GSFC CALIBRATION SUMMARY REPORT
NASA 48-INCH INTEGRATING HEMISPHERE SOURCE

Code 920.1 Office of Standards and Calibrations
Calibration Technicians: John Cooper and Reginald Galimore

Attachment 2.[redacted] 2.10

1. Introduction

During the period of November 15 through 25, 1991, a NASA 48-inch diameter integrating hemisphere source and support equipment were sent to Johnson Space Center in Houston, Texas as part of a calibration effort for a FIRE Project mission based at Ellington field. Technicians involved in the calibration were Reginald Galimore and John Cooper of Hughes STX, contracting for The Office of Standards and Calibrations (Code 920.1).

The hemisphere was used as a source for several pre-flight calibrations of the ER-2 mounted MAS (MODIS Aircraft Simulator). Since the hemisphere could not be tilted to accommodate the downward-looking MAS instrument, a 45° angle mirror from Ames was used to direct light from the hemisphere into the MAS entrance aperture. The spectral transmittance of the mirror was later determined after the mission, when the mirror was shipped to the Office of Standards and Calibrations to be characterized.

A radiance calibration of the hemisphere was done at GSFC before shipping to establish a baseline for the FIRE mission. Five additional measurements were made on three dates during the mission. This was done to identify changes caused by stresses of transportation, to gather a significant amount of data for statistical analysis, and to ascertain the stability of the system under changing humidity conditions. Variations about the mean were found of 1 to 2 percent at the 1 sigma level in and near the visible, to approximately 4 percent in the near-infrared. Radiance values shown in this report result from an average of the five measurements taken at Houston, filtered to remove noise spikes.

2. Equipment and Procedures

An Optronic 746 Automated Spectroradiometer System was used to transfer the calibrations of two standard lamps (designated F227 and F269) to the 12.7cm aperture of the hemisphere. The Optronic Labs standard lamps were operated at a current of 8.0 amps. The hemisphere was operated at 6.5 amps with all twelve lamps on for the spectral radiance measurements. Three types of detector/grating combinations were used in the system: a silicon detector with a grating blazed at 750nm, a cooled germanium detector with a grating blazed at 1600nm, and a cooled lead sulfide detector with a 2500nm blazed grating. Measurements were made at 50nm intervals over the wavelength region of 400nm to 2300nm to cover calibrations for MAS channels 2 through 6.

Lamp level ratios were taken using the silicon / 750nm grating combination only t 850nm, and turning lamps off one at a time from twelve lamps to one. Because lamp level ratios are probably wavelength dependent, the ratios shown in this report may not apply for wavelengths greater than 1000nm. Lamp levels 2 and 4 are approximately 2% off from normal ratios, reflecting the difficulties of the hemisphere's power supply to hold at 6.5 amps for lower lamp levels. Since the hemisphere's power supply showed evidence of damage in transit to Houston, that is likely the cause of the instability. It is recommended that calibrations of the MAS instrument at lower lamp levels (particularly levels 1 to 4) be treated with an additional +-2% error bar. (More lamp level experiments will be conducted at GSFC in the coming weeks.)

3. Calculations

Radiance values were calculated from irradiance with this formula:

$$L_\lambda = (I_\lambda K),\ K=(a/b)^2/\pi F$$

Where L is radiance in uW/cm^2 sr nm, I is irradiance of the source, and K is a calibration constant. F is the fractional amount of light which reaches the aperture of the 746 spectrometer, and is given by the formula:

$$F=(Z-\mathrm{sqrt}(Z^2-4X^2Y^2))/2,\ X=a/c,\ Y=c/b,\ Z=1+(1+X^2)Y^2$$

Where a is the radius in centimeters of the 746 entrance aperture, b is the radius of the hemisphere's aperture, and c is the distance between both apertures.

Radiance values for the hemisphere were then filtered against a Planck function which was normalized to the average of the radiance data at 1300nm.

Calculated spectral radiance for the hemisphere before and after shipment to JSC are given in Table 1. Averaged filtered values for JSC and estimates of precision at each wavelength are given in Table 2. Figure 1 shows a corresponding plot of the average radiance of the hemisphere. Table 3 contains calibration dates and environmental conditions, as well as lamp level ratios taken at JSC.

Hemisphere Radiance in [uW/(ster cm^2 nm)]

Location/Run#>>	GSFC1	JSC1	JSC2	JSC3	JSC4	JSC5	GSFC2
Wavelength	11/7/91	11/16/91	11/20/91	11/20/91	11/22/91	11/22/91	12/26/91
400nm	1.34	1.39	1.18	1.31	1.39	1.43	1.42
450nm	3.24	2.43	2.27	2.32	2.31	2.39	3.29
500nm	6.00	6.36	5.86	5.95	5.77	5.84	6.00
550nm	9.21	9.54	8.94	9.09	8.88	8.94	9.13
600nm	12.32	13.03	12.20	12.46	12.66	12.81	12.15
650nm	15.43	15.98	15.17	15.59	15.61	15.57	15.17
700nm	17.87	18.58	17.65	18.12	18.13	18.16	17.65
750nm	19.83	20.54	19.76	20.26	20.22	20.22	19.64
800nm	21.29	21.67	21.47	21.98	21.82	21.82	22.03
850nm	22.12	22.85	22.44	22.99	22.77	22.84	22.88
900nm	22.50	23.35	22.80	21.83	23.21	23.30	22.96
950nm	22.09	23.00	22.82	22.23	21.59	21.63	22.99
1000nm	21.86	23.12	22.79	23.08	23.92	23.45	22.98
1050nm	21.67	22.79	22.52	22.72	23.19	23.00	22.58
1100nm	20.82	21.83	21.72	22.03	22.01	21.90	21.59
1150nm	19.84	20.70	20.61	20.72	20.91	20.79	20.53
1200nm	18.90	19.91	19.59	19.78	19.91	19.79	19.56
1250nm	17.95	18.79	18.72	18.90	18.99	19.02	18.71
1300nm	16.88	17.65	17.69	17.83	17.86	17.84	17.55
1350nm	15.33	15.69	15.92	16.03	16.05	16.02	15.89
1400nm	13.68	13.86	14.10	14.44	14.31	14.31	14.05
1450nm	12.71	13.16	12.98	13.29	13.57	13.44	12.97
1500nm	12.28	12.53	12.48	12.65	12.91	12.80	12.51
1550nm	11.52	12.06	11.71	11.68	12.51	12.34	11.86
1600nm	11.04	11.67	11.51	11.62	10.51	10.88	11.34
1650nm	10.28	10.80	10.56	10.80	9.86	10.18	10.52
1700nm	9.38	9.94	9.65	9.82	9.28	9.15	9.30
1750nm	8.42	9.14	8.90	8.94	8.14	8.28	8.78
1800nm	7.68	8.22	8.16	8.17	7.62	7.73	8.09
1850nm	6.70	7.28	7.47	7.17	6.77	6.76	7.13
1900nm	5.37	5.45	5.23	5.70	5.15	5.55	5.58
1950nm	5.15	5.30	4.43	5.46	5.13	5.28	5.08
2000nm	4.83	5.19	5.01	5.52	5.26	5.14	5.11
2050nm	4.73	5.18	4.92	4.89	4.90	5.01	4.70
2100nm	4.30	4.37	4.47	4.54	4.51	4.46	4.42
2150nm	3.91	4.76	4.27	4.13	3.92	4.13	4.10
2200nm	3.46	3.76	3.95	3.96	3.71	3.93	3.96
2250nm	3.36	3.64	3.63	3.70	3.50	3.66	3.31
2300nm	2.91	3.12	2.79	3.08	2.79	3.05	2.92
2350nm		2.74	2.63	2.58	2.75	2.81	2.50
2400nm		2.52	2.34	2.51	2.22	2.44	2.34

TABLE 1

Hemisphere Radiance in [uW/(ster cm^2 nm)]

Wavelength	Average Filtered Radiance at JSC	1 Sigma Precision of JSC runs
400nm	1.34	6.7%
450nm	3.08	4.4%
500nm	5.96	3.5%
550nm	9.08	2.7%
600nm	12.63	2.3%
650nm	15.58	1.6%
700nm	18.13	1.6%
750nm	20.20	1.2%
800nm	21.75	0.8%
850nm	22.78	0.8%
900nm	23.20	0.9%
950nm	23.28	1.4%
1000nm	23.27	1.7%
1050nm	22.84	1.0%
1100nm	21.90	0.5%
1150nm	20.75	0.5%
1200nm	19.80	0.6%
1250nm	18.88	0.6%
1300nm	17.78	0.5%
1350nm	15.94	0.8%
1400nm	14.20	1.4%
1450nm	13.29	1.6%
1500nm	12.68	1.3%
1550nm	12.06	2.7%
1600nm	11.24	4.1%
1650nm	10.44	3.5%
1700nm	9.57	3.2%
1750nm	8.68	4.5%
1800nm	7.98	3.2%
1850nm	7.09	4.0%
1900nm	5.42	3.7%
1950nm	5.12	7.1%
2000nm	5.23	3.2%
2050nm	4.98	2.2%
2100nm	4.47	1.3%
2150nm	4.24	6.7%
2200nm	3.86	2.7%
2250nm	3.62	1.9%
2300nm	2.97	4.9%
2350nm	2.70	3.2%
2400nm	2.41	4.6%

TABLE 2

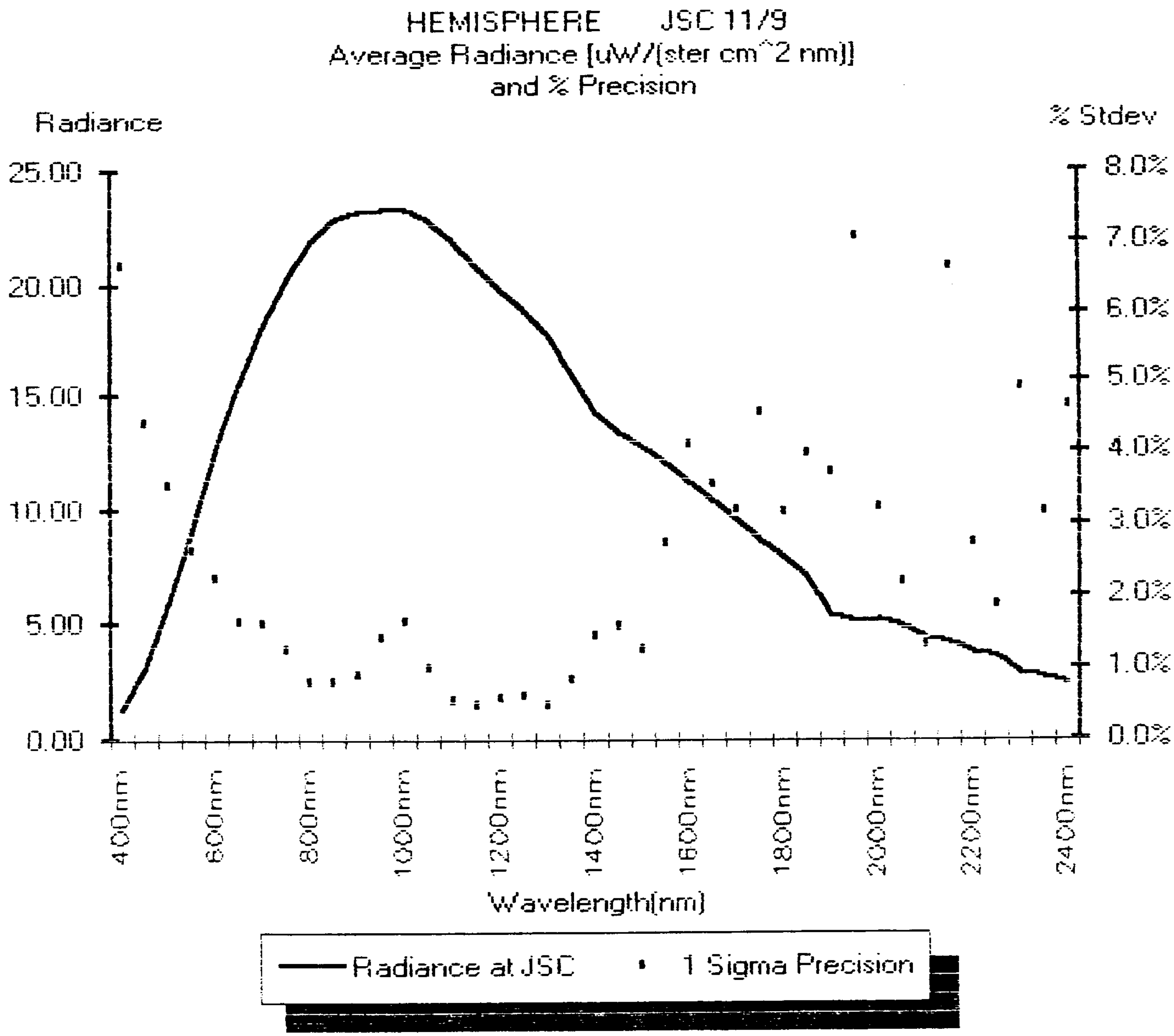
HEMISPHERE JSC 11/9
Average Radiance [uW/(ster cm^2 nm)]
and % Precision
Radiance
% Stdev
25.00
20.00
15.00
10.00
5.00
0.00
8.0%
7.0%
6.0%
5.0%
4.0%
3.0%
2.0%
1.0%
0.0%
400nm
600nm
800nm
1000nm
1200nm
1400nm
1600nm
1800nm
2000nm
2200nm
2400nm
Wavelength(nm)
Radiance at JSC
1 Sigma Precision

FIGURE 1

Additional Hemisphere Calibration Information

Location/Run#:		GSFC1	JSC1	JSC2	JSC3	JSC4	JSC5	GSFC2
Date:		7-Nov	16-Nov	20-Nov	20-Nov	22-Nov	22-Nov	26-Dec
Temperature:		24c	26c	24c	24c	24c	24c	21c
Humidity:		34%	70%	34%	33%	45%	45%	32%
Lamp Standard:		f227	f269	f227	f269	f269	f269	f269
Si detector cut on:		400nm	400nm	400nm	400nm	400nm	400nm	400nm
Ge detector cut on:		1000nm	800nm	900nm	900nm	1000nm	1000nm	800nm
PbS detector cut on:		1600nm	1600nm	1600nm	1600nm	1600nm	1600nm	1600nm
Distance from source:		32.4cm	32.1cm	32.2cm	32.2cm	32.2cm	32.2cm	33.1cm
746 aperture radius:	a=	1.3cm	1.3cm	1.3cm	1.3cm	1.3cm	1.3cm	1.3cm
source aperture radius:	b=	12.7cm	12.7cm	12.7cm	12.7cm	12.7cm	12.7cm	12.7cm
source distance:	c=	32.4cm	32.1cm	32.2cm	32.2cm	32.2cm	32.2cm	33.1cm
X = a/c:	X=	0.0392	0.0396	0.0394	0.0394	0.0394	0.0394	0.0384
Y = c/b:	Y=	2.5496	2.5276	2.5354	2.5354	2.5354	2.5354	2.6063
Z = 1+(1+X^2)*Y^2:	Z=	7.5105	7.3986	7.4384	7.4384	7.4384	7.4384	7.8028
View Factor:	F=	0.0013	0.0014	0.0013	0.0013	0.0013	0.0013	0.0013
Calibration Constant:	K=	2.3902	2.3546	2.3673	2.3673	2.3673	2.3673	2.4833

11/20/91 Hemisphere Ratios of Lamp Levels

Lamps On	Output @ 850nm	Ratio to 12 Lamps	Ideal Ratio	Percent Difference
1	0.544	0.084	0.083	0.59%
2	1.059	0.163	0.167	-2.10%
3	1.620	0.250	0.250	-0.15%
4	2.110	0.325	0.333	-2.47%
5	2.680	0.413	0.417	-0.89%
6	3.230	0.498	0.500	-0.46%
7	3.760	0.579	0.583	-0.68%
8	4.280	0.659	0.667	-1.08%
9	4.865	0.750	0.750	-0.05%
10	5.410	0.834	0.833	0.03%
11	5.920	0.912	0.917	-0.49%
12	6.490	1.000	1.000	0.00%

TABLE 3