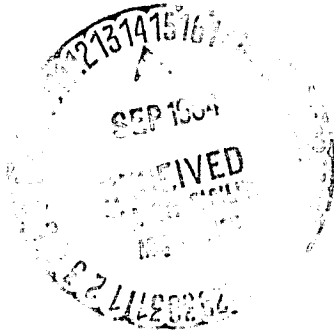


## **General Disclaimer**

### **One or more of the Following Statements may affect this Document**

- This document has been reproduced from the best copy furnished by the organizational source. It is being released in the interest of making available as much information as possible.
- This document may contain data, which exceeds the sheet parameters. It was furnished in this condition by the organizational source and is the best copy available.
- This document may contain tone-on-tone or color graphs, charts and/or pictures, which have been reproduced in black and white.
- This document is paginated as submitted by the original source.
- Portions of this document are not fully legible due to the historical nature of some of the material. However, it is the best reproduction available from the original submission.

SGT



PRELAUNCH ABSOLUTE RADIOMETRIC CALIBRATION OF THE REFLECTIVE BANDS ON THE LANDSAT-4 PROTOFLIGHT THEMATIC MAPPER

(E84-10180) PRELAUNCH ABSOLUTE RADIOMETRIC CALIBRATION OF THE REFLECTIVE BANDS ON THE LANDSAT-4 PROTOFLIGHT THEMATIC MAPPER (NASA) 96 p HC A05/MF A01 N84-31751 CSCL 08B G3/43 00180 Unclas

J. L. Barker

National Aeronautics and Space Administration Goddard Space Flight Center Greenbelt, Maryland 20771

D. L. Ball and K. C. Leung

Computer Sciences Corporation 8728 Colesville Road Silver Spring, Maryland 20910

J. A. Walker

Santa Barbara Research Center 75 Coromar Drive Goleta, California 93017



PRELAUNCH ABSOLUTE RADIOMETRIC CALIBRATION OF THE  
REFLECTIVE BANDS ON THE LANDSAT-4  
PROTOFLIGHT THEMATIC MAPPER

ABSTRACT

The results on the absolute radiometric calibration of the Landsat-4 Thematic Mapper (TM), as determined during pre-launch tests with a 122-centimeter Integrating Sphere (IS), are presented. Detailed results for the best calibration of the protoflight TM are presented, as well as summaries of other tests performed on the sensor from June 1981 to March 1983. The dynamic range of the TM is within a few percent of that required in all bands, except bands 1 and 3. Three detectors failed to pass the minimum SNR specified for their respective bands: band 5, channel 3 (dead), and band 2, channels 2 and 4 (noisy or slow response). Estimates of the absolute calibration accuracy for the TM show that the detectors are typically calibrated to 5-percent absolute error for the reflective bands; 10-percent full-scale accuracy was specified. Ten tests performed to transfer the detector absolute calibration to the internal calibrator show a 5-percent range at full scale in the transfer calibration; however, in two cases band 5 showed a 10-percent difference and a 7-percent difference. These errors are given under the assumption of identical operating conditions for all transfer tests; known temperature sensitivities for the TM have not yet been included.

KEYWORDS: absolute radiometric calibration, dynamic range, noise, signal to noise, gain, offset.

## CONTENTS

Introduction

Absolute Calibration of the Reflective Bands

    Calibration of the Detectors

        Gain and Offset Determination and Dynamic Range

        Signal-to-Noise Determination

    Calibration of the IC

    Estimated Errors in the TM/PF Calibration

Discussion of Results

    Radiometric Performance Requirements

    Calibration of the Detectors

    Calibration of the IC

Recommendations

    Protoflight TM

    Flight Unit TM

Appendix - Spectral Radiances for the IC

References

## INTRODUCTION

Since the 1972 launch of the Landsat-1 satellite, views of natural and manmade features on the surface of the Earth have been routinely provided to data users at a relatively coarse resolution (<150 meters) on a repeating basis (once every 18 days). These images have had a profound effect in many areas, including agricultural production; water resource, rangeland, and forestry management; land use and urban and regional planning; geologic survey and mineral resource management; oceanography; cartography; and disaster warning and relief. Landsat data have been used in many studies involving hydrology, agriculture, geology, forestry, and land resources in addition to urban area delineation.

The latest in the series of Landsat platforms (Landsat-4) was launched from Vandenberg Air Force Base, California, on July 16, 1982. It carried a new sensor, the Thematic Mapper (TM), that will observe the Earth through atmospheric windows in the visible, near-infrared, middle-infrared, and thermal-infrared portions of the electromagnetic spectrum. Although this sensor will return new information to users of Landsat data, its value will depend critically on how well the TM can be calibrated.

Absolute calibration of a satellite instrument (or absolute radiometry) may be defined as the ability to relate the voltage or digital output of the sensor to the input radiance. It includes the determination of the accuracy to which that conversion is made. Absolute calibration demands the use of a carefully controlled and monitored standard source that can be directly related to absolute standards maintained by the National Bureau of Standards (NBS). In a system like Landsat, the calibration must provide the relationship between the digital counts output by the sensor to the radiance input to the detectors in each spectral band. Achieving absolute accuracy to some specified value allows the determination of relative scene spectral radiance. With known solar irradiance at the ground and known atmospheric characteristics, the scene reflectance may be determined. Understanding the sensor characteristics and how they may change with time allows the accurate detection and analysis of temporally varying features and comparison with other sensors such as the Multispectral Scanner (MSS).

This paper discusses the prelaunch absolute calibration of the protoflight TM reflective band detectors and the onboard internal calibrator that will be used to correct observed scene radiance values and to monitor the health of the sensor. The results of the calibration and estimates of its

accuracy are presented. The TM thermal band requires a different approach to calibration and is discussed in Lansing and Barker (1983). The procedures and the standard source used to calibrate the sensor and the internal calibrator are discussed in Barker et al. (1983a). In-orbit characterization of the TM is presented in Barker et al. (1983b). An excellent summary of the TM instrument and its major subsystems is given in Engel (1980).

## ABSOLUTE CALIBRATION OF THE REFLECTIVE BANDS

### CALIBRATION OF THE DETECTORS

#### Gain and Offset Determination and Dynamic Range

Six different detector calibration tests were performed on the Thematic Mapper (TM) with the 122-centimeter (diameter) Integrating Sphere [IS(122)] to determine gain, offset, and the resulting measured dynamic range of the instrument. The dates and test designations for the six calibration tests are given in Barker et al. (1983a). Certain key assumptions must be made to interpret the data from the IS(122) calibrations of the TM:

- Radiance output from the IS(122) in each TM band and at each level is known; that is, the sphere has not changed characteristics from the time of its calibration until the TM calibration is performed.
- Due to alignment and TM operating mode, the detectors are seeing the peak output from the IS(122).
- The TM voltage response to radiance is linear and uniform.

Some of these assumptions may not be true for certain calibration tests.

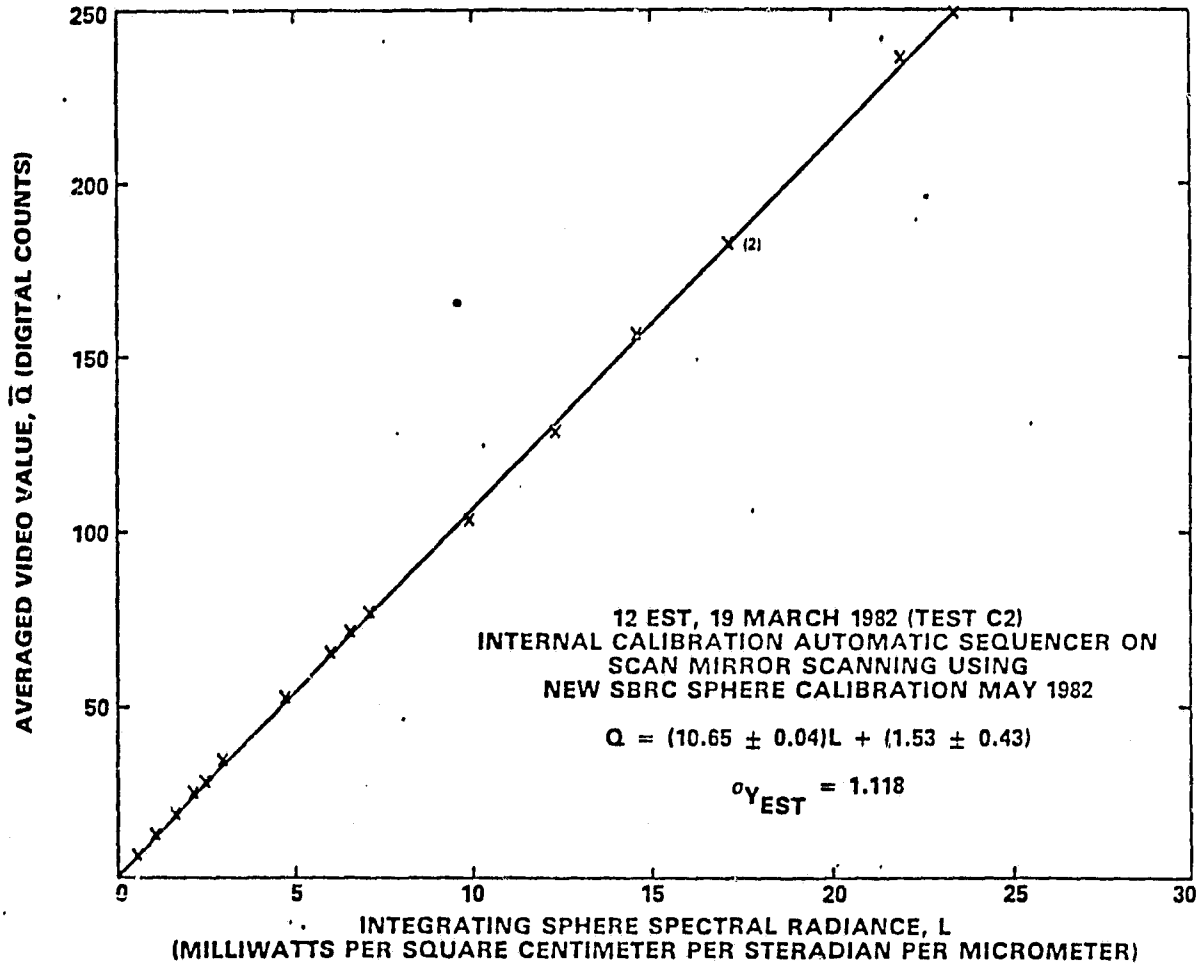
During each test, TM data were acquired as the lamps in the IS(122) were switched off according to the test sequences described in Barker et al. (1983a). The test sequences used in the detector calibration give 20 different radiance levels. These data were analyzed to determine the characteristics of the 96 detectors in the reflective bands. Selection of the proper gain resistors to establish the dynamic range of the individual detectors was performed only once (test A in Barker et al., 1983a).

Sample results for band 3, channel 9, from test C2 are shown in Figure 1; the residuals for that data are shown in Figure 2. Gain, offset, dynamic range, and signal-to-noise

ORIGINAL PAGE IS  
OF POOR QUALITY.

Figure 1

ILLUSTRATIVE TM/PF RADIOMETRIC ABSOLUTE DETECTOR CALIBRATION FOR  
CHANNEL 9 OF BAND 3 (624-693 nm)

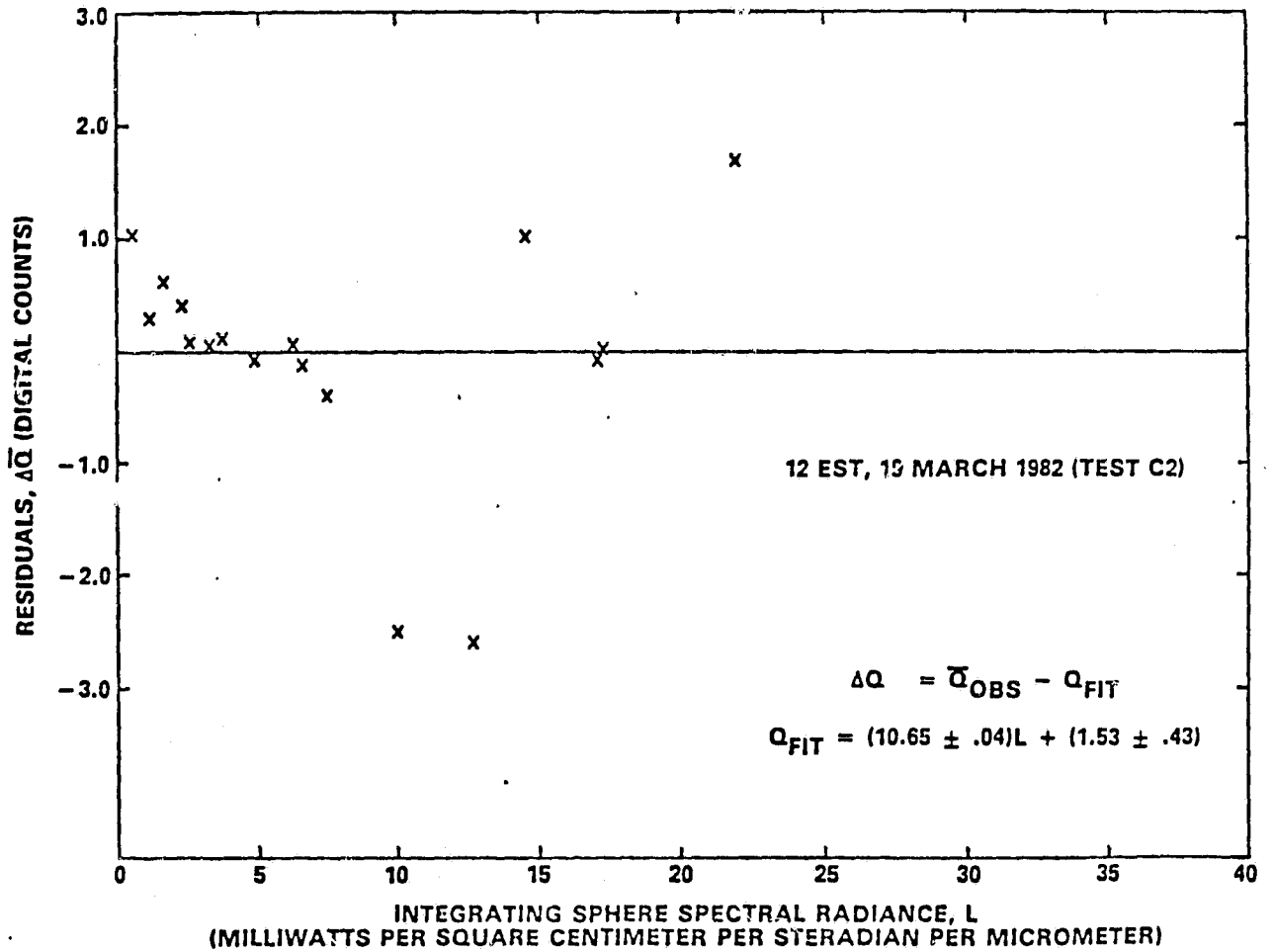


361-BA/AB(9)183  
JLB/DB 2/83

ORIGINAL PAGE IS  
OF POOR QUALITY

Figure 2

ILLUSTRATIVE TM/PF RADIOMETRIC ABSOLUTE DETECTOR CALIBRATION  
RESIDUALS FOR CHANNEL 9 OF BAND 3 (624-693 nm)



361-BA/AB19\*183  
JLB/DB2/83



ratio (SNR) for these parameters for test C2 are given in Tables 1 through 7; statistics for these parameters are given in Tables 8 through 13 for the same test. Results for the other tests are given in Barker et al. (1983c). The gain and offset are calculated by a least-squares fit to data, such as shown in Figures 1 and 2. The calibration equation is as follows:

$$\bar{Q}_{ijk} = g_{ik} L_{ijk} + O_{ik}$$

where  $\bar{Q}_{ijk}$  is the averaged digital count TM output for detector  $i$  (1 to 16) in band  $k$  (1 to 5 and 7) and radiance level  $j$  (1 to 20),  $L_{ijk}$  is the corresponding spectral radiance (milliwatts per square centimeter per steradian per micrometer), and  $g_{ik}$  and  $O_{ik}$  are the derived gain and offset for the  $i$ th detector in band  $k$ . The least-squares fit gives values of  $g_{ik}$  and  $O_{ik}$  as well as their standard errors. The band-averaged gain and offset, the band-averaged SNR, and the derived dynamic range for each band are summarized in Table 14.

The information presented in Tables 1 through 14 should be considered estimates of the best results possible from the TM calibration, not examples of actual calibrations of the TM with the IS(122). A complete set of derived calibration parameters from all six tests has been obtained. A summary of average gains and offsets for three of the tests is given in Table 15. Table 16 shows average gain changes between tests in percent for odd-numbered, even-numbered, and all detectors by band compared to test C2. Although all gains are lower in the March 1982 tests than they were during the initial radiometric calibration, all bands and detectors appear to be within specified values for accuracy and dynamic range. Calculated offset values increased in nearly all bands; values for test C2 are nearly those expected for the background level of two or three digital counts, while those for test A were not.

The apparent systematic nature of the residuals shown in Figure 2 is probably due to the integrating sphere calibration and not to the TM detectors. Other sources of information, such as the sphere calibration of the flight unit TM in July 1982 and the analog-to-digital test measurements on both the protoflight and flight units, show that the TM detectors are extremely linear. Special care was taken in the sphere calibration for the flight unit tests in July 1982, and preliminary results from those tests indicate no such systematic effects.

Table 1

## EXPLANATORY INFORMATION FOR DERIVED RADIOMETRIC CALIBRATION PARAMETER TABLES

**1. CALIBRATION EQUATION:**

$$\text{COUNTS} = \text{GAIN} * \text{RADIANCE} + \text{OFFSET} \quad (Q = G * L + O)$$

**2. UNITS FOR QUANTITIES:**

- A. DIGITAL COUNTS
- B. RADIANCE -- MILLIWATTS PER SQUARE CENTIMETER PER  
STERADIAN PER MICROMETER (i.e., SPECTRAL RADIANCE)
- C. GAIN -- DIGITAL COUNTS PER "RADIANCE UNITS"
- D. OFFSET -- DIGITAL COUNTS

**3. SNR IS SIGNAL TO NOISE RATIO AT:**

- LSR -- LOWER SCENE RADIANCE (SPECIFIED)
- MSL -- MINIMUM SATURATION LEVEL RADIANCE (SPECIFIED)

**4. RADIANCE IS GIVEN AT:**

- MIN -- RADIANCE AT MINIMUM (ZERO COUNTS)
- MSL -- RADIANCE AT MINIMUM SATURATION LEVEL (243 COUNTS)
- MAX -- RADIANCE AT MAXIMUM (255 COUNTS)

Table 2  
**TM/PF BAND 1 DERIVED RADIOMETRIC CALIBRATION PARAMETERS**

CHAN	GAIN	OFFSET	SNR		RADIANCES			COMMENTS
			LSR	MSL	MIN	MSL	MAX	
1	15.647	3.18	47.	147.	-0.204	15.327	16.094	
2	15.763	2.40	43.	138.	-0.152	15.264	16.026	
3	15.929	2.65	51.	157.	-0.166	15.089	15.842	
4	15.928	2.59	37.	122.	-0.163	15.094	15.847	
5	15.810	2.67	53.	166.	-0.169	15.201	15.960	
6	15.734	2.51	51.	160.	-0.160	15.285	16.048	
7	15.685	2.58	53.	165.	-0.165	15.327	16.092	
8	15.755	2.66	47.	150.	-0.169	15.254	16.016	
9	15.824	2.64	53.	166.	-0.167	15.190	15.948	
10	15.859	2.47	49.	155.	-0.156	15.166	15.923	
11	15.686	2.53	50.	160.	-0.161	15.330	16.095	
12	15.815	2.51	42.	137.	-0.159	15.207	15.966	
13	15.694	2.56	53.	170.	-0.163	15.320	16.085	
14	15.758	2.43	48.	152.	-0.154	15.266	16.027	
15	15.782	2.59	48.	154.	-0.164	15.234	15.994	
16	15.873	2.37	43.	137.	-0.149	15.159	15.915	
SNR COMPUTED AT SPECTRAL RADIANCE			4.00	14.29	[AT 0 COUNTS]	[AT 243 COUNTS]	[AT 255 COUNTS]	
SPECIFIED VALUE OF SNR			32.	85.				

361-BA/AB(11\*)  
 JLB/DB2/83

Table 3  
TM/PF BAND 2 DERIVED RADIOMETRIC CALIBRATION PARAMETERS

CHAN	GAIN	OFFSET	SNR		RADIANCES			COMMENTS
			LSR	MSL	MIN	MSL	MAX	
1	8.174	2.99	58.	285.	-0.366	29.363	30.831	NOISY  SLOW RESPONSE
2	8.117	2.33	24.	179.	-0.287	29.648	31.127	
3	8.014	2.41	53.	296.	-0.301	30.021	31.519	
4	8.144	2.44	40.	151.	-0.300	29.538	31.011	
5	8.196	2.43	59.	293.	-0.297	29.353	30.817	
6	8.183	2.54	61.	302.	-0.311	29.384	30.851	
7	8.057	2.32	51.	303.	-0.288	29.873	31.363	
8	8.079	2.52	51.	317.	-0.312	29.768	31.253	
9	8.075	2.39	53.	308.	-0.296	28.797	31.283	
10	8.093	2.35	53.	296.	-0.290	29.737	31.220	
11	7.998	2.36	57.	304.	-0.296	30.087	31.587	
12	8.014	2.33	55.	311.	-0.291	30.032	31.529	
13	8.117	2.32	51.	285.	-0.285	29.653	31.132	
14	8.141	2.47	58.	276.	-0.304	29.546	31.020	
15	8.195	2.38	59.	283.	-0.290	29.363	30.828	
16	7.979	2.43	55.	304.	-0.304	30.150	31.654	
SNR COMPUTED AT SPECTRAL RADIANCE			3.00	29.12	[AT 0 COUNTS]	[AT 243 COUNTS]	[AT 255 COUNTS]	
SPECIFIED VALUE OF SNR			35.	170.				

Table 4  
**TM/PF BAND 3 DERIVED RADIOMETRIC CALIBRATION PARAMETERS**

CHAN	GAIN	OFFSET	SNR		RADIANCES			COMMENTS
			LSR	MSL	MIN	MSL	MAX	
1	10.777	2.13	47.	204.	-0.197	22.350	23.463	
2	10.602	1.57	50.	247.	-0.148	22.772	23.904	
3	10.590	1.89	48.	236.	-0.179	22.768	23.901	
4	10.531	1.46	47.	253.	-0.139	22.936	24.075	
5	10.624	1.59	47.	229.	-0.149	22.723	23.852	
6	10.663	1.62	47.	229.	-0.152	22.637	23.762	
7	10.582	1.55	49.	241.	-0.146	22.818	23.952	
8	10.535	1.51	47.	256.	-0.144	22.922	24.061	
9	10.645	1.53	44.	246.	-0.144	22.683	23.811	
10	10.567	1.49	47.	240.	-0.141	22.856	23.992	
11	10.556	1.24	45.	240.	-0.117	22.903	24.040	
12	10.643	1.49	45.	229.	-0.140	22.692	23.819	
13	10.685	1.44	42.	218.	-0.135	22.608	23.731	
14	10.640	1.66	45.	239.	-0.156	22.683	23.811	
15	10.769	1.53	44.	209.	-0.142	22.422	23.536	
16	10.484	1.63	43.	239.	-0.156	23.022	24.166	
SNR COMPUTED AT SPECTRAL RADIANCE			1.86	19.29	[AT 0 COUNTS]	[AT 243 COUNTS]	[AT 255 COUNTS]	
SPECIFIED VALUE OF SNR			26.	143.				

361-BA/AB(11°)  
 JLB/DB2/83

Table 5  
TM/PF BAND 4 DERIVED RADIO-METRIC CALIBRATION PARAMETERS

CHAN	GAIN	OFFSET	SNR		RADIANCES			COMMENTS
			LSR	MSL	MIN	MSL	MAX	
1	10.972	2.53	76.	359.	-0.231	21.917	23.010	
2	10.817	1.94	74.	306.	-0.179	22.286	23.395	
3	11.019	1.96	70.	360.	-0.178	21.876	22.965	
4	10.831	1.82	76.	310.	-0.168	22.267	23.374	
5	10.812	1.75	69.	346.	-0.162	22.313	23.422	
6	10.932	1.95	63.	344.	-0.179	22.049	23.146	
7	10.813	2.22	78.	326.	-0.205	22.267	23.377	
8	10.881	1.76	76.	315.	-0.162	22.170	23.273	
9	10.860	1.89	84.	304.	-0.174	22.201	23.306	
10	11.291	1.73	63.	356.	-0.153	21.369	22.432	
11	10.753	1.93	67.	400.	-0.179	22.419	23.535	
12	10.901	1.79	60.	320.	-0.164	22.128	23.229	
13	11.055	1.67	79.	368.	-0.151	21.829	22.915	
14	10.911	1.92	61.	385.	-0.176	22.095	23.195	
15	10.771	1.69	65.	348.	-0.157	22.403	23.517	
16	10.828	2.00	65.	303.	-0.184	22.257	23.365	
SNR COMPUTED AT SPECTRAL RADIANCE			1.36	21.43	[AT 0 COUNTS]	[AT 243 COUNTS]	[AT 255 COUNTS]	
SPECIFIED VALUE OF SNR			32.	240.				

**TM/PF BAND 5 DERIVED RADIOMETRIC CALIBRATION PARAMETERS**

Table 6

CHAN	GAIN	OFFSET	SNR		MIN	RADIANCES		COMMENTS
			LSR	MSL		MSL	MAX	
1	76.569	3.28	42.	184.	-0.043	3.131	3.288	DEAD DETECTOR
2	76.830	2.94	43.	198.	-0.038	3.125	3.281	
3	-	-	-	-	-	-	-	
4	77.698	2.85	43.	182.	-0.037	3.091	3.245	
5	76.806	3.00	37.	172.	-0.035	3.125	3.281	
6	76.888	3.03	36.	190.	-0.039	3.121	3.277	
7	77.412	3.01	33.	156.	-0.039	3.100	3.255	
8	77.166	3.14	43.	193.	-0.041	3.108	3.264	
9	76.966	3.02	40.	184.	-0.039	3.118	3.274	
10	76.969	2.92	40.	183.	-0.038	3.119	3.275	
11	77.665	3.04	42.	175.	-0.039	3.090	3.244	
12	77.755	2.88	44.	179.	-0.037	3.088	3.242	
13	77.555	3.11	45.	177.	-0.040	3.093	3.248	
14	77.242	2.95	45.	183.	-0.038	3.108	3.263	
15	77.309	3.14	44.	177.	-0.041	3.103	3.258	
16	77.742	2.97	48.	185.	-0.038	3.087	3.242	
SNR COMPUTED AT SPECTRAL RADIANCE			0.40	3.00	[AT 0 COUNTS]	[AT 243 COUNTS]	[AT 255 COUNTS]	
SPECIFIED VALUE OF SNR			13.	75.				

Table 7  
**TM/PF BAND 7 DERIVED RADIOMETRIC CALIBRATION PARAMETERS**

CHAN	GAIN	OFFSET	SNR		RADIANCES			COMMENTS
			LSR	MSL	MIN	MSL	MAX	
1	148.235	2.95	30.	169.	-0.020	1.619	1.700	
2	146.770	2.36	25.	172.	-0.016	1.640	1.721	
3	147.693	2.37	31.	194.	-0.016	1.629	1.711	
4	147.723	2.42	26.	172.	-0.016	1.629	1.710	
5	147.729	2.26	29.	192.	-0.015	1.630	1.711	
6	146.698	2.45	27.	176.	-0.017	1.640	1.722	
7	147.815	2.28	13.	99.	-0.015	1.629	1.710	
8	145.350	2.37	28.	198.	-0.016	1.655	1.738	
9	147.910	2.34	27.	178.	-0.016	1.627	1.708	
10	144.747	2.45	25.	166.	-0.017	1.662	1.745	
11	146.976	2.31	26.	185.	-0.016	1.638	1.719	
12	147.933	2.49	27.	171.	-0.017	1.626	1.707	
13	146.146	2.15	30.	200.	-0.015	1.648	1.730	
14	147.462	2.69	25.	156.	-0.018	1.630	1.711	
15	146.199	2.15	31.	204.	-0.015	1.647	1.729	
16	148.492	2.57	29.	169.	-0.017	1.619	1.700	
SNR COMPUTED AT SPECTRAL RADIANCE SPECIFIED VALUE OF SNR			0.17	1.59	[AT 0 COUNTS]	[AT 243 COUNTS]	[AT 255 COUNTS]	
			5.	45.				



Table 8

**TM/PF BAND 1  
AVERAGE, STANDARD DEVIATION AND COEFFICIENT OF VARIATION FOR  
DERIVED RADIOMETRIC CALIBRATION PARAMETERS**

CHAN	GAIN	OFFSET	SNR		RADIANCES			
			LSR	MSL	MIN	MSL	MAX	
<b>MEAN:</b>								
ODD	15.757	2.67	51.	161.	-0.170	15.252	16.014	
EVEN	15.811	2.49	45.	144.	-0.158	15.212	15.971	
ALL	15.784	2.58	48.	152.	-0.164	15.232	15.992	
<b>SIGMA:</b>								
ODD	0.096	0.21	3.	8.	0.014	0.090	0.094	
EVEN	0.071	0.10	4.	13.	0.006	0.068	0.071	
ALL	0.086	0.18	5.	13.	0.012	0.079	0.083	
<b>COEF. VAR. (%):</b>								
ODD	0.61	7.9	6.	5.	-8.2	0.6	0.6	
EVEN	0.45	4.0	29.	9.	-3.8	0.4	0.4	
ALL	0.54	7.0	10.	9.	-7.3	0.5	0.5	

361-BA/AB(11a\*)  
JLB/DBZ/83

Table 9  
**TM/PF BAND 2**  
**AVERAGE, STANDARD DEVIATION AND COEFFICIENT OF VARIATION FOR**  
**DERIVED RADIOMETRIC CALIBRATION PARAMETERS**

CHAN	GAIN	OFFSET	SNK		RADIANCES			
			LSR	MSL	MIN	MSL	MAX	
MEAN:								
ODD	8.104	2.45	55.	295.	-0.302	26.689	31.170	
EVEN	8.094	2.43	50.	267.	-0.300	29.725	31.208	
ALL	8.098	2.44	52.	281.	-0.301	29.707	31.189	
SIGMA:								
ODD	0.080	0.22	3.	10.	0.026	0.301	0.316	
EVEN	0.070	0.08	12.	65.	0.010	0.256	0.268	
ALL	0.072	0.16	9.	47.	0.019	0.276	0.291	
COEF. VAR. (%):								
ODD	0.99	8.9	5.	3.	-8.6	1.0	1.0	
EVEN	0.86	3.3	24.	24.	-3.3	0.9	0.9	
ALL	0.89	6.6	17.	17.	-6.3	0.9	0.9	

351-BA/AB(11a\*)  
 JLB/DB2/83

Table 10

**TM/PF BAND 3  
AVERAGE, STANDARD DEVIATION AND COEFFICIENT OF VARIATION FOR  
DERIVED RADIOMETRIC CALIBRATION PARAMETERS**

CHAN	GAIN	OFFSET	SNR		RADIANCES			
			LSR	MSL	MIN	MSL	MAX	
MEAN:								
ODD	10.654	1.61	46.	228.	-0.151	22.659	23.786	
EVEN	10.583	1.55	46.	241.	-0.147	22.815	23.949	
ALL	10.618	1.58	46.	235.	-0.149	22.737	23.867	
SIGMA:								
ODD	0.084	0.28	2.	16.	0.025	0.190	0.199	
EVEN	0.064	0.08	2.	10.	0.007	0.138	0.146	
ALL	0.081	0.20	2.	14.	0.018	0.181	0.194	
COEF. VAR. (%):								
ODD	0.79	17.4	4.	7.	-16.6	0.8	0.8	
EVEN	0.60	5.2	4.	4.	-4.8	0.6	0.6	
ALL	0.76	12.7	4.	6.	-12.1	0.8	0.8	

361-BA/AB(11a\*)  
JLB/DB2/83

Table 11  
**TM/PF BAND 4\***  
**AVERAGE, STANDARD DEVIATION AND COEFFICIENT OF VARIATION FOR**  
**DERIVED RADIOMETRIC CALIBRATION PARAMETERS**

CHAN	GAIN	OFFSET	SNR		RADIANCES			
			LSR	MSL	MIN	MSL	MAX	
<b>MEAN:</b>								
ODD	10.882	1.95	73.	351.	-0.180	22.153	23.256	
EVEN	10.924	1.86	67.	330.	-0.171	22.077	23.176	
ALL	10.903	1.91	70.	341.	-0.175	22.115	23.216	
<b>SIGMA:</b>								
ODD	0.117	0.29	7.	28.	0.027	0.242	0.254	
EVEN	0.154	0.10	7.	29.	0.299	0.299	0.313	
ALL	0.134	0.22	7.	30.	0.020	0.268	0.280	
<b>COEF. VAR. (%):</b>								
ODD	1.08	14.9	10.	8.	-15.0	1.1	1.1	
EVEN	1.41	5.4	10.	9.	-174.8	1.4	1.4	
ALL	1.23	11.5	10.	9.	-11.4	1.2	1.2	

361-BA/AB(11a\*)  
 JLB/DB2/83

Table 12

**TM/PF BAND 5  
AVERAGE, STANDARD DEVIATION AND COEFFICIENT OF VARIATION FOR  
DERIVED RADIOMETRIC CALIBRATION PARAMETERS**

CHAN	GAIN	OFFSET	SNR		RADIANCES			
			LSR	MSL	MIN	MSL	MAX	
MEAN:								
ODD	77.183	3.08	40.	175.	-0.040	3.108	3.164	
EVEN	77.286	2.96	43.	187.	-0.038	3.106	3.261	
ALL	77.238	3.02	42.	181.	-0.039	3.107	3.262	
SIGMA:								
ODD	0.418	0.10	4.	9.	0.001	0.016	0.017	
EVEN	0.404	0.09	4.	7.	0.001	0.016	0.017	
ALL	0.406	0.11	4.	10.	0.002	0.016	0.017	
COEF. VAR. (%):								
ODD	0.54	3.2	10.	5.	-2.5	0.5	0.5	
EVEN	0.52	3.0	9.	4.	-2.6	0.5	0.5	
ALL	0.53	3.6	10.	6.	-5.1	0.5	0.5	

361-BA/AB(11a\*)  
JLB/D92/83

Table 13  
**TM/PF BAND 7**  
**AVERAGE, STANDARD DEVIATION AND COEFFICIENT OF VARIATION FOR**  
**DERIVED RADIOMETRIC CALIBRATION PARAMETERS**

CHAN	GAIN	OFFSET	SNR		RADIANCES			
			LSR	MSL	MIN	MSL	MAX	
MEAN:								
ODD	147.338	2.35	27.	178.	-0.016	1.633	1.715	
EVEN	146.897	2.47	26.	173.	-0.017	1.637	1.719	
ALL	147.117	2.41	27.	175.	-0.016	1.635	1.717	
SIGMA:								
ODD	0.807	0.25	6.	34.	0.002	0.010	0.010	
EVEN	1.299	0.11	2.	12.	0.001	0.015	0.015	
ALL	1.063	0.20	4.	25.	0.001	0.013	0.013	
COEF. VAR. (%):								
ODD	0.55	10.6	22.	19.	-12.5	0.6	0.6	
EVEN	0.88	4.5	8.	7.	-5.9	0.9	0.9	
ALL	0.72	8.3	15.	14.	-6.2	0.8	0.8	

361-BA/AB(11s\*)  
 JLB/DB2/83

Table 14

**SUMMARY OF TM/PF CALIBRATION PARAMETERS**

BAND	DYNAMIC RANGE		GAIN (counts/(mWcm <sup>-2</sup> sr <sup>-1</sup> μm <sup>-1</sup> ))	OFFSET (counts)	SIGNAL-TO-NOISE RATIO	
	RMIN <sup>a</sup> (mWcm <sup>-2</sup> sr <sup>-1</sup> μm <sup>-1</sup> )	RMAX <sup>b</sup> (mWcm <sup>-2</sup> sr <sup>-1</sup> μm <sup>-1</sup> )			SPEC (MSL) <sup>c</sup>	OBS (MSL) <sup>c</sup>
1	-0.152	15.842	15.78 ± 0.54%	2.58 ± 0.18	85	152 ± 9%
2	-0.284	30.817	8.10 ± 0.89%	2.44 ± 0.16	170	281 ± 17%
3	-0.117	23.463	10.62 ± 0.76%	1.58 ± 0.20	143	235 ± 6%
4	-0.151	22.432	10.90 ± 1.23%	1.91 ± 0.22	240	341 ± 9%
5	-0.037	3.242	77.24 ± 0.53%	3.02 ± 0.11	75	180 ± 6%
7	-0.015	1.700	147.12 ± 0.72%	2.41 ± 0.20	45	175 ± 14%

<sup>a</sup>RMIN IS THE LARGEST MINIMUM RADIANCE OBSERVED IN THE BAND (0 COUNTS).

<sup>b</sup>RMAX IS THE SMALLEST MAXIMUM RADIANCE OBSERVED IN THE BAND (255 COUNTS)

<sup>c</sup>MSL IS THE MINIMUM SATURATION LEVEL RADIANCE FOR THE BAND.

Table 15

# TM/PF CALCULATED DETECTOR GAINS AND OFFSETS

BAND	A1: CALCULATED <sup>b, c</sup>		B: CALCULATED <sup>b, c</sup>		C2: CALCULATED <sup>b, c</sup>	
	GAIN <sup>a</sup>	OFFSET <sup>a</sup>	GAIN <sup>a</sup>	OFFSET <sup>a</sup>	GAIN <sup>a</sup>	OFFSET <sup>a</sup>
1	16.59 ± 0.09	0.44 ± 0.34	15.97 ± 0.09	---	15.78 ± 0.09	2.58 ± 0.18
2	8.14 ± 0.07	0.89 ± 0.07	7.93 ± 0.07	---	8.10 ± 0.07	2.44 ± 0.16
3	10.66 ± 0.09	0.81 ± 0.20	10.33 ± 0.09	---	10.62 ± 0.08	1.58 ± 0.20
4	11.32 ± 0.13	0.92 ± 0.22	11.31 ± 0.14	---	10.90 ± 0.13	1.91 ± 0.22
5	81.45 ± 0.38 <sup>d</sup>	1.53 ± 1.08 <sup>d</sup>	---	---	77.24 ± 0.40 <sup>d</sup>	3.02 ± 0.11 <sup>d</sup>
7	152.31 ± 1.48	2.57 ± 0.74	---	---	147.12 ± 1.06	2.41 ± 0.20

<sup>a</sup> ALL GAINS ARE IN UNITS OF DIGITAL COUNTS/(mW cm<sup>-2</sup> sr<sup>-1</sup> μ<sup>-1</sup>), OFFSETS IN DIGITAL COUNTS. DATA GIVEN ARE MEANS ± STANDARD DEVIATION FOR 16 DETECTORS.

<sup>b</sup> IS(122) TESTS DESIGNATION FROM TABLE 2: A—JUNE, 1981; B—NOVEMBER 1981; C—MARCH 1982.

<sup>c</sup> SOURCES: TEST A FROM OSGOOD AND LANSING (1981), TABLES III AND IV.  
TEST B FROM YOUNG (1982), TABLES III, IV, V, AND VI.  
TEST C FROM UNPUBLISHED COMPUTER PRINTOUTS, WITH NEW IS(122) RADIANCE LEVELS.

(SPHERE WAS RECALIBRATED IN MAY 1982.)

<sup>d</sup> BAND 5 DATA EXCLUDE DETECTOR 3 (DEAD).

<sup>e</sup> TEST B DATA WERE TAKEN FOR BANDS 1 THROUGH 4 ONLY. YOUNG (1982) REPORTS GAINS ONLY (NO OFFSETS).



Table 16

**SUMMARY OF AVERAGE GAIN CHANGES IN PERCENT BY TEST REFERENCED TO TEST C2**

BAND	TEST						
	A1	A2	B	C1	C2	C3	
1 ODD EVEN ALL	5.28	5.22	1.17	0.82	—	-0.03	
	4.91	4.83	1.13	0.91	—	-0.02	
	5.09	5.03	1.15	0.86	—	-0.02	
2 ODD EVEN ALL	0.48	0.24	-1.95	-0.29	—	-0.63	
	0.45	0.21	-2.01	-0.32	—	-0.67	
	0.47	0.22	-1.98	-0.30	—	-0.65	
3 ODD EVEN ALL	0.45	0.20	-2.22	-0.32	—	-0.55	
	0.23	-0.01	-2.29	-0.23	—	-0.51	
	0.34	-0.09	-2.25	-0.28	—	-0.53	
4 ODD EVEN ALL	3.91	4.00	3.75	0.62	—	0.08	
	3.78	3.88	3.69	0.61	—	0.06	
	3.85	3.94	3.72	0.62	—	0.07	
5 ODD EVEN ALL	5.45	4.75	-b	-0.17	—	-0.02	
	5.45	4.78	—	-0.28	—	-0.18	
	5.45	4.77	—	-0.23	—	-0.11	
7 ODD EVEN ALL	3.59	3.09	-b	0.01	—	-0.12	
	3.47	4.77	—	0.06	—	-0.09	
	3.53	3.93	—	0.03	—	-0.11	

<sup>a</sup>GAIN CHANGE DEFINED AS: VALUE = 100% x (CURRENT - REFERENCE) ÷ REFERENCE.

<sup>b</sup>NO BANDS 5 AND 7 DATA TAKEN DURING TEST B.

Our choice of test C2 as the best calibration of the TM for use during postlaunch activities was dictated by several considerations:

- The IS(122) was recalibrated in May 1982; these output radiances were used to obtain the results presented in Tables 2 through 7 and are not affected by any significant use of the IS(122) from March to May 1982. Tests A and B, however, are well removed in time and sphere usage from both May (and February) 1982 and June 1980 sphere calibrations.

- A change in IS(122) output in the blue wavelengths from the June 1980 to the February and May 1982 sphere calibrations (2 to 4 percent or worse at some wavelengths according to Walker (1982a, b)) may in particular affect TM band 1.

- The cooled focal plane assembly (CFPA) (bands 5, 6, and 7) was removed from the TM in August 1981 for repair. This invalidates the band 5 and 7 calibrations during the A tests.

- Alignment of the IS(122) and the TM was questionable during test B; in addition, no CFPA data were taken during that test.

- One 25-watt lamp burned out after the February 1982 sphere calibration check; the new lamp was calibrated during May 1982.

Changes made in the CFPA in August 1981 may explain most of the observed differences in bands 5 and 7 between tests A and C. Changes in sphere output from June 1980 to February and May 1982 should also be considered for bands 5 and 7 as well as band 1. It is not clear, however, that changes in the sphere can account for more than 1 or 2 percent of the observed differences in band 4 (see Table 16).

To further evaluate the accuracy of the calibration of the TM with the IS(122), errors have been computed for detectors 1, 8, 9, and 16 in each band. These are based on computed errors in gain and offset from the least-squares fit and standard deviations for the averaged digital counts from the highest observed sphere radiance level in each band that does not saturate. The errors are part of the transfer error in the calibration from the IS(122) to the TM. These results are listed in Table 17. The error, in percent, in

Table 17

**COMPUTED ERRORS IN SPECTRAL RADIANCE FOR CALIBRATION OF TM/PF DETECTORS WITH IS (122)**

CHANNEL	BAND						
	1	2	3	4	5	7	
1	1.11	0.76	0.68	0.69	0.65	0.81	
8	1.06	0.58	0.59	0.70	0.62	0.70	
9	0.95	0.64	0.57	0.70	0.62	0.80	
16	1.10	0.70	0.60	0.70	0.66	0.81	

VALUE IS FRACTIONAL ERROR IN SPECTRAL RADIANCE AT HIGHEST UNSATURATED SPHERE BRIGHTNESS LEVEL IN BAND, IN PERCENT:

$$\frac{\Delta L}{L} (\%) = 100 * \sqrt{\frac{(\Delta \bar{Q})^2 + (\Delta O)^2}{(\bar{Q} - O)^2} + \left(\frac{\Delta G}{G}\right)^2}$$

$\bar{Q}, \Delta \bar{Q}$  AVERAGED VIDEO DIGITAL COUNT AND ITS STANDARD DEVIATION

$O, \Delta O$  OFFSET AND ITS STANDARD DEVIATION

$G, \Delta G$  GAIN AND ITS STANDARD DEVIATION

radiance for the highest unsaturated sphere level is computed as follows, based on the calibration curve  $Q = GL + O$ :

$$\frac{\Delta L}{L} (\%) = 100 * \sqrt{\frac{(\Delta Q)^2 + (\Delta O)^2}{(Q - O)^2} + \left(\frac{\Delta G}{G}\right)^2}$$

These values provide a measure of the full-scale precision of the calibration of the TM. Other sources of error in the calibration, such as errors in the radiance output by the IS(122) in a TM band and the relative spectral response in the band, are also contributing to the transfer error from the IS(122) to the TM. The estimated error in the TM calibration is discussed in a later section.

The measured dynamic range, minimum saturation level (MSL), and maximum radiances for each detector were presented in Tables 1 through 13. They are computed from the inverted calibration curve  $L = (Q - O)/G$  at digital count values of zero, 243, and 255. The MSL radiance is computed at 95 percent of full scale. This level was chosen by Santa Barbara Research Center (SBRC) as a measure of both full-scale SNR and dynamic range and allowed for possible errors in the calibration as well as in setting the detector gain. The measured dynamic range of the TM is summarized in Table 18 for the full-scale values. The table gives the average MSL radiance, its standard deviation, and the minimum MSL radiance, which is computed as follows:

$$RMIN_i = \text{Minimum } (RMSL_{ij})$$

where  $RMIN_i$  is the minimum MSL in band  $i$  and  $RMSL_{ij}$  are the MSL radiances for all  $j$  detectors in band  $i$ . For example, the  $RMIN$  value for band 1 occurs in detector 3 (see Table 2). (Similar values are given in Table 14 for the lowest maximum observable radiance and the highest minimum observable radiance in each band.) The minimum MSL values given in Table 18 have also been compared to the specified dynamic range for each TM band. Each band saturates at a higher level than specified, up to 15 percent for band 3. The within-band variability of the measured dynamic range is about 1 percent. Although this would lead to minimal stripping in a TM scene, it should be compared to the specified relative accuracy level of one digital count. The range of variability by bands is from 1.3 to 3.0 digital counts.

#### Signal-to-Noise Determination

The SNR ratio for each detector was calculated at two standard radiance levels for each test. First, the mean (signal)

Table 18

# AVERAGE DYNAMIC RANGE OF THE TM FROM COMPUTED RADIANCE LEVELS

	BAND						
	1	2	3	4	5	7	
AVERAGE MSL	15.232	29.707	22.737	22.115	3.107	1.035	
STANDARD DEV OF MSL	0.079	0.276	0.181	0.268	0.016	0.013	
MINIMUM MSL	15.089	29.353	22.350	21.369	3.087	1.619	
SPECIFICATION	14.29	29.12	19.29	21.43	3.00	1.59	
RATIO $\frac{SPEC.}{AVER.}$ (%)	93.8	98.0	84.8	96.9	96.6	97.2	
RATIO $\frac{S. DEV}{AVER.}$ (%)	0.5	0.9	0.8	1.2	0.5	0.8	

**NOTES:**

MSL IS MINIMUM SATURATION LEVEL SPECTRAL RADIANCE ( $mWcm^{-2} sr^{-1} \mu m^{-1}$ )

COMPARING OBSERVED MSL WITH SPECIFICATION

1. SATURATES AT A HIGHER LEVEL (UP TO 15%) THAN SPECIFICATION.
2. WITHIN-BAND VARIABILITY IS ABOUT 1%.

and standard deviation (noise) for each detector were calculated from a large number of scans at each standard source radiance level. The resulting SNR values at each radiance level were then fit by a linear function of spectral radiance. Finally, the fitted straight lines were evaluated at two reference levels, and the high and low SNRs shown in Tables 1 through 7 resulted. Only three channels do not meet the specifications: 5/3 (dead), 2/4 (slow response), and 2/2 (noisy). When band 2/channel 2 data were examined, it was noticed that the SNR-versus-radiance curve showed a pronounced trend typical of a Schott-noise square root curve (Osgood and Lansing, 1981). Detector 2/4 does not show a significant problem until rapidly changing intensities are presented to it. Thus, the gain/offset determinations from the largely static IS(122) radiance levels show no appreciable difference when compared to other detectors in band 2. The 2/4 detector does, however, have a much slower response time to changing radiance values, particularly those characteristic of the TM internal calibrator (IC) light pulse. Under these conditions, the detector is sluggish but still useful.

#### CALIBRATION OF THE IC

The purpose of the calibration transference was to determine the radiance value for each detector in each band for each IC lamp configuration. As the TM was viewing the eight radiance levels provided by the IC lamps, its output was monitored. By the procedure outlined in Barker et al. (1983a,b), an average integrated calibration pulse value in digital counts was determined for each lamp configuration for each detector. These values were then converted to spectral radiance using calibration coefficients (gains and offsets) determined during the absolute calibration test with the IS(122). The IC data are nominally taken between the two radiance level series that make up the IS(122) test (Barker et al., 1983a), with the IC automatic sequencer on and the lamps operating in normal mode. Some data have also been collected for the backup mode of IC operation. Because the data collection for the calibration transference is a part of the calibration of the TM with the IS(122), this test is always performed in an ambient environment, not in a vacuum test chamber; the IS(122) is too big to fit inside a vacuum chamber. To obtain data taken during in-orbit-like conditions (in vacuum), it is necessary to transfer the results to a set of data taken in these conditions and as close in time and instrument operating conditions to the absolute calibration test as may be feasible; even so, differences due to so-called vacuum shift may still be noted. Several tests have been performed to transfer the IS(122) calibration of the TM detectors to the IC and are listed in Table 19. Three additional sets of IC data taken in vacuum

Table 19  
**DATES OF TRANSFERS OF CALIBRATION TO THE  
 TM/PF INTERNAL CALIBRATOR**

TEST DESIGNATION	DATA COLLECT		LOCATION	TEST ENVIRONMENT	IC MODE	REMARKS
	DATE	TIME				
1	30 JUNE 1981	02:29:58	HAC/SBRC	AMBIENT	NORMAL	T <sub>CFPA</sub> = 95K
2	30 JUNE 1981	03:03:05	HAC/SBRC	AMBIENT	BACKUP	T <sub>CFPA</sub> = 95K
3	30 JUNE 1981	04:26:44	HAC/SBRC	AMBIENT	NORMAL	T <sub>CFPA</sub> = 105K
4	30 JUNE 1981	06:55:33	HAC/SBRC	AMBIENT	NORMAL	T <sub>CFPA</sub> = 105K
5	30 JUNE 1981	07:20:49	HAC/SBRC	AMBIENT	BACKUP	T <sub>CFPA</sub> = 105K
6	3 NOV 1981	-	GE/VF	AMBIENT	NORMAL	BANDS 5, 6, 7 OFF
7 <sup>a</sup>	20 MAR 1982	21:29:50	GE/VF	AMBIENT	NORMAL	REFERENCE
8 <sup>b</sup>	18 SEPT 1981	-	HAC/EL SEGUNDO	VACUUM	NORMAL	
9 <sup>b</sup>	9 MAR 1982	12:43:00	GE/VF	VACUUM	NORMAL	SPECIAL TEST 1, PASS 2
10 <sup>b</sup>	9 MAR 1982	12:46:30	GE/VF	VACUUM	NORMAL	SPECIAL TEST 1, PASS 3

<sup>a</sup> TEST NUMBER 7 IS THE REFERENCE TEST.

<sup>b</sup> TESTS 8, 9, AND 10 ARE DATA SETS OBTAINED IN VACUUM AND HAVE BEEN INCLUDED FOR COMPARISON.

361-BA/AB(49)  
 JLB/DB2/83

chamber tests have been included. Some comments on these tests are in order.

First, although any set of IC data may potentially be used to establish the calibration transference, data collected as close in time and environmental conditions to the TM detector absolute calibration as possible are to be preferred to minimize effects of environmental changes on the transfer. Although the March 1982 test (test 7 in Table 19) was performed 1 day after the three IS(122) calibrations (tests C), this test has been selected as the reference for intercomparison of transfer test results as well as for postlaunch operations. This is because it is closest to the date of launch, a large volume of IS(122) data is available, and continuity of absolute calibration of the CFPA detectors with postlaunch operational activities exists.

Second, four data sets have been included for comparison purposes: the November 1981 test, which lacks CFPA detector data, and three sets taken from vacuum chamber testing. Tests 9 and 10 were special tests performed in vacuum at General Electric and designed to mimic expected in-orbit operational conditions (E. Beyer, General Electric, private communication, 1982).

Third, there are only two tests for the backup mode of IC operation; none was performed during the March 1982 test series. If the backup mode is to be used during postlaunch operations, a set of transference data for the backup mode will have to be constructed from other sources. Internal lamp self-consistency problems have been noted with these data sets taken in backup mode.

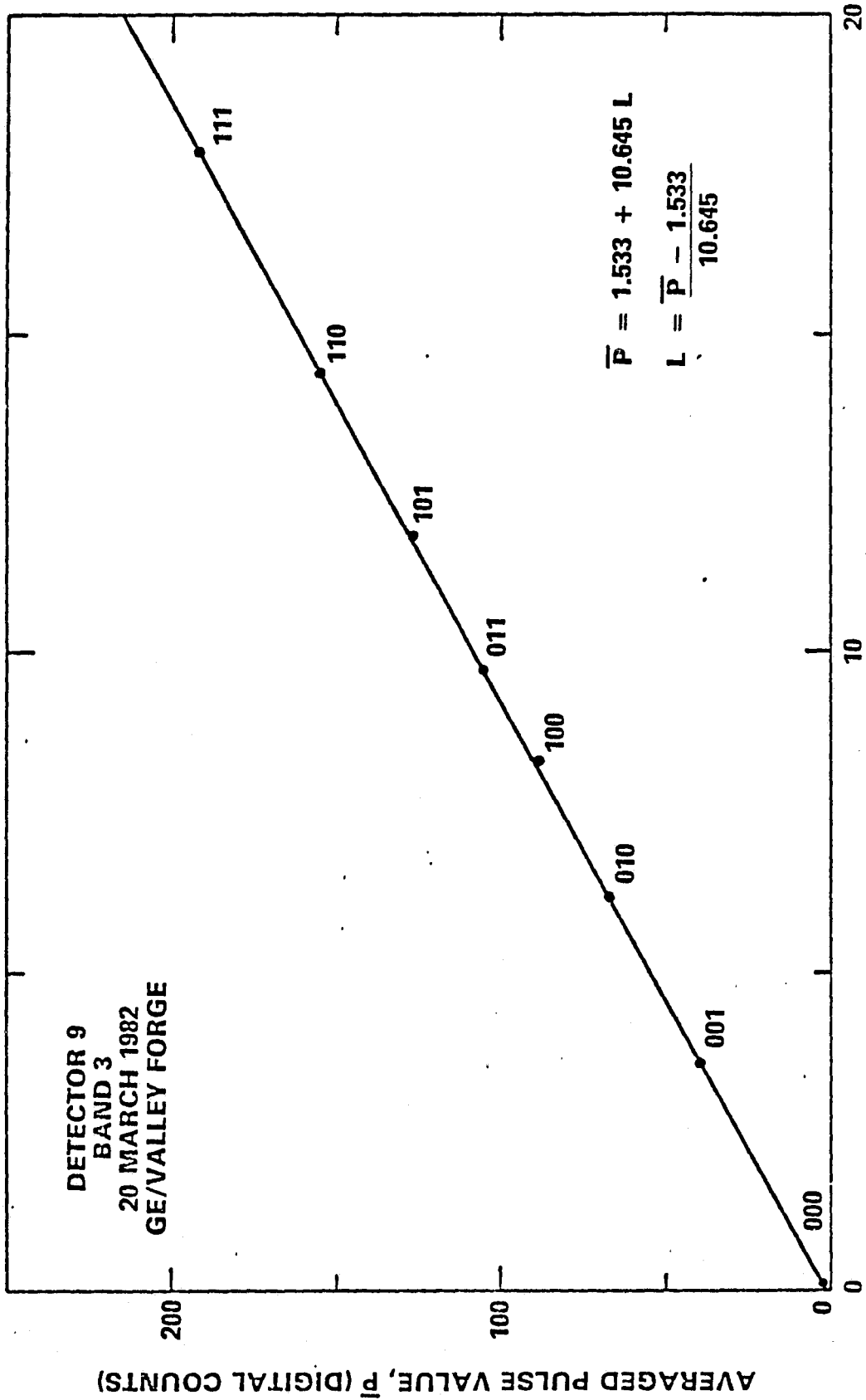
The results of the calibration transference for test 7 of Table 19, which was selected as the reference transference data set for the TM, are presented in the appendix along with the results of test 9. For each IC lamp configuration and each detector, the averaged observed digital count output obtained with the Hughes pulse integration scheme and the corresponding spectral radiance are given. The spectral radiances were computed using the observed digital counts and gains and offsets given in Tables 2 through 7 for tests 7 and 9. An illustrative plot of average calibration pulse value against lamp radiance is shown in Figure 3 for the reference test (test 7).

To evaluate the repeatability of the calibration transfer from the IS(122) to the IC lamps, a straight-line, least-squares fit was performed for each detector using all eight IC lamp levels between a given test and the reference test. An example of one such comparison is shown in Figure 4. The



Figure 3

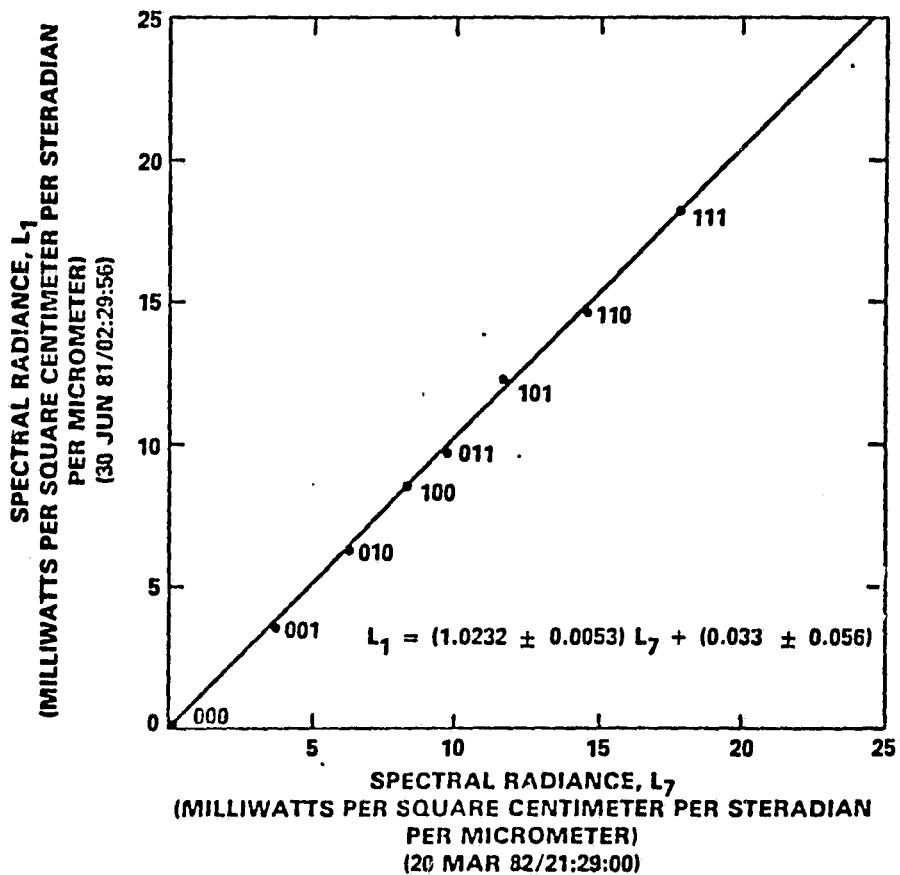
TM/PF GAIN AND OFFSET FROM INTERNAL CALIBRATION DATA



ORIGINAL PAGE IS  
OF POOR QUALITY

Figure 4

TM/PF: COMPARISON OF CALIBRATION TRANSFER RESULTS, BAND 3/CHANNEL 9



361-BA/AB(9)83  
JLB/DH2/83

fit was computed two ways, one using radiance value comparisons and one with digital counts. The result of these comparisons is given in detail elsewhere (Barker et al., 1983d) and will only be briefly summarized here. For each test comparison, a slope and intercept and their respective standard deviations and a figure of merit for the overall fit were computed by the method of least squares for each detector. For the data shown in Figure 4, the results are summarized in Table 20. The figure of merit used is the standard error of the estimate. For either radiance or digital count comparison, the figure of merit is less than 0.45 percent of full-scale IC lamp output (lamp configuration 111). These values are typical, not best estimates.

To evaluate the error involved in the transfer of the absolute calibration to the IC, the error in the calibration of the detectors must be determined, as shown in Table 17. Because the detectors are calibrated first and the calibration is then transferred to the IC, this error is twice that given in Table 17. Thus, the error in the transfer is typically 1 to 2 percent, depending on the band. This estimate is included in the error propagation analysis discussed in the next section.

#### ESTIMATED ERRORS IN THE TM/PF CALIBRATION

It was noted in Barker et al. (1983a) that the IS(122) is calibrated against a secondary standard that is related to standards set by the National Bureau of Standards (NBS). The overall sequence of calibrations is shown in Figure 5. Each standard lamp has a rated lifetime during which its output will not change. For example, the Optronics Laboratories, Inc., standard (NBS) used by SERC has a rating of 50 hours of use with the calibration holding to within 1 percent for that period. The IS(122) is used for long periods of time in calibrating the TM and, if the sphere were calibrated directly against the SBRC standard, the standard calibration would quickly degrade. Thus, the SBRC standard is used to calibrate secondary standards similar in design and characteristics to the SBRC standard (for example, see Campbell, 1980 and Walker, 1982c). In Figure 5, the lamp filament symbol labeled "PRI" on the upper left represents an Optronics standard quartz-halogen 1000-watt lamp that has been calibrated against an NBS standard lamp. The vendor-stated uncertainty in the transfer of calibration from the NBS lamp to the Optronics standard (SBRC lamp S466) is 1.3 percent at a wavelength of 450 nanometers, 0.9 percent at 1600 nanometers, and 3.1 percent for 1600 to 2500 nanometers. These errors are mainly due to uncertainty

Table 20

**TM/PF INTERNAL CALIBRATOR  
DERIVED COMPARISON FOR BAND 3, CHANNEL 9 BETWEEN  
TEST 1 (JUNE 1981) AND TEST 7 (MARCH 1982)**

	COMPARISON OF RADIANCE VALUES			FIGURE OF MERIT <sup>a</sup>
	EXPECTED VALUE	DERIVED VALUE	STANDARD DEVIATION	
INTERCEPT	0.0	0.0334	0.05594	0.0815
SLOPE	1.0	1.0232	0.00534	

	COMPARISON OF DIGITAL COUNTS			FIGURE OF MERIT <sup>a</sup>
	EXPECTED VALUE	DERIVED VALUE	STANDARD DEVIATION	
INTERCEPT	0.0	-0.6114	0.6057	0.8724
SLOPE	1.0	1.0288	0.00537	

<sup>a</sup>FIGURE OF MERIT IS

$$\sigma_{Y \text{ est}} = \sqrt{\frac{\sum_{i=1}^N (Y_i - a - bX_i)^2}{N-2}}$$

WHERE  $i=1, 2, \dots, 8$  IS THE IC LAMP CONFIGURATION,  $a$  AND  $b$  ARE THE INTERCEPT AND SLOPE OF THE FIT, RESPECTIVELY.

in the NBS scale of irradiance. The cumulative root sum of square error at each step in the calibration is then given by

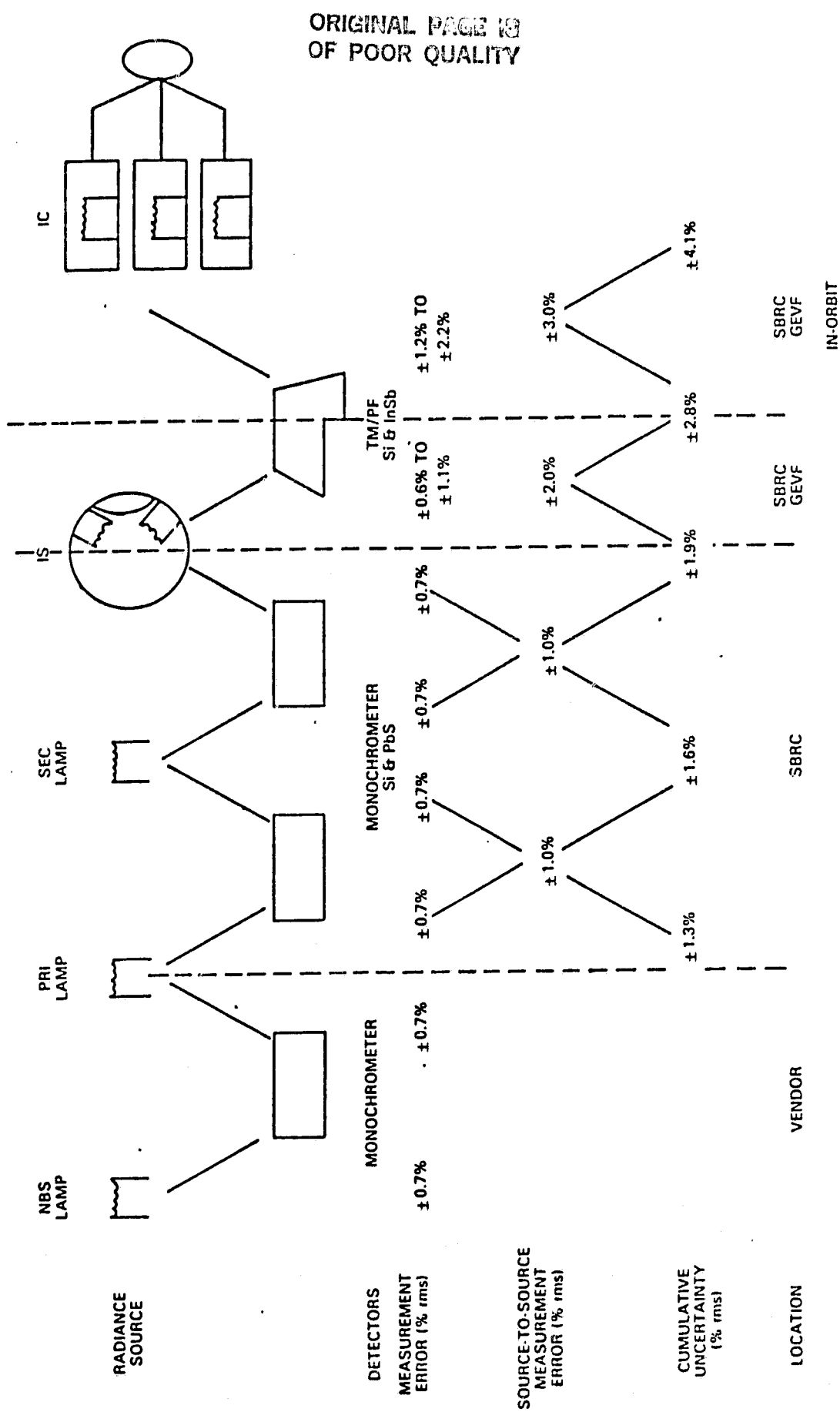
$$\sigma_{\text{cum}} = \left( \sigma_{\text{cal}}^2 + \sigma_{\text{trans}}^2 \right)^{1/2}$$

where  $\sigma_{\text{cum}}$  is the cumulative standard error,  $\sigma_{\text{cal}}$  is the source calibration error at the previous step, and  $\sigma_{\text{trans}}$  is the transfer error or source-to-source measurement error. Thus, at 450 nanometers, the known error in the calibration of the IS(122) is 1.9 percent. The IS(122) must be recalibrated periodically to ensure that the output of the sphere has not changed significantly due to lamp aging or spectral changes in the surface of the sphere. For example, study of data from June 1980, February 1982, and May 1982 (Walker, 1982b) has shown a decreased output from the IS(122) in the blue wavelengths. The overall change is a net decrease by 2 to 4 percent for the brighter radiance levels.

The transfer error associated with the spectral calibration of the IS(122) by the secondary standards has been specified to be less than or equal to 2.0 percent. This error is the standard deviation obtained when comparing spectral radiance values at 50-nanometer intervals between 450 and 2500 nanometers for two separate measurements at each lamp level setting. Values are typically between 1 and 2 percent. These are higher than those for the transfer from the standard lamp S466 to the secondary standards, primarily because the signal levels differ more in the IS(122) calibration. This standard deviation is an indicator of the consistency and precision of the IS(122) calibration. The absolute accuracy of the calibration is not so clearly defined. Campbell (1980) points out that two different measurement techniques used at SBRC gave results that differed by as much as 7 to 8 percent at some wavelengths; typical values are 2 to 3 percent. There is presently no known reason why either of the two methods should give results that are any more, or less, correct than the other. The method selected is the one that provides a higher signal level and, therefore, a better SNR. The other method provides a good SNR at certain wavelength and lamp level combinations, but still gives different results.

Thus, the precision of measurement of the transfer of the NBS calibration to the IS(122) calibration is typically 2 percent but depends on wavelength (5 percent in the infrared). Due to the differences noted above between methods of calibrating the IS(122) with the secondary standards and uncertainties in the NBS scale of irradiance, the absolute accuracy of the calibration of the IS(122) is no better than 5 percent. In Figure 5, the cumulative errors are given for

Figure 5  
**ESTIMATED ABSOLUTE RADIOMETRIC CALIBRATION ACCURACY  
 FOR THE LANDSAT THEMATIC MAPPER SENSOR**



a wavelength of 450 nanometers; these are typical values and are higher in the infrared and lower in the red. The precision of calibration of the TM with the IS(122) is 2.8 percent (at 450 nanometers). The absolute accuracy based on the above discussion is then no better than 5 percent, due to a typical difference of 2 to 3 percent between IS(122) calibration methods and to uncertainties in the NBS scale of irradiance. The transfer of the detector calibration to the IC is then no better than 6 percent.

To summarize, the absolute calibration of the TM reflective band detectors is affected by

- Uncertainty in the NBS irradiance scale (typically 1.2 percent)
- Transfer errors between lamp standards (typically 1.0 percent)
- Differences between methods used to calibrate the IS(122) with a secondary standard (typically 2 to 3 percent)
- Changes in IS(122) lamps and interior surface between calibrations of the IS(122) with the secondary standard (2 to 4 percent between June 1980 and May 1982)

In Figure 5, the cumulative percent error given for the calibration of the protoflight (PF) TM and the IC are for the March TM calibration and the May IS calibration. Due to other uncertainties mentioned earlier, these are lower than the estimated absolute accuracy quoted.

## DISCUSSION OF RESULTS

### RADIOMETRIC PERFORMANCE REQUIREMENTS

The prelaunch radiometric calibration procedures are designed to ensure that the TM meets its performance requirements. The radiometric specifications can be divided into three groups: dynamic range, sensitivity, and accuracy. The requirements are listed in Table 21.

The TM is designed for land observations: the reflective bands are therefore designed for maximum dynamic range for the expected land radiance levels (Fraser, 1975; Duck, 1977). This range can be tested using a well-calibrated external source. The radiometric sensitivity is expressed in terms of SNR for reflective bands. The relative accuracy requirements are quite stringent: about 1 quantum level for

Table 21

# TM RADIOMETRIC SPECIFICATIONS FOR REFLECTIVE BANDS

BAND	WAVELENGTH <sup>b</sup>		SPECIFICATION <sup>a</sup>					
	RANGE	BAND WIDTH	CONSTANT		SNR <sup>f</sup>	MSL <sup>e</sup>		SNR <sup>f</sup>
			IN-BAND RADIANCE <sup>c</sup>	SPECTRAL RADIANCE <sup>d</sup>		IN-BAND RADIANCE <sup>c</sup>	SPECTRAL RADIANCE <sup>d</sup>	
1	0.45-0.52	0.07	0.28	4.00	32	1.00	14.29	85
2	0.52-0.60	0.08	0.24	3.00	35	2.33	29.12	170
3	0.63-0.69	0.07	0.13	1.86	26	1.35	19.29	143
4	0.76-0.90	0.14	0.19	1.36	32	3.00	21.43	240
5	1.55-1.75	0.20	0.08	0.40	13	0.60	3.00	75
7	2.08-2.35	0.27	0.046	0.17	5	0.43	1.59	45

<sup>a</sup>SOURCE: GSFC SPECIFICATION: THEMATIC MAPPER SYSTEM AND ASSOCIATED TEST EQUIPMENT, GSFC 400-8-D-210, REVISION B, APRIL 1978, SECTION 3.2.9, TABLES IV AND V.

<sup>b</sup>WAVELENGTH IN MICROMETERS ( $\mu\text{m}$ ).

<sup>c</sup>IN-BAND RADIANCE ( $\text{mW cm}^{-2} \text{sr}^{-1}$ ).

<sup>d</sup>SPECTRAL RADIANCE ( $\text{mW cm}^{-2} \text{sr}^{-1} \mu\text{m}^{-1}$ ) = IN-BAND RADIANCE DIVIDED BY WAVELENGTH BANDWIDTH.

<sup>e</sup>MINIMUM SATURATION LEVEL (DIGITAL COUNTS = 243) RADIANCE (EITHER IN-BAND OR SPECTRAL).

<sup>f</sup>MINIMUM SIGNAL-TO-NOISE RATIO AT GIVEN INPUT RADIANCE.



between-detector accuracy and 2 percent for between-band accuracy. The overall absolute accuracy specified for the TM is 10 percent.

While in orbit, the TM must rely on its IC to convert individual channel voltages into correct scene radiance values and to monitor the health of the individual detectors, because there are no provisions for performing an external calibration with the Sun or other extraterrestrial body. It is thus very important that the prelaunch absolute calibration of the detectors be accurately transferred to the IC lamps. The absolute accuracy actually attained during the calibration of the TM was stated earlier to be no better than 5 percent for the detectors and 6 percent for the IC. This requirement has thus been met. The relative band-to-band accuracy of the IC is discussed in Barker et al. (1983b).

## CALIBRATION OF THE DETECTORS

### Gain and Offset Variability

#### Long-Term Gain Stability

The long-term stability of TM radiometry is quite good. Measurements of its absolute calibration over 9 months (from June 1981 to March 1982) showed that the variations are between 3 and 5 percent (Table 16), well within the required 10-percent accuracy. Variability of individual channels is also within specification.

The within-band variability is quite good. Table 22 summarizes the within-band standard deviations of all the tests. While the band-averaged gain values change by 3 to 5 percent, there is no appreciable change in the within-band spread of individual channel gain values. This indicates that the observed absolute calibration variations are due to changes affecting the whole system, and that the relative accuracy within a single TM band has not deteriorated. The small within-band variability implies that there will be very little striping in an image, even if no calibration by the IC is performed.

#### Short-Term Reproducibility of Channel Gain

The short-term reproducibility can be established by repeated measurements. The three sets of tests performed in March 1982 were used to obtain an estimate. Although they were different because of mirror scanning mode and IC sequencing mode, they were still the best and most complete set of repeated measurements available. Table 23 shows the

Table 22  
**STANDARD DEVIATIONS OF TM/PF AVERAGE GAINS**

TEST	BAND						
	1	2	3	4	5	7	
A1	0.090	0.071	0.092	0.134	(0.378) <sup>a</sup>	(1.487) <sup>a</sup>	
A2	0.093	0.071	0.091	0.135	(0.551) <sup>a</sup>	(4.369) <sup>a</sup>	
B	0.092	0.068	0.086	0.137	—	—	
C1	0.097	0.073	0.079	0.132	0.384	1.059	
C2	0.086	0.072	0.081	0.134	0.406	1.063	
C3	0.091	0.073	0.080	0.133	0.390	1.047	
MEAN	0.092	0.071	0.084	0.134	0.390	1.056	
STANDARD DEVIATION	0.00362	0.00986	0.0057	0.0016	0.0055	0.0083	

<sup>a</sup>VALUES FOR COOLED FOCAL PLANE BANDS FOR TEST A ARE NOT TO BE TRUSTED DUE TO REPAIR OF CFPA IN SEPTEMBER 1981. THESE VALUES WERE NOT INCLUDED IN MEANS AND STANDARD DEVIATION FOR BANDS 5 AND 7.

361-BA/AB(49)  
 JLB/DBZ/83

mean and standard deviations for the three band-averaged gain values. The short-term reproducibility is excellent, indicating the TM to be a very good instrument. However, noticing the small standard deviations of all the band-averaged gain values, it is obvious that the short-term reproducibility of individual channels is also very good. As an example, Table 24 shows the short-term reproducibility of channel 16. This channel was selected because of the somewhat large coherent noise component observed (Barker et al., 1983b). The reproducibility is good. Good within-band variability and stable short-term performance guarantee that the raw image of the TM will show little stripping and that neighboring scenes will show similar radiance levels. Post-launch observations lead to similar conclusions (Barker et al., 1983b).

### Offset Stability

The value of individual channel offsets is closely tied to the corresponding gain value. They are obtained through a least-squares linear fit to the IS(122) radiance measurements. Because of this, change in gain and offset values cannot be totally separated. However, some interesting conclusions can still be drawn:

- Channel 1 offset values for all reflective bands are high. Table 25 gives a comparison of the channel 1 offset and the mean offset for the same band. In most cases, these channel 1 values are the largest positive numbers for that band. No corresponding trend in the gain values is observed.

- There was a very strong odd-even effect for the cooled focal plane bands for test A. After the assembly was repaired, this effect disappeared.

- The offset values for all channels within a single TM band are close to one another. From Table 25, it can be seen that the standard deviations for all bands for both tests A1 and C2 are small, on the order of 0.25 digital count. These numbers can be further reduced if channel 1 is removed from the computation of the mean. This improvement will not affect the data analysis, because the offset values are treated individually in the radiometric correction algorithm. The smallness of the standard deviations does, however, indicate that the channels are well balanced within a band.

- The offset values are quite stable for all the absolute calibration tests. Table 26 shows the mean offset values for all bands and all tests. All mean offset values are positive.

Table 23

**THE MEAN AND STANDARD DEVIATIONS OF GAINS DURING THE THREE MARCH ABSOLUTE CALIBRATION TESTS**

TESTS	TM/PF GAIN (BAND-AVERAGED)						
	BAND						
	1	2	3	4	5	7	
C1	15.92	8.06	10.59	10.97	77.06	147.17	
C2	15.78	8.10	10.62	10.90	77.24	147.12	
C3	15.78	8.04	10.56	10.91	77.16	146.96	
MEAN	15.83	8.07	10.59	10.93	77.15	147.08	
STANDARD DEVIATION	0.081	0.031	0.030	0.038	0.090	0.110	

361-BA/AB(49)  
JLB/DS2/83

Table 24

**THE MEAN AND STANDARD DEVIATIONS OF THE GAIN VALUES OF CHANNEL 16 DURING THE THREE MARCH ABSOLUTE CALIBRATION TESTS, SHOWING EXCELLENT SHORT-TERM REPRODUCIBILITY**

TM/PF GAIN (CHANNEL 16)						
TESTS	BAND					
	1	2	3	4	5	7
C1	15.99	7.96	10.46	10.89	77.52	148.51
C2	15.87	7.98	10.48	10.83	77.74	148.49
C3	15.83	7.92	10.43	10.84	77.60	148.28
MEAN	15.90	7.95	10.47	10.85	77.62	148.43
STANDARD DEVIATION	0.083	0.031	0.025	0.032	0.111	0.172

361-BA/AB(49)  
JLB/DB2/83

Table 25

TM/PF OBSERVED OFFSET VALUES SHOWING THE MEAN, STANDARD DEVIATION, MINIMUM, MAXIMUM, AND CHANNEL 1 VALUES FOR ALL BANDS AND FOR TEST A1 AND C2

TEST	BAND	MEAN	$\sigma^b$	MIN	MAX	CHANNEL 1
A1	1	0.44	0.34	0.31	1.19	1.19
	2	0.89	0.16	0.72	1.36	1.36
	3	0.81	0.20	0.53	1.22	1.22
	4	0.92	0.22	0.54	1.41	1.41
	5	1.53 <sup>a</sup>	1.08 <sup>a</sup>	0.79 <sup>a</sup>	5.19 <sup>a</sup>	1.84 <sup>a</sup>
	7	2.57 <sup>a</sup>	0.74 <sup>a</sup>	1.35 <sup>a</sup>	3.86 <sup>a</sup>	3.83 <sup>a</sup>
C2	1	2.58	0.18	2.37	3.18	3.18
	2	2.44	0.16	2.32	2.99	2.99
	3	1.58	0.20	1.24	2.13	2.13
	4	1.91	0.22	1.67	2.53	2.53
	5	3.02	0.11	2.85	3.28	3.28
	7	2.41	0.20	2.15	2.95	2.95

<sup>a</sup>COOLED FOCAL PLANE VALUES ARE NOT TO BE USED BECAUSE THE PLANE WAS REMOVED AND SERVICED AFTER THE A TEST.

<sup>b</sup>STANDARD DEVIATION.

361-8A/83(49)  
JLB/DB2/83

Table 26

**TM/PF MEAN OFFSET VALUES FOR ALL BANDS FOR ALL TESTS**

BAND	TEST					
	1	2	3	4	5	6
1	0.44	0.46	—	2.45	2.58	2.54
2	0.89	0.92	—	2.39	2.44	2.45
3	0.81	0.86	—	1.48	1.58	1.57
4	0.91	0.95	—	1.78	1.91	1.89
5	1.53 <sup>a</sup>	1.77 <sup>a</sup>	—	2.83	3.02	2.94
7	2.54 <sup>a</sup>	2.68 <sup>a</sup>	—	2.32	2.41	2.43

<sup>a</sup>COOLED FOCAL PLANE VALUES ARE NOT TO BE USED BECAUSE THE FLAME WAS REMOVED AND SERVICED AFTER THE A TEST.

361-BA/AB(49)  
JLB/DB2/83

### Signal-to-Noise Ratio

The computed SNRs for all bands for test C2 are presented in Tables 2 through 7. All but five detectors satisfied the specifications by significant amounts; two of the five passed, but barely (1/4 and 7/7). Channel 3 of band 5 is dead, and channels 2 and 4 of band 2 are bad, one due to noise (2/2) and the other due to slow response (2/4). The 5/3 detector is the only one for which no usable data are obtainable, and this should be treated as dead in the post-launch data processing. Most TM detectors satisfied the specifications although the error in the computed SNR values is somewhat high (typically 4 to 5 for all bands) due to the large scatter.

### Dynamic Range

Table 18 gives the ratio of the specified to the average MSL radiance by band, the minimum observed MSL radiance, and the ratio of the standard deviation of the average to the average value. All detectors are within 1 percent of the average, except in band 4 (1.2 percent). The larger standard deviation there is due largely to detector 10, which is an outlier and is less sensitive than the other band 4 detectors. All bands have somewhat poorer dynamic range than specified; band 3 is the worst case, with band 1 next. Bands 2, 4, 5, and 7 are only slightly different from the required values. Whether this will adversely affect TM image data for these bands is not presently known.

A stated requirement for the archived radiometrically corrected data produced by the Landsat-4 Scrounge data processing system for the TM has been that the original raw data must be retrievable. To guarantee this, the radiometric lookup tables used to generate the corrected data should expand or leave the same any raw digital count value. For example, if the original value is 100, the specified dynamic range for the corrected data may give a value slightly greater than 100 by some fraction. The minimum saturation level radiance given in Table 21 for each band is thus appropriate for this requirement because the TM gains have already been set to give a saturation value 5 percent higher than the MSL. However, the postlaunch performance of the TM must also be considered. Data presented in Barker et al. (1983b) show that the gains determined with IC data have shown an exponential-like decline for bands 1 through 4 and have stabilized at approximately 3 to 6 percent below pre-launch values presented here. Bands 5 and 7, however, have shown an oscillatory behavior. Band 7 seems to show no change overall, except for the 2-month oscillation. Band 5 has shown an increase after launch and then the oscillation



and possibly some decrease. The largest change was an increase of 8 percent in band 5. If we recommended using the prelaunch MSL radiances as the upper limit to the dynamic range for the data processing corrections, we would risk loss of some image data in bands 5 and 7. Hence, for bands 5 and 7, we recommend using radiance values 10 percent lower than the maximum possible values for RMAX. Table 27 gives the upper and lower radiance limits for each band that we recommend for use in the postlaunch data processing systems.

### CALIBRATION OF THE IC

The two most important parameters derived from these test comparisons are the slope, which measures the relative change between tests, and the standard error of the estimates, which is a measure of the goodness of fit. The major contributor to the latter is noise due to the IC pulse integration and averaging procedure.

To determine to what extent the IC lamp levels may vary due to differences in environment or operating conditions, other IC lamp data are presently being studied. The standard deviation of the average calibration pulse for a lamp state is typically 0.5 digital count. The average difference between forward and reverse mirror sweep scans is typically 0.5 digital count; both values are band dependent. The forward-reverse differences are uncorrected for dark background. These problems are related to overall IC stability under a variety of operating and environmental conditions and are discussed in more detail by Barker et al. (1983b). Present estimates of repeatability with the transfer data indicate that the IC gives calibration radiances repeatable to the 5-percent level or better, except for band 5; band 5 is better than 7 percent. Table 28 shows figure-of-merit values for the comparisons between transfer tests 1 and 7 and between tests 9 and 7. The latter is a comparison of ambient to vacuum calibration transfer. Table 29 shows results for the derived slope for the same test comparisons. Differences noted particularly in band 5 may be attributed to slight differences in operating conditions. The other bands typically show changes of 5 percent or less. The differences between tests 1 and 7 for bands 5 and 7 should be ignored due to changes made in the CFP A in September 1981; these changes introduced a discontinuity between previous calibrations and those performed in March 1982.

Typically, the radiance comparisons between tests have shown more variability than the digital count comparisons (see Table 20). This may be understood by noting that there are slight differences in environment or operating conditions

Table 27

**TM/PF DYNAMIC RANGE RECOMMENDED  
RADIANCE VALUES FOR RADIOMETRIC LOOKUP  
TABLE GENERATION IN DATA PROCESSING SYSTEMS**

DYNAMIC RANGE ( $\text{mWcm}^{-2}\text{sr}^{-1}\mu\text{m}^{-1}$ )	BAND						
	1	2	3	4	5	7	
RMAX	15.089	29.353	22.350	21.369	2.925	1.534	
RMIN	-0.152	-0.284	-0.117	-0.151	-0.037	-0.015	

361-BA/A8-(50g)-2  
JLB/DB2/83

Table 28

**TM/PF INTERNAL CALIBRATOR  
AVERAGE COMPARISON SLOPE VALUES BY BAND**

TEST 1 TO TEST 7						
	BAND					
	1	2	3	4	5	7
DIGITAL COUNTS	1.0256	1.0311	1.0278	1.0363	0.9450	1.0058
RADIANCE	0.9758	1.0262	1.0244	0.9979	0.8962	0.9715

TEST 9 TO TEST 7						
	BAND					
	1	2	3	4	5	7
DIGITAL COUNTS	0.9879	0.9998	1.0365	1.0451	0.9657	0.9812
RADIANCE	0.9884	1.0074	1.0412	1.0487	0.9374	0.9675

361-BA/AB(49)  
JLB/DB2/83

Table 29  
**TM/PF INTERNAL CALIBRATOR**  
**AVERAGE GOODNESS OF A FIT ( $\rho_{y_{est}}$ ) VALUES BY BAND**

TEST 1 TO TEST 7						
	BAND					
	1	2	3	4	5	7
DIGITAL COUNTS	1.35	0.79	0.93	0.79	0.27	0.44
RADIANCE	0.081	0.097	0.087	0.069	0.0033	0.0029

TEST 9 TO TEST 7						
	BAND					
	1	2	3	4	5	7
DIGITAL COUNTS	0.79	0.75	1.04	1.26	0.23	0.62
RADIANCE	0.050	0.093	0.098	0.116	0.0028	0.0042

$\rho_{y_{est}}$  UNITS ARE DIGITAL COUNTS OR MILLIWATTS CM<sup>-2</sup> STER<sup>-1</sup> μm<sup>-1</sup> (RADIANCE).

361-BA/AB(49)  
 JLB/DB2/83

between the different transfer tests that have not been accounted for. In particular, Clemann et al. (1982) has noted a linear correlation between various temperature parameters, particularly the calibration shutter flag temperature, and the digital output of the TM. Thus, the sensitivity of the TM (gain and offset) changes slightly with these internal temperatures; we are presently studying these effects with these and other TM IC data to firmly establish the correlation and the overall degree of stability of the IC (Barker et al., 1983d). Even so, the results of the transfer test comparisons show good repeatability (5 percent or better for all bands except band 5) without including operational differences; when they are included in the analysis, we can expect to see a significant improvement. The results for tests 1, 3, and 4 that were taken during the June 1981 absolute calibration show that the above considerations are valid. The variation in slope values among these three tests is less than 0.7 percent in all bands.

#### RECOMMENDATIONS

Our study of the prelaunch absolute radiometric calibration of the protoflight TM reflective bands has shown several areas where improvements in the calibration can be realized, particularly when applied to the flight unit TM. Accordingly, we have separated our recommendations into two categories: protoflight and flight.

#### PROTOFLIGHT TM

The best calibration of the protoflight TM reflective bands prior to launch was performed in March 1982. The test designated C2 in this paper is to be preferred due to the operating configuration and the state of calibration of the IS(122) afterwards. Tables 1 through 13 summarize the important parameters for this test for all detectors. Additional evaluation of the TM absolute detector calibration is still in progress and is concentrating on the areas of temperature dependence and the effect of nonuniform analog-to-digital conversions on the calibration of the TM. In addition, the raw data from the IS(122) calibration is being examined to ensure that the peak output of the IS(122) was seen by all TM detectors and to evaluate the impact of a non-flat (IS(122) output (if any) on the detector calibration. We are also evaluating the feasibility of recollecting prelaunch calibration data to study the effect of a drifting background (DC restore of offset voltage to a nominal reference corresponding to 2 or 3 digital counts) during an image scan. In-orbit data are also being obtained to study this effect.

The calibrations of the IC that best characterize the transfer from the IS(122) to the IC are the March 20 transfer (test 7 in this paper) for determining the ambient characteristics of the IC and the March 9 transfer (test 9 in this paper) for referencing the vacuum characteristics and transferring the calibration from ambient to vacuum (by comparison with test 7). The use of these data sets as a reference for in-orbit data is discussed in Barker et al. (1983c). Additional studies of protoflight TM data, both prelaunch and in-orbit, to study temperature dependencies of the IC (particularly due to the calibration shutter flag) are needed. (See Clemann et al., 1982). The dependence of the IC calibration on such parameters as the number of minor frames centered on the pulse to average, number of scans to average, etc., are discussed in Barker et al. (1983b).

#### FLIGHT UNIT TM

Recommendations for the calibration of the flight unit TM have been developed through experience with the protoflight calibration and application of the calibration while radio-metrically correcting in-orbit protoflight data. Changes to the calibration procedures and to the type and quantity of data collected should be made as follows:

- Cross-calibration of all Landsat integrating spheres (one for TM and two for MSS) directly at NBS rather than more than one step (lamp source) removed from NBS as is presently the case; include the thermal band in the calibration if possible
- Operation of the IS(122) in scanning mode for all tests (already done; see Lansing 1981) and, increase the size of the video data window collected in each scan
- Use of multiple IC data collects during sphere calibration to improve statistics of the calibration transfer to the IC and to allow for correction of temperature dependencies
- Use of a linear ramp for system-level measurement of analog-to-digital conversion and inclusion of these measurements in the IS(122) calibration
- Calibration of a lamp source small enough to use during thermal vacuum chamber testing to measure change in TM detectors and IC due to so-called "vacuum shift" (compared to the ambient IS(122) calibration)
- Collection and study of sufficient background data to characterize changes in reference level during an image scan

## APPENDIX - SPECTRAL RADIANCES FOR THE IC

The averaged digital counts and their corresponding spectral radiance values for each lamp configuration of the TM IC calibration transfer are given in the following tables. Two reference sets are given, March 20, 1982 (test 7 in Table 22) and March 9, 1982 (test 9), representative of ambient and vacuum conditions, respectively. Tables A-1 through A-16 pertain to test 7, Tables A-17 through A-32 pertain to test 9. Tables A-1 through A-8 and A-17 through A-24 give the averaged digital counts,  $\bar{Q}$ , determined by the Hughes averaging procedure (Barker et al., 1983b) for the eight lamp configurations (100, 110, 010, 011, 111, 101, 001, and 000, where 1 indicates lamp on, and 0, lamp off). Using the gains and offsets for each detector given in Tables 2 through 7. The corresponding radiance values are computed as follows:

$$L = \frac{\bar{Q} - O}{G}$$

where  $L$  is the resulting radiance,  $\bar{Q}$  is the averaged digital count,  $G$  the gain, and  $O$  is the offset. These values are presented in Tables A-9 through A-16 and A-25 through A-32. Each table gives mean values (MEAN), standard deviations (SDEV), standard deviations of the mean (SMEN), and coefficients of variation (CVAR) for odd-numbered, even-numbered, and all detectors in a band. Values for detector 4, band 2, are not given in Tables A-1 through A-16 because the Hughes computer program treated it as a dead detector (like band 5, channel 3). Values for this detector are presented in the other tables, derived directly from raw data taken in thermal vacuum testing.

Finally, Tables A-33 through A-40 give the ratio of digital counts for test 7 to test 9 for all eight lamp configurations. These tables are presented to aid in evaluating the so-called "vacuum shift" generally noted in the response of a satellite sensor between ambient and vacuum operating conditions. The mean values and standard deviations given have the same meaning as before (e.g., Tables A-1 through A-8).

ORIGINAL PAGE IS  
OF POOR QUALITY

Table 'A-1. Lamp 100 for Test 7 in Digital Counts

CHANNEL	BAND					
	TM1	TM2	TM3	TM4	TM5	TM7
1	107.69	102.53	90.99	92.12	47.25	61.09
2	104.79	92.95	91.94	96.76	68.07	57.11
3	109.76	100.11	89.71	92.70	—	59.34
4	106.56	—	91.32	97.34	67.93	57.06
5	107.94	101.71	90.13	91.30	45.82	58.97
6	104.48	92.60	92.85	98.21	66.91	56.85
7	107.01	99.46	89.58	91.40	46.05	58.41
8	104.79	91.23	91.58	97.23	67.23	56.43
9	106.39	100.47	89.79	91.87	45.85	59.19
10	105.29	90.47	92.14	101.11	66.55	56.45
11	107.84	99.53	89.03	90.86	46.10	58.88
12	105.62	90.15	92.78	98.30	67.04	57.83
13	108.10	100.37	89.78	97.88	45.87	58.36
14	105.47	91.46	91.56	97.88	66.46	58.08
15	108.89	100.35	90.60	89.84	46.64	59.48
16	104.96	90.15	91.33	96.57	68.25	59.70
MEAN ODD	107.95	100.56	89.95	91.61	46.23	59.21
MEAN EVEN	105.25	91.29	91.94	97.93	67.30	57.44
MEAN ALL	106.60	96.24	90.94	94.77	57.47	58.33
SDEV ODD	1.04	1.06	0.63	1.00	0.54	0.86
SDEV EVEN	0.65	1.13	0.62	1.44	0.70	1.09
SDEV ALL	1.63	4.91	1.18	3.47	10.90	1.32
SMEN ODD	0.37	0.39	0.22	0.35	0.20	0.30
SMEN EVEN	0.23	0.43	0.22	0.51	0.25	0.39
SMEN ALL	0.41	1.27	0.30	0.87	2.81	0.33
CVAR ODD	0.97	1.05	0.70	1.09	1.16	1.46
CVAR EVEN	0.62	1.25	0.67	1.47	1.04	1.90
CVAR ALL	1.53	5.10	1.30	3.66	18.97	2.27

9214531/93



ORIGINAL PAGE IS  
OF POOR QUALITY

Table A-2. Lamp 110 for Test 7 in Digital Counts

CHANNEL	BAND					
	TM1	TM2	TM3	TM4	TM5	TM7
1	174.48	180.62	155.73	184.85	87.56	106.21
2	169.00	157.38	160.44	181.46	125.46	110.28
3	178.64	177.00	154.07	185.57	—	103.95
4	170.13	—	159.72	182.28	125.62	110.45
5	175.68	179.49	154.79	183.10	85.77	103.49
6	168.16	156.22	161.91	183.86	123.76	110.07
7	173.85	176.04	153.90	183.26	86.18	103.02
8	167.96	154.04	159.97	182.47	124.25	109.31
9	173.67	177.55	154.65	184.08	85.66	103.88
10	169.03	153.05	160.89	189.43	123.18	109.08
11	175.05	176.01	153.12	182.13	86.23	103.24
12	168.94	152.41	161.79	183.65	123.96	111.73
13	175.87	176.77	154.43	186.13	85.88	102.56
14	169.14	154.57	159.81	183.21	122.85	111.96
15	177.06	177.64	155.55	180.49	87.00	103.83
16	168.91	152.51	159.10	180.90	125.52	114.47
MEAN ODD	175.54	177.64	154.53	183.70	86.33	103.77
MEAN EVEN	168.91	154.31	160.45	183.41	124.33	110.92
MEAN ALL	172.22	166.75	157.49	183.55	106.59	107.35
SDEV ODD	1.69	1.63	0.86	1.86	0.71	1.10
SDEV EVEN	0.67	1.91	1.02	2.65	1.10	1.76
SDEV ALL	3.64	12.17	3.19	2.21	19.64	3.95
SMEN ODD	0.60	0.58	0.30	0.66	0.27	0.39
SMEN EVEN	0.24	0.72	0.36	0.94	0.39	0.62
SMEN ALL	0.91	3.14	0.80	0.55	5.07	0.99
CVAR ODD	0.96	0.92	0.56	1.01	0.83	1.06
CVAR EVEN	0.40	1.24	0.63	1.44	0.88	1.59
CVAR ALL	2.11	7.30	2.03	1.21	18.43	3.68

9214(53)/83

ORIGINAL PAGE IS  
OF POOR QUALITY

Table A-3. Lamp 010 for Test 7 in Digital Counts

CHANNEL	BAND					
	TM1	TM2	TM3	TM4	TM5	TM7
1	70.42	81.40	68.27	96.56	43.66	48.83
2	65.60	66.63	70.91	87.77	60.54	55.96
3	71.58	79.26	67.14	96.21	—	47.35
4	67.21	—	70.56	87.98	60.37	55.89
5	70.53	80.34	67.35	94.81	42.48	46.98
6	65.64	66.26	71.56	89.00	59.46	55.85
7	69.67	78.67	66.92	95.42	42.53	46.87
8	66.89	65.30	70.66	88.25	59.60	55.36
9	69.46	79.23	67.03	95.64	42.32	47.08
10	66.07	64.70	70.98	91.34	59.09	55.21
11	70.26	78.70	66.45	94.54	42.58	46.87
12	66.70	64.44	71.33	88.75	59.46	56.50
13	70.73	78.61	67.04	96.57	42.41	46.51
14	66.18	65.35	70.55	88.41	58.87	56.66
15	70.92	79.44	67.48	93.67	43.14	47.40
16	65.79	64.21	70.41	87.58	60.54	58.03
MEAN ODD	70.45	79.45	67.21	95.43	42.70	47.24
MEAN EVEN	66.14	65.27	70.87	88.64	59.74	56.18
MEAN ALL	68.29	72.84	69.04	92.03	51.79	51.71
SDEV ODD	0.69	0.97	0.53	1.04	0.51	0.71
SDEV EVEN	0.57	0.92	0.41	1.20	0.66	0.89
SDEV ALL	2.31	7.38	1.95	3.67	8.82	4.69
SMEN ODD	0.24	0.34	0.19	0.37	0.19	0.25
SMEN EVEN	0.20	0.35	0.15	0.42	0.23	0.32
SMEN ALL	0.58	1.91	0.49	0.92	2.28	1.17
CVAR ODD	0.98	1.22	0.79	1.09	1.20	1.50
CVAR EVEN	0.86	1.41	0.58	1.35	1.11	1.59
CVAR ALL	3.38	10.13	2.82	3.99	17.03	9.06

9214(53)/83

ORIGINAL PAGE IS  
OF POOR QUALITY

Table A-4. Lamp 011 for Test 7 in Digital Counts

CHANNEL	BAND					
	TM1	TM2	TM3	TM4	TM5	TM7
1	115.88	127.03	105.64	140.70	66.56	80.75
2	109.45	106.48	111.09	135.10	92.42	88.90
3	118.09	124.15	104.29	141.01	—	78.88
4	110.05	—	110.64	135.87	92.20	88.95
5	116.22	126.09	104.81	138.96	64.86	78.42
6	109.28	106.03	112.32	137.14	91.07	88.65
7	115.37	123.45	104.23	139.48	65.10	78.11
8	108.56	104.33	110.83	136.06	91.41	87.95
9	114.88	124.55	104.67	140.23	64.94	78.85
10	109.35	103.49	111.45	141.03	90.68	87.85
11	116.47	123.51	103.68	138.40	65.23	78.28
12	109.44	103.19	112.08	136.84	91.15	90.03
13	116.90	123.79	104.43	141.78	64.95	77.86
14	109.70	104.47	110.77	136.49	90.50	90.04
15	117.38	124.68	105.31	137.29	66.07	78.93
16	109.48	102.90	110.37	134.80	92.67	92.36
MEAN ODD	116.40	124.66	104.63	139.73	65.39	78.76
MEAN EVEN	109.46	104.41	111.19	136.67	91.52	89.34
MEAN ALL	112.93	115.21	107.91	138.20	79.33	84.05
SDEV ODD	1.06	1.29	0.63	1.49	0.67	0.90
SDEV EVEN	0.31	1.38	0.70	1.94	0.84	1.47
SDEV ALL	3.66	10.53	3.45	2.30	13.52	5.59
SMEN ODD	0.37	0.45	0.22	0.53	0.25	0.32
SMEN EVEN	0.11	0.52	0.25	0.69	0.30	0.52
SMEN ALL	0.91	2.72	0.86	0.57	3.49	1.40
CVAR ODD	0.91	1.03	0.60	1.07	1.03	1.15
CVAR EVEN	0.29	1.33	0.63	1.42	0.92	1.65
CVAR ALL	3.24	9.14	3.20	1.66	17.04	6.65

92141531/83

ORIGINAL  
OF POOR QUALITY

Table A-5. Lamp 111 for Test 7 in Digital Counts

CHANNEL	BAND					
	TM1	TM2	TM3	TM4	TM5	TM7
1	219.59	225.38	192.57	226.49	109.72	137.32
2	211.38	196.39	199.73	227.68	156.74	142.16
3	224.37	220.79	190.43	227.93	—	135.04
4	214.33	—	198.57	228.72	157.23	142.98
5	221.09	223.94	191.50	225.09	107.65	134.49
6	210.74	194.99	201.58	230.68	154.82	142.49
7	219.16	219.61	190.35	225.02	108.17	133.76
8	210.77	192.43	198.81	229.24	155.27	141.49
9	218.43	221.51	191.11	226.80	107.56	135.00
10	212.19	191.17	200.44	236.84	154.19	141.22
11	220.93	219.58	189.53	224.08	108.32	134.29
12	212.93	190.52	201.40	230.66	155.32	144.57
13	221.70	220.73	191.18	229.33	107.85	133.38
14	212.11	192.97	199.06	229.98	153.85	144.86
15	223.27	221.53	192.65	222.79	108.83	134.84
16	211.50	190.28	198.27	227.12	156.80	147.78
MEAN ODD	221.07	221.64	191.16	225.94	108.30	134.76
MEAN EVEN	211.99	192.68	199.73	230.12	155.53	143.44
MEAN ALL	216.53	208.12	195.45	228.03	133.49	139.10
SDEV ODD	2.04	2.04	1.09	2.13	0.77	1.20
SDEV EVEN	1.21	2.31	1.29	3.01	1.27	2.19
SDEV ALL	4.96	15.10	4.57	3.31	24.41	4.80
SMEN ODD	0.72	0.72	0.39	0.75	0.29	0.42
SMEN EVEN	0.43	0.87	0.46	1.07	0.45	0.78
SMEN ALL	1.24	3.90	1.14	0.83	6.30	1.20
CVAR ODD	0.92	0.92	0.57	0.94	0.71	0.89
CVAR EVEN	0.57	1.20	0.65	1.31	0.82	1.53
CVAR ALL	2.29	7.26	2.34	1.45	18.29	3.45

921453a/783

ORIGINAL PAGE IS  
OF POOR QUALITY

Table A-6. Lamp 101 for Test 7 in Digital Counts

CHANNEL	BAND					
	TM1	TM2	TM3	TM4	TM5	TM7
1	153.06	148.24	128.50	135.88	69.78	92.41
2	148.69	133.10	132.09	143.70	100.07	89.80
3	156.65	145.15	126.91	136.16	—	90.40
4	150.17	—	131.46	144.39	100.00	89.84
5	154.16	147.41	127.63	134.55	68.18	89.84
6	148.24	132.18	133.43	145.53	98.52	89.58
7	152.47	144.44	126.90	134.92	68.55	89.50
8	147.94	130.39	131.62	144.46	98.85	88.91
9	152.23	145.93	127.54	135.57	68.13	90.29
10	148.92	129.57	132.70	150.21	98.05	88.93
11	153.99	144.42	126.30	134.26	68.58	89.91
12	149.02	128.84	133.38	145.49	95.76	91.00
13	154.59	145.64	127.46	136.99	68.28	89.37
14	149.20	130.56	131.85	145.12	97.95	91.25
15	156.82	145.84	128.38	132.70	69.28	90.65
16	148.97	129.03	131.27	143.63	100.21	93.58
MEAN ODD	154.12	145.88	127.45	135.13	68.68	90.30
MEAN EVEN	148.89	130.53	132.23	145.32	99.05	90.36
MEAN ALL	151.51	138.72	129.84	140.22	84.88	90.33
SDEV ODD	1.57	1.35	0.76	1.33	0.62	0.97
SDEV EVEN	0.69	1.61	0.86	2.11	0.92	1.56
SDEV ALL	2.94	8.06	2.58	5.53	15.70	1.25
SMEN ODD	0.55	0.48	0.27	0.47	0.24	0.34
SMEN EVEN	0.24	0.61	0.30	0.75	0.33	0.55
SMEN ALL	0.74	2.08	0.65	1.38	4.05	0.31
CVAR ODD	1.02	0.93	0.60	0.99	0.91	1.07
CVAR EVEN	0.46	1.23	0.65	1.45	0.93	1.72
CVAR ALL	1.94	5.81	1.99	3.94	18.50	1.38

9214(3-1)/03

ORIGINAL PAGE NO  
OF POOR QUALITY

Table A-7. Lamp 001 for Test 7 in Digital Counts

CHANNEL	BAND					
	TM1	TM2	TM3	TM4	TM5	TM7
1	48.61	48.53	40.67	47.30	25.73	34.96
2	45.36	42.04	42.38	49.78	34.81	35.42
3	49.27	47.20	39.85	47.17	—	33.80
4	46.65	—	42.10	49.96	34.63	35.31
5	48.47	47.88	39.97	46.35	24.71	33.46
6	45.52	41.91	42.94	50.54	34.26	35.25
7	48.13	46.89	39.65	46.80	24.94	33.39
8	45.80	41.36	42.48	50.06	34.35	35.06
9	47.80	47.24	39.73	46.79	24.73	33.72
10	45.94	40.91	42.62	51.77	33.88	35.07
11	49.37	46.93	39.40	46.31	24.83	33.59
12	46.40	40.80	42.75	50.56	34.24	35.77
13	48.57	47.17	39.81	47.35	24.87	33.19
14	45.93	41.39	42.46	50.44	34.00	36.04
15	48.92	47.38	40.22	45.89	25.27	33.88
16	45.61	40.98	42.35	49.88	34.96	37.01
MEAN ODD	48.52	47.40	39.91	46.74	25.01	33.75
MEAN EVEN	45.90	41.34	42.48	50.37	34.39	35.62
MEAN ALL	47.21	44.57	41.20	48.56	30.01	34.68
SDEV ODD	0.46	0.56	0.39	0.53	0.37	0.54
SDEV EVEN	0.44	0.49	0.27	0.65	0.38	0.66
SDEV ALL	1.42	3.17	1.37	1.96	4.86	1.13
SMEN ODD	0.16	0.20	0.14	0.19	0.14	0.19
SMEN EVEN	0.15	0.18	0.10	0.23	0.13	0.23
SMEN ALL	0.36	0.82	0.34	0.49	1.25	0.28
CVAR ODD	0.95	1.18	0.98	1.13	1.47	1.59
CVAR EVEN	0.95	1.18	0.64	1.28	1.11	1.84
CVAR ALL	3.01	7.12	3.32	4.04	16.18	3.25

BR/CSM/26

ORIGINAL PAGE IS  
OF POOR QUALITY

Table A-8. Lamp 000 for Test 7 in Digital Counts

CHANNEL	BAND					
	TM1	TM2	TM3	TM4	TM5	TM7
1	2.71	2.68	2.61	2.70	2.92	2.84
2	2.20	2.21	2.18	2.22	2.57	2.39
3	2.34	2.28	2.39	2.33	—	2.36
4	1.69	—	2.32	2.22	2.57	2.42
5	2.35	2.12	2.16	2.06	2.69	2.19
6	2.26	2.26	2.22	2.27	2.73	2.44
7	2.28	2.09	2.16	2.06	2.64	2.56
8	2.15	2.20	2.39	2.33	2.84	2.39
9	2.34	2.10	2.19	2.05	2.60	2.31
10	1.85	2.10	2.14	2.04	2.60	2.47
11	2.25	2.17	2.07	2.05	2.63	2.28
12	1.66	2.10	2.12	2.01	2.58	2.35
13	2.19	2.12	2.01	2.04	2.69	2.13
14	2.17	2.16	2.25	2.05	2.59	2.52
15	2.21	2.10	1.99	2.04	2.80	2.15
16	2.25	2.24	2.26	2.04	2.63	2.50
MEAN ODD	2.33	2.21	2.20	2.17	2.71	2.35
MEAN EVEN	2.03	2.18	2.23	2.15	2.64	2.44
MEAN ALL	2.18	2.20	2.22	2.16	2.67	2.39
SDEV ODD	0.16	0.20	0.21	0.24	0.12	0.24
SDEV EVEN	0.25	0.06	0.09	0.13	0.10	0.06
SDEV ALL	0.26	0.15	0.16	0.18	0.11	0.18
SMEN ODD	0.06	0.07	0.07	0.08	0.04	0.09
SMEN EVEN	0.09	0.02	0.03	0.04	0.04	0.02
SMEN ALL	0.06	0.04	0.04	0.05	0.03	0.04
CVAR ODD	6.99	9.09	9.48	10.88	4.25	10.31
CVAR EVEN	12.53	2.83	4.09	5.87	3.76	2.35
CVAR ALL	11.89	6.75	7.06	8.48	4.08	7.34

9214031/83

ORIGINAL COPY  
OF FOOT CATALOG

Table A-9. Lamp 100 for Test 7 in Radiance Units

CHANNEL	BAND					
	TM1	TM2	TM3	TM4	TM5	TM7
1	6.679	12.177	8.246	8.165	0.574	0.392
2	6.496	11.163	8.523	8.766	0.848	0.373
3	6.724	12.191	8.292	8.235	—	0.386
4	6.528	—	8.533	8.819	0.838	0.370
5	6.658	12.114	8.334	8.282	0.557	0.384
6	6.481	11.005	8.556	8.805	0.831	0.371
7	6.657	12.057	8.319	8.248	0.556	0.380
8	6.482	10.981	8.549	8.774	0.830	0.372
9	6.556	12.146	8.290	8.286	0.556	0.384
10	6.483	10.889	8.579	8.802	0.827	0.373
11	6.714	12.148	8.317	8.271	0.554	0.385
12	6.520	10.959	8.577	8.854	0.825	0.374
13	6.724	12.081	8.268	8.245	0.551	0.385
14	6.538	10.932	8.449	8.795	0.822	0.376
15	6.736	11.956	8.271	8.184	0.563	0.392
16	6.463	10.995	8.556	8.734	0.840	0.385
MEAN ODD	6.681	12.109	8.292	8.239	0.559	0.386
MEAN EVEN	6.499	10.969	8.540	8.794	0.833	0.374
MEAN ALL	6.590	11.586	8.416	8.516	0.705	0.380
SDEV ODD	0.060	0.078	0.031	0.045	0.008	0.004
SDEV EVEN	0.028	0.087	0.043	0.037	0.009	0.005
SDEV ALL	0.104	0.584	0.133	0.289	0.141	0.007
SMEN ODD	0.021	0.027	0.011	0.016	0.003	0.002
SMEN EVEN	0.010	0.033	0.015	0.013	0.003	0.002
SMEN ALL	0.026	0.151	0.033	0.072	0.037	0.002
CVAR ODD	0.893	0.642	0.370	0.551	1.357	1.111
CVAR EVEN	0.436	0.792	0.503	0.425	1.027	1.252
CVAR ALL	1.580	5.036	1.582	3.393	20.072	1.965

921453a/7B3



ORIGINAL PAGE IS  
OF POOR QUALITY

Table A-10. Lamp 110 for Test 7 in Radiance Units

CHANNEL	BAND					
	TM1	TM2	TM3	TM4	TM5	TM7
1	10.947	21.731	14.252	16.617	1.101	0.697
2	10.570	19.101	14.984	16.596	1.595	0.735
3	11.048	21.786	14.370	16.664	—	0.688
4	10.519	—	15.028	16.660	1.580	0.731
5	10.943	21.604	14.420	16.773	1.078	0.685
6	10.528	18.779	15.032	16.639	1.570	0.734
7	10.919	21.562	14.398	16.743	1.074	0.682
8	10.492	18.756	15.040	16.607	1.569	0.736
9	10.808	21.691	14.384	16.776	1.074	0.687
10	10.502	18.622	15.085	16.624	1.562	0.737
11	10.998	21.710	14.388	16.758	1.071	0.687
12	10.524	18.727	15.061	16.683	1.557	0.738
13	11.044	21.494	14.318	16.685	1.067	0.687
14	10.578	18.683	14.864	16.615	1.552	0.741
15	11.056	21.387	14.302	16.599	1.085	0.696
16	10.492	18.809	15.019	16.522	1.576	0.754
MEAN ODD	10.970	21.621	14.354	16.702	1.079	0.688
MEAN EVEN	10.526	18.783	15.014	16.618	1.570	0.738
MEAN ALL	10.748	20.296	14.684	16.660	1.341	0.713
SDEV ODD	0.085	0.134	0.058	0.070	0.011	0.005
SDEV EVEN	0.033	0.153	0.068	0.048	0.013	0.007
SDEV ALL	0.238	1.472	0.346	0.074	0.254	0.026
SMEN ODD	0.030	0.047	0.021	0.025	0.004	0.002
SMEN EVEN	0.012	0.058	0.024	0.017	0.005	0.002
SMEN ALL	0.059	0.380	0.087	0.018	0.066	0.007
CVAR ODD	0.775	0.621	0.405	0.418	1.036	0.749
CVAR EVEN	0.317	0.816	0.454	0.287	0.857	0.934
CVAR ALL	2.214	7.253	2.358	0.444	18.962	3.701

971453m/103

ORIGINAL FILED IN  
OF POOR QUALITY

Table A-11. Lamp 010 for Test 7 in Radiance Units

CHANNEL	BAND					
	TM1	TM2	TM3	TM4	TM5	TM7
1	4.297	9.592	6.137	8.570	0.527	0.310
2	4.010	7.921	6.540	7.935	0.750	0.365
3	4.328	9.589	6.161	8.553	—	0.305
4	4.057	—	6.562	7.955	0.740	0.362
5	4.292	9.506	6.190	8.606	0.511	0.303
6	4.012	7.787	6.559	7.062	0.734	0.364
7	4.277	9.477	6.178	8.619	0.511	0.302
8	4.013	7.771	6.564	7.948	0.732	0.365
9	4.223	9.515	6.153	8.633	0.511	0.302
10	4.010	7.705	6.577	7.936	0.730	0.365
11	4.318	9.544	6.178	8.613	0.509	0.303
12	4.059	7.750	6.562	7.978	0.728	0.365
13	4.343	9.400	6.140	8.584	0.507	0.303
14	4.045	7.724	6.475	7.927	0.724	0.366
15	4.330	9.404	6.124	8.540	0.517	0.310
16	3.995	7.743	6.560	7.904	0.741	0.373
MEAN ODD	4.301	9.503	6.158	8.590	0.513	0.305
MEAN EVEN	4.025	7.772	6.550	7.943	0.735	0.366
MEAN ALL	4.163	8.695	6.354	8.266	0.631	0.335
SDEV ODD	0.039	0.075	0.024	0.034	0.007	0.003
SDEV EVEN	0.026	0.072	0.032	0.024	0.008	0.003
SDEV ALL	0.146	0.897	0.204	0.335	0.115	0.032
SMEN ODD	0.014	0.026	0.009	0.012	0.003	0.001
SMEN EVEN	0.009	0.027	0.011	0.009	0.003	0.001
SMEN ALL	0.036	0.232	0.051	0.084	0.030	0.008
CVAR ODD	0.911	0.786	0.395	0.395	1.363	1.039
CVAR EVEN	0.637	0.921	0.494	0.307	1.138	0.947
CVAR ALL	3.506	10.317	3.216	4.053	18.143	9.441

9214531/18

ORIGINAL PAGE IS  
OF POOR QUALITY

Table A-12. Lamp 011 for Test 7 in Radiance Units

CHANNEL	BAND					
	TM1	TM2	TM3	TM4	TM5	TM7
1	7.202	15.175	9.605	12.593	0.827	0.525
2	6.791	12.830	10.330	12.310	1.165	0.590
3	7.247	15.190	9.669	12.620	—	0.518
4	6.747	—	10.367	12.376	1.151	0.586
5	7.182	15.089	9.716	12.690	0.805	0.515
6	7.786	12.646	10.382	12.366	1.145	0.588
7	7.190	15.035	9.703	12.694	0.802	0.513
8	6.747	12.603	10.376	12.342	1.144	0.589
9	7.093	15.128	9.689	12.739	0.804	0.517
10	6.739	12.498	10.406	12.338	1.140	0.590
11	7.264	15.146	9.705	12.692	0.801	0.517
12	6.762	12.586	10.391	12.389	1.135	0.592
13	7.285	14.966	9.639	12.673	0.797	0.518
14	6.807	12.529	10.255	12.344	1.133	0.592
15	7.274	14.925	9.636	12.589	0.814	0.525
16	6.748	12.591	10.371	12.265	1.154	0.605
MEAN ODD	7.217	15.082	9.670	12.661	0.807	0.519
MEAN EVEN	6.766	12.612	10.360	12.340	1.146	0.591
MEAN ALL	6.992	13.929	10.015	12.500	0.988	0.555
SDEV ODD	0.064	0.098	0.040	0.056	0.010	0.004
SDEV EVEN	0.026	0.108	0.048	0.041	0.010	0.006
SDEV ALL	0.238	1.279	0.359	0.172	0.175	0.038
SMEN ODD	0.023	0.035	0.014	0.020	0.004	0.002
SMEN EVEN	0.009	0.041	0.017	0.014	0.004	0.002
SMEN ALL	0.059	0.330	0.090	0.043	0.045	0.009
CVAR ODD	0.885	0.652	0.419	0.440	1.237	0.836
CVAR EVEN	0.390	0.858	0.460	0.332	0.900	0.987
CVAR ALL	3.400	9.185	3.580	1.379	17.731	6.824

92141531/83

ORIGINAL VALUES  
OF POOR QUALITY

Table A-13. Lamp 111 for Test 7 in Radiance Units

CHANNEL	BAND					
	TM1	TM2	TM3	TM4	TM5	TM7
1	13.830	27.208	17.671	20.412	1.390	0.907
2	13.258	23.907	18.691	20.870	2.002	0.952
3	13.919	27.250	17.803	20.508	—	0.898
4	13.294	—	18.717	20.948	1.987	0.952
5	13.815	27.028	17.876	20.656	1.363	0.895
6	13.235	23.517	18.752	20.922	1.974	0.955
7	13.808	26.970	17.842	20.604	1.358	0.890
8	13.209	23.508	18.727	20.905	1.971	0.957
9	13.637	27.135	17.809	20.710	1.358	0.897
10	13.224	23.333	18.828	20.823	1.965	0.959
11	13.923	27.158	17.837	20.660	1.356	0.898
12	13.305	23.483	18.783	20.996	1.961	0.960
13	13.963	26.916	17.758	20.593	1.351	0.898
14	13.306	23.400	18.553	20.902	1.954	0.964
15	13.984	26.743	17.746	20.527	1.367	0.908
16	13.175	23.542	18.755	20.790	1.979	0.978
MEAN ODD	13.860	27.051	17.793	20.584	1.363	0.899
MEAN EVEN	13.251	23.527	18.726	20.894	1.974	0.960
MEAN ALL	13.555	25.407	18.259	20.739	1.689	0.929
SDEV ODD	0.113	0.169	0.064	0.096	0.013	0.006
SDEV EVEN	0.049	0.183	0.081	0.065	0.015	0.008
SDEV ALL	0.326	1.828	0.487	0.183	0.316	0.032
SMEN ODD	0.040	0.060	0.023	0.034	0.005	0.002
SMEN EVEN	0.017	0.069	0.029	0.023	0.005	0.003
SMEN ALL	0.081	0.472	0.122	0.046	0.082	0.008
CVAR ODD	0.817	0.624	0.361	0.468	0.949	0.656
CVAR EVEN	0.370	0.777	0.431	0.312	0.770	0.885
CVAR ALL	2.403	7.195	2.668	0.880	18.693	3.469

921415301/83

ORIGINAL PAGE IS  
OF POOR QUALITY

Table A-14. Lamp 101 for Test 7 in Radiance Units

CHANNEL	BAND					
	TM1	TM2	TM3	TM4	TM5	TM7
1	9.579	17.770	11.726	12.154	0.868	0.604
2	9.281	16.110	12.311	13.106	1.264	0.556
3	9.668	17.812	11.805	12.180	—	0.596
4	9.266	—	12.344	13.162	1.250	0.592
5	9.581	17.689	11.863	12.282	0.849	0.593
6	9.262	15.842	12.361	13.133	1.242	0.594
7	9.556	17.640	11.846	12.272	0.847	0.590
8	9.221	15.828	12.349	13.114	1.240	0.595
9	9.453	17.775	11.837	12.309	0.846	0.595
10	9.234	15.721	12.418	13.150	1.236	0.597
11	9.656	17.761	11.848	12.307	0.844	0.596
12	9.264	15.786	12.392	13.183	1.233	0.598
13	9.687	17.657	11.795	12.240	0.840	0.597
14	9.313	15.734	12.236	13.125	1.230	0.601
15	9.709	17.507	11.779	12.163	0.855	0.605
16	9.236	15.867	12.365	13.080	1.251	0.613
MEAN ODD	9.611	17.701	11.812	12.238	0.850	0.597
MEAN EVEN	9.260	15.841	12.347	13.132	1.243	0.598
MEAN ALL	9.435	16.833	12.080	12.685	1.060	0.598
SDEV ODD	0.085	0.099	0.047	0.065	0.009	0.005
SDEV EVEN	0.031	0.131	0.057	0.036	0.011	0.007
SDEV ALL	0.192	0.967	0.281	0.464	0.203	0.006
SMEN ODD	0.030	0.035	0.016	0.023	0.004	0.002
SMEN EVEN	0.011	0.049	0.020	0.013	0.004	0.002
SMEN ALL	0.048	0.250	0.070	0.116	0.053	0.001
CVAR ODD	0.886	0.559	0.394	0.529	1.113	0.866
CVAR EVEN	0.331	0.824	0.459	0.274	0.906	1.093
CVAR ALL	2.031	5.744	2.323	3.658	19.194	0.958

92141531/83

ORIGINAL PAGE IS  
OF POOR QUALITY

Table A-15. Lamp 001 for Test 7 in Radiance Units

CHANNEL	BAND					
	TM1	TM2	TM3	TM4	TM5	TM7
1	2.903	5.571	3.577	4.080	0.293	0.216
2	2.726	4.891	3.849	4.423	0.415	0.225
3	2.927	5.589	3.584	4.103	—	0.213
4	2.765	—	3.859	4.445	0.409	0.223
5	2.897	5.545	3.513	4.125	0.283	0.211
6	2.734	4.811	3.875	4.444	0.406	0.224
7	2.904	5.532	3.601	4.123	0.283	0.210
8	2.738	4.808	3.870	4.439	0.404	0.225
9	2.854	5.555	3.528	4.135	0.282	0.212
10	2.741	4.765	3.893	4.432	0.402	0.225
11	2.922	5.572	3.615	4.128	0.281	0.213
12	2.775	4.800	3.877	4.474	0.403	0.225
13	2.932	5.526	3.591	4.131	0.281	0.212
14	2.760	4.781	3.835	4.447	0.402	0.226
15	2.936	5.492	3.593	4.103	0.286	0.217
16	2.724	4.832	3.884	4.422	0.411	0.232
MEAN ODD	2.909	5.548	3.595	4.116	0.284	0.213
MEAN EVEN	2.745	4.812	3.867	4.441	0.407	0.226
MEAN ALL	2.827	5.205	3.731	4.278	0.349	0.219
SDEV ODD	0.027	0.032	0.014	0.020	0.004	0.002
SDEV EVEN	0.019	0.041	0.020	0.018	0.005	0.003
SDEV ALL	0.088	0.381	0.142	0.169	0.063	0.007
SMEN ODD	0.010	0.011	0.005	0.007	0.002	0.001
SMEN EVEN	0.007	0.016	0.007	0.006	0.002	0.001
SMEN ALL	0.022	0.098	0.035	0.042	0.016	0.002
CVAR ODD	0.926	0.576	0.396	0.477	1.578	1.062
CVAR EVEN	0.707	0.860	0.508	0.400	1.152	1.248
CVAR ALL	3.102	7.326	3.796	3.942	18.158	3.152

92145361/83

ORIGINAL PAGE IS  
OF POOR QUALITY

Table A-16. Lamp 000 for Test 7 in Radiance Units

CHANNEL	BAND					
	TM1	TM2	TM3	TM4	TM5	TM7
1	-0.030	-0.038	0.045	0.015	-0.005	-0.001
2	-0.012	-0.015	0.058	0.026	-0.005	0.000
3	-0.019	-0.016	0.047	0.034	-	-0.000
4	-0.057	-	0.082	0.037	-0.004	-0.000
5	-0.020	-0.038	0.054	0.029	-0.004	-0.001
6	-0.016	-0.035	0.056	0.029	-0.004	-0.000
7	-0.019	-0.028	0.057	-0.014	-0.005	0.002
8	-0.032	-0.040	0.083	0.053	-0.004	0.000
9	-0.019	-0.035	0.062	0.015	-0.006	-0.000
10	-0.039	-0.030	0.061	0.027	-0.004	0.000
11	-0.018	-0.025	0.079	0.012	-0.005	-0.000
12	-0.054	-0.029	0.059	0.020	-0.004	-0.001
13	-0.023	-0.024	0.054	0.033	-0.005	-0.000
14	-0.017	-0.038	0.055	0.012	-0.005	-0.001
15	-0.024	-0.034	0.043	0.032	-0.004	-0.000
16	-0.008	-0.023	0.059	0.004	-0.004	-0.000
MEAN ODD	-0.022	-0.030	0.055	0.019	-0.005	0.000
MEAN EVEN	-0.029	-0.030	0.064	0.026	-0.004	-0.000
MEAN ALL	-0.025	-0.030	0.060	0.023	-0.004	-0.000
SDEV ODD	0.004	0.008	0.012	0.016	0.001	0.001
SDEV EVEN	0.019	0.009	0.011	0.015	0.000	0.001
SDEV ALL	0.014	0.008	0.012	0.016	0.001	0.001
SMEN ODD	0.001	0.003	0.004	0.006	0.000	0.000
SMEN EVEN	0.007	0.003	0.004	0.005	0.000	0.000
SMEN ALL	0.003	0.002	0.003	0.004	0.000	0.000
CVAR ODD	-19.167	-26.384	21.066	84.395	-10.836	4520.922
CVAR EVEN	-65.269	-29.657	17.791	57.237	-10.501	-203.816
CVAR ALL	-54.693	-26.931	20.288	68.263	-13.204	-561.405

9214153c1/83

ORIGINAL PAGE IS  
OF POOR QUALITY

Table A-17. Lamp 100 for Test 9 in Radiance Units

CHANNEL	BAND						
	TM1	TM2	TM3	TM4	TM5	TM7	
1	105.94	101.19	95.56	97.12	44.79	59.30	
2	104.91	94.71	96.49	101.32	63.93	57.87	
3	108.22	98.77	94.37	97.07	—	58.36	
4	106.25	89.04	95.69	102.31	65.29	58.27	
5	106.88	100.55	94.90	95.69	44.64	57.93	
6	104.68	94.81	97.00	103.31	64.44	58.09	
7	105.65	98.42	93.88	96.09	45.27	49.95	
8	105.12	93.05	95.67	102.04	65.06	57.65	
9	105.53	99.40	94.06	95.71	44.77	58.20	
10	105.32	92.75	96.10	106.10	64.31	57.08	
11	106.57	98.38	93.01	95.19	45.52	58.08	
12	105.55	93.13	96.75	102.62	65.47	58.53	
13	107.19	99.16	94.19	97.26	44.83	57.84	
14	105.57	93.53	96.04	102.29	64.13	58.77	
15	107.55	99.71	94.93	93.97	44.86	57.30	
16	105.71	91.89	95.12	101.55	64.60	59.33	
MEAN	ODD	106.69	99.45	94.36	96.01	44.96	57.19
MEAN	EVEN	105.39	92.74	96.11	102.69	64.65	58.20
MEAN	ALL	106.04	96.09	95.23	99.35	55.46	57.70
SDEV	ODD	0.96	1.01	0.79	1.14	0.32	2.97
SDEV	EVEN	0.52	1.84	0.64	1.51	0.57	0.70
SDEV	ALL	1.00	3.75	1.13	3.68	10.18	2.15
SMEN	ODD	0.34	0.36	0.28	0.40	0.12	1.05
SMEN	EVEN	0.18	0.65	0.23	0.53	0.20	0.25
SMEN	ALL	0.25	0.94	0.28	0.92	2.63	0.54
CVAR	ODD	0.90	1.01	0.84	1.19	0.71	5.18
CVAR	EVEN	0.49	1.98	0.67	1.47	0.88	1.21
CVAR	ALL	0.94	3.90	1.19	3.71	18.36	3.72

921453-1/83



ORIGINAL PAGE IS  
OF POOR QUALITY

Table A-18. Lamp 110 for Test 9 in Radiance Units

CHANNEL	BAND					
	TM1	TM2	TM3	TM4	TM5	TM7
1	170.75	177.91	162.38	193.28	82.93	103.02
2	167.12	160.01	166.06	192.33	118.07	110.37
3	175.02	173.94	160.55	193.89	—	102.11
4	169.15	150.33	164.91	194.38	120.73	111.24
5	172.62	176.84	161.74	191.45	83.14	101.19
6	166.78	159.73	166.85	195.71	119.26	110.96
7	170.93	173.35	159.92	191.17	84.12	87.38
8	167.39	156.98	164.75	193.55	120.10	109.84
9	170.84	175.08	160.27	191.42	83.30	101.81
10	167.78	156.42	165.38	201.24	118.92	108.82
11	172.42	173.41	158.52	190.04	84.60	101.38
12	168.12	155.61	166.39	194.19	121.26	111.67
13	173.45	174.29	160.39	194.49	83.20	101.09
14	168.09	157.59	165.05	193.62	118.55	112.04
15	173.79	175.61	161.70	188.38	83.26	101.10
16	168.55	154.92	163.36	192.14	119.26	112.99
MEAN ODD	172.48	175.06	160.68	191.76	83.51	99.88
MEAN EVEN	167.87	156.45	165.34	194.65	119.52	110.99
MEAN ALL	170.18	165.75	163.01	193.21	102.71	105.44
SDEV ODD	1.57	1.66	1.24	2.05	0.62	5.09
SDEV EVEN	0.78	3.06	1.11	2.90	1.09	1.32
SDEV ALL	2.66	9.90	2.66	2.85	18.62	6.77
SMEN ODD	0.56	0.59	0.44	0.73	0.24	1.80
SMEN EVEN	0.28	1.08	0.39	1.03	0.39	0.47
SMEN ALL	0.67	2.47	0.66	0.71	4.81	1.69
CVAR ODD	0.91	0.95	0.77	1.07	0.75	5.10
CVAR EVEN	0.47	1.96	0.67	1.49	0.92	1.19
CVAR ALL	1.56	5.97	1.63	1.47	18.13	6.42

92/4153-1/83

ORIGINAL PAGE IS  
OF POOR QUALITY

Table A-19. Lamp 010 for Test 9 in Radiance Units

CHANNEL	BAND					
	TM1	TM2	TM3	TM4	TM5	TM7
1	68.40	80.37	70.06	100.35	41.21	46.78
2	64.76	68.17	72.18	93.79	56.96	54.98
3	69.59	78.25	69.19	99.99	—	46.09
4	65.93	64.10	71.59	94.84	58.15	55.36
5	68.53	79.68	69.49	98.54	41.03	45.60
6	64.81	68.13	72.53	95.59	57.21	55.21
7	67.88	77.79	68.71	98.87	41.62	39.36
8	64.87	66.76	71.53	94.49	57.91	54.79
9	67.85	78.68	68.81	98.61	41.07	45.90
10	65.25	66.66	71.93	98.18	57.22	54.16
11	68.30	77.95	68.00	98.05	41.77	45.70
12	65.34	66.07	72.25	94.99	58.38	55.58
13	68.71	78.09	68.88	100.10	41.16	45.67
14	65.43	67.13	71.75	94.68	57.15	55.67
15	69.03	79.16	69.39	96.83	41.24	45.56
16	65.20	65.93	71.06	93.82	57.54	56.16
MEAN ODD	68.54	78.75	69.07	98.92	41.30	45.08
MEAN EVEN	65.20	66.62	71.85	95.05	57.57	55.24
MEAN ALL	66.87	72.68	70.46	96.98	49.98	50.16
SDEV ODD	0.59	0.92	0.62	1.20	0.28	2.35
SDEV EVEN	0.40	1.32	0.48	1.40	0.53	0.61
SDEV ALL	1.79	6.36	1.53	2.36	8.41	5.50
SMEN ODD	0.21	0.33	0.22	0.42	0.11	0.83
SMEN EVEN	0.14	0.47	0.17	0.50	0.19	0.22
SMEN ALL	0.45	1.59	0.38	0.59	2.17	1.38
CVAR ODD	0.86	1.17	0.90	1.21	0.68	5.21
CVAR EVEN	0.61	1.98	0.66	1.48	0.92	1.11
CVAR ALL	2.68	8.75	2.18	2.43	16.83	10.97

921415301/R3

ORIGINAL PAGE IS  
OF POOR QUALITY

Table A-20. Lamp 011 for Test 9 in Radiance Units

CHANNEL	BAND					
	TM1	TM2	TM3	TM4	TM5	TM7
1	112.53	123.71	108.14	144.70	62.60	77.36
2	107.35	107.63	112.79	142.32	86.73	87.14
3	114.65	121.03	106.91	144.95	—	76.60
4	108.34	101.08	111.97	143.79	88.68	87.86
5	113.11	123.08	107.59	143.14	62.53	75.89
6	107.10	107.58	113.42	144.90	87.72	87.64
7	111.86	120.53	106.40	143.23	63.35	65.91
8	107.67	105.53	112.03	143.50	89.30	86.83
9	111.88	121.63	106.68	143.20	62.79	76.41
10	107.77	105.31	112.33	149.02	87.60	85.93
11	112.80	120.71	105.48	142.34	63.80	76.25
12	107.76	104.67	113.21	143.94	89.04	83.19
13	113.65	121.13	106.76	145.53	62.74	75.93
14	107.90	106.05	112.29	143.51	87.12	88.48
15	114.20	122.31	107.59	140.46	62.76	75.96
16	108.24	104.31	111.36	142.45	87.82	89.35
MEAN ODD	113.08	121.77	106.96	143.44	62.94	75.04
MEAN EVEN	107.77	105.27	112.43	144.18	87.87	87.68
MEAN ALL	110.42	113.52	109.69	143.81	76.24	81.36
SDEV ODD	1.03	1.16	0.85	1.64	0.47	3.72
SDEV EVEN	0.41	2.09	0.68	2.12	0.78	1.06
SDEV ALL	2.85	8.67	2.92	1.87	12.89	7.04
SMEN ODD	0.36	0.41	0.30	0.58	0.18	1.32
SMEN EVEN	0.15	0.74	0.24	0.75	0.28	0.38
SMEN ALL	0.71	2.17	0.73	0.47	3.33	1.76
CVAR ODD	0.91	0.96	0.79	1.14	0.75	4.96
CVAR EVEN	0.38	1.98	0.61	1.47	0.89	1.21
CVAR ALL	2.58	7.64	2.66	1.30	16.91	8.65

9214(53)/R3

ORIGINAL PAGE IS  
OF POOR QUALITY

Table A-21. Lamp 111 for Test 9 in Radiance Units

CHANNEL	BAND					
	TM1	TM2	TM3	TM4	TM5	TM7
1	214.74	221.32	200.09	234.37	104.35	133.54
2	209.67	199.49	206.57	238.14	147.81	142.50
3	219.99	216.62	198.11	235.75	—	132.44
4	211.31	187.01	205.11	240.52	151.31	143.58
5	217.21	220.22	199.69	233.37	104.78	131.50
6	208.94	199.24	207.51	241.50	149.45	143.20
7	214.87	215.63	197.26	232.73	105.90	113.39
8	209.67	195.56	204.97	239.95	150.36	141.79
9	214.77	218.09	198.08	233.63	105.07	132.29
10	210.34	195.37	205.62	245.47	149.06	140.40
11	217.01	215.97	195.85	232.59	106.67	131.72
12	210.09	193.76	207.13	240.64	151.93	144.17
13	218.09	217.41	198.15	236.82	104.92	131.41
14	210.57	196.79	205.28	240.33	148.43	144.53
15	219.30	218.78	199.72	230.85	104.92	131.41
16	211.19	193.16	203.31	238.70	149.35	145.80
MEAN ODD	217.00	218.01	198.37	233.76	105.23	129.71
MEAN EVEN	210.22	195.05	205.69	240.66	149.71	143.25
MEAN ALL	213.61	206.53	202.03	237.21	128.95	136.48
SDEV ODD	2.08	2.02	1.43	1.89	0.79	6.64
SDEV EVEN	0.83	3.98	1.36	2.24	1.40	1.69
SDEV ALL	3.82	12.24	4.01	4.08	23.00	8.41
SMEN ODD	0.74	0.71	0.51	0.67	0.30	2.35
SMEN EVEN	0.30	1.41	0.48	0.79	0.50	0.60
SMEN ALL	0.95	3.06	1.00	1.02	5.94	2.10
CVAR ODD	0.96	0.93	0.72	0.81	0.75	5.12
CVAR EVEN	0.40	2.04	0.66	0.93	0.94	1.18
CVAR ALL	1.79	5.93	1.99	1.72	17.83	6.16

921415301/83

ORIGINAL PAGE IS  
OF POOR QUALITY

Table A-22. Lamp 101 for Test 9 in Radiance Units

CHANNEL	BAND					
	TM1	TM2	TM3	TM4	TM5	TM7
1	149.49	144.50	133.46	141.60	66.21	89.88
2	146.97	133.92	126.62	149.32	93.72	90.21
3	152.87	141.22	131.85	141.57	—	88.94
4	148.41	125.76	135.85	151.55	95.83	90.88
5	151.08	143.72	132.90	139.93	66.28	88.23
6	146.58	134.06	137.50	152.33	94.55	90.62
7	149.39	140.72	131.24	140.18	67.03	76.48
8	147.15	131.48	135.84	150.37	95.32	89.81
9	149.40	142.22	131.66	140.06	66.37	88.82
10	147.45	131.35	136.35	156.69	94.47	88.92
11	150.79	140.83	130.22	139.40	67.40	88.51
12	147.50	130.25	137.08	151.52	96.19	91.28
13	151.75	141.96	131.76	142.11	66.43	88.30
14	147.74	132.34	136.10	150.92	94.09	91.65
15	152.41	142.65	132.94	137.44	66.48	88.33
16	148.25	129.91	134.90	149.85	94.74	92.48
MEAN ODD	150.90	142.23	132.00	140.28	66.60	87.19
MEAN EVEN	147.51	131.13	136.28	151.57	94.86	90.73
MEAN ALL	149.20	136.68	134.14	145.93	81.67	88.96
SDEV ODD	1.38	1.35	1.05	1.51	0.45	4.36
SDEV EVEN	0.63	2.65	0.81	2.30	0.86	1.12
SDEV ALL	2.04	6.08	2.39	6.12	14.61	3.58
SMEN ODD	0.49	0.48	0.37	0.53	0.17	1.54
SMEN EVEN	0.22	0.94	0.29	0.81	0.30	0.40
SMEN ALL	0.51	1.52	0.60	1.53	3.77	0.89
CVAR ODD	0.92	0.95	0.79	1.08	0.68	5.00
CVAR EVEN	0.42	2.02	0.59	1.51	0.91	1.24
CVAR ALL	1.36	4.45	1.78	4.20	17.89	4.02

ES/10/35/12/29

ORIGINAL PAGE IS  
OF POOR QUALITY

Table A-23. Lamp 001 for Test 9 in Radiance Units

CHANNEL	BAND					
	TM1	TM2	TM3	TM4	TM5	TM7
1	46.23	46.46	40.84	47.71	24.25	33.67
2	44.06	41.77	42.74	50.87	32.40	34.76
3	46.94	45.09	40.19	47.53	—	33.01
4	44.82	39.39	42.27	51.36	33.03	34.94
5	46.44	45.94	40.31	46.79	24.03	32.69
6	44.22	41.90	42.91	51.87	32.84	34.83
7	45.78	44.85	39.93	47.06	24.45	28.23
8	44.32	40.91	42.32	51.38	33.11	34.59
9	45.85	45.25	39.96	46.84	24.10	32.84
10	44.41	40.79	42.54	53.22	32.64	34.31
11	46.20	44.86	39.47	46.62	24.51	32.80
12	44.63	40.56	42.86	51.64	33.18	35.10
13	46.51	45.18	40.04	47.52	24.10	32.71
14	44.58	41.25	42.59	51.53	32.52	35.24
15	46.65	45.54	40.27	45.95	24.19	32.75
16	44.70	40.54	42.39	51.21	32.92	35.68
MEAN ODD	46.32	45.40	40.13	47.00	24.23	32.34
MEAN EVEN	44.47	40.89	42.58	51.63	32.83	34.93
MEAN ALL	45.40	43.14	41.35	49.32	28.82	33.63
SDEV ODD	0.39	0.57	0.40	0.59	0.18	1.69
SDEV EVEN	0.27	0.80	0.25	0.71	0.29	0.42
SDEV ALL	1.01	2.42	1.31	2.47	4.45	1.79
SMEN ODD	0.14	0.20	0.14	0.21	0.07	0.60
SMEN EVEN	0.09	0.28	0.09	0.25	0.10	0.15
SMEN ALL	0.25	0.61	0.33	0.62	1.15	0.45
CVAR ODD	0.85	1.25	0.99	1.25	0.76	5.23
CVAR EVEN	0.60	1.95	0.58	1.37	0.87	1.20
CVAR ALL	2.23	5.61	3.16	5.02	15.43	5.33

9214531/83

ORIGINAL PAGE IS  
OF POOR QUALITY

Table A-24. Lamp 000 for Test 9 in Radiance Units

CHANNEL	BAND					
	TM1	TM2	TM3	TM4	TM5	TM7
1	3.19	2.92	2.93	2.80	2.84	2.76
2	2.66	2.36	2.35	2.23	2.66	2.42
3	2.64	2.44	2.53	2.39	—	2.32
4	2.45	2.42	2.31	2.14	2.57	2.38
5	2.73	2.33	2.31	2.17	2.51	2.28
6	2.71	2.53	2.41	2.37	2.66	2.45
7	2.49	2.24	2.28	2.13	2.62	2.94
8	2.78	2.32	2.49	2.47	2.82	2.56
9	2.47	2.21*	2.28	2.15	2.48	2.22
10	2.50	2.20	2.33	2.16	2.61	2.53
11	2.42	2.27	2.08	2.12	2.50	2.27
12	2.49	2.23	2.35	2.17	2.59	2.44
13	2.46	2.24	2.20	2.07	2.57	2.09
14	2.70	2.28	2.46	2.19	2.63	2.47
15	2.49	2.22	2.16	2.09	2.54	2.11
16	2.70	2.36	2.57	2.23	2.65	2.56
MEAN ODD	2.61	2.36	2.35	2.24	2.58	2.37
MEAN EVEN	2.62	2.34	2.41	2.25	2.65	2.48
MEAN ALL	2.62	2.35	2.38	2.24	2.62	2.42
SDEV ODD	0.26	0.24	0.27	0.25	0.12	0.31
SDEV EVEN	0.12	0.11	0.09	0.11	0.08	0.07
SDEV ALL	0.20	0.18	0.20	0.19	0.10	0.22
SMEN ODD	0.09	0.08	0.10	0.09	0.05	0.11
SMEN EVEN	0.04	0.04	0.03	0.04	0.03	0.02
SMEN ALL	0.05	0.04	0.05	0.05	0.03	0.06
CVAR ODD	9.86	10.12	11.51	10.98	4.81	12.97
CVAR EVEN	4.76	4.57	3.75	5.11	2.88	2.70
CVAR ALL	7.47	7.61	8.29	8.27	3.96	9.14

9214ES31/83

Table A-25. Lamp 100 for Test 9 in Radiance Units

CHANNEL	BAND					
	TM1	TM2	TM3	TM4	TM5	TM7
1	6.567	12.014	8.670	8.621	0.542	0.380
2	6.503	11.380	8.953	9.188	0.794	0.378
3	6.627	12.024	8.733	8.631	—	0.379
4	6.509	10.634	8.948	9.277	0.804	0.378
5	6.591	11.972	8.783	8.688	0.542	0.377
6	6.494	11.276	8.945	9.271	0.799	0.379
7	6.571	11.928	8.726	8.681	0.546	0.323
8	6.503	11.206	8.937	9.216	0.802	0.380
9	6.502	12.013	8.692	8.639	0.542	0.378
10	6.485	11.171	8.954	9.244	0.798	0.377
11	6.633	12.005	8.694	8.673	0.547	0.379
12	6.516	11.206	8.951	9.250	0.805	0.379
13	6.666	11.931	8.681	8.647	0.538	0.381
14	6.545	11.185	8.870	9.199	0.792	0.380
15	6.651	11.877	8.673	8.567	0.540	0.381
16	6.510	11.212	8.916	9.194	0.793	0.382
MEAN ODD	6.601	11.971	8.706	8.643	0.542	0.372
MEAN EVEN	6.508	11.159	8.934	9.230	0.798	0.379
MEAN ALL	6.555	11.565	8.820	8.937	0.679	0.376
SDEV ODD	0.054	0.053	0.039	0.039	0.003	0.020
SDEV EVEN	0.020	0.223	0.030	0.035	0.005	0.002
SDEV ALL	0.062	0.447	0.122	0.305	0.132	0.014
SMEN ODD	0.019	0.019	0.014	0.014	0.001	0.007
SMEN EVEN	0.007	0.079	0.010	0.013	0.002	0.001
SMEN ALL	0.015	0.112	0.031	0.076	0.034	0.004
CVAR ODD	0.825	0.444	0.450	0.453	0.593	5.417
CVAR EVEN	0.301	1.997	0.331	0.384	0.646	0.446
CVAR ALL	0.944	3.869	1.387	3.412	19.462	3.804

9214(531)783



ORIGINAL PAGE IS  
OF POOR QUALITY

Table A-26. Lamp 110 for Test 9 in Radiance Units

CHANNEL	BAND					
	TM1	TM2	TM3	TM4	TM5	TM7
1	10.709	21.400	14.869	17.385	1.040	0.675
2	10.450	19.425	15.514	17.601	1.499	0.736
3	10.821	21.404	14.982	17.419	—	0.675
4	10.457	18.159	15.520	17.777	1.517	0.737
5	10.749	21.280	15.075	17.545	1.043	0.670
6	10.441	19.208	15.496	17.723	1.512	0.740
7	10.733	21.228	14.967	17.474	1.048	0.576
8	10.456	19.120	15.494	17.626	1.516	0.739
9	10.629	21.386	14.912	17.452	1.043	0.672
10	10.424	19.039	15.510	17.671	1.507	0.735
11	10.830	21.386	14.900	17.494	1.050	0.674
12	10.472	19.127	15.494	17.650	1.522	0.738
13	10.889	21.188	14.877	17.441	1.033	0.677
14	10.512	19.054	15.356	17.570	1.497	0.742
15	10.848	21.140	14.872	17.332	1.036	0.677
16	10.469	19.111	15.425	17.560	1.496	0.744
MEAN ODD	10.776	21.302	14.932	17.443	1.042	0.662
MEAN EVEN	10.460	19.030	15.476	17.647	1.508	0.739
MEAN ALL	10.618	20.166	15.204	17.545	1.291	0.700
SDEV ODD	0.086	0.106	0.073	0.065	0.006	0.035
SDEV EVEN	0.028	0.372	0.058	0.074	0.010	0.003
SDEV ALL	0.174	1.203	0.288	0.125	0.241	0.046
SMEN ODD	0.030	0.037	0.026	0.023	0.002	0.012
SMEN EVEN	0.010	0.132	0.020	0.026	0.004	0.001
SMEN ALL	0.044	0.301	0.072	0.031	0.062	0.012
CVAR ODD	0.796	0.497	0.486	0.371	0.584	5.278
CVAR EVEN	0.265	1.957	0.374	0.422	0.678	0.403
CVAR ALL	1.643	5.963	1.896	0.712	18.664	6.609

921413-01/83

Table A-27. Lamp 010 for Test 9 in Radiance Units

CHANNEL	BAND					
	TM1	TM2	TM3	TM4	TM5	TM7
1	4.168	9.466	6.304	8.915	0.495	0.296
2	3.957	8.111	6.660	8.491	0.703	0.358
3	4.203	9.463	6.355	8.897	—	0.296
4	3.977	7.571	6.659	8.588	0.712	0.358
5	4.165	9.426	6.392	8.952	0.495	0.293
6	3.960	8.014	6.651	8.565	0.705	0.360
7	4.163	9.368	6.347	8.938	0.499	0.251
8	3.948	7.952	6.646	8.522	0.710	0.361
9	4.121	9.448	6.320	8.906	0.494	0.295
10	3.958	7.947	6.666	8.542	0.705	0.357
11	4.193	9.450	6.324	8.939	0.499	0.295
12	3.973	7.954	6.649	8.550	0.714	0.359
13	4.214	9.335	6.312	8.903	0.491	0.298
14	3.997	7.943	6.588	8.502	0.702	0.359
15	4.210	9.370	6.302	8.832	0.493	0.297
16	3.958	7.958	6.622	8.480	0.702	0.361
MEAN ODD	4.180	9.416	6.332	8.910	0.495	0.290
MEAN EVEN	3.966	7.931	6.643	8.530	0.707	0.359
MEAN ALL	4.073	8.673	6.487	8.720	0.608	0.325
SDEV ODD	0.032	0.051	0.032	0.038	0.003	0.016
SDEV EVEN	0.017	0.157	0.027	0.039	0.005	0.001
SDEV ALL	0.113	0.775	0.163	0.200	0.109	0.037
SMEN ODD	0.011	0.018	0.011	0.014	0.001	0.006
SMEN EVEN	0.006	0.055	0.010	0.014	0.002	0.000
SMEN ALL	0.028	0.194	0.041	0.050	0.028	0.009
CVAR ODD	0.764	0.547	0.502	0.430	0.597	5.481
CVAR EVEN	0.421	1.976	0.407	0.454	0.659	0.370
CVAR ALL	2.781	8.935	2.511	2.292	17.967	11.500

83/00251126

ORIGINAL PAGE IS  
OF POOR QUALITY

Table A-28. Lamp 111 for Test 9 in Radiance Units

CHANNEL	BAND					
	TM1	TM2	TM3	TM4	TM5	TM7
1	6.988	14.769	9.837	12.957	0.775	0.502
2	6.658	12.972	10.490	12.978	1.091	0.578
3	7.031	14.802	9.916	12.977	—	0.503
4	6.639	12.111	10.494	13.107	1.105	0.578
5	6.985	14.721	9.987	13.077	0.775	0.498
6	6.648	12.836	10.485	13.076	1.101	0.581
7	6.967	14.673	9.909	13.041	0.779	0.431
8	6.665	12.751	10.490	13.026	1.104	0.581
9	6.904	14.766	9.877	13.012	0.777	0.501
10	6.639	12.723	10.490	13.045	1.100	0.577
11	7.030	14.797	9.875	13.058	0.782	0.503
12	6.655	12.771	10.497	13.040	1.108	0.579
13	7.078	14.639	9.857	13.013	0.769	0.505
14	6.692	12.723	10.398	12.977	1.090	0.582
15	7.072	14.635	9.849	12.833	0.771	0.505
16	6.670	12.769	10.466	12.971	1.091	0.584
MEAN ODD	7.007	14.725	9.888	13.002	0.775	0.493
MEAN EVEN	6.658	12.707	10.476	13.027	1.099	0.580
MEAN ALL	6.833	13.716	10.182	13.015	0.948	0.537
SDEV ODD	0.058	0.069	0.049	0.063	0.005	0.025
SDEV EVEN	0.020	0.254	0.034	0.051	0.007	0.003
SDEV ALL	0.185	1.058	0.306	0.057	0.167	0.048
SMEN ODD	0.021	0.024	0.017	0.022	0.002	0.009
SMEN EVEN	0.007	0.090	0.012	0.018	0.003	0.001
SMEN ALL	0.046	0.264	0.077	0.014	0.043	0.012
CVAR ODD	0.830	0.468	0.496	0.483	0.597	5.167
CVAR EVEN	0.294	2.001	0.324	0.393	0.648	0.441
CVAR ALL	2.705	7.711	3.007	0.435	17.619	8.948

9214534/83

ORIGINAL PAGE IS  
OF POOR QUALITY

Table A-29. Lamp 101 for Test 9 in Radiance Units

CHANNEL	BAND						
	TM1	TM2	TM3	TM4	TM5	TM7	
1	13.521	26.711	18.368	21.130	1.320	0.881	
2	13.150	24.289	19.336	21.836	1.886	0.955	
3	13.644	26.729	18.528	21.218	—	0.881	
4	13.104	22.663	19.338	22.038	1.911	0.956	
5	13.569	26.573	18.647	21.421	1.325	0.875	
6	13.121	24.037	19.308	21.912	1.904	0.960	
7	13.534	26.476	18.496	21.317	1.329	0.752	
8	13.139	23.896	19.312	21.889	1.908	0.959	
9	13.406	26.712	18.463	21.338	1.326	0.879	
10	13.107	23.851	19.319	21.587	1.899	0.953	
11	13.673	26.707	18.436	21.451	1.334	0.881	
12	13.126	23.888	19.322	21.911	1.917	0.958	
13	13.733	26.501	18.410	21.270	1.313	0.884	
14	13.208	23.869	19.158	21.851	1.883	0.962	
15	13.732	26.408	18.403	21.275	1.317	0.884	
16	13.155	23.903	19.236	21.860	1.883	0.965	
MEAN	ODD	13.601	26.602	18.469	21.303	1.323	0.864
MEAN	EVEN	13.139	23.799	19.289	21.861	1.899	0.958
MEAN	ALL	13.370	25.201	18.879	21.582	1.630	0.911
SDEV	ODD	0.115	0.127	0.088	0.104	0.007	0.046
SDEV	EVEN	0.035	0.481	0.068	0.127	0.013	0.004
SDEV	ALL	0.253	1.487	0.431	0.311	0.297	0.058
SMEN	ODD	0.041	0.045	0.031	0.037	0.003	0.016
SMEN	EVEN	0.012	0.170	0.024	0.045	0.005	0.001
SMEN	ALL	0.063	0.372	0.108	0.078	0.077	0.014
CVAR	ODD	0.846	0.478	0.475	0.488	0.561	5.284
CVAR	EVEN	0.266	2.022	0.350	0.579	0.695	0.402
CVAR	ALL	1.890	5.900	2.281	1.440	18.239	6.329

921415361/83

ORIGINAL PAGE IS  
OF POOR QUALITY

Table A-30. Lamp 001 for Test 9 in Radiance Units

CHANNEL	BAND					
	TM1	TM2	TM3	TM4	TM5	TM7
1	9.351	17.312	12.186	12.674	0.822	0.586
2	9.172	16.211	12.738	13.626	1.182	0.599
3	9.430	17.322	12.272	12.670	—	0.586
4	9.155	15.141	12.761	13.823	1.197	0.599
5	9.387	17.240	12.360	12.780	0.824	0.582
6	9.157	16.072	12.743	13.755	1.190	0.601
7	9.360	17.179	12.257	12.758	0.827	0.502
8	9.171	15.963	12.750	13.658	1.184	0.602
9	9.275	17.316	12.224	12.723	0.823	0.585
10	9.142	15.941	12.763	13.725	1.189	0.597
11	9.452	17.312	12.219	12.784	0.829	0.586
12	9.168	15.962	12.739	13.736	1.200	0.600
13	9.506	17.204	12.197	12.703	0.816	0.589
14	9.221	15.953	12.636	13.656	1.180	0.603
15	9.493	17.118	12.203	12.603	0.819	0.589
16	9.190	15.977	12.711	13.655	1.180	0.606
MEAN ODD	9.407	17.250	12.240	12.712	0.823	0.576
MEAN EVEN	9.172	15.902	12.730	13.704	1.189	0.601
MEAN ALL	9.289	16.576	12.485	13.208	1.018	0.588
SDEV ODD	0.079	0.076	0.058	0.063	0.004	0.030
SDEV EVEN	0.025	0.321	0.043	0.068	0.008	0.003
SDEV ALL	0.134	0.731	0.258	0.516	0.189	0.024
SMEN ODD	0.028	0.027	0.020	0.022	0.002	0.011
SMEN EVEN	0.009	0.113	0.015	0.024	0.003	0.001
SMEN ALL	0.033	0.183	0.064	0.129	0.049	0.006
CVAR ODD	0.840	0.441	0.470	0.494	0.526	5.197
CVAR EVEN	0.273	2.017	0.335	0.493	0.652	0.447
CVAR ALL	1.439	4.412	2.066	3.908	18.583	4.120

921453e1/83

ORIGINAL PAGE IS  
OF POOR QUALITY

Table A-31. Lamp 000 for Test 9 in Radiance Units

CHANNEL	BAND					
	TM1	TM2	TM3	TM4	TM5	TM7
1	2.751	5.318	3.592	4.117	0.274	0.207
2	2.643	4.858	3.883	4.524	0.383	0.221
3	2.781	5.325	3.617	4.136	—	0.207
4	2.652	4.536	3.875	4.574	0.388	0.220
5	2.768	5.309	3.645	4.165	0.274	0.206
6	2.651	4.810	3.873	4.566	0.388	0.221
7	2.754	5.279	3.627	4.146	0.277	0.176
8	2.644	4.753	3.874	4.560	0.388	0.222
9	2.731	5.307	3.610	4.140	0.274	0.206
10	2.645	4.751	3.885	4.560	0.386	0.220
11	2.784	5.313	3.622	4.157	0.276	0.207
12	2.663	4.770	3.887	4.573	0.390	0.220
13	2.800	5.281	3.613	4.147	0.271	0.209
14	2.674	4.763	3.847	4.547	0.383	0.221
15	2.792	5.267	3.597	4.109	0.272	0.209
16	2.667	4.776	3.887	4.545	0.385	0.223
MEAN ODD	2.770	5.300	3.615	4.140	0.274	0.204
MEAN EVEN	2.655	4.752	3.876	4.556	0.386	0.221
MEAN ALL	2.713	5.020	3.746	4.348	0.334	0.212
SDEV ODD	0.024	0.022	0.017	0.020	0.002	0.011
SDEV EVEN	0.012	0.095	0.014	0.017	0.003	0.001
SDEV ALL	0.062	0.291	0.136	0.216	0.058	0.012
SMEN ODD	0.008	0.008	0.006	0.007	0.001	0.004
SMEN EVEN	0.004	0.033	0.005	0.006	0.001	0.000
SMEN ALL	0.016	0.073	0.034	0.054	0.015	0.003
CVAR ODD	0.858	0.423	0.483	0.479	0.817	5.584
CVAR EVEN	0.448	1.991	0.369	0.378	0.655	0.450
CVAR ALL	2.298	5.780	3.624	4.963	17.405	5.606

921453-1/83

ORIGINAL PAGE IS  
OF POOR QUALITY

Table A-32. Lamp 100 for Test 9 in Radiance Units

CHANNEL	BAND					
	TM1	TM2	TM3	TM4	TM5	TM7
1	0.000	-0.009	0.075	0.024	-0.006	-0.001
2	0.017	0.004	0.073	0.027	-0.004	0.000
3	-0.000	0.003	0.060	0.039	-	-0.000
4	-0.009	-0.003	0.081	0.029	-0.004	-0.000
5	0.004	-0.012	0.068	0.039	-0.006	0.000
6	0.013	-0.001	0.074	0.038	-0.005	0.000
7	-0.006	-0.010	0.069	-0.008	-0.005	0.004
8	0.007	-0.024	0.093	0.065	-0.004	0.001
9	-0.011	-0.022	0.070	0.024	-0.007	-0.001
10	-0.001	-0.018	0.080	0.038	-0.004	0.001
11	-0.007	-0.012	0.080	0.018	-0.007	-0.000
12	-0.001	-0.013	0.080	0.035	-0.004	-0.000
13	-0.007	-0.010	0.071	0.036	-0.007	-0.000
14	0.017	-0.024	0.075	0.025	-0.004	-0.001
15	-0.006	-0.020	0.059	0.037	-0.008	-0.000
16	0.021	-0.008	0.089	0.022	-0.004	-0.000
MEAN ODD	-0.004	-0.011	0.069	0.026	-0.007	0.000
MEAN EVEN	0.008	-0.011	0.081	0.035	-0.004	0.000
MEAN ALL	0.002	-0.011	0.075	0.031	-0.005	0.000
SDEV ODD	0.005	0.008	0.007	0.016	0.001	0.002
SDEV EVEN	0.010	0.011	0.007	0.014	0.000	0.001
SDEV ALL	0.010	0.009	0.009	0.015	0.001	0.001
SMEN ODD	0.002	0.003	0.003	0.006	0.000	0.001
SMEN EVEN	0.004	0.004	0.002	0.005	0.000	0.000
SMEN ALL	0.003	0.002	0.002	0.004	0.000	0.000
CVAR ODD	-119.580	-67.327	10.356	61.327	-14.551	1148.270
CVAR EVEN	125.825	-97.003	8.655	38.706	-9.390	6348.906
CVAR ALL	477.553	-80.049	12.152	49.208	-27.966	1590.828

92141531/103

ORIGINAL PAGE 17  
OF POOR QUALITY

Table A-33. Lamp 100 Ratio of Digital Counts, Ambient to Vacuum

CHANNEL	BAND					
	TM1	TM2	TM3	TM4	TM5	TM7
1	1.01658	1.01319	0.95217	0.94851	1.05498	1.03020
2	0.99891	0.98138	0.95280	0.95502	1.06485	0.98692
3	1.01429	1.01356	0.95056	0.95505	—	1.01677
4	1.00286	—	0.95438	0.95154	1.04038	0.97919
5	1.00988	1.01155	0.94975	0.95417	1.02633	1.01786
6	0.99815	0.97664	0.95723	0.95062	1.03835	0.97861
7	1.01287	1.01058	0.95420	0.95127	1.01713	1.16935
8	0.99688	0.98043	0.95728	0.95283	1.03328	0.97890
9	1.00817	1.01081	0.95455	0.95993	1.02412	1.01701
10	0.99972	0.97540	0.95880	0.95297	1.03472	0.98906
11	1.01187	1.01160	0.95724	0.95450	1.01267	1.01372
12	1.00066	0.97851	0.95894	0.95790	1.02403	0.98808
13	1.00849	1.01223	0.95314	0.95431	1.02320	1.00902
14	0.99900	0.97795	0.95335	0.95692	1.03637	0.98829
15	1.01250	1.00646	0.95442	0.95604	1.03973	1.02740
16	0.99293	0.98113	0.96022	0.95095	1.05655	1.00628
MEAN ODD	1.01183	1.01125	0.95325	0.95422	1.02831	1.03767
MEAN EVEN	0.99864	0.97873	0.95663	0.95358	1.04107	0.98692
MEAN ALL	1.00523	0.99610	0.95494	0.95390	1.03511	1.01229
SDEV ODD	0.00276	0.00209	0.00250	0.00340	0.01448	0.05365
SDEV EVEN	0.00295	0.00252	0.00286	0.00288	0.01323	0.00909
SDEV ALL	0.00741	0.01691	0.00313	0.00306	0.01484	0.04549
SMEN ODD	0.00098	0.00074	0.00089	0.00120	0.00547	0.01897
SMEN EVEN	0.00104	0.00095	0.00101	0.00102	0.00468	0.00322
SMEN ALL	0.00185	0.00437	0.00078	0.00076	0.00383	0.01137
CVAR ODD	0.27298	0.20648	0.26262	0.35663	1.40807	5.17062
CVAR EVEN	0.29569	0.25761	0.29887	0.30231	1.27044	0.92144
CVAR ALL	0.73730	1.69728	0.32767	0.32049	1.43346	4.49350

9214 (57) 83



ORIGINAL PAGE IS  
OF POOR QUALITY

Table A-34. Lamp 110 Ratio of Digital Counts, Ambient to Vacuum

CHANNEL	BAND					
	TM1	TM2	TM3	TM4	TM5	TM7
1	1.02181	1.01521	0.95905	0.95638	1.05584	1.03098
2	1.01130	0.98356	0.96616	0.94348	1.06257	0.99919
3	1.02064	1.01757	0.95965	0.95708	—	1.01798
4	1.00578	—	0.96857	0.93775	1.04052	0.99294
5	1.01770	1.01498	0.95701	0.95640	1.03167	1.02275
6	1.00828	0.97802	0.97037	0.93946	1.03771	0.99199
7	1.01708	1.01551	0.96235	0.95862	1.02454	1.17889
8	1.00339	0.98126	0.97097	0.94274	1.03449	0.99515
9	1.01657	1.01406	0.96497	0.96170	1.02831	1.02042
10	1.00744	0.97841	0.97284	0.94128	1.03588	1.00240
11	1.01525	1.01496	0.96590	0.95838	1.01928	1.01835
12	1.00484	0.97943	0.97234	0.94569	1.02230	1.00057
13	1.01406	1.01422	0.96279	0.95700	1.03230	1.01459
14	1.00623	0.98086	0.96827	0.94620	1.03630	0.99926
15	1.01885	1.01155	0.96202	0.95811	1.04439	1.02706
16	1.00217	0.98443	0.97392	0.94150	1.05245	1.01308
MEAN ODD	1.01774	1.01476	0.96172	0.95796	1.03383	1.04138
MEAN EVEN	1.00618	0.98085	0.97043	0.94226	1.04028	0.99932
MEAN ALL	1.01196	0.99894	0.96607	0.95011	1.03727	1.02035
SDEV ODD	0.00250	0.00157	0.00313	0.00188	0.01251	0.05581
SDEV EVEN	0.00279	0.00261	0.00281	0.00295	0.01220	0.00671
SDEV ALL	0.00646	0.01762	0.00533	0.00844	0.01235	0.04413
SMEN ODD	0.00089	0.00055	0.00111	0.00067	0.00473	0.01973
SMEN EVEN	0.00099	0.00099	0.00099	0.00104	0.00431	0.00237
SMEN ALL	0.00161	0.00455	0.00133	0.00211	0.00319	0.01103
CVAR ODD	0.24598	0.15432	0.32566	0.19647	1.20968	3.35921
CVAR EVEN	0.27696	0.26654	0.28967	0.31338	1.17250	0.67097
CVAR ALL	0.63818	1.76433	0.55182	0.82916	1.19088	4.32450

9214 (5/7) B3

STANDARD UNIT OF  
OF POOR QUALITY

Table A-35. Lamp 010 Ratio of Digital Counts, Ambient to Vacuum

CHANNEL	BAND					
	TM1	TM2	TM3	TM4	TM5	TM7
1	1.02964	1.01281	0.97439	0.96220	1.05929	1.04378
2	1.01289	0.97744	0.98236	0.93587	1.06283	1.01786
3	1.02859	1.01290	0.97040	0.96218	—	1.02734
4	1.01947	—	0.98572	0.92774	1.03820	1.00969
5	1.02917	1.00820	0.96920	0.96209	1.03053	1.03032
6	1.01280	0.97268	0.98658	0.93102	1.03939	1.01143
7	1.02643	1.01132	0.97386	0.96507	1.02184	1.19092
8	1.01580	0.97819	0.98785	0.93395	1.02917	1.01042
9	1.02379	1.00690	0.97422	0.96988	1.03030	1.02573
10	1.01270	0.97058	0.98687	0.93037	1.03277	0.01935
11	1.02875	1.00960	0.97726	0.96422	1.01934	1.02559
12	1.02094	0.97527	0.98716	0.93428	1.01840	1.01650
13	1.02946	1.00671	0.97327	0.96471	1.03044	1.01828
14	1.01148	0.97344	0.98325	0.93373	1.03000	1.01774
15	1.02734	1.00352	0.97249	0.96745	1.04607	1.04034
16	1.00908	0.97398	0.99083	0.93356	1.05218	1.03322
MEAN ODD	1.02790	1.00899	0.97313	0.96472	1.03397	1.05029
MEAN EVEN	1.01439	0.97451	0.98633	0.93256	1.03787	1.01702
MEAN ALL	1.02114	0.99290	0.97973	0.94864	1.03605	1.03366
SDEV ODD	0.00188	0.00320	0.00256	0.00293	0.01406	0.05742
SDEV EVEN	0.00399	0.00276	0.00281	0.00276	0.01399	0.00752
SDEV ALL	0.00768	0.01804	0.00728	0.01683	0.01365	0.04312
SMEN ODD	0.00067	0.00113	0.00090	0.00104	0.00531	0.02030
SMEN EVEN	0.00141	0.00104	0.00099	0.00098	0.00495	0.00266
SMEN ALL	0.00192	0.00466	0.00182	0.00421	0.00352	0.01078
CVAR ODD	0.18310	0.31681	0.26278	0.30368	1.35941	5.45680
CVAR EVEN	0.39358	0.28344	0.28500	0.29619	1.34815	0.73934
CVAR ALL	0.75221	1.81699	0.74280	1.77429	1.31769	4.17183

9214 (57) 83

ORIGINAL PAGE IS  
OF POOR QUALITY

Table A-36. Lamp Oil Ratio of Digital Counts, Ambient to Vacuum

CHANNEL	BAND					
	TM1	TM2	TM3	TM4	TM5	TM7
1	1.02977	1.02682	0.97689	0.97238	1.06329	1.04383
2	1.01955	0.98929	0.98488	0.94922	1.06562	1.02023
3	1.03001	1.02570	0.97549	0.97282	—	1.02983
4	1.01586	—	0.98906	0.94495	1.04082	1.01240
5	1.02748	1.02447	0.97329	0.97078	1.03724	1.03323
6	1.02039	0.98555	0.99030	0.94643	1.03825	1.01146
7	1.03135	1.02420	0.97954	0.97380	1.02769	1.18496
8	1.01202	0.98863	0.98932	0.94818	1.03521	1.01299
9	1.02680	1.02405	0.98120	0.97929	1.03421	1.03203
10	1.01468	0.98272	0.99212	0.94642	1.03520	1.02239
11	1.03249	1.02314	0.98297	0.97234	1.02248	1.02663
12	1.01557	0.98583	0.99005	0.95066	1.02372	1.02081
13	1.02865	1.02193	0.97818	0.97422	1.03524	1.02543
14	1.01674	0.98513	0.98650	0.55110	1.03885	1.01765
15	1.02785	1.01945	0.97874	0.97744	1.05288	1.03911
16	1.01139	0.98643	0.99112	0.94629	1.05528	1.03365
MEAN ODD	1.02930	1.02372	0.97829	0.97413	1.03900	1.05188
MEAN EVEN	1.01577	0.98622	0.98904	0.94791	1.04162	1.01895
MEAN ALL	1.02254	1.00622	0.98366	0.96102	1.04040	1.03541
SDEV ODD	0.00192	0.00221	0.00318	0.00224	0.01426	0.05412
SDEV EVEN	0.00313	0.00236	0.00256	0.00236	0.01299	0.00724
SDEV ALL	0.00755	0.01949	0.00621	0.01378	0.01316	0.04101
SMEN ODD	0.00068	0.00078	0.00112	0.00100	0.00539	0.01913
SMEN EVEN	0.00111	0.00089	0.00090	0.00084	0.00459	0.00256
SMEN ALL	0.00189	0.00503	0.00155	0.00344	0.00340	0.01025
CVAR ODD	0.18633	0.21633	0.32456	0.29104	1.37281	5.14487
CVAR EVEN	0.30833	0.23916	0.25856	0.24933	1.24732	0.71077
CVAR ALL	0.73812	1.93688	0.63154	1.43373	1.26530	3.96038

9214 (5/7) 83

ORIGINAL PAGE IS  
OF POOR QUALITY

Table A-37. Lamp 111 Ratio of Digital Counts, Ambient to Vacuum

CHANNEL	BAND					
	TM1	TM2	TM3	TM4	TM5	TM7
1	1.02255	1.01834	0.96242	0.96637	1.05149	1.02832
2	1.00817	0.98446	0.96691	0.95610	1.06044	0.99763
3	1.01992	1.01928	0.96123	0.96683	—	1.01958
4	1.01430	—	0.96910	0.95091	1.03912	0.99588
5	1.01787	1.01691	0.95898	0.96453	1.02746	1.02279
6	1.00861	0.97866	0.97143	0.95519	1.03596	0.99504
7	1.01999	1.01846	0.96495	0.96687	1.02137	1.17969
8	1.00524	0.98399	0.96997	0.95537	1.03263	0.99787
9	1.01701	1.01566	0.96481	0.97079	1.02376	1.02051
10	1.00881	0.97852	0.97477	0.96484	1.03440	1.00578
11	1.01809	1.01671	0.96772	0.96343	1.01550	1.01949
12	1.01350	0.98323	0.97233	0.95855	1.02235	1.00283
13	1.01658	1.01550	0.96485	0.96837	1.02798	1.01495
14	1.00731	0.98061	0.96968	0.95694	1.03653	1.00229
15	1.01810	1.01254	0.96460	0.96507	1.03722	1.02607
16	1.00148	0.98509	0.97519	0.95147	1.04985	1.01358
MEAN ODD	1.01876	1.01667	0.96370	0.96653	1.02925	1.04143
MEAN EVEN	1.00843	0.98208	0.97105	0.95617	1.03891	1.00136
MEAN ALL	1.01360	1.00053	0.96737	0.96135	1.03440	1.02139
SDEV ODD	0.00185	0.00199	0.00284	0.00233	0.01185	0.05602
SDEV EVEN	0.00413	0.00287	0.00311	0.00443	0.01153	0.00521
SDEV ALL	0.00630	0.01801	0.00475	0.00634	0.01226	0.04372
SMEN ODD	0.00065	0.00070	0.00100	0.00083	0.00448	0.01980
SMEN EVEN	0.00146	0.00109	0.00110	0.00157	0.00407	0.00220
SMEN ALL	0.00157	0.00465	0.00119	0.00158	0.00317	0.01093
CVAR ODD	0.18115	0.19551	0.29420	0.24153	1.15102	5.37872
CVAR EVEN	0.40922	0.29274	0.32029	0.46323	1.10937	0.62009
CVAR ALL	0.62142	1.80049	0.49111	0.65937	1.18562	4.28040

9214 (5/7) 83

ORIGINAL PAGE IS  
OF POOR QUALITY

Table A-38. Lamp 101 Ratio of Digital Counts, Ambient to Vacuum

CHANNEL	BAND					
	TM1	TM2	TM3	TM4	TM5	TM7
1	1.02384	1.02590	0.96283	0.95966	1.05394	1.02811
2	1.01172	0.99391	0.96685	0.96235	1.06773	0.99547
3	1.02477	1.02783	0.96250	0.96179	—	1.01640
4	1.01183	—	0.96769	0.95278	1.04352	0.98855
5	1.02037	1.02564	0.96032	0.96156	1.02855	1.01824
6	1.01134	0.98595	0.97037	0.95535	1.04190	0.98852
7	1.02063	1.02640	0.96692	0.96253	1.02280	1.17014
8	1.00536	0.99171	0.96891	0.96066	1.03705	0.99000
9	1.01892	1.02608	0.96865	0.96792	1.02644	1.01654
10	1.00992	0.98644	0.97325	0.95861	1.03779	1.00018
11	1.02121	1.02549	0.96989	0.96319	1.01749	1.01586
12	1.01025	0.98917	0.97304	0.96020	1.02678	0.99693
13	1.01870	1.02591	0.96740	0.96395	1.02783	1.01208
14	1.00986	0.98654	0.96876	0.96155	1.04103	0.99555
15	1.02236	1.02237	0.96565	0.96557	1.04205	1.02630
16	1.00491	0.99326	0.97309	0.95848	1.05777	1.01192
MEAN ODD	1.02135	1.02570	0.96552	0.96327	1.03130	1.03796
MEAN EVEN	1.00940	0.98957	0.97024	0.95875	1.04420	0.99589
MEAN ALL	1.01537	1.00884	0.96788	0.96101	1.03818	1.01692
SDEV ODD	0.00212	0.00143	0.00340	0.00264	0.01246	0.05368
SDEV EVEN	0.00269	0.00357	0.00266	0.00332	0.01280	0.00776
SDEV ALL	0.00677	0.01882	0.00383	0.00373	0.01389	0.04296
SMEN ODD	0.00075	0.00051	0.00120	0.00093	0.00471	0.01898
SMEN EVEN	0.00095	0.00135	0.00094	0.00117	0.00452	0.00274
SMEN ALL	0.00169	0.00486	0.00096	0.00093	0.00359	0.01074
CVAR ODD	0.20760	0.13937	0.35245	0.27365	1.20833	5.17174
CVAR EVEN	0.26621	0.36035	0.27433	0.34649	1.22552	0.77920
CVAR ALL	0.66634	1.86595	0.39597	0.38828	1.33786	4.22420

9214 (5/7) 03

ORIGINAL PAGE IS  
OF POOR QUALITY

Table A-39. Lamp 001 Ratio of Digital Counts, Ambient to Vacuum

CHANNEL	BAND					
	TM1	TM2	TM3	TM4	TM5	TM7
1	1.05146	1.04451	0.99600	0.99148	1.06109	1.03827
2	1.02959	1.00639	0.99150	0.97856	1.07448	1.01892
3	1.04968	1.04698	0.99141	0.99238	—	1.02372
4	1.04080	—	0.99589	0.97282	1.04821	1.01057
5	1.04364	1.04214	0.99154	0.99065	1.02835	1.02383
6	1.02951	1.00013	1.00048	0.97432	1.04336	1.01193
7	1.05134	1.04547	0.99314	0.99457	1.01993	1.18282
8	1.03333	1.01094	0.99906	0.97431	1.03743	1.01379
9	1.04255	1.04413	0.99406	0.99887	1.02633	1.02681
10	1.03431	1.00274	1.00180	0.97279	1.03803	1.02232
11	1.04690	1.04614	0.99828	0.99330	1.01318	1.02414
12	1.03961	1.00589	0.99754	0.97925	1.03199	1.01908
13	1.04438	1.04390	0.99415	0.99640	1.03189	1.01456
14	1.03020	1.00346	0.99696	0.97897	1.04545	1.02254
15	1.04877	1.04043	0.99884	0.99872	1.04440	1.03442
16	1.02039	1.01089	0.99924	0.97401	1.06214	1.03743
MEAN ODD	1.04734	1.04421	0.99468	0.99455	1.03217	1.04608
MEAN EVEN	1.03222	1.00578	0.99781	0.97563	1.04763	1.01959
MEAN ALL	1.03978	1.02627	0.99624	0.98509	1.04042	1.03284
SDEV ODD	0.00346	0.00199	0.00295	0.00326	0.01604	0.05571
SDEV EVEN	0.00646	0.00407	0.00326	0.00286	0.01410	0.00850
SDEV ALL	0.00935	0.02007	0.00339	0.01020	0.01651	0.04087
SMEN ODD	0.00122	0.00070	0.00104	0.00115	0.00606	0.01970
SMEN EVEN	0.00228	0.00154	0.00115	0.00101	0.00498	0.00300
SMEN ALL	0.00234	0.00518	0.00085	0.00255	0.00426	0.01022
CVAR ODD	0.33060	0.19035	0.29686	0.32777	1.55416	5.32574
CVAR EVEN	0.62552	0.40424	0.32670	0.29305	1.34576	0.83342
CVAR ALL	0.89954	1.95558	0.34051	1.03594	1.58657	3.95704

9714 (27) 13

ORIGINAL PAGE IS  
OF POOR QUALITY

Table A-40. Lamp 000 Ratio of Digital Counts, Ambient to Vacuum

CHANNEL	BAND					
	TM1	TM2	TM3	TM4	TM5	TM7
1	0.84874	0.91923	0.89045	0.96452	1.02899	1.03095
2	0.82790	0.93593	0.93088	0.99516	0.96443	0.98961
3	0.88600	0.93615	0.94493	0.97528	—	1.01958
4	0.66905	—	1.00238	1.03837	0.99856	1.01477
5	0.86007	0.90883	0.93514	0.95015	1.06775	0.96033
6	0.83347	0.89097	0.92072	0.95662	1.02787	0.99653
7	0.91706	0.93409	0.94489	0.96833	1.00652	0.86978
8	0.77547	0.94652	0.96031	0.94695	1.00904	0.93608
9	0.94653	0.95327	0.96037	0.95465	1.04489	1.04369
10	0.74076	0.95658	0.91749	0.94547	0.99682	0.97597
11	0.92982	0.95312	0.99323	0.96937	1.05126	1.00525
12	0.66705	0.94242	0.90272	0.92591	0.99784	0.95587
13	0.89245	0.94876	0.91475	0.98278	1.04554	1.01587
14	0.80438	0.94893	0.91328	0.93633	0.98298	1.02037
15	0.88726	0.94791	0.92152	0.97628	1.10142	1.01589
16	0.83299	0.94940	0.87937	0.91275	0.98982	0.97583
MEAN ODD	0.89599	0.93767	0.93816	0.96767	1.04948	0.99517
MEAN EVEN	0.77139	0.93858	0.92839	0.95719	0.99592	0.95463
MEAN ALL	0.83369	0.93814	0.93328	0.96243	1.02092	0.98990
SDEV ODD	0.03350	0.01647	0.03100	0.01106	0.02982	0.05622
SDEV EVEN	0.06606	0.02200	0.03774	0.04083	0.01853	0.02744
SDEV ALL	0.08186	0.01853	0.03374	0.02939	0.03630	0.04308
SMEN ODD	0.01184	0.00582	0.01096	0.00391	0.01127	0.01988
SMEN EVEN	0.02336	0.00831	0.01334	0.01443	0.00655	0.00970
SMEN ALL	0.02046	0.00478	0.00844	0.00735	0.00937	0.01077
CVAR ODD	3.73879	1.75689	3.30486	1.14304	2.84126	5.64935
CVAR EVEN	8.56443	2.34332	4.06499	4.26516	1.86012	2.78666
CVAR ALL	9.81898	1.97488	3.61549	3.65395	3.55556	4.35184

9214 (5/7) 83

## REFERENCES

- Barker, J. L., R. B. Abrams, D. L. Ball, and K. C. Leung, "Radiometric Calibration and Processing Procedures" (paper presented at Landsat-4 Scientific Characterization Early Results Symposium, Goddard Space Flight Center, Greenbelt, Maryland, 1983a)
- , "Characterization of Radiometric Calibration of Landsat-4 TM Reflective Bands" (paper presented at Landsat-4 Scientific Characterization Early Results Symposium, Goddard Space Flight Center, Greenbelt, Maryland, 1983b)
- , D. L. Ball, and K. C. Leung, "TM/PF Engineering Data Evaluation: Prelaunch Absolute Calibration," NASA/GSFC Technical Memorandum, in preparation, 1983c
- , D. L. Ball, and K. C. Leung, "TM/PF Engineering Data Evaluation: Transfer of the Prelaunch Absolute Calibration to the Internal Calibrator," NASA/GSFC Technical Memorandum, in preparation, 1983d
- Campbell, J. C., "Preliminary Radiometric Tests To Determine a Technique for Calibration of NASA's 48-inch Diameter Spherical Integrating Source," Santa Barbara Research Center, HS236-6926, 1980
- Clemann, D., J. Lansing, and C. Rodil, "Protoflight Radiance-Temperature Study," Santa Barbara Research Center, HS236-8076, 1982
- Duck, K. I., "Revised Thematic Mapper Radiometric Assessment," National Aeronautics and Space Administration/Goddard Space Flight Center (NASA/GSFC) Internal Memorandum, 1977
- Engel, J. C., "Thematic Mapper: An Interim Report on Anticipated Performance," Proceedings of AIAA Sensor Systems for the 80's Conference, 1980
- Fraser, R. S., "Radiances for Thematic Mapper," NASA/GSFC Internal Memorandum, 1975
- Lansing, J. C., "Test Requirement Changes: AC02, BL07, SRT," Santa Barbara Research Center, HS236-7708, 1981
- , and J. L. Barker, "Thermal Band Characterization of Landsat-4 Thematic Mapper" (paper presented at Landsat-4 Scientific Characterization Early Results Symposium, Goddard Space Flight Center, Greenbelt, Maryland, February 1983)



Osgood, R. L., and J. C. Lansing, "TM AC02R Test Result Summary, Protoflight Model," Santa Barbara Research Center, HS236-7552, 1981

Walker, J. A., "Comparisons of 48SIS Calibrations--NASA and SBRC," Santa Barbara Research Center, HS236-8160, 1982a

--, "48 SIS Calibration Data for GE Po'st T.V. Test Configuration," Santa Barbara Research Center, HS236-7995, 1982b

--, "Calibration Results of Secondary Standards of Irradiance SS13 and SS14," Santa Barbara Research Center, NS236-8161, 1982c

Young, J. B., "Apparent PFM Radioactive Calibration Changes at General Electric," Santa Barbara Research Center, HS236-7881, 1982