AOP-90

SOLAR THERMAL TECHNOLOGY PROGRAM

FY90 Annual Operating Plan

December, 1989

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Sandia National Laboratories
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and

Solar Energy Research Institute
Golden, Colorado

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Approved: ______________________
B. W. Marshall
Manager, Energy Conversion and
Process Science Department
Sandia National Laboratories

Approved: ______________________
B. P. Gupta
Program Manager, Solar Thermal Program
Solar Energy Research Institute

Approved: ______________________
Howard S. Coleman
Director, Solar Thermal Technology Division
U. S. Department of Energy

TABLE OF CONTENTS

Page

PREFACE iii
SECTION I: SOLAR THERMAL PROGRAM OVERVIEW I-1
SECTION II: FY 1990 TASK DETAIL II-1
1. HIGH FLUX PHOTON PROCESSES II-1
Task A. Photon Interaction with Materials and Chemicals II-1
Subtask A-1. Solar Photochemical Destruction of Hazardous Contaminants in Water II-1
Subtask A-2. Improved Catalysts for Photochemical Removal of Hazardous Contaminants from Water II-2
Subtask A-3. High Temperature Photo/Thermal Chemistry II-3
Task B. High Flux Optics II-7
Task C. Materials II-9
Task D. Receiver/Reactor Modelling II-11
2. CONCENTRATOR DEVELOPMENT II-14
Task A. Heliostats II-14
Task B. Parabolic Dishes II-16
Task C. Optical Materials II-18
Task D. Structural Dynamics II-20
3. ELECTRIC SYSTEMS DEVELOPMENT II-21
Task A. Central Receiver Technology II-21
Task B. Distributed Receiver Technology II-23
Task C. Conversion Technology II-25
4. TECHNOLOGY DEVELOPMENT II-27
Task A. Next-Generation Commercial Systems II-27
Subtask A-1. Project Development II-27
Subtask A-2. Partner-Driven R&D II-28
Subtask A-3. Design Assistance and CORECT Support II-28
Task B. Photochemical Systems II-29
Subtask B-1. Identification of Application Opportunities II-29
Subtask B-2. Solar Processing of Dilute Aqueous Organic Chemicals II-31
Subtask B-3. High-Temperature Solar Destruction of Toxic Chemicals II-33
Task C. Advanced Electric Technology II-36
Subtask C-1. Identify and Evaluate Potential Solar Electric Technologies and Applications II-36
Subtask C-2. Joint Venture Consortia II-37
Subtask C-3. Development Requirements II-37
Subtask C-4. System Experiment II-38
SECTION III: FY 1990 RESOURCE SUMMARY III-1
SECTION IV: MAJOR MILESTONE SUMMARY IV-1
SECTION V: MANAGEMENT AND IMPLEMENTATION PLAN V-1

Figures

Figure I-1. Solar Thermal Technology Program Work Breakdown Schedule I-2
Figure V-1. Solar Thermal Program Management Organization V-3

Tables

Table III-1. FY89 Solar Thermal Program Budget Summary III-1
Table III-2. FY90 Solar Thermal Program Field Laboratory Budget Detail III-2
Table III-3. Solar Thermal Subtask Level Budget for FY90 .... III-3
Table V-1. FY90 Program Activity Field Management Responsibilities V-3

PREFACE

This annual Operating Plan (AOP) provides detailed plans for the fiscal year 1990 (FY90) research and development (R&D) activities of the Department of Energy's (DOE) Solar Thermal Technology Program (STTP). A major restructuring of the Solar Thermal Technology Program has been completed by the field laboratories and the DOE Solar Thermal Technology Division.

Beginning in FY89, a single AOP which integrates the work of both of the major field laboratories, Sandia National Laboratories (SNL) and the Solar Energy Research Institute (SERI), was prepared. This differed from past years in which each organization, including the involved DOE Operations Offices, prepared their individual planning documents. A single AOP is consistent with the structure and implementation strategy of the new program plan that requires close coordination of work at the lead laboratories.

SECTION I

SOLAR THERMAL PROGRAM OVERVIEW

PROGRAM GOAL:

The goals of the Solar Thermal program are to 1) increase our environmentally neutral, renewable energy supply options, 2) reduce our dependence on imported energy sources, 3) open new domestic and overseas markets, and 4) enhance our national superiority in energy.

PROGRAM OBJECTIVES:

- Continue the development of high-performance and reliable solar thermal components and systems that will be competitive for electricity and process heat applications.
- Develop new applications for using highly concentrated sunlight for chemical and material processes.
- Enhance U.S. industrial capability to introduce solar thermal technology into the national and international marketplace.

PROGRAM STRATEGY:

- Provide cost-shared assistance to industry for additional near-term market penetration efforts through refinement and optimization of existing solar thermal electric systems.
- Through component and system innovation, aggressively improve solar thermal electric technology for achievement of program goals for the late 1990's.
- Emphasize the versatility and unique attributes of concentrated sunlight to develop markets that foster the U.S. solar thermal industry and contribute to achievement of the long-term cost and performance goals.
- Develop a growing constituent base in the user/supplier industries and foster technology exchange among industry, universities, users, and the federal laboratories.
- Strengthen the scientific base of the program in areas such as energy conversion processes, advanced optics, and photon-matter interactions.

PROGRAM STRUCTURE:

The Solar Thermal program is structured to provide a balance of activity that exploits near-term commercialization opportunities, improves readiness to meet long range performance and cost, and maintains a forward looking research thrust to open new applications.[1]

There are four major program elements:

1) High Flux Photon Processes,
2) Concentrators Development
3) Electric System Development, and
4) Technology Development.

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[1] "Bringing Solar Thermal Technology to the Marketplace", U.S. DOE Report to Congress, CE-0233, Aug. 1988.

Each activity has a number of tasks as shown in Figure I-1, Work Breakdown Schedule.

Figure I-1. SOLAR THERMAL TECHNOLOGY PROGRAM WORK BREAKDOWN SCHEDULE

1. *HIGH FLUX PHOTON PROCESSES*
   - A. PHOTON INTERACTION WITH MATERIALS AND CHEMICALS
   - B. HIGH FLUX OPTICS
   - C. MATERIALS PROCESSING
   - D. RECEIVER/REACTOR MODELLING
2. *CONCENTRATOR DEVELOPMENT*
   - A. HELIOSTATS
   - B. PARABOLIC DISHES
   - C. OPTICAL MATERIALS
   - D. STRUCTURAL DYNAMICS
3. *ELECTRIC SYSTEMS DEVELOPMENT*
   - A. CENTRAL RECEIVER TECHNOLOGY
   - B. DISH RECEIVER TECHNOLOGY
   - C. CONVERSION DEVICES
4. *TECHNOLOGY DEVELOPMENT*
   - A. NEXT GENERATION COMMERCIAL SYSTEMS
   - B. PHOTOCHEMICAL PROCESSING
   - C. ADVANCED ELECTRIC TECHNOLOGY

ACTIVITY SUMMARY:

The objective and key milestones are listed below for each activity.

1) HIGH FLUX PHOTON PROCESSES

Objective: Develop and maintain the scientific and theoretical base for solar thermal technology and conduct fundamental studies on advanced concepts and applications including solar chemistry and materials processing.

Key Milestones:

- Establish a scientific understanding of the effects of concentrated, high energy photons on chemicals and materials (FY 92).
- Explore the use of steady/transient heating with concentrated sunlight for materials processing and treatment (FY 93).
- Explore new applications of concentrated sunlight such as solar lasers for communication or isotope separation (ongoing).

2) CONCENTRATOR DEVELOPMENT

Objective: Develop cost effective concentrators and optical materials to support the variety of solar thermal applications.

Key Milestones:

- Commercial, low cost, high performance polymer reflective materials (FY 91).
- Stretched-membrane heliostat commercial readiness established (FY 93).
- Stretched-membrane dish commercial readiness (FY 95).

3) ELECTRIC SYSTEMS DEVELOPMENT

Objective: Continue the development of the components and systems needed to establish technical readiness of solar thermal electric power production applications to penetrate major national and international markets by the late 1990's.

Key Milestones:

- Performance and readiness of reliable Stirling engine for liquid metal receivers confirmed by solar tests (FY 91).
- Performance and readiness of central receiver advanced molten salt and air receivers verified by solar tests (FY 92).
- Performance and readiness of isothermal, liquid metal vapor receivers for parabolic dish concentrators verified by solar tests (FY 92).
- Integration of dish, receiver, engine, and controls, into a commercial product (FY 93).

4) TECHNOLOGY DEVELOPMENT

Objective: In collaboration with industrial partners develop systems that will result in 1) competitive solar thermal electric systems based on refinement and optimization of current commercially available systems, 2) systems for solar-driven process that destroys toxic chemicals, and 3) advanced solar thermal electric systems that will improve performance and cost competitiveness in the mid-1990's.

Key Milestones:

- Verify R&D based improvements to commercial solar thermal electric systems through in-field testing (FY 91).
- Build and operate a pilot scale process demonstration for solar destruction of chemicals in water at a toxic waste site (FY 91).
- Build and operate a pilot scale process demonstration for solar destruction of hazardous chemicals at high temperature (FY93).
- Implement improved competitive solar thermal electric commercial system (FY 94).
- Initiate operation of next-generation electric systems experiment (FY 93).

SECTION II

FY 1990 TASK DETAIL

1. HIGH FLUX PHOTON PROCESSES

Task A. Photon Interaction with Materials and Chemicals

Subtask A-1. Solar Photochemical Destruction of Hazardous Contaminants in Water

Objectives: Perform laboratory testing to determine the range of application of solar treatment of contaminated water, test promising methods of improving the efficiency of the process, improve the understanding of the solar resource in the near UV portion of the spectrum, and provide the necessary analytical chemistry support for the water treatment tasks.

Rationale: The complete mineralization of organic contaminants in water and the potential to remove trace metal ions by suspended titanium dioxide powder activated by sunlight has been demonstrated. This technology has the potential to be economically competitive as a water treatment process. Treatment of organic contaminants in underground water is the number one priority within the DOE plants. Through systems and market analysis, specific applications which utilize the process to maximum advantage need to be evaluated on a laboratory scale using synthetic water solutions which model contaminated water. This provides an economical means of establishing the range of applicability of the process. New catalyst variations designed to maximize the efficiency of the destruction process and the use of the solar resource should likewise be tested for effectiveness in promising applications. The fact that TiO_2 utilizes photons in the near UV portion of the solar spectrum which accounts for only about 1% of the solar resource requires that more detailed knowledge of this part of the spectrum be obtained so that process systems can be designed to make the maximum utilization of the available energy. Study of water containing contaminants at levels of a few ppm or below requires sensitive analytical techniques and tight laboratory protocols to obtain credible data.

FY 1990 Task Description: As research in other tasks in the program suggests promising improvements in the photocatalyst, the new versions will be prepared and tested on standard compounds such as trichloroethylene to compare them with the current base case catalyst, (DeGussa) TiO_2. The kinetics and efficiency of destruction of new organic compounds, suggested by application studies and input from the Solar Thermal Water Treatment Review Panel will be determined to expand the range of applicability of the solar detoxification process. The composition of representative ground waters will be identified and used as the basis for preparation of mixtures that model real water systems for use in experimentation. This information and methodology will be provided to other tasks in the program. The potential for interference in the destruction process by heavy metal ions will be tested as will the possibility that such metal ions might be removed by a solar process. The chemical analysis capability will continue to be upgraded, both in-house, as appropriate, and by use of outside chemical analysis laboratories. In order to obtain a more quantitative understanding of the available solar resource in the near UV region, monitoring will be done at Albuquerque, NM, and Golden, CO.

Available models (LOWTRAN and SPCTRAL2) will be used to calculate instantaneous photo flux at hourly intervals at sea level and one mile altitude, at the solstices and equinoxes for 40 degree north latitude.

FY 1991 Activity Description: Improvements in the destruction of organic contaminants by a photocatalytic system and removal of heavy metals, if warranted, will be tested. The applicability of the process to new compounds, mixtures, and ground water types will be evaluated, based on systems analysis and guidance from specific applications requirements.

FY 1989 Accomplishments: Most of the effort in FY 1989 was on empirical experiments to show solar flux induced effects on materials and chemicals. Such data were helpful in establishing the presence and influence of solar flux on chemical and materials processing.

Major Milestones:

Sep 1990 — Assess the availability of near UV component of global normal and diffuse radiation and document a model that will allow predictions to be made at other sites.

FY 1991

Q3 1991 — Evaluate most promising solar approaches for removal of metals from contaminated water.

Subtask A-2. Improved Catalysts for Photochemical Removal of Hazardous Contaminants from Water

Objectives: Identify factors which limit the efficiency of titanium dioxide (TiO_2) as a photocatalyst for destruction of organic contaminants in water, identify improvement strategies, and identify dopants for TiO_2 or new active semiconductor catalysts that will extend the active range of the catalysts to longer wavelengths in the solar spectrum.

Rationale: Quantum yields for the destruction of organic contaminants in water are less than one percent using available forms of TiO_2. This coupled with the cutoff of activity at wavelengths beyond about 360nm significantly impacts the processing rate of a solar water treatment system. Processing rate will increase linearly with increasing quantum yield and shifting the active range to longer wavelengths can have a dramatic effect on processing rate due to the availability of greater numbers of photons in the solar spectrum.

FY 1990 Task Description: Using the techniques developed in FY 1989, work will continue on the identification of means to improve the efficiency of TiO_2 for destruction of organic compounds in water. Different forms of TiO_2 and samples from different sources will be screened to maximize activity. When factors reducing activity are identified methods of overcoming them will be attempted. Using the resources of both in-house (SERI and SNL) and outside experts, means of doping TiO_2 to increase the active wavelength range will be identified and tested. At the same time other promising photocatalysts will be identified for testing. Initial screening and determination of chemical kinetics at the catalyst surface will be carried out using the photocurrent action spectra and photocurrent-voltage methods developed in FY 1989.

FY 1991 Activity Description: Modified forms of TiO_2 or new semiconductor photocatalysts with greater efficiency or greater utilization of the solar spectrum will be studied in more detail to overcome perceived problems, if any. If catalyst deactivation, inhibition by reaction intermediates, or substances present in water to be treated are found to be problems, methods to overcome them will be explored.

FY 1989 Accomplishments: Laboratory capability was established for studying semiconductor photocatalysts using photocurrent action spectroscopy, and photocurrent-voltage curves. The set of photophysical and photochemical pathways that can occur after the absorption of a photon by solid TiO_2 was documented and the kinetics of the reaction of hole and electron sites in water suspensions were determined.

Major Milestones:

Feb 1990	Identify potential photocatalysts that will extend the active region toward the visible in the solar spectrum and assess the potential for improving the efficiency for water treatment.

FY 1991

Q4 1991	Select second generation photo catalyst for development.

Subtask A-3. High Temperature Photo/Thermal Chemistry

Objective: Measure the destruction and removal efficiency, identify products of incomplete reaction, and determine the quantum yields for waste destruction, as appropriate, for representative organic compounds identified as hazardous wastes.

Rationale: Concentrated organic hazardous wastes and organic compounds in contaminated soils are currently destroyed predominantly by incineration. Siting difficulties for new facilities and the production of potentially hazardous by-products (the products of incomplete reaction (PIRs)) provide opportunity for alternative technologies. In parallel with market and systems studies, work is required to establish the chemical processes which are open to solar technology. Preliminary laboratory work at the University of Dayton, University of Houston, and SERI has identified photothermal reactions, steam reforming over a rhodium catalyst, and pyrolysis as potential solar driven chemistries. Field work by SNL and SERI has shown technical feasibility for waste destruction in solar furnaces.

Initial work has identified the variables critical to determining effective reaction conditions. These are: temperature, catalyst, photon flux (irradiance) and wavelength, diluent gas (inert or reactive), residence time, reactant absorbance coefficient, concentration and overall quantum or thermal efficiency. Reactant quantum efficiencies and absorbance coefficients are not generally available in the literature so must be determined for each compound of interest. Quantum and/or thermal efficiency for reactant destruction is a key parameter in photo-division processes since they will determine the plant throughput for a given solar flux level. The nature of PIRs is important for determining plant compliance with environmental regulations and the potential solar advantage.

FY 1990 Task Description: The focus of effort will be the determination of destruction efficiencies, quantum yields for representative reactions, and identification of PIRs. Work on laboratory reactors will be done at SERI and the University of Dayton. The University of Dayton has established a photo/thermal reaction system with solar simulator and laser light sources coupled to a gc-mass spectrometer. This system can be used to advantage to study selected compounds for the purpose of measuring quantitative destruction efficiencies and the yields of chromatographable PIRs. Under favorable conditions quantum yields will be determined for a model system. At SERI the molecular beam mass spectrometer, MBMS, coupled to catalytic and photothermal reactors with solar simulator and laser light sources, will be used to screen selected classes of compounds for destruction efficiency under the full range of possible solar conditions. These studies complement work at Dayton and that being done at SNL and the University of Houston on steam reforming of hazardous wastes. The MBMS allows rapid screening of compounds and direct detection of PIRs, including those that would not normally be seen in a gc-ms analytical and detection system. Compounds and classes of compounds chosen for study will be selected based on developing systems and market assessments. Field testing will be done to verify that promising results from the laboratory can be achieved under solar conditions, to verify the results of reactor modeling studies, and to test the evolution of reactor design.

Sandia will complete the technical assessment of the solar driven catalytic reforming of toxic organic solvents. To support modelling of the DCAR reactor, the physical properties of the catalyst and its porous ceramic support will be measured and experiments will be performed with improved quantification in order to develop better mass and energy balance data. Additional reforming experiments will be performed that examine nitrogen and sulfur containing organics and at least one aromatic compound and one high molecular weight alkane that is a reasonable surrogate for the oils removed by degreasing processes. Whenever possible, toxic organics important for the HAZWRAP and Superfund programs will be used.

Sandia's studies of the reforming of methane in the CAESAR reactors (mounted on DLR's 17-meter dish at the PAN facility near Lampoldshausen, FRG) will be completed, including experiments with a radially non-uniform absorber. Analysis of data from these experiments and post-test examination of absorbers will be completed.

FY 1991 Activity Description: Work will focus on compounds and approaches identified as most promising by a combination of the laboratory and field work, the market analysis, and systems analyses done in FY 1990. Experiments that define the practical range of operating conditions of a commercial system will be performed. A detailed conceptual design of a commercial system will be developed. Ways to generate reforming inlet streams from commercial waste streams, by removing toxic wastes from contaminated soils by steam or thermal stripping of activated carbon beds will be examined.

FY 1989 Accomplishments: The emphasis of laboratory work at SERI was on developing the capability to use the unique features of the molecular beam mass spectrometer (MBMS) for use in the study of photolytic, thermal, and catalytic reactions of hazardous compounds. Laser and solar simulator light sources were set up and reactors constructed to simulate a variety of possible reaction conditions. A literature survey was carried out to provide relevant background information. The ability to identify PICs under pyrolytic, oxidative and steam reforming conditions was demonstrated. Work at the Universities of Dayton and Houston focused on the identification of PICs in reactions of dioxin and determining the efficiency of steam reforming of chlorinated solvents over rhodium catalysts. In other work at the University of Houston, photocatalysts for synthetic reactions were evaluated. Field tests demonstrated that dioxins could be destroyed to EPA requirements, and preliminary tests of steam reforming of chlorinated solvents were carried out in a new solar reactor.

Destruction of organics by steam reforming catalyzed by radiantly heated rhodium metal supported on a porous ceramic alumina matrix was demonstrated by both laboratory and pilot-scale experiments. Methane, methylene chloride, and trichloroethane were destroyed during steam reforming experiments conducted at the University of Houston in a bench-top flow reactor that was heated by an infrared radient energy source. Methane, 1-propanol, and trichloroethylene were destroyed during steam reforming experiments conducted at Sandia National Laboratories in DCAR (Direct Catalytic Absorption Receiver) reactor heated by Sandia's solar furnace.

Large-scale CO_2 reforming of methane over rhodium deposited on a porous ceramic matrix was demonstrated in the CAESAR (CAtalytically Enhanced Solar Absorption Receiver) reactor during experiments performed at the DLR PAN facility. These experiments showed that the CAESAR reactor performed satisfactorily over a range of steady-state and transient operating conditions during both thermal and reforming tests, and that the most severe limitation on CAESAR performance is the peaked solar flux distribution across the absorber. A maximum conversion (69%) of methane to carbon monoxide and hydrogen was achieved.

Major Milestones:

Dec 1989	Complete CAESAR experiments using a non-uniform absorber.
Mar 1990	Compare PIRs in photo, catalytic and thermal processes in order to show the benefits of the solar process.
Apr 1990	Complete draft final report documenting the CAESAR experiments.
Sep 1990	Determine quantum yields for destruction of representative hazardous organic compounds in a high flux system.

Sep 1990	Complete initial phase survey of steam reforming of representative toxic organic solvents.
FY 1991	
Q2 1991	Complete redesign, installation, and testing of improvements to steam reforming facility temperature, flow control, and trace product analysis systems.
Q3 1991	Complete experiments that define the practical range of operating conditions for a commercial system.
Q3 1991	Complete studies of feed systems for a commercial system.
Q4 1991	Demonstrate photo catalytic hazardous waste destruction process in an on-sun experiment.

Resources:

In-House:	1125K
Subcontracts:	410K
Total:	1535K

Task B. High Flux Optics

Objectives: The main objective of this task is to explore new and innovative methods to achieve extremely high solar flux concentrations and to continue development of potential applications utilizing this high flux.

Rationale: The generation of extremely high solar flux concentrations represents a research area with challenges and abundant potential. The challenges lie mainly in the ability to produce and control concentrated solar flux at levels which, up to now, have been achieved only at a fairly small scale. The potential is limited only by our imagination and our ability to probe new areas of technology with this new capability. Continuing development of research tools to explore new and innovative concepts is essential to generate technology which can form the basis for future commercial applications and utilize the full potential of this solar capability.

FY 1990 Task Description: The initial effort in this task will be to complete fabrication and installation of the High Flux Solar Furnace at SERI. This will include the installation, alignment and operational tests of the heliostat, primary mirror data acquisition and experiment support systems. Following the initial operational tests, the system will undergo a characterization of the flux obtainable in a single-stage configuration (i.e., without a secondary concentrator). Characterization will include the entire range of planned operational arrangements and conditions.

Throughout the year there will be a continuing effort to improve the existing capabilities of the furnace and to develop new ones. Increasing the flux by incorporating a secondary concentrator will be a major focus. The ability to redirect the concentrated flux in a downward direction will be another important activity. Both an analytical and experimental effort to determine appropriate designs for both flat and mildly concentrating turning mirrors are planned.

While improvements to the furnace capability are an important part of the task, providing support to other research tasks is the primary purpose of the furnace. After the characterization phase of testing, the initial experiments in support of both photochemistry and materials processing will be scheduled. It is anticipated that these two research support activities will be conducted throughout the year. As part of the continuing support to the furnace activities by the University of Chicago, they will fabricate a single reflective secondary concentrator based on the analysis conducted in FY 1989. The flux generated at the exit of the secondary will be measured and characterized. This will serve to validate the analytical predictions developed in FY 1989.

High flux research activities will continue at the University of Chicago in two major areas. The first will advance the solar-pumped laser work and the second will move toward achievement of flux concentrations approaching 80,000 suns. The laser research will demonstrate continuous lasing in Cr:Nd:GSGG with efficiencies approaching 3%. Frequency coupling with this lasant is also possible. Additionally, lasing in Alexandrite (a tuneable lasant) will be demonstrated. With the use of clear YAG (n=1.8) as a secondary material, it is possible to achieve an ultra-high flux of 80,000 Suns. Flux concentrations from this type secondary will be measured with a calorimetric technique.

FY 1991 Activity Description: The main focus of FY 1991 work will be in evaluation, development and demonstration of high flux solar applications. Work will continue on both laser pumping and frequency doubling with an emphasis on demonstration of viable concepts with cost-effective potential. Additional efforts will be made to identify, analyze and conduct experiments relating to new, innovative high flux applications.

FY 1989 Accomplishments: During FY 1989 the HIgh Flux Solar Furnace was designed, engineered and its parts were fabricated. On-site construction began and progressed on schedule. This system consists of a flat, tracking heliostat; a 23-facet primary concentrator; a control and assembly building; and associated data acquisition hardware and software. At the end of FY 1989, the major portion of the site development was completed, including grading, foundations, buildings and electrical and mechanical systems. In addition, the major optical elements (i.e., the heliostat and primary) were in the process of installation and alignment.

Through a subcontracted effort at the University of Chicago, continuing research in high flux optics applied to laser pumping made several significant accomplishments. The first was to achieve lasing with a GSGG laser at a measured threshold of 1 kW/cm^2. This laser was end pumped using a two-stage system with a 40 cm primary and an acrylic secondary. The second major achievement was to complete a redesign of the optical system so that a much higher threshold laser could be pumped. Improvements to both the primary and secondary are estimated to yield an increase in overall lasing efficiency from 0.5% to 5%. New materials for secondary concentrators with extremely high index and solar transmission were also developed during the year.

In addition to the research in laser pumping, the University of Chicago has been involved in analytical support for the furnace. Modelling and analysis tools for various types of secondary concentrators for use in the furnace were developed. These tools for secondary analysis will be incorporated into the SERI-developed code for furnace analysis (SOLFUR).

Resources:		
	In-House:	420K
	Subcontracts:	100K
	Total:	520K

Major Milestones:

Dec 1989 High Flux Solar Furnace operational.

Jun 1990 Identify optical components for a wavelength shifting system and document expected efficiencies in solar applications.

FY 1991

Q4 1991 Test wavelength shifting concept in a solar-powered experiment.

Task C. Materials Processing

Objectives: The objectives of this project are to identify, analyze, and understand beneficial transformations on material surfaces induced by highly concentrated solar radiation, so that new methods for industrial application of materials processing can be developed and demonstrated.

Rationale: Surface processing technologies are at the leading edge of materials research worldwide and are expected to stay there as technology demands greater performance from the materials used in all processing and products. Almost all the action of interest during the lifetime of a component occurs at a surface or an interface between two materials. Modification of the surface region can provide increased wear resistance, corrosion resistance, improved high temperature performance, or superior optical or electronic properties to a material, while at the same time reducing cost, consumed energy, and/or consumption of strategic materials in producing the material. Furthermore, it is possible to construct surface phases which are not accessible through conventional bulk processes, thereby significantly expanding the opportunities to make materials with beneficial characteristics. Additional reasons to pursue research in surface modification technology is to reduce lifetime energy costs in the production of materials. Increased usage of surface treatments can reduce the total energy consumed in manufacturing by reducing the amount of bulk materials processing. (Manufacturing accounts for 27% of all the energy consumed in the United States.) Very large reductions in energy consumption per unit of production can be achieved in the range of 10^3 to 10^8, depending upon the particular process envisioned. Better performance, as in a decrease of the coefficient of friction for tribological coatings or an increase in service lifetime in a corrosion resistant coating, can lead to substantial lifetime energy savings involved in the use of improved materials. Current research efforts in surface processing technology at SERI involves the use of highly concentrated solar beams to deliver the energy necessary to transform the surface of various materials in beneficial ways. Current work at Sandia and Georgia Tech involves improving the oxidation resistance of carbon fibers and performing systems analysis to better understand the economics of solar processing. Highly concentrated solar energy provides a controllable means of delivering large flux densities (>1 MW/t^2) of broadband radiation to solid surfaces. This incident photon flux and/or the resulting thermal energy can cause phase changes, atomic migrations, and chemical reactions on a surface without greatly perturbing the bulk properties of materials. This flux can be delivered in large quantities over large areas, or can be tailored in size to match a given process. Large focal lengths are possible and this means that one has great flexibility in the design of a manufacturing process. The flux is delivered directly to the point of use, which means that there is little waste heat (no heat rejection facilities required) and that cold wall (extremely clean environment) reactions are possible. Furthermore, there are only reflective losses involved in directing and concentrating the sunlight; there are no conversion losses in going to electricity and then back to light or other radiation. This means that use of a solar furnace is relatively nonpolluting (no greenhouse gases, no interaction with the ozone layer, no airborne emissions, no excess heat). In addition, systems analysis indicates that solar processing is already cost competitive in some locations with more conventional methods of surface modification and manufacturing.

FY 1990 Task Description: The approach in FY90 is to continue research initiated in earlier years to explore the capability of concentrated solar radiation to induce beneficial surface modification of materials. Increased emphasis will be placed upon research into systems of commercial interest as well as bringing the capability of film growth from vapor phase reactions on line. Specifically the assembly of high vacuum system with mass flow control for film growth experiments, and experiments will be conducted on SERI's solar furnace. These experiments will study solar induced vapor phase deposition of SiC, TiN, TiB_2, and C on metal substrates. Analytical work will be conducted on heat treated steel samples and claddings from powder melt that resulted from previous research, and the results will be interpreted to establish desired treatment conditions. In addition, processes that may have some immediate commercial interest will be explored. These are joining cast-to-size alloy forms; thermal treatment of engineered materials; and creation of new alloy phases from previously deposited metal layers.

A technical review panel meeting will be held to provide guidance in selecting areas to pursue. Industry representatives will be informed of the benefits of solar processing. Via a subcontract the national importance and impact of this area of solar research will be assessed.

In parallel, work on rapid thermal processing of carbon fiber tows will be continued to improve their oxidation resistance. An improved system for exposing carbon fibers to high flux will be constructed and put into operation. This will allow exposure of large samples and better control of the atmosphere. Larger samples will allow more accurate measurement of properties. Also the analysis to compare the solar furnace to other heat sources will be refined.

FY 1991 Activity Description: Study carburization and nitridation (diffusion) rates and microstructural benefits from processing under high thermal gradients. Formulate thermal and microstructural models to predict effects of different sized beams and fluxes on various materials. Conduct exploratory work at high flux: a. 5 k/22 k suns (at Vortek); b. 8.5 k suns. Initiate theoretical work on a detailed description of the absorption of broadband radiation by solids and the thermal profile of targets of varying geometry in beams of varying shape. Conduct some collaborative work on rapid thermal annealing of photovoltaic materials.

FY 1989 Accomplishments: Progress was made in several areas of solar processing research in FY89. Phase transformation hardening of steel was demonstrated at fluxes of 200 W/cm^2. Strips of 4340 steel (24" x 6" x 0.5" and 12" x 6" x 0.25") were hardened by translating them under the beam at various speeds. Fully hardened areas were formed in the 0.1" thick plate penetrating to 4 nm below the surface. The heat affected zone penetrated completely through the samples, indicating that substantially higher fluxes are required in order to form thin transition zones between the hardened and unhardened areas. Nitride grade steels were hardened at fluxes up to 180 W/cm^2. Interesting needle like hardened regions were formed with softer regions of steel between the needles, which show that unusual growth of material phases may occur under high flux conditions. It is concluded that higher fluxes, perhaps near 10,000 suns are required to explore the interesting areas of transformation hardening.

A vacuum chamber with a fused silica port was designed and assembled with manual leak and low vacuum capability. Preliminary tests indicated that it is possible to grow interesting metallurgical coatings, such as metal nitrides, borides and carbides, by flowing reactive gases over substrates heated in the solar beam. Attempts were made at growing SiC, TiN, TiB_2, and hard carbon coatings. Impurities resulting from insufficient cleaning of the chamber under low vacuum conditions pointed to the necessity of going to high vacuum capability and ultra high purity gases. A new vacuum and flow control system was designed and assembled for testing in FY90.

Three commercial processes were reviewed for possible application of the solar process. These are: a. joining of cast-to-size aerospace alloy forms for the layup of carbon fiber composites; b. rapid thermal processing of engineered beryllium alloys; c. reaction of predeposited films on selected substrates to form special alloy surface phases. These appear to be viable processes for treatment in a solar furnace, and some interest from industrial concerns has been expressed in exploratory work.

Sandia conducted systems analysis to compare the cost of installing and running a solar furnace for a generic application to the cost of installing and running an arc lamp for the same application. Results of the analysis indicate that for the Albuquerque location, the solar furnace is more cost effective under most conceivable scenarios of operation. For highest flux requirements (>500 W/cm^2), the cost of operation per delivered energy is less than half that of the high power arc lamps.

Research at GTRI has confirmed that solar processed carbon fiber tows exhibit improved oxidation resistance in oxygen asher experiments, as compared to as supplied materials.

Resources:	In-House:	450K
	Subcontracts:	90K
	Total:	540K

Major Milestones:

May 1990 — Review and evaluate merits of carbon fiber treatment with high solar flux.

Jul 1990 — Evaluate the benefits of solar surface treatment of metals for specific applications.

FY 1991

Q3 1991 — Produce composite samples using solar treated carbon fibers.

Q4 1991 — Compare thin film production on metal surfaces at 2000 and 8000 suns

Task D. Receiver/Reactor Modelling

Objectives: To develop computer codes which are capable of predicting the performance of waste detoxification receiver/reactors.

Rationale: Commercialization of receiver/reactor technologies will require a capability to predict receiver/reactor behavior via detailed analytical models. Validated models can be used to give guidance to experimental programs and to complement and extrapolate the costly experimental data. In addition, results from models support systems studies aimed at estimating the economic potential of the processes. Finally, the ultimate application of these models will be to help design receiver/reactor systems for water detoxification and destruction of chemical wastes.

FY90 Task Description: SERI modeling activities will build upon progress made in FY89. The computer model developed in FY89 which predicts local absorption of solar energy within a receiver will be extended to account for infrared transport, convective coupling to a flowing gas, and chemical reactions. Experiments will be designed for the SERI solar furnace with the purpose of validating the model first for a purely thermal receiver and then for a receiver which photocatalytically decomposes trichloroethylene in air. The model will also be adapted to the destruction of dilute aqueous tricholoroethylene in a trough-type collector. Data from the SERI trough experiment will be used to validate this model. Kinetic and mass transfer data are needed for both receivers. These data are currently being collected under other tasks.

For both receivers, certain radiative transport properties of the absorbers are needed. These include single scatter albedo, scattering phase function, and extinction and scattering coefficients. For the high-temperature receiver, these properties are needed for both the solar band and for the infrared band. For the aqueous tricholoroethylene reactor, data in the ultraviolet are mainly needed. Experiments to determine these properties will be carried out on an existing polar nephelometer.

Sandia researchers will compare numerical predictions with thermal and chemical (methane and catalytic TCE conversion) data from the DCAR (homogeneous absorber) tests, CAESAR (variable porosity absorber) tests and thermal data from testing at Almeria, Spain. These comparisons will be used to evaluate both the present model and the absorber characterization and will be used to identify areas for improvement.

FY 1991 Activity Description: As experimental work and systems studies continue, it is to be expected that certain receiver/reactor applications and systems will prove most beneficial and will receive the most attention. Modelling efforts will be aimed at these applications by developing models of these receiver/reactors and by validation of the models with experimental data.

FY 1989 Accomplishments: SERI researchers initiated and completed a detailed literature review on radiative transport modelling. This review led to the conclusion that in order to properly assess capabilities of the various techniques as they would be applied to a solar receiver/reactor problem, it would be necessary to actually implement two or more such techniques. To that end, three computer codes were developed, validated, and compared for conditions expected in a receiver/reactor. The first code employs the discrete ordinates method, the second employs the Monte Carlo method and the third employs the two-flux method. The codes were developed to solve radiative transport in participating media in a geometry similar to that expected for receiver/reactors, a two-dimensional asymmetric cylinder.

To date, all three codes have been validated against published solutions for limiting cases, i.e., the one-dimensional slab problem (a very short cylinder) and the infinite cylinder problem.

Sandia researchers developed a detailed model of the CAESAR receiver/reactor. This receiver/reactor reforms methane with carbon dioxide in a closed flow reactor. Solar energy is focused on a porous foam alumina absorber which is impregnated with a rhodium catalyst. Methane and carbon dioxide flowing over the catalyzed absorber react to form carbon monoxide, hydrogen and water vapor. The radiation transport (for the solar and infrared spectrum) was modeled with an enhanced two-flux technique while empirical correlations were used for the convective heat transfer and the chemical reaction rates. Radiative properties needed for the model were measured. The model allows one to characterize the absorber thermally and chemically, provides design guidance for the absorber, helps to interpret test data, and can be extended to receiver/reactors designed for chemical waste destruction. As far as the CAESAR receiver/reactor is concerned, the model showed that it would be necessary to radially tailor the absorber to match the solar flux distribution and that a multiple layer absorber would be needed. In addition, it was found that the initially planned rhodium loading was insufficient and that the initial chosen optical density was excessive. Results show that the receiver chemical efficiency should be about 50% and the thermal efficiency should be about 70%.

Resources:	In-House:	495K
	Subcontracts:	160K
	Total:	655K

Major Milestone:

Dec 1990	Complete comparison of models with thermal receiver data and with tricholorethylene decomposition receivers. Recommend areas of improvement for the models and for experimental methods used to take the validating data.

2. CONCENTRATOR DEVELOPMENT

Task A. Heliostats

Objective: Establish commercial readiness of the heliostat for central receiver solar thermal electric applications.

Rationale: The heliostat is the component of the central receiver system that collects and concentrates sunlight by tracking the sun. The heliostat comprises the largest cost element and has a direct effect on the overall performance of the central receiver system. Therefore, it is essential to minimize the cost without significantly sacrificing performance. The stretched membrane heliostat has gone through research and two stages of development and appears capable of best meeting program needs. This is because of the simplicity and light weight of the stretched-membrane technology. These concentrators have the potential to cost significantly less than the current concentrators. Current estimates show for large quantity builds, heliostats have the potential to be produced for approximately $\$70/m^2$. This cost reduction would allow a dramatic step towards attractive, competitive system costs.

Commercial readiness is the time when sufficient industrial manufacturing and in-field operating experience exists so industry can confidently respond to market opportunities without government support. Our goal is to accomplish this by FY93. To do so will require the evaluation of two 50 m^2 prototype mirror modules and the design, fabrication, and evaluation of commercial-scale prototype stretched-membranes heliostats that incorporate new and optimized pedestal, structure, and tracking.

FY 1990 Task Description: The optical evaluation of the two improved stretched-membrane mirror modules will be completed and documented. Paralleling the FY89 effort of SAIC, a contract will be issued to SKI for the design of a market-ready stretched-membrane heliostat, integrating the existing mirror module with a drive, support, and controls. Both SAIC and SKI will fabricate prototypes of the fully integrated heliostats at the STTF for testing and evaluation by Sandia.

Evaluation of the optical performance of the two large-area glass-mirror heliostats will be completed. Testing of the 150-m^2 heliostat will be performed using the low-cost drive, which will also be evaluated.

FY 1991 Activity Description: Stretched-membrane heliostats will continue development, fabrication, and evaluation in pursuit of the commercial readiness goals. Design and fabrication of membrane heliostats will be completed, with only long-term evaluation of market-ready prototypes remaining to complete the development efforts.

FY 1989 Accomplishments: Two improved conceptual designs for stretched-membrane heliostats were completed and documented; both are significant improvements over the first-generation designs. Sandia's evaluation of the two 50-m^2 prototype mirror modules, representative of the conceptual designs, illustrated the significant improvement over first-generation designs, especially in wind. SAIC completed the design of a 100 m^2 market-ready heliostat, which is directed at near-term commercial opportunities.

Optical evaluation of the two large-area glass-mirror heliostats was not completed as planned. Preliminary results for the ATS 150-m^2 heliostat showed very good optical performance; no evaluation has been performed on the 200-m^2 heliostat. The drive on the SPECO 200-m^2 heliostat was repaired, but later failed during a qualification test under static loads. The drive on the 150-m^2 heliostat, which had worked well, was replaced with a prototype of the new low-cost drive. The new drive performed up to standards, but was damaged by water that collected inside and froze. The drive was modified by the manufacturer and testing has been resumed.

Resources:		
	In-House:	525K
	Subcontracts:	500K
	Total:	1025K

Major Milestones:

Dec 1989	Initiate fabrication of first prototype of SAIC's 100-m^2 market-ready heliostat.
Jan 1990	Complete testing and documentation of 2 improved prototype stretched-membrane mirror modules.
Apr 1990	Complete testing and documentation of the low-cost drive.
Jun 1990	Complete design of SKI's market-ready prototype heliostat.
Jul 1990	Compete fabrication of SAIC's prototype 100-m^2 market-ready prototype heliostat.
Sep 1990	Initiate fabrication of first prototype of SKI's market-ready prototype heliostat.
Sep 1990	Complete testing and documentation of 2 large-area glass-mirror heliostats.
FY 1991	
Q2 1991	Complete fabrication of SKI's prototype
Q4 1991	Complete performance testing and documentation of the two prototype market-ready stretched-membrane heliostats.

Task B. Parabolic Dishes

Objective: Bring parabolic dish concentrator technology to technical readiness for use in dish-Stirling electric and chemical reactor systems.

Rationale: The parabolic dish is the largest cost component in a solar thermal dish system. It is also the first of the system components, dish, receiver, and engine, whose performance determines the overall efficiency of the system. Therefore, if we are to develop competitive dish-Stirling electric and chemical reactor systems, it is essential that we minimize the cost of the dish while maintaining a high level of optical performance,

The optical performance and projected costs of the stretched-membrane heliostats encouraged us to apply this technology to the development of light weight, high performance parabolic dish concentrators. The application of the stretched-membrane techniques to forming highly contoured dishes is considerably more complex than to relatively flat heliostats. However, stretched-membrane dishes have the potential for reducing the cost of conventional glass-metal dishes ($200/m^2) by 40 to 50% while maintaining high optical performance.

FY 1990 Task Description: In FY90, we will continue to develop the single element and faceted stretched-membrane dishes, and improve analytical tools for the evaluation of faceted dishes.

The single element, stretched-membrane dish project will see the completion and testing of a 7-meter diameter optical element during the FY90. If optical testing shows that the dish performance is good, we will proceed with the design of a 12-meter diameter dish.

Contracts will be placed for the faceted, stretched-membrane dish project. The fabrication of facets and the design of a support pedestal will be completed in FY90. The facets will be tested at SERI.

The completion of the 7-meter single element module and the optical elements of the faceted dish will bring us to a major program decision point. At this point, the performance and cost data for the various options will be analyzed, and we will select the most promising dish concepts for fabrication and full-scale testing.

FY 1991 Activity Description: Based on the accomplishments made during FY90 and funding levels, we will continue the development of stretched-membrane parabolic dish concentrators during FY91. These projects could include the single element stretched-membrane dish and as many as 2 faceted stretched-membrane dish concentrators.

FY 1989 Accomplishments: Activities in the Parabolic Dish Task area during FY89 included completion of the testing of the LaJet Innovative Concentrator; continued development of the single element stretched-membrane dish; start of a faceted stretched-membrane dish project; modification of computer codes for predicting the performance of solar concentrators; and completion of instrumentation for measuring the performance of solar concentrators.

During FY89, the LaJet Innovative Concentrator was aligned on sun and tested at the Solar Thermal Test Facility. Total power through the receiver aperture was measured to be 128 kW_T, corresponding to a collector efficiency of about 85% at an insolation of 1000 W/m^2 and peak flux of about 2800 suns. Stiffening of the structure and on-sun alignment of the facets resulted in performance that exceeded initial expectations of the as-received concentrator. Much of the technology developed by LaJet is being used to improve the concentrator for the Cummins/Sunpower/LaJet dish-Stirling project.

In FY87, we initiated a project to apply the stretched-membrane approach to the development of a high performance dish. During FY 89, Solar Kinetics, Inc. (SKI) of Dallas, Texas demonstrated that steel membranes could be repeatedly formed (at sizes up to 3m diameter) to an accurate parabolic shape (3 milliradians, 1σ) using a combined uniform and nonuniform loading technique. SKI engineers then designed a 7-meter diameter optical element that will be delivered to Sandia for evaluation during FY90. If these tests are successful and funding allows, we will proceed with the design of a 12-M diameter stretched-membrane dish.

This fiscal year we also started a project to develop a near-term solar concentrator that uses large, stretched-membrane facets for optical elements. The facets are more like heliostat facets than the single element dish; that is, they do not require a deep contour. These facets should be more easily fabricated and require less development than the single element dish, although the performance of the concentrator is expected to be about 10% less than the single element dish. The project comprises 2 phases, and we expect to produce a fully-integrated, faceted stretched-membrane concentrator for testing at Sandia's Solar Thermal Test Facility in FY91.

Analytical and experimental tools for evaluating dish concentrators are an important part of this task. During FY89, the OPTDISH code was enhanced to include edge-masking of the dish, and the graphical output was modified to include a spot plot of slope residuals. A multi-facet concentrator ray-trace code, called ODMF, was developed to model either single- or multi-facet dishes. This code was used to evaluate the relative performance of 11, 12, 17, and 19 facet dish configurations. Twelve facets appear to be near optimal.

A systems study was also performed to determine how much less a 12 facet stretched-membrane dish would have to cost in order to provide electricity for the same cost as the McDonnell-Douglas glass-mirror dish. The results showed that the faceted dish need only be 88% the cost of the McDonnell-Douglas dish to be cost-effective. With a secondary concentrator, it could cost as much as 96% the cost of the McDonnell-Douglas dish.

The Scanning Hartmann Optical Tester (SHOT) is completely operational and has been used to test several dishes fabricated by DOE and NASA.

		Baseline	GRH Return
Resources:	In-House:	925K	1075K
	Subcontracts:	1006K	1475K
	Total:	1931K	2550K

Major Milestones:

Feb 1990	Complete Fabrication of the 7-Meter Single Element Module
May 1990	Complete Validation of SHOT
May 1990	Complete On-Sun Testing of the 7-Meter Single Element Module
Jun 1990	Complete Computer Model of the Faceted Dish Support Structure
Jun 1990	Complete Optical Testing of the Facets for the Faceted Dish
Jul 1990	Program Decision Point: Dish Designs To Fabricate and Test
Aug 1990	Complete Validation of OPTDISH and ODMF Optical Codes Using the Data from SHOT
FY 1991	
Q1 1991	Complete the design of the Faceted Dish Concentrators
Q3 1991	Complete the design of the Single Element Stretched-Membrane Dish
Q3 1991	Assemble the Faceted Dishes at the STTF in Albuquerque for Testing

Task C. Optical Materials

Objectives: Research and develop optical materials that have a high quality optical performance, are of lower cost, and have increased lifetimes for use on concentrators.

Rationale: Light weight, durable, and efficient optical reflective materials are necessary if we are to achieve the cost and performance goals for heliostats and parabolic dishes.

FY 1990 Task Description: The major effort in Task 3 is the development of silvered polymer films for use on concentrators, primarily heliostats and parabolic dishes. A small project to develop a silvered stainless steel mirror will be completed in FY90 with the completion of a cost study.

SERI, working with industry and supported by Sandia, will perform research on silvered polymer film reflectors that focuses on three major unresolved issues. First, we will try to identify a method for correcting the delamination problem that has been observed when the silvered polymer is applied to large structures and exposed to moisture. The adhesion between silver and the polymer is weak and is further reduced in the presence of water (the process is reversible). We will continue and extend adhesion and delamination tests that were started in FY89, including evaluation of alternate seaming techniques. SERI and Sandia will supply samples of the best materials for field tests.

Second, excellent progress has been made in slowing the rate of silver corrosion. Work will continue, at a reduced level, to define alternatives to coil-coated aluminum substrates and to define the limitations on the current best materials.

Though significant progress has been made to extend the life of reflective films to at least five years, it will be necessary to occasionally replace the film in the course of a heliostat's anticipated 30-year life. The materials needed to form a replaceable reflector are being developed and Sandia will demonstrate the replacement of the film on a 50-m^2 stretched-membrane heliostat. Preliminary work was started at SERI in FY89 to compare the performance of adhesives that could be used for easy in-field replacement of the polymer film. These tests will be continued and extended to alternative means of film attachment.

SERI will also initiate an effort aimed at the characterization of mirror concepts specifically to meet the needs of photochemical reactors.

A cost study will be undertaken to determine the relative cost of producing stainless steel mirrors and polymer films.

FY 1989 Accomplishments: Excellent progress was made to reduce the rate of corrosion of silvered polymer mirrors. Polymer mirrors have failed in Arizona and at other sites within 1 to 2 years of outdoor exposure. Other outdoor tests, up to 7 years on PMMA films supplied by the 3M Company, show the good performance of unsilvered polymer. Similar test results identified that the corrosion problem occurs at the silver-polymer interface. Detailed mechanistic studies that led to a better understanding of the cause of degradation at the silver interface have resulted in significant modifications. Based on accelerated laboratory tests, there is a reasonable expectation that resistance to corrosion can be attained for the life goal of 5 years. Based on these results, the 3M Company has produced a new silvered polymer mirror product, ECP 305.

We investigated adhesion and delamination of silver on 2 polymers, poly methyl merthacrylate (PMMA) and polyethylene terephthalat (PET). The adhesion of silver to PET is excellent, which suggests the approach of providing PET-like bonding sites on the surface of the PMMA. Experiments using inorganic interlayers were initiated using aluminum, nickel, and inconel and will be extended to other metals and metal oxides, and to organic interlayers.

During FY89, Sandia completed the initial development of the optical mirror "stack" with the application of protective hard coats to the top of the high performance, sol-gel planarized, silver mirrors. This could result in much simplified, low weight, and lower cost solar concentrators. Since the resulting mirrors are a thin glass, they should demonstrate lifetime and desirable characteristics of glass mirrors and also greater flexibility.

		Baseline	GRH Return
Resources:	In-House:	750K	900K
	Subcontracts:	200K	200K
	Total:	950K	1100K

Major Milestones:

Jun 1990	Complete and document preliminary evaluation of UV-Enhanced Mirrors for Photochemical Applications
Jul 1990	Complete the Sol-Gel Mirror Production Cost Study
Jul 1990	Complete and Document Replaceable Film Study
Sep 1990	Document Studies of Polymer Film-to-Silver Adhesion

Task D. Structural Dynamics

Objectives: Develop analytical and experimental data which will allow concentrator weight and cost to be minimized while maximizing structural integrity and performance.

Rationale: Cost saving can be achieved by reducing a concentrator's weight. However, to maintain or to improve the optical performance, it is necessary to make a rigid light weight structure that survives static and dynamic wind loading. Currently, concentrators are overdesigned due to lack of understanding of how wind loads interact with concentrators. This is particularly true for stretched membrane concentrators. To improve concentrator structured design, we need the tools and the data base to allow thorough analysis and understanding of the structural dynamics associated with wind loads and their effect on the design of solar concentrators.

FY 1990 Task Description: Due to funding limits and the expected small near-term impact on concentrator cost, no further work will be conducted in this area. Documentation of activities to date will be completed.

FY 1989 Accomplishments: Installation of the test equipment was completed, and calibration tests have been performed. Strains during low level winds (less than 15 mph) have been measured.

Resources:		Baseline	GRH Return
	In-House:	50K	50K
	Subcontracts:	–	–
	Total:	50K	50K

Major Milestone:

Jan 1990	Complete documentation of initial wind load studies.

3. ELECTRIC SYSTEMS DEVELOPMENT

Task A. Central Receiver Technology

Objectives: Demonstrate the feasibility of the direct absorption receiver concept and develop the basic analytical and experimental understanding of the thermal, fluid dynamics, and materials issues of central receivers. Also, demonstrate extended operation of commercial-scale molten salt pump and valve components.

Rationale: The current development path is intended to achieve a long-term goal of cutting receiver costs by 50% while increasing annual performance by 15%. This could reduce the cost of energy produced from central receiver systems by up to 20%. To achieve these goals, current efforts are centered on developing receivers that eliminate the need for tubes to contain the working fluid. The principal concept being investigated is the falling-salt-film direct absorption receiver (DAR). In a DAR, the heat absorbing fluid (a molten nitrate salt) flows in a thin, wavy film down a flat, near-vertical panel (rather than through tubes) and absorbs the concentrated solar flux directly. Potential advantages of the DAR include a simplified design, improved thermal performance, increased reliability and operating life, and reduced capital and operating costs. Before the DAR technology can be implemented, however, we need a better understanding of flow and energy transfer phenomena, and materials issues.

The volumetric air receiver is another innovative receiver design that is being developed. The volumetric receiver utilizes a three-dimensional porous absorber, on which the solar flux is concentrated and volumetrically absorbed. Air is drawn through the absorber, convectively transferring energy from the absorber to the air. The volumetric receiver is simple, it can be relatively inexpensive and moderately efficient, and it can produce high temperature (>550°C) air for electricity or process heat.

In addition to development of advanced receivers, the long-term functionality of molten salt components (including full-scale pumps and valves) needs to be demonstrated.

FY 1990 Task Description: Work will center on demonstrating the direct absorption receiver concept and developing a basic analytical and experimental understanding of the thermal, fluid dynamics, and materials issues of the direct absorption and the volumetric air receiver. Testing to demonstrate the extended operation of commercial-scale pump and valve components for molten salt receivers will be completed. The following activities are planned:

- Complete the installation of the panel research experiment (PRE) and conduct salt flow characterization testing and solar characterization testing.

- Continue the analytical activities on the salt-film DAR, including flow, thermal and structural analysis, performance calculations, and system integration trade-off studies.

- Complete the commercial-scale pump and valve testing and performance and reliability evaluation.

- Continue interactions with the IEA/SSPS on Tasks III, receivers, the planned Spanish IFR concept experiment, and all other testing at the Plataforma Solar de Almeria.

- Initiate optical characterization and solar furnace testing of volumetric receiver absorber samples (i.e., wire mesh and ceramic foams).

- Refine the computer model of the volumetric receiver absorber.

- Design, fabricate, and build an optimized volumetric receiver absorber to test at the Plataforma Solar de Almeria.

- Expand and coordinate joint activities with Bechtel International that will lead to development of a commercial-scale volumetric receiver.

- Complete a comparative evaluation of central receiver systems which use molten salt and air as the working fluid.

- Continue the laboratory tests to understand the breakdown of films subjected to intense radiation.

FY 1989 Accomplishments: Testing and analysis was concentrated on the direct absorption receiver, the volumetric receiver, and the molten salt pump and valve loops. Specific accomplishments include:

- Completed the design and fabrication of the 6-m long panel research experiment. The frame, panel, and manifolds were designed and fabricated.

- Completed a simulation model of the direct absorption receiver, this model will aid in the development of controls and in the characterization of the receiver performance.

- Completed water flow testing to evaluate the effects of panel tilt on the wave development in the falling film. A 15° panel tilt will reduce droplet ejection by 30-40%.

- Successfully designed, built, and tested (using water flow tests) an intermediate manifold which will eliminate the droplet ejection problems with the DAR.

- Began the modifications to a salt loop which will be used for making thermocapillary breakdown measurements with molten salt.

- Completed tests of a co-current air flow with the falling-liquid film to evaluate the air curtain effect on the wave and droplet formation. The co-current air flow will not benefit the DAR.

- Initiated a design and system study of alternative DAR designs. This primarily focused on an design and evaluation of a quad-panel cavity DAR which retains the same 15-20% reduction in LEC over the salt-in-tube receiver.

- Completed the evaluation of the porous ceramic "foam" absorber that was tested on the volumetric receiver test bed at the Plataforma Solar de Almeria. The absorber did not degrade in the high temperature, high flux environment and produced outlet air as hot as 730°C. Receiver efficiencies ranged from 58-78%.

- Completed 2400 hours of operation on the pump and valve hot loop, qualified valve packing materials for up to 1000 hours of service. An interim report has been drafted.

Resources:	In-House FTE:	750K
	Subcontracts:	475K
	Total:	1225K

Major Milestones:

Nov 1989	Complete installation of the PRE
Jan 1990	Initiate the salt flow testing on the PRE
May 1990	Complete the comparative study of salt and air receivers
Jun 1990	Complete the Phase I solar testing of the PRE
Jun 1990	Complete 4000 hrs of operation on the molten salt pump and valve hot loop, complete 2000 hrs of operation on the cold loop
Aug 1990	Complete testing of an optimized volumetric receiver absorber

Task B. Distributed Receiver Technology

Objective: To continue development of the reflux receiver through analytical, design, and experimental activities

Rationale: Stirling dish-electric systems have been identified as having potential for meeting the Department of Energy (DOE) long-term energy cost goals. Dish-electric systems based on Stirling engine technology were successfully demonstrated by Advanco Corp. and McDonnell Douglas Corp. and showed the potential for high efficiency. To reach the ultimate potential for dish electric systems, a high efficiency, low maintenance, and low cost receiver is required. The current development thrust is to improve the longevity and reduce the O&M costs of these systems, as well as to improve performance.

The reflux receiver coupled with the Stirling engine has is an optimum match for the Stirling engine's capability and requirements. In addition, the reflux heat-pipe receiver may be readily applied to other solar thermal applications, with significant life and performance advantages over conventional tube receivers.

FY 1990 Task Description: Work will continue to develop the reflux receiver through analytical, design, and experimental activities. At Sandia the following activities are planned:

- Continue the analytical and design activities on the reflux receiver, including bench tests and on-sun testing of full-scale receivers at the STTF and system integration trade-off studies.
- Provide STTF support and facility upgrade for the testing activities associated with the sodium reflux receiver.
- Integrate a reflux receiver with the STM4-120 kinematic Stirling engine and controls, and initiate a hybridization study for the STM system.
- Continue materials compatibility studies and stress analysis of reflux receivers with emphasis on the thermal cycling environment. The emphasis in FY90 will be to select candidate materials based on a review of the prior work.
- Perform system analyses based on the results of developmental and experimental activities.

FY 1989 Accomplishments:

- Further expanded the CIRCE computer code to support the development of dish-Stirling systems.
- Bench tested reflux pool-boiler and heat-pipe receiver concepts at the STTF.
- Successfully tested a full-scale reflux pool-boiler solar receiver on-sun and demonstrated the high-performance potential of the reflux receiver concept.
- Provided technical support to dish-Stirling developments by industry (Cummins Engine Co., Stirling Technology Co., Stirling Thermal Motors).

Resources:	In-House:	800K
	Subcontracts:	400K
	Total:	1200K

Major Milestones:

Oct 1989	Complete bench tests of heat-pipe receivers.
Nov 1989	Complete on-sun testing of a reflux pool boiler at the STTF.
May 1990	Decision on heat-pipe vs. pool-boiler receivers for further development.
Jul 1990	Complete preliminary design of a hybrid reflux receiver.

Task C. Conversion Technology

Objective: To test and evaluate conversion devices applicable to solar thermal electric technology. In particular, Stirling cycle heat engines are to be considered. These include a Stirling Thermal Motors kinematic Stirling engine and free-piston Stirling engines under preliminary design by Stirling Technology Company and Cummins Engine Company.

Rationale: Stirling engines have been identified as the most efficient power conversion unit currently available for solar-electric systems (with a demonstrated net efficiency of 29%, a dish-Stirling engine system holds the record for solar-to-electric power conversion). These engines are available in power levels of 3 to 50 kWe and are suitable for small-modular solar systems designed to deliver electric power directly to the utility grid. In addition, Stirling engines used in a solar power system can be hybridized to run on both solar energy and natural gas so that power can be produced during low periods of solar insolation.

Several U.S. companies are developing Stirling engines for several applications such as heat pumps, auxiliary power units, and transportation. Therefore, development costs for Stirling engines are financed primarily by non-solar applications. U.S. manufacturers are following the technology closely in order to be in the position to quickly begin manufacturing when technology and market conditions are appropriate.

FY 1990 Task Description: Test and evaluate the performance of the Stirling Thermal Motors (STM) kinematic engine both in a test cell and on-sun and complete the final design of a free-piston Stirling engine (FPSE). At Sandia the following activities are planned:

- Continue testing of the STM 4-120 kinematic Stirling engine at the Engine Test Facility.
- Integrate hardware with a second STM kinematic Stirling for on-sun testing.
- Initiate a cooperative agreement with Cummins Engine Company to improve the reliability/manufacturability of the STM 4-120 kinematic Stirling engine being evaluated by Sandia.

- Provide project management and technical support to continue with the FPSE final design and hardware procurements.

- Provide DRTF support to the testing activities associated with the Stirling engine.

FY 1989 Accomplishments:

- Initiated operation of the Sandia Engine Test Facility.

- Began testing of the STM 4-120 kinematic Stirling engine at Sandia's Engine Test Facility.

- Completed the procurement for a second STM kinematic Stirling engine for on-sun testing.

- Initiated through the DOE-NASA Interagency agreement two preliminary designs for an FPSE (designated the Advanced Stirling Conversion System (ASCS)).

Resources:	In-House FTE:	450K
	Subcontracts:	825K
	Total:	1275K

Major Milestones:

Feb 1990	Initiate Final Design of Advanced Stirling Conversion System
Sep 1990	Initiate on-sun testing of the STM 4-120 Stirling

4. TECHNOLOGY DEVELOPMENT

Task A. Next-Generation Commercial Systems

Objectives: Through cost-shared agreements, this task will provide R&D support to the commercial solar thermal electric industry. The R&D activities will improve and optimize the costs and performance of their existing technologies. This will maintain and enhance their ability to compete with other energy technologies through the mid-1990's.

Key Milestones:

- Verify R&D improvements to commercial systems through in-field tests (FY 91).
- Commercial implementation of competitive system based on R&D results and in-field tests (FY 92).

Rationale: In-place commercial solar electric technologies may be improved to the extent that competitiveness can be maintained and enhanced for favorable market opportunities. This requires a significant reduction in the cost of electricity produced. This task will provide the R&D support to the existing industry for the required improvements and system optimization.

Subtask A-1. Project Development

FY 1990 Task Description: In FY 89 a Commerce Business Daily announcement was used to obtain expressions of interest in the project and a follow-up Request for Quotation produced four responses. Selection criteria were as follows:

1) The R&D program must be for a currently available solar thermal electric system.

2) The proposed approach must achieve electrical energy costs that are competitive in a U.S. market with less attractive electricity purchase agreements than those currently in place and without the benefit of tax credits.

3) The industrial partner must be able and committed to achieve commercial implementation of a verified approach in FY 92.

4) The industrial partner must contribute at least 50 percent of the project cost.

Two of the respondents did not meet the requirements of the selection criteria. At the end of FY 89, clarifications were being sought from the two that met the criteria. One or more commercial partners will be selected in early FY90.

Resources:	In-House:	100K
	Subcontracts:	612K
	Total:	712K

Major Milestone:

Dec 1989 — Award multi-year R&D system improvement contracts with one or more industrial partners.

Subtask A-2. Partner-Driven R&D

FY 1990 Task Description: This task will provide the required R&D necessary to improve the selected system(s). Contract monitoring and test planning (instrumentation, diagnostics, and data systems) support will be provided to the industrial partner(s) in FY 90.

Resources:	In-House:	50K
	Subcontracts:	0
	Total:	50K

Major Milestone:

Oct 1990 — Receive annual progress report(s) from the industrial partners.

Subtask A-3. Design Assistance and CORECT Support

Objectives: The objectives of this task are to accelerate the use of solar thermal systems through cooperative efforts with private industry, to assist and educate potential users, and to support industry and users in the selection, design, characterization, and demonstration of promising solar thermal systems.

Rationale: In order to be effective, the solar thermal program requires a continual flow of information to and from the industry and users. The program's dissemination of R&D results to industry, and the reciprocal communication of industry's needs to the program, are necessary to keep the R&D relevant and to ensure developments are rapidly implemented by industry. This task fosters this flow of information by providing direct technical assistance to industry as well as through conferences, workshops, and publications. This task also provides an interface among CORECT, the solar thermal program and industry to foster near-term applications of solar thermal systems in the international marketplace.

FY 1990 Task Description: The Design Assistance Center at Sandia receives requests for assistance and coordinates efforts with SERI to provide information and fulfill industry requests for technology evaluation, application screening, data, and design evaluation to assist industry and users in implementing the solar thermal option. Existing analysis tools and data will be used to provide this assistance and additional industry needs for improved techniques will be considered and acted upon. The primary focus of the workshops and meetings activity is SOLTECH 90 where sessions will be conducted jointly with industry for specific federal, state and local agency and international audiences.

FY 1991 Activity Description: Continue the R&D program with the selected joint venture partner(s) to develop component and system modifications that will enhance the future competitiveness of their solar thermal electric system. Continue the Design Assistance Center activities and cooperation with CORECT.

Resources:	In-House:	100K
	Subcontracts:	25K
	Total:	125K

Milestones:

Mar 1990 Participate in the SOLTECH 90 joint meeting.

Ongoing Provide assistance for specific solar thermal projects as requested

FY 1991

Milestones for this activity will depend on the specific system(s) and joint venture partner(s) selected early in FY 90.

Task B. Photochemical Systems

Subtask B-1. Identification of Application Opportunities

Objectives: Identify market opportunities for Solar Detoxification of Water processes, demonstrate the solar advantages in those markets, and develop and maintain links to industry that will allow bidirectional information exchange.

Rationale: Contaminated water has become a major problem facing the US. Conventional technologies either do not actually destroy the contaminants or are expensive. Solar treatment of contaminated water offers several advantages, including the fact that the contaminants are treated right in the water without initial transfer, the entire process takes place at ambient temperatures, overall energy requirements are low, and the catalyst involved (TiO_2) is quite safe and nontoxic.

An important feature of this project is that the impetus for developing these solar technologies come from the marketplace, not simply from the potential of the technology. Because of this, the process of carefully identifying and defining the most promising role of solar technology in the market is very important.

For example, groundwater treatment has been selected as the most obvious and most promising first application. However, the process has substantial potential for application to a variety of other situations, including effluent streams from industrial processes as diverse as paper and pulp processing, electronics manufacturing, and textile processing.

FY90 Task Description:

Solar Detoxification of Water

The major effort in this subtask this year will be the site selection process for the system experiment to be built in FY91 in cooperation with the DOE HAZWRAP program. This activity will involve surveying candidate DOE sites with documented ground water contamination problems. This data will be used in conjunction with the results from a conceptual design effort that will delineate all of the major features of a commercial plant, and will assess how that plant will interface with the site. This combination of the site data with the conceptual design will allow us to select the most promising site for this early system experiment.

Another major effort will involve the incorporation of new data from the laboratory and field tests into cost and performance models. Analysis of the results from these models will enable the comparison of this process with conventional processes on a levelized cost basis, and will help to guide further research plans.

Industry Participation

A significant effort will be made this year to establish and maintain a strong industrial involvement program. This will involve a variety of activities ranging from organized workshops (in which the solar technologies are presented and industrial comments are solicited), to one-on-one meetings between the labs and the various industrial concerns. The goal of these efforts is to cultivate one or more parties that are interested in capturing a piece of the future solar detoxification market by establishing an early position in the technology. These parties should represent the vangard of a constituency for the solar thermal process that will help to drive both the technology and the research efforts in the most favorable market directions.

Oversight and Review

Finally, the Solar Detoxification of Water Review Board that was constituted in FY89 will continue to meet and provide valuable feedback to the labs on the fundamental scientific aspects and industrial applications of these processes.

FY89 Accomplishments: A survey of the nature of ground water problems identified chlorinated solvents (particularly trichloroethylene, TCE) as probably the most prevalent contaminant commonly found in the U.S. A preliminary systems analysis of the Solar Detoxification of Water process on these chlorinated solvents demonstrated that it has substantial promise for cost competitiveness with conventional treatment processes for a variety of situations (e.g. ground water that contains organic molecules that are only weakly adsorbed onto activated carbon).

The base case analysis was based on reaction rates available today, and sensitivity analysis showed the magnitude of improvements in throughput that will be needed for future cost competitiveness. A follow-on analysis defined the range of process parameters that would justify the use of additional oxidizing agents.

Field visits were made to several sites that have ground water contamination problems; these visits included discussions about possible future HAZWRAP systems experiments on these sites. This effort will provide a baseline system to use in guiding future research efforts, and in the site selection process that will be started in FY90.

A Review Board was constituted for the Solar Detoxification of Water technology, and input and guidance was sought in a kick-off meeting.

Resources:	In-House:	225K
	Subcontracts:	125K
	Total:	325K

Major Milestones:

Mar 1990 — Conduct a workshop for industrial participants at SOLTEC 90 to encourage industrial involvement in photochemical systems.

Aug 1990 — Complete a conceptual design of a commercial-scale SDW system.

Sep 1990 — Complete site selection process for the first system experiment.

FY 1991

Q2 1991 — Assess the cost and performance of an advanced process using improved catalyst materials.

Q4 1991 — Identify a second major target application.

Subtask B-2. Solar Processing of Dilute Aqueous Organic Chemicals

Objectives: Perform the laboratory and field testing to enable us to site, design, construct and operate a pilot- scale plant treating ground water beginning in 1991.

Rationale: This process addresses one of the largest remediation problems facing the nation today, ground water contaminated with hazardous and toxic chemicals. Systems analysis work in FY89 demonstrated that this solar process had significant potential not only to be cost competitive with conventional processes available today, but to offer several other advantages to site remediation operations. These advantages included a.) this process involves handling the wastes only once, with no transfers from one medium to another, b.) the process is completely self-contained and on- site, thus limiting the operator's liability, c.) complete mineralization of the wastes (e.g. to CO_2 and HCl), and d.) low temperatures and small energy requirements.

FY 1990 Task Description: It is expected that nearly all of the Solar Detoxification of Water activities undertaken in FY90 and FY91 will be focused on developing this technology to be ready for the HAZWRAP demonstration project in late FY91. This goal will provide the direction, the timing, and the overall context that will define these activities.

Efforts in FY90 will continue the three-step testing process begun in FY89. As results are defined in the laboratory on the bench-scale apparatus, they are transferred to the small-scale field apparatus for outdoor, on-sun, verification. Finally, these concepts are tested at the large scale test facility to flush out any problems with scale-up to full-size systems.

One area of emphasis this year will be expanding the single- component results from FY89 to increasingly complex multi- component mixtures. The results from these mixtures will lead to tests on samples of ground water from DOE-DP sites under consideration for the HAZWRAP pilot-scale plant. This information will feed directly into the site selection effort, and eventually into the plant design, scheduled to begin in early FY91.

Another critical area of effort in FY90 will be the development of the TiO_2 catalyst system. Specific objectives will include identifying optimum methods for immobilizing the catalyst, defining and improving the lifetime of the catalyst, and improving the performance of the catalyst. The in-house techniques employed here will extend beyond the type of laboratory test conducted in FY89 to include detailed surface analytic techniques using advanced microscopic and spectroscopic techniques. In addition, an extensive effort will be made to identify promising external sources of both support matrix and catalyst materials.

One effort focused directly on the demonstration project is the site analysis and selection, which will be tied closely to the testing outlined above and will include development of a preliminary conceptual design. This design will be closely connected with ongoing activities in process/reactor modeling, reactor design, development of controls and instrumentation, and of course engineering-scale testing of the key concepts. Obviously, much of the work in this area will take advantage of inputs from the other two areas. For example, the whole area of reactor design includes catalyst immobilization techniques, modeling of the chemical and radiation processes involved, and experience gained through tests on engineering-scale systems.

The culmination of these efforts should be a technology that is ready to proceed to a pilot-scale experiment in the field beginning in FY91.

FY 1989 Accomplishments: Efforts in FY1989 provided convincing evidence of the efficacy of the solar process in destroying both chlorinated hydrocarbon solvents and textile dyes. The sensitivity of the reaction rates to a large number of process parameters was tested. These parameters included solar flux, pH, temperature, and addition of other oxidizers.

Important preliminary data were collected on catalyst immobilization and lifetimes. Initial tests indicated that although immobilized catalysts were slightly less effective than small suspended particles, the difference was small. Initial tests were also run on catalyst lifetime. They showed that the effective lifetime of the catalyst was long enough that the tests required to see any significant reduction in activity would have to be both extensive and lengthy.

Both small and large scale outdoor field test units were brought on-line. Knowledge gained in the laboratory has been transferred to these field systems, and a growing body of on-sun data has been collected. One initial result of these larger tests has been that several significant problems have been noted in achieving tight seals. The information gained in correcting these problems on the test equipment will be directly applied to the pilot scale systems.

Resources:	In-House:	900K
	Subcontracts:	0
	Total:	900K

Major Milestones:

Jun 1990 Complete tests on multiple compound mixtures that model those found in real sites under consideration for system experiment.

Aug 1990 Select a preferred catalyst immobilization scheme for use in the first demonstration experiment.

FY 1991

Q2 1991 Complete outdoor tests on advanced catalyst materials.

Q4 1991 Expand the range of tested chemicals to include other common contaminants (such as pesticides, wood preservatives, and heavy metals).

Subtask B-3. High-Temperature Solar Destruction of Toxic Chemicals

Objectives: Identify market opportunities for Solar Destruction of Hazardous Waste processes, demonstrate the solar advantages in those markets, and develop and maintain links to industry that will allow bidirectional information exchange.

Rationale: Management of low-Btu hazardous wastes is a growing national concern. Whereas wastes with high Btu content can be profitably burned for their heat content, disposal of the remaining low-Btu wastes is likely to become more and more difficult.

The solar technologies represented under this heading offer substantial potential in several areas. These solar processes should reduce the air emissions caused by incineration of these low-Btu wastes for the following reasons.

1. Eliminating the fuel required to incinerate the low-Btu wastes eliminates both the fuel-created combustion products and decreases the total volume of gas treated (by eliminating the extra air required to burn the fuels.

2. Because the solar processes operate at lower temperatures they should also decrease the emission of NO_x, as well as lessening the material requirements on the reactor vessel.

3. Finally, the products of incomplete combustion in conventional incineration appear to be caused largely by anomalies in the combustion process such as rogue (oversized) droplets, and quenching on cold surfaces. Because the heating in a solar process is radiative, good designs should not have cold surfaces, and because 1) the hazardous materials will pass through a solar heated porous frit, and 2) the solar flux will illuminate an entire volume (as opposed to a "flame front" in incinerators), it will be much more difficult for rogue droplets to escape destruction.

The high-temperature Solar Detoxification of Chemical Wastes has potential for application to a wide variety of situations including remediation of contaminated soil destroying concentrated low-Btu effluent streams from manufacturing processes and steam stripping of contaminated carbon (from carbon adsorption beds). In response to this range of environmental remediation and waste management needs, the project embraces a range of technological options that should increase both the probability and the potential range of solar applicability.

An important feature of this project is that the impetus for developing these solar technology come from the marketplace, not simply from the potential of the technology. Because of this, the process of carefully identifying and defining the most promising role of solar technology in the market will be the main thrust of the efforts in this area in FY90.

FY 1990 Task Description:

Solar Detoxification

The efforts in FY90 under this subtask will be primarily market assessment and systems analysis. Those efforts will be focused on identifying markets with strong potential for this technology, and quantifying the potential solar advantages. This effort will involve substantial investigation of current markets, and expected market trends in disposal and treatment of hazardous waste materials. The markets will be assessed by continuing to establish contacts with industrial entities, and by using the data newly collected by the US EPA on releases of toxic and hazardous chemicals into the environment. Conceptual configurations of the solar processes will be developed, and the technical and economic performance of the solar systems will be evaluated relative to conventional techniques.

Several potential processes are represented under this heading. Both photolytic oxidation and thermal/catalytic reforming of various hazardous organic compounds have been demonstrated in the laboratory and in well-controlled field experiments. The wide variety of possible solar configurations and processes enhances the attractiveness of using solar thermal technology for solving environmental problems. When the market assessment activity outlined here is combined with the data from the lab and field tests under high flux photon processes that are ongoing in these areas, these processes should find applicability to a wide variety of waste management and environmental remediation problems.

Industry Participation

A significant effort will be made this year to establish and maintain a strong industrial involvement program. This will involve a spectrum of activities ranging from organized workshops (in which the solar technologies are presented and industrial comments are solicited), to one-on-one meetings between the labs and the various industrial concerns. The goal of these efforts is to cultivate one or more parties that are interested in capturing a piece of the future solar detoxification market by establishing an early position in the technology. These parties should represent the vangard of a constituency for the solar thermal process that will help to drive both the technology and the research efforts in the most favorable market directions.

Oversight and Review

Finally, the Solar Destruction of Chemical Waste Review Board that was constituted in FY89 will continue to meet and provide valuable feedback to the labs on both the fundamental scientific aspects and the industrial applications of these processes.

FY 1989 Accomplishments: Major accomplishments in FY1989 included a convincing and repeatable demonstration of six-9s destruction efficiency (DE) and a marked solar effect in field tests of the solar oxidation of dioxin. Other important results include successful field experiments on both oxidation and reforming of a variety of chlorinated solvent streams, including projected throughput for the reforming process of up to 20 kg/hr. Important laboratory results included reforming results from the University of Houston which predicted four-9s destruction of the solvents at 850°C in a field reactor. The University of Dayton also conducted some important tests that used Cl_2 molecules as a sensitizer or homogeneous catalyst agent, and SERI laboratory tests using the molecular beam mass spectrometer (MBMS) identified substantial reductions in the products of incomplete reaction with steam reforming when compared to pyrolysis.

A strong beginning was made in characterizing some of the markets in which the Solar Destruction of Hazardous Waste processes may find application. More than 30 waste generators, solvent distributors and recyclers, and commercial waste management and environmental remediation firms were contacted and interviewed. From these efforts have come a much better idea of the areas that offer the most promise. These will form the basis for the 1990 effort.

A Review Board was constituted for the Solar Destruction of Hazardous Waste technology, and input and guidance was sought in a kick-off meeting.

Resources:	In-House:	150K
	Subcontracts:	150K
	Total:	300K

Major Milestone:

Aug 1990	Identify the most promising applications of the Solar Detoxification of Hazardous Waste processes, develop a conceptual configuration, and compare the system performance and cost with conventional alternatives.
Fy 1991 Q4 1991	Evaluate the cost and performance of SDCW designs in selected applications.

Task C. Advanced Electric Technology

Subtask C-1. Identify and Evaluate Potential Solar Electric Technologies and Applications

Objective: Identify and evaluate advanced solar thermal electric technologies that can provide a cost-attractive option for specific applications within the next five years.

Rationale: Dish and central receiver technologies have been studied for the past ten years and are nearly ready for implementation in certain applications. It is believed that there is considerable private sector interest to apply these basic technologies in specific markets. However, to initiate the application of these technologies, some DOE assistance may be required.

FY 1990 Task Description: A promising solar electric technology will be identified by formally requesting information from the technical community through the use of formal procurement processes currently available within the DOE/SNL/SERI structure. Through this procurement process, called a Request for Information, the national and international communities will be asked to identify opportunities for an advanced solar thermal electric system that can be cost competitive in United States and international markets. The potential value and cost-effectiveness of each of the proposed systems will be evaluated by a team of SNL/SERI personnel using established system study tools and information provided by the industrial participants.

Based on the evaluations, market/technology combinations will be identified early in FY90 as those most likely to be cost-effective for specific applications.

FY89 Accomplishments: In July of 1989, a request for information (RFI) was forwarded to over 130 organizations who have been involved in solar energy projects. Additionally, the RFI was advertised in the Wall Street Journal to maximize the program's visibility. Ten companies have responded to the RFI with descriptions of a variety of solar thermal systems that are candidates for further development and field testing by around 1993. These responses are currently being evaluated and will be used to develop a request for proposal (RFP), which will be sent to all of those who responded to the RFI.

Resources:	In-House:	50K
	Subcontracts:	0
	Total:	50K

Major Milestone:

Nov 1989 The responses to the Request for Information will be evaluated.

Subtask C-2. Joint Venture Consortia

Objective: To issue a request for proposal that will result in the formation of industry, user, government consortia. These consortia will provide the necessary resources to field a competitive, next generation solar thermal electric system experiment within five years.

Rationale: Joint-venture consortia are required to field a system experiment based on the technology application identified in Subtask 1. A joint venture involving technical and financial resources will be required to reduce the risk to the organizational participants.

FY 1990 Task Description: Based on the results of Subtask 1, a request for proposal (RFP) will be issued in mid-FY90. The RFP will request a detailed description of how the government and industry can work together to develop and field a solar thermal electric generating experiment. The project will be a public show case for state-of-the-art solar thermal electric technology. Following the system experiment, the government's role will cease and the industrial partner will market the solar electric technology. Contract award is expected to lead toward the organization of industry, user, and/or government consortia that will provide the necessary resources to field a competitive, solar thermal electric system experiment within five years. Joint-venture consortia are required to field a system experiment based on the technology application identified in Subtask 1. A joint venture involving technical and financial resources will be required to reduce the risk to the organizational participants.

FY89 Accomplishments: This subtask will not be be implemented until mid FY90.

Resources:	In-House:	170K
	Subcontracts:	0
	Total:	170

Major Milestone:

Dec 1990 Consortia will be identified and joint venture contracts will be issued.

Subtask C-3. Development Requirements

Objective: This activity will identify development work which will have to be performed in order to reduce the risk of fielding a joint-venture system experiment.

Rationale: In order to reduce the risk of fielding a cost-effective system experiment, some component-level development may be required.

FY 1990 Task Description: Advanced technology solar thermal electric systems may be cost effective in some electric markets, but at unacceptable risks to the joint-venture partners. A joint SNL-SERI team will work with the consortia members to identify where component-level development and reliability data will be required to reduce the financial and performance risk to an acceptable level. The conclusions of this study will be used to prioritize work in the core development programs, and could result in the development of some components required for meeting critical schedules.

FY89 Accomplishments: This task will not be implemented until FY91.

Resources:	In-House:	30K
	Subcontracts:	0
	Total:	30K

Major Milestone:

Mar 1991 Identify potential development requirements.

Subtask C-4. System Experiment

Objective: This activity will field a cost-effective system experiment within the next five years.

Rationale: The importance of this mission lies in the need for the near-term development of low-cost critical components (e.g., concentrators, receivers, and conversion devices) for solar thermal energy systems. This need can best be met by developing a near-term, joint-venture project that involves the installation and operation of a solar electric system that uses a significant number of the solar unique components. Solar systems must be fielded so that volume production will eventually allow components to be produced within the solar thermal program's cost and reliability goals.

The power ratings, costs, and performance of the near-term plant must be acceptable to the joint venture investors. In particular, near-term plants must produce energy cost effectively in the selected market place. The near-term collaborative project will establish an industrial base, provide valuable system performance data, and will reduce the risk for private ventures that will follow.

FY 1990 Task Description: This task will not be implemented until FY91.

SECTION III

FY 1990 RESOURCE SUMMARY

Total program resources available in FY90 consist of $13,783K in new budget authority (including $150K in capital equipment funds). If the GRH sequestered funds are released, an additional $769K will become available for operating expenses. Table III-1 shows the allocation of these resources by program activity. Table III-2 shows the breakdown between the lead laboratories. Table III-3 shows the program budget at the task level.

TABLE III-1. FY89 SOLAR THERMAL PROGRAM BUDGET SUMMARY

($ in Thousands)

PROGRAM ACTIVITY	ACTIVITY TOTAL	GRH ADDED
1. HIGH FLUX PHOTON PROCESSES	3320	3320
2. CONCENTRATOR DEVELOPMENT	3956	4725
3. ELECTRIC SYSTEM DEVELOPMENT	3700	3700
4. TECHNOLOGY DEVELOPMENT		
A. NEXT GENERATION COMMERCIAL SYSTEMS	887	887
B. PHOTOCHEMICAL SYSTEMS	1550	1550
C. ADVANCED ELECTRIC SYSTEMS	250	250
CAPITAL EQUIPMENT	150	150
TOTAL	13783	14582
DOE/HQ	1569*	800
TOTAL	15382	15382

*Includes GRH sequester

TABLE III-2. FY90 SOLAR THERMAL PROGRAM FIELD LABORATORY BUDGET DETAIL

($ in Thousands)

	SANDIA				SERI				LABS TOTAL	
PROGRAM ACTIVITY	FTE	In-House	Contract	Total	FTE	In-House	Contract	Total	FTE	Dollars
1. HIGH FLUX PHOTON PROCESSES	3.8	570	53	623	12.8	1920	777	2697	16.6	3320
2. CONCENTRATOR DEVELOPMENT	9	1350	1656	3006	6	900	50	950	15	3956
	10	**1500**	**2047**	**3547**	**7**	**1050**	**128**	**1178**	**17**	**4725***
3. ELECTRIC SYSTEMS DEVELOPMENT	13	1950	1700	3650	0.3	50	0	50	13.3	3700
4. TECHNOLOGY DEVELOPMENT										
A. NEXT GEN COMMERCIAL SYS	1	150	662	812	0.5	75	0	75	1.5	887
B. PHOTOCHEMICAL SYSTEMS	3	450	0	450	5.5	825	275	1100	8.5	1550
C. ADVANCED ELECTRIC SYSTEMS	1.5	225	0	225	0.2	25	0	25	1.7	250
SUBTOTALS:	31.3	4695	4071	8766	25.3	3795	1102	4897	56.6	13663
Subtotals*:	**32.3**	**4845**	**4462**	**9307**	**26.3**	**3945**	**1180**	**5125**	**58.6**	**14432**
CAPITAL EQUIPMENT				75				75		150
LAB TOTAL				8841				4972		13813
Lab Total*				**9382**				**5200**		**14582**

***Includes GRH Return**

TABLE III-3. SOLAR THERMAL SUBTASK LEVEL BUDGET FOR FY90

	FTE	In-House	Contract	Total
1. HIGH FLUX PHOTON PROCESSES				
A. Photon Interaction	7.5	1125	410	1535
B. High Flux Optics	2.8	420	100	520
C. Materials	3.0	450	90	540
D. Modelling	3.3	495	160	655
	16.6	2490	830	3320
2. CONCENTRATOR DEVELOPMENT				
A. Heliostat	3.5	525	500	1025
B. Parabolic Dishes	6.2	925	1006	1931
	7.2	**1075**	**1475**	**2550***
C. Optical Materials	5.0	750	200	950
	6.0	**900**	**200**	**1100***
D. Structural Dynamics	0.3	50	0	50
	15.0	2250	1706	3956
	17.0	**2550**	**2175**	**4725***
3. ELECTRIC SYSTEMS DEVELOPMENT				
A. Central Receiver	5.0	750	475	1225
B. Dish Receiver	5.3	800	400	1200
C. Conversion Devices	3.0	450	825	1275
	13.3	2000	1700	3700
4. TECHNOLOGY DEVELOPMENT				
A. Next Generation Commercial Systems	1.5	225	662	887
B. Photochemical Systems	8.5	1275	275	1550
C. Advanced Electric Systems	1.7	250	0	250
	11.7	1750	937	2687

***Includes GRH Return**

SECTION IV

MAJOR MILESTONE SUMMARY

The major milestones for each program task are summarized below in chronological order and by task reference. This set of major milestones forms the basis for progress reporting and tracking in the FY90 Quarterly Status Reports.

	Date	Activity-Task Reference	Descriptive Title
First Quarter, FY90			
SN	Oct 1989	3B	Complete bench tests of heat-pipe receivers.
SN	Nov 1989	2A	Initiate fabrication of first prototype of SAIC's 100-m^2 market-ready heliostat.
SN	Nov 1989	3A	Complete installation of the PRE.
SN	Nov 1989	3B	Complete on-sun testing of a reflux pool boiler at the STTF.
SN	Nov 1989	4C-1	The responses to the Request for Information will be evaluated.
SN	Dec 1989	1A-3	Complete CAESAR experiments using a non-uniform absorber.
SE	Dec 1989	1B	High Flux Solar Furnace operational.
SN	Dec 1989	4A-1	Award multi-year R&D system improvement contracts with one or more industrial partners.
Second Quarter, FY90			
SN	Jan 1990	2A	Complete testing and documentation of 2 improved prototype stretched-membrane mirror modules.
SN	Jan 1990	2D	Complete documentation of initial wind load studies.
SN	Jan 1990	3A	Initiate the salt flow testing on the PRE.
SE	Feb 1990	1A-2	Identify potential photocatalysts that will extend the active region toward the visible in the solar spectrum and assess the potential for improving the efficiency water treatment.
SN	Feb 1990	2B	Complete Fabrication of the 7-Meter Single Element Module.

SN	Feb 1990	3C	Initiate Final Design of Advanced Stirling Conversion System.
SE	Mar 1990	1A-3	Compare PIRs in photo, catalytic and thermal processes in order to show the benefits of the solar process.
SN/SE	Mar 1990	4A-3	Participate in the SOLTECH 90 joint meeting.
SN/SE	Mar 1990	4B-1	Conduct a workshop for industrial participants at SOLTEC 90 to encourage industrial involvement in photochemical systems.

<u>Third Quarter, FY90</u>

SN	Apr 1990	2A	Complete testing and documentation of the low-cost drive.
SN	Apr 1990	1A-3	Complete draft final report documenting the CAESAR experiments.
SN	May 1990	1C	Review and evaluate merits of carbon fiber treatment with high solar flux.
SE	May 1990	2B	Complete Validation of SHOT
SN	May 1990	2B	Complete On-Sun Testing of the 7-Meter Single Element Module.
SN	May 1990	3A	Complete the comparative study of salt and air receivers.
SN	May 1990	3B	Decision on heat-pipe vs. pool-boiler receivers for further development.
SE	June 1990	1B	Identify optical components for a wavelength shifting system and document expected efficiencies in solar applications.
SN	June 1990	2A	Complete design of SKI's market-ready prototype heliostat.
SE	June 1990	2B	Complete Computer Model of the Faceted Dish Support Structure.
SN	June 1990	2B	Complete Optical Testing of the Facets for the Faceted Dish.
SE	June 1990	2C	Complete and document preliminary evaluation of UV-Enhanced Mirrors for Photochemical Applications.
SN	June 1990	3A	Complete the Phase I solar testing of the PRE.
SN	June 1990	3A	Complete 4000 hrs of operation on the molten salt pump and valve hot loop, complete 2000 hr. of operation on the cold loop.

SE	June 1990	4B-2	Complete tests on multiple compound mixtures that model those found in real sites under consideration for system experiment.

<u>Fourth Quarter, FY90</u>

SE	July 1990	1C	Evaluate the benefits of solar surface treatment of metals for specific applications.
SN	July 1990	2A	Compete fabrication of SAIC's prototype 100-m^2 market-ready prototype heliostat.
SN	July 1990	2B	Program Decision Point: Dish Designs To Fabricate and Test.
SN	July 1990	2C	Complete the Sol-Gel Mirror Production Cost Study.
SN	July 1990	2C	Complete and Document Replaceable Film Study.
SN	July 1990	3B	Complete preliminary design of a hybrid reflux receiver.
SE	Aug 1990	2B	Complete Validation of OPTDISH and ODMF Optical Codes Using the Data from SHOT.
SN	Aug 1990	3A	Complete testing of an optimized volumetric receiver absorber.
SN	Aug 1990	4B-1	Complete a conceptual design of a commercial-scale SDW system.
SE	Aug 1990	4B-2	Select a preferred catalyst immobilization scheme for use in the first system experiment.
SE	Aug 1990	4B-3	Identify the most promising applications of the Solar Detoxification of Hazardous Waste processes, develop a conceptual configuration, and compare the system performance and cost with conventional alternatives.
SE	Sep 1990	1A-1	Assess the availability of near UV component of global normal and diffuse radiation at the Golden, CO site and document a model that will allow predictions to be made at other sites.
SE	Sep 1990	1A-3	Determine quantum yields for destruction of representative hazardous organic compounds in a high flux system.
SN	Sep 1990	1A-3	Complete initial phase survey of steam reforming of representative toxic organic solvents.
SN	Sep 1990	2A	Initiate fabrication of first prototype of SKI's market-ready heliostat.

SN	Sep 1990	2A	Complete testing and documentation of 2 large-area glass-mirror heliostats.
SE	Sep 1990	2C	Document Studies of Polymer Film-to-Silver Adhesion.
SN	Sep 1990	3C	Initiate on-sun testing of the STM 4-120 Stirling.
SE	Sep 1990	4B-1	Complete site selection process for the first demonstration.

<u>First Quarter, FY91</u>

1D	Complete comparison of models with thermal receiver data and with tricholorethylene decomposition receivers. Recommend areas of improvement for the models and for experimental methods used to take the validating data.
2B	Complete the design of the Faceted Dish Concentrators.
4A-2	Receive annual progress report(s) from the industrial partners.
4C-2	Consortia will be identified and joint venture contracts will be issued.

<u>Second Quarter, FY91</u>

1A-3	Complete redesign, installation, and testing of improvements to steam reforming facility temperature, flow control, and trace product analysis systems.
2A	Complete fabrication of SKI's prototype market-ready stretched-membrane heliostat.
4B-1	Assess the cost and performance of an advanced process using improved catalyst materials.
4B-2 4C-3	Complete outdoor tests on advanced catalyst materials. Identify potential development requirements.

<u>Third Quarter, FY91</u>

1A-1	Evaluate most promising solar approaches to removal of metals from contaminated water.
1A-3	Complete experiments that define the practical range of operating conditions for a commercial system.
1A-3	Complete studies of feed systems for a commercial system.
1C	Produce composite samples using solar treated carbon fibers.

2B	Complete the design of the Single Element Stretched-Membrane Dish.
2B	Assemble the Faceted Dishes at the STTF in Albuquerque for Testing.

<u>Fourth Quarter, FY91</u>

1A-2	Select second generation photo catalyst for development.
1A-3	Demonstrate photo catalytic hazardous waste destruction process in an on-sun experiment.
1B	Test wavelength shifting concept in a solar-powered experiment.
1C	Produce composite samples using solar treated carbon fibers.
2A	Complete performance testing and documentation of the two market-ready prototype stretched-membrane heliostats.
4B-1	Identify a second major target application.
4B-2	Expand the range of tested chemicals to include other common contaminants (such as pesticides, wood preservatives, and heavy metals).
4B-3	Evaluate the cost and performance of SDCW designs in selected applications.

SECTION V

MANAGEMENT AND IMPLEMENTATION PLAN

1. PROGRAM MANAGEMENT

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

Implementation of the Solar Thermal Technology Program, as defined by the Multi-Year Program Plan, legislative requirements, resource availability, and the Annual Operating Plan, requires careful tracking of research and development activities to assure satisfactory progress toward the overall program goals. Milestones and decision points are established for each program task and are used to determine the necessity for redirecting activities in view of program priorities and available program resources.

Solar Thermal Program Management and Organization

The DOE Division of Solar Thermal Technology is one of two divisions reporting to the Office of Solar Heat Technologies under the Deputy Assistant Secretary for Renewable Energy. The Division is responsible for managing and reporting the status and progress of the Solar Thermal Technology Program. Policy formulation, planning, resource allocation, and evaluation activities are performed by the Division of Solar Thermal Technology. DOE operations offices and field laboratories have been assigned responsibility for implementing the program.

Field Laboratory Management and Organization

Specific implementation of the Solar Thermal Technology Program is assigned to two field laboratories, the Solar Energy Research Institute in Golden, Colorado and Sandia National Laboratories in Albuquerque, New Mexico. Together, these two field laboratories are responsible for implementation of the core research and development activities and the specific missions 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.

A field Laboratory Management Council (LMC) provides the focus for interaction with the DOE program management and for planning and coordination of the field activities. The LMC is co-chaired by a senior management representative from each laboratory and is composed of the field Activity Leaders and Activity Coordinators. Functions of the LMC include:

- Program planning and strategic development as requested by DOE program management.

- Field management coordination and program integration including development of an Annual Operating Plan, periodic progress reports, and interaction with DOE program management.

- Division of responsibilities and budgets between the two field laboratories in accordance with interest, capability, staff resources, and availability of supporting technical facilities.

- Conduction of special studies and assessments which assist in the overall program planning, justification, priorities, and strategic development.

In order to provide a clear delineation of management responsibilities for each program activity, a lead responsibility and a coordination responsibility are assigned by laboratory for each of the six current program activities. In each case, the activity coordination responsibility will reside at the laboratory which does not have the activity leader responsibility. Assignment of activity leader responsibility by laboratory will be reviewed by the Laboratory Management Council annually to ensure appropriate representation of capabilities, efficient management, and orderly technical progress. Also, it is expected that the mission structure of the program will change as ongoing missions are completed and new ones are defined. The cognizant laboratory is responsible for designating the specific individual for each function. Field activity management responsibilities for FY89 are listed in Table V-1.

The Activity Leader is responsible for:

- Planning and scheduling, with the Activity Coordinator, the specific research and development activities to meet the objectives and goals of the program activity.

- Serving as the point of contact for interaction with the cognizant DOE Solar Thermal Division Program Manager.

- Representing the program activity as a member of the Laboratory Management Council.

- Maintaining activity resource expenditures within the level established in the Annual Operating Plan. This includes the SNL/SERI split and the subcontract activities.

- Summary and reporting of the program activity budget information.

- Preparing program activity input for Quarterly Status Reports, Annual Technical Report, and other such documents as needed.

- Working with the Activity Coordinator in defining and coordinating specific support from each field laboratory.

The Activity Coordinator is responsible for:

- Executing the responsibilities of the Activity Leader in the absence of or at the request of the Activity Leader.

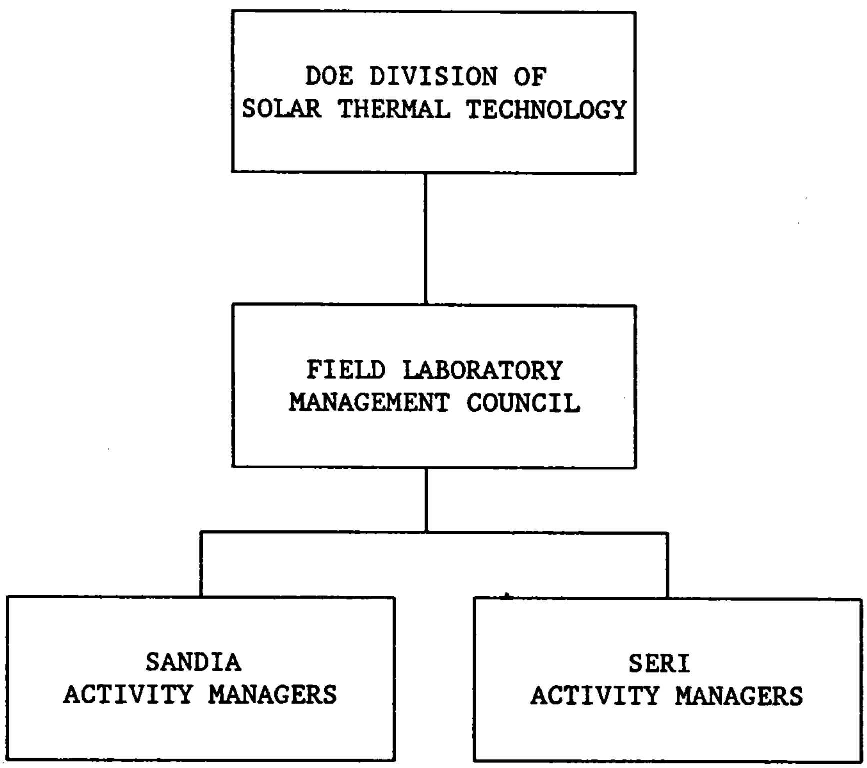
- Obtaining and coordinating specific support from project managers within his laboratory.

TABLE V-1. FY90 PROGRAM ACTIVITY FIELD MANAGEMENT RESPONSIBILITIES

PROGRAM ACTIVITY		LEADER/COORDINATOR
RESEARCH		
1.	High Flux Photon Processes	SERI/SNL
2.	Concentrator Development	SNL/SERI
3.	Electric Systems Development	SNL/SERI
TECHNOLOGY DEVELOPMENT		
4A.	Next-Generation Commercial Systems	SNL/SERI
4B.	Photochemical Systems	SERI/SNL
4C.	Advanced Electric Systems	SNL/SERI

The Solar Thermal Program field management organization, illustrating the coordinating function of the LMC is shown in Figure V-1.

FIGURE V-1. SOLAR THERMAL PROGRAM MANAGEMENT ORGANIZATION



2. REPORTING

The DOE Solar Thermal Technology Program management is kept informed of program progress and management issues on a continuing basis through a variety of formal and informal means such as site visits, frequent telephone communication, weekly highlights, quarterly reports, periodic program reviews, and other topical meetings. The Quarterly Status Report is the primary formal mechanism for documentation of program progress, current planning, budget status, and other relevant management information. Beginning in FY89, joint, program-level quarterly reports were published by the field laboratories.

3. DISSEMINATION OF RESEARCH & DEVELOPMENT RESULTS

The objective of information dissemination efforts is to make the technology base and specific R&D results developed through the DOE Solar Thermal Program readily available to all. In-house and subcontracted R&D results are documented in written technical reports and are also presented in the form of papers at program reviews, professional society conferences, industry association meetings, workshops, and seminars.

Press releases and periodic laboratory publications such as SERI's newsletter "In Review" and Sandia's "Science News" and "Sandia Technology" are used to highlight technical achievements and important new results.

Technical reports published by the laboratories are submitted to the DOE Technical Information Center (TIC) at Oak Ridge, Tennessee for entry into the national data base on energy technology, and for sale by the National Technical Information Service (NTIS). SERI and Sandia also make limited immediate distribution of technical reports to targeted industry, laboratory, and university representatives.

4. TECHNOLOGY TRANSFER

The Solar Thermal Technology Program supports a number of technology transfer related activities to insure the prompt, accurate, and continuous flow of significant research and technology development information to industry and other users.

Topical reports/publications are periodically prepared and distributed to indicate the status of the solar thermal technologies and projects. Technical reports and papers on all aspects of the program's R&D are published and widely distributed. Each year, several meetings/workshops are conducted to bring interested organizations, as well as researchers, scientists, engineers, and users together in a technical forum to exchange technical and programmatic information. DOE also participates in International Energy Agency (IEA) meetings and workshops. Industrial and end user representative and foreign and domestic researchers/scientists/engineers are encouraged to visit the field laboratories, solar thermal project sites, and test facilities to exchange information and ideas.

Sandia and SERI use several additional mechanisms for technology transfer. Direct involvement in conducting significant portions of the R&D work through subcontracts to industry and universities offers a direct avenue for technology transfer and participation with the solar thermal community. Continuing academic and industry involvement through postdoctoral, sabbatical, visiting scientist, summer faculty, and student programs afford the opportunity for first-hand interactions with laboratory staff and facilities.

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