PROJECT ADMINISTRATION DATA SHEET

[X] ORIGINAL

[ ] REVISION NO. ____

Project No. A-2950 DATE: 5/22/81

Project Director: Mr. T. B. Elfe ~~School~~/Lab EMSL/SEB

Sponsor: Jet Propulsion Laboratory; California Institute of Technology; Pasadena, California 91103

Type Agreement: Contract No. 956047 under NASA Prime Contract No. NAS7-100

Award Period: From 5/12/81 To ~~10/11/81~~ 7/31/83 (Performance) ----- (Reports)

Sponsor Amount: $28,994 ~~$115180~~ 4-2-84 Contracted through:

Cost Sharing: None GTRI/~~XXX~~

Title: Dish - Stirling Solar Receiver Heat Transfer Analysis

ADMINISTRATIVE DATA OCA CONTACT Duane Hutchison x 4820

1) Sponsor Technical Contact: Edwin Y. W. Chow; Jet Propulsion Laboratory; California Institute of Technology; 4800 Oak Grove Drive; Pasadena, California 91103 (213) 354-4321

2) Sponsor Admin./Contractual Contact: Randall L. Taylor, Senior Contract Negotiator; Jet Propulsion Laboratory; California Institute of Technology; 4800 Oak Grove Drive; Pasadena, California 91603 (213) 577-9511

See Revision #3

Reports: See Deliverable Schedule Security Classification: None

Defense Priority Rating: DO-A2 under DMS Reg 1

RESTRICTIONS

See Attached Government Supplemental Information Sheet for Additional Requirements.

Travel: Foreign travel must have prior approval - Contact OCA in each case. Domestic travel requires sponsor approval where total will exceed greater of $500 or 125% of approved proposal budget category.

Equipment: Title vests with Government; however, none authorized/proposal.

COMMENTS:

COPIES TO:

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Research Property Management
Accounting Office
Procurement/EES Supply Services
Research Security Services
~~Reports Coordinator~~ (OCA)
Legal Services (OCA)
Library, Technical Reports
EES Research Public Relations (2
Project File (OCA)
Other: ____

GEORGIA INSTITUTE OF TECHNOLOGY OFFICE OF CONTRACT ADMINISTRATION

SPONSORED PROJECT TERMINATION/CLOSEOUT SHEET

Date June 5, 1985

Project No. A-2950 ~~School~~/Lab EMSL

Includes Subproject No.(s) N/A

Project Director(s) T.B. Elfe GTRC / ~~GTX~~

Sponsor ~~Jet Propulsion Laboratory; California Institute of Technology~~

Title Dish-Stirling Solar Heat Receiver Heat Transfer Analysis

Effective Completion Date: 4/2/84 (Performance) 4/2/84 (Reports)

Grant/Contract Closeout Actions Remaining:

- [ ] None
- [X] Final Invoice or Final Fiscal Report
- [X] Closing Documents
- [X] Final Report of Inventions -already submitted
- [X] Govt. Property Inventory & Related Certificate
- [ ] Classified Material Certificate
- [ ] Other _____

Continues Project No. _____ Continued by Project No. _____

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Other Heyser MH

Jones

FORM OCA 69.285

A-2950

FINANCIAL REPORT

COVERING PERIOD

5/12/81-5/31/81[1]

CONTRACT #956044

PROJECT #A-2950

REPORT DATE: 6/12/81

Category	Reporting Period	Cumulative
Direct Labor[1]	$0.00	$0.00
Overhead[1]	$0.00	$0.00
Materials	$0.00	$0.00
Other		
Computer[1]	$0.00	$0.00

[1]Due to the fact that the project was initiated after time charges and computer charges for May had been accumulated, no charges for the month of May were made.

FINANCIAL REPORT

COVERING PERIOD

6/1/81 - 6/30/81

CONTRACT #956044

PROJECT #A-2950

REPORT DATE: 7/14/81

Category	Reporting Period	Cumulative
Direct Labor	$1085.65	$1085.65
Overhead	$ 792.52	$ 792.52
Retirement	$ 120.61	$ 120.61
Materials	$ 0.78	$ 0.78
Other		
Computer	$ 83.41	$ 83.41
Total	$2082.97	$2082.97

FINANCIAL REPORT

COVERING PERIOD

7/1/81 - 7/31/81

CONTRACT #956044

PROJECT #A-2950

REPORT DATE: 8/17/81

Category	Reporting Period	Cumulative
Direct Labor	$2525.34	$3610.99
Overhead	$1894.01	$2686.53
Retirement	$ 276.37	$ 396.98
Materials	$ 1.56	$ 2.34
Other		
Travel	$ 716.69	$ 716.69
Computer	$ 312.25	$ 395.66
Total	$5726.22	$7809.19

A-2950

FINANCIAL REPORT

COVERING PERIOD

8/1/81 - 8/31/81

CONTRACT #956044

PROJECT # A-2950

REPORT DATE: 9/11/81

Category	Reporting Period	Cumulative
Direct Labor	$747.45	$4358.44
Overhead	$560.59	$3247.12
Retirement	$ 56.91	$ 453.89
Materials	$ 2.33	$ 4.67
Other		
Travel	$ 0	$ 716.69
Computer	$ 44.10	$ 439.76
Total	$1411.38	$9220.57

FINANCIAL REPORT

COVERING PERIOD

9/1/81 - 9/30/81

CONTRACT #956044

PROJECT # A-2950

REPORT DATE: 10/14/81

Category	Reporting Period	Cumulative[1]
Direct Labor	$ 58.80	$4415.10
Overhead	44.10	3289.61
Retirement	0	456.91
Materials	1.14	6.54
Other		
Travel	$ 0	$ 716.69
Computer	45.37	485.13
Total	$ 149.41	$9369.98

[1]Appropriation Statement for August was not available when September report was prepared. Therefore, labor, overhead, retirement, and materials charges were estimated and slightly incorrect. This report is accurate, however.

A-2950

FINANCIAL REPORT

COVERING PERIOD

10/1/81 - 10/31/81

CONTRACT #956044

PROJECT # A-2950

REPORT DATE: 11/12/81

Category	Reporting Period	Cumulative
Direct Labor	0	$4415.10
Overhead	0	3289.61
Retirement	0	456.91
Materials (Photocopy)	$1.32	7.86
Other		
Travel	0	716.69
Computer (Storage)	9.86	494.99
Total	$11.18	$9381.16

A-2950

FINANCIAL REPORT

COVERING PERIOD

11/1/81 - 11/30/81

CONTRACT #956044

PROJECT # A-2950

REPORT DATE: 12/14/81

Category	Reporting Period	Cumulative
Direct Labor	0	$4415.10
Overhead	0	3289.61
Retirement	0	456.91
Materials (Photocopy)	$0.42	8.28
Other		
Travel	0	716.69
Computer (Storage)	9.86	504.85
Total	$10.28	$9391.44

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FINANCIAL REPORT

COVERING PERIOD

12/1/81 - 12/31/81

CONTRACT #956044

PROJECT # A-2950

REPORT DATE: 1/25/82

Category	Reporting Period	Cumulative
Direct Labor	20.43	$4435.53
Overhead	15.32	3304.93
Retirement	2.36	459.27
Materials (Photocopy)	0	8.28
Other		
Travel	0	716.69
Computer (Storage)	9.16	514.01
Total	$47.27	$9438.71

A-2950

FINANCIAL REPORT

COVERING PERIOD

2/1/82 - 2/28/82

CONTRACT #956044

PROJECT # A-2950

REPORT DATE: 3/10/82

Category	Reporting Date	Cumulative
Direct Labor	9.08	$4444.61
Overhead	6.81	3311.74
Retirement	1.06	460.33
Materials (Photocopy)	0	8.64
Other		
Travel	0	716.69
Computer (storage)	0.23	514.74
Total	17.18	$9456.75

A-2950

FINANCIAL REPORT

COVERING PERIOD

3/1/82 - 3/31/82

CONTRACT #956044

PROJECT # A-2950

REPORT DATE: 4/9/82

Category	Reporting Date	Cumulative
Direct Labor	4.54	$4449.15
Overhead	3.41	3315.15
Retirement	0.53	460.86
Materials (Photocopy)	0.72	9.36
Other		
Travel	0	716.69
Computer (storage)	0.17	514.91
Total	9.37	$9466.12

A-2950

FINANCIAL REPORT

COVERING PERIOD

4/1/82 - 4/30/82

CONTRACT $956044

PROJECT # A-2950

REPORT DATE: 5/27/82

Category	Reporting Date	Cumulative
Direct Labor	4.54	$4453.69
Overhead	3.41	3318.86
Retirement	0.53	461.39
Materials (Photocopy)	0.42	9.78
Other		
Travel	0	716.69
Computer (storage)	0.10	515.01
Total	9.00	$9475.12

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FINANCIAL REPORT

COVERING PERIOD

5/1/82 - 5/31/82

CONTRACT #956044

PROJECT # A-2950

REPORT DATE: 6/10/82

Category	Reporting Date	Cumulative
Direct Labor	0.00	$4,453.69
Overhead	0.00	3,318.56
Retirement	0.00	461.39
Materials (Photocopy)	0.24	10.02
Other		
Travel	0.00	716.69
Computer (storage)	0.00	515.01
Total	0.24	$9,475.36

FINANCIAL REPORT

COVERING PERIOD

6/1/82 - 6/30/82

CONTRACT #956044

PROJECT # A-2950

REPORT DATE: 7/9/82

Category	Reporting Date	Cumulative
Direct Labor	0	4453.69
Overhead	0	3318.56
Retirement	0	461.39
Materials (Photocopy)	0.48	10.50
Other		
Travel	0	716.69
Computer (adjustment)	-1.00	514.01
Total	-0.52	9474.84

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FINANCIAL REPORT

COVERING PERIOD

7/1/82 - 7/31/82

CONTRACT #956044

PROJECT # A-2950

REPORT DATE: 8/17/82

Category	Reporting Date	Cumulative
Direct Labor	4.84	4458.53
Overhead	2.87	3321.43
Retirement	.93	462.32
Materials (Photocopy)	.30	10.80
Other		
Travel	0	716.69
Computer	0	514.01
Total	8.94	9483.78

FINANCIAL REPORT

COVERING PERIOD

8/2/82 - 8/31/82

CONTRACT #956044

PROJECT # A-2950

REPORT DATE: 9/22/82

Category	Reporting Date	Cumulative
Direct Labor	4.84	4463.37
Overhead	2.94	3324.37
Retirement	1.03	463.35
Materials (Photocopy)	.36	11.16
Other		
Travel	0	716.69
Computer	0	514.01
Total	9.17	9312.95

A-2950

FINANCIAL REPORT

COVERING PERIOD

9/1/82 - 9/30/82

CONTRACT #956044

PROJECT # A-2950

REPORT DATE: 10/14/82

Category	Reporting Date	Cumulative
Direct Labor	0	4463.37
Overhead	0.17	3324.54
Retirement	0	463.35
Materials (Photocopy)	0.36	11.52
Other		
Travel	0	716.69
Computer	0	514.01
Total	0.53	9493.48

A-2950

FINANCIAL REPORT

COVERING PERIOD

10/1/82 - 10/31/82

CONTRACT #956044

PROJECT # A-2950

REPORT DATE: 10/14/82

Category	Reporting Date	Cumulative
Direct Labor	4.83	4468.20
Fringe Benefits	0.96	464.31
Overhead	2.90	3327.44
Retirement	0	463.35
Materials (Photocopy)	0.36	11.88
Other		
Travel	0	716.69
Computer	0	514.01
Total	9.05	9502.53

FINANCIAL REPORT

COVERING PERIOD

11/1/82 - 11/30/82

CONTRACT #956044

PROJECT # A-2950

REPORT DATE: 11/14/82

Category	Reporting Date	Cumulative
Direct Labor	4.81	4473.01
Fringe Benefits	0.96	465.27
Overhead	2.89	3330.33
Materials (Photocopy)	0.36	12.24
Other		
Travel	0	716.69
Computer	0	514.01
Total	9.02	9511.55

FINANCIAL REPORT

COVERING PERIOD

12/1/82 - 12/31/82

CONTRACT #956044

PROJECT # A-2950

REPORT DATE: 1/19/83

Category	Reporting Date	Cumulative
Direct Labor	4.84	4477.85
Fringe Benefits	0.97	466.24
Overhead	2.97	3333.30
Materials (Photocopy)	0.48	12.72
Other		
Travel	0	716.69
Computer	0	514.01
Total	9.26	9520.81

FINANCIAL REPORT

COVERING PERIOD

1/3/83 - 1/31/83

CONTRACT #956041

PROJECT # A-2950

REPORT DATE: 2/8/83

Category	Reporting Date	Cumulative
Direct Labor	0	4477.85
Fringe Benefits	0	466.24
Overhead	0	3333.30
Materials (Photocopy)	0	12.72
Other		
Travel	0	716.69
Computer	0	514.01
Total	0	9520.81

FINANCIAL REPORT

COVERING PERIOD

2/1/83 - 2/28/82

CONTRACT #956041

PROJECT # A-2950

REPORT DATE: 3/14/83

Category	Reporting Date	Cumulative
Direct Labor	9.68	4487.53
Fringe Benefits	2.12	468.36
Overhead	5.85	3339.15
Materials (Photocopy)	.60	13.32
Other		
Travel	.00	716.69
Computer	.00	514.01
Total	18.25	9539.06

FINANCIAL REPORT

COVERING PERIOD

3/1/83 - 3/31/83

CONTRACT #956041

PROJECT # A-2950

REPORT DATE: 5/20/83

Category	Reporting Date	Cumulative
Direct Labor	4.84	4492.37
Fringe Benefits	1.04	469.40
Overhead	2.95	3342.10
Materials (Photocopy)	0.36	13.68
Other		
Travel	.00	716.69
Computer	.00	514.01
Total	9.19	9548.25

FINANCIAL REPORT

COVERING PERIOD

4/1/83 - 4/29/83

CONTRACT #956041

PROJECT # A-2950

REPORT DATE: 5/20/83

Category	Reporting Date	Cumulative
Direct Labor	.00	4492.37
Fringe Benefits	.00	469.40
Overhead	0.17	3342.27
Materials (Photocopy)	0.36	14.04
Other		
Travel	.00	716.69
Computer	.00	514.01
Total	0.53	9548.78

FINANCIAL REPORT

COVERING PERIOD

5/2/83 - 5/31/83

CONTRACT #956041

PROJECT # A-2950

REPORT DATE: 6/21/83

Category	Reporting Date	Cumulative
Direct Labor	851.09	5343.46
Fringe Benefits	172.75	642.15
Overhead	587.63	3929.90
Materials (Photocopy)	0.00	14.04
Other		
Travel	.00	716.69
Computer	221.13	735.14
Total	1832.60	11381.38

FINANCIAL REPORT

COVERING PERIOD

6/1/83 - 6/30/83

CONTRACT #956041

PROJECT # A-2950

REPORT DATE: 7/27/83

Category	Reporting Date	Cumulative
Direct Labor	3496.06	8839.52
Fringe Benefits	482.04	1124.19
Overhead	2179.35	3950.75
Materials (Photocopy)	54.94	68.98
Other		
Travel	.00	716.69
Computer	584.22	1319.36
Total	6796.61	18177.99

FINANCIAL REPORT

COVERING PERIOD

9/1/83 - 9/30/83

CONTRACT #956041

PROJECT # A-2950

REPORT DATE: 8/14/83

Category	Reporting Date	Cumulative
Direct Labor	928.24	11622.64
Fringe Benefits	85.96	1574.79
Overhead	633.81	7968.51
Materials	55.00	250.19
Other		
Travel	.00	716.69
Computer	213.82	1695.12
Total	1916.83	23800.94

FINAL REPORT

"DISH-STIRLING SOLAR HEAT RECEIVER HEAT TRANSFER ANALYSIS"

Prepared for

Jet Propulsion Laboratory
California Institute of Technology

Prepared by

Thomas B. Elfe, Senior Research Scientist
Georgia Tech Research Institute

April 1985

Contract #956041
Georgia Tech Project # A-2950

INTRODUCTION

This program was originally intended to provide analytical support for the JPL test program on the Dish Stirling Solar Receiver (DSSR). Design and fabrication of this receiver had begun at Fairchild Stratos Division and was later taken over by Advanco Corporation after Fairchild discontinued operations in the solar thermal area. Georgia Tech had done considerable optical and thermal modeling in support of the Fairchild program. The original Statement of Work on the present program called for optical, thermal, and structural modeling to characterize the behavior of the DSSR with the JPL Test Bed Concentrator (TBC).

After considerable optical analysis had been carried out on the TBC-DSSR combination, the DSSR tests were discontinued. The Georgia Tech program was redirected to study re-aiming of facets to redistribute flux and to develop targeting techniques to facilitate facet alignment.

DSSR OPTICAL ANALYSIS

The Georgia Tech optical analysis program was modified to model the TBC. The program was originally developed to model symmetrical concentrators, so that "source points" were taken along a single parabola on the concentrator surface. From each of these source points, a cone of rays (vertex at source point) representing various areas of the solar disk was directed so that the cone axis was aimed at the focal point. A slope error was then applied to the entire cone so that the cone axis had twice the nominal surface normal error. The rays from the totality of these source points were collected on 3-dimensional symmetrical surfaces to determine flux on that surface. Typically, 900 or so source points proved adequate.

In order to model the TBC, a number of changes were made. Source points were chosen at random locations on the concentrator surface and were located over the entire surface. When a source point fell on a missing facet, it was discarded and a new point selected. Many more source points were necessary. For most of the cases, 16,000 to 32,000 were used.

Perhaps the most significant change was that the systematic error involved in approximating a paraboloid with spherical facets had to be included in the model. This was accomplished by constructing a data file containing center of curvature coordinates and radius of curvature for every facet. Since the center of each facet lay on the paraboloid surface, this data file contained sufficient information to calculate the equation of the normal at every source point. Reflected ray equations were then calculated and slope errors and sun size accounted for as in the symmetrical version.

The new version of the program has two very convenient features. First, it is easy to calculate flux patterns in cases wherein some of the facets are covered to reduce total flux. Logic is inserted into the program directing that if a source point falls on a covered facet, it is to be discarded and another source point specified by the random number generator. The other convenient feature is that re-aiming of some of the facets to modify the flux pattern can be simulated by modifying the data file to move facet center of curvature locations.

In the DSSR tests, the plan was to cover facets to reduce flux to 25 percent of maximum. After testing extensively in this mode, a series of 50 percent flux tests were planned before the final series of 100 percent

flux tests. The optical analysis program was used to calculate flux patterns for a number of combinations of covered facets which produced the 25 percent and 50 percent flux conditions as well as for the uncovered configuration. The tests were terminated during the 50 percent flux runs and we were directed to divert our planned thermal and structural analysis tasks to optical problems in slightly different areas.

TBC ALIGNMENT AND FLUX DISTRIBUTION

In early tests on the TBC, it was determined that maximum achievable flux was too high for most aperture plate materials. JPL carried out a number of tests and developed techniques for achieving a more uniform flux distribution across the receiver aperture without appreciably increasing the intercept factor on a 20 cm diameter aperture. The technique consisted of re-aiming some of the facets near the center of the paraboloid (designated as "A" mirrors) so that the flux from these facets focused a few centimeters ahead of the receiver aperture. This had two beneficial effects. One was to lower the peak flux on the aperture plate planes, and the other was to minimize the receiver flux at small radii where receiver tubes are not present on Stirling receivers.

Although the technique that JPL had developed was quite successful in achieving the desired flux patterns, it was very time consuming. The alignment was done at night, using a distant, high intensity point source of light. Only the facet being aligned was uncovered, so that considerable covering and uncovering of facets was necessary.

E. W. Dennison of JPL suggested that the optical analysis program should be capable of analyzing the flux pattern for a given alignment configuration and then plotting the images of the individual facets (when illuminated from a distant, but not infinitely distant source). If successful, this would allow us to draw targets which could be located near the focal plane and used to align all facets without covering and uncovering.

This task met with a high degree of success. The optical analysis program was modified so that the source was a point source, 1650 feet from the concentrator vertex. Next, what we have been calling "source points" (i.e., points on the concentrator from which rays are traced) are no longer chosen randomly, but are chosen to lie on the edges of each facet (20 source points outline each facet, and one ray is traced from the facet center).

We found that there is no single target plane location for which the images of all facets are distinct. It is possible to locate a target for B&C mirrors about 3/4 meter behind the focal plane and later locate a separate target approximately that far ahead of the focal plane and achieve distinct images. Figure 1 shows the two targets. Figure 2 shows the B&C target illuminated at the end of the alignment. The alignment process now requires approximately one night instead of a week.

The most awkward part of the new technique is establishing where each group of mirrors should be focused (and which mirrors constitute a group). Since the optical modeling is carried out using an analysis program, it is straightforward to predict the flux pattern, either on the aperture plane or on a receiver surface, resulting from a given configuration. It is not straightforward to answer the reverse question:

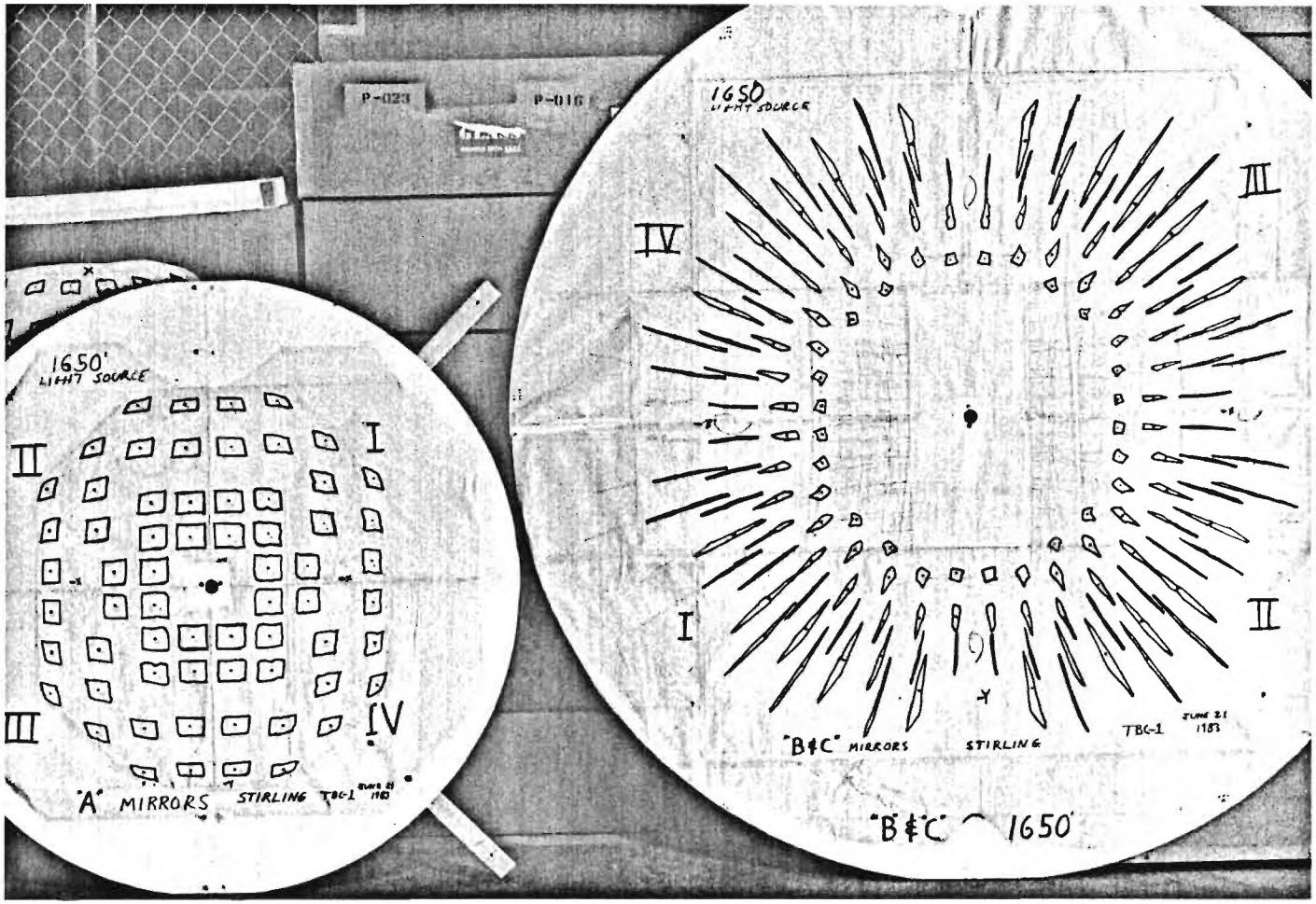

Figure 1. Alignment Targets.

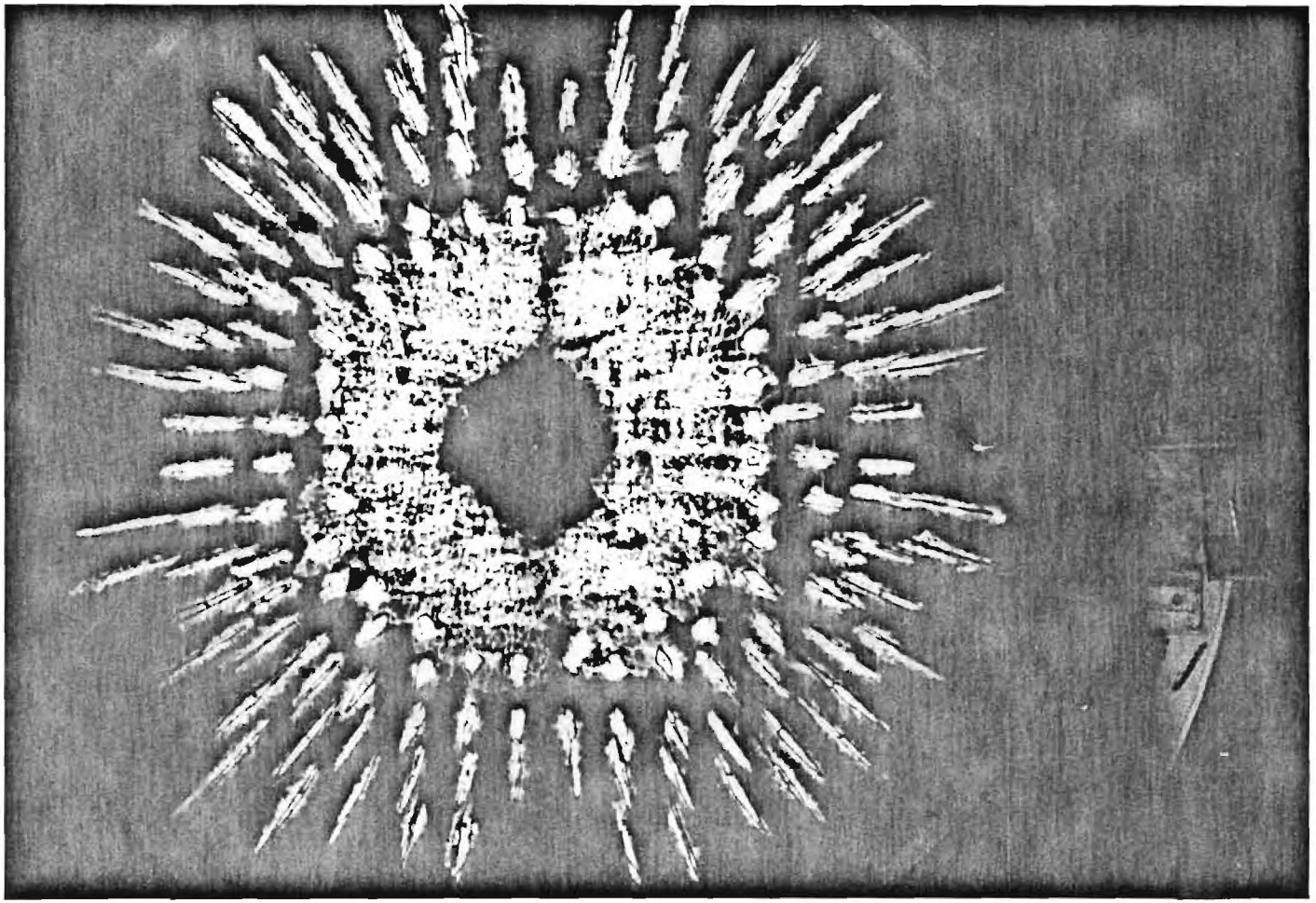

Figure 2. B-C Target Illuminated.

given a flux pattern, what configuration of facet alignments is required to produce it? We analyzed a large number of alignment configurations before finding one which was considered optimal.

CONCLUSIONS AND RECOMMENDATIONS

There were two significant results of this program. The capability of the optical analysis program was expanded so that it is very useful for faceted concentrators as well as single surface concentrators. Second, the alignment targets are a very useful tool for concentrator alignment. The analysis work did provide the intended support for the DSSR test program until the tests were terminated.

There are two major areas which should be pursued further. One is improving the methodology of determining how to realign facets to best achieve a given flux pattern. The other is investigating how much of the optical analysis program could be run on a suitable micro-computer and developing such software.