Central Receiver Technology: The Solar Two Projected,*** to be presented at the 1996 National Heat Transfer Conference, August 3-5, 1996, Houston, Texas.

Price, H., D. Whitney, H. Beebe, ***SMUD Kokhala Power Tower Study,*** presented at the American Society of Mechanical Engineers International Solar Energy Conference, March 31-April 3, 1996, San Antonio, Texas.

Price, H., ***Integration of Solar Thermal Electric Technologies with Gas Turbine Systems,*** presented at the Electric Power Research Institute Gas Turbine Workshop, March 27-28, 1996, Denver, Colorado.

Price, H., ***Solar Thermal Hybrids: The Next Step,*** presented at the SOLTECH/UPVG 1996 Annual Meeting, March 13, 1996, Palm Springs, California.

Stine, W.B., ***Solar Electric Applications of Stirling Engines,*** presented at the 7th International Conference on Stirling Machines, November 1995, Tokyo, Japan.

Strachan, J.W., R.B. Diver, and C. Estrada, ***Dish/Stirling Systems: Overview of an Emerging Commercial Solar Thermal Electric Technology,*** presented at the 1995 Annual Meeting of the Mexican Solar Energy Association, October 1995.

Tyner, C.E., J.P. Sutherland, and W.R. Gould, Jr., ***Solar Two: A Molten Salt Power Tower Demonstration*** in VDI Berichte 1200, Verein Deutscher Ingenieure: SolarThermische Kraftwerke II Tagung Stuttgart, 11 und 12 Oktober 1995. ISBN 3-18-091200-6.

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