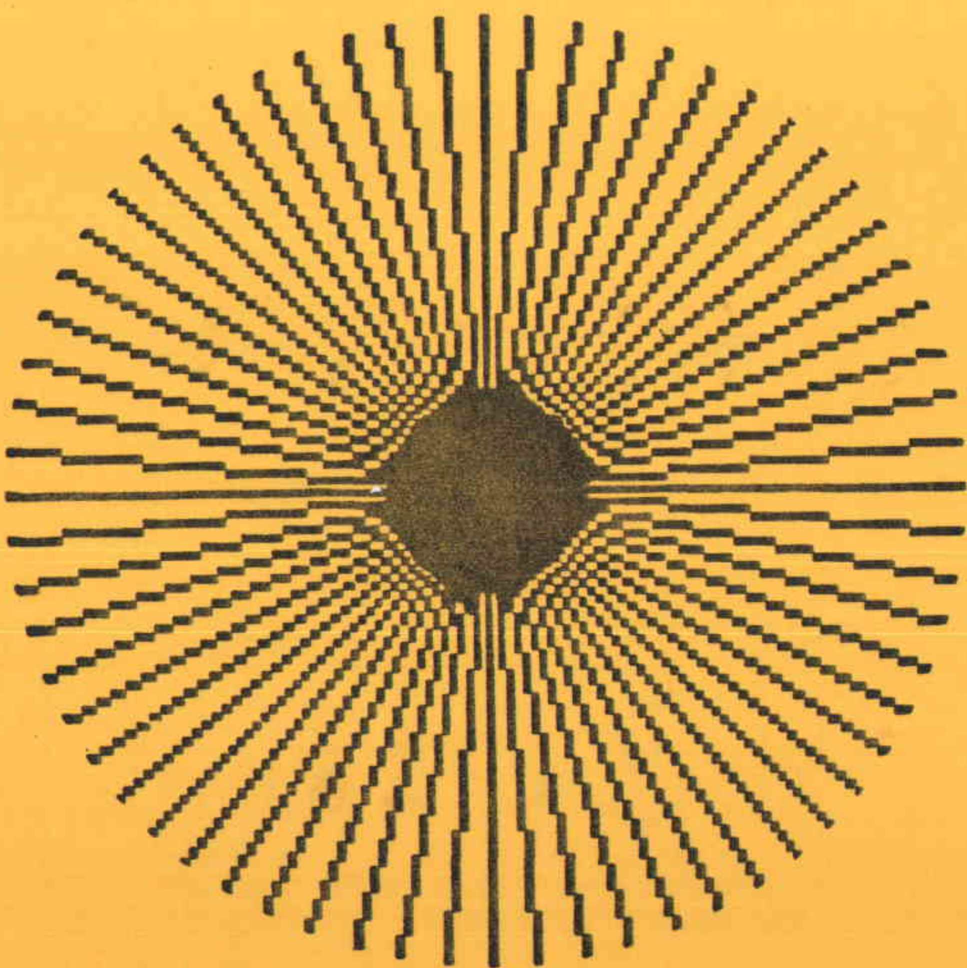
Distributed Receiver
Development Plan 1987-1988

Sandia National Laboratories
Albuquerque, New Mexico

FEBRUARY 1987



Department of Energy
Solar Thermal Technology Program

DISTRIBUTED RECEIVER DEVELOPMENT PLAN

1987-1988

Solar Energy Department
Sandia National Laboratories
Albuquerque, New Mexico 87185
February 1987

Approved: Donald G. Schueler
D. G. Schueler, 6220 2-11-87
Manager Solar Energy Department

Approved: Dean C. Graves for 2/6/87
C. E. Garcia
Director Energy Technology Division
Albuquerque Operations Office
Department of Energy

CONTENTS

Chapter	Title	Page
1	INTRODUCTION	1
2	THE DOE FIVE-YEAR SOLAR THERMAL TECHNOLOGY PROGRAM PLAN	2
3	DISTRIBUTED RECEIVER DEVELOPMENT PROJECT PLAN, FY87 AND FY88	5
	R&D TASK 2, CONCENTRATORS	6
	Status and Planned Activities	6
	Subtask 2.1, Line-Focus Concentrators	6
	Subtask 2.2, Point-Focus Concentrators	6
	Subtask 2.3, DRTF Support	8
	Subtask 2.4, (FMDF) Management	8
	Resource Requirements, Task 2	8
	R&D TASK 3, RECEIVERS	8
	Status and Planned Activities	9
	Subtask 3.1, Receiver Analysis	9
	Subtask 3.2, Receiver Development	9
	Subtask 3.3, DRTF Support	10
	Resource Requirements, Task 3	10
	R&D TASK 4, HEAT ENGINES	10
	Status and Planned Activities	11
	Subtask 4.1, Heat Engine Analysis	11
	Subtask 4.2, Stirling Development	11
	Resource Requirements, Subtasks 4.1, 4.2, and 4.4	11
	Subtask 4.3, Thermal Electric Converters	12
	Resource Requirements, Subtask 4.3	13
	Subtask 4.4, DRTF Support	13
	R&D TASK 6, TRANSPORT AND STORAGE	13
	Status and Planned Activities	14
	Subtask 6.1, Code Development	14
	Subtask 6.2, Thermochemical Transfer Development	14
	Subtask 6.3, Field-Scale Thermochemical Experiment	16
	Subtask 6.4, DRTF Support	17
	Resource Requirements, Task 6	17
	R&D TASK 8, BALANCE OF PLANT	17
	Status and Planned Activities	17
	Resource Requirements, Task 8	18
	R&D TASK 10, DISTRIBUTED RECEIVER SYSTEMS	18
	Status and Planned Activities	18
	Subtask 10.1, Systems Engineering and Analysis	18
	Resource Requirements, Subtask 10.1	20

CONTENTS (Continued)

Chapter	Title	Page
3	R&D TASK 10 (continued)	
	Subtask 10.2, Distributed Receiver Test Facility (Operation and Maintenance)	20
	Resource Requirements, Subtask 10.2	20
	Subtask 10.3, Shenandoah Solar Total Energy Data Evaluation	21
	Resource Requirements, Subtask 10.3	21
	Subtask 10.4, Industrial Process Heat Reports	22
	Resource Requirements, Subtask 10.4	22
	R&D TASK 11, SYSTEMS EXPERIMENTS	22
	Status and Planned Activities	22
	Subtask 11.1, Small Community Solar Experiments (SCSE)	22
	Resource Requirements, Subtask 11	23
4	RESOURCES AND IMPLEMENTATION	24
	Major Milestones for FY87 and FY88	24
	Resource Requirements Summary	24
	Summary of Deliverables	24
	Major Reports	26
	Management Plan	27
	Project Planning	27
	Project Reporting	27
	Solar Thermal Program Documentation Support	27
	Technology Transfer	27
	Interagency Coordination	27
	Procurement Plan	30
	Procurement Strategy	30
	Procurement Policy and Practices	30
	Unsolicited Proposal Funding	30
	Small and Minority Business Policy	30
	Project Organization and Key Personnel	33

FIGURES

Number	Title	Page
2.1	Solar Thermal Technology Organizational Structure and Responsibilities	2
4.1	Major Milestones for FY87 and FY88	24
4.2	Organizational Structure for SNLA's Solar Thermal Projects	33

TABLES

Number	Title	Page
2.1	The Major R&D Tasks of the DOE Solar Thermal Technology Program	3
2.2	Solar Thermal Technology Long-Term Targets	4
3.1	SNLA Distributed Receiver Project Subtask Structure	5
4.1	Resource Requirements Summary, Distributed Receiver Development Project, FY87 and FY88	28
4.2	Procurement Summary for FY87 Major Anticipated Contracts	31
4.3	Major Procurement Summary, Active Contracts Placed on FY86 Budget Authority	32

CHAPTER 1. INTRODUCTION

The detailed program planning for the Department of Energy's (DOE's) Solar Thermal Technology Program is performed annually by two major field centers, SNLA and SERI, and by two DOE operations offices, AL and SAN. These five organizations each prepare and publish their individual planning documents describing detailed plans for the succeeding two fiscal years so that the research and development (R&D) activities for any year are defined at least a year in advance and revisions can be made in an orderly and timely manner. This document is the detailed program plan for SNLA's Solar Thermal Projects for FY87 and FY88. During this period SNLA will assume complete responsibility for the Central Receiver R&D . This document, however, will discuss only the Distributed Receiver Project. The development plan for the Central Receiver Program for FY87 and FY88 is covered in a complementary document by SNLA..

So that this plan may be viewed in its proper context, a summary of the DOE Five-Year Research and Development Plan[1] is presented in Chapter 2.

Chapter 3 presents the detailed plans for SNLA's distributed receiver development projects. Each activity is identified by a task number that directly correlates with the task numbers defined in the DOE Five-Year R&D Plan. The description of each task includes an explanatory narrative text and resource requirements (manpower and funding).

Chapter 4 provides summary information of SNLA's FY87 and FY88 Solar Thermal Distributed Receiver Projects Plan in several formats: a compilation of major milestones, a summary of resource requirements, a description of the management plan, a listing of proposed contracted procurements, and the organizational structure and key personnel within SNLA.

[1]"National Solar Thermal Technology Program: Five-Year Research and Development Plan, 1986-1990," DOE/CE-0160, U.S. Department of Energy, Office of Conservation and Renewable Energy, September 1986..

CHAPTER 2. THE DOE FIVE-YEAR SOLAR THERMAL TECHNOLOGY PROGRAM AND PLAN

This chapter summarizes the DOE Solar Thermal Technology Program as described in the Five-Year Plan.

The purpose of the Solar Thermal Technology Program is to develop an alternative source of energy based on collection and conversion of solar energy. To do this, the program supports research and development to improve cost and performance and to broaden areas of applicability for solar energy. This work complements the work of private industry and will provide technically proven systems for incorporation into the nation's energy supply industry.

The major obstacles to industrial and commercial use of solar energy are (a) high cost, (b) lack of performance verification, (c) unproven system reliability and life, (d) perceived technical and financial risk due to lack of operational experience, and (e) uncharacterized operations and maintenance costs. The major activities of SNLA's program focus on these issues.

Implementation of the Solar Thermal Technology Program is carried out through SNLL, SNLA, and SERI. SNLL has been responsible for central receiver technology. However, this responsibility is being transferred to SNLA. SERI is responsible for research of materials and innovative concepts for solar thermal technology. SNLA is responsible for design and development of solar thermal distributed receiver technology, including fabrication, testing, and evaluation of components, subsystems, and systems for production of electricity and industrial process heat, cogeneration, and fuels and chemicals production. The organizational structure is shown in Figure 2.1.

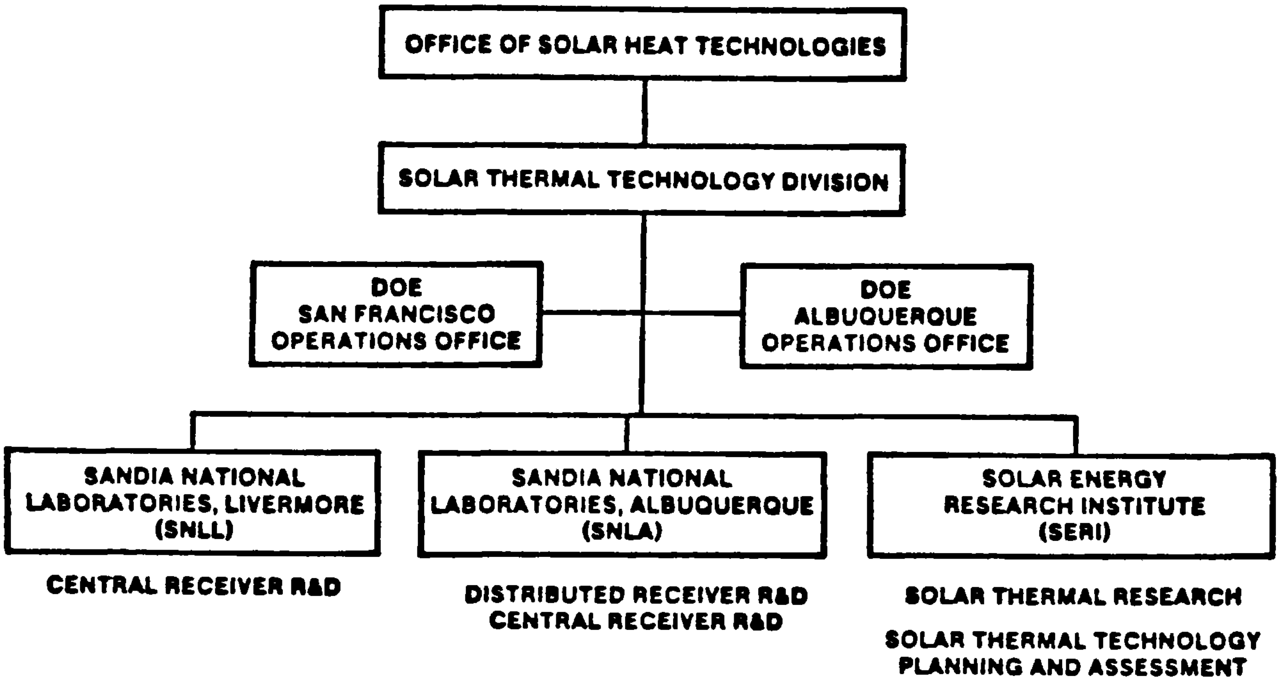


Figure 2.1. Solar Thermal Technology Organizational Structure and Responsibilities

The Solar Thermal Technology Development Program is divided into three broad categories: (1) Collection Technology, (2) Energy Conversion Technology, and (3) Systems and Application Technology. These categories are subdivided into 11 major R&D Tasks, which are listed and defined in Table 2.1.

Table 2.1. The Major R&D Tasks of the DOE Solar Thermal Technology Program

R&D Task	Definition
COLLECTION TECHNOLOGY	
1. Optical materials	Development of materials for the reflective and refractive surfaces of concentrators or the transmissive and absorptive components of receivers
2. Concentrators	Development of heliostats, dishes, troughs, and bowls (not including receivers)
3. Receivers	Development of components that convert solar radiation to thermal or chemical energy
ENERGY CONVERSION TECHNOLOGY	
4. Heat engines	Development of components that convert thermal energy to electricity or shaft power through thermodynamic processes
5. Direct conversion	Development of components that convert solar radiation to electricity or chemical energy without the use of a heat engine
6. Transport and storage	Development of components that convey energy to the point of use or allow delay of its use
SYSTEMS & APPLICATIONS TECHNOLOGY	
7. Innovative concepts and applications	Entry point activities for promising component and system concepts that constitute major departures from conventional solar thermal technology
8. Balance of plant	Development, characterization, and optimization of other components necessary to construct and operate a complete solar thermal facility
9. Central receiver systems	Activities related to the analysis and development of central receiver applications from a system perspective
10. Distributed receiver systems	Activities related to the analysis and development of distributed receiver applications on a system level

Table 2.1. (Continued)

R&D Task	Definition
11. System experiments	Activities related to the design construction, startup, operation, and testing of solar thermal installations

System-level planning targets expressed in terms of annual efficiency, capital costs, and energy cost have been developed to meet the need for quantitative program goals. These targets are used to provide direction for R&D planning activities, to measure progress, to assess alternative technology options, and to make rational component decisions. The system-level targets for solar thermal technologies as presented in the Five-Year Plan are summarized in Table 2.2 for plants producing electricity and for plants producing heat. The long-term prospects for solar thermal technologies attaining the system goals must be judged on the basis of systems analyses, cost projections, and data from operating systems.

Table 2.2. Solar Thermal Technology Long-Term Targets

Characteristic	System Product: Electricity	System Product: Heat
System annual efficiency	22%-28%	56%-68%
System capital cost[a]	$1000-1200/kWe	$270-430/kWt
System capacity factor	0.26-0.5	0.24-0.29
System energy cost[b]	$.04-.05/kWhe	$7-9/MBtu

[a]Normalized to engine or process capable of handling peak field thermal output; includes indirect costs; 1984 $.

[b]Energy costs levelized in real dollars; economic assumptions differ between electric and heat systems; 1984 $.

To date, the efforts of industry and the federal government have led to steadily decreasing energy costs from solar thermal systems. Continuing evolution of system components and designs will further reduce costs and increase the number of economically attractive applications. As the manufacturing production rates for solar components gradually rise, production costs will decrease, contributing to further improvements in the economics of solar thermal energy.

CHAPTER 3. DISTRIBUTED RECEIVER DEVELOPMENT PROJECT PLAN, FY87 AND FY88

The primary area of responsibility for SNLA's Solar Thermal Projects is distributed receiver component and systems development. This is reflected in the Task and Subtask structure in Table 3.1, which indicates that, during FY87 and FY88, SNLA proposes to participate in seven of the eleven major tasks described in the DOE 5-Year Plan. The remainder of this chapter contains the detailed R&D plans for FY87 and FY88 for each task and subtask in the SNLA Distributed Receiver Development Project.

Table 3.1. SNLA Distributed Receiver Project Subtask Structure

Task 2.	CONCENTRATORS	
	Subtask 2.1	Line-Focus Concentrators
	Subtask 2.2	Point-Focus Concentrators
	Subtask 2.3	DRTF Support
	Subtask 2.4	FMDF Management
Task 3.	RECEIVERS	
	Subtask 3.1	Receiver Analysis
	Subtask 3.2	Receiver Development
	Subtask 3.3	DRTF Support
Task 4.	HEAT ENGINES	
	Subtask 4.1	Heat Engine Analysis
	Subtask 4.2	Stirling Engine Development
	Subtask 4.3	Thermal Electric Converters
	Subtask 4.4	DRTF Support
Task 6.	TRANSPORT AND STORAGE	
	Subtask 6.1	Code Development
	Subtask 6.2	Thermochemical Transport Development
	Subtask 6.3	Field-Scale Thermochemical Experiment
	Subtask 6.4	DRTF Support
	Subtask 6.5	Project Management
Task 8.	BALANCE OF PLANT	
	Subtask 8.1	Control Systems Development
Task 10.	DISTRIBUTED RECEIVER SYSTEMS	
	Subtask 10.1	Systems Engineering and Analysis
	Subtask 10.2	Distributed Receiver Test Facility
	Subtask 10.3	Shenandoah STEP Evaluation
	Subtask 10.4	Industrial Process Heat Reports
Task 11.	SYSTEM EXPERIMENTS	
	Subtask 11.1	Small Community Solar Experiments

R&D TASK 2, CONCENTRATORS

The collector is the component in a solar system that gathers the energy provided by the sun and concentrates it at a location where it can be practically used as a "high quality" heat source. Therefore, concentrators which can be used to efficiently and economically collect the solar energy are critical for the success of any solar system. The purpose of the Concentrator Task is the development of high performance, low cost solar concentrators to serve as an energy source for thermal processing and electrical power generation.

The solar concentrator task at SNLA is divided into two primary areas defined by the geometric configuration of the solar collector; these subtasks are line-focus and point-focus concentrators. The development of heliostats, another concentrator used in central receiver solar systems, is the responsibility of the Central Receiver Division. Under the Concentrator Task Sandia also provides technical support to the DOE/AL Office for the Texas Tech University for the Fixed-Mirror, Distributed-Focus (FMDF) solar concentrator project. The FMDF effort is a fourth subtask under the Concentrator Task.

Another area of investigation which can fall within any of the four subtasks of the Concentrator Task is solar materials development. SERI has the principal responsibility in the Solar Thermal Program for research on materials, mirrors, absorber coatings, etc., for use in solar systems. Sandia is involved in materials development in areas where it has special expertise and where a specific, well-defined concentrator application exists.

Status and Planned Activities

Subtask 2.1, Line-Focus Concentrators -- Six contracts for the development of line-focus collector components were placed in March of 1985. The projects were selected based on their importance in improving the performance, operation or maintenance of generic line-focus concentrator systems. Two of these contracts were to improve sun-tracking control systems; two were aimed at developing better receivers by improving the glass-receiver-tube seals and an evacuated receiver; one was for improved steel-laminated glass optical surfaces; and the last was for the development of an inexpensive embedded post for field mounting collector supports. These contracts are complete and the components have been delivered to Sandia's Distributed Receiver Test Facility for test and evaluation. The tests will be completed during FY87 on a not-to-interfere basis. Once the results have been evaluated, a follow-on round of component development contracts aimed at further line-focus concentrator component improvements is planned through a RFQ issued in FY88.

Subtask 2.2, Point-Focus Concentrators -- The activities which constitute the Point-Focus Concentrator subtask are: the Innovative Concentrator Project, the Stretched Membrane and Dish Concentrator Development Projects and the Sol-Gel Metal Mirror Development Project.

Contractors in the DOE/AL Innovative Concentrator Project completed Phase I detailed design by demonstrating the fabricability of their respective optical elements and presenting the detailed design of all concentrator subsystems at Design Reviews held during FY86. Acurex Corporation and LaJet Energy Company have begun Phase II construction of their respective collector designs. The Acurex Innovative Concentrator utilizes thin sheet metal which is stamped to form a ribbed parabolic shape as the substructure of the parabolic dish. Additional sheets of steel which have reflective silver film applied to the front surface are bonded to the ribbded structure to form the completed concentrator. The LaJet concentrator design utilizes 95 stretched membrane, facets made with silver polymer film. Entech, Inc., the third Innovative Concentrator Project participant, is under contract with the DOE to evaluate antireflective coatings for their Fresnel lens collector and to assess the relative merits of several rim-supported tracking and drive systems which could be used for both their dome lens and a large stretched membrane collector. The Acurex collector was delivered to the Distributed Receiver Test Facility for installation, check out and testing in October 1986. The LaJet collector will be delivered in January of 1987. Sandia is the Technical Manager for the DOE Innovative Concentrator Project.

Stretched membrane technology continues to show potential for considerable weight and cost reductions for heliostats. In FY86 Sandia issued a Request for Proposals for a project to apply the stretched membrane approach to the development of a large facet, point-focus solar collector. The thrust of this particular initiative is the development of a light weight, high performance solar concentrator composed of a small number of optical facets (if possible, only one). The project has been organized into three phases; Phase I, initiated on FY86 BA, is the design of an optical element; Phase II is the detailed design of the balance of the collector system; and Phase III is the construction and testing of the collector. The contracts for Phase I will be placed during the first quarter of FY87 and it is anticipated that Phases II and III will begin in FY88 and FY89 respectively. The project will require about two and one-half years to complete.

The stretched membrane dish development is receiving high priority and, while the potential impact on energy costs is attractive, the risks are also high. The Acurex Innovative Concentrator and Solar Kinetics Point-Focus Concentrator designs present viable alternatives in a structurally integrated concentrator optical element which would employ more conventional manufacturing processes. The Acurex collector has been built and Solar Kinetics, Inc. is completing a FY85 contract to Sandia to develop a design. Their design features a light weight monocoque in which two thin sheet metal "skins" are bonded to an accordian pleated, sheet metal ribbing to form the gores of the parabolic dish. If detailed design is judged to be successful by the Technical Review Committee, as determined by its performance potential, estimated weight, and manufacturability, a concentrator will be built and installed on an existing pedestal drive for testing and evaluation.

Sandia performs work in the optical materials area in support of SERI's activities, to develop materials for specific concentrator designs, and where special expertise exists in-house. One area of special interest over the last two years has been the development of silver-stainless steel, structural mirrors. Unlike glass mirrors which must be separately supported, the advantage of the steel mirror is that it can support itself and carry structural loads imposed on the collector by wind and gravity. Sandia has demonstrated that high quality structural mirrors can be made and protected using a sol-gel glass coating. Mirrors made at SNLA have demonstrated a specular reflectivity of 94% within a 15 mr cone angle. The optical quality of these mirrors does not yet equal that of the best glass mirrors but, because they can carry the gravity and wind loads, the structural mirror has the potential to substantially reduce the weight and therefore the cost of the solar concentrator. A conservative estimate of the collector weight reduction possible would be 10 kg/m^2, or about 15% -- a dramatic weight and cost reduction. In FY87 the focus of the structural, stainless steel mirror development effort will be directed at producing mirrors on thin foils for possible use on stretched membrane concentrators for both dishes and heliostats. The elimination of laminated polymer film reflectors for these applications would reduce process costs and greatly improve durability.

In addition to the aforementioned activities, Sandia will continue to provide testing for line-focus and point-focus concentrator systems to industry and other agencies such as NASA at the Distributed Receiver Test Facility and optical materials evaluation in our Optical Measurements Laboratories.

Subtast 2.3, DRTF Support -- See Task 10.2

Subtask 2.4, Fixed-Mirror Distributed-Focus (FMDF) System -- The Fixed-Mirror, Distributed-Focus (FMDF) solar energy concept is being developed by Texas Tech University under a contract from DOE/AL. The contract was for a three-phase R&D program that was scheduled for completion in August 1986. The contract has been extended to January 1987 to permit completion of the final phase of the R&D program.

Current phase plans are to complete unfinished tasks with emphasis on conducting a two-week test to measure performance of the system using improved mirrors procured during the program. Emphasis is also being placed upon completing topical reports and the project final report required by the contract. In addition, SNLA distributed receiver personnel are providing data and information for use by Pacific Northwest Laboratory and SERI in their evaluation of the FMDF concept.

As with other DOE/AL contracts in the Distributed Receiver Project, SNLA provides technical support to the AL project office. These activities will include, in FY87, detailed reviews of TTU final project reports and a review of the intertechnology comparison being completed by SERI and PNL.

Resource Requirements, Task 2

Costs (k$)	FY87	FY88
In-house	609	728
Contracts	920	1020
Total costs (k$)	1529	1732
Manpower (man-yr)	4.2	4.7

R&D TASK 3, RECEIVERS

The receiver is a key component of a distributed solar thermal power system. Its design must meet the requirements imposed by the concentrator and the power conversion or thermal process subsystem.

The long-term goal is to develop receivers with 90% to 95% annual efficiencies that can be manufactured for $30 to 40/m^2$ of concentrator aperture area (see Five-Year Plan). The objective of this task for FY87 and FY88 is to continue to develop the analytical and experimental tools and techniques necessary to design efficient receivers, to make cost-effective trade-offs, and to build and test prototypes to evaluate receiver performance.

Thermal losses from receivers have typically been higher than expected. It has become evident that improved receiver performance can be a cost effective way of improving solar thermal system performance. Considerable effort has, therefore, been directed at identifying and quantifying the various losses.

Our plans for the next 2 years are to:

- Continue to develop analytical (computer modeling) tools for receiver design analysis.
- Develop an understanding of receiver performance via modeling, building and operating prototype receivers, and receiver experimentation to measure performance and reliability.

These activities will be directed toward developing receivers for thermochemical transport and dish electric applications.

Status and Planned Activities

Subtask 3.1, Receiver Analysis -- Receiver design computer codes have been and will continue to be the cornerstone of the receiver task. The CIRCE code that was made operational in 1986 will be expanded to support receiver development activities under Task 3.2. The models will continue to integrate the concentrator with the receiver and thermal loads. Codes will be validated with existing receiver data, data taken from receivers under development, and with data taken from experiments specifically designed to explore thermal loss mechanisms. An important objective of this effort is a fundamental understanding of energy loss mechanisms and design guidelines for minimizing them.

The development of experimental devices for the measurement of flux and temperatures in a receiver will be continued. These devices will include adaptation of the Inframetrics 525 video imaging radiometer to the measurement of temperature distribution inside cavity receivers and experimentation with the SERI/GIT multicolor pyrometer.

A carefully controlled and well-instrumented laboratory experiment to segregate receiver loss mechanisms will be initiated. A spare Shenandoah receiver will be used for the experiment. The Shenandoah receiver is a reasonably representative cavity design. It is also easy to disassemble so that various apertures and insulation configurations can be tested. This experiment will help to validate thermal loss codes.

Subtask 3.2, Receiver Development -- A significant development in FY86 was the evolution of the "reflux" receiver concept as a viable receiver option. The reflux receiver utilizes a boiling metal such as sodium as an intermediate heat transfer fluid. Unlike a conventional heat pipe, the evaporator section is shaped to optimize the collection of solar energy, and condensed sodium is returned to the evaporator by gravity and distributed over the absorber by wicking. Analysis of preliminary designs suggests that simple, low cost, reliable, efficient receivers are possible. Potential applications for this concept include kinematic and free piston Stirling engines, LMTEC, and thermochemical energy transport.

In FY 87-88 the reflux approach will be developed and evaluated for several applications. A 20 kW Sandia built receiver/reformer will be tested at the Weizmann Institute of Science (WIS) beginning in June 1987 as part of a U.S.-Israel bilateral agreement. This will be the first experimental verification of the reflux concept and will help form the basis for the design of a 75 kW receiver/reformer for the CLOE Phase II experiment (See Task 6) in which the receiver will be mounted on a test bed concentrator.

A reflux receiver for the STM4-120 engine (See Task 4) will be designed, built, tested, and used as a source of heat for testing the engine. The contract with STM will be placed in March 1987 for delivery in May 1988. After a period of acceptance and bench testing in the Engine Test Facility, the unit will begin on-sun testing late in FY88. A gas combustor heat input for the STM4-120 is being pursued by STM and GRI. A successful development here would permit a solar-gas hybrid concept to be developed. The hybrid concept is of great interest for dish-electric power plants where it could increase capacity factor greatly. The gas combustion receiver would be ready for integration into a solar receiver at about the end of FY88.

The reflux receiver is also an attractive heat input option for free piston Stirling engines and will be developed and evaluated as part of the contracts with NASA/LeRC described in Task 4.

Direct catalytic absorption receiver/reactor (DCAR) concepts will also be investigated. Absorption of concentrated sunlight directly on a catalytic matrix has the potential to circumvent flux limitations inherent in conventional reactors and is a solar unique capability. An objective of the Receiver Task will be to complete an analytical technical assessment of the feasibility, performance, and cost advantages of this approach by the second quarter of FY88.

Other receiver concepts will be pursued where appropriate. Tube receivers, e.g. ORC and Shenandoah, will be operated and modeled to gain a better understanding of thermal loss mechanisms, and tube receiver/reactors for thermochemical energy transport will be designed, built, and tested for CLOE Phase I (See Task 6).

Subtask 3.3, DRTF Support -- See Task 10.2

Resource Requirements, Task 3

Costs (k$)	FY86	FY87
In-house	318	587
Contracts	450	810
Total costs (k$)	768	1397
Manpower (man-yr)	2.2	3.8

R&D TASK 4, HEAT ENGINES

The objectives outlined for this task are the evaluation and development of heat engine technologies applicable to Distributed Receiver Systems. The development of small, low-cost, efficient, long-lived heat engines are of the utmost importance to the dish-electric concept. The Solar Thermal Five-Year Plan cites the need for engine performance and cost in the long term to be 41% annual efficiency and $300/ kWe to support the system-level goal of $0.05/kWhe. Alternate combinations of cost and performance that provide equivalent cost-effective results would, of course, be acceptable.

Task 4 has been organized into four subtasks: Heat Engine Analysis, Stirling Engine Cycles, Thermal Electric Converters, and DRTF Support. The primary R&D activities in the past few years have involved the dish-electric concept in which a heat engine and generator are located at the focus of a parabolic dish concentrator for heat-to-electric energy conversion. These activities will continue to be the main thrust of the project. Conceptual studies, designs, hardware development, and testing will take place during FY87 and FY88 through both in-house activities and contracts.

Status and Planned Activities

Subtask 4.1, Heat Engine Analysis -- The objective for the Heat Engine Analysis subtask is to analyze advanced energy conversion devices which show potential for development and for meeting program goals in the mid- and long-term. Computer codes developed at SNLA can support analyses and trade-off studies of performance and economic capabilities. Sandia will continue to upgrade and utilize its library of programs to analyze heat engines for Distributed Receiver Systems.

Sandia will perform economic comparison analysis on RTEC as component performance projections become available from Hughes. A thorough projected system performance analysis will be undertaken after the results of experimental data provide an indication of the anticipated mass flows and heat transfer requirements. Close liaison will be maintained with SERI to remain current in evaluating the prospects of RTEC as a dish-electric engine candidate.

Subtask 4.2, Stirling Engine --A very attractive engine for solar use is the Stirling cycle, and in particular the free piston Stirling engine (FPSE). This engine has the potential for high reliability, long life at low maintenance, and high cycle efficiencies. The FPSE is currently under development by several companies including Mechanical Technology, Inc. (MTI), Sunpower, Inc., and Stirling Technology Co. (STC). SNLA sponsored through NASA/LeRC the conceptual design of a solarized FPSE by means of two competitive R&D contracts placed in September 1986. The conceptual design is scheduled to be completed in January 1988. Detailed design of a prototype design will be initiated in mid FY88 with fabrication to begin in late FY88. This work will be coordinated with LeRC's free-piston Stirling being developed for space applications.

In FY86 SNLA contracted to purchase a Stirling Thermal Motors engine STM4-120 with a scheduled delivery during the second quarter of FY87. The STM4-120 will be initially tested in the Engine Test Facility (ETF). During these tests a generator, control package and gas-fired heater will be fitted to the engine. On-sun characterization of the engine will begin in late FY88 and continue through FY89. The on-sun testing at the DRTF will be grid connected and will be conducted on TBC-1. An STM reflux receiver will be the heat source (see Task 3). Control, heat rejection, and power conditioning will utilize Sandia-build equipment.

Resource Requirements, Task 4.1, 4.2 and 4.4

Costs (k$)	FY87	FY88
In-house	339	363
Contracts	510	1245
Total costs (k$)	849	1608
Manpower (man-yr)	2.3	2.4

Subtask 4.3, Thermal Electric Converters -- Conversion of thermal energy to electricity without the use of machinery with moving parts is highly desirable. Thermally regenerative electrochemical systems, capable of achieving thermal to electric conversion without the use of major moving parts, have the potential for reducing O&M costs for heat engines to an absolute minimum. The objective of this task is to engineer and develop promising energy conversion devices applicable to solar thermal systems and to conduct the necessary studies to determine converter optionswith the most potential. Two thermal electric converter systems of interest in this regard are the Liquid Metal Thermal Electric Converter (LMTEC), currently under development in-house, and the Regenerative Thermal Electrochemical Converter (RTEC) in research by Hughes under a SERI contract.

As a result of a study comparing presently available and long-term engines the LMTEC was chosen as one of the most promising technologies for dish-electric applications. Projected peak efficiency for a LMTEC using mercury as the working fluid is 35% at 600°C. This value puts the annual efficiency of a mercury LMTEC based solar power plant in the 25%+ range at temperatures and performance achievable with present-day concentrator and receiver technology.

Current LMTEC technology relies upon Beta" Alumina Solid Electrolyte (BASE), a fast ion conductor material across which a pressure differential is maintained for the expansion of the liquid metal working fluid. The ionization necessary for the expansion of the working fluid requires the use of a porous electrode on the low pressure side which can allow for ionic and atomic diffusion of the metal prior to vaporization and condensation in the working cycle. The use of an electromagnetic pump to recirculate the working fluid renders the LMTEC free of moving parts and allows for high reliability, durability, and virtually no maintenance.

Evaluation of the current sodium-based LMTEC technology and performance projections pointed toward the very attractive possibility of developing a mercury-exchanged BASE electrolyte in order to operate a LMTEC at higher efficiencies and at lower temperatures. Results of preliminary experiments conducted at the University of Wisconsin, the University of Pennsylvania, and Oak Ridge National Laboratory have been positive and indicate that mercury exchanged BASE material should be achievable. However, because a mercury-based electrolyte does not now exist, a substantial mercury LMTEC R&D effort is not yet warranted and will not be undertaken until reasonable assurance of success in electrolyte development is achieved.

To identify engineering and materials issues a sodium-based Bench Test Module was designed and fabricated in FY86. All the major hardware and components for the BTM have been assembled, and a test lab has been outfitted. Testing of the BTM is scheduled throughout FY87 with low-risk component and material upgrades being incorporated as required. The experience gained from BTM testing will be used to configure BTMII sodium based module which will incorporate sodium refluxing for heat input. The fabrication of BTMII will be initiated at the beginning of FY88 and testing will start in the third quarter of FY88. The design of a 1 kW mercury-based prototype will begin late in FY88 (assuming success in electrolyte development).

The synthesis of the mercury BASE material started in FY87 and will be pursued through FY87 and FY88. It is anticipated that more than 95% mercury exchange in single-crystal BASE will be accomplished by scientists at the University of Pennsylvania by the end of FY87. The characterization of the electrical and mechanical properties of single-crystal BASE material will be undertaken as the crystals become available from the exchange experiments. The equipment for conducting electrical measurements in single crystals exists and minimal modifications are needed for mercury BASE measurements. Because practical sized electrolyte tubes require polycrystalline BASE material, a significant part of the single-crystal effort is a more thorough understanding of the mechanism of exchange which can be extrapolated to the polycrystalline mercury exchange. Significant insight into these mechanisms is expected by early FY88.

The synthesis of polycrystalline BASE material by analogous exchange procedures started in FY87 at the University of Wisconsin will continue through FY87. This development work will receive increasing attention in FY88 as single-crystal work concludes. Significant exchange (>60%) should be achieved by mid FY88. When polycrystalline material samples become available electrical measurements will be performed using the same or similar apparatus to that available at the University of Pennsylvania and being used for the single-crystal work. It is anticipated that these electrical measurements can be obtained in mid FY88. Mechanical measurements on polycrystalline BASE samples and tubes should be available in late FY88.

Resource Requirements, Task 4.3

Costs (k$)	FY87	FY88
In-house	270	304
Contracts	260	430
Total costs (k$)	530	734
Manpower (man-yr)	1.8	1.9

Subtask 4.4, DRTF Support -- The first-generation organic Rankine cycle (ORC) engine development for JPL by Ford and Barber-Nichols for dish-electric systems was delivered to SNLA Distributed Receiver Test Facility (DRTF) and integrated with the Test Bed Concentrator (TBC-1) in FY85. Characterization began in FY86 and will be completed in FY87. The engine will be retained at the DRTF for possible trouble-shooting activities in support of SCSE#1 in which a similar engine is employed.

A Brayton cycle Advanced Gas Turbine, the AGT-101 is being developed by Garrett Turbine Engine Company through NASA/LeRC for the DOE automotive program. In prior years, JPL secured a commitment from NASA to fabricate a 1600°F AFT for the solar thermal program. This assembly is known as the Solarized Automotive Gas Turbine (SAGT-1A). The SAGT-1A was delivered to SNLA's DRTF in FY86. Testing of this unit will be completed during FY87 on a not-to-interfere basis.

R&D TASK 6, TRANSPORT AND STORAGE

The efficient transport and storage of thermal energy is critical to the development of parabolic dish system technologies. Present sensible heat transport methods at the medium to low temperature range (≤ 400°C) cost a significant percentage of the collected energy in transport (piping losses) to deliver the energy to the use point. Because of the very high temperature capability of parabolic dishes and the extensive piping required to deliver energy from a large collector field, low thermal-loss energy transport technology needs to be developed.

The objectives of this task are to identify, understand, and evaluate high-efficiency, low-cost energy transport and storage systems suitable for high-temperature (>400°C) solar thermal distributed receiver applications. A primary candidate for low-loss energy delivery at these temperatures is the concept of thermochemical (TC) energy transport. The current emphasis of Task 6 activities is on developing and demonstrating the technology of TC transport for point-focus distributed-receiver, central-electric applications. The relevant long-term goals for transport systems are 94% efficiency at 65 $/m^2. The objectives of this task are being addressed through a program of complimentary computer modelling and experimental studies. The task is divided into four subtasks which reflect these activities.

Status and Planned Activities

Subtask 6.1, Code Development -- The model development activity is aimed at obtaining the necessary computational tools for making performance/economics evaluations of sensible and TC energy transport systems for distributed receiver applications.

Development of the initial version of the Closed Loop Efficiency Analysis (CLEA) code, which began in FY85, was completed in FY86. This is a single-loop, steady-state performance model for thermochemical energy transport based on the CO_2/CH_4 reforming/ methanation system. Computations for conditions representative of closed-loop experiments conducted in the CLEA laboratory facility during FY86 show excellent agreement with the experimental measurements. The CLEA code has aided in interpreting and understanding the experimental laboratory results and in designing the field-scale Closed Loop Operations Experiment (CLOE). Documentation of this version of the CLEA code, called 86.1, is underway and will be completed in the third quarter of FY87. The next phase of CLEA code development, the addition of costing algorithms, will be initiated in mid FY87.

Action was initiated at SNLA in FY86 to obtain a distributed receiver system analysis code capable of modeling both sensible and TC energy transport systems. The approach was to modify the existing steady-state sensible energy transport performance code, SOLTES, by incorporating models for TC transport obtained from the CLEA code. This activity was undertaken as part of the Task 10 Central Engine Study and will be operational on an interim basis in early FY87.

Subtask 6.2, TC Transport Development -- Experiments with a scaled-up (10 kW) closed-loop SO_3 dissociation facility at the Physical Science Laboratory, New Mexico State University (PSL/NMSU) were terminated early in FY86. As a result of these experiments, the SO_3 dissociation chemical system was rejected as a candidate for the field-scale TC energy transport experiment. A final report on the NMSU experiments has been completed and will be published in the second quarter of FY87.

Materials corrosion experiments to identify alloys suitable for use in the high temperature oxidation/sulfidation environments characteristic of an SO_3 dissociation TC transport system were also brought to a conclusion in FY86. Candidate materials were exposed to SO_2/O_2 and SO_3 gas mixtures at temperatures of 500 and 900°C for periods of one, four, and eight weeks, and also under cyclic conditions (between 200 and 900°C) for four weeks. Two reports have been published and the final report is in preparation and will be completed in the second quarter of FY87.

Mechanical properties experiments for the purpose of indentifying alloys suitable for use in the high-temperature, corrosive environments of the dissociation reactors of an

SO_3 TC transport system were also concluded in FY86. Constant load creep tests and welding experiments were performed on candidate materials (both as-received and aged specimens) to determine high-temperature mechanical properties, weld-cracking characteristics, and postservice weldability. These tests have been completed and final reports will be published in early FY87.

Experiments continued during FY86 in the Closed Loop Efficiency Analysis (CLEA) TC energy transport facility at SNLA. This is a laboratory-scale (2.5 kW) facility based on the CO_2/CH_4 reforming/methanation chemical system. It is a single loop employing one reformer and one methanator that can be operated in open- and closed-loop configurations under steady-state or simulated solar conditions. A significant accomplishment was the completion of 12 successive simulated solar cycles which demonstrated that the CO_2/CH_4 TC energy transport system can be operated in a stable, closed-loop mode, starting up and shutting down, as it must do daily in a solar application, without triggering either process instabilities or carbon deposition. In order to achieve higher conversion and better selectivity in the endothermic reaction, and higher overall efficiencies, an endothermic reactor capable of reaction temperatures between 900 and 1000°C was designed and fabricated. It will be installed and tested in mid FY87.

Experiments in the CLEA laboratory facility will continue during FY's 87 and 88. Emphasis will be on obtaining data and operational experience pertinent to the field-scale TC energy transport experiment, CLOE. The laboratory facility will also be available, if needed, to help trouble-shoot problems encountered in CLOE tests. Advanced capability steady-state and transient tests will be conducted at reformer temperatures up to 1000°C. These will begin in the third quarter of FY87 and will support CLOE Phase II.

The first phase of the catalyst evaluation and development studies being performed at the University of Houston in support of the CO_2/CH_4 TC transport system was completed in FY86. Over 35 potential methanation catalysts were screened. A commercial formulation (Englehard, 0.5% rhodium on 1/8-in. alumina pellets) showed high activity for both methanation and CO_2 reforming with no deactivation after over 300 hrs. in the methanator. Preliminary intrinsic kinetics were determined for both methanation and CO_2 reforming. Tests conducted in Houston's Process Development Unit (PDU) reformer at a power level of 2-3 kW successfully demonstrated the applicability of the catalyst to CO_2 reforming and yielded bed temperature profiles needed for computer model calibration.

Catalyst development and reactor modelling studies will continue at the University of Houston in FY87. Planned activities include the following: 1) determination of rate equations, heat transfer parameters, and deactivation rates and mechanisms for rhodium-based catalysts in pellet form, and 2) modification of existing computer models to incorporate information obtained in number 1 above. These models will aid in designing endothermic and exothermic reactors for the field-scale experiment (CLOE) and the 20 kW receiver/reformer to be tested at the Weizmann Institute (see Task 3). The University of Houston will also test and evaluate titanate-based catalysts supplied by SNLA for comparison with the commercial rhodium catalysts. The Houston work, in addition to directly supporting the CLOE experiment, may result in the development of more cost-effective catalysts for TC transport.

A series of coking experiments were initiated at SNLA in FY86 to investigate carbon deposition rates and changing gas compositions in the presence of candidate reformer and methanator materials in representative gas environments (mixtures of CO, H_2,

CO_2 and CH_4). Initial tests on seven candidate materials in gas mixtures of 1:1-CO:H_2 over temperatures from 900 to 400°C showed more than two orders of magnitude difference in coking between plain carbon steel, which had the greatest coking, and quartz and copper for which coking was essentially negligible. These coking experiments will be continued in FY87 for different gas mixtures, temperatures and materials. One aspect in particular to be investigated is the effect of CO_2 concentration on reducing the coking rate.

Mechanical properties experiments were initiated in FY86 to evaluate the creep and weldability characteristics of candidate alloys in representative CO_2/CH_4 reforming environments. Initial screening tests revealed some promising candidates. These experiments will be continued in FY87 and will include both as-received and aged specimens and long term tests (>1000 hrs.). The results will be used to identify alloys to be used in the field-scale Closed Loop Operations Experiment (CLOE) and for TC transport systems in general.

Subtask 6.3, Field-Scale Closed Loop Operations Experiment -- As a follow-up to the modelling and experimental activities described above, the next logical step in developing TC transport technology is to proceed to TC transport testing at larger than laboratory scale and under more realistic conditions. A field-scale experiment including multiple endothermic receiver/reactors (both conventionally and solar heated) and as many commercially available components as possible, will be a major step in demonstrating the practical feasibility of TC transport for solar applications.

The first step in defining the field-scale experiment was taken in December, 1985, with the selection of the chemical system to be used. Based upon results from the TC transport laboratory experiments and materials corrosion studies, the CO_2/CH_4 reforming/methanation system was selected for the field-scale experiment.

As presently conceived, the Closed Loop Operations Experiment (CLOE) will be conducted in two phases. Phase I will involve conservative, state-of-the-art receiver/reactor designs that will ensure successful operation of the system. Heat input will be by conventional sources (electrical heating) to provide better control and more flexibility in performing the experiments. Phase II will involve advanced receiver/reactor design concepts capable of operating at higher temperatures, and at least one of these units will be mounted on a parabolic concentrator in the DRTF to provide data and operational experience in a true solar environment.

Conceptual and preliminary designs of CLOE-Phase I were completed in FY86. Four receiver/reformer/recuperator units, three sized for 80 kW_t energy input and the fourth for 130 kW_t (the heat rate for a 15 m dish), will be manifolded in parallel and connected through a piping network to a single 320 kW_t methanator unit. The methanator will be a staged configuration (based on conventional commercial methanator designs) capable of delivering energy at three output temperatures representative of the needs of electrical power generation and IPH applications. A contract for the detailed design of CLOE-Phase I was awarded near the end of FY86. The detailed design will be completed in May 1987. Contracts will be awarded for the fabrication, assembly, and construction of CLOE-Phase I beginning in Aug 1987. Construction is expected to be completed in April 1988 with checkout and startup operations completed by the end of FY88. The experimental program will be initiated early in FY89.

Subtask 6.4, DRTF Support -- See Task 10.2

Resource Requirements, Task 6

Costs (k$)	FY87	FY88
In-house	804	783
Contracts	770	630
Total costs (k$)	1574	1413
Manpower (man-yr)	5.4	5.1

R&D TASK 8, BALANCE OF PLANT

This task consists of R&D on all those elements of distributed solar thermal systems that are not specifically included in the other tasks. The most important area is that of development of appropriate controls, both for subsystems, such as collector tracking controls or receiver fluid controls, and for the entire system. Other balance of plant considerations include field wiring and protection, interfaces between solar systems and their applications, safety, etc.

Status and Planned Activities

The primary focus of the Balance-of-Plant (BOP) task is the development of economical and reliable control systems. A study of the current state-of-the-art control system hardware and strategies has been completed. A report on this study will be completed in early FY87. With this background information, the requirements for distributed receiver control systems can be accurately evaluated. This assessment of controls development needs, as well as other balance-of-plant needs, will be completed by March of 1987 and will be documented in the form of a multi-year development plan.

In order to best identify the BOP needs, a working relationship will be maintained with other task groups on the solar thermal distributed receiver project. A component optimization study for the STM4-120 will be undertaken in conjunction with the Heat Engine Task. The study will emphasize the control issues that arise from transient operation of the engine. Past experiences with the prototype ORC engine have shown that solar transients serve as major obstacles to successful engine operation. December 1987 is the scheduled completion date of this design study. The appropriate controls will be procured, installed and checked out on the STM4-120 in the ETF in mid FY88. This control system will then support KSE on-sun testing at the DRTF beginning in late FY88.

In addition, assistance will be provided on the control issues that arise in the stretched membrane concentrator development described in Task 2 and the Closed Loop Operations Experiment outlined in Task 6.

Automated control developments in the photovoltaic and central receiver programs will be closely monitored, with particular interest in the tracking and remote communication issues. The photovoltaics program is currently developing a low cost tracking control system that will have direct applications in distributed receiver systems. Their controls will use custom built electronics that may prove to have substantial cost reduction benefits in large production runs. For the smaller sized dish fields that are currently envisioned, it might be preferable to avoid custom built electronics and use control hardware that is already in general production. In the past few years, a wide variety of industrial application personal computers have become available and the prices have dropped significantly. In addition, these units are built for rough service applications and have already received considerable testing. To evaluate the possibilities of these commercial systems, an advanced development in-house effort to implement industrial PC's into the tracking and possibly the engine control systems will begin in the second quarter of FY87.

Dish cleaning and maintenance of the stretched membrane concentrator is also included in the Task 8 responsibilities. For FY87 and 88 no substanatial efforts are planned. Documentation on previous studies will be gathered and minor laboratory experiments on cleaning techniques and abrasion resistance will be conducted.

Resource Requirements, Task 8

Costs (k$)	FY87	FY88
In-house	150	192
Contracts	20	50
Total costs (k$)	170	242
Manpower (man-yr)	1.0	1.2

R&D TASK 10, DISTRIBUTED RECEIVER SYSTEMS

The purpose and goal of the system task is to develop the tools and expertise to provide guidance from the system level about performance and cost trade-offs, and to provide the means to investigate component interaction that can aid in directing component development. Toward that end, the capability is being developed for both parametric analysis and detailed systems analysis on a consistent basis that will be useful throughout the distributed solar thermal program. The system studies fall into two major technological headings--dish electric and central engine. There are a few topics which do not fit into this scheme, but benefit from the study expertise developed from the others.

Also, the activities of this task provide for the operation and maintenance of the Distributed Receiver Test Facilities (DRTF) and for analysis and evaluation of systems tests, in particular the Solar Total Energy Project at Shenandoah, GA, and the Industrial Process Heat Projects.

Status and Planned Activities

Subtask 10.1, Systems Engineering and Analysis -- A study currently underway investigating the central engine concept is providing the vehicle for development of many areas. One area is code development where in the SOLTES code will provide detailed system analysis required to examine peak and off-peak performance and component interaction. Another code that will be used for parametric analysis is the SYSMOD code already applied in the heat engine assessment completed in FY86.

The Central Engine Study involves the comparison of thermochemical and sensible transport in the context of electric energy production plants in the size range of 500 kWe - 50 MWe. The study is focusing on existing technology in the power-cycle. A survey of organic and steam Rankine machinery has been undertaken by Mechanical Technology, Inc., under contract to SNLA in an effort to identify available applicable technology that requires no solar funded development. This contract will be completed in February 1987. The Transport task is providing the bulk of the thermochemical transport information while the Systems task is developing sensible transport information based on NaK. Physical, operational and cost information on the NaK sensible system is developing by contact with experienced industry personnel. Use of expertise developed under programs elsewhere in DOE has highlighted the constraints of NaK as a field transport fluid. As the TC transport task continues code enhancement in conjunction with lab experiments, the system task assimilates the same. Additionally, the design of the field-scale experiment is providing better cost data on the system than was previously available. The field-scale experiment itself will, of course, add refinement to the understanding of such a system in the applications at hand. At the completion of Phase II in August 1987, analysis of the performance and economics of systems consisting of dish fields, transport and conversion cycle will be available. Sensitivity studies regarding those performance or economic assumptions most critical or most uncertain will follow quickly after.

A methodology for performing second law of thermodynamic analyses of thermal energy systems will be developed and applied to the Central Engine Studies. This capability is needed because first law analyses alone are not sufficient for selecting operating strategies and controls that provide the highest electrical conversion efficiencies for thermal energy systems. This methodology will be developed by mid FY88.

As a basis for comparison, a base case central engine design analysis was initiated in FY86 and will be completed in November 1987. The updating of the analysis will be on-going. The base case concept is meant to provide operating and cost models on currently existing or near-term hypothetical solar thermal systems. In conjunction with the base-case development, the Systems task will keep abreast of emerging technologies such as the LMTEC, RTEC, Kalina cycle, and Cheng cycle.

A comparable base-case dish-electric system will be developed using a solar Stirling design on which data is available. The base-case will provide the vehicle for comparison of proposed improvements in dish-electric systems. The methodology will be as consistent as possible with the central engine studies already underway.

The Central Engine Study will continue through FY87 and will lead naturally into a hybrid central engine study. Two issues make hybridizing attractive: one is extension of working day beyond the solar limits (increased capacity factor) and the other is using fossil energy to provide superheat to de-couple the power cycle operating temperature and the solar field operating temperature. The Hybrid System Study will be started early in FY88. As a companion study, dish-electric hybrid operations will also be investigated. This will involve estimating the cost of hybridizing engines as well as the potential benefits derived from the increased operation. This task will utilize results of the gas/solar hybrid Stirling study conducted under a GRI/Advanco contract and completed in FY86.

Both technologies require a rational basis for obtaining annualized energy costs. The economics methodology itself will follow the DOE MYPP. However, the yearly energy output derivation for various systems is not nearly as straightforward. Comparison of the diverse set of systems, including some transient nature inherent in solar but so often ignored, must be consistent and coherent and should encompass fundamentals of all renewable energy sources. The field component currently represents the most difficult component to address on an annual basis due to its complex interaction with the transient nature of the energy source. The initial activity will consist of modelling the performance of the transport component of a thermally connected field of dishes, much like that of the central engine sensible system, with the intent of developing a simple yet accurate annual performance model. The process will provide a rationale for simplification without sacrificing fundamental principles. By following the central engine study, the activity should commence in early FY88 with completion in mid FY88.

Resource Requirements, Subtask 10.1

Costs (k$)	FY87	FY88
In-house	405	528
Contracts	150	150
Total costs (k$)	555	678
Manpower (man-yr)	2.7	3.3

Subtask 10.2, Distributed Receiver Test Facility (Operation and Maintenance) -- The Distributed Receiver Test Facility supports testing of point and line focus components and associated energy conversion systems. The facility includes two 11 m Test Bed Concentrators, a LaJet-460 concentrator, a rotating platform for testing of line focus components, four line-focus systems installed under the MISR project, and an Engine Test Facility. The Verification Module for Small Community Solar Experiment #1 has also been installed at the DRTF.

The DRTF will be maintained and operated as required to support testing by the various tasks, including testing of engines, receivers, the SCSE verification modules, the concentrators from the Innovative Concentrator program, and the thermochemical Closed Loop Operations Experiment. Test requirements and resources to support specific tests are included under the relevant task descriptions. Resources for Task 10.2 support maintenance, operations, and upgrade of the facility. Planned upgrades include completion of development of a video-based flux mapper in FY87 and fabrication of a large Cold Water Cavity Calorimeter suitable for use on the Innovative Concentrators. Flat budget assumes no upgrades in FY88, but more facilities (e.g. Acurex and LaJet concentrators) to maintain.

The facility will be used, also, to conduct reimbursible tests for other programs and agencies on the basis of non-interference with previously scheduled solar thermal test requirements.

Resource Requirements, Subtask 10.2

Costs (k$)	FY87	FY88
In-house	180	195
Contracts	220	200
Total costs (k$)	400	395
Manpower (man-yr)	1.5	1.5

<u>Subtask 10.3, Shenandoah Solar Total Energy Project</u> -- The Solar Total Energy Project (STEP), located at Shenandoah, GA, produces electricity, process steam, and chilled water for air-conditioning through use of the cogeneration concept. A series of Test Operations Phase experiments were performed in FY85 and two sets of Continuous Operations experiments were performed in FY86 for the purpose of evaluating the performance of the facility. To improve its performance, extensive modifications were planned for the STEP facility to begin in FY86 and be completed in early FY87. The modifications include conversion of the silicone heat transfer from a low pressure (225 kPa) to a high pressure (963 kPa) system, changing the field controls from a central to a distributed system using solid state electronics and thermocouples as temperature sensors for improved reliability, and associated reductions in manpower requirements, and the installation of a natural gas fired, steam superheater to improve the electrical output of the turbine/alternator. The boiler tube bundle is to also be replaced with a new one with 40% greater surface for better heat transfer characteristics and improved safety.

Plans for the STEP plant in FY87 are for Georgia Power to first complete the field control modifications, install a surge tank to provide for pressurization of the Syltherm heat transfer fluid, and install the new boiler tube bundle. The fossil fired heater will be ASME recertified for the higher pressure rating and all modifications to this point tested by the end of November 1986. The gas fired, steam superheater is scheduled to arrive by the end of November and be installed by the end of December. Sandia will contract with Georgia Power at that time to perform tests to establish a new performance baseline for the plant. When these experiments are complete the results will be evaluated and Georgia Power will begin their own "comercial operations beginning in the April-June time frame. The commercial operations will continue throughout the remainder of the fiscal year, interrupted only by unscheduled shutdowns for repairs or by scheduled component tests.

Sandia plans to contract with Georgia Power to conduct component and system tests of general benefit to the solar community such as tests of silvered versus aluminum film for use on concentrators, periodic field reflectance mapping, tests to determine the effect of cleaning aluminized film, measurements of the thermal losses of receivers, and the relative effects of the various mechanisms for heat loss (conductive, convective, and radiative). A detailed test plan has not yet been worked out. It is worthy of note that Georgia Power has, for the last several years, maintained a Shenandoah operation budget approaching $1M per year.

SNLA has contracted with Georgia Power to produce a summary report of their DOE activities during the period of 1977 through October 1985. The report is scheduled for completion by March 1987. SNLA has also contracted with Cal Poly to prepare a Test Operations Phase report and to prepare a summary of the Continuous Operations tests. Both of these documents will be completed in March 1987.

<u>Resource Requirements, Subtask 10.3</u>

Costs (k$)	FY87	FY88
In-house	60	48
Contracts	100	80
Total costs (k$)	160	128
Manpower (man-yr)	0.4	0.3

Subtask 10.4, Industrial Process Heat Reports -- The Industrial Process Heat Projects, some of which have been in operation for eight years, have outlived their usefulness. The trough (and flat plate) technologies represented are obsolete and the projects are too small in most cases to provide the industrial host with enough energy to justify his operating and maintenance expense. Most of the industrial hosts have abandoned their projects; in many cases because of non-solar factors within the firm, but in other cases because of substandard performance which could not be improved cost-effectively.

The SNLA reporting contracts with the industrial hosts were allowed to lapse as their periods of performance expired throughout FY86. None of these will be extended in FY87. The only activity planned for FY87 is SNLA manpower for the completion of an IPH "wrapup" report. This report will be completed in March 1987.

Resource Requirements, Subtask 10.4

Costs (k$)	FY87	FY88
In-house	60	0
Contracts	0	0
Total costs (k$)	60	0
Manpower (man-yr)	0.4	0

R&D TASK 11, SYSTEMS EXPERIMENTS

Systems experiments are tests of solar energy equipment assembled into full functional systems. They are performed in real or simulated environments and are extensively instrumented to measure system performance in detail. System experiments constitute the final step in solar energy development projects.

Status and Planned Activities

Subtask 11.1, Small Community Solar Experiments (SCSE) -- Two experiments are planned to evaluate solar electric plants in a small-community-utility environment, one to be located at Osage City, KS (SCSE#1), and the other on Molokai Island, HI (SCSE#2). Barber-Nichols was selected as the prime contractor for the site at Osage City. Power Kinetics, Inc. was selected as the contractor for the Molokai experiment.

The SCSE projects are structured in four phases:

1. Module Verification
2. Solar Plant Design
3. Solar Plant Installation
4. Solar Plant Operation and Maintenance

Sandia's responsibility to these DOE/AL contracted projects is to provide technical and management support to DOE/AL and to provide all services required at the DRTF to evaluate the module verification units. Close day-to-day contact will be maintained with the responsible contractors.

Module Verification Tests of the SCSE#1 module will be completed at the DRTF and the equpment for the SCSE#1 at Osage City will be fabricated and installation will begin. In FY88 the installation of SCSE#1 will be completed, checkout and startup will be conducted and operation of the plant will commence.

Module Verification testing at the DRTF for SCSE#1 was to have been completed in FY87. Serious problems with the PKI concentrator and the Barber-Nichols ORC engine caused the schedule to slip. Sandia devoted far more manpower to management support and DRTF support than was budgeted in FY86. The same will be true in FY87 if problems persist. The budget shown below (which includes $100K in contracted DRTF technicians) assumes nearly on-schedule progress for both SCSE#1 and SCSE#2.

The SCSE#2 (Molokai, Hawaii) currently has the module verification test scheduled to begin at the DRTF in December 1986 and Molokai site construction to begin in January 1987. However, due to unanticipated concentrator design problems, the revised schedule is yet to be determined. Note comments above on budgeting Sandia support.

An automated data system similar to the "ODAS" used at several DOE PV experimental sites is being designed by SNLA for both SCSE's and special software for these dish-electric applications will be written. The data system will be installed at the DRTF and its operation checked-out during the Module Verification testing. The data system will provide weather and operational data for each experiment. After installing the data systems at Osage City and Molokai, the site data will be sent via telephone to Albuquerque for reduction and report writing.

<u>Resource Requirements, Task 11</u>

Costs (k$)	FY87	FY88
In-house	285	353
Contracts	120	1060
Total costs (k$)	405	1413
Manpower (man-yr)	2.0	2.3

CHAPTER 4. RESOURCES AND IMPLEMENTATION

This chapter provides summary information in several formats for the FY86 and FY87 plans for SNLA's Solar Thermal Projects. This information includes:

Major Milestone Charts
Resource Requirements Summary Table
Management Plan
Procurement Plan
Project Organization and Key Personnel

Major Milestones for FY87 and FY88

The most important milestones have been assembled onto the Major Milestone Chart in Figure 4.1. The selection of these milestones reflects both the focus of the projects on the most critical R&D needs for distributed receiver technology and the importance of achieving these milestones to realize the Solar Thermal Technology Program goals.

Resource Requirements Summary

The manpower and budgetary resources required for the plans described in Chapter 3 are summarized in Table 4.1. The resource allocations follow the emphasis within the project on concentrator and engine R&D needs while still maintaining a reasonable balance among all aspects of distributed receiver technology development.

Summary of Deliverables

The following is a list of deliverables for FY87 and FY88. In the case of reports, the dates listed are estimated publication dates and the deliverable includes the author(s) and title. The distribution of all reports will be UC-62, Rev. 74 and the Sandia Distributed Receiver Standard Distribution.

Date	Deliverable
Oct 86	Workshop, Concentrating Solar Collectors: Key Technical Issues, Albuquerque, NM
Oct 86	Cameron, C. P., and V. E. Dudley. "Acurex Solar Corporation Modular Industrial Solar Retrofit Qualification Test Results"
Oct 86	Cameron, C. P., and V. E. Dudley. "The BDM Corporation Modular Industrial Solar Retrofit Qualification Test Results"
Oct 86	Cameron, C. P., and V. E. Dudley. "Custom Engineering, Inc., Modular Industrial Solar Retrofit Qualification Test Results"
Oct 86	Cameron, C. P., V. E. Dudley, and A. A. Lewandowski. "Foster Wheeler Solar Development Corporation Modular Industrial Solar Retrofit Qualification Test Results"
Oct 86	Cameron, C.P. and V. E. Dudley. "Solar Kinetics, Inc., Modular Industrial Solar Retrofit Qualification Test Results"

Date	Deliverable
Nov 86	Linker, K. L. "Heat Engine Development for Solar Thermal Dish-Electric Power Plants"
Jan 87	Acurex Contractor Report, "Development of an Evacuated Receiver for Line-Focus Solar Thermal Collectors"
Mar 87	Georgia Power Company. "Solar Total Energy Project Summary Report"
Mar 87	Ratzel, A. C., B. D. Boughton, R. B. Diver, and T. R. Mancini. "CIRCE.001: A Computer Code for Analysis of Point-Focus Concentrators with Flat Targets"
Apr 87	Adkins, D. R. "A Review of the Control Strategies and Hardware Used in Solar Thermal Applications"
Apr 87	Diver, R. B. and C. E. Andraka. "CAV2--A PC Based Computer Program for Predicting Incident Solar Flux Distributions Inside Dish Cavity Receivers"
Apr 87	Diver, R. B., J. A. Leonard, and T. R. Mancini. "Proceedings of the Solar Concentrating Collector Workshop"
Apr 87	Linker, K. L. "Analysis of Steam Injected Gas Turbines for Solar Thermal Applications"
May 87	Harley, E. L. "Solar Industrial Process Heat (IPH) Project Technical Report"
May 87	Mancini, T. R. "Innovative Point-Focus Concentrator Projects"
May 87	McCrary, J. H. and G. E. McCrary. "Experimental Studies of a Closed-Loop Sulfur Oxide Energy Conversion and Transport System"
Jun 87	Fish, J. D. "Documentation of the CLEA Code Version 86.1: Single-Loop, Steady-State Performance Model for Thermochemical Energy Transport Based on CO2 Reforming of Methane"
Jun 87	JPL, Contractor's Report. "Alkalai Metal Thermal Electric Converter Electrode Development"
Jun 87	MTI, Contractor's Report. "Engine Availability Study Final Report"
Jun 87	Muir, J. F. "Performance/Economic Analysis of Thermochemical Versus Sensible Energy Transport for Distributed Receiver Solar Thermal Systems"
Jun 87	Stine, W. B., and A. A. Heckes. "Performance Evaluation of the Solar Total Energy Project (STEP) at Shenandoah, Georgia, April 1984 to December 1984"
Jun 87	Strachan, J. W. "Fluxmapping of LaJet's LEC-460"

Date	Deliverable
Aug 87	Argonne National Laboratory, Contractor's Report. "Stirling Reliability and Failure Modes and Effects Analysis"
Aug 87	Weirick, L. J. "Final Report on Oxidation/Sulfidation of Material Candidates for Distributed Solar Receiver Thermochemical Transport Program in SO3"
Aug 87	Conference, Solar Thermal Technology Annual Conference, Albuquerque, NM
Sep 87	Lukens, L. L., J. P. Abbin, C. E. Andraka, and J. B. Moreno. "A Liquid Metal Thermal Electric Converter"
Nov 87	Diggs, J. M. "Results of Phase II of Central Engine Study"
Mar 88	Solar Kinetics, Inc., Contractor's Report. "Final Report on Stretched Membrane Conceptual Design"
Mar 88	La Jet Energy Co., Contractor's Report. "Final Report on Stretched Membrane Conceptual Design"
May 88	MTI, Contractor's Report. "Final Report on Free-Piston Stirling Engine Design"
May 88	STC, Contractor's Report. "Final Report on Free-Piston Stirling Engine Design"
Aug 88	Conference, Solar Thermal Technology Annual Conference, Albuquerque, NM

Major Reports

The following reports are considered to be "major reports" for FY87. The distribution described will be in addition to the above described distribution for all reports.

Harley, E. L. "Solar Industrial Process Heat (IPH) Project Technical Report"

Draft Completion	Reviewers	Supplemental Distribution
March 1987	Solar Kinetics Acurex W. Stine, Cal Poly C. Kutscher, SERI W. Bigelow, ETEC Sandia Peer Review Sandia Management	Industrial Hosts Companies System Contractor Companies SEIA EPRI GRI IGT

Georgia Power Company. "Solar Total Energy Project Summary Report"

Draft Completion	Reviewers	Supplemental Distribution
March 1987	J. Cummings, EPRI	EPRI
	S. Jeter, GIT	Edison Institute
	D. Russell, Auburn Univ.	SEIA
	M. Brown, PG&E	Bleyle of America
	A. Lewandoski, SERI	Southern Company
	D. Block, Florida Solar Ctr.	SCE
	Sandia Peer Review	PG&E
	Sandia Management	SDG&E
	GPC Management	APS
		PNM
		SWPS

Management Plan

Management encompasses project planning, coordination, control, reporting, and programmatic support and technology transfer.

Project Planning -- The primary project planning activities consist of (1) supporting the preparation and regular revision of the Five Year Research and Development Plan, and (2) preparation of this 2-year Sandia (SNLA) Development Plan on an annual basis.

Project Reporting -- Project reporting is conducted at several levels. Within the federal Solar Thermal Technology Program weekly and quarterly reports are prepared, and oral reviews are conducted on a quarterly basis. The quarterly reports coincide with and serve as documentary support for the oral reviews. In addition, material on distributed receiver technology development is prepared for the Solar Thermal Technology Annual Evaluation Report which for FY87 will incorporate the material formerly found in the Solar Thermal Program Summary Document.

Solar Thermal Program Documentation Support -- The DOE Office of Solar Heat Technologies is engaged in preparing summary technology transfer documentation of the major results of completed R&D efforts across the solar heat and solar thermal technologies. This effort is being conducted mainly by support contractors. During FY87, the Sandia Distributed Receiver Project does not anticipate direct support to this effort beyond incidental review and consultation. Resources, therefore, have not been budgeted for this activity.

Technology Transfer -- Some of the most important technology transfer activities include frequent technology exchanges or briefings with a wide variety of visitors from various industries, federal agencies, and universities. These take place over the telephone as well as face-to-face.

Interagency Coordination -- Coordination of R&D efforts between SNLA and NASA on solar thermal electric technology is rapidly increasing because of NASA's growing interest in space solar dynamic technology in the range of tens to hundreds of kilowatts. This cooperative, mutually beneficial liaison will be maintained.

Table 4.1

RESOURCE REQUIREMENTS SUMMARY

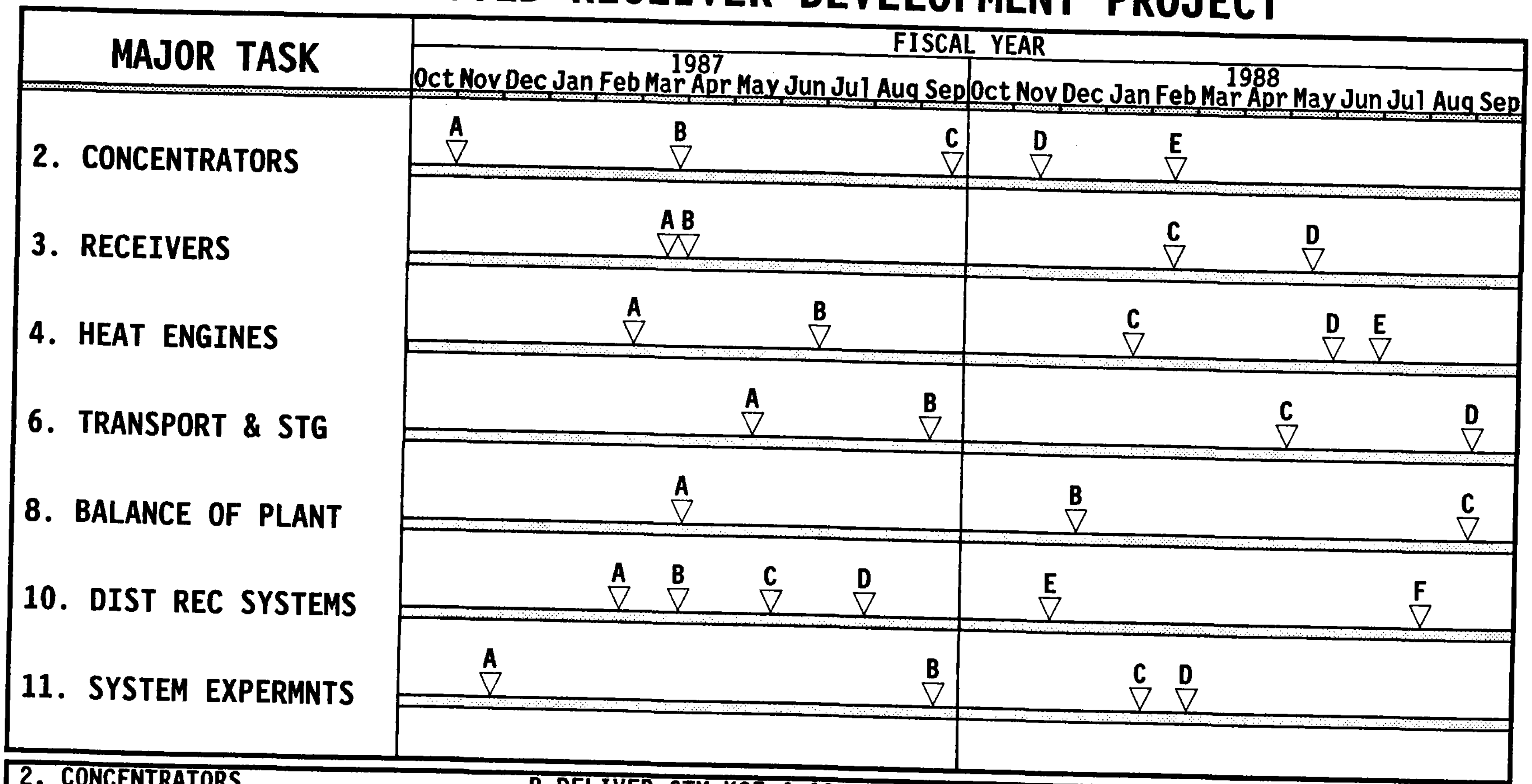
DISTRIBUTED RECEIVER PROJECT -- FY87/88

TASK	FY 1987 In-house MY	FY 1987 In-house $k*	FY 1987 $CNTR	FY 1987 $TOT	FY 1988 In-house MY	FY 1988 In-house $k*	FY 1988 $CNTR	FY 1988 $TOT
COLLECTION TECHNOLOGY								
2.0 CONCENTRATORS	4.2	609	920	1529	4.7	728	1020	1732
3.0 RECEIVERS	2.2	318	450	768	3.8	587	810	1397
ENERGY CONVERSION TECHNOLOGY								
4.0 HEAT ENGINES	4.1	609	770	1379	4.3	667	1675	2342
6.0 TRANSPORT AND STORAGE	5.4	804	770	1574	5.1	783	630	1413
8.0 BALANCE OF PLANT	1.0	150	20	170	1.2	192	50	242
SYSTEMS & APPLICATIONS TECHNOLOGY								
10.0 DISTR RECEIVER SYSTEMS	5.0	705	470	1175	5.1	771	430	1201
11.0 SYSTEM EXPERIMENTS	2.0	285	120	405	2.3	353	1060	1413
TOTALS	23.9	3480	3520	7000	26.5	4081	5675	9740

----

* In-house costs include all SNLA non-contracted costs. These include not only labor and overhead, but also travel, computer charges, drafting, test, shop, tech art, and stockroom withdrawals.

DISTRIBUTED RECEIVER DEVELOPMENT PROJECT



2. CONCENTRATORS
   - A= PLACE STR MEMB CONTRACTS
   - B= COMPL PDR STR MEMB DESIGNS
   - C=COMPL DRTF TESTS OF IC'S
   - D= COMPL DDR STR MEMB DESIGNS
   - E= PLACE STR MEMB PHII CONTRACT
3. RECEIVERS
   - A=PLACE CONTRACT REFLUX REC FOR KSE
   - B=SHIP TC RECEIVER TO ISRAEL
   - C=COMPL FEAS STUDY/CONCEPT DES OF DCAR
   - D=COMPL FAB REFLUX REC FOR KSE
4. HEAT ENGINES
   - A=COMPL 1ST LMTEC BENCH MODULE TEST
   - B=DELIVER STM KSE 4-120 TO DRTF
   - C=COMPL FPSE DETAIL DESIGN
   - D=BEGIN TESTS OF REFLUX LMTEC BTM II
   - E=BEGIN ON-SUN TESTING OF KSE
6. TRANSPORT & STG
   - A=COMPL DETAIL DES TC FIELD EXPR
   - B=PLACE FLD-SCALE EXP CONSTR CNTRCT
   - C=COMPL FLD-SCALE EXP CONSTRUCTION
   - D=COMPL TC FIELD-SCALE EXP C/O & STARTUP
8. BALANCE OF PLANT
   - A=COMPL CONTROLS DEVEL NEEDS ASSESSMT
   - B=COMPL ADVANCED CNTRLS STUDY FOR KSE
   - C=INSTALL ADV CONTROLS ON KSE
10. DIST REC SYSTEMS
   - A=COMPL ENGINE AVAIL CONTRACT
   - B=FINAL DFT SHEN STEP SUMMARY REP
   - C=BEGIN OPRN VIDEO FLUX MAPPER
   - D=COMPL PHII OF CNTRL ENG STUDY
   - E=COMPL DISH-CENTRAL BASE CASE
   - F=COMPL DISH-ELECTRIC BASE CASE
11. SYSTEM EXPERMNTS
   - A=COMPL DRTF TESTS OF SCSE1 MODULE
   - B=COMPL DRTF TESTS OF SCSE2 MODULE
   - C=COMPL SCSE1 C/O & STARTUP (DOE/AL)
   - D=COMPL SCSE2 C/O & STARTUP (DOE/AL)

DR8788 1-30-87

FIGURE 4.1

Procurement Plan

Procurement Strategy -- Procurements for the distributed receiver development program are initiated by Sandia, upon approval of this Distributed Receiver Development Plan by DOE/HQ. The procurement summary listed in Table 4.2 provides a list of those new procurements that are anticipated in FY87. Table 4.3 lists the major active contracts placed on FY86 or prior year Budget Authority.

Procurement Policy and Practices -- Sandia's procurement rules are similar to the DOE regulations; however, they are not identical. In the substantive cases where they are not, but which have impact on the program, measures are taken to assure that programmatic requirements are met. An example of this is the policy of advertising competitive procurements in Commerce Business Daily and any other appropriate publication. (This is not generally done on Sandia procurements.) With few exceptions, R&D procurements in this program are competitive, with the sole source option being used only in instances where it is very clear that a certain contractor is the only one who can fulfill the function.

Unsolicited Proposal Funding -- Sandia, through its prime contract held by AT&T Technologies with the U.S. Department of Energy, is excluded from funding unsolicited proposals which have been submitted to the Laboratory. These proposals are returned unopened with instructions regarding the proper route of submittal to DOE/HQ. Once such a proposal is submitted through the proper channels, reviewed, and accepted for funding by the appropriate Division Director (DOE/HQ), SNLA can place the contract as a result of a written request from that Director. In implementing this procedure, Headquarters and SNLA will reach an agreement regarding the source of funding prior to a formal request being sent to SNLA to place a contract. It is expected that most approved unsolicited proposals will be of sufficient value to fit within the scope described in this plan and will not require additional funding. Exceptions will occur where the proposals are approved using additional criteria and where funds have been reserved at Headquarters for funding such proposals.

Small and Minority Business Policy -- It is both DOE policy and Sandia policy to maximize the use of small and minority businesses in carrying out the programs under their management.

TABLE 4.2

PROCUREMENT SUMMARY FOR FY87
MAJOR ANTICIPATED CONTRACTS

TITLE	TASK	VALUE	PROJ ENGR	START	COMPLT
POINT FOC CONC DEV	2.2	375	T. MANCINI	APR 87	JUN 88
STR MEMB CONC DEV	2.2	415	T. MANCINI	MAY 87	MAY 88
STRUCTURAL MIRROR DEV.	2.2	100	T. MANCINI	JUN 87	JAN 89
TEMPERATURE MAPPING TOOL	3.1	20	R. DIVER	NOV 86	SEP 87
TECHNICAL SUPPORT	3.1	110	R. DIVER	DEC 86	SEP 89
RECEIVER HEAT LOSS TESTS	3.1	80	R. DIVER	DEC 86	MAY 88
TC RECEIVER	3.2	190	R. DIVER	APR 87	JAN 88
ENGINE/RECEIVER TEST FACILITY	4.2	175	S. MURPHY	NOV 86	JUN 87
KSE RECEIVER	4.2	150	K. LINKER	MAR 87	MAY 88
FR PIST STRLG ENG PHII LONG LEAD	4.2	180	K. LINKER	JUN 87	JUN 88
LMTEC BTM COMP UPGRD (MISC)	4.3	80	L. LUKENS	FEB 87	SEP 87
HG-BETA-ALUMINA STUDY I	4.3	100	W. HAMMETTER	MAY 87	DEC 88
HG-BETA-ALUMINA STUDY II	4.3	80	W. HAMMETTER	MAY 87	DEC 88
CATALYST DEVELOPMENT	6.2	50	J. FISH	MAR 87	JUN 88
TC FLD-SCALE EXP CONSTR	6.3	620	J. MUIR	MAY 87	MAR 88
GENERAL ANALYTICAL SUPPORT	10.1	100	J. DIGGS	NOV 86	SEP 88
BASE CASE STUDY, DISH-CENTRAL	10.1	50	J. DIGGS	MAR 87	JAN 88
LABOR HOUR CONTRACT	10.2	220	J. OTTS	OCT 86	SEP 87
DRTF CONSTRUCTION	10.2	70	M. QUINTANA	DEC 86	DEC 87
SHENANDOAH TESTS	10.3	100	A. HECKES	FEB 87	JAN 88
SCSE DRTF SUPPORT	11.1	100	J. OTTS	OCT 86	SEP 87
OSAGE CITY DATA SYSTEM	11.1	10	E. RUSH	NOV 86	SEP 88
MOLOKAI DATA SYSTEM	11.1	10	J. OTTS	JAN 87	NOV 87

TABLE 4.3

SANDIA NATIONAL LABORATORIES
DISTRIBUTED RECEIVER PROJECT
PROCUREMENT SUMMARY

MAJOR ACTIVE CONTRACTS PLACED ON
FY86 AND PRIOR YEAR BUDGET AUTHORITY

CONTRACTOR	TASK	TITLE	VALUE	TYPE	PROJ ENGR	PO/PR	COMPLT	BAL
SOLAR KINETICS INC	2.2	STRETCHED MEMBRANE CONCPT	551	SMALL	T. MANCINI	53-9663A	SEP 87	525
LAJET ENERGY CO	2.2	STRETCHED MEMBRANE CONCPT	496	SMALL	T. MANCINI	53-9663B	SEP 87	496
UNIVERSITY OF NEW MEXICO	2.2	SOL-GEL PORE ANALYSES	31	UNIV	C. BRINKER	02-2456	DEC 87	28
XYTORR	2.2	THIN FILM COATING SERVICE	22	SMALL	W. BOYD	53-5358	NOV 86	2
CLARKSON UNIVERSITY	3.1	TEMPERATURE MAPPING TOOL	33	UNIV	R. DIVER	32-3242	MAR 87	13
TBD	3.2	TECHNICIAN SUPPORT	60	TBD	R. DIVER	01-9646	SEP 87	60
ARGONNE NAT LAB	4.1	FMEA STUDY FOR STIRLING	220	GOVT	K. LINKER	32-7644	FEB 87	1
NASA LeRC	4.2	FREE PIS STRLNG ENG DESGN	700	GOVT	K. LINKER	DOE/ALO	SEP 87	200
STIRLING THERMAL MOTORS	4.2	COML KIN STIRLING ENGINE	300	SMALL	K. LINKER	53-8452	SEP 87	193
CERAMATEC	4.3	BETA ALUMINA TUBES	11	SMALL	C. ANDRAKA	01-9440	DEC 86	11
UNIVERSITY OF WISCONSIN	4.3	HG BETA DOUBLE PRIME ALUM	49	UNIV	W. HAMMETTER	95-2054	SEP 86	0
UNIVERSITY OF PENNSYLVANIA	4.3	HG BETA ALUMINA RESEARCH	100	UNIV	W. HAMMETTER	64-9240	SEP 86	0
UNIVERSITY OF HOUSTON	6.2	CATALYSIS, REACTOR RESRCH	75	UNIV	J. FISH	53-7216	JUN 87	52
UNIVERSITY OF PITTSBURGH	6.2	CORROSION OF ALLOYS	50	UNIV	L. WEIRICK	64-1068	APR 87	5
RESOURCE ANALYSIS INTERNAT	6.3	TC CLOSED LOOP DESIGN	231	SMALL	E. RUSH	01-0447	MAY 87	166
TECHNADYNE ENG CONS	10.1	ENGINEERING PROGRAMM SUP	175	SMALL	M. FEWELL	14-1523	DEC 87	46
MECHANICAL TECHNOLOGY INC	10.1	SOLAR ENGN AVAILBLTY STDY	206	LARGE	J. DIGGS	64-7930	JAN 87	46
UNM (NMERI)	10.1	TECHNICAL SUPPORT	80	UNIV	J. LEONARD	64-9556	MAY 87	35
EG&G	10.2	SOLAR TEST SUPPORT	590	LARGE	C. CAMERON	52-5653	JUL 88	309
MISSOURI RESEARCH LAB	10.2	LABOR HOUR CONTRACT	103	LARGE	J. OTTS	48-0942	SEP 87	0
BROWN FIRED HEATER CO.	10.3	STEAM SUPERHEATER	38	SMALL	E. RUSH	01-0572	SEP 86	30
GEORGIA POWER CO	10.3	SUMMARY REPORT	25	LARGE	A. HECKES	53-8034	DEC 86	11
CALIFORNIA POLYTECHNIC	10.3	SHENANDOAH ENGINEERING	51	UNIV	A. HECKES	56-8775	OCT 86	0
TECH REPS, INC.	10.4	TECH SUPPORT SERVICES	50	SMALL	E. HARLEY	32-6527	OCT 86	0
WG ASSOCIATES	11.1	PKI ANALYSIS	75	SMALL	C. CAMERON	56-8420	SEP 87	29
UNIVERSITY OF HI MANOA	11.1	SMALL COMM EXPER SUPPORT	49	UNIV	J. OTTS	56-6959	FEB 87	16

Project Organization and Key Personnel

Sandia uses a matrix organizational structure which incorporates a broad range of supporting materials, engineering, computational, fabrication, and testing capabilities which are directly available for the varied needs of the project organizations. The Solar Thermal Projects at SNLA are conducted within the Solar Energy Department under the Director of Advanced Energy Technology. Specific responsibility for the distributed receiver projects is assigned to two divisions. This project structure, along with the task assignments, is displayed in Figure 4.2. This structure does not display the relationship and roles of the various functional supporting organizations. This support is arranged and provided at the division and staff member working level, which permits considerable efficiency and flexibility. About 40% of internal labor is provided to the Solar Thermal Projects from functional organizations.

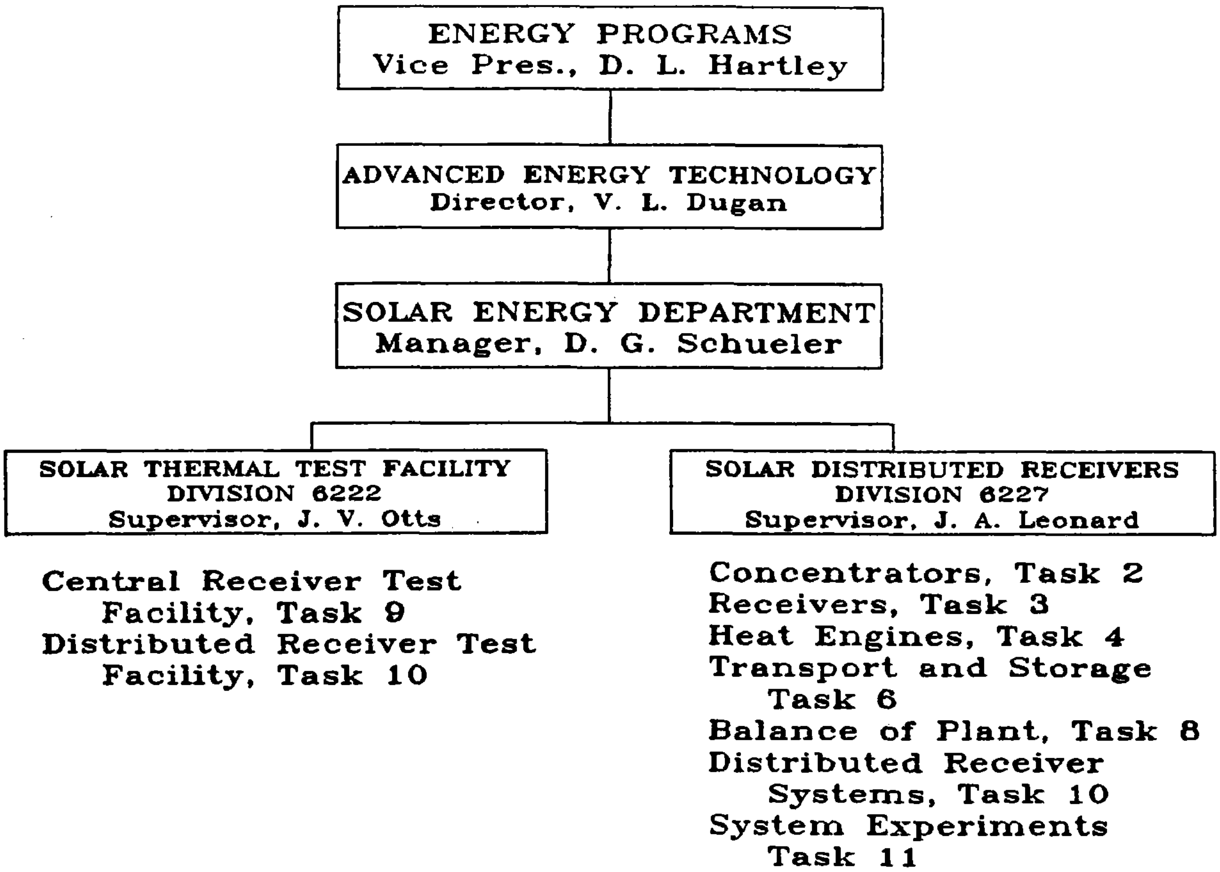


Figure 4.2. Organizational Structure for SNLA's Solar Thermal Projects