SOLAR ♦ THERMAL ♦ ELECTRIC

Quarterly Progress Report

Second Quarter, FY96

April 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: SECOND 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 energy was used to heat salt and generate steam for the first time. Most of the heliostats were brought on line.

Dish/Engine Joint Venture Programs

- Cummins fielded a CFIC engine/alternator at the Ft. Huachuca, Arizona, test site.
- Cummins completed Phase 1 of its USJVP and SAIC started Phase 2.
- SAIC and International Power Associates have formed a limited liability corporation, called Solar Energy International Corporation, to market dish/Stirling systems.
- STM has accumulated more than 6000 hours of gas-fired operation on its Generation III, 4-120 Stirling engines.

Manufacturing and Technical Support

- We conducted technology roadmapping for all of the solar thermal electric technologies. The results of the roadmapping effort will be integrated into the DOE solar thermal electric strategic plan.
- We completed development of the modified SOLERGY code that will be used by the Daggett Leasing SEGS operators to prioritize plant upgrades.

SolMaT

- Based on completion of its Phase 1 Heliostat Manufacturing project, SAIC is now projecting a heliostat price of \$113 per m^2 for a production of 2000 units per year.
- Solar Kinetics, Inc. has substantially completed its Phase 1 Heliostat Manufacturing project and that work has resulted in a reduction in the cost of its large-area glass/metal heliostat by 10% to 12%.
- A fourth SolMaT contract, to work on manufacturing improvements for dish concentrators, was started with McDonnell Douglas Corporation.

Systems and Markets Analysis

- We initiated a joint effort with Princeton Economic Research Institute, NREL Analytic Studies, and Sun♦Lab to verify the FY95 tax equalization study.
- We completed a draft interim report on KJC O&M Cost Reduction Study.
- Sun♦Lab supported the International Energy Agency Egyptian solar thermal electric team.
- We generated cloud-cover maps for Egypt, India/Middle East, and South America.

Concentrator Technology

- Kansas Structural, Inc. delivered prototype Fiberglas® for test and evaluation.
- The Edtek project to fabricate blow-formed concentrator facets and gores was started.

Power Tower Technology

- Sun♦Lab supported Bechtel and Rockwell with startup by providing technical assistance with receiver preheat and initial salt flow through the receiver.
- Most of the thermomechanical fatigue experiments on advanced materials for the Rockwell CRADA central receiver were completed.
- We tested an impedance heating system as a potential alternative to heat trace and found it to work well.
- Efforts to refurbish the NSTTF, including repairing the heliostat field, upgrading the data acquisition system, and bringing the elevation module into service, are progressing well.

Dish Conversion Technology

- Sun♦Lab successfully tested the STM 4-120 Stirling engine with a second-generation felt-wick heat-pipe receiver. The power output of the engine improved from 17 kW_e to 21.5 kW_e under similar operating conditions, and the net system efficiency improved from 21.7% to 27.1%.
- We began testing a prototype materials-compatibility heat pipe and have begun fabrication of 12 more units.
- We began a detailed design of a hybrid heat-pipe solar receiver.
- We completed validation of a portable emissions bench and compiled a report on the emissions requirements several states.

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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.

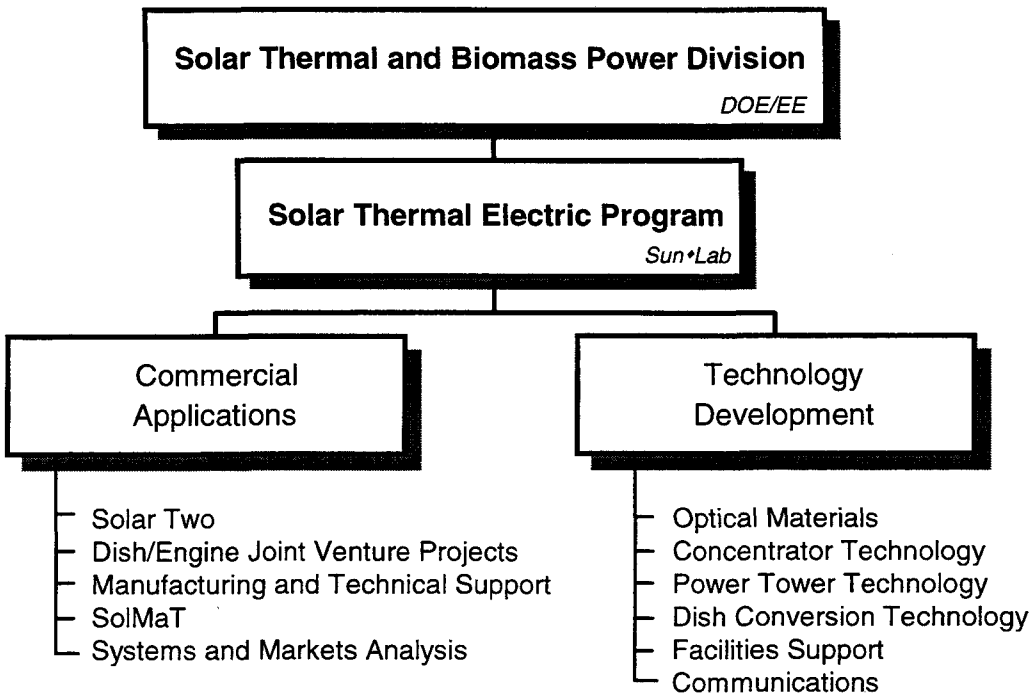
— industry/laboratory teams will extend the performance and reliability of critical system components (concentrators, receivers, optical materials, etc.) through focused research and development.

— 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 (SCE) 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 SCE 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

- We made 1,556 of the 1,818 Solar One heliostats serviceable and brought 25 of the 108 LUGO heliostats on line.
- We completed water flow testing and began salt flow tests.
- The receiver was used to heat salt with sunlight.
- We used the steam generator for the first time to generate steam using solar-heated salt.

Test and Evaluation

- We continued preparation and review of test procedures.

Operations and Maintenance

- Energy Services, Inc. began to support Bechtel Corporation's startup and became familiar with plant operations.

Programmatic

- A Steering Committee meeting was held on January 11, 1996.
- The TAC held its quarterly meeting on February 20. Project status as well as test and evaluation were discussed. Science Applications International Corporation (SAIC) and Solar Kinetics, Inc. (SKI) made presentations on their SolMaT heliostat activities.

Sun♦Lab Support

Sun♦Lab provided:

- technical assistance during receiver operation tests.
- major on-site support of the heliostat trouble-shooting activities.
- strategies for thawing frozen receiver panels.
- infrared survey of major salt equipment to identify sources of heat loss.

Planned Activities for Next Quarter

- Electricity will be produced from solar energy.
- The 100-hour acceptance test will be performed.
- The plant will be turned over to SCE for operation.
- The Solar Two dedication will occur on June 5.

Issues

- Unforeseen problems with the heliostat field, the receiver, and the salt systems have significantly delayed acceptance, which is now scheduled for next quarter.

Major Milestones

Milestone	Planned	Actual
Plant acceptance; initiation of operations.	Feb 96 *Delayed.*	
Formal dedication of Solar Two.	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 and managed to install a power conversion unit (PCU) on the CPG-460 solar concentrator at the Ft. Huachuca, Arizona, Strategic Environmental Research and Development Program (SERDP) system. Engine/alternator output, however, was limited to 2 to 3 kW_e. 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.

Accomplishments

- Cummins installed a PCU on the CPG-460 solar concentrator at the SERDP Ft. Huachuca, Arizona, test site.
- Cummins continued to operate dish-concentrators and calorimeters 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.
- Thermacore continued full-scale thermal-cycle testing of felt-wick and sintered-powder-wick heat-pipe receivers on quartz lamps at its Lancaster, Pennsylvania, facility.
- We reviewed the design of a Cummins next-generation glass/metal dish, which will feature trapezoidal-shaped parabolic gore facets and an elevation-over-azimuth drive.

Planned Activities for Next Quarter

- Cummins will implement changes to the CFIC engine design that will hopefully resolve the engine's durability and performance problems.
- Cummins will deliver a PCU to the Cal Poly Pomona test site.
- Cummins will deliver a demonstration system to 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

- Phase 2 of the project started in mid-January.
- The Phase 2 Work Plan for the project was updated by SAIC and STM.
- A limited liability corporation, Solar Energy International Corporation, was formed by SAIC and International Power Applications to market energy and sell dish/Stirling systems.
- A new, low-cost controller has been developed and integrated into the design. The Phase 1 dish control software has been revised.
- The solar-only/gas-only receiver design configuration is established. The gas burner is under test and preliminary indications are that it will meet California emission standards.
- STM has accumulated more than 6000 hours of testing on its Generation III 4-120 engines and test rigs and achieved thermal-to-mechanical efficiencies greater than 40% and power outputs (gas-fired) greater than 30 kW.
- On-sun testing of the Phase 1 dish/Stirling system continues at SAIC's Golden, Colorado, test site. As of the end of March, the system had accumulated more than 200 hours of on-sun operation; it generated more than 1.6 MW hours of power; and it set a new system maximum power output record of 21.6 kW_e.

Planned Activities for Next Quarter

- We will make a decision on the heat-pipe receiver.
- SAIC will establish 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 for an April 30, 1996 deadline.

Cummins USJVP

Status

Thermacore completed integration of a heat pipe with the Aisin-Seiki engine in late January. The completed power conversion system was sent to Cummins for testing on-sun. This testing was begun in mid-February and continued through March. The engine produced 20 kW_e at 26% thermal-to-electric efficiency with a solar insolation of 950 W/m^2. The system power was limited by the capability of the heat pipe.

Accomplishments

- A review of the Thermacore second-generation hybrid heat pipe was held in January. Additional stress analysis is required.
- Thermacore completed integrating the Aisin-Seiki engine with a heat pipe.
- Cummins operated a complete dish/Stirling power system in February at a power level of 20 kW_e and a thermal-to-electric efficiency of 26%.
- Cummins completed Phase 1 of the USJVP in March.

Planned Activities for Next Quarter

- Phase 2 of the program will be initiated.
- Cummins will perform a detailed, "bottoms-up" planning exercise for Phase 2.
- NREL will complete assembly of its 30-kW_e Brayton engine for Cummins.

Issues

- Cummins has ended its working relationship with CFIC.

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 until Jul 96.*	
Initiate backup NREC Brayton engine test cell testing at Cummins.	Apr 95 *Delayed until Jun 96.*	
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 until May 96.*	
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	
Make decision on heat-pipe receiver. (SAIC)	May 96	
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 this 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, which 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 task conducted technology roadmapping for all of the STE technologies. The results of the roadmapping effort will be integrated into the DOE STE strategic plan. Assistance to SEGS I and II operators also continued. The modified SOLERGY code was completed and transferred to other operators. Training on the use of the code is underway. Additionally, the MATS task assisted Cummins on some of the critical issues involving engine reliability. In Mexico, presentations about solar electric technology are now being presented to critical audiences throughout the country. Additionally, MATS coordinated with the SolMaT task to assist in reducing the cost of facet manufacturing. A CRADA is also being developed 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

- Technology roadmapping, which has been used in other U.S. industries, has been applied to the STE program as part of the strategic planning. The technology roadmapping effort produced roadmaps for each of the three solar thermal technologies. The roadmaps outlined the technology development needs for each of these technologies through the year 2015. A number of new technology development needs were identified, including the requirement to begin developing standard solar/hybrid designs, the need to reduce the cost and improve the design of drive mechanisms, and the need to decide on how research on reflective films should be conducted.

- Sun♦Lab's Manufacturing Technology team brainstormed alternate ways of fabricating SAIC's stretched-membrane facets. The purpose was to investigate alternatives that could lead to a reduction in manufacturing cost. The brainstorming resulted in five concepts that were presented to SAIC on February 28, following a SolMaT Quarterly Review Meeting. Several new designs for facet manufacturing were presented along with modeled results of how they might perform optically. These various designs are being considered by the manufacturer and appropriate follow-ups will be implemented next quarter.

- Sun♦Lab engineers are working in conjunction with Cummins to reduce the wear of the linear bushings that support the free pistons in the Stirling engine. Various formulations of the dry film lubricant, molybdenum disulfide, have been applied to both the bushings and the road and are being investigated for durability and performance.

- A CRADA is still being negotiated with a flat-plate manufacturing company to commercialize a new solar selective coating using both a batch and a strip coating process. Final approval of the CRADA was delayed because of issues related to intellectual property rights. However, related in-house research has continued and Sun♦Lab staff have developed processes that are immediately ready to be commercialized as soon as the CRADA is signed.

- Sun♦Lab engineers completed the modification of the SOLERGY code to predict solar electric generating systems (SEGS) plant performance. This quarter the code was used to begin assessing the value of proposed plant modification at Daggett, California. Training on the code has begun and will continue next quarter.

- In support of technology applications in Mexico Sun♦Lab staff completed technology presentations for trough/dish technologies for presentation to Mexican energy officials. Efforts are underway to present this information to selected Mexican audiences throughout the country. An important goal is to help identify a potential demonstration of a dish/Stirling system.

Planned Activities for Next Quarter

- Based on the response by SAIC to Sun♦Lab's ideas for manufacturing facets, appropriate follow-up will be implemented, including additional modeling and/or testing prototype designs.
- Sun♦Lab engineers will continue to train the SEGS operators to apply the modified SOLERGY code.
- A new effort will be initiated with Daggett Leasing Company to identify cost-effective ways to conduct field concentrator alignments.
- The CRADA for developing the absorber coating is expected to be completed.
- Support to Cummins will continue in order to assist in improving the reliability of the engine.

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	
Obtain a project proposal from key Mexican research institutions for a demonstration project.	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 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

- SAIC has completed Phase 1 efforts, plans to have a final report completed in May, and plans to start on Phase 2 shortly thereafter. During the quarter, SAIC and its lower-tier contractors, Rockwell and Bechtel Corporation, completed tooling development for the heliostat structural components, developed a new low-cost heliostat facet, investigated heliostat drive issues, and developed cost estimates for Phase 2. Based on Phase 1 efforts, SAIC is now estimating a heliostat price of $\$113/m^2$ for a production rate of 2000 units per year. Phase 2 will validate these estimates with a small heliostat build including site installation and operation.

- SKI has completed its preliminary market assessment and is currently drafting the final market report. SKI has also completed its heliostat design analysis and cost analysis, which showed a reduction in the cost of the large-area glass/metal heliostat by 10% to 12%. SKI also organized a DFMA workshop that was conducted at Peerless-Winsmith on January 26 in Springville, New York. The goals of this DFMA workshop were to reduce manufacturing cost and to develop a drive specification that could be accepted by all current major concentrator manufacturers as a standard. Other participants included Advanced Thermal Systems, McDonnell Douglas, Cummins, and SAIC. A list of about 30 ideas were judged worthy of further investigation. The cost reduction potential of these ideas was significant: for a production run of 1000 units, about 22% reduction in drive cost would result if the ideas are implemented. This cost reduction would allow Peerless-Winsmith to almost exactly hit the cost target identified by workshop participants. In addition, the workshop participants acknowledged a willingness to work together to identify common needs and help reduce the costs of the first small builds.

- Rockwell conducted a project mid-point review on March 4 in which it presented the majority of its technical results for the contract. Rockwell expects to complete Phase 1 early and will use the remainder of the time to prepare a Phase 2 plan. Rockwell developed new leads and most of these have shown great potential. Specifically, Rockwell investigated inertial welding and mechanical forming as a means for making the nozzle/header welds. Rockwell identified a new method for fit-up of the receiver tubes, an assembly setup that was a time-consuming process in the Solar Two receiver fabrication. Rockwell improved methods for insulation installation, and identified improved instrumentation and control methods. These improvements should lead to substantial capital cost reductions, operating and maintenance cost reductions, and plant availability improvements.

- MDA started work on a 12-month contract to investigate and demonstrate manufacturing methods to decrease the cost of concentrators for dish/engine systems. The following three technical tasks will be completed under this contract: (1) produce sag glass mirrors for the dish facets, (2) produce a section of the concentrator structure using a composite material, and (3) demonstrate the integration of the glass mirror to

the composite structure. After the components are integrated, they will undergo on-sun testing to determine the dish focal plane flux distribution and these data will be compared to existing systems and analyses. MDA started concept drawings for the concentrator center support structure and they developed process documentation describing the proposed methods of joining the facet to the center support structure.

- The Sandia Manufacturing Center team brainstormed alternate ways of fabricating SAIC's stretched membrane facets. The purpose was to investigate alternatives that could lead to a reduction in manufacturing cost. The following five concepts resulted from the session and these were presented to SAIC on February 28: segmented pivots, thermal expansion, orthogonal stretch with noncompliant clamps, orthogonal stretch with compliant clamps, and moving the ring into a pretensioned membrane. SAIC is evaluating the design alternatives.

- The SolMaT initiative sponsored a DFMA workshop at Cummins on March 27 and 28. This DFMA focused on the mirror mount assembly that connects the mirror facet to the structure of the Cummins 140-m^2 dish concentrator. There are 150 of these mounts used on each concentrator, so there is a large potential cost impact associated with simplifying this component. A major accomplishment of the workshop was reducing the part count from 33 parts to 6 parts. Cummins staff were extremely pleased with the results and plan two additional DFMA workshops for next quarter.

Planned Activities for Next Quarter

- SAIC will submit a plan for Phase 2. The plan will be reviewed by Sun♦Lab to determine the merits of proceeding with this validation phase of the SAIC heliostat manufacturing project.

- SKI will complete its Phase 2 business plan and proposal and will conduct the final design reviews. Sun♦Lab will review final results of the SKI Phase 1 effort and decide whether to proceed to a Phase 2 validation effort.

- Rockwell will complete Phase 1 of its central receiver manufacturing project. It will submit a summary report and its Phase 2 plan. This plan will be reviewed by Sun♦Lab to determine the merits of proceeding to Phase 2. Contract management will be transferred to Sandia for Phase 2 of the Rockwell project.

- MDA will produce a draft specification for the composite structure, place a contract with its glass supplier, prepare the draft facet drawings, prepare the facet attachment drawings, initiate the final center structure design and analysis, and initiate the design of the facet/structure integration.

- The Sandia Manufacturing Center will follow up with SAIC after SAIC has made a decision about how to proceed with manufacturing methods for the low-cost facet. This could include helping SAIC set up a test or building a prototype.

- Two concurrent DFMA workshops will be conducted at Cummins. One will focus on a structure weldment and the other will focus on the controls electronics package for the Cummins 30-kW_e dish/Stirling system.

Major Milestones

Milestone	Planned	Actual
Sponsor DFMA workshop for heliostat developer.	Mar 96	Dec 95
Complete SAIC Phase 1 heliostat work.	Apr 96	
Complete SKI Phase 1 heliostat work.	Apr 96	
Complete Rockwell Phase 1 heliostat 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 joint effort was initiated to carry out the next step in the analysis of the tax equity issues. A significant effort focused on activities that help support international development of STE technologies in Mexico, Egypt, and India. We completed a draft second interim report that documents the accomplishments of the operation and maintenance (O&M) Cost Reduction Program with KJC Operating Company (KJCOC).

Accomplishments

- A joint effort was initiated between Princeton Economic Research Institute (PERI), NREL Analytic Studies Division, and Sun♦Lab to verify the tax equalization study performed in FY95. PERI is revising its cash flow model, FATE2-P (Financial Analysis Tool for Electric Energy Projects), to perform tax equity analysis. The model was used to reproduce a study by Oak Ridge National Laboratories (ORNL) that investigated the taxes paid by solar power projects and natural gas combined-cycle power projects. Good agreement was found between the FATE2-P model and the ORNL study results. The ORNL study had shown that solar power projects carry a substantially higher tax burden than conventional fossil power plants.

- Sun♦Lab joined a team of International Energy Agency STE experts that visited Egypt to help develop plans for Egypt's first large-scale STE plant. Terms of reference for a feasibility study were defined and provided to the responsible Egyptian organization, the New and Renewable Energy Development Authority, for its consideration. The first solar plant is likely to be a 30-MW parabolic trough field integrated with a gas-fired power plant. Cloud-cover maps developed by Sun♦Lab proved to be very useful in screening candidate sites for the first solar thermal plant.

- We reviewed and provided comments for the World Bank on a feasibility study to build an Integrated Solar Combined-Cycle System (ISCCS) in Rajasthan, India. We joined a mission to India and to Germany to resolve these comments with the technical and financial authorities. In addition, we helped the World Bank develop the Request for Proposal for the project.

- We generated monthly and annual cloud-cover maps for Egypt, most of the Middle East, a large section of Asia (including India and the west half of China), and South America below the equator. Cloud-cover maps provide a valuable tool for making a first-cut evaluation of the direct normal insolation at sites with limited solar radiation data.

- We initiated systems analysis to support SCE's efforts to convert Solar Two to a commercial plant.

- We completed a draft of the second interim report that documents the accomplishments of the O&M Cost Reduction Program. Sun♦Lab provided comments to KJCOC on the report.

- We helped 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

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

- The tax equalization study will reproduce the Chapman study (FY95), which identified tax strategies that can help equalize the tax burdens between conventional fossil and renewable power technologies.

- We will continue to support the India solar thermal project by attending meetings at the World Bank (Washington, D.C.) and hosting tours of the solar thermal plants in California.

- We will complete a report that examines potential Kokhala hybridization options at Solar Two.

- We will generate cloud-cover maps for Africa, Australia, and North America.

- 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 a new coating that will significantly reduce heat losses.

Major Milestones

Milestone	Planned	Actual
Complete draft Tax Equalization Plan for solar thermal electric technologies.	Jun 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

SAIC of McLean, Virginia, has continued its Phase 2 investigation with promising results. SAIC is investigating protective alumina hardcoats as an alternative to thin-glass for SAIC's dish concentrator and heliostat. Two other subcontracts initiated in FY95 for developing advanced reflector materials were completed last quarter. SAIC of San Diego, California, completed its work on investigating diamond-like coatings for protection of polymer films. Industrial Solar Technologies completed its subcontract for developing a silvered Teflon reflector. Performance of both materials failed to achieve results necessary to warrant further investigation at this time. In-house work has been adversely impacted by the loss of a staff technician and by reorganization activities that occurred last quarter. Steps are being taken to minimize the staffing impact for the remainder of FY96.

Accomplishments

- NREL staff have been approached by Rockwell to enter into a CRADA to evaluate commercially available reflector materials and advanced reflector materials identified by Rockwell for application to heliostats. We will evaluate the merits of the potential CRADA as NREL and Rockwell proceed with negotiating the joint statement of work.

- A mid-subcontract review involving SAIC-McLean, SAIC of Golden, Colorado, and Sun♦Lab staff was held to review progress and examine future directions for the SAIC-McLean subcontract to develop "A Cost Effective Process for High Volume Production of Enhanced Lifetime Solar Reflective Materials." Accomplishments, future commercialization pathways, and manufacturing requirements were discussed.

- Negotiations have continued between NREL staff and a reflector manufacturer to further the development and commercialization of an all-polymeric reflector. The reflector was developed by Dow Chemical Company under a previous NREL subcontract. Dow has licensed the rights to the material to the manufacturer.

- We initiated optical characterization and accelerated testing of a new commercial reflector introduced by Southwall Technologies.

- We completed fabricating a video-based reflectometer for measuring spectral reflectance of new and weathered materials. The equipment will undergo testing and debugging before replacing existing equipment.

- The final draft of the CRADA to commercialize the new black-nickel-based solar-selective-absorber coating has been submitted to DOE for final approval. The final draft consists of tasks specifically directed toward the commercialization scale-up from the laboratory processes to an intermediate-sized and full-scale production line. The CRADA duration will be for nine months.

- A contract has been placed with Surface Optics, Inc. (SOC) to perform optical/thermal modeling studies of candidate solar selective pigment coating systems. The deliverables for this contract will include a preliminary coating system design, a report detailing SOC results, and identification of areas where additional work may be needed.

- We completed documenting the results of the thin-glass survey.

Planned Activities for Next Quarter

- We will finalize the CRADA for development of a black-nickel-based selective coating for low- to mid-temperature solar applications.
- Staff from the manufacturer licensing the Dow all-polymeric reflector material will meet at NREL to discuss a collaborative arrangement for advancing the material.
- We will begin hail testing on an SAIC dish facet in support of SAIC's USJVP contract.

Major Milestones

Milestone	Planned	Actual
Initiate CRADA for mid-temperature selective absorber development.	Feb 96 *Delayed until May 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	
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 procured hardware for the Video SHOT system.
- We prepared for presentation of "Transforming the Sandia 2-*f* Optical Performance Measurement System to Color" at the American Society of Mechanical Engineers (ASME) International Solar Conference.
- The components for the BCS at NREL are in place with the exception of the target. Mechanical design drawings for the target are currently being prepared.

Planned Activities for Next Quarter

- We will complete the prototype Video SHOT system.
- We will assist Cummins with setting up a Video SHOT system.
- We will present "Transforming the Sandia 2-*f* Optical Performance Measurement System to Color" at the ASME International Solar Conference.
- As soon as the design drawings are complete, the target for the BCS will be fabricated, the system components will be assembled, and NREL staff will be trained in the target's operation.

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 support for training SCE personnel to maintain and repair the Solar One heliostats at Solar Two.
- We provided support to Solar Two for solving communications problems between the Heliostat Array Controller and the LUGO heliostats at Solar Two.
- We trained SCE personnel to operate the BCS at Solar Two.

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, Edtek, Inc. to produce a blow forming die and design an aluminum quenching subsystem, SAIC to evaluate advanced drive concepts, and SKI and Allied/Signal to complete a component conceptual design.

Accomplishments

- Kansas Structural Inc. delivered two 22-in. by 26-in. prototype composite facets for the test bed concentrator (TBC) to Sandia. The 2-*f* test indicated facet figure merit in the range of 1 to 2 mr with 60% to 70% of the image reflecting the target.
- Nine prototype foam facets were subjected to thermal tests and 2-*f* optical evaluation. Test results and mechanical analysis provided clues to key design criteria.
- Edtek, Inc. produced a small-scale blow forming die and fabricated an aluminum-formed piece.
- Edtek, Inc. completed the design for the aluminum quenching subsystem, and materials have been ordered for demonstration on the small scale forming system.
- Aluminum coupons were prepared by Edtek, Inc. and sent to BNW for coating.
- SAIC continues to evaluate several advanced drive concepts. The down-select decision has been delayed until next quarter.
- SKI and AlliedSignal have completed design-to-cost goals and preliminary market analysis.
- SKI and AlliedSignal have completed preliminary component conceptual design.

Planned Activities for Next Quarter

- Kansas Structural Inc. is fabricating more 22-in. by 26-in. facets for extended testing and is scheduled to deliver a Cummins gore facet on May 15. We will evaluate temperature curing and temperature performance of the facets.
- We will continue to test and evaluate alternative foam-facet designs.
- We will refine foam-facet mechanical analysis tools and design criteria.
- The SAIC drive project will down-select from three alternative concepts.
- SKI and AlliedSignal will complete system conceptual design, component review, and commercialization plans.
- SKI and AlliedSignal will complete a project report.

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	
Complete SKI/AlliedSignal project.	Jul 96	
Test heliostat-type foam facets.	Sep 96	

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 the 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 supported Bechtel and Rockwell with startup by providing technical assistance with receiver preheat and initial salt flow through the receiver. An infrared camera, purchased last quarter, displayed the thermal image of the receiver in the control room for the operators, providing real time feedback of the receiver thermal response.

- A majority of the thermomechanical fatigue experiments were completed on advanced materials for the Rockwell CRADA on advanced central receiver development.

- The second phase of transient freezing experiments to investigate freezing of flowing molten salt in cold pipes was completed this quarter. These experiments aimed to quantify the minimum receiver and piping startup conditions and measure the effect of wall thickness. The results indicted there was little effect of wall thickness over the range of tubes that we tested. The measured penetration distances from these experiments were much greater than those predicted from correlations in the literature, primarily because the literature values were based on constant wall temperature condition, whereas the tubes in our tests were allowed to heat up and had a finite heat capacitance.

- The majority of testing of an impedance heating system, which could be a potential alternative to heat trace, has been completed. In this heating system, current flows through the pipe to heat it instead of heating mineral insulated cable that transfers the heat to the pipe. We found that the impedance heating system worked well and did not cause problems with instrumentation.

- Efforts to refurbish the test facility are progressing well. We have begun an in-house effort to bring the elevation module into service by the end of FY96. This in-house effort should be more cost effective than having outside contractors complete the work.

- Due to software/hardware upgrade incompatibility problems with the new heliostat field computer, we will use the existing HP 1000/900 computer until time permits us to perform a phased-in upgrade.

- The heliostat field refurbishment is progressing well. Several heat-collector elements have been repaired and we plan to have sufficient operational heat-collector elements for the heliostat field plus spare boards by the end of the fiscal year.

- 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. Repair of heliostat field motors and communications systems is proceeding, and we expect to have sufficient motors for the entire field plus replacements available by this summer.

- The reverse engineering of the Bailey process control system has been completed.

Planned Activities for Next Quarter

- Continue to provide technical support for Solar Two.
- Continue Rockwell CRADA activities.
- Continue NSTTF refurbishments and modifications.
- Complete a report on the SMUD Combined Cycle Power Plant study.

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 *Delayed until Jan 96.*	Cancelled
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	
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

A long-awaited test of the Stirling Thermal Motors (STM) 4-120 engine with a Sun♦Lab heat-pipe receiver was performed this quarter, with encouraging results. The test demonstrated that the heat pipe significantly improves the performance of the system while reducing the heater head temperatures. The Northern Research Engineering Company (NREC) Brayton system is nearly ready for on-sun testing, following delays at NREC. We have also initiated several tests to determine long-term materials compatibility for the felt wick and several heater-head materials used by our commercial partners. Hybrid (gas-fired) receiver development and support is increasing as the USJVPs begin to make progress. We have an emissions test bench nearly ready for deployment to customer sites. We continue to directly support our commercial partners through design, analysis, and test support for both engines and receivers.

Accomplishments

- Sun♦Lab successfully tested the STM 4-120 Stirling engine with a second-generation felt-wick heat-pipe receiver. The power output of the engine improved from 17 kW_e to 21.5 kW_e under similar operating conditions, and the net system efficiency improved from 21.7% to 27.1% (neglecting dish parasitics). We have discussed the results with STM.

- We supported a Cummins test of its heat pipe receiver on an Aisin-Seiki 25-kW_e Stirling engine. We provided infrared thermography support during the test, as well as design and processing advice prior to the test. The system operated without any heat-pipe problems.

- NREC has completed integrating its Brayton engine with the DLR volumetric receiver. NREC has been unable to run the system because of difficulties in igniting the burner. Sun♦Lab is preparing safety documentation and will provide technician support at the NREC site in the next quarter.

- We completed fabrication and filling of a third-generation felt-wick heat-pipe receiver. We incorporated improvements in wick attachment and cleaning procedures over the second-generation design. Testing will begin in mid-April. We have instrumented the third-generation felt-wick receiver to determine startup thermal-wave departure from axial symmetry and the effects of this departure on thermal stresses.

- We began the durability test on the third-generation bench-scale receiver. This latest design improves bonding to substrate and implements sodium reflux cleaning to reduce oxide contamination.

- We performed a test run on a prototype heat pipe for materials durability study. Ten to twelve of these simplified sodium heat pipes will be constructed over the next few months with various test materials and sodium processing procedures. Durability testing will begin immediately after fabrication and will last for 10,000 operating hours.

- Sun♦Lab personnel started detailed design of their hybrid receiver this quarter, including computational-fluid-dynamics and finite-element thermal-stress calculations for the primary heat exchanger.

- Sun♦Lab personnel held discussions with suppliers to determine the best way to fabricate the Sun♦Lab hybrid receiver primary heat exchanger, and they initiated a survey of potential recuperator suppliers.

- NREL tested a prototype of the Sun♦Lab hybrid receiver candidate radiant burner through its operating range, mainly to determine radiant efficiency, allowing the calibration of a burner model used for receiver design.

- Sun♦Lab began extensive accuracy and reliability testing of the hybrid burner emissions testing system. We generated a draft report that describes the capabilities and site requirements for the portable system, and summarizes current state emissions regulations.

- Sun♦Lab attended a design review of the Cummins second-generation hybrid receiver in Abilene, Texas. Heat transfer predictions, discussed in detail, appear

satisfactory. Cummins performed further work on stress and cost considerations, which will be included in a Phase 1 summary report.

- We continue to analyze the Stirling Technology Company (STC) NaK capsule tests, with the objective of completing the analysis and documentation by May of this year.
- Under our supervision, AdTech continues elevated temperature fatigue tests on Thermacore's spherical-powder nickel wick.
- We have completed the documentation of felt-wick-receiver buckling-pressure tests and predictions and reported to our industry partners and other interested parties.
- Sun♦Lab personnel hosted the visit of Dr. Vladimir Baturkin, Kiev Polytechnic Institute, Ukraine, and exchanged information on felt-wick technology.
- We received two new TBC control units in late February. The first unit has been installed and checked out, including the automated acquire and escape control via a supervisory computer. The second unit will be installed after a software update is completed by the vendor.
- We initiated discussions with the Institute for Physics and Power Engineering, Obninsk, Russia, to determine if its sodium heat-pipe technology could extend reflux receiver wick lifetime.
- We continue to work with two graduate students in Mechanical Engineering at North Carolina Agricultural and Technical State University (NCA&T) to model reflux receiver thermal performance and thermal stress, under the auspices of the DOE Science and Technology Alliance.

Planned Activities for Next Quarter

- We will test the STM 4-120 engine with an improved third-generation felt-wick heat-pipe receiver and compare the results to the direct illumination receiver results, in support of the SAIC USJVP program.
- We will begin on-sun testing of the NREC/DLR hybrid Brayton engine in support of the Cummins USJVP program.
- We will test the third-generation felt-wick heat-pipe receiver on the TBC and then on Sandia's power tower. We will analyze test data to determine startup thermal-wave departure from axial symmetry.
- We will begin fabrication of about 12 materials compatibility capsules to test different materials and processing combinations.
- We will finalize design of a Sun♦Lab gas-fired hybrid heat-pipe receiver.
- We will make final validation runs to ensure proper operation of the emissions bench, map out emissions of the test burner, and prepare to make site visits for emissions testing of our industrial partner's hybrid receivers.
- Cummins will start on Phase 2 of its hybrid receiver contract. In this phase Cummins will begin fabrication of the second-generation hybrid heat-pipe receiver and prepare for ground testing and on-sun testing.
- We will continue test and analysis support of the Joint Venture Program engine and receiver tasks.
- We will complete metallurgical analysis of the STC NaK capsule tests.
- We will complete elevated-temperature fatigue testing of the spherical-powder nickel wick.
- We will continue collaborations with NCA&T under the auspices of the DOE Science and Technology Alliance.

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.*	
Complete testing of NREC Brayton system.	May 96	

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 the next year will be an effort 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 Central Receiver Test Facility field. This quarter approximately 50 control boards for the heat-collector elements (HCEs) were repaired and 20 repaired HCEs were placed in the field.
- We continue to refurbish the elevating module in the tower. The hydraulic fluid was drained and all the filters changed this quarter.
- We received and initiated installation of the first new controller for the Distributed Receiver Test Facility.
- We prepared a Work for Others proposal to have Applied Physics Laboratory use the NSTTF for conducting boresite measurements on a new radome. The work will be done at the 260 level on the tower beginning in May 1996.
- We received ES&H approval for Sandia to sell (or give away) the approximately 200,000 pounds of solar salt from the Molten Salt Storage Experiment.

Planned Activities for Next Quarter

- We will continue to repair and modify the heliostat field.
- We will initiate the installation of the second controller for the Distributed Receiver Test Facility.
- We will begin the fabrication, installation, and testing for the Work for Others contract with Applied Physics Laboratory.

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 second quarter of FY96, the Sun♦Lab Communications Team met two of its milestones and began planning work for the next milestones.

Accomplishments

- The Sun♦Lab and Solar Two brochures were completed, printed, and initially distributed at Soltech '96 in March.
- The Sun♦Lab booth was completed and used at Soltech '96.

Planned Activities for Next Quarter

- Anne Van Arsdall of Sandia and Barry Olsan of Southern California Edison will collaborate on plans for the Solar Two conference center to be ready for the Solar Two dedication June 5.
- Jim Jones of NREL, Van Arsdall, and Rich Diver of Sandia will collaborate on dish/Stirling brochures and a booth for the Olympic Games in Atlanta.
- Jones, Van Arsdall, Olsan, 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 Mike Mehos of NREL are creating a draft World Wide Web site for a development server.
- The team is making a distribution plan for mailings of the Solar Two brochure.

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	
Create brochure on dish/Stirling for the 1996 Summer Olympic Games.	Jul 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	
Establish 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

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