SAND80-0587C

THE U. S. NATIONAL PHOTOVOLTAICS PROGRAM

AND

APPLICATIONS EXPERIMENTS IN THE INTERMEDIATE SECTOR

ABSTRACT

A brief overview of the U. S. National Photovoltaics Program is presented. The Department of Energy (DOE) commercial readiness goals for photovoltaics technology are summarized and the role of the national labs, research centers, and institutes in the strategy for achievement of these goals is outlined. Some examples of the flat-plate and concentrator photovoltaics experiments that are under construction through the DOE Program Research and Development Announcments (PRDAs) are discussed. These experi- are intended to establish system feasibility and demonstrate the applicability of photovoltaics as an alternative energy source in the intermediate sector (industrial, commercial, and agricultural). Installed system costs for the proposed PRDAs are given and concentrator technology requirements for achievement of DOE commercial readiness goals are presented. Some new DOE activities intended to further assist the commercialization of photovoltaics are briefly outlined. These new activities include the completion of an International Photovoltaics Plan.

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THE NATIONAL PHOTOVOLTAICS PROGRAM IN THE USA

The national effort of the United States to develop and help commercialize photovoltaics (PV) as an alternative energy source is a part of the national energy policy of the United States (US)[1]. The national photovoltaics effort is institutionalized through Public Law 95-590 - Solar Photovoltaic Energy Research, Development and Demonstration Act of 1978 (RD&D Act of 1978). The RD&D Act of 1978 authorizes a 10 year, $1.5 billion, federal effort in photovoltaics that is being implemented by the Department of Energy (DOE) through its photovoltaics program.

THE OBJECTIVE OF THE DOE PHOTOVOLTAICS PROGRAM IS TO REDUCE SYSTEM COSTS TO A COMPETITIVE LEVEL IN BOTH DISTRIBUTED AND CENTRALIZED GRID CONNECTED APPLICATIONS. EQUALLY IMPORTANT THE PROGRAM WILL ALSO RESOLVE THE TECHNICAL, INSTITUTIONAL, LEGAL, ENVIRONMENTAL AND SOCIAL ISSUES INVOLVED IN FOSTERING WIDESPREAD ADOPTION OF PHOTOVOLTAIC ENERGY SYSTEMS.

The model of the RD&D process, shown in Figure 1, describes the DOE Photovoltaics Program. This idealized model defines major program milestones and the steps between initial concepts and their possible widespread commercial use. The process begins with the Basic Research supported within the Office of Energy Research (ER) with the identification of promising concepts. Successful concepts are transferred to the Photovoltaics Program within Energy Technology (ET) for Advanced Research and Development as shown on the top line of Figure 1. Continuing market analysis develops the needs and requirements of the technology. This will provide the focus and thrust of the development. The top line shows the subsequent steps followed

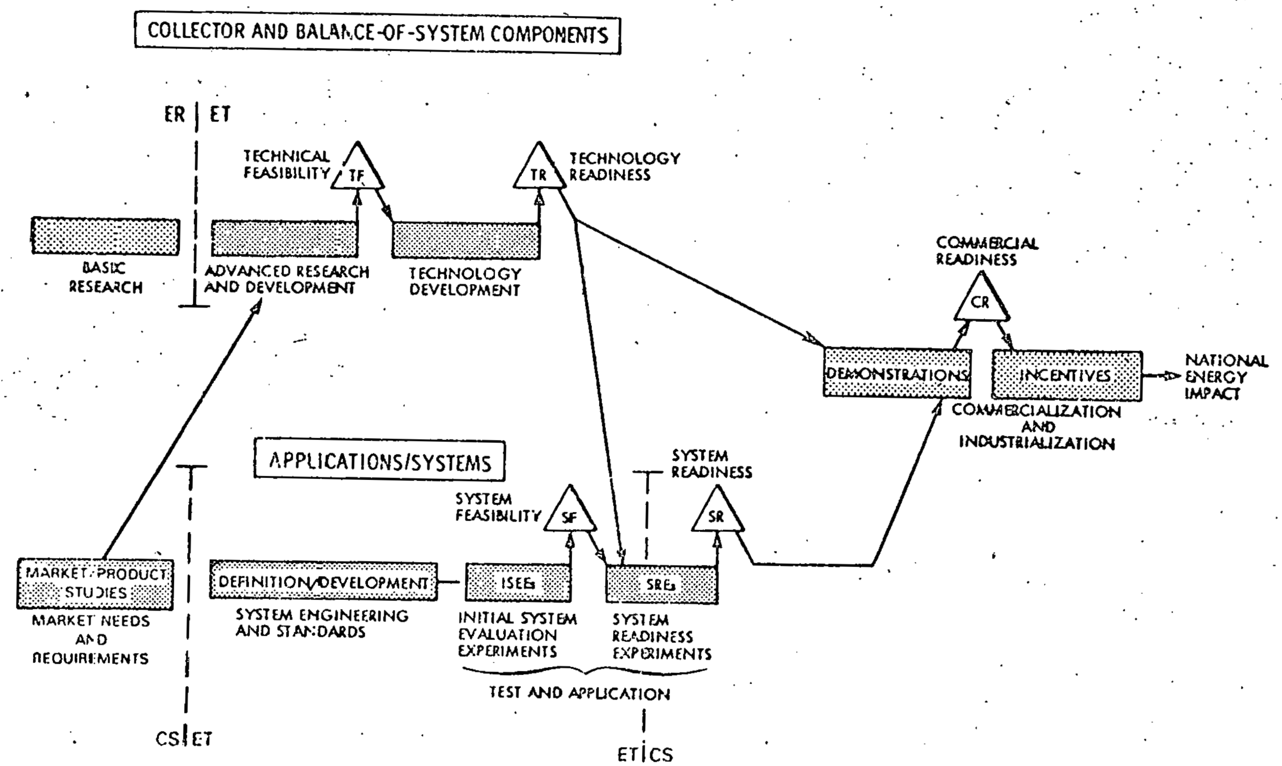

Figure 1. Research, Development and Demonstration Process for Components and Systems

in the development of low-cost components for photovoltaic systems. The transition between each major Program activity is identified by the milestones indicated. Each milestone is described in Table 1. At each step, a winnowing process occurs where the most promising components or techniques are carried to the next step.

While potential low-cost components are essential to Program success, they still must be incorporated into systems that meet the requirements of specified applications. The "Applications/Systems" line is also focused by analysis of the market and user requirements, leading to definition of several alternative systems and their requirements on components. This is followed by system development, where breadboard systems are tested in a laboratory environment. The most attractive candidate systems are carefully instrumented and tested in the end user's environment in a set of Initial System Evaluation Experiments (ISEEs) to establish system feasibility and, finally in larger scale System Readiness Experiments (SREs). Systems successfully emerging from System Readiness Experiments meet the user requirements and have the potential of being produced commercially at the price goal established for that application assuming the necessary market size and investment commitments.

The transfer between ET and Conservation and Solar Applications (CS)* occurs during the early phase of the System Readiness Experiments. This allows a real-world test of the technology-ready components in a fully integrated system before commercialization. During the Commercialization stage, the photovoltaic systems that achieve System Readiness are produced by the private sector, with appropriate incentives to develop the market for the system and

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*CS and the solar part of ET have recently been merged.

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Table 1. Key Milestones in the Photovoltaic RD&D Process

Milestone	Definitions/Requirements
Technical Feasibility (TF) of Components	Technical Feasibility is reached for a particular technology when: (a) stable and reproducible performance characteristics have been achieved; (b) a laboratory-scale process has been defined that yields products with consistent characteristics and ; (c) analysis indicates that mass production is technically feasible and likely to yield a technically and economically viable product after suitable technology development.
Technology Readiness (TR) of Components	Technology Readiness is achieved: (a) with a successful subscale demonstration of all the individual steps in a production process that would yield economically competitive and reliable products if produced in sufficient quantity and; (b) when prototypes are available for intensive performance and reliability analysis.
System Feasibility (SF)	System Feasibility is achieved in a given application when a photovoltaic system concept is first carried through design, installation and operation in an actual user's environment.
System Readiness (SR)	System Readiness is accomplished when fully integrated systems, using available technology ready components or prototypes thereof are designed, built and successfully operated in an actual user's environment.
Commercial Readiness (CR) of Components & Systems	Commercial Readiness in a given application class is accomplished when products or systems are offered for sale at a given price.

to induce the sales volumes necessary to achieve economies of scale in production, marketing, installation and servicing. The life-cycle cost-competitive systems that emerge are then ready for widespread commercialization. Additional methods of facilitating early commercialization are implemented during this stage.

Technical, commercial, institutional, and other considerations result in the following photovoltaic system application sectors:

- SMALL REMOTE
- RESIDENTIAL
- INTERMEDIATE
  - Agricultural
  - Service/Commercial/Institutional
  - Industrial
  - Residential Load Centers
- UTILITY CENTRAL STATIONS

Thus, for the three major energy-significant sectors in the US, the National Photovoltaics Program translates into the specific commercialization goals shown in Table 2*. A recently completed Solar Energy Domestic Policy Review in the US concluded that in the "maximum practical case", 1 Quad** of primary fuel per year could be replaced by photovoltacis by the year 2000. This estimate also translates into a national goal expressed in a quantity of alternative energy. In the shorter term, however, the program goals are to demonstrate Technology Readiness at an array factory price of $\$2.80/W_p$ in 1980 and achieve Commercial Readiness in 1982 at this array price. Several projects are now in place at Sandia intended to achieve this objective for photovoltaic concentrators.

* The peak watt (W_p) used throughout this paper is defined as the power output of the PV system at an insolation level of $1 kW/$m^2$.

**1 Quad = 10^{15} BTU = 293×10^9 kwh

TABLA 2

OBJETIVOS PARA DESARROLLO COMERCIAL DEL PROGRAMA FOTOVOLTAICO DEL DOE (EN DOLARES DE 1980)

	RESIDENCIAL	INTERMEDIO	ESTACION CENTRAL
AÑO DEL OBJETIVO	1986	1986	1990
COSTO CAPITAL DEL SISTEMA ($/$W_p$)*	1.60-2.20	1.6- 2.60	1.10-1.80
OBJETIVO PARA COSTO DE FABRICA POR PANEL ($/$W_p$)	0.70	0.70	0.15-0.40
COSTO DEL SISTEMA -- SVS*	1.80	1.80	1.20-1.40
COSTO DEL SUBSISTEMA DE PANELES INSTALADOS	1.50	1.50	1.00-1.20
RESTO DEL SISTEMA -- SVS	0.30	0.30	0.20
ESCALA DE PRODUCCION (MW_p/1 AÑO)	100-1000	100-1000	500-2500
PRECIO DE ENERGIA PARA EL CONSUMIDOR (¢/kW_h)	3.5-10.5	5.0-13.5	4.0-10.0

* DOLARES POR ~~CADA PUNTO MAXIMO (p) DE WATT (VATIO)~~ VATIO MAXIMO ($/$W_p$)

** SVS -- SOBRE LA VIDA DEL SISTEMA

NATIONAL STRATEGY

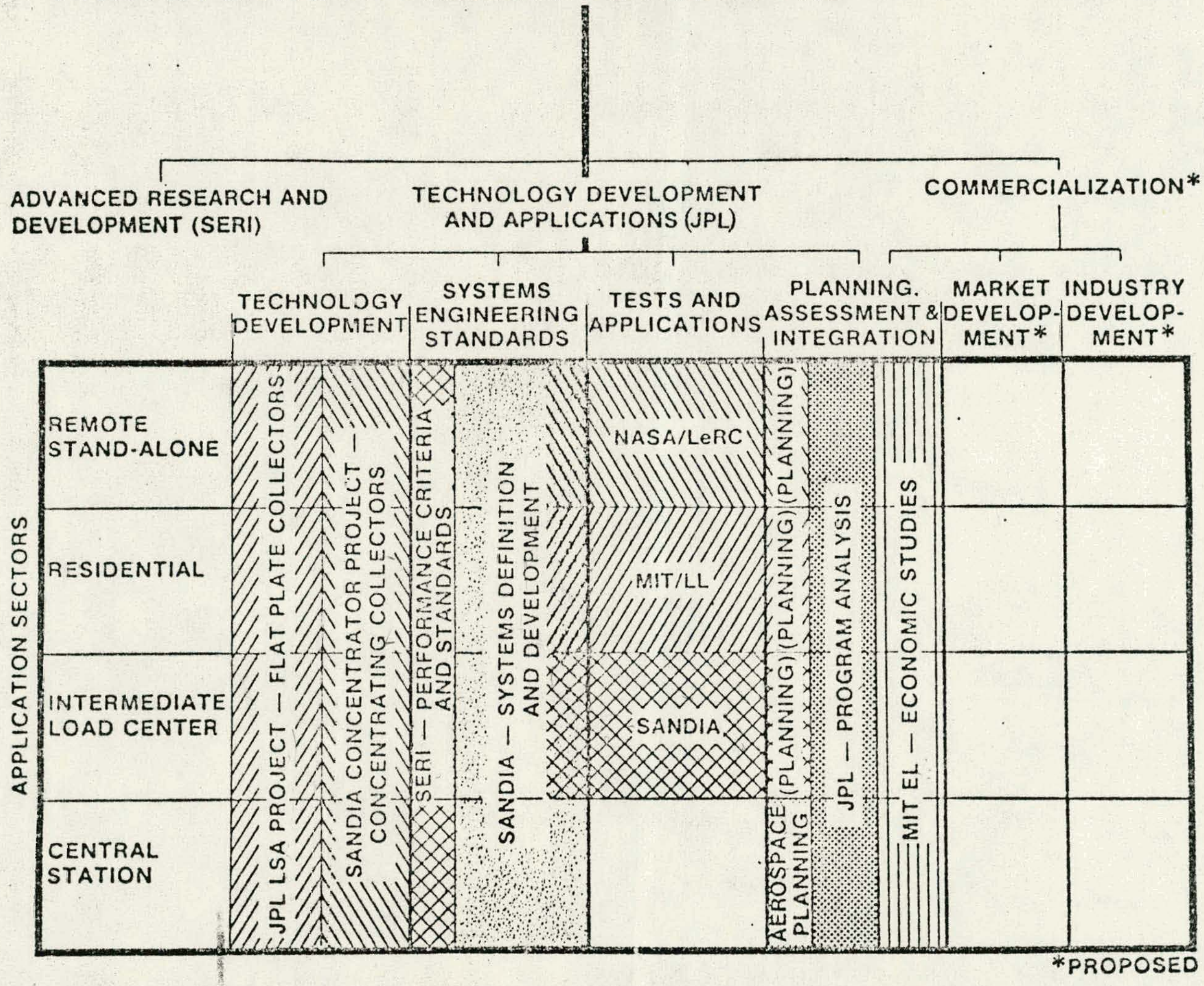
The strategy that has been adopted in the US for achievement of PV system cost reduction and commercialization goals include:

- AGGRESSIVE ADVANCED RESEARCH AND DEVELOPMENT TO BRING CONCEPTS TO TECHNICAL FEASIBILITY
- INTENSIVE TECHNOLOGY DEVELOPMENT TO IDENTIFY, DEVELOP, AND DEMONSTRATE COST-EFFECTIVE DESIGNS AND PRODUCTION PROCESSES FOR COMPONENTS, THEREBY ESTABLISHING THEIR TECHNICAL READINESS
- DEFINITION, DEVELOPMENT, DESIGN AND REAL-WORLD TESTING OF COMPLETE PV SYSTEMS TO DEMONSTRATE FEASIBILITY AND COMMERCIAL READINESS
- IMPLEMENTATION OF COMMERCIALIZATION STRATEGIES THAT WILL ENCOURAGE MARKET PENETRATION AND STIMULATE EMPLACEMENT OF APPROPRIATE PRODUCTION CAPACITY

The national Photovoltaics Program is being implemented by DOE through institutional arrangements illustrated in Figure 2. Primary responsibility for advanced research and development is vested in the Solar Energy Research Institute (SERI). The Jet Propulsion Laboratory (JPL) serves as the lead center for technology development and applications (TD&A) and is complemented by several laboratories and institutes as shown in the matrix of applications sectors vs TD&A activities shown in Figure 2. The matrix also illustrates that JPL has the responsibility for flat panel PV collectors for all application sectors whereas Sandia Labs is responsible for technology development of concentrator PV collectors for all application sectors. Sandia Labs, furthermore, is also contracted to conduct systems engineering for all applications sectors and tests and applications for the intermediate sectors. The commercialization program has been proposed and will be implemented in the future.

Figure 2

PHOTOVOLTAICS PROGRAM STRUCTURE



The objective of this talk is the presentation of information on the applications experiments that are being managed by Sandia Labs under the aegis of the DOE National Photovoltaics Program. As such, the structure of the program[2] at Sandia Labs is further amplified in Figure 3. Sandia's responsibilities in the three major TD&A areas shown in the matrix of Figure 2 correspond to the four major projects shown in Figure 3 (the test and applications work is broken down into the applications experiments and the system and component testing). These four project areas are broken down into the eight tasks shown at the bottom of the project chart. In addition there is a project integration task intended to ensure coordination of project activities and goals consistent with the National Program.

PV systems have the potential of replacing a significant amount of fossil fuel energy consumed for electrical energy production used in the intermediate sector in the US. This is illustrated in Figure 4 which shows that 64% of the electricity produced in the US is consumed in the industrial and commercial portions of the intermediate sector. Many PV intermediate applications also have loads that match the solar profile (daily and seasonal).

PRDA EXPERIMENTS

In 1978 the DOE - with technical support from Sandia Labs - issued two Program Research and Development Announcements (PRDA-35 for flat panels and PRDA-38 for concentrators) inviting proposals from private industry to conduct design studies leading to the fabrication, installation, operation and evaluation of on-site PV applications experiments in the range 20-500 kilowatts peak output for intermediate applications. This program was designed to proceed in the following three phases:

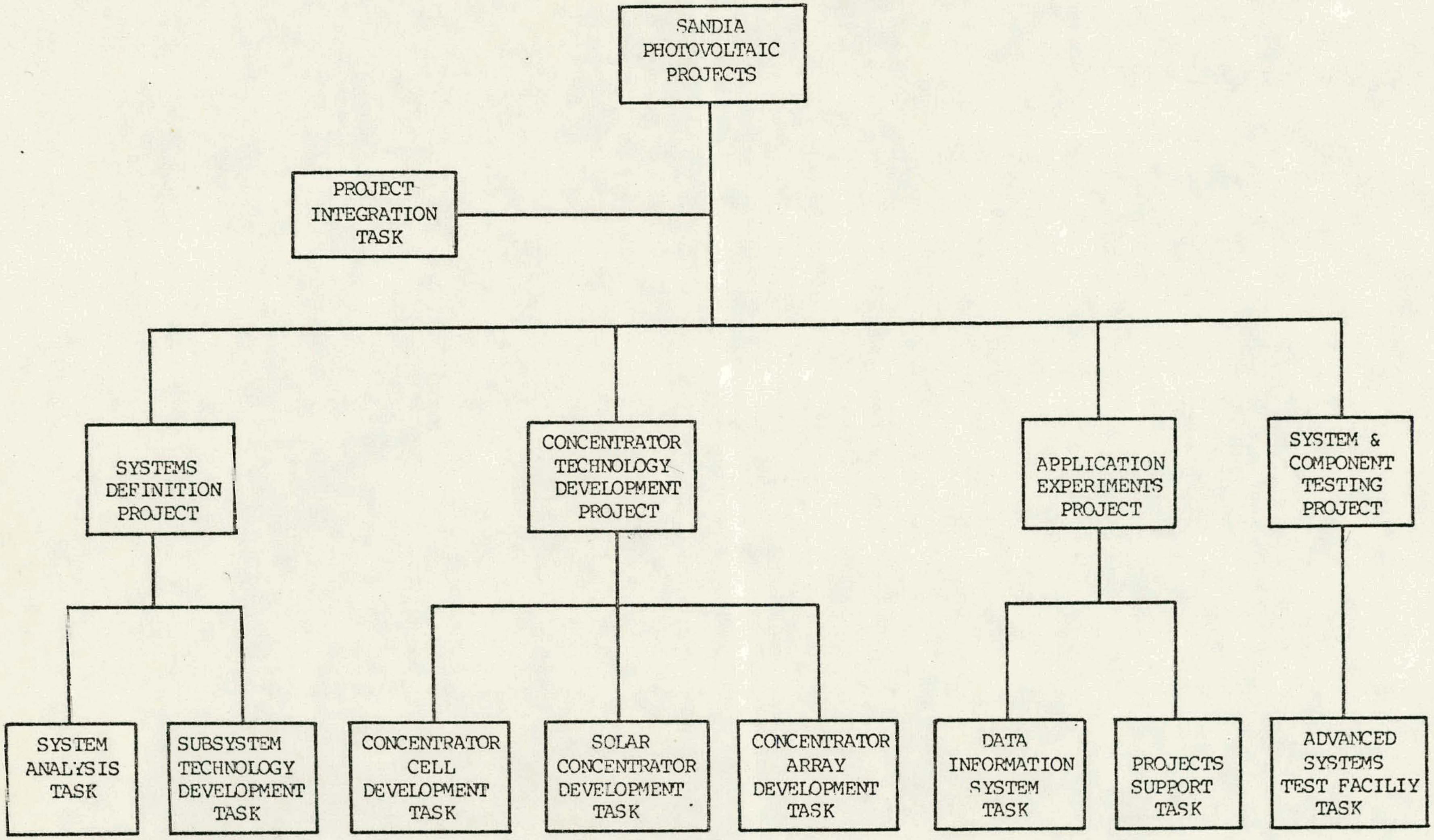
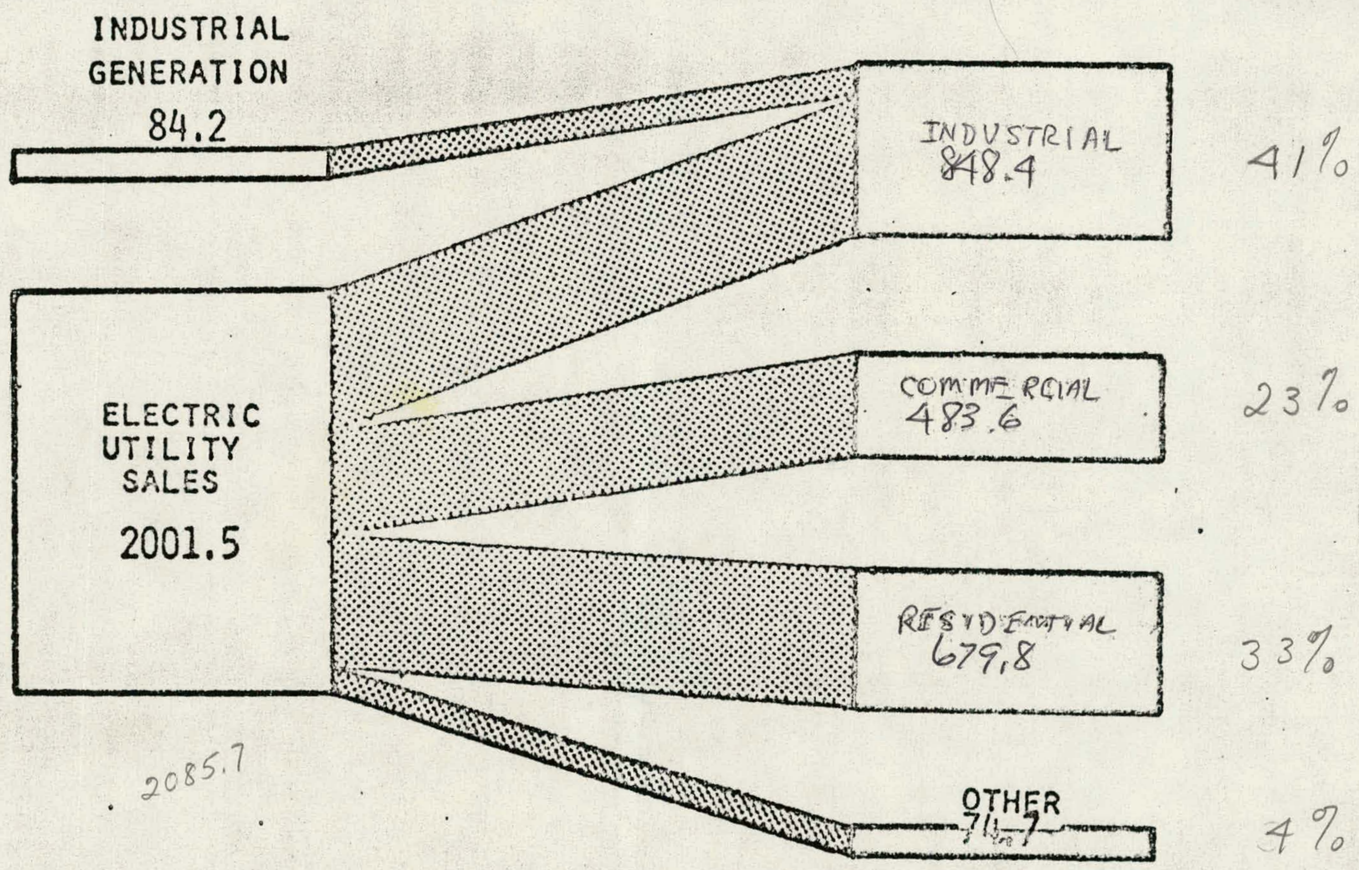


Figure ~~I-1~~ 3. FY80 Sandia Photovoltaic Project Structure

Figure 4

1978 ELECTRICAL POWER CONSUMPTION FORECAST*

BILLIONS OF KWH



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*ELECTRICAL WORLD, SEPT. 15,1978

PHASE 1 - SYSTEM DESIGN

Systems analysis, component development, preliminary and detailed design

PHASE 2 - FABRICATION AND INSTALLATION

Component procurement, fabrication, installation, operational check

PHASE 3 - EVALUATION

Operation, maintenance, tests and experiments, disposition

Following a competitive evaluation, twenty-nine designer/user teams were selected[3] to participate in the Phase I activities - twelve in the flat panel designs and seventeen in the concentrator designs. The design activity began in June 1978 and terminated in February 1979. Of the twenty-nine designer/user teams, four of the flat panel designs and five of the concentrator designs were selected for Phase II - FABRICATION AND INSTALLATION. The flat panel and concentrator applications projects are listed in Tables 3 and 4 respectively. It should be noted that six of the prime contractors (designers) in Tables 3 and 4 are companies operating for profit, two are publicly owned utilities, and one is a university. This reflects the policy in the PV Program of maximum private industry participation to allow private enterprise the opportunity to acquire experience in PV technology and thus facilitate commercialization. Of the nine site owners that will utilize the PV systems, however, only two are private enterprise, two are publicly owned utilities, and five are government (municipal, county, state or federal) facilities.

TABLE 3 - PRDA FLAT PANEL EXPERIMENTS

CONTRACTOR /OWNER	LOCATION	APPLICATION	SYSTEM SIZE (kWp)
LEA CO. ELECTRIC COOP. /LEA County Electric Coop.	LOVINGTON, NM	SHOPPING CENTER - Electrical only -	150
NEW MEXICO STATE UNIV. /El Paso Electric Company	EL PASO, TX	~~UPS~~ Uninterrupted Power Supply FOR CONTROL COMPUTER - Electrical only	20
SCIENCE APPLICATIONS, INC. / Oklahoma City, OK	OKLAHOMA CITY, OK	Oklahoma Center for SCIENCE & ART ~~CENTER~~ - Electrical Only - Sellback -	150
SOLAR POWER CORP. / Beverly MA School District	BEVERLY, MA	Beverly HIGH SCHOOL /CH Patten Vocational school - Sellback -	150

TABLE 4 PRDA

CONCENTRATOR EXPERIMENTS

CONTRACTOR / OWNER	SITE OWNER / LOCATION	APPLICATION	SYSTEM SIZE (kWp)
• ACUREX	KAUAI, HI	Hospital-Electrical & Domestic Hot Water	~~85~~ 60
• ARIZONA PUBLIC SERVICE	PHOENIX, AZ	Airport Terminal-Electrical Only	~~250~~ 225 ?
• BDM CORP.	CRADDOCK DEVEL Co/ ALBUQUERQUE, NM	Office Bldg.-Electrical & Heat	50
• E-SYSTEMS, Inc	AIRPORT AUTHORITY, DALLAS-FT. WORTH, TX	Airport Physical Plant-Electrical & Boiler Preheat	30
• GENERAL ELECTRIC	ORLANDO, FL	Amusement Park-Electrical & Chilled Water	~~110~~ ~~330~~ 110

The geographic distribution of the projects is shown in Figure 5. Also illustrated in Figure 5 are seven other intermediate PV projects that are in operation or are under construction but were not part of the PRDA Projects. It can be seen that most of these projects are in the sun belt.

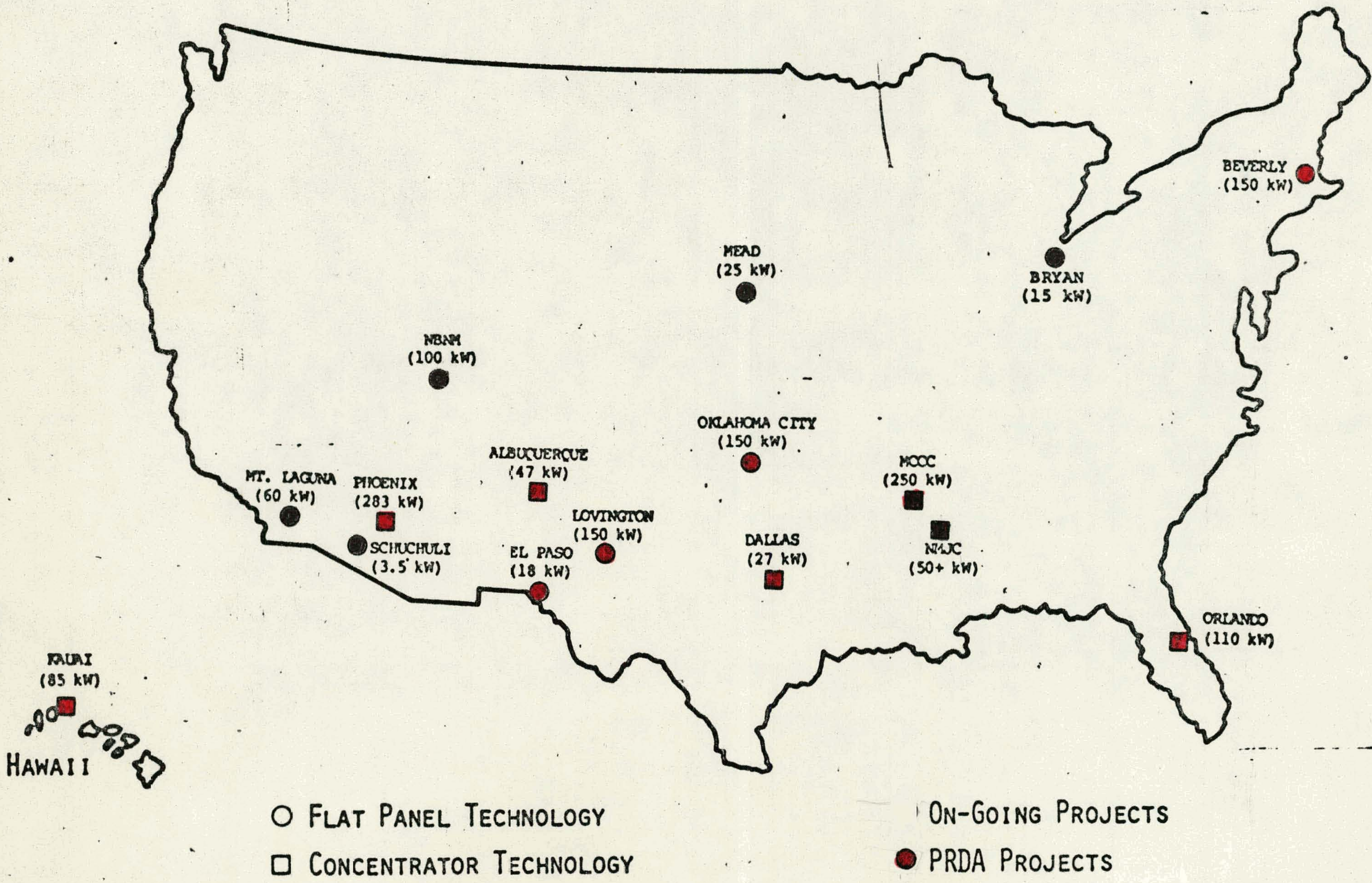
FLAT PLATE EXPERIMENTS

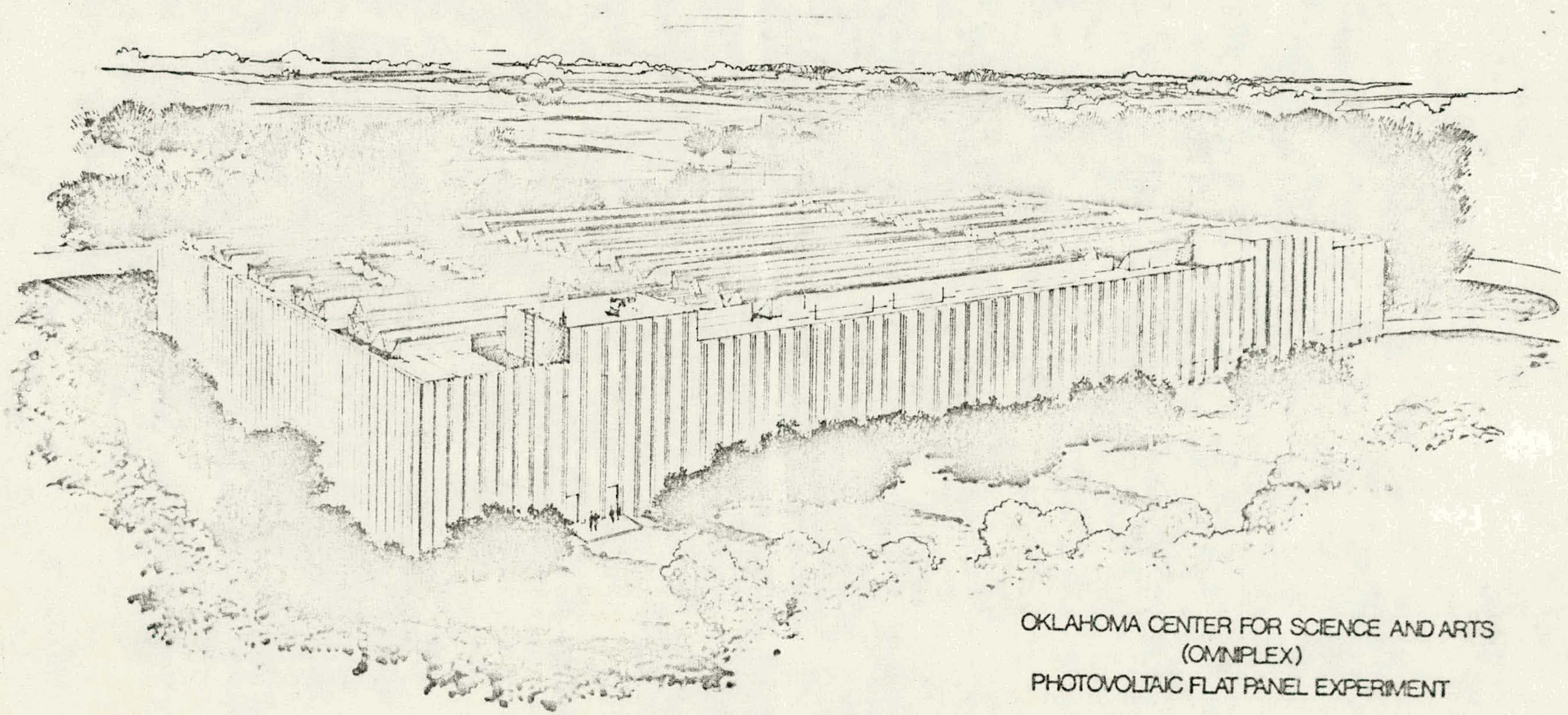
Figure 6 shows an artist's illustration of the flat panel PV system that will be constructed by Science Applications, Incorporated (SAI) for the Oklahoma Center for Science and Arts in Oklahoma City. The initial system design had a nominal rating of 350 kW utilizing reflector augmentation of photovoltaic modules which are arranged to maximize summer output and to match the summer output to the summer load. The initial design was scaled down to 150 kW. The data presented is for the initial design.

The baseline system consists of 3780 photovoltaic collector modules, utilizing polycrystalline silicon cells, and companion mirror reflectors arranged in modular fashion on the roof of the Center. The panel-reflector geometry is illustrated in Figure 7. Total annual system output is more than 450 MWh, of which over 420 MWh will be used on-site to displace about 43 percent of the projected (1981) load. Another 30 MWh is returned to the utility under a sellback agreement. The total amount of energy displacement per year is approximately 850 barrels of oil. The entire system is fully automatic, and is designed for safety and ease in maintenance, operation, and repair. It is equipped with the appropriate controls, a power monitoring system, a weather station, and other sensors for acquisition of experimental data. The design data is summarized in Table 5.

Figure 5

PHOTOVOLTAIC INTERMEDIATE-SIZE APPLICATION EXPERIMENTS





OKLAHOMA CENTER FOR SCIENCE AND ARTS
(OMNIPLEX)
PHOTOVOLTAIC FLAT PANEL EXPERIMENT

Figure 6

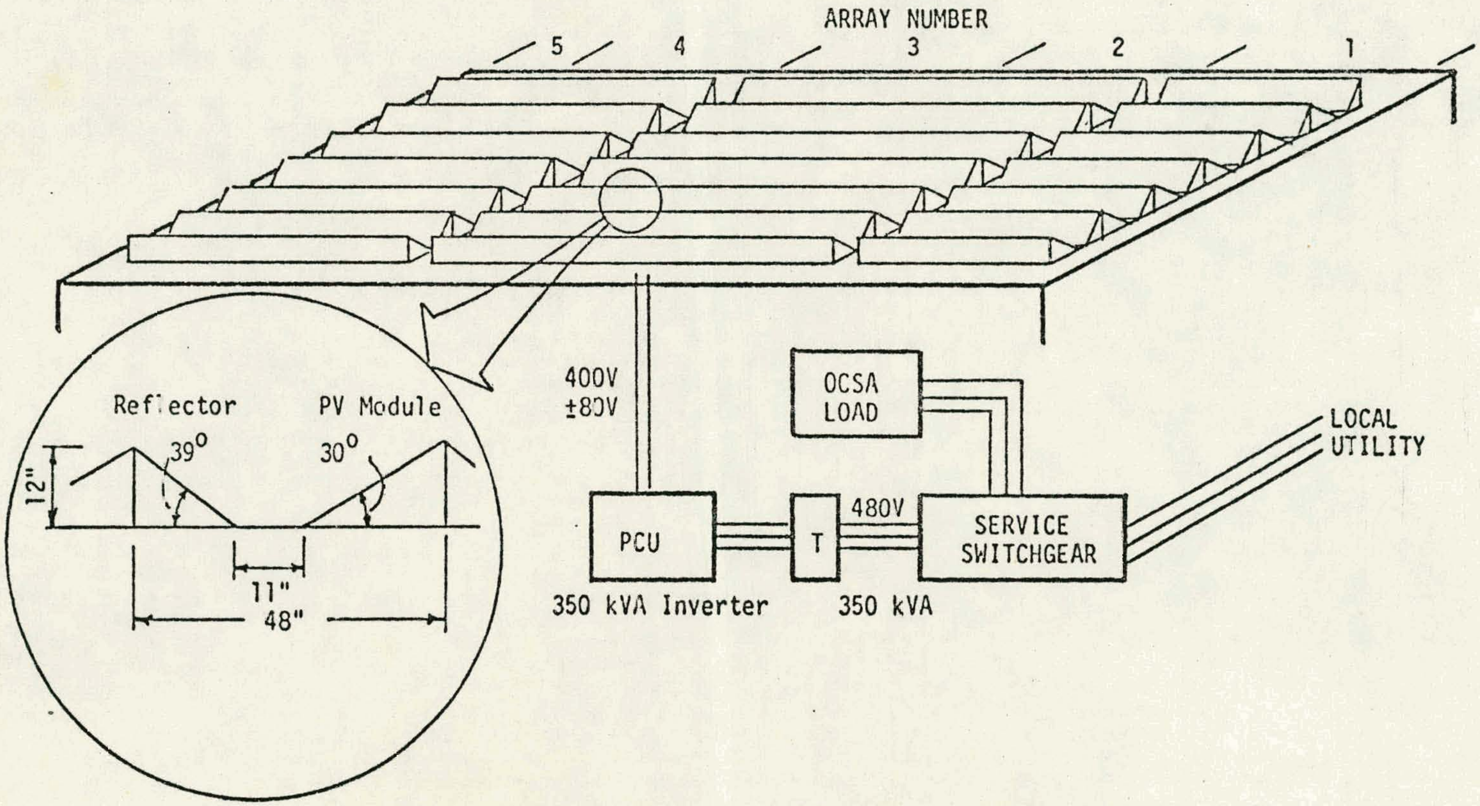


Fig. 7. System Design

With the exception of the reflector augmentation and the use of polycrystalline silicon cells,* the SAI system is representative of the other three PRDA flat panel experiments.

CONCENTRATOR EXPERIMENTS

The concentrator experiments, on the other hand, show more variation in design because of the variety of optical concentration alternatives and tracking modes. Furthermore, the concentrator systems may be more susceptible to cost effective utilization of the thermal energy in the intermediate sector.

Figure 8 shows an artist's conception of the E-Systems Concentrator System to be built at the Dallas-Fort Worth Airport. This system will use E-Systems linear fresnel lens concentrators (seen in the insert of Figure 8) with Applied Solar Energy Corporation (ASEC) single crystal silicon solar cells. The power source will provide 25 kW_e (AC) and 140 kW_t to the Central Utility Facility at the airport to power the continuous-duty emergency lighting system. The lighting system consists of high efficiency fluorescent and mercury vapor lamps. Since the PV system will supply only a very small fraction (1/3%) of the total load, no energy storage will be required. The electrical output will power a continuous lighting load within the utility plant and the thermal output will preheat low temperature boiler feedwater.

A block diagram of the power system is shown in Figure 9. With a direct current insolation of 1000 w/m^2, 27 kW_e will be produced at 260 volts at a cell temperature of 55°C. The coolant is a 30% solution of ethylene glycol/water.

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*All other PRDA experiments will use single crystal silicon cells.

TABLE 5. DESIGN FEATURES FOR THE OKLAHOMA CENTER FOR SCIENCE AND ART PV SYSTEM

SOLAR CELLS

Polycrystalline Silicon

9.4 cm x 9.4 cm

	25°C	45°C
Watts	0.99	0.89
Volts	0.44	0.40
Amps	2.23	2.24

PV MODULES

Tempered Glass
Si Rubber Encapsulation

0.6m x 1.22 m x 2.11 cm

72 cells (6 strings of 12)

	25°C	45°C
Watts	71.1	64.6
Volts	5.3	4.8
Amps	13.4	13.5

30 degrees due south from horizontal

SERIES STRING

84 Modules in Series

	25°C	45°C
kW	6.0	5.4
Volts	445	403
Amps	13.4	13.5

ARRAY

5 or 10 Series Strings

	25°C	45°C
kW*	60	54
Volts	445	403
Amps	134	135

*10 Strings with no augmentation

SYSTEM

5 Arrays

3780 Modules (2809 m^2)

Reflectors - (2322 m^2)

	25°C	45°C
KW*	269	244
Volts	445	403
Amps	605	606

Augmented Output - 333 kW_p

Open Circuit Voltage - 600

Convective Cooling

Wind - 172 km/nr

REFLECTOR

Laminated Glass

0.48 m x 1.22 m

39 degrees due north from horizontal

35% summer augmentation

UTILITY INTERFACE

500 kVa

480V 3ϕ 4 wire

ENERGY

450 mwh/yr

420 mwh/yr on site (43% of 1981 load)

30 mwh/yr sellback

850 barrels of oil/yr

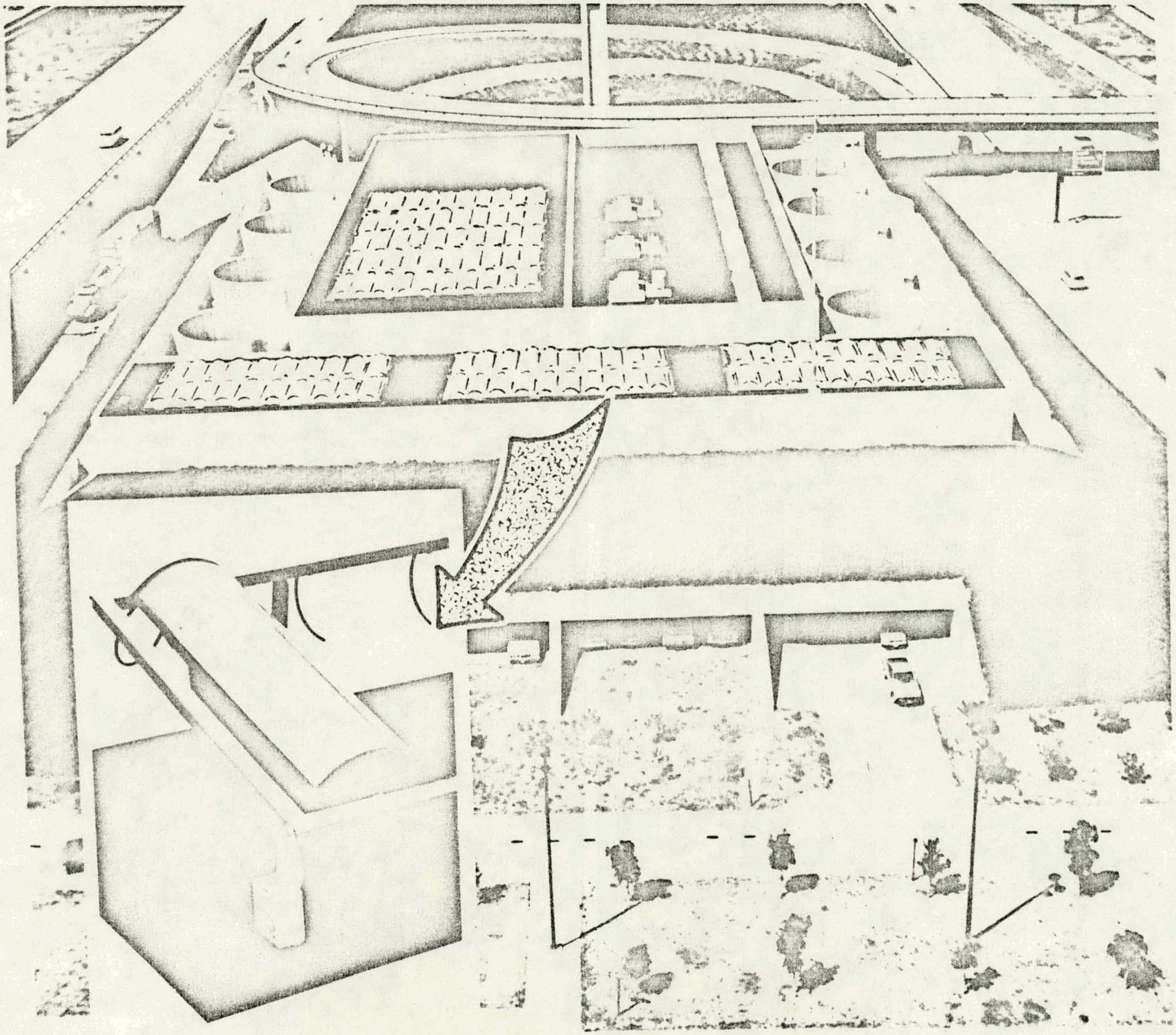


Figure 8

Dallas-Ft. Worth Airport

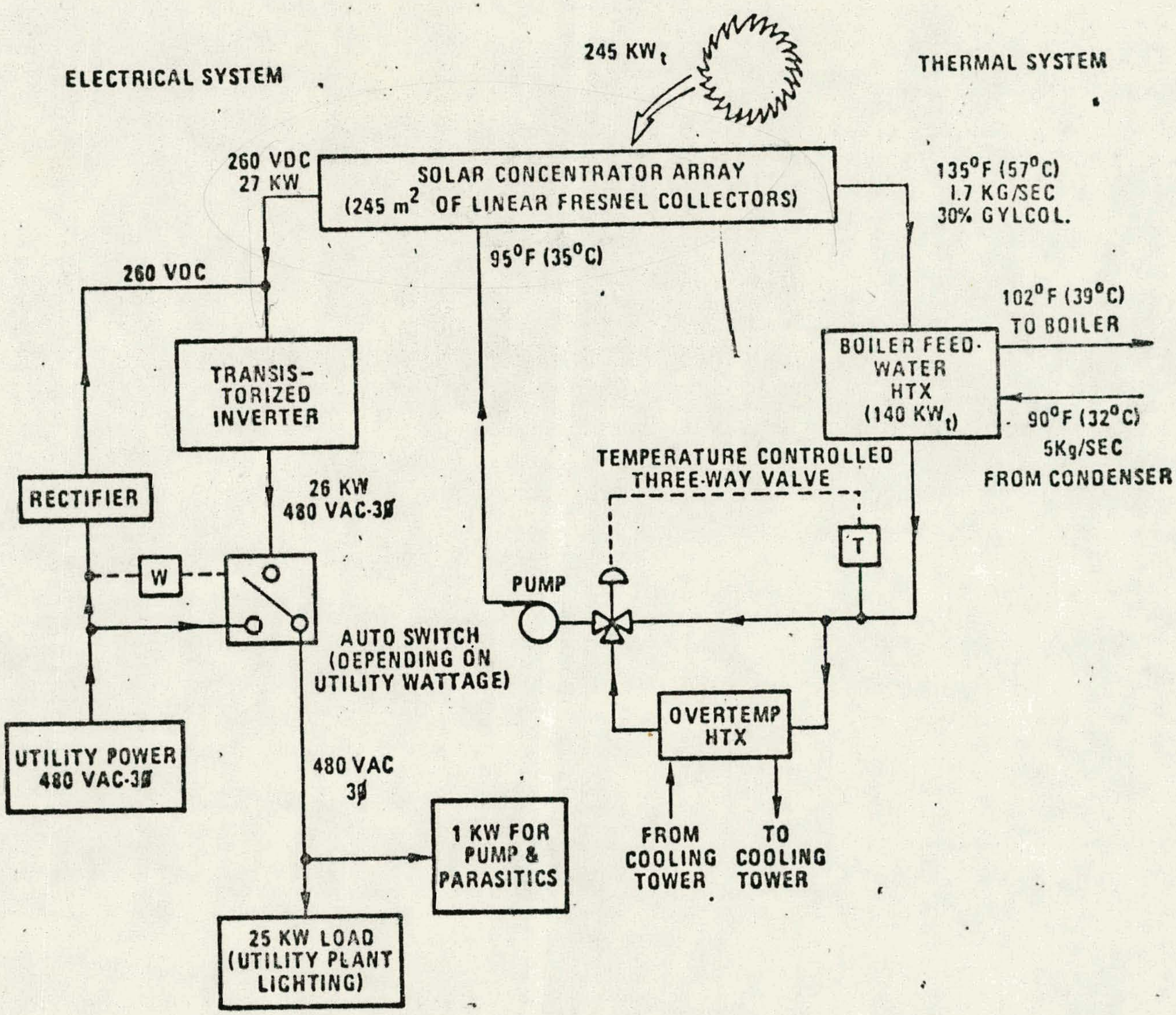


Figure 9 *BLOCK DIAGRAM OF THE FRESNEL/PHOTOVOLTAIC/PHOTOTHERMAL POWER SYSTEM FOR DFW AIRPORT*

The electrical interface utilizes a DC-to-AC inverter with an efficiency of 97%. Thus at peak conditions, 25 kW of 480 AC power will be available for the invariant load and 1 kW_e for the parasitic requirements - pump motor, tracking motor, and central power. Supplenental power from the grid is mixed with the PV power at the DC level because the Texas Power and Light Company prohibits mixing of on site generated AC electricity with utility AC power. The supplemental utility power losses, however, are small. Whenever the wattage drawn from the utility exceeds the 25 kW_e being met by the PV system (e.g., when clouds attenuate the sunlight) an automatic switch will disconnect the PV system and the load will be met directly with utility power.

The thermal interface is simply a single pass, counterflow, shell and tube heat exchanger and the glycol solution used to cool the PV system heats boiler feedwater from the condenser to the boiler of the steam Rankine cycle heat engine. The feedwater flow rate varies since the Rankine cycle heat engine is used to drive chillers for meeting variable air-conditioning needs of the terminals, hotels and other facilitics at the Airport. In the event of a feedwater stoppage, a three way valve will divert the glycol solution through an over-temperature heat exchanger cooled with water from the plant cooling towers. Some design features of the system are summarized in Table 6. Note that 1-1/2 axis tracking corresponds to azimuth tracking and periodic (3-7 days) adjustments of tilt angle in the north-south direction to adjust for declination angle. Figures 10 and 11 show a cutaway illustration of the collector and of the receiver, respectively.

TABLE 6. DESIGN FEATURES FOR THE DALLAS-FORT WORTH AIRPORT CONCENTRATOR PV SYSTEM

CELLS

4.52 cm x 3.66 cm wide

0.49 watts @ 1000 w/m^2 and 55°C

13.4% efficient @ 21 suns and 55°C

RECEIVER

53 silicon solar cells

39% ethylene glycol coolant

26 watts @ 1000 w/m^2 and 55°C

COLLECTOR

Fresnel lens - 91.4 cm Aperture x 244 cm

Concentration Ratio - 25

Optical efficiency - 85%

Tracking - 1-1/2

ARRAY

10 collectors (modules)

26 Volts

ΔT (coolant) - 40°F (22°C)

SYSTEM

11 arrays in parallel

260 volts

27 kW_e

Total Collector Aperture Area - 245 m^2

Efficiencies

	Electrical	Thermal
Peak	10.2%	56%
Annual	8.4%	49%

Energy Costs - 20 year levelized

7¢/KWh - $7/MMBTU

Figure 12 shows an artist's illustration of the PV Concentrator system to be built at Sea World in Orlando, Florida. This system will produce a peak power output of 330 kW* and a net annual electrical energy of 355 MWh. In addition, the system will produce 3.56×10^5 ton-hours of cooling with a lithium bromide absorption chiller for air conditioning a shark exhibit. The overall system efficiency is estimated to be 11.7%. One notes from Figure 12 that the arrays will be mounted on turntables that will track the suns azimuth. The turntable is illustrated in Figure 13 which also shows that the collectors will be parabolic troughs. Each turntable array will mount twenty four 2.1 x 9.2 meter parabolic collectors. The turntable is supported by 16 wheels that roll on tracks. The parabolic collector and receiver are shown in Figure 14.

Figure 15 shows an artist's illustration of the PV system to be built by BDM in Albuquerque. This figure illustrates a roof mounted parabolic trough system with one axis tracking for a professional building.

The above three concentrator systems illustrate the diversity in design and power (30-330kW_p) of the five concentrator systems to be built.

COSTS

Figures 16 and 17 show the proposed costs vs system size for the flat panel and concentrator projects that were proposed for the PRDAs. The lines that have been drawn through the points are a visual fit to illustrate the trend toward decreasing cost/W_p with increasing system size for both flat panels and concentrators. The decreasing costs are expected because of economies

*The original system design has been scaled down to 110 kW.

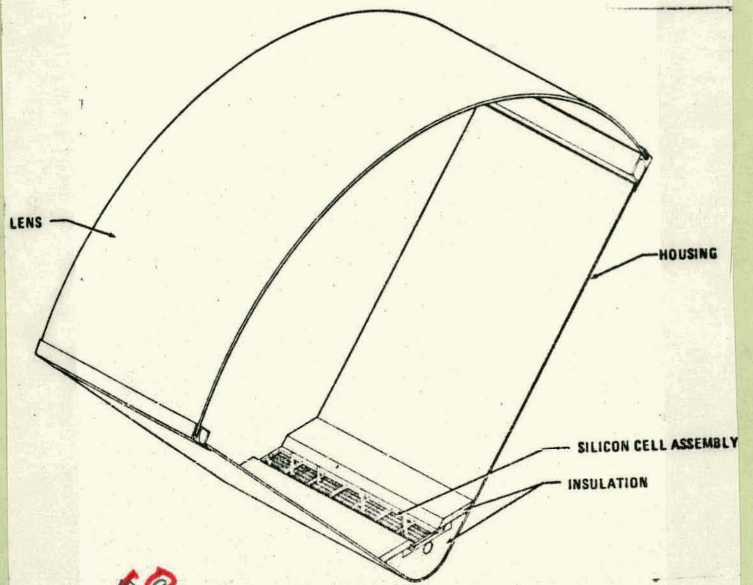


Fig. 10a - E-Systems Fresnel/
Photovoltaic Concentrator

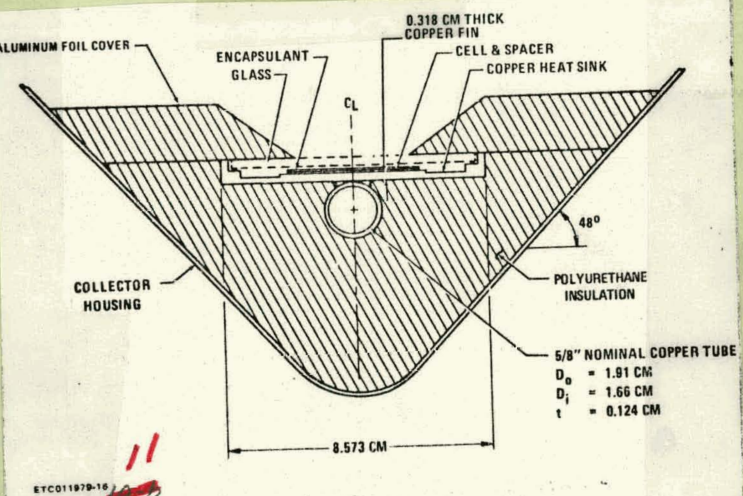
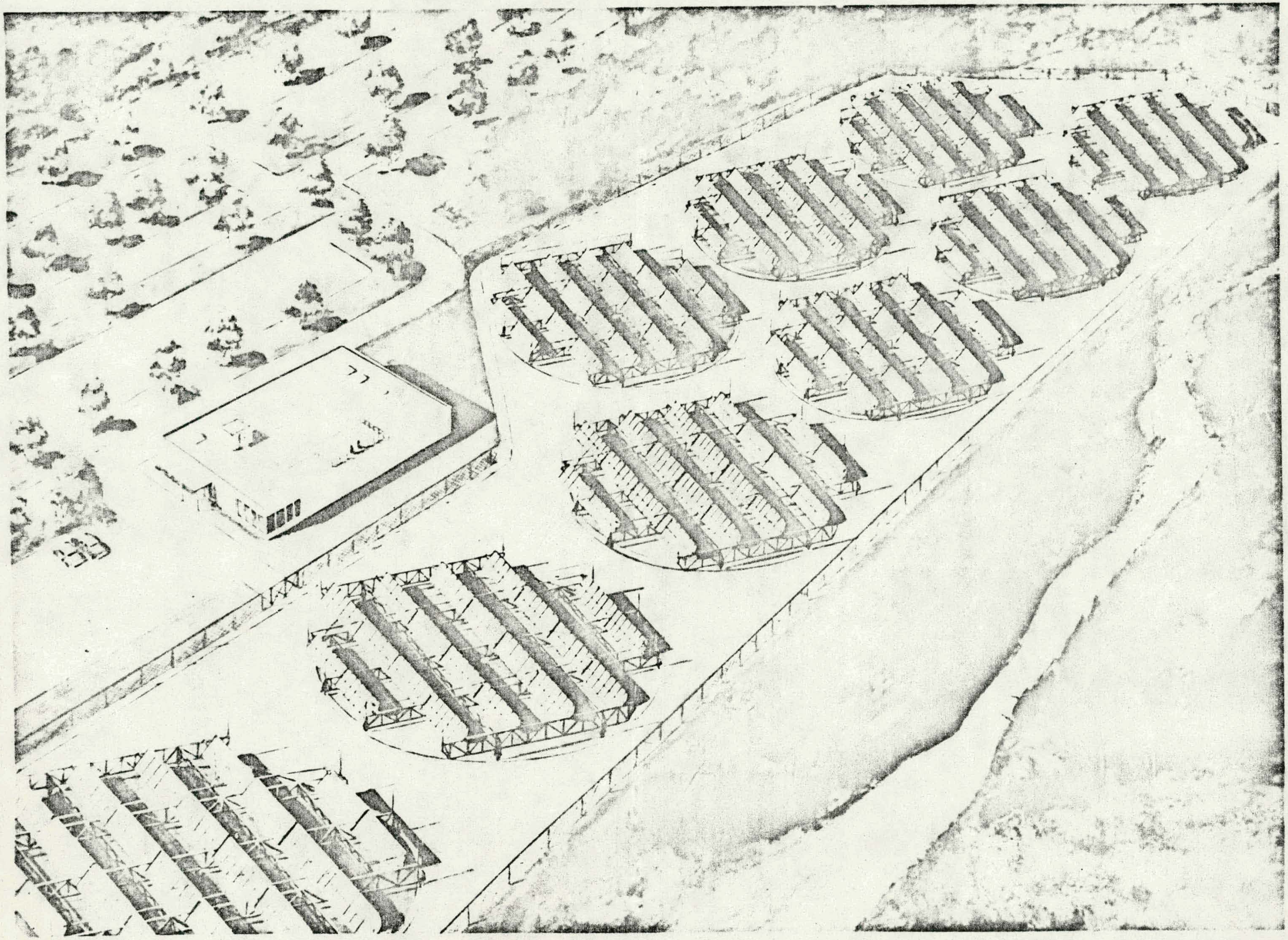


Fig. 11 - Photovoltaic Receiver

Fig 10



Sea World, Orlando, Florida

Figure 12

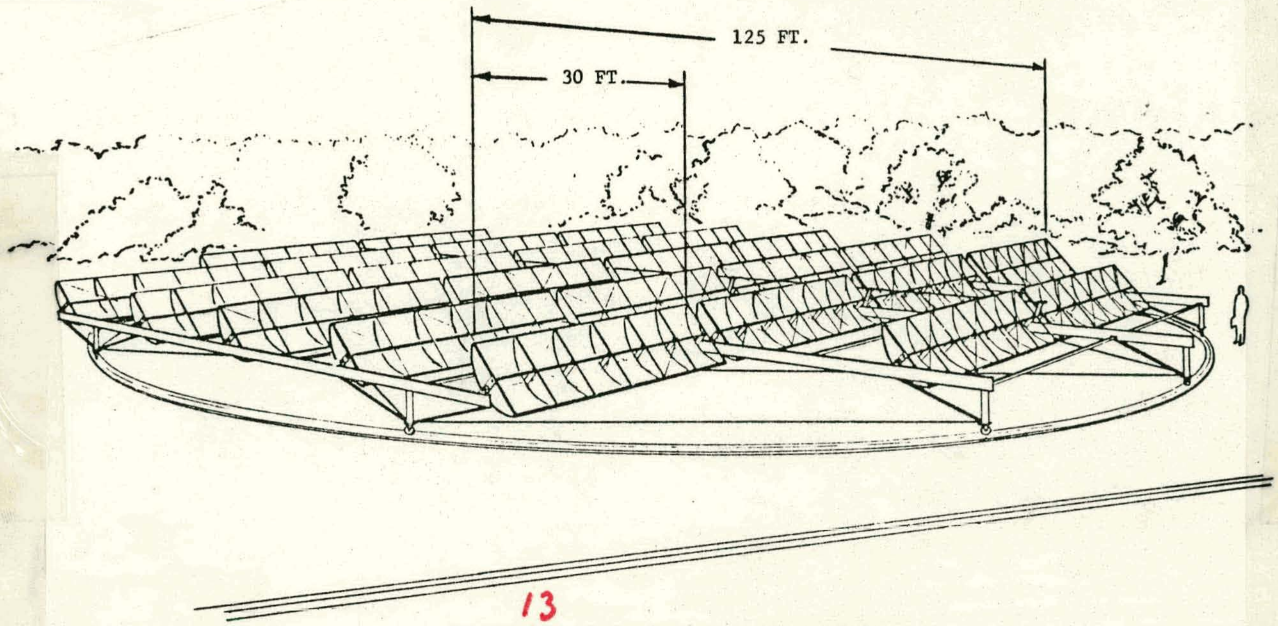


Fig. ~~4~~ 13. Solar Array Turntable

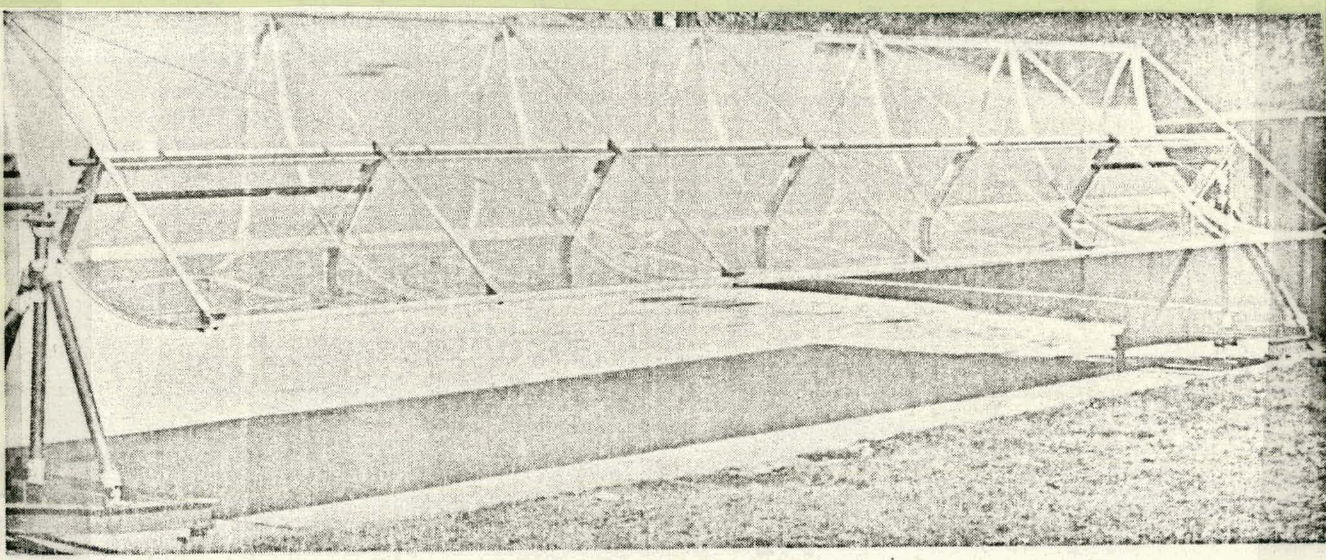


Fig. ~~5~~ 14. Collector Structure and Optics

BDM

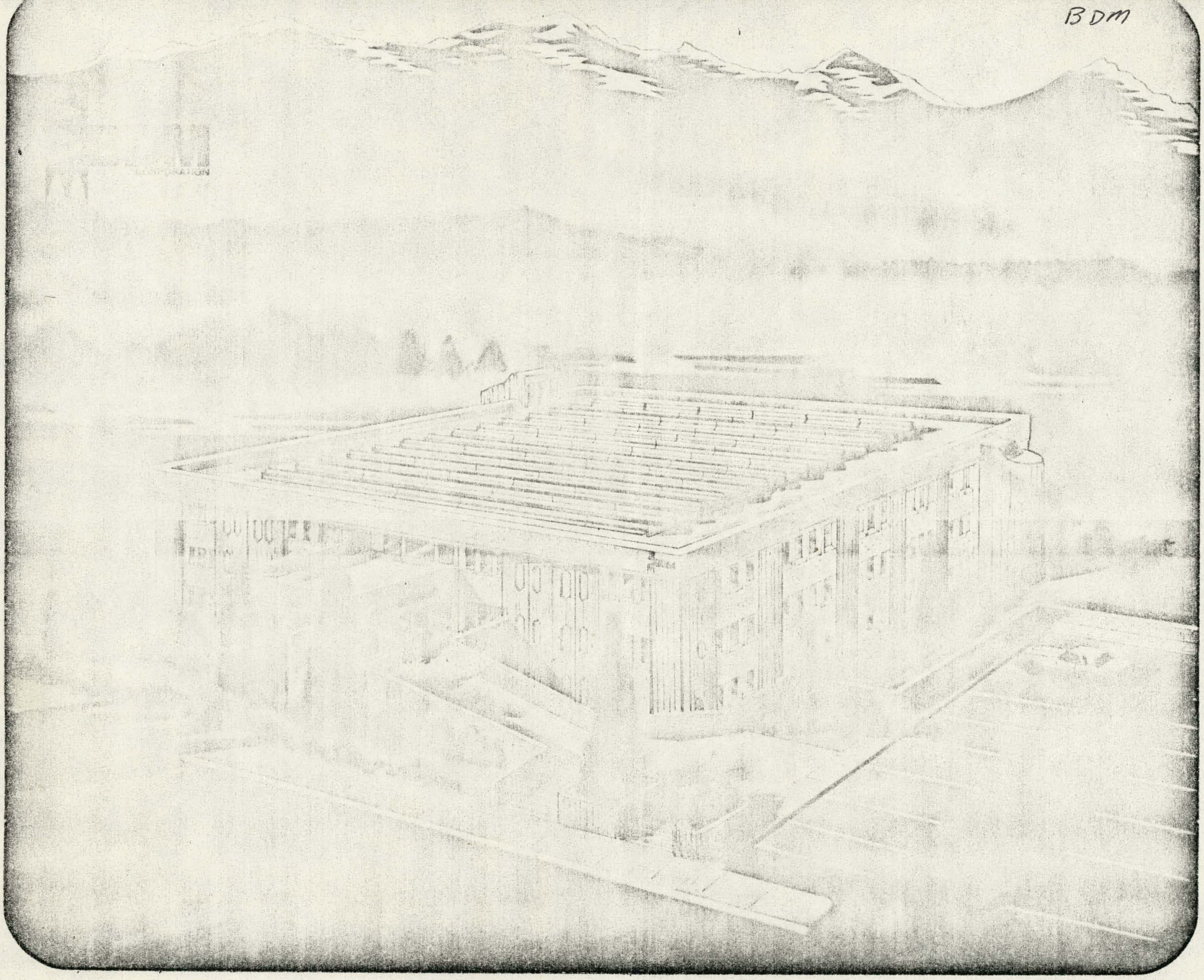


Fig 15

of scale; namely, certain costs are directly proportional to the power of the array (eg. modules, structures and foundations, module instrumentation, etc.) whereas other costs do not increase linearly with power (such as switchgear, regulators, inverters, etc). The proposed costs suggest that flat-panel systems currently cost about $\$7/W_p$ less than concentrator systems. This is not unexpected since the concentrator technology is less mature. Figures 16 and 17 also show that proposed costs for flat-plate experiments range from $\$12\text{-}50/W_p$ and concentrator costs range from $\$17\text{-}55/W_p$. The average price of the nine experiments selected for construction is $\$26/W_p$ and the costs range from $18 to $\$38/W_p$ with array module prices ranging from $\$8\text{-}11/W_p$.

CONCLUSION

All of the PRDA contracts for Phase II - FABRICATION AND INSTALLATION - have been awarded and the projects are underway. It is currently expected that construction of all nine projects will be completed between December 1980 and June 1981. These applications experiments will greatly enchance our experience in PV systems for the intermediate sector and will demonstrate system feasibility.

In order to achieve Commercial Readiness in 1982 at $\$2.80/W_p$ and at $\$0.70/W_p$ in 1986 for the residential and intermediate sectors, the key requirements for concentrator technology have been identified and are listed in Tables 7 and 8. These technology requirements are very challenging but the National Photovoltaics Program will continue to receive strong support as an integral part of the US energy policy.

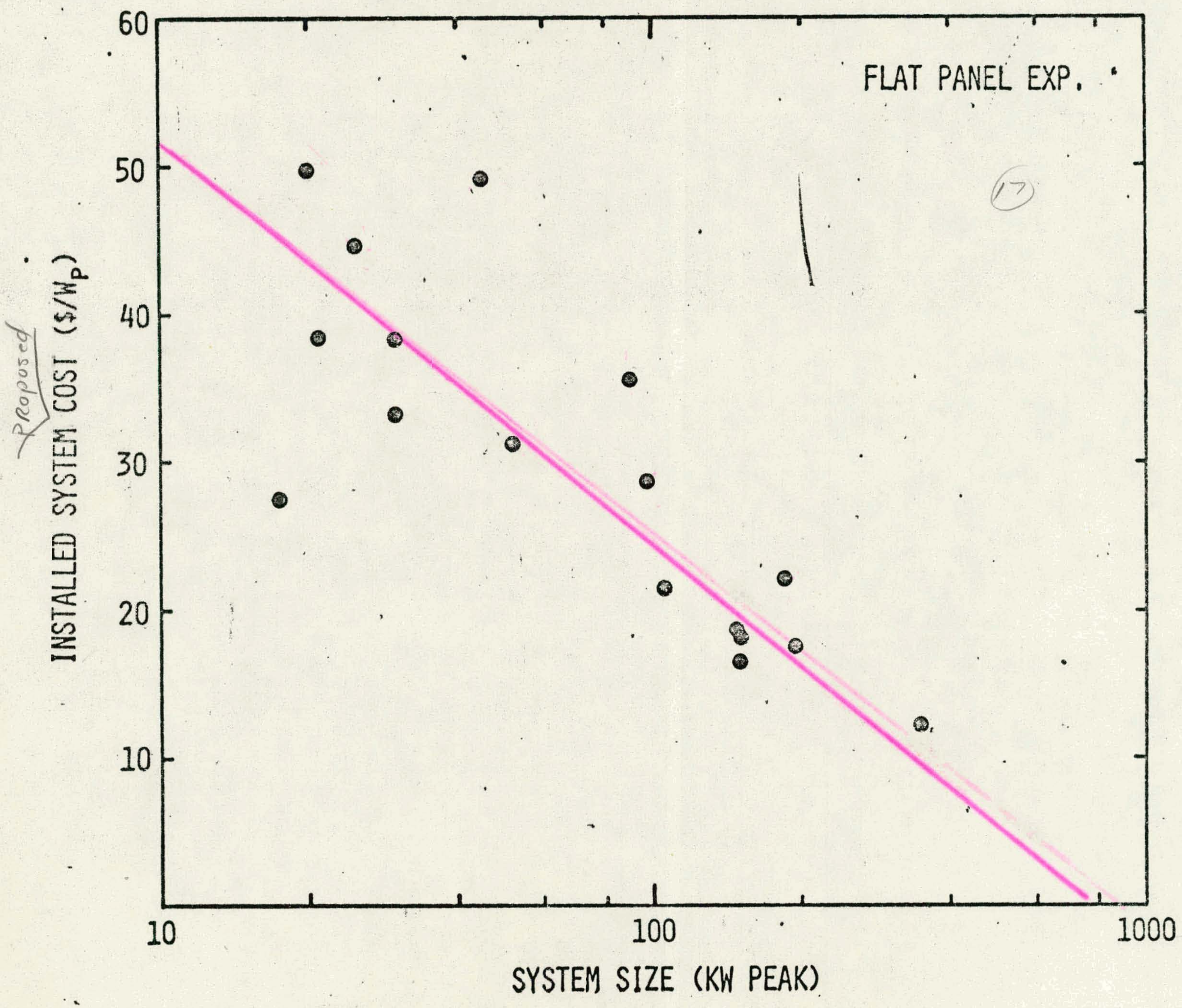

60
50
40
30
20
10
10
100
1000
FLAT PANEL EXP.
Proposed
INSTALLED SYSTEM COST ($/W$_P$)
SYSTEM SIZE (KW PEAK)
17

Fig 16

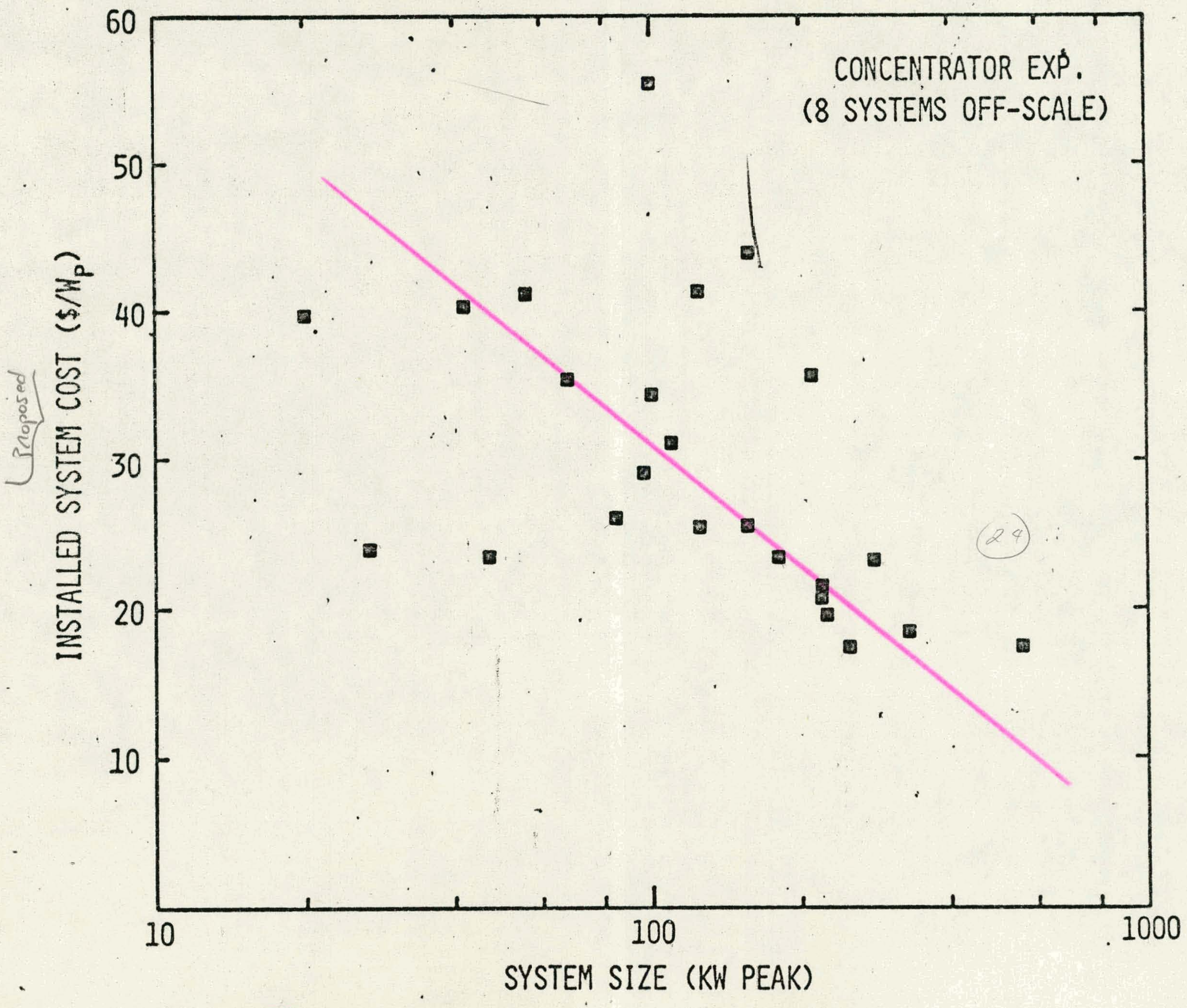

CONCENTRATOR EXP.
(8 SYSTEMS OFF-SCALE)
INSTALLED SYSTEM COST ($/Wp)
Proposed
60
50
40
30
20
10
10
100
1000
SYSTEM SIZE (KW PEAK)
24

Fig ~~13~~ 17

TABLE 7. KEY REQUIREMENTS FOR $2.80/$W_p$ CONCENTRATOR TECHNOLOGY

- ARRAY EFFICIENCIES IN THE 10-12% RANGE
- SILICON SOLAR CELLS AT $.35/$CM^2$ OR LESS
- TOTAL INSTALLED ARRAY COSTS IN THE RANGE OF $400/$M^2$
- 5-10 YEAR ARRAY RELIABILITY
- FACTORY PRODUCTION RATES OF 1-10 MW_p (10^4 - 10^5 M^2) PER YEAR

TABLE 8. KEY REQUIREMENTS FOR $0.70/$W_p$ CONCENTRATOR TECHNOLOGY

- Array Efficiencies in the 15-18% Range
- Silicon Solar Cells at $0.10/$cm^2$ or Less
- Total Installed Array Costs in the Range of:
  - $200/$m^2$ Without Thermal Utilization
  - $320/$m^2$ With Thermal Utilization
- Average Annual Maintenance in the Range of 1% of Initial Cost
- Factory Production Rates of 100-1000 MW_p (10^6 - 10^7 m^2) per Year

As has been pointed out, a large part of the National Program supports the development of the photovoltaics industry in the US. The current industry serves commercial customers mostly for remote applications and the DOE applications experiments of the type described in this paper. To further assist in the transition to an automated, low cost production industry some new efforts are now underway or are planned. Some of these new efforts are summarized in Table 9. The development of an International Photovoltaics Plan in November of 1979 may be of particular interest to Latin American Countries.

TABLE 9. NEW ACTIVITIES IN THE U.S. PHOTOVOLTAICS PROGRAM

Development of an International Photovoltaics Plan. The photovoltaic Act (Public Law 95-590) specifies that DOE shall develop a plan "for demonstrating applications of solar photovoltaic energy systems and facilitating their widespread use in other nations ...". This plan was completed in November 1979 and supported a program that provides near and mid-term demands for industry products, aid in market development, and assistance in meeting the electric energy requirements of developing countries.

Multi-Year Purchase Strategy for Photovoltaic Systems. During FY '79 and FY '80, a major multi-year photovoltaic systems purchase strategy was designed for implementation beginning in FY '81. System purchases will be directed toward the most promising grid-connected applications and are intended to be large enough to encourage a competitive industry.

Increased Emphasis on Commercialization Strategies. Major issues to be investigated include the electric utility interface, valuation of the photovoltaic energy produced, control requirements and the rate structure to be offered to the system owner. FInancing, property taxes, methods of valuing photovoltaic systems at resale, standards, incentives to initial production, and purchases and strategies for targeting market development will be considered.

Section (5) Procedure for Cost Shared Technology Proposals. Section (5) of the Photovoltaic Research, Development and Demonstration Act sets forth procedures whereby any public or private entity may apply for federal assistance in purchasing or installing photovoltaic systems. The federal government is authorized to provide up to 75% of the purchasing and installation cost of the system. Observation and monitoring of the systems are required for a period of up to 3 years. The Jet Propulsion Laboratory Photovolatiac Lead Center will prepare administrative rules implementing this program. It is anticipated that the broad scope of the rules will require that an Environmental Impact Statement be prepared on the program as a whole.

REFERENCES

1. National Photovoltaic Program - Multi-Year Program Plan, U. S. Department of Energy, DOE/ET-0105D, June 6, 1979.

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3. Summay of Photovoltiac Application Experiment Designs, Edited by E. L. Burgess, Sandia Laboratories, and E. A. Walker, Special Programs Division, DOE, ALO-71, UC-63a, October 1979.