JPL PUBLICATION 77-82

# Results of the 1974 Through 1977 NASA/JPL Balloon Flight Solar Cell Calibration Program



National Aeronautics and
Space Administration

**Jet Propulsion Laboratory**
California Institute of Technology
Pasadena, California

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L. B. Sidwell

January 15, 1978

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# Preface

The work described in this report was performed by the Control and Energy Conversion Division of the Jet Propulsion Laboratory. All flights were conducted with the cooperation of the National Scientific Balloon Facility, located in Palestine, Texas. A summary of the data from six of the nine balloon flights made from 1974 through 1977 is presented.

# Acknowledgment

The author wishes to express his appreciation for the excellent cooperation and support provided by the entire staff of the National Scientific Balloon Facility.

Gratitude is also extended to the following JPL people for their cooperation and support during the transfer of this project from one individual to another: R. G. Downing, R. F. Greenwood, G. M. Hill, J. J. Kos, and R. S. Mueller. The preflight, flight, and postflight support by R. S. Weiss has been extremely invaluable in assuring the success of the later flights in this series. The cooperation and patience extended by all the participating organizations was greatly appreciated.

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# Abstract

The Jet Propulsion Laboratory has been calibrating solar cells on high-altitude balloons since 1962. This report covers the flights from 1974 through 1977. During this time, seven solar cell calibration flights and two R&D flights with a spectroradiometer as a payload were attempted. There were two R&D flights, and one calibration flight that failed. Each calibration flight balloon was designed to carry its payload to an altitude of 36.6 km (120 kft). R&D flight balloons were designed for a payload altitude of 47.5 km (150 kft). At the end of the flight period the upper (solar cell calibration system) and lower (consolidated instrument package [CIP]) payloads are separated from the balloon and descend via parachutes. The calibrated solar cells recovered in this manner are used as primary intensity reference standards during solar simulator testing of solar cells and solar arrays with similar spectral response characteristics. This method of calibration has become the most widely accepted technique for developing space standard solar cells.

The flights were conducted by NASA/JPL with the cooperation and assistance of the National Science Foundation's National Scientific Balloon Facility operated by the National Center for Atmospheric Research (NCAR) and located in Palestine, Texas.

# Results of the 1974 Through 1977 NASA/JPL Balloon Flight Solar Cell Calibration Program

## I. Introduction

The primary source of electrical power for unmanned spacecraft, during the present space era, has been the direct conversion of solar energy through the use of solar cell panels. To accurately compute the power available from a panel it is necessary to know the conversion efficiency of the solar cells that make up the panel. This is most accurately determined by high-altitude calibrations of representative cells.

The solar cells were mounted on standard modules, by each participant, and returned to JPL for the calibration flight. The cells are resistively loaded near their short-circuit current point and exposed to the extraterrestrial Sun on top of a high-altitude balloon. Cell output and cell temperature are measured and recorded twice each second for a period of three hours or more while pointed at the Sun by an automatic Sun tracker. The recorded raw data are computer corrected for temperature and Earth-Sun distance, then averaged over 200 data points. The computer data are analyzed for time of day and average cell output. A group of 200 consecutive data points are selected as the calibration scan and becomes the calibration values for that group of cells. These calibrated cells can now be used to accurately set the output of solar simulators for testing other cells or panels, with similar characteristics, to determine their conversion efficiency under space conditions. Using the terrestrial Sun, similar determinations can be made; however, the accuracy will suffer greatly. The affecting factors of the atmosphere become evident by referring to Table 1. More complete descriptions of the balloon system, Sun tracker and computer program, and data reduction as presently used can be found in Ref. 1. The solar cell calibration program is a continuing program to provide AMO calibrated cells for the industry.

## II. Balloon Flight Payloads

Table 2 lists the participating organizations, serial numbers of the cells and the assigned flights during the 1974 through 1977 series of solar cell calibration flights. All cells were mounted on the standard JPL module according to the *JPL Procedure for Balloon Flight Solar Cell Modules* (Ref. 3). This procedure outlines physical size, critical dimensions, materials, workmanship, and procedures for assembling standard cells. The prefabricated standard modules were provided by JPL to the participants for mounting of their cells. Prior to the flight, the cells to be standardized were returned for preflight calibration on the JPL X25L Spectrolab Solar Simulator. Mounting of the standard cells on the Sun tracker and testing of the assembly was done before shipping to the National Scientific Balloon Facility (NSBF). Upon arrival at the NSBF the tracker and cell payload are rechecked and then calibrated through the NSBF telemetry data system. During the flight, data are recorded on magnetic tape which is then returned to JPL for computer processing and analysis. Figure 1 shows a typical cell payload and Fig. 2 shows the payload for the spectroradiometer R&D flights. Figures 3 through 9 show the mounting locations of each cell on the successful flights. Tracker mounting, prelaunch and launch are shown in Figs. 10 to 12.

**Table 1. Attenuation of solar radiation by the Earth's atmosphere**

| Pressure, mbar[b] | Altitude[a] Miles | $10^3$ feet | Kilometers | Wavelength regions, μm: 0.12 to 0.20 | 0.20 to 0.29 | 0.29 to 0.32 | 0.32 to 0.35 | 0.35 to 0.55 | 0.55 to 0.9 | 0.9 to 2.5 | 2.5 to 7 | 7 to 20 | Altitude, km | IUGG[c] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.2 | 37 | 200 | 60 | $O_2$ absorbs almost completely. | Solar irradiation intensity approximates extra atmospheric. Attenuation by scattering increases markedly toward shorter wavelengths. | | | | | | | | Above 60 | 110 km<br>CHEMOSPHERE |
| 7.5 | 20 | 108 | 33 | | (0.20 to 0.21 μm, absorption by $O_2$) Absorption by $O_3$ appreciable. | $O_3$ absorption not important. | | | | | Energy small | Energy very small | 60 to 33 | |
| 227 | 6.8 | 36 | 11 | | No radiation penetrates below about 11 km. | $O_3$ absorption attenuates more than loss by scattering. | $O_3$ absorption significantly attenuates radiation. | Irradiation diminished mostly by scattering by permanent gases in atmosphere. | $H_2O$ responsible for major absorption; $CO_2$ absorbs slightly at 2 μm. Water vapor (or ice crystals) found up to about 70,000 feet. | | | Strong $O_3$ absorption at 9.6 μm. Strong $CO_2$ absorption 12-17 μm. | 33 to 11 | 20 km<br>STRATOSPHERE |
| 795 | 1.2 | 6.6 | 2 | | | | Highly variable dust, haze ($H_2O$), and smoke responsible for attenuation in regions 0.32 to 0.7 μm. | | Energy transmitted with small loss down to 2 km. | Energy penetrates to sea level only through "windows" at approximately 1.2, 1.6, and 2.2 μm. | No significant penetration below 2 km, except in "windows" at approximately 3.8 and 4.9 μm. | Energy transmitted with moderate loss. Many absorption bands due to atmospheric gases. | 11 to 2 | 11 km<br>TROPOSPHERE |
| 1013 | Sea level | | | | | Appreciable penetration through "clear" atmosphere to sea level. About 7% / About 30% | Penetration through "clear" atmosphere to sea level about 40%. | Dust may rise to more than 4 kilometers. | | | | | 2 to sea level | 0 km |

[a]NASA/JPL balloon flight program altitude = 36.6 km (120 kft).
[b]One mbar = 100 N/m$^2$.
[c]Nomenclature recommended by International Union of Geodesy and Geophysics (IUGG).

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## Table 2. Participant List 74-77

| Participant | Cells | Flight |
|---|---|---|
| AFAPL | 74-131 | 75-2 |
| | 74-132 | 74-1,75-1 |
| | 74-133 | 74-1 |
| | 74-134 | 74-1,75-1 |
| | 74-136 | 74-2,75-2 |
| COMSAT | 74-203 | 75-2 |
| | 74-204 | 75-2 |
| | 76-125A | 76-3 |
| | 76-125B | 76-3 |
| ESTEC | 73-142 | 75-2 |
| | 73-143 | 75-2 |
| | 75-121 | 75-2 |
| | 75-122 | 75-2 |
| | 75-123 | 75-2 |
| | 75-124 | 75-2 |
| GSFC | 74-111 | 75-1 |
| | 74-112 | 75-1 |
| | 74-113 | 75-1 |
| | 74-114 | 75-2 |
| | 74-115 | 75-2 |
| HAC | 74-141 | 74-2 |
| | 74-143 | 74-1 |
| | 74-145 | 74-2 |
| | 74-146 | 74-1 |
| | 74-148 | 74-1 |
| | 74-149 | 74-1 |
| | 74-150 | 74-2 |
| | 74-152 | 74-2 |
| | 74-153 | 74-2 |
| | 74-155 | 74-2 |
| | 74-156 | 74-1 |
| | 74-157 | 74-1 |
| | 76-101 | 76-3 |
| | 76-103 | 76-3 |
| | 76-105 | 76-3 |
| | 76-106 | 76-3 |
| LSMC | 74-101 | 74-1 |
| | 74-103 | 74-1 |
| | 74-105 | 74-2 |
| | 74-107 | 74-2 |
| NEC | 75-101A | 75-1 |
| | 75-101B | 75-1 |
| | 75-102A | 75-2 |
| | 75-102B | 75-2 |
| OCLI | 77-122 | 77-1 |
| | 77-123 | 77-1 |
| | 77-124 | 77-1 |
| RAE | 74-192 | 74-1 |
| | 74-193 | 75-1 |
| | 74-194 | 74-2 |
| SAT | 74-211 | 75-1 |
| | 74-213 | 75-2 |
| SHARP | 74-181 | 74-1 |
| TRW | 77-101 | 77-1 |
| | 77-102 | 77-1 |
| | 77-103 | 77-1 |
| | 77-105 | 77-1 |
| | 77-110 | 77-1 |
| | 77-111 | 77-1 |
| | 77-113 | 77-1 |
| | 77-114 | 77-1 |
| UNIVERSITY OF TOKYO | 74-141 | 74-1 |
| | 75-111 | 75-1 |
| | 75-113 | 75-2 |
| | 75-115 | 75-2 |
| JPL | 73-007 | 75-1 |
| | 73-008 | 75-1 |
| | 73-009 | 75-1 |
| | 73-010 | 75-1 |
| | 73-151 | 74-2,75-1 |
| | 73-152 | 74-2,75-1 |
| | 73-153 | 75-1 |
| | 73-154 | 75-1 |
| | 73-155 | 75-1 |
| | 73-156 | 75-1 |
| | 73-157 | 75-1 |
| | 73-159 | 75-2 |
| | 73-160 | 75-2 |
| | 73-17[illegible] | 75-2 |
| | 73-174 | 75-2 |
| | 73-175 | 74-1,74-2,75-1,75-2 |
| | 73-176 | 74-1,74-2,75-1,75-2 |
| | 73-182 | 74-1,75-1,77-1 |
| | 73-183 | 74-1,74-2,75-1,75-2,76-3, 77-1 |
| | 74-001 | 74-1 |
| | 74-002 | 74-1 |
| | 74-003 | 74-2 |
| | 74-004 | 74-2 |
| | 74-005 | 74-1,75-1 |
| | 74-006 | 74-1 |
| | 74-007 | 74-2 |
| | 74-008 | 74-2 |
| | 74-009 | 74-1 |
| | 74-010 | 74-1 |
| | 74-011 | 74-2 |
| | 74-012 | 74-1 |
| | 74-013 | 74-1 |
| | 74-014 | 74-1 |
| | 74-205 | 75-2,76-3,77-1 |
| | 75-001 | 75-1 |
| | 75-002 | 75-2 |
| | 75-003 | 75-1 |
| | 75-004 | 75-2 |
| | 75-005 | 75-1 |
| | 75-006 | 75-2 |
| | 75-007 | 75-1 |
| | 75-008 | 75-2 |

**Table 2 (contd)**

| Participant | Cells | Flight |
|---|---|---|
| JPL | 75-009 | 75-1 |
| | 75-010 | 75-2 |
| | 75-011 | 75-1 |
| | 75-012 | 75-2 |
| | 75-013 | 75-1 |
| | 75-014 | 75-2 |
| | 75-015 | 75-1 |
| | 75-016 | 75-2 |
| | 76-001 | 76-3,77-1 |
| | 76-002 | 76-3 |
| | 76-003 | 76-3 |
| | 77-001 | 77-1 |
| | 77-002 | 77-1 |
| | 77-003 | 77-1 |
| | 77-004 | 77-1 |
| | 77-005 | 77-1 |
| | 77-006 | 77-1 |
| | 77-007 | 77-1 |
| | 77-008 | 77-1 |
| | BFS-17A | 74-1,74-2,75-1,<br>75-2,76-3,77-1 |
| | BFS-17B | 74-1,74-2,75-1,75-2 |
| | BFS-106A | 74-1 |
| | BFS-106B | 74-1 |
| | BFS-108A | 74-1 |
| | BFS-108B | 74-1 |
| | BFS-109A | 74-1 |
| | BFS-109B | 74-1 |
| | BFS-110A | 74-2 |
| | BFS-110B | 74-2 |
| | BFS-111A | 74-1 |
| | BFS-111B | 74-1 |
| | BFS-112A | 74-2 |
| | BFS-112B | 74-2 |
| | BFS-114A | 74-1 |
| | BFS-114B | 74-1 |
| | BFS-115A | 75-1 |
| | BFS-115B | 75-1 |
| | BFS-118A | 74-2 |
| | BFS-118B | 74-2 |
| | BFS-307 | 74-2 |
| | BFS-309 | 74-2 |
| | BFS-402 | 74-2 |
| | BFS-409 | 75-2 |
| | BFS-503 | 74-2 |
| | BFS-505 | 74-2 |
| | BFS-506 | 74-2 |
| | BFS-517A | 77-1 |
| | BFS-517B | 77-1 |
| | BFS-517C | 77-1 |
| | BFS-518A | 74-2 |
| | BFS-518B | 74-2 |
| | BFS-518C | 74-2 |
| | BFS-601 | 74-2 |
| | MO-05 | 77-1 |
| | SL-10 | 76-3 |
| | SL-11 | 76-3 |
| | SL-12 | 76-3 |
| | SL-13 | 76-3 |
| JPL | SP-10 | 76-3 |
| | SP-11 | 76-3 |
| | SP-12 | 76-3 |
| | SP-13 | 76-3 |
| | SP-20 | 77-1 |
| | SP-21 | 77-1 |
| | ST-10 | 76-3 |
| | ST-11 | 76-3 |
| | ST-12 | 76-3 |
| | ST-13 | 76-3 |
| | ST-20 | 77-1 |
| | ST-21 | 77-1 |
| | SX-10 | 76-3 |
| | SX-11 | 76-3 |
| | SX-12 | 76-3 |
| | SX-13 | 76-3 |
| | SX-20 | 77-1 |
| | SX-21 | 77-1 |
| | TSS-31 | 76-3 |
| | TSS-32 | 76-3 |
| | TSS-33 | 76-3 |
| | TSS-34 | 76-3 |
| | TSS-35 | 76-3 |
| | TSS-36 | 76-3 |

Totals

| | |
|---|---|
| Cells (non JPL) | 65 |
| Cells JPL | 124 |
| Cells flown one time | 189 |

Participant Names

AFAPL = Air Force Aero Propulsion Lab.
COMSAT = Communications Satellite Corp.
ESTEC = European Space Research Organization (Holland)
GSFC = Goddard Space Flight Center
HAC = Hughes Aircraft Co.
ISAS = Institute of Space and Aeronautical Science (University of Tokyo, Japan)
LSMC = Lockheed Missiles and Space Co.
NEC = Nippon Electric Co., Ltd. (Japan)
OCLI = Optical Coating Lab. Inc.
RAE = Royal Aircraft Establishment (England)
SAT = Société Anonyme de Télécommunications (France)
SFC = Sharp Corp. (Japan)

JPL Cell Identification

BFS = Balloon Flight Standard
MO = Motorola
SL = Spectrolab
SP = Solar Power
ST = Solar Technology
SX = Solarex
TSS = Terrestrial Secondary Standard

For cell locations on each flight, refer to Figs. 3 through 9.

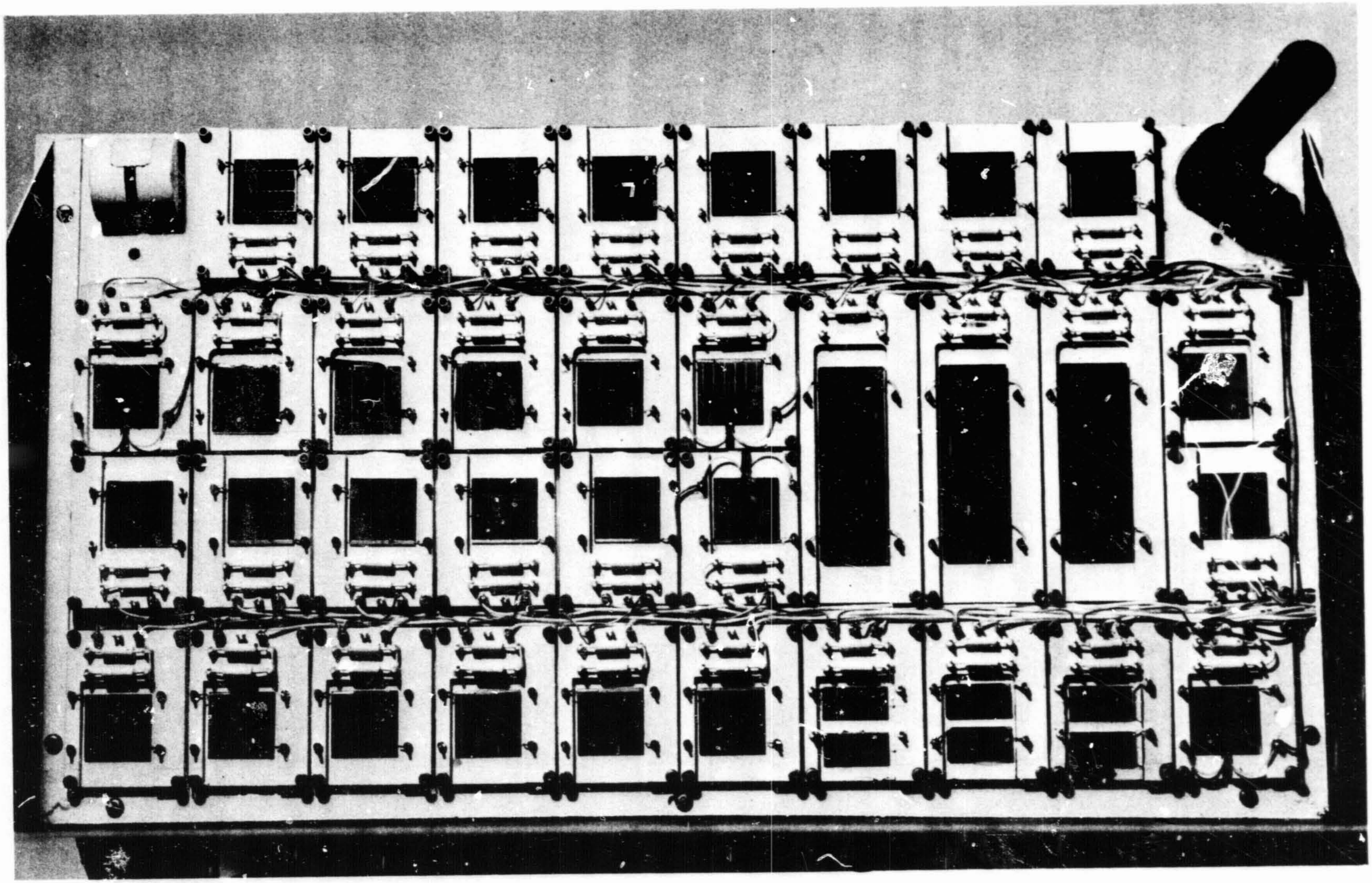

Fig. 1. Typical solar cell payload

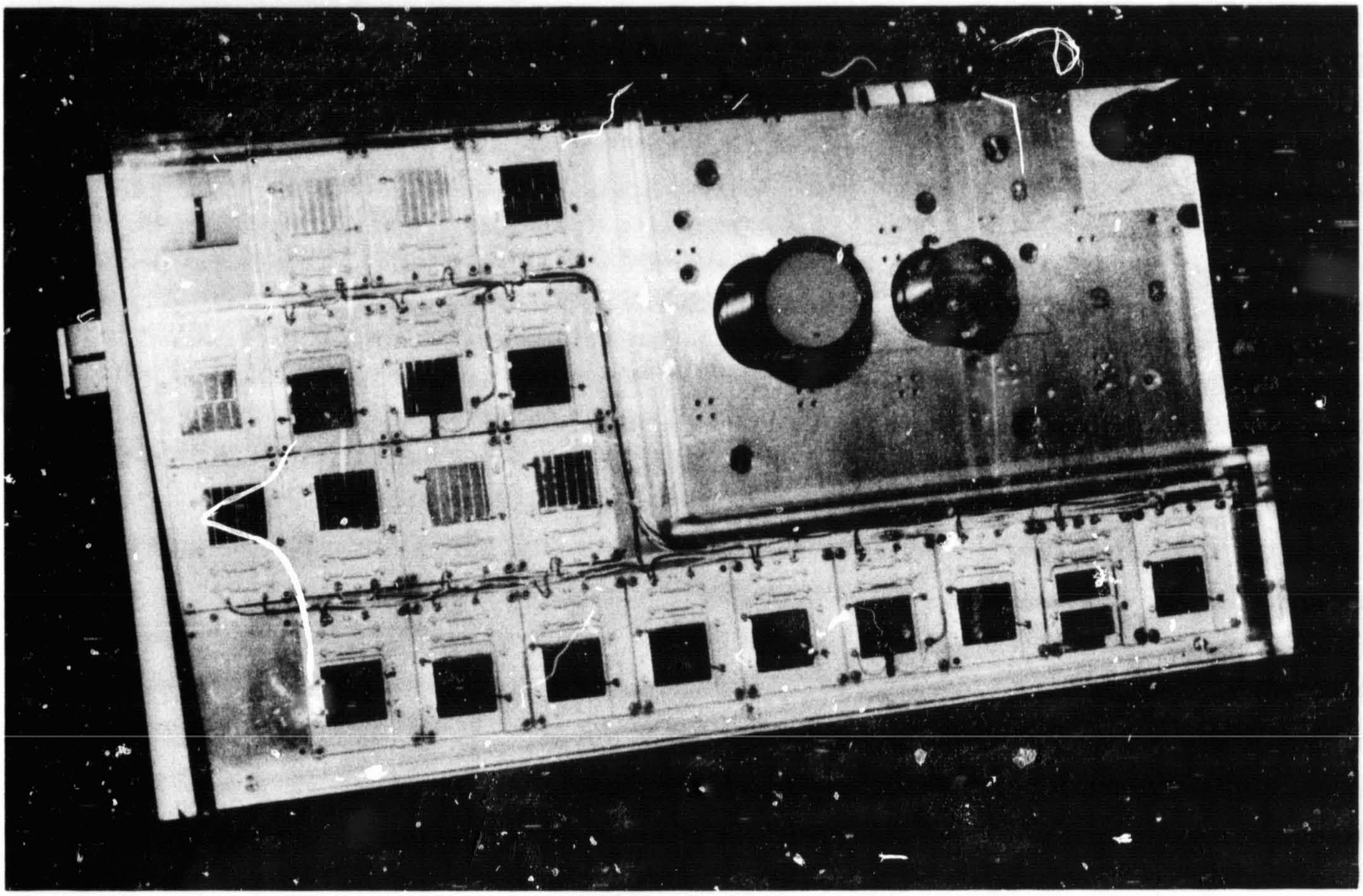

Fig. 2. Spectroradiometer payload

## III. Balloon Flight Performance and California Data

### A. Flight 74-1 (NSBF 858P)

Flight 74-1 was launched on Saturday, October 12, at 0720 hours CDT. Telemetry indicated a tracker malfunction; however, by manipulating the tracker on-off commands from the tower, 75% of the data were of an acceptable nature. Examination of the tracker after the flight revealed that one of the drive gears had worked loose. The magnetic data tape was returned to JPL for computer processing. Analysis of the computer output indicated adequate data around solar noon to provide calibration of the cell payload.

Table 3 lists the cells by serial number identifying the data channel assigned to the cells, the corrected millivolt calibration value, the 95% confidence level, and the standard deviation for the 100 data points averaged to provide the calibration value. Average temperature during this data scan is listed as a footnote at the lower right-hand corner. The pre- and post-flight simulator calibrations and their relationship to each other as well as to the corrected flight data are shown. For a more complete discussion of the data reduction methods used see Ref. 1.

### B. Flight 74-2 (NSBF 864P)

Launch of this flight was accomplished on schedule at 0755 hours on October 24, 1974. Some of the cells were affected by stray reflections and were reflown on a later flight.

The data for this flight were taken continuously from 1032 hours through tracker turn-off at 1321 hours. In viewing the raw data during the flight it was evident that some of the cells were not producing the correct output. It was later determined that these cells were receiving unanticipated reflections. Analysis of the computer corrected data indicated that the rest of the cells were unaffected. Corrected data for all the cells are shown on Table 4. Comments for these tables are the same as for flight 74-1 data tables.

Table 3. Balloon flight 74-1 at 120,000 ft, adjusted data, 1 AU, 28°C on October 12, 1974

| MODULE NUMBER | CHANNEL NUMBER | TEMP. INTENSITY ADJ. AVERAGE | 95 PERCENT CONF. LIMITS | STANDARD DEVIATION |
|---|---|---|---|---|
| 74- 001 | 1 | 77.86 | .01447 | .06709 |
| 74- 002 | 2 | 77.99 | .01704 | .07903 |
| 74- 005 | 3 | 78.56 | .01625 | .07534 |
| 74- 006 | 4 | 78.55 | .01980 | .09182 |
| 74- 009 | 5 | 82.13 | .01695 | .07860 |
| 74- 010 | 6 | 81.84 | .01846 | .08558 |
| 74- 132 | 7 | 78.41 | .01589 | .07368 |
| 74- 134 | 8 | 83.99 | .02002 | .09282 |
| 73- 175 | 9 | 68.08 | .01691 | .07839 |
| 74- 103 | 10 | 69.43 | .01467 | .06800 |
| 74- 101 | 11 | 73.33 | .01509 | .06998 |
| 74- 013 | 12 | 69.46 | .01567 | .07265 |
| 74- 014 | 13 | 68.36 | .01535 | .07118 |
| 73- 176 | 14 | 67.44 | .01675 | .07769 |
| 74- 148 | 15 | 82.62 | .01348 | .06250 |
| 74- 149 | 16 | 84.18 | .01682 | .07801 |
| 74- 156 | 17 | 76.72 | .01311 | .06080 |
| 74- 157 | 18 | 78.31 | .01601 | .07426 |
| 74- 143 | 19 | 74.48 | .01454 | .06742 |
| 74- 146 | 20 | 73.94 | .01071 | .04965 |
| 74- 171 | 21 | 66.65 | .00933 | .04326 |
| 73- 182 | 22 | 68.54 | .0123[illegible] | .05721 |
| BFS- 106A | 23 | 64.50 | .00992 | .04600 |
| BFS- 106B | 24 | 64.57 | .01384 | .06418 |
| BFS- 108A | 25 | 67.11 | .01642 | .07612 |
| BFS- 108B | 26 | 68.19 | .00980 | .04544 |
| BFS- 109A | 27 | 70.71 | .01598 | .07410 |
| BFS- 109B | 28 | 67.60 | .01175 | .05450 |
| 74- 181 | 29 | 65.30 | .01428 | .06623 |
| 74- 192 | 30 | 71.42 | .01380 | .06401 |
| 74- 012 | 31 | 71.20 | .01467 | .06800 |
| BFS- 111A | 32 | 67.00 | .01219 | .05650 |
| BFS- 111B | 33 | 67.61 | .00992 | .04601 |
| BFS- 114A | 34 | 70.26 | .01232 | .05714 |
| BFS- 114B | 35 | 70.66 | .01079 | .05005 |
| BFS- 17A | 36 | 60.80 | .01347 | .06245 |
| BFS- 17B | 37 | 60.47 | .00993 | .04605 |
| 73- 183 | 38 | 67.76 | .00828 | .03839 |

• INDICATES CHANNEL FOR WHICH NO TEMPERATURE COEFFICIENT WAS PROVIDED.

AVERAGE TEMPERATURE (DEG.C) AT FLOAT ALTITUDE = 40.71

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Table 3 (contd)

| ORGAN-IZATION CODE | MODULE NUMBER | | AMO, SOLAR SIM. 1 AU, 28 DEG.C PRE-FLT | POS-FLT | COMPARISON, SOLAR SIMULATOR & FLT PRE-FLT VS. POS-FLT (PERCENT) | FLIGHT VS. PRE-FLT (PERCENT) | COMMENTS |
|---|---|---|---|---|---|---|---|
| JPL | 74- | 001 | 74.67 | 74.70 | -.04 | 4.10 | |
| JPL | 74- | 002 | 74.86 | 74.80 | .08 | 4.01 | |
| JPL | 74- | 005 | 75.73 | 75.67 | .08 | 3.60 | |
| JPL | 74- | 006 | 75.52 | 75.38 | .19 | 3.85 | |
| JPL | 74- | 009 | 78.51 | 78.24 | .34 | 4.40 | |
| JPL | 74- | 010 | 78.35 | 78.00 | .45 | 4.26 | |
| AFAPL | 74- | 132 | 75.50 | 75.20 | .40 | 3.71 | |
| AFAPL | 74- | 134 | 80.10 | 79.85 | .31 | 4.63 | |
| JPL | 73- | 175 | 67.38 | | | 1.03 | |
| LSMC | 74- | 103 | 69.28 | 68.93 | .51 | .21 | |
| LSMC | 74- | 101 | 71.94 | 71.68 | .36 | 1.89 | |
| JPL | 74- | 013 | 69.51 | 69.22 | .42 | -.08 | |
| JPL | 74- | 014 | 68.34 | 68.09 | .37 | .03 | |
| JPL | 73- | 176 | 66.52 | | | 1.36 | |
| HAC | 74- | 148 | 80.88 | 81.07 | -.23 | 2.11 | |
| HAC | 74- | 149 | 82.55 | 82.49 | .07 | 1.94 | |
| HAC | 74- | 156 | 74.95 | 75.02 | -.09 | 2.31 | |
| HAC | 74- | 157 | 75.69 | 75.80 | -.15 | 3.35 | |
| HAC | 74- | 143 | 73.78 | 73.32 | .62 | .94 | |
| HAC | 74- | 146 | 72.91 | 72.61 | .41 | 1.40 | |
| ISAS | 74- | 171 | 67.23 | 66.80 | .64 | -.88 | |
| JPL | 73- | 182 | 67.88 | | | .96 | |
| JPL | BFS- | 106A | 63.81 | 63.88 | -.11 | 1.07 | |
| JPL | BFS- | 106B | 63.31 | 63.34 | -.05 | 1.95 | |
| JPL | BFS- | 108A | 66.06 | 65.80 | .39 | 1.57 | |
| JPL | BFS- | 108B | 67.10 | 66.33 | 1.15 | 1.59 | |
| JPL | BFS- | 109A | 69.75 | 69.67 | .11 | 1.36 | |
| JPL | BFS- | 109B | 66.58 | 66.38 | .30 | 1.50 | |
| SEC | 74- | 181 | 65.78 | 65.39 | .59 | -.73 | |
| RAE | 74- | 192 | 70.83 | 70.81 | .03 | .82 | |
| JPL | 74- | 012 | 70.52 | 70.57 | -.07 | .95 | |
| JPL | BFS- | 111A | 66.63 | 66.20 | .65 | .56 | |
| JPL | BFS- | 111B | 67.36 | 67.25 | .16 | .37 | |
| JPL | BFS- | 114A | 69.54 | 69.38 | .23 | 1.03 | |
| JPL | BFS- | 114B | 70.18 | 70.18 | .00 | .68 | |
| JPL | BFS- | 17A | 59.66 | | | 1.88 | |
| JPL | BFS- | 17B | 59.20 | | | 2.11 | |
| JPL | 73- | 183 | 67.10 | | | .97 | |

Table 4. Balloon flight 74-2 at 120,000 ft, adjusted data, 1 AU, 28°C on October 24, 1974

| MODULE NUMBER | | CHANNEL NUMBER | TEMP. INTENSITY ADJ. AVERAGE | 95 PERCENT CONF. LIMITS | STANDARD DEVIATION |
|---|---|---|---|---|---|
| 74- | 003 | 1 | 77.88 | .00740 | .04529 |
| 74- | 004 | 2 | 78.03 | .00770 | .04716 |
| 74- | 007 | 3 | 79.04 | .00403 | .02468 |
| 74- | 008 | 4 | 78.83 | .00659 | .04036 |
| 74- | 011 | 5 | 73.26 | .01208 | .07400 |
| BFS- | 307 | 6 | 63.07 | .01902 | .11649 |
| BFS- | 309 | 7 | 63.61 | .00822 | .05033 |
| BFS- | 402 | 8 | 61.96 | .00785 | .04808 |
| 73- | 175 | 9 | 67.70 | .00664 | .04063 |
| BFS- | 503 | 10 | 65.77 | .00838 | .05134 |
| 74- | 136 | 11 | 81.59 | .00935 | .05723 |
| 74- | 105 | 12 | 74.58 | .01046 | .06405 |
| 74- | 107 | 13 | 72.03 | .00431 | .02641 |
| 73- | 176 | 14 | 66.80 | .02013 | .12327 |
| 74- | 150 | 15 | 83.92 | .00355 | .02176 |
| 74- | 152 | 16 | 84.10 | .00696 | .04263 |
| 74- | 153 | 17 | 77.85 | .00985 | .06030 |
| 74- | 155 | 18 | 76.60 | .00699 | .04282 |
| 74- | 141 | 19 | 73.70 | .00989 | .06059 |
| 74- | 145 | 20 | 73.51 | .00843 | .05164 |
| 74- | 194 | 21 | 57.05 | .00456 | .02795 |
| 73- | 182 | 22 | 68.09 | .00000 | .00002 |
| BFS- | 505 | 23 | 65.84 | .01152 | .07053 |
| BFS- | 601 | 24 | 66.87 | .01080 | .06614 |
| 73- | 151 | 25 | 71.17 | .00620 | .03794 |
| 73- | 152 | 26 | 71.15 | .00000 | .00003 |
| BFS- | 518A | 27 | 22.90 | .00444 | .02717 |
| BFS- | 518B | 28 | 22.30 | .00763 | .04671 |
| BFS- | 518C | 29 | 65.98 | .00472 | .02890 |
| BFS- | 110A | 30 | 69.41 | .00958 | .05864 |
| BFS- | 110B | 31 | 66.83 | .00384 | .02352 |
| BFS- | 112A | 32 | 67.96 | .00653 | .04000 |
| BFS- | 112B | 33 | 69.51 | .00479 | .02932 |
| BFS- | 118A | 34 | 59.39 | .00709 | .04344 |
| BFS- | 118B | 35 | 58.21 | .00459 | .02810 |
| BFS- | 17A | 36 | 60.56 | .00396 | .02427 |
| BFS- | 17B | 37 | 60.65 | .00000 | .00000 |
| 73- | 183 | 38 | 67.64 | .01033 | .06329 |

* INDICATES CHANNEL FOR WHICH NO TEMPERATURE COEFFICIENT WAS PROVIDED.

AVERAGE TEMPERATURE (DEG.C) AT FLOAT ALTITUDE = 44.66

Table 4 (contd)

| ORGAN-IZATION CODE | MODULE NUMBER | AMO, SOLAR SIM. 1 AU, 28 DEG. C | | COMPARISON, SOLAR SIMULATOR & FLT | | COMMENTS |
|---|---|---|---|---|---|---|
| | | PRE-FLT | POS-FLT | PRE-FLT VS. POS-FLT (PERCENT) | FLIGHT VS. PRE-FLT (PERCENT) | |
| JPL | 74- 003 | 74.57 | 74.53 | .05 | 4.25 | |
| JPL | 74- 004 | 74.59 | 74.58 | .01 | 4.41 | |
| JPL | 74- 007 | 75.49 | 75.60 | -.15 | 4.49 | |
| JPL | 74- 008 | 75.29 | 75.49 | -.27 | 4.49 | |
| JPL | 74- 011 | 70.89 | 70.73 | .23 | 3.23 | |
| JPL | BFS- 307 | 60.88 | 60.85 | .05 | 3.47 | |
| JPL | BFS- 309 | 61.54 | 61.50 | .06 | 3.25 | |
| JPL | BFS- 402 | 60.49 | 59.78 | 1.17 | 2.37 | |
| JPL | 73- 175 | 67.38 | 67.29 | .13 | .48 | |
| JPL | BFS- 503 | 67.27 | 65.87 | 2.08 | -2.28 | |
| AFAPL | 74- 136 | 80.05 | 79.98 | .09 | 1.88 | |
| LSMC | 74- 105 | 73.68 | 73.73 | -.07 | 1.20 | |
| LSMC | 74- 107 | 71.81 | 71.26 | .77 | .30 | |
| JPL | 73- 176 | 66.52 | 66.55 | -.05 | .42 | |
| HAC | 74- 150 | 81.90 | 82.26 | -.44 | 2.41 | |
| HAC | 74- 152 | 82.48 | 82.65 | -.21 | 1.93 | |
| HAC | 74- 153 | 75.77 | 75.90 | -.17 | 2.67 | |
| HAC | 74- 155 | 75.44 | 74.82 | .82 | 1.51 | |
| HAC | 74- 141 | 72.85 | 72.62 | .32 | 1.15 | |
| HAC | 74- 145 | 72.56 | 72.17 | .54 | 1.30 | |
| RAE | 74- 194 | 57.65 | 57.00 | 1.13 | -1.06 | |
| JPL | 73- 182 | 67.88 | 67.64 | .35 | .31 | |
| JPL | BFS- 505 | 65.24 | 65.36 | -.18 | .92 | |
| JPL | BFS- 601 | 66.43 | 66.62 | -.29 | .66 | |
| JPL | 73- 151 | 69.90 | 69.90 | .00 | 1.79 | |
| JPL | 73- 152 | 69.82 | 69.67 | .21 | 1.87 | |
| JPL | BFS- 518A | 22.85 | 23.10 | -1.09 | | |
| JPL | BFS- 518B | 21.35 | 21.11 | 1.12 | 4.24 | |
| JPL | BFS- 518C | 64.80 | 64.86 | -.09 | 1.79 | |
| JPL | BFS- 110A | 68.58 | 68.90 | -.47 | 1.19 | |
| JPL | BFS- 110B | 65.60 | 65.40 | .30 | 1.84 | |
| JPL | BFS- 112A | 67.19 | 67.87 | -1.01 | 1.13 | |
| JPL | BFS- 112B | 68.63 | 68.96 | -.48 | 1.27 | |
| JPL | BFS- 118A | 58.88 | 58.73 | .25 | .86 | |
| JPL | BFS- 118B | 57.22 | 57.24 | -.03 | 1.70 | |
| JPL | BFS- 17A | 59.66 | 59.99 | -.55 | 1.48 | |
| JPL | BFS- 17B | 59.20 | 59.29 | -.15 | 2.38 | |
| JPL | 73- 183 | 67.10 | 67.09 | .01 | .80 | |

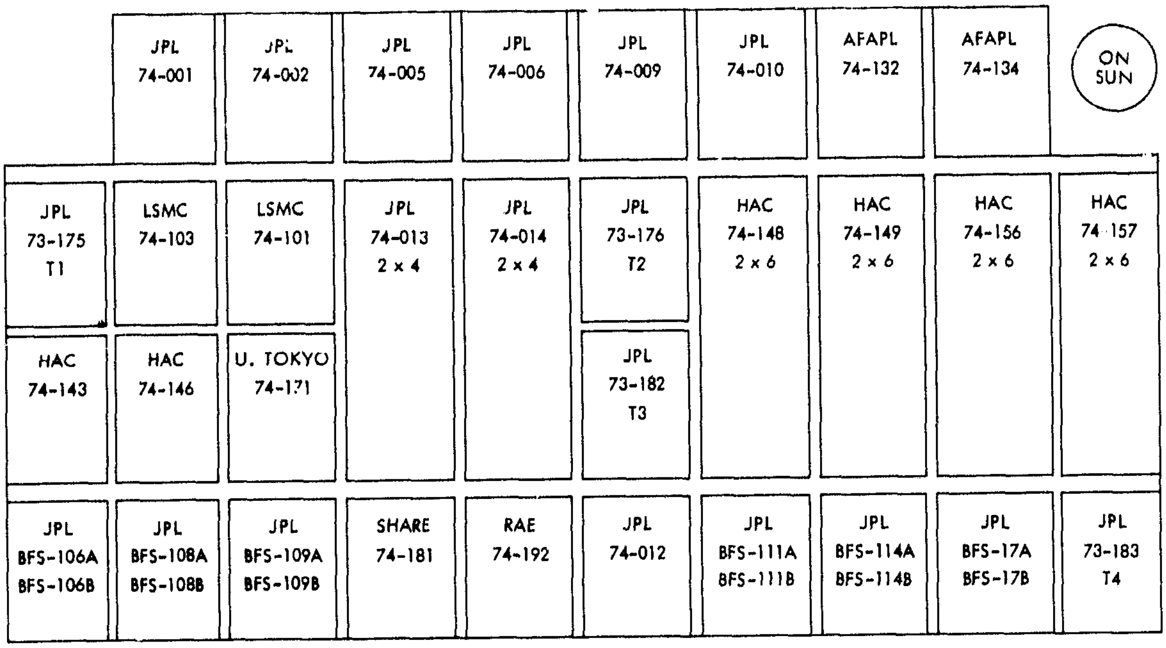


Fig. 3. Solar cell calibration module location chart, balloon flight 74-1

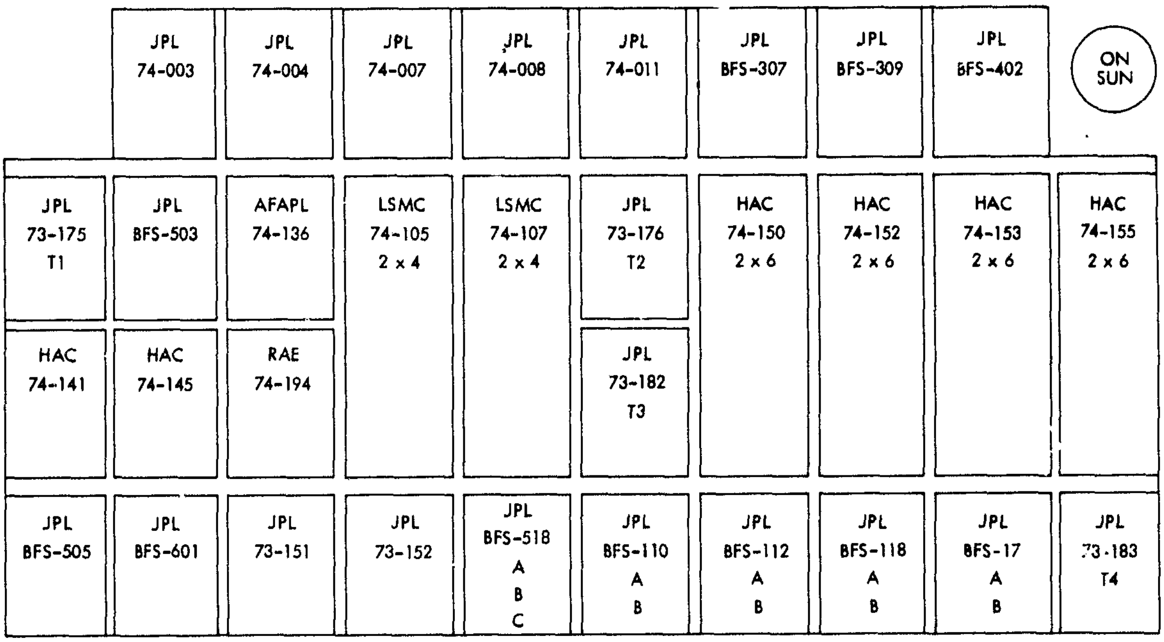


Fig. 4. Solar cell calibration module location chart, balloon flight 74-2

## C. Flight 75-1 (NSBF 895P)

On June 6, 1975 at 0618 hours, flight 75-1 was launched. The flight was uneventful; all data were of the best quality; and recovery was accomplished with no problem. Flight data were reduced at JPL, and the calibrated cells with their data were returned to the participants.

Good-quality data were received at all times during the six-hour float time at 36.48 km (119.7 kft). The data tape was processed, and cells were returned to the participants. Data for this flight are found in Table 5.

## D. Flight 75-2 (NSBF 905P)

Flight 75-2 was launched at 0610 hours on June 27, 1975. The balloon was at float altitude of 36.28 km (119 kft) for 5.4 hours. All data taken during this time were of high quality. Termination and recovery were accomplished with no problems.

The high-quality data received from this flight were recorded and processed in the usual manner. Calibration data and cells were returned to the participants. Table 6 lists the data for this flight.

## E. Flight 75-3 (NSBF 917P)

This flight was an R&D flight slated for 45.7 km (150 kft) altitude with a spectroradiometer and twenty JPL cells forming the payload. Launch was accomplished at 0732 hours on September 8, 1975. The system rose to an altitude of 43.6 km (143 kft). The data were bad and intermittent; however, the tracker motor current monitor indicated an on-Sun tracking condition. Good cell data came through for a few minutes at 1115 hours, but did not last. At 1330 hours the balloon started losing altitude. It was determined that the balloon was a leaker, and the flight was terminated at 1356 hours. Both payloads (upper and lower) were sighted by the spotter plane; however, the solar cell payload was lost because the locating beeper antenna failed to deploy. Several days later the solar cell payload was located and returned to NSBF. Investigation of the solar cell payload indicated that the failure to acquire data was caused by a small battery exploding and shorting out various components of the data system. At this time a second R&D flight was planned for the next year.

## F. Flight 76-1 (NSBF 987P)

This flight is a reflight of the 75-3 flight and was launched at 0751 hours on September 24, 1976. A redesign in the tracker data system eliminated the need for batteries and the hazards involved in their use. Some preliminary data were acquired during ascent and showed the system to be functioning perfectly. Eighteen minutes after reaching float altitude the balloon ruptured, and the flight was immediately terminated at 1145 hours. Because of the apparent low reliability of the 45.7 km (150 kft) balloon in conjunction with a top payload, this was the last R&D flight attempted at this altitude.

## G. Flight 76-2 (NSBF 1000P)

The payload for this calibration flight consisted of thirty-two cells and was launched at 0848 hours on December 3, 1976. Because of a failure in the tracker elevation drive clutch, no valid data were retrieved from this flight. In all other respects, this was a perfect flight.

## H. Flight 76-3 (NSBF 1026P)

This flight was a reflight of the 76-2 flight and was launched on June 10, 1977 at 0650 hours. The launch and float periods were uneventful and high-quality data were acquired. Termination was started at 1350 hours. At 1500 hours a report was received from the spotter plane that the top payload had not separated from the balloon, resulting in no deployment of the parachute. The recovery crew located the top payload and returned it to the NSBF. Examination of the tracker system revealed extensive impact damage to the telemetry system and the tracker. One cell was lost at the landing site and five other cells (all JPL) were damaged. The balance of the cells were in good condition. Computer processing of the data tape was accomplished and the data analyzed. All of the participants' cells with their calibration data were returned. It was later determined that the upper payload separation command from the spotter plane did not activate the payload separation system. An explanation for this malfunction was not determined.

Float altitude was reached at 0930 hours. The tracker was turned on and immediately locked onto the Sun. Because of the low Sun angle at this early hour, good data was not received until 1000 hours. Total good data time was three hours and fifty minutes. In spite of the free fall (attached to the balloon) from the float altitude of 35.9 km (117.8 kft), very few cells were damaged. The damaged cells are identified in the data by the type of damage listed in the comments column on Table 7. In viewing Table 7 it will be noted that the output format of the data has been changed to provide all data on one page for easier referencing. The number of data points used to average the data for calibration was increased to 200 at this time. There are no other changes in the computer program from previous years. After data reduction, the calibration data and cells were returned to the participants.

Table 5. Balloon flight 75-1 at 119,000 ft on June 6, 1975

| MODULE NUMBER | | CHANNEL NUMBER | TEMP. INTENSITY ADJ. AVERAGE | 95 PERCENT CONF. LIMITS | STANDARD DEVIATION |
|---|---|---|---|---|---|
| 75- | 001 | 1 | 71.54 | .00881 | .05393 |
| 75- | 003 | 2 | 75.82 | .01374 | .08413 |
| 75- | 005 | 3 | 78.06 | .01135 | .06953 |
| 75- | 007 | 4 | 80.69 | .00720 | .04408 |
| 75- | 009 | 5 | 76.67 | .01021 | .06249 |
| 75- | 011 | 6 | 77.17 | .01132 | .06932 |
| 75- | 013 | 7 | 76.96 | .01055 | .06458 |
| 75- | 015 | 8 | 78.40 | .01123 | .06877 |
| 73- | 175 | 9 | 67.58 | .00915 | .05600 |
| 74- | 132 | 10 | 77.02 | .00763 | .04674 |
| 74- | 134 | 11 | 81.80 | .01615 | .09891 |
| 74- | 193 | 12 | 61.65 | .00974 | .05964 |
| 74- | 211 | 13 | 82.87 | .01124 | .06884 |
| 73- | 176 | 14 | 66.78 | .00915 | .05606 |
| 74- | 111 | 15 | 41.83 | .00611 | .03739 |
| 74- | 112 | 16 | 42.74 | .01294 | .07924 |
| 74- | 113 | 17 | 39.20 | .00582 | .03566 |
| 75- | 111 | 18 | 61.58 | .00975 | .05972 |
| 74- | 005 | 19 | 76.73 | .00642 | .03934 |
| 73- | 007 | 20 | 65.70 | .01046 | .06407 |
| 73- | 008 | 21 | 66.99 | .01050 | .06432 |
| 73- | 009 | 22 | 69.99 | .00608 | .03722 |
| 73- | 010 | 23 | 70.18 | .00837 | .05128 |
| 73- | 162 | 24 | 68.01 | .00458 | .02806 |
| 73- | 151 | 25 | 70.78 | .00583 | .03571 |
| 73- | 152 | 26 | 70.93 | .01127 | .06899 |
| 73- | 153 | 27 | 74.79 | .01233 | .07550 |
| 73- | 154 | 28 | 75.44 | .01138 | .06966 |
| 73- | 155 | 29 | 59.52 | .00851 | .05208 |
| 73- | 156 | 30 | 61.38 | .01402 | .08585 |
| 73- | 157 | 31 | 64.38 | .01072 | .06567 |
| BFS- | 115A | 32 | 57.81 | .00626 | .03831 |
| BFS- | 115B | 33 | 57.86 | .00854 | .05233 |
| 75- | 101A | 34 | 57.71 | .00953 | .05834 |
| 75- | 101B | 35 | 57.31 | .00864 | .05291 |
| BFS- | 17A | 36 | 60.20 | .01141 | .06985 |
| BFS- | 17B | 37 | 60.17 | .01122 | .06872 |
| 73- | 183 | 38 | 66.48 | .00881 | .05397 |

• INDICATES CHANNEL FOR WHICH NO TEMPERATURE COEFFICIENT WAS PROVIDED.

AVERAGE TEMPERATURE (DEG.C) AT FLOAT ALTITUDE = 51.84

Table 5 (contd)

| ORGANIZATION CODE | MODULE NUMBER | | AMO, SOLAR SIM. 1 AU, 28 DEG.C PRE-FLT | POS-FLT | COMPARISON, SOLAR SIMULATOR & FLT PRE-FLT VS. POS-FLT (PERCENT) | FLIGHT VS. PRE-FLT (PERCENT) | COMMENTS |
|---|---|---|---|---|---|---|---|
| JPL | 75- | 001 | 72.15 | 71.70 | .62 | -.85 | |
| JPL | 75- | 003 | 77.20 | 77.00 | .26 | -1.82 | |
| JPL | 75- | 005 | 78.95 | 79.07 | -.15 | -1.15 | |
| JPL | 75- | 007 | 81.74 | 81.55 | .23 | -1.31 | |
| JPL | 75- | 009 | 77.67 | 77.35 | .41 | -1.30 | |
| JPL | 75- | 011 | 78.10 | 77.85 | .32 | -1.21 | |
| JPL | 75- | 013 | 76.95 | 77.59 | -.83 | .01 | |
| JPL | 75- | 015 | 79.20 | 78.90 | .38 | -1.02 | |
| JPL | 73- | 175 | 68.08 | 68.42 | -.50 | -.74 | |
| AFAPL | 74- | 132 | 76.80 | 76.81 | -.01 | .28 | |
| AFAPL | 74- | 134 | 82.45 | 81.70 | .91 | -.79 | |
| RAE | 74- | 193 | 60.34 | 59.95 | .65 | 2.13 | |
| SAT | 74- | 211 | 82.78 | 82.87 | -.11 | .11 | |
| JPL | 73- | 176 | 67.70 | 67.95 | -.37 | -1.38 | CHIPPED CELL |
| GSFC | 74- | 111 | 48.20 | 48.29 | -.19 | -15.22 | |
| GSFC | 74- | 112 | 45.05 | 45.50 | -1.00 | -5.42 | |
| GSFC | 74- | 113 | 38.82 | 38.96 | -.36 | .97 | |
| U OF T | 75- | 111 | 63.77 | 63.48 | .45 | -3.55 | |
| JPL | 74- | 005 | 76.80 | 77.87 | -1.39 | -.09 | |
| JPL | 73- | 007 | 66.68 | 66.71 | -.04 | -1.49 | |
| JPL | 73- | 008 | 68.11 | 67.95 | .23 | -1.68 | |
| JPL | 73- | 009 | 70.62 | 70.64 | -.03 | -.90 | |
| JPL | 73- | 010 | 71.10 | 71.50 | -.56 | -1.31 | |
| JPL | 73- | 182 | 68.70 | 68.75 | -.07 | -1.02 | |
| JPL | 73- | 151 | 70.90 | 70.40 | .71 | -.17 | |
| JPL | 73- | 152 | 70.82 | 70.11 | 1.00 | .15 | |
| JPL | 73- | 153 | 74.60 | 74.44 | .21 | .25 | |
| JPL | 73- | 154 | 75.80 | 75.06 | .98 | -.47 | |
| JPL | 73- | 155 | 60.44 | 60.25 | .31 | -1.55 | |
| JPL | 73- | 156 | 62.43 | 61.95 | .77 | -1.72 | |
| JPL | 73- | 157 | 65.39 | 64.60 | 1.21 | -1.56 | |
| JPL | BFS- | 115A | 58.30 | 57.36 | 1.61 | -.85 | |
| JPL | BFS- | 115B | 59.00 | 57.71 | 2.19 | -1.98 | |
| NEC | 75- | 101A | 63.35 | 61.60 | 2.76 | -9.78 | |
| NEC | 75- | 101B | 63.00 | 61.05 | 3.10 | -9.92 | |
| JPL | BFS- | 17A | 60.17 | 60.68 | -.85 | .06 | |
| JPL | BFS- | 17B | 60.00 | 60.35 | -.58 | .28 | |
| JPL | 73- | 183 | 68.15 | 68.23 | -.12 | -2.52 | CHIP. FILT |

Table 6. Balloon flight 75-2 at 118,400 ft, June 6, 1975

| MODULE NUMBER | CHANNEL NUMBER | TEMP. INTENSITY ADJ. AVERAGE | 95 PERCENT CONF. LIMITS | STANDARD DEVIATION |
|---|---|---|---|---|
| 75- 002 | 1 | 67.21 | .01415 | .08666 |
| 75- 004 | 2 | 71.80 | .01187 | .07272 |
| 75- 006 | 3 | 77.70 | .01051 | .06434 |
| 75- 008 | 4 | 80.34 | .01313 | .08041 |
| 75- 010 | 5 | 76.47 | .01781 | .10907 |
| 75- 012 | 6 | 76.86 | .02142 | .13114 |
| 75- 014 | 7 | 79.20 | .01204 | .07372 |
| 75- 016 | 8 | 78.11 | .01405 | .08607 |
| 73- 175 | 9 | 67.25 | .00896 | .05484 |
| 74- 136 | 10 | 81.29 | .01323 | .08103 |
| 74- 203 | 11 | 88.79 | .01053 | .06449 |
| 74- 204 | 12 | 88.74 | .01329 | .08141 |
| 74- 213 | 13 | 82.63 | .01661 | .10173 |
| 73- 176 | 14 | 66.31 | .01386 | .08487 |
| 74- 114 | 15 | 31.09 | .01295 | .07932 |
| 74- 115 | 16 | 13.44 | .00865 | .05295 |
| 75- 113 | 17 | 63.62 | .01511 | .09253 |
| 75- 115 | 18 | 63.73 | .01419 | .08690 |
| 75- 121 | 19 | 76.83 | .01995 | .12218 |
| 75- 122 | 20 | 66.95 | .01962 | .12015 |
| 75- 123 | 21 | 73.30 | .01897 | .11618 |
| 75- 124 | 22 | 66.74 | .01167 | .07148 |
| 73- 142 | 23 | 57.21 | .01561 | .09562 |
| 73- 182 | 24 | 67.88 | .01115 | .06826 |
| 73- 143 | 25 | 66.85 | .00689 | .04221 |
| BFS- 409 | 26 | 68.22 | .00861 | .05273 |
| BFS- 505 | 27 | 65.18 | .01518 | .09295 |
| 73- 159 | 28 | 78.82 | .01709 | .10467 |
| 73- 160 | 29 | 79.46 | .02001 | .12256 |
| 73- 171 | 30 | 74.75 | .01307 | .08002 |
| 73- 174 | 31 | 80.44 | .01222 | .07486 |
| 74- 131 | 32 | 75.38 | .01358 | .08313 |
| 74- 205 | 33 | 91.16 | .00615 | .03768 |
| 75- 102A | 34 | 59.57 | .00945 | .05788 |
| 75- 102B | 35 | 58.70 | .01710 | .10469 |
| BFS- 17A | 36 | 60.21 | .01669 | .10192 |
| BFS- 17B | 37 | 60.47 | .01868 | .11440 |
| 73- 183 | 38 | 66.94 | .01571 | .09619 |

* INDICATES CHANNEL FOR WHICH NO TEMPERATURE COEFFICIENT WAS PROVIDED.

AVERAGE TEMPERATURE (DEG.C) AT FLOAT ALTITUDE = 47.88

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Table 6 (contd)

| ORGAN-IZATION CODE | MODULE NUMBER | | AMO, SOLAR SIM. 1 AU, 28 DEG.C PRE-FLT | POS-FLT | COMPARISON, SOLAR SIMULATOR & FLT PRE-FLT VS. POS-FLT (PERCENT) | FLIGHT VS. PRE-FLT (PERCENT) | COMMENTS |
|---|---|---|---|---|---|---|---|
| JPL | 75- | 2 | 67.70 | 67.89 | -.28 | -.73 | |
| JPL | 75- | 4 | 73.00 | 72.60 | .55 | -1.66 | |
| JPL | 75- | 6 | 78.60 | 78.56 | .05 | -1.16 | |
| JPL | 75- | 8 | 81.05 | 80.60 | .56 | -.88 | |
| JPL | 75- | 10 | 77.45 | 77.18 | .35 | -1.29 | |
| JPL | 75- | 12 | 77.77 | 77.40 | .48 | -1.19 | |
| JPL | 75- | 14 | 78.94 | 79.45 | -.65 | .33 | |
| JPL | 75- | 16 | 77.50 | 78.40 | -1.16 | .78 | |
| JPL | 73- | 175 | 68.08 | 67.94 | .21 | -1.24 | |
| AFAPL | 74- | 136 | 81.99 | 81.90 | .11 | -.86 | |
| COMSAT | 74- | 203 | 89.15 | 88.70 | .50 | -.40 | |
| COMSAT | 74- | 204 | 88.75 | 88.52 | .26 | -.01 | |
| SAT | 74- | 213 | 82.50 | 82.57 | -.08 | | |
| JPL | 73- | 176 | 67.70 | 66.96 | 1.09 | -2.09 | |
| GSFC | 74- | 114 | 27.19 | 27.03 | .59 | 12.55 | |
| GSFC | 74- | 115 | 12.60 | 12.76 | -1.27 | 6.25 | |
| U OF T | 75- | 113 | 65.66 | 65.44 | .34 | -3.21 | |
| U OF T | 75- | 115 | 65.81 | 65.47 | .52 | -3.27 | |
| ESTEC | 75- | 121 | 77.60 | 76.85 | .97 | -1.00 | |
| ESTEC | 75- | 122 | 68.70 | 68.65 | .07 | -2.61 | |
| ESTEC | 75- | 123 | 74.70 | 73.60 | 1.47 | -1.91 | |
| ESTEC | 75- | 124 | 67.77 | 67.67 | .15 | -1.55 | |
| ESTEC | 73- | 142 | 57.80 | 57.10 | 1.21 | -1.04 | |
| JPL | 73- | 182 | 68.70 | 68.65 | .07 | -1.20 | |
| ESTEC | 73- | 143 | 69.30 | 68.75 | .79 | -3.67 | |
| JPL | BFS- | 409 | 69.35 | 68.77 | .84 | -1.66 | |
| JPL | BFS- | 505 | 66.10 | 66.29 | -.29 | -1.41 | |
| JPL | 73- | 159 | 79.80 | 79.40 | .50 | -1.25 | |
| JPL | 73- | 160 | 80.25 | 80.00 | .31 | -1.00 | |
| JPL | 73- | 171 | 75.15 | 75.00 | .20 | -.54 | |
| JPL | 73- | 174 | 80.60 | 80.67 | -.09 | -.20 | |
| AFAPL | 74- | 131 | 75.36 | 75.10 | .35 | .03 | |
| COMSAT | 74- | 205 | 90.90 | 89.72 | 1.30 | .28 | |
| NEC | 75- | 102A | 64.60 | 63.47 | 1.75 | -8.43 | |
| NEC | 75- | 102B | 63.50 | 62.38 | 1.76 | -8.17 | |
| JPL | BFS- | 17A | 60.17 | 60.47 | -.50 | .06 | |
| JPL | BFS- | 17B | 60.00 | 60.32 | -.53 | .78 | |
| JPL | 73- | 183 | 68.15 | 67.77 | .56 | -1.81 | |

**Table 7. Balloon flight 76-3 at 116,850 ft on June 10, 1977**

| CHANNEL NUMBER | MODULE NUMBER | ORGANIZATION CODE | TEMP. INTENSITY ADJ. AVERAGE | 95 PERCENT CONF. LIMITS | STANDARD DEVIATION | AMO, SOLAR SIM. 1 AU, 28 DEG.C PRE-FLT | POS-FLT | COMPARISON, SOLAR SIMULATOR & FLT PRE-FLT VS. POS-FLT (PERCENT) | FLIGHT VS. PRE-FLT (PERCENT) | COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | SP20 | JPL | 53.06 | .00642 | .04537 | 56.35 | 55.50 | -1.51 | -5.84 | |
| 2 | 77-102 | TRW | 72.02 | .00506 | .03578 | 72.96 | 72.45 | -.70 | -1.29 | |
| 3 | 77-005 | JPL | 76.05 | .00885 | .06259 | 76.35 | 75.80 | -.72 | -.39 | VIOLET |
| 4 | 77-001 | JPL | 66.85 | .00673 | .04760 | 68.00 | 67.80 | -.29 | -1.69 | SOLAREX-.002 |
| 5 | 74-205 | JPL | 91.28 | .00517 | .03654 | 88.79 | 88.50 | -.33 | 2.81 | BLACK |
| 6 | 77-124 | OCLI | 79.13 | .00144 | .01016 | 79.00 | 78.28 | -.91 | .17 | |
| 7 | 77-101 | TRW | 74.65 | .00491 | .03473 | 75.80 | 75.65 | -.20 | -1.52 | |
| 8 | SX-21 | JPL | 75.13 | .00201 | .01423 | 76.76 | 76.05 | -.92 | -2.12 | |
| 9 | ST-20 | JPL | 63.63 | .00546 | .03861 | 64.30 | 63.40 | -1.40 | -1.04 | |
| 10 | 73-183 | JPL | 66.82 | .00316 | .02236 | 68.32 | 68.33 | .01 | -2.19 | T100K-T4 |
| 11 | 77-110 | TRW | 73.71 | .00558 | .03946 | 73.86 | 73.63 | -.31 | -.21 | |
| 12 | 77-122 | OCLI | 73.08 | .00618 | .04370 | 73.64 | 73.30 | -.46 | -.76 | |
| 13 | BFS-17A | JPL | 60.46 | .00390 | .02757 | 60.75 | 60.85 | .16 | -.48 | |
| 14 | 77-113 | TRW | 78.59 | .00245 | .01733 | 78.95 | 78.80 | -.19 | -.46 | |
| 15 | 77-003 | JPL | 77.22 | .00618 | .04370 | 77.90 | 77.64 | -.33 | -.87 | GREEN |
| 16 | 77-007 | JPL | 60.99 | .00681 | .04814 | 62.21 | 61.80 | -.66 | -1.95 | GAAS |
| 17 | SX-20 | JPL | 74.84 | .00264 | .01868 | 76.15 | 76.00 | -.20 | -1.72 | |
| 18 | 77-004 | JPL | 76.78 | .00738 | .05217 | 77.78 | 77.60 | -.23 | -1.28 | GREEN |
| 19 | SP-21 | JPL | 54.89 | .00665 | .04700 | 57.78 | 57.73 | -.09 | -5.01 | |
| 20 | 77-105 | TRW | 72.71 | .00508 | .03589 | 74.40 | 74.18 | -.30 | -2.27 | |
| 21 | 76-001 | JPL | 67.38 | .00716 | .05065 | 68.95 | 68.90 | -.07 | -2.28 | T5K-T3 |
| 22 | 77-123 | OCLI | 77.20 | .00698 | .04932 | 77.50 | 77.05 | -.58 | -.39 | |
| 23 | 73-182 | JPL | 67.96 | .00639 | .04516 | 69.00 | 68.93 | -.10 | -1.51 | T100K-T1 |
| 24 | 77-103 | TRW | 71.49 | .00513 | .03628 | 72.45 | 72.43 | -.03 | -1.32 | |
| 25 | MO-05 | JPL | 70.06 | .00727 | .05139 | 70.92 | 70.94 | .03 | -1.22 | |
| 26 | 77-008 | JPL | 53.24 | .00705 | .04988 | 54.71 | 54.66 | -.09 | -2.70 | GAAS |
| 27 | 77-114 | TRW | 78.77 | .00642 | .04537 | 79.22 | 78.80 | -.53 | -.57 | |
| 28 | ST-21 | JPL | 64.91 | .00718 | .05080 | 66.00 | 65.45 | -.83 | -1.65 | |
| 29 | 77-006 | JPL | 76.30 | .00513 | .03628 | 77.15 | 76.30 | -1.10 | -1.10 | VIOLET |
| 30 | 77-002 | JPL | 71.04 | .00659 | .04657 | 71.79 | 70.90 | -1.24 | -1.04 | SL.002 TEX |
| 31 | 77-111 | TRW | 73.02 | .00000 | .00002 | 73.67 | 73.60 | -.10 | -.89 | |
| 32 | BFS-517A | JPL | 21.45 | .00456 | .03227 | 21.86 | 21.77 | -.41 | -1.88 | RED FILTER |
| 33 | BFS-517B | JPL | 21.69 | .00419 | .02966 | 21.93 | 21.30 | -2.87 | -1.08 | BLUE FILTER |
| 34 | BFS-517C | JPL | 64.72 | .00673 | .04760 | 65.40 | 65.40 | .00 | -1.04 | 1X2 |
| 39 | 100-MV | | 102.53* | .00503 | .03555 | .00 | .00 | .00 | .00 | |
| 40 | 80-MV | | 82.17* | .00201 | .01423 | .00 | .00 | .00 | .00 | |
| 41 | 50-MV | | 51.34* | .00489 | .03457 | .00 | .00 | .00 | .00 | |
| 42 | 0-MV | | .00* | .00000 | .00000 | .00 | .00 | .00 | .00 | |

* INDICATES CHANNEL FOR WHICH NO TEMPERATURE COEFFICIENT WAS PROVIDED.

AVERAGE TEMPERATURE (DEG.C) AT FLOAT ALTITUDE = 56.53

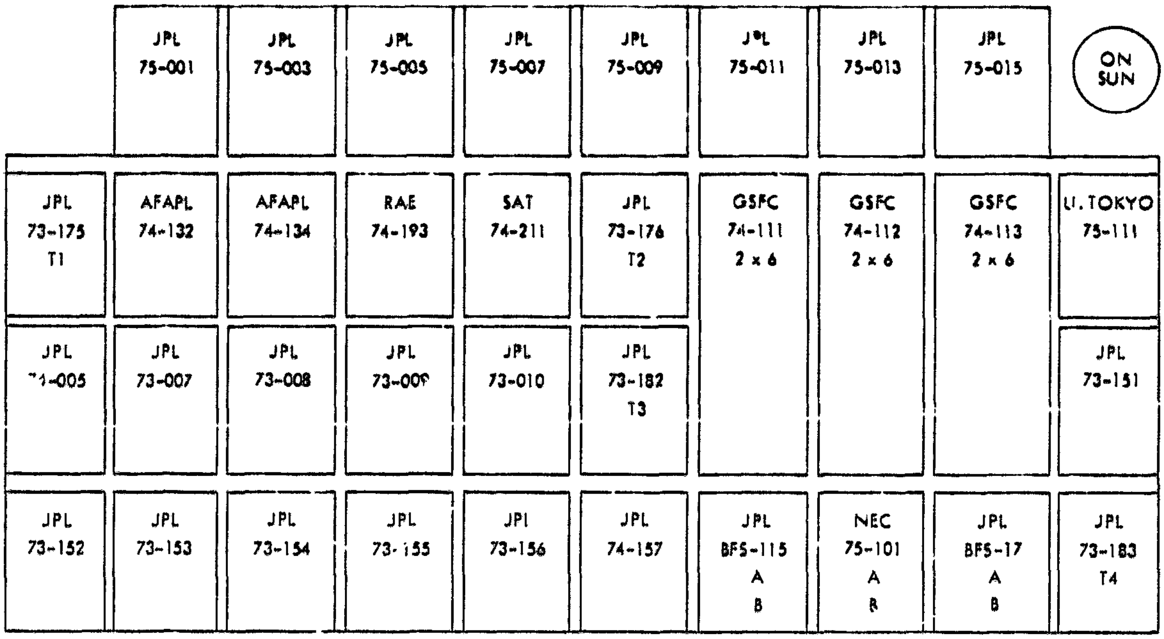


**Fig. 5. Solar cell calibration module location chart, balloon flight 75-1**

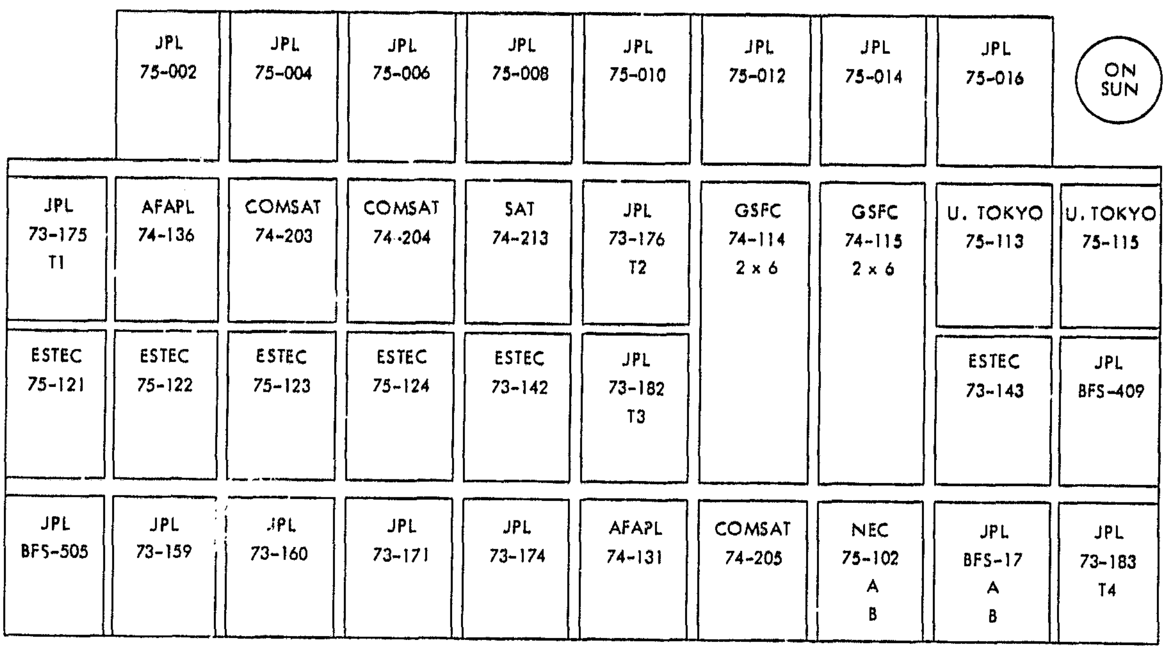


**Fig. 6. Solar cell calibration module location chart, balloon flight 75-2**

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | JPL SX10 | JPL SL10 | JPL ST10 | JPL SP10 | JPL 74-205 BLACK | JPL SX11 | JPL SL11 | HAC 76-106 | ON SUN |
| COMSAT 76-125 A B | | JPL 73-183 T4 | JPL SX12 | JPL SL12 | JPL BFS17 A | HAC 76-105 | JPL ST11 | JPL SP11 | |
| | | JPL ST12 | JPL SP12 | HAC 76-103 | JPL SX13 | JPL SL13 | JPL 76-001 T3 | JPL ST13 | JPL SP13 |
| | | HAC 76-101 | JPL TSS 31 | JPL TSS 32 | JPL TSS 33 | JPL TSS 34 | JPL TSS 35 | JPL TSS 37 | |

**Fig. 7. Solar cell calibration module location chart, balloon flight 76-2**

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | JPL SX10 | JPL SL10 | JPL ST10 | JPL SF10 | JPL 74-205 BLACK | JPL SX11 | JPL SL11 | HAC 76-101 | ON SUN |
| COMSAT 76-125 A B | | JPL 73-183 T4 | JPL SX12 | JPL SL12 | JPL BFS 17 A | HAC 76-105 | JPL ST11 | JPL SP11 | JPL 76-002 |
| | | JPL ST12 | JPL SP12 | HAC 76-103 | JPL SX13 | JPL SL13 | JPL 76-001 T3 | JPL ST13 | JPL SP13 |
| | | HAC 76-106 | JPL TSS 31 | JPL TSS 32 | JPL TSS 33 | JPL TSS 34 | JPL TSS 35 | JPL TSS 37 | JPL 76-003 |

**Fig. 8. Solar cell calibration module location chart, balloon flight 76-3**

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | SP20 | TRW 77-102 | JPL 77-005 VIOLET | JPL 77-001 0.002 SOLAREX | 74-205 BLACK | OCLI 77-124 | TRW 77-101 | SX21 | ON SUN |
| | ST20 | 73-183 T4 | TRW 77-110 | OCLI 77-122 | BFS 17A | TRW 77-113 | JPL 77-003 GREEN | JPL 77-007 GaAs | |
| | SX20 | JPL 77-004 GREEN | SP21 | TRW 77-105 | 76-001 T3 | OCLI 77-123 | 73-182 T1 | TRW 77-103 | |
| | MO-05 | JPL 77-008 GaAs | TRW 77-114 | ST21 | JPL 77-006 VIOLET | JPL 77-002 SL 0.002 TEX | TRW 77-1111 | BFS-17 A B C | |

**Fig. 9. Solar cell calibration module location chart, balloon flight 77-1**

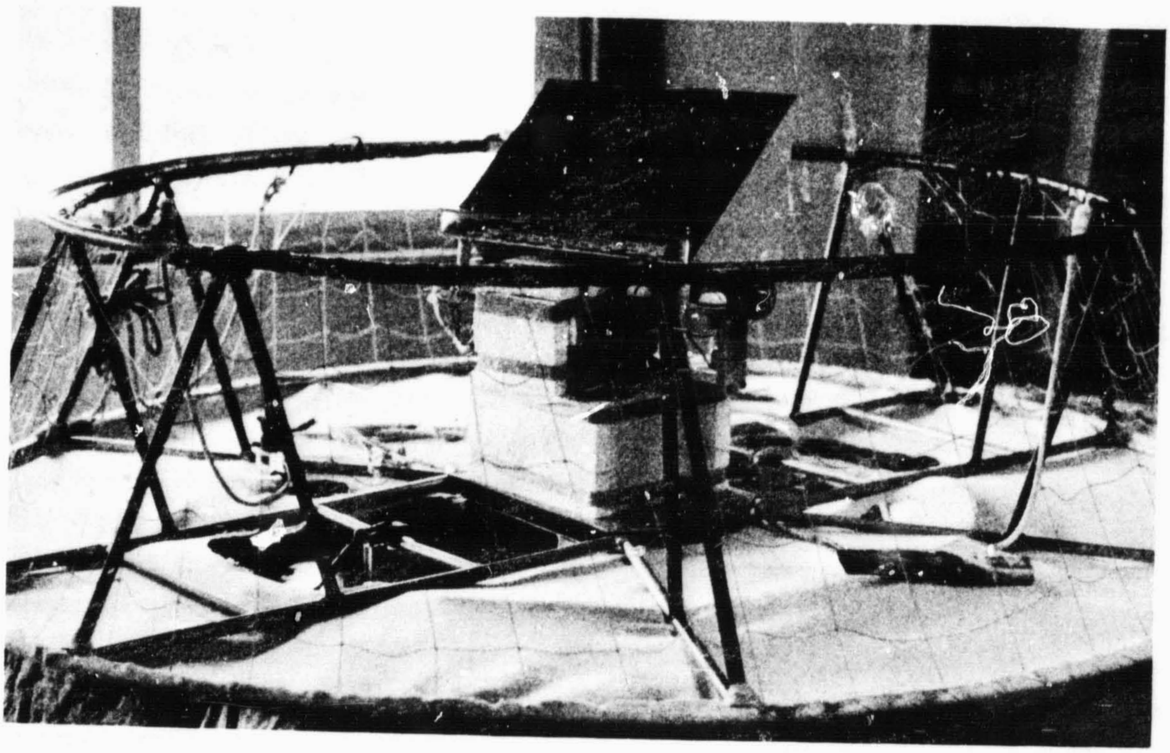

**Fig. 10. Sun tracker mounted on balloon top hoop**

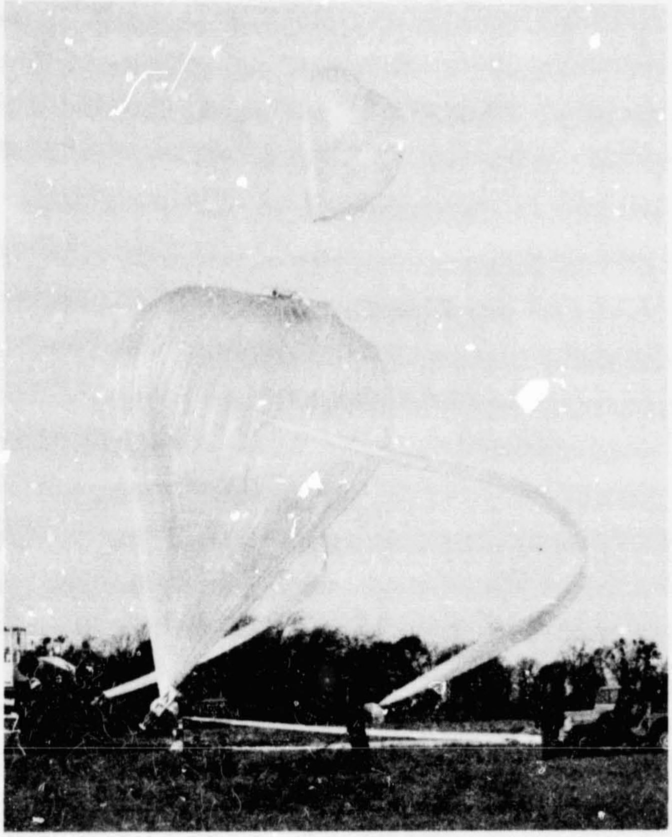

Fig. 11. Balloon system with top-mounted Sun tracker

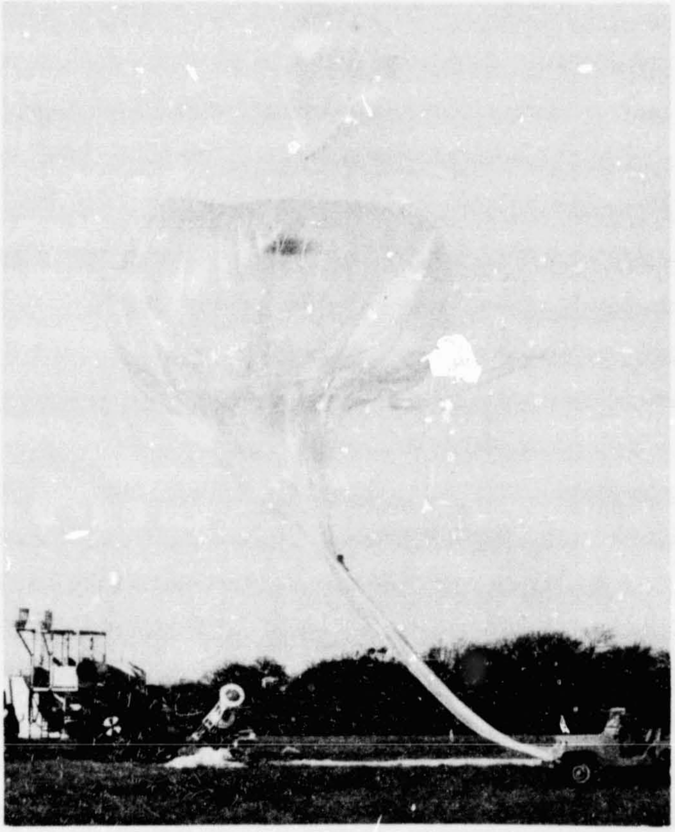

Fig. 12. Balloon launch with top-mounted Sun tracker

## I. Flight 77-1 (NSBF 1030P)

The 0802-hours launch on August 11, 1977 was uneventful as was the float and termination phases of this flight. The tracker was energized at 1030 hours at an altitude of 35.3 km (116 kft) with Sun lock accomplished at 1033 hours. Termination of the flight occurred at 1507 hours. Since the last flight (76-3), a method of verification of separation of the top payload was developed by the NSBF personnel and worked very well on this flight.

All data during the four-hour float period were of high quality. On return to JPL the data from around solar noon were reduced to provide the cell calibration data. The computer printout for this flight is found in Table 8.

# IV. Data Reduction Changes

In an effort to improve the quality of the calibration data greater flexibility is continually being added to the computer data reduction program. The most recent change (effective with Flight 76-3) permits the computer to run sequential data scans between two clock times (i.e., 15 minutes before to 15 minutes after solar noon). Data from each 200 data points can now be averaged and the most representative scan used for the calibration data on the cells.

In addition to the format changes mentioned earlier, JPL has provided for a computer output data page for each participant listing all their specific cells. This page provides early data to be returned with each participant's cells. As other methods to provide more accurate or representative data becomes available, they will be incorporated into the program. JPL has endeavored to provide the highest quality and most accurate data available from the Balloon Flight Solar Cell Calibration Program in a timely manner after each flight.

# V. Conclusions

JPL has been calibrating solar cells using high-altitude balloons since 1962. Table 9 lists the data generated on one standard cell (BFS-17A) that has flown on most of the calibration flights during this program. Repeatibility of this cell to its average calibration value is better than 1%. The conclusions to be drawn are: (1) balloon flight calibration of solar cells is a stable and reliable method of obtaining AM0 calibrations, and (2) silicon solar cells when properly used and cared for are reliable standards for a number of years.

**Table 8. Balloon flight 77-1 at 118,367 ft on August 11, 1977**

| CHANNEL NUMBER | MODULE NUMBER | ORGANIZATION CODE | TEMP. INTENSITY ADJ. AVERAGE | 95 PERCENT CONF. LIMITS | STANDARD DEVIATION | AMO, SOLAR SIM. 1 AU, 28 DEG.C PRE-FLT | POS-FLT | COMPARISON, SOLAR SIMULATOR & FLT PRE-FLT VS. POS-FLT (PERCENT) | FLIGHT VS. PRE-FLT (PERCENT) | COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|
| 2 | SL10 | JPL | 67.92 | .00509 | .03599 | 67.17 | 49.65 | -26.08 | 1.11 | CELL CHIPPED |
| 3 | ST10 | JPL | 51.06 | .00656 | .04640 | 52.35 | 51.59 | -1.45 | -2.46 | CELL CHIPPED |
| 4 | SP10 | JPL | 53.18 | .00464 | .03281 | 54.69 | .00 | .00 | -2.77 | RES DAMAGED |
| 5 | 74-205 | JPL | 91.09 | .00704 | .04978 | 88.47 | 88.87 | .45 | 2.96 | BLACK |
| 6 | SX11 | JPL | 69.34 | .00364 | .02571 | 70.87 | 70.68 | -.27 | -2.15 | |
| 7 | SL11 | JPL | 68.73 | .00311 | .02197 | 68.93 | 68.73 | -.29 | -.29 | |
| 8 | 76-101 | HUGHES | 94.82 | .00627 | .04433 | 93.65 | 93.07 | -.62 | 1.25 | |
| 9 | 76-125A | COMSAT | 88.18 | .00710 | .05023 | 87.32 | 87.38 | .07 | .99 | |
| 10 | 76-125B | COMSAT | 86.21 | .00462 | .03267 | 86.11 | 85.90 | -.24 | .12 | |
| 11 | 73-183 | JPL | 66.84 | .00465 | .03287 | 68.24 | 68.32 | .12 | -2.04 | TEMP-CHIP FL |
| 12 | SX12 | JPL | 72.24 | .00659 | .04661 | 73.03 | 72.97 | -.08 | -1.09 | |
| 13 | SL12 | JPL | 68.24 | .00450 | .03185 | 68.88 | 68.62 | -.38 | -.93 | |
| 14 | BFS-17A | JPL | 60.35 | .00537 | .03797 | 60.56 | 60.79 | .38 | -.35 | |
| 15 | 76-105 | HUGHES | 94.10 | .00374 | .02643 | 93.00 | 92.40 | -.65 | 1.18 | |
| 16 | ST11 | JPL | 46.28 | .00708 | .05003 | 46.70 | 44.99 | -3.66 | -.90 | STAINED |
| 17 | SP11 | JPL | 50.35 | .00460 | .03256 | 51.91 | 51.53 | -.73 | -3.00 | |
| 18 | ST12 | JPL | 51.58 | .00749 | .05299 | 52.83 | 52.87 | .08 | -2.37 | |
| 19 | SP12 | JPL | 50.66 | .00668 | .04723 | 52.41 | 52.30 | -.21 | -3.35 | |
| 20 | 76-103 | HUGHES | 94.43 | .00776 | .05484 | 93.20 | 92.97 | -.25 | 1.32 | |
| 21 | SX13 | JPL | 71.88 | .00606 | .04285 | 72.76 | 72.90 | .19 | -1.20 | |
| 22 | SL13 | JPL | 68.60 | .00702 | .04966 | 68.75 | 68.47 | -.41 | -.22 | |
| 23 | 76-001 | JPL | 67.44 | .00591 | .04179 | 69.01 | 69.05 | .06 | -2.28 | TEMP |
| 24 | ST13 | JPL | 51.61 | .00575 | .04069 | 53.29 | 52.98 | -.58 | -3.15 | |
| 25 | SP13 | JPL | 45.97 | .00555 | .03924 | 49.44 | 48.78 | -1.33 | -7.02 | |
| 26 | 76-106 | HUGHES | 93.49 | .00341 | .024[illegible] | 92.35 | 91.76 | -.64 | 1.23 | |
| 27 | TSS-31 | JPL | 66.96 | .00741 | .05237 | 68.12 | 68.17 | .07 | -1.70 | |
| 28 | TSS-32 | JPL | 67.20 | .00710 | .05018 | 68.45 | 68.49 | .06 | -1.82 | |
| 29 | TSS-33 | JPL | 66.18 | .00717 | .05067 | 67.27 | 67.34 | .10 | -1.63 | |
| 30 | TSS-34 | JPL | 65.86 | .00653 | .04618 | 66.73 | 66.73 | .00 | -1.31 | |
| 31 | TSS-35 | JPL | 66.12 | .00546 | .03861 | 67.42 | 67.35 | -.10 | -1.93 | |
| 32 | TSS-37 | JPL | 64.45 | .00621 | .04393 | 65.77 | 65.80 | .05 | -2.00 | |
| 33 | 76-003 | JPL | 84.34 | .00853 | .06029 | 84.20 | 83.61 | -.70 | .16 | TEXTURED |
| 34 | 76-002 | JPL | 76.43 | .00605 | .04275 | 77.40 | 77.00 | -.52 | -1.25 | VIOLET |
| 39 | 100-MV | | 101.50• | .00648 | .04585 | .00 | .00 | .00 | .00 | |
| 40 | 80-MV | | 81.14• | .00638 | .04515 | .00 | .00 | .00 | .00 | |
| 41 | 50-MV | | 50.60• | .03246 | .22955 | .00 | .00 | .00 | .00 | |
| 42 | 0-MV | | .00• | .00000 | .00000 | .00 | .00 | .00 | .00 | |

• INDICATES CHANNEL FOR WHICH NO TEMPERATURE COEFFICIENT WAS PROVIDED.

AVERAGE TEMPERATURE (DEG.C) AT FLOAT ALTITUDE = 56.41

**Table 9. Repeatability of standard solar cell BFS-17A for 29 flights over a 15-year period**

| Flight date | Output, MV | Flight date | Output, MV |
|---|---|---|---|
| 9/5/63 | 60.07 | 8/5/70 | 60.32 |
| 8/3/64 | 60.43 | 4/5/74 | 60.37 |
| 8/8/64 | 60.17 | 4/23/74 | 60.37 |
| 7/28/65 | 59.90 | 5/8/74 | 60.36 |
| 8/9/65 | 59.90 | 10/12/74 | 60.80 |
| 8/13/65 | 59.93 | 10/24/74 | 60.56 |
| 7/29/65 | 60.67 | 6/6/75 | 60.20 |
| 8/4/66 | 60.25 | 6/27/75 | 60.21 |
| 8/12/66 | 60.15 | 6/10/77 | 60.35 |
| 8/26/66 | 60.02 | 8/11/77 | 60.46 |
| 7/14/67 | 60.06 | | |
| 7/25/67 | 60.02 | Total | 1746.89 |
| 8/4/67 | 59.83 | | |
| 8/10/67 | 60.02 | Average | 60.24 |
| 7/19/68 | 60.31 | | |
| 7/29/68 | 60.20 | Low 59.83 | −0.676% |
| 8/26/69 | 60.37 | | |
| 9/8/69 | 60.17 | High 60.80 | +0.935% |
| 7/28/70 | 60.42 | | |

Average $\bar{x}$ = 60.24

Maximum deviation from $\bar{x}$ = 0.935%

Each data point is an average of 20 to 30 points per flight for period 9/5/63 to 8/5/70.

For flights on 4/5/74 through 7/1/75 each data point is an average of 100 or more flight data points.

For flights starting in September 1975, each data point is an average of 200 data points.

# References


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2. Gas, P. R., "Solar Radiations," in *Handbook of Geophysics*, C. F. Campen, Jr., et al., eds. Chapter 16: pp. 14-32, MacMillan Co., New York, 1960.

3. Greenwood, R. F., *Solar Cell Modules Balloon Flight Standard, Fabrication of*, Procedure No. EP50443, Revision C, Jet Propulsion Laboratory, Pasadena, California, June 11, 1974 (JPL internal document).