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(NASA-CR-170123) RESULTS OF THE 1982 NASA/JPL BALLOON FLIGHT SOLAR CELL CALIBRATION PROGRAM (Jet Propulsion Lab.) 16 p HC A02/MF A01 CSCL 10A N83-21510 Unclas G3/44 03184

Results of the 1982 NASA/JPL Balloon Flight Solar Cell Calibration Program

R.G. Downing
R.S. Weiss

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The research described in this publication was carried out by the Jet Propulsion Laboratory, California Institute of Technology, under contract with the National Aeronautics and Space Administration.

CONTENTS

PREFACE

The work described in this report was performed by the Control and Energy Conversion Division of the Jet Propulsion Laboratory. The flight was conducted with the cooperation of the National Scientific Balloon Facility, located in Palestine, Texas.

ABSTRACT

The 1982 solar cell calibration balloon flight was successfully completed on July 21, meeting all objectives of the program. Twenty-eight modules were carried to an altitude of 36.0 kilometers. The calibrated cells can now be used as reference standards in simulator testing of cells and arrays.

I. INTRODUCTION

The primary source of electrical power for unmanned space vehicles is the direct conversion of solar energy through the use of solar cells. As advancing cell technology continues to modify the spectral response of solar cells to utilize more of the sun's spectrum, designers of solar arrays must have information detailing the impact of these modifications on cell conversion efficiency to be able to confidently minimize the active cell area required and, hence, the mass of the array structure.

Since laboratory simulation of extra-atmospheric solar radiation has not been accomplished on a practical scale with sufficient fidelity, high altitude exposure must be taken as the best representation of space itself. While a theoretical prediction (Reference 1) and experimental evidence have suggested that an altitude greater than 30 kilometers is sufficient to give space equivalent calibration, the final decision as to an adequate altitude must await the results of the space shuttle solar cell calibration experiment scheduled for May 1984.

To reach and maintain the chosen altitude of 36 kilometers, the calibration program makes use of balloons provided and launched by the National Scientific Balloon Facility, Palestine, Texas.

II. PROCEDURE

To insure electrical and mechanical compatibility with other components of the flight system, the cells are mounted by the participants on JPL-supplied standard modules according to directions in Reference 2, which details materials, techniques, and workmanship standards for assembly. The JPL standard module is a machined copper block 3.7 cm x 4.8 cm x 0.3 cm thick, rimmed by 0.3 cm thick fiberglass, painted a high reflectance white, with insulated solder posts and is permanently provided with a precision (0.1 percent, 20 ppm/°C) load resistor appropriate for scaling the cell output to the telemetry constraints. This load resistor, 0.5 ohm for a 2 cm x 2 cm cell, for example, also loads the cell in its short circuit current condition.

The mounted cells are then subjected to preflight measurements in the JPL X25L solar simulator. These measurements, when compared to postflight measurements under the same conditions, may be used to detect cell damage or instabilities. Prior to shipment to the launch facility, the modules are mounted on the sun tracker bed plate (Figure 1). Upon arrival at the Palestine Facility, the tracker and module payload are checked for proper operation, and the data acquisition and Pulse Code Modulation telemetry systems are calibrated. Mounting of the assembly onto the balloon is then accomplished (Figure 2).

At operating altitude the sun tracker bed plate is held pointed at the sun to within ± 1 deg. The response of each module, temperatures of representative modules, sun lock information, and system calibration voltages are sampled twice each second and telemetered to the ground station where they are presented in teletype form for real-time assessment and are also recorded on magnetic tape

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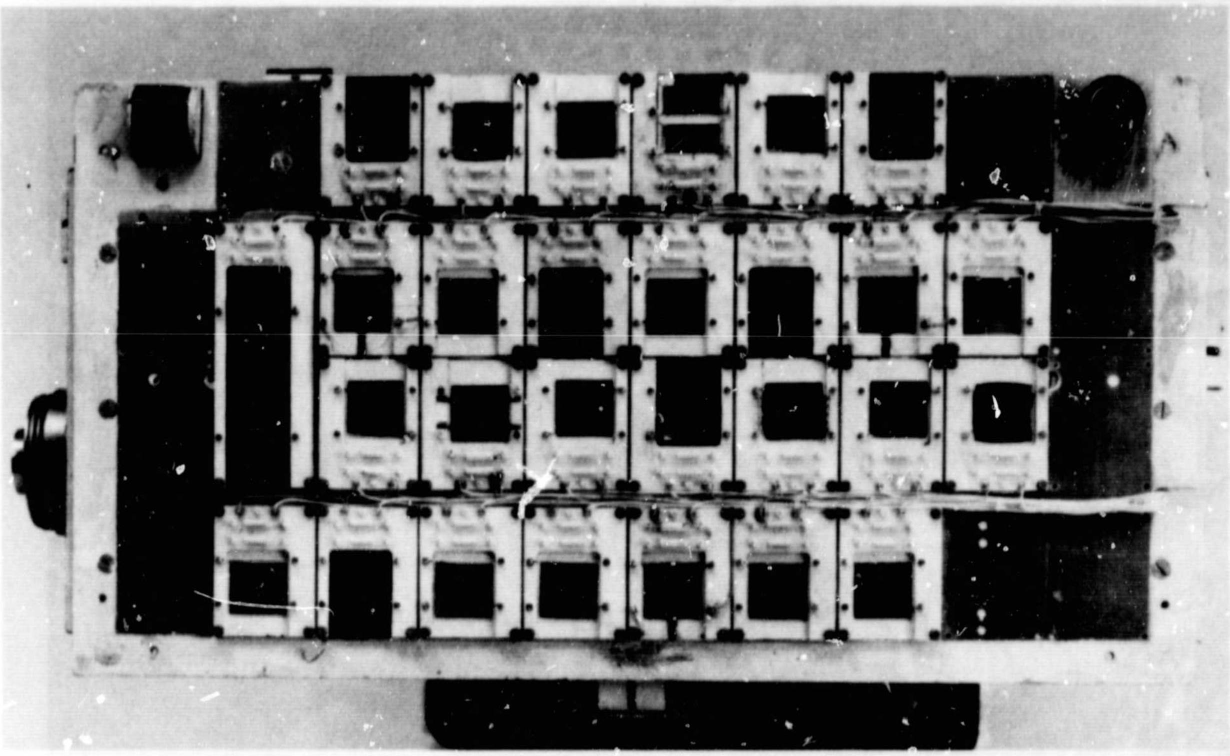

Figure 1. 1982 Solar Module Payload

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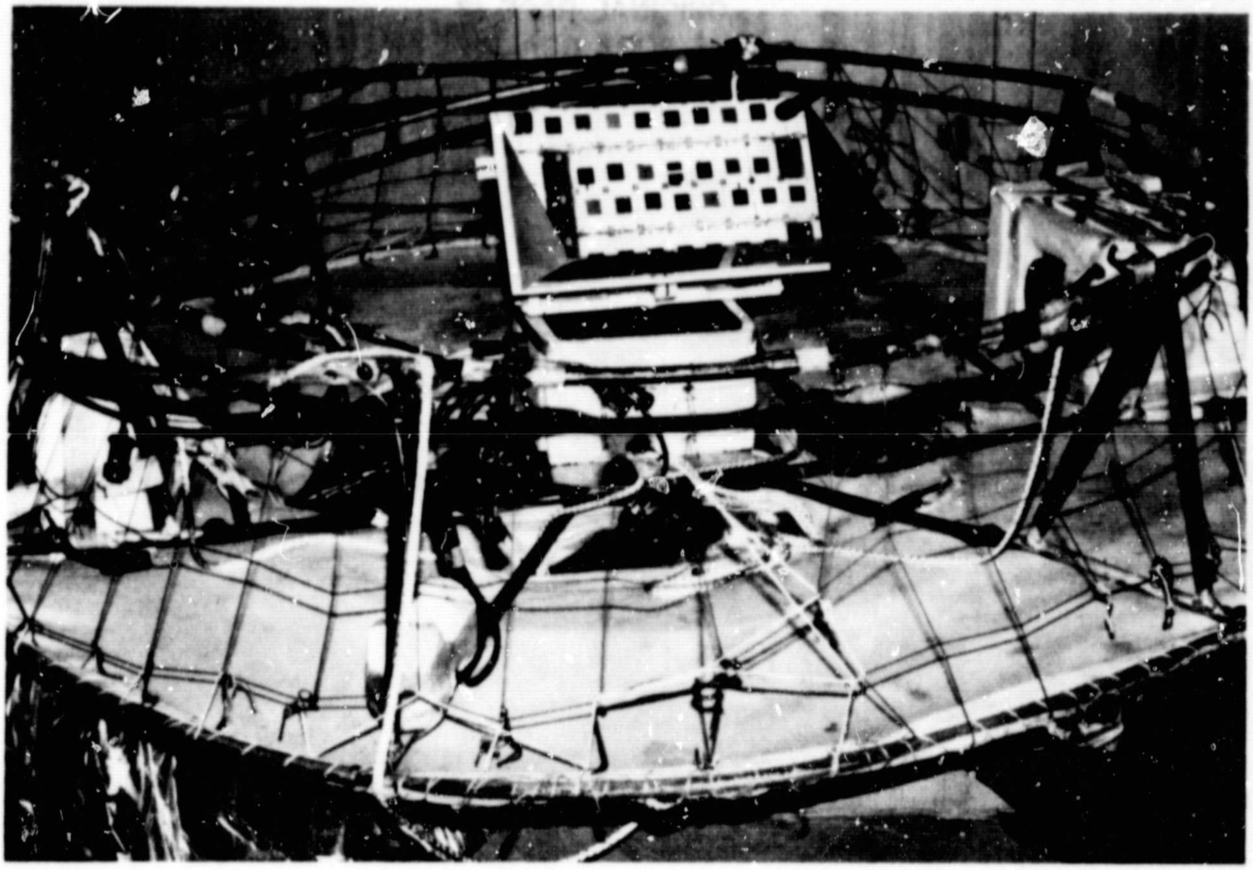

Figure 2. Balloon Mount

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for later processing. Float altitude information is obtained from data supplied by the balloon facility. A plot of altitude in kilometers versus Central Daylight Time for the 1982 flight is shown in Figure 3.

III. SYSTEM DESCRIPTION

A solar tracker mounted in a frame on top of the balloon carries the module payload, while the transmitter of the data link is located in the lower gondola along with batteries for power and ballast for balloon control. At completion of the experiment, the upper payload and lower gondola are returned by parachutes and recovered. A more complete description of the system, including the sun tracker, can be found in Reference 3.

IV. DATA REDUCTION

The raw data as taken from the magnetic tape is corrected for temperature and sun-earth distance according to the formula (Reference 4):

$$V_{28,1} = V_{T,R}(R^2) - \alpha(T-28)$$

where

$V_{T,R}$ = measured module output voltage at temperature T and distance R

R = sun-earth distance in astronomical units

α = module output temperature coefficient (supplied by participants)

T = module temperature in °C.

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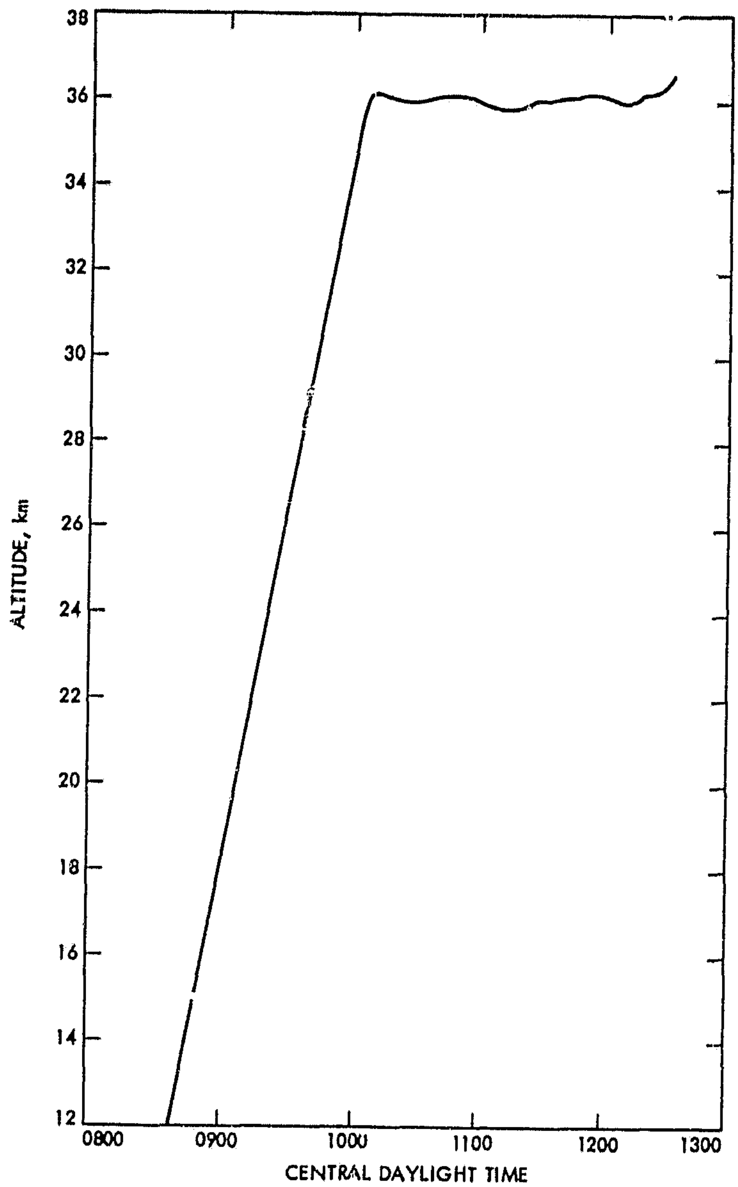

Figure 3. Flight 1982 Altitude Versus Time

The calibration value is taken to be the average of 200 consecutive data points taken around the time of solar noon after indicated temperature stability.

The flight data were thus reduced, and modules with their data and calibration values were returned to the participants. This information is collected in Table 1. The placement of modules on the field of the tracker bed for the 1982 flight is shown in Figure 4.

A detailed discussion of data reduction and an analysis of system error may be found in Reference 3. The error in the calibration values due to radiation absorption and scattering by the residual atmosphere at float altitude is estimated to be less than 0.2 percent (Reference 1).

V. MONITOR CELLS

Several standard modules have been flown repeatedly over the 20-year period of calibration flights. The record of the one with the longest history, BFS-17A, appears in Table 2. This data shows a standard deviation of 0.23 percent and a maximum deviation of 0.58 percent from the mean.

In addition, the uniformity of the solar irradiance (i.e., no spurious reflections, shadowing) over the field of the modules has been demonstrated since the location of this module was changed in that field from flight to flight.

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Table 1. Cell Calibration Data

BALLOON FLIGHT 82-1   DATE 7-21-82   ALTITUDE 36.00 KM   RV=1.0161

CHANNEL NUMBER	MODULE NUMBER	ORGANIZATION CODE	TEMP. INTENSITY ADJ. AVERAGE	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	78-104	HUGHES	81.19	.03732	79.60	79.60	.00	2.00	CUST RERUN
2	79-013	JPL	79.07	.04284	78.90	78.70	-.25	.21	SOL-VJC
3	79-011	JPL	55.14	.04838	55.10	55.00	-.18	.06	HAC GAAS SL
4	BFS-17A	JPL	59.86	.05084	60.70	60.70	.00	-1.38	MONITOR
5	82-120	TRW	75.84	.06333	75.00	75.00	.00	1.12	
6	81-139	HUGHES	24.14	.05410	22.40	22.10	-1.34	7.76	81 SPARE W/F
7	[illegible]-182	HUGHES	73.39	.04973	73.00	72.80	-.27	.54	
8	[illegible]	JPL	67.51	.05081	68.30	68.60	.44	-1.16	T3 MONITOR
9	[illegible]-151	MELCO	61.45	.05455	60.40	60.30	-.17	1.75	GAAS
10	78-110	HUGHES	95.41	.06216	92.80	92.90	.11	2.81	CUST RERUN
11	82-153	SHARP	59.43	.02878	58.70	58.70	.00	1.24	GAAS
12	82-170	HUGHES	77.56	.04872	76.60	76.40	-.26	1.26	K4 3/4
13	73-182	JPL	68.03	.04714	68.50	68.70	.29	-.68	T1 MONITOR
14	83-008	JPL	81.33	.03878	80.70	80.60	-.12	.78	K6 3/4
15	82-122	TRW	75.87	.07464	75.20	75.10	-.13	.90	
16	79-205	JPL	89.61	.07483	86.60	86.70	.12	3.48	TEX
17	82-154	SHARP	58.91	.05033	58.50	58.30	-.34	.71	GAAS
18	82-172	HUGHES	80.69	.06064	79.90	79.60	-.38	.98	K6 3/4
19	79-013	JPL	56.13	.03721	56.50	56.40	-.18	-.66	HAC GAAS WL
20	82-152	MELCO	61.22	.05025	60.50	60.40	-.17	1.20	GAAS
21	82-001	JPL	55.68	.05119	56.00	55.80	-.36	-.57	HAC GAAS SL
22	81-002	JPL	86.82	.05109	84.90	84.80	-.12	2.26	K7
23	82-174	HUGHES	88.35	.06512	86.80	86.50	-.35	1.79	K7
24	80-004	JPL	78.09	.04620	77.10	77.10	.00	1.24	K4 3/4
25	80-006	JPL	80.45	.05202	78.50	78.40	-.13	2.49	K6 1/2
26	73-183	JPL	66.97	.06074	67.70	68.20	.74	-1.09	T4 MONOTOR
27	81-004	JPL	77.52	.04633	76.40	76.20	-.26	1.46	K4 3/4
28	81-006	JPL	72.46	.04437	71.30	71.40	.14	1.63	K4 3/4
39	100-MV		99.33*	.04495	.00	.00	.00	.00	
40	80-MV		79.54*	.04703	.00	.00	.00	.00	
41	50-MV		49.83*	.04952	.00	.00	.00	.00	
42	0-MV		.00*	.00000	.00	.00	.00	.00	

* INDICATES CHANNEL FOR WHICH NO TEMPERATURE COEFFICIENT WAS PROVIDED.

AVERAGE TEMPERATURE (DEG.C) AT FLOAT ALTITUDE = 49.40

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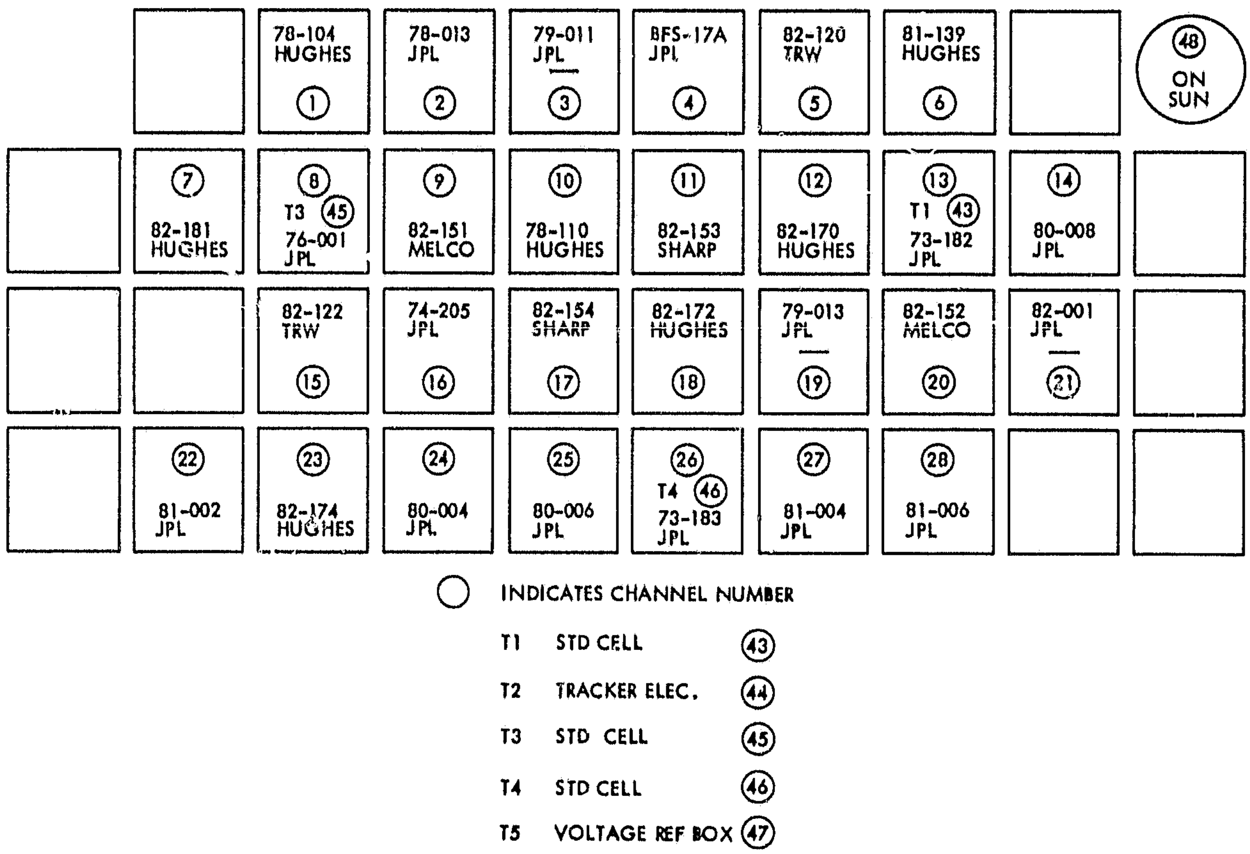

Figure 4. 1982 Module Location Chart

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Table 2. Repeatability of Standard Solar Cell BFS-17A
(34 flights over a 20-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	7/20/78	60.49
7/25/67	60.02	8/8/79	60.14
8/4/67	59.83	7/24/80	60.05
8/10/67	60.02	7/25/81	60.07
7/19/68	60.31	7/21/82	59.86
7/29/68	60.20		
8/26/69	60.37	Mean	60.22
9/8/69	60.17	Std. Deviation	0.23
7/28/70	60.42	Maximum Deviation	0.58

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.

VI. CONCLUSIONS

As emphasized by the history of repeatability of cell BFS-17A, viz, ± 1% (see Table 2), silicon cells, when properly cared for, are stable for long periods of time and may be used as standards with confidence.

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