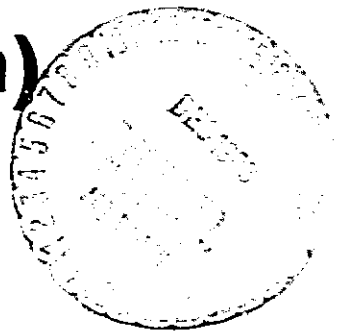
Analysis of Multispectral Scanner (MSS) and Thematic Mapper (TM) Performance (Pre-launch and Post-launch)



John L. Barker
NASA/Goddard Space Flight Center

for

Fifth Meeting of the Landsat Technical Working Group (LTWG)

September 28-30, 1983

Analysis of Multispectral Scanner (MSS) and Thematic Mapper (TM) Performance (Pre-launch and Post-launch)

Landsat Sensor Characterization

Systematic Characteristics of Sensors Associated with Imagery

Spectral (Wavelength, λ)

- Absolute Location
- Relative Variability

Radiometric (Radiance, L)

- Absolute Accuracy
- Relative Precision
  - Coherent
  - Random

Geometric

- Location of Pixel
  - Absolute Rectification
  - Relative Registration
- Size of Pixel (IFOV)
  - Absolute (MTF, LSF)
  - Relative

Representative Characteristics of Imagery Associated with Sensors and Processing

Spectral

- Spectral Striping
- Light Leaks
- Out-of-Band Response

Radiometric

- Histogram Range
- Dynamic Range
- Radiometric Striping
  - Within Line (Droop and Saturation)
  - Between Lines (Gain, Offset,...)
  - Between Scans (Droop and Saturation)
- Coherent Noise
- Unequal B in Sizes
- Non-Linearity
- Quantization Noise

Geometric

- Image Orientation
- Image Projection
- Overlap/Underlap
- Focus (Sharpness)

Radiometric Variables

Contributing to
Landsat Image Data Quality for Scanning Sensors
from a User's Perspective on Product

Between Scenes ("Corrected")	Within Scenes ("Uncorrected")
Sensor (MSS or TM)	Scan (Forward or Backward)
Spectral Band	Line (Unresampled Channel)
Date (Day-of-Year)	Saturation (Target or Lamp)
Time-of-Day (Day or Night)	Droop
WRS Path (SWATH)	
WRS Row (Scene)	

Flow of Information from Landsat

Observable Data

Radiance, Q (by Location in an Image)

Inferrable Variable

Radiance, L

Spectral Radiance, L_λ

Directional Reflectance or Albedo, R

- Atmosphere
- Target

Information

Spectral Transforms

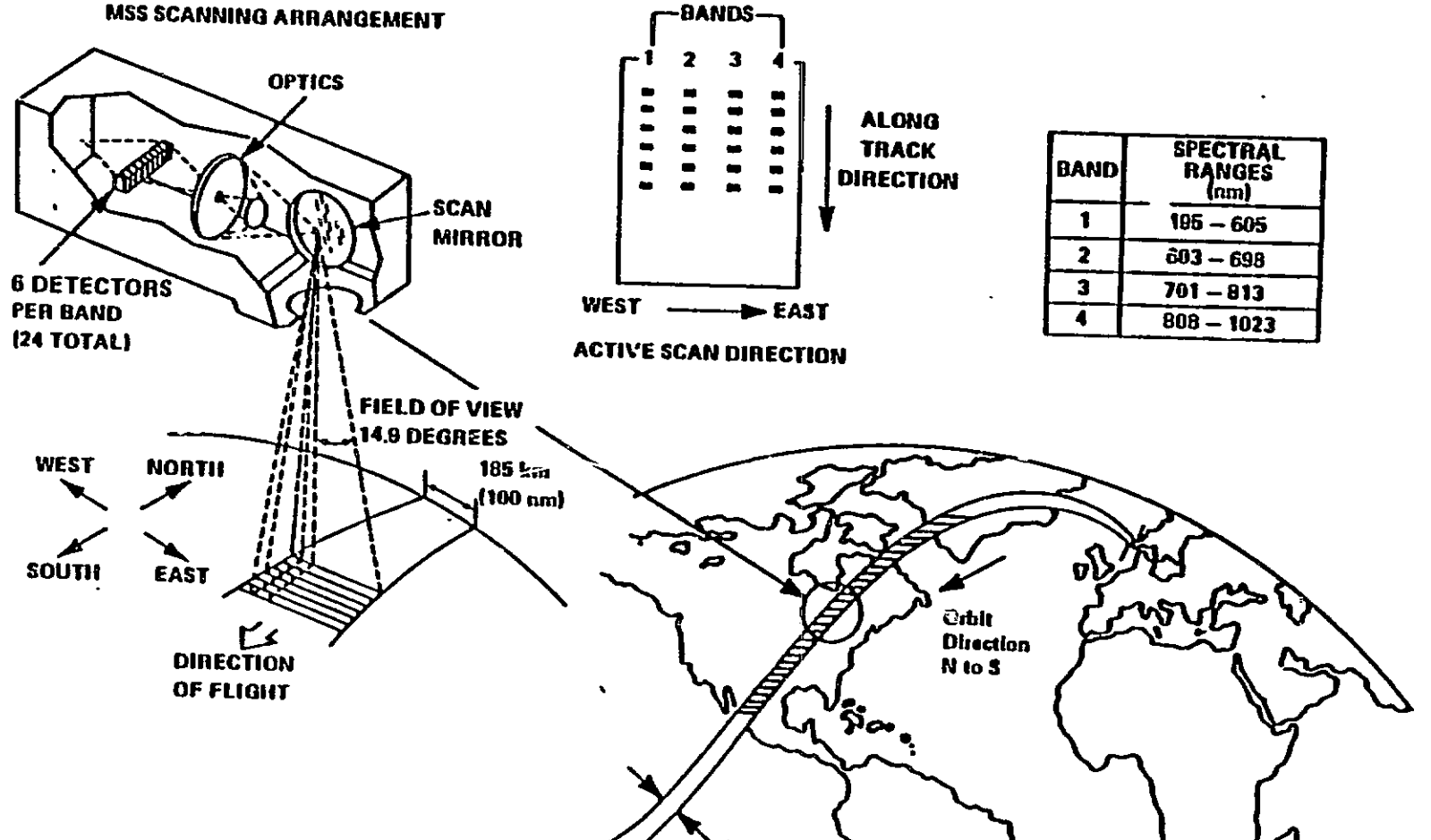
Spatial Maps

- Point Features
- Linear Features
- Areal Features (Extensive or Intensive Variables)
- 3-D Features (Topography)

Temporal Patterns

Use (Decision Models)

Perspective of MSS Data Acquisition



BAND	SPECTRAL RANGES (nm)
1	195 – 605
2	603 – 698
3	701 – 813
4	808 – 1023

GROUND IFOV
ALL BANDS – 82.7 X 57 m
DATA RATE – 15.06 Mbps
QUANTIZATION LEVELS – 64

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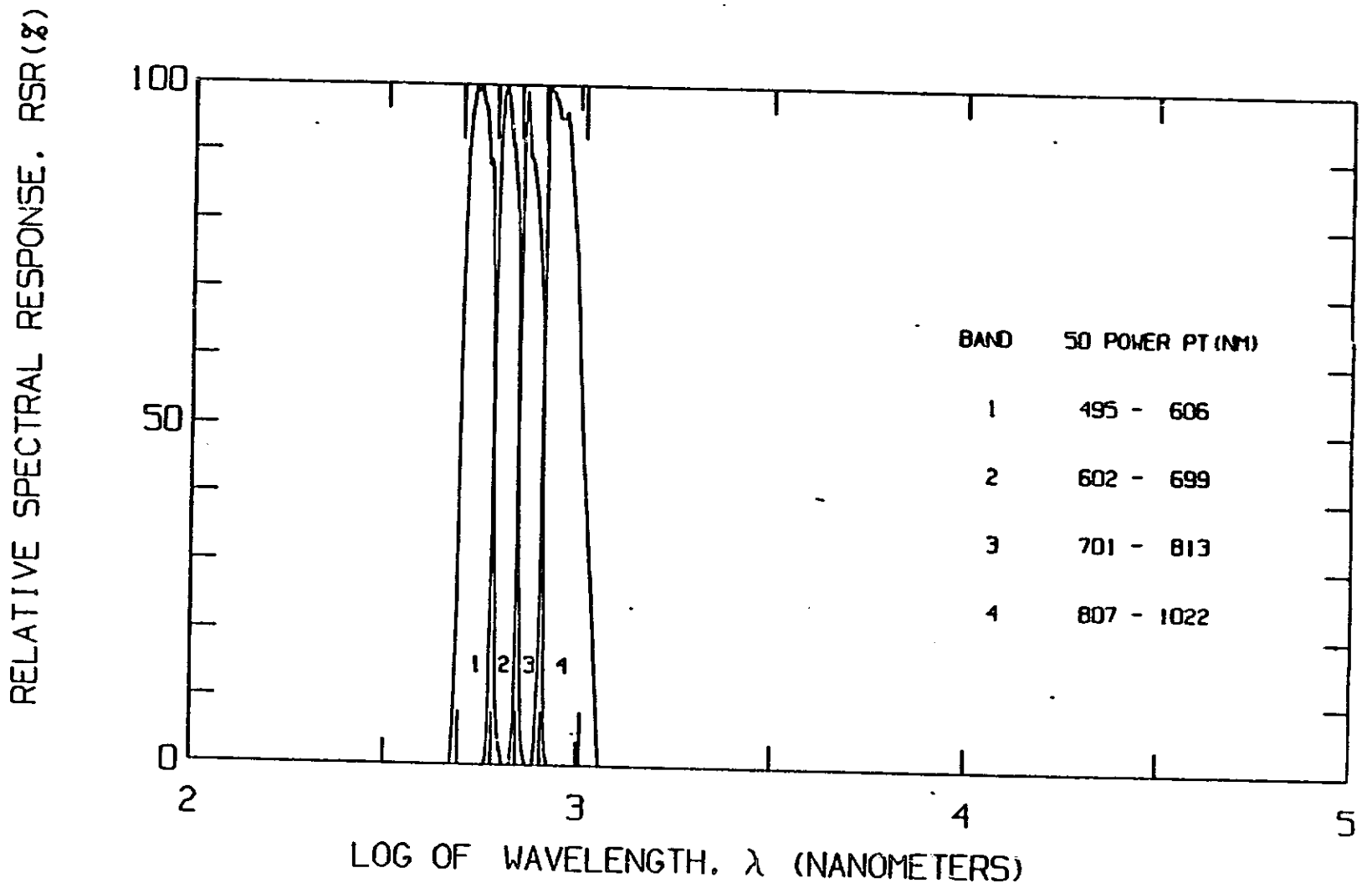
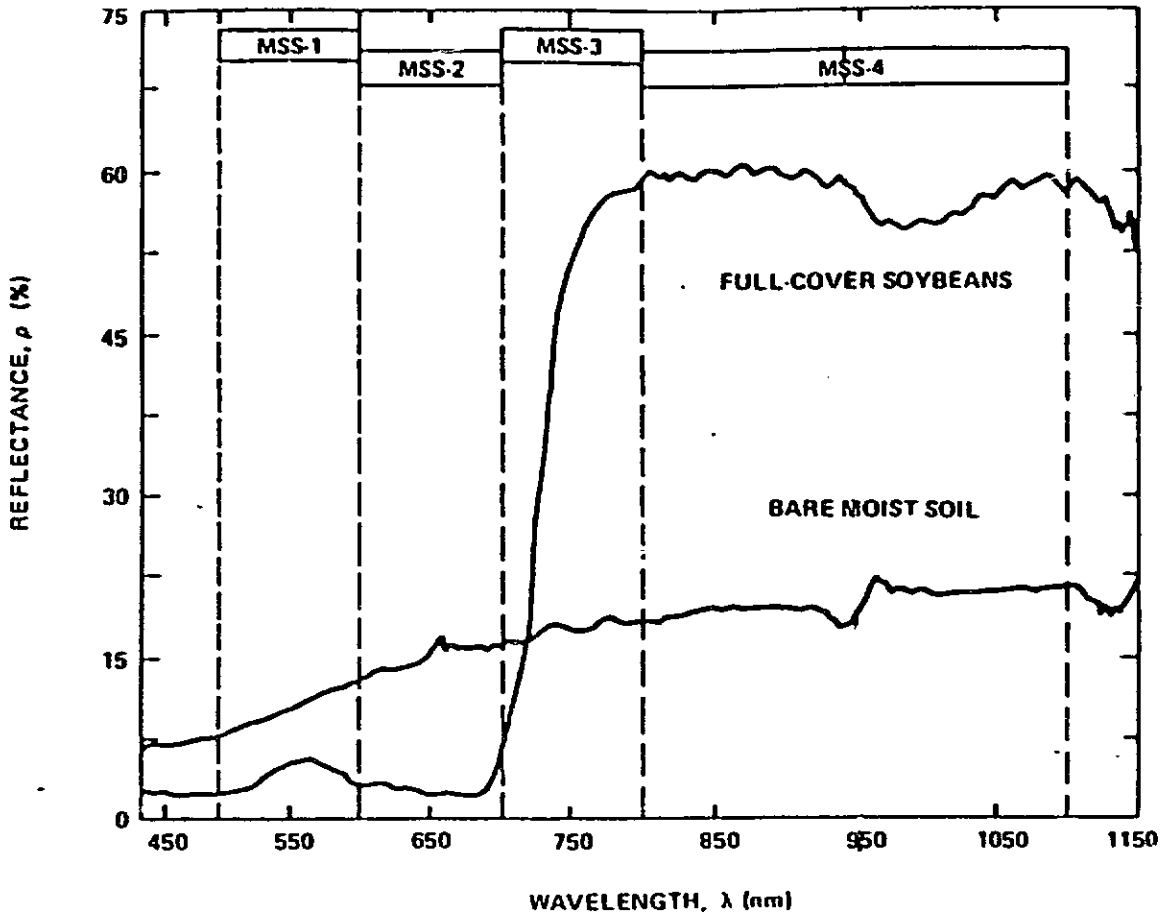
MSS Differences for Landsat 3 and Landsat 4

Parameter	Landsat 3	Landsat 4	Comment
IFOV	0.086 milliradians 79 meters	0.1172 milliradians 82 meters	Altitude-Dependent
Scan Angle	11.60 ±0.05 degrees	14.90 ±0.06 degrees	No change
Scan Nonlinearity	+2, −4.3 percent deviation mean scan rate	+2.4, −5.0 percent deviation from mean scan rate	No change in scan mirror mount's spring constant, yet a larger scan angle was required. This increased the scan nonlinearity.
MTF	Larger than 0.29 for 0.075 mradian bars	Larger than 0.36 for 0.102 mradian bars	Scan angle dependent correction made.
Backup Start of Scan Pulse	No requirement	Inserts a pseudo-scan monitor pulse if start of scan is not detected.	New requirement due to problems noted for Landsat 3.

Landsat-4 Multispectral Scanner Bands



Reflectance Spectra of Soybeans and Soil Used for MSS Output Simulations



Band 1 (500 to 600 nm) Spectral Characterization by Means and Standard Deviations: MSS-1, 2, 3, PF and F

	SCANNER	BAND EDGE (nm) LOWER	BAND EDGE (nm) UPPER	WIDTH* (nm)	SLOPE INTERVAL (nm) LOWER	SLOPE INTERVAL (nm) UPPER	SPECTRAL FLATNESS POSITIVE	SPECTRAL FLATNESS NEGATIVE
MEANS	PF	495	605	109	15	23	5.1[b]	8.9[b]
	F	497	607	109	15	21	5.0	11.2[b]
	1*	501	599	98	15	27	7.1[b]	16.1[b]
	1**	499	597	98	15	27	6.1[b]	14.6[b]
	2	497	598	101	15	22	5.4[b]	14.1[b]
	3	497	593	96	16	22	5.4[b]	19.2[b]
STANDARD DEVIATIONS	PF	0.5	1.2	0.8	0.3	1.0	1.0	2.7
	F	0.8	0.8	0.5	0.6	0.7	0.6	3.4
	1*	6.5	4.1	3.5	1.6	5.6	2.4	6.4
	1**	5.3	3.0	3.5	1.8	5.4	0.4	5.8
	2	1.4	1.4	1.8	1.2	0.6	2.4	3.5
	3	3.7	2.5	3.8	3.2	3.4	1.5	7.8

*WITH OUTLIER CHANNEL INCLUDED
**WITH OUTLIER CHANNEL EXCLUDED

a — NO FILTER SPECIFICATION
b — FAILS TO MEET FILTER SPECIFICATION

BOXES INDICATE CHARACTERISTICS WHERE DIFFERENCES BETWEEN PF OR F AND ALL PREVIOUS SCANNERS (1,2,3) WERE GREATER THAN DIFFERENCES BETWEEN TWO SETS OF PF MEASUREMENTS.

Band 2 (600 to 700 nm) Spectral Characterization by Means and Standard Deviations: MSS-1, 2, 3, PF and F

	SCANNER	BAND EDGE (nm) LOWER	BAND EDGE (nm) UPPER	WIDTH* (nm)	SLOPE INTERVAL (nm) LOWER	SLOPE INTERVAL (nm) UPPER	SPECTRAL FLATNESS POSITIVE	SPECTRAL FLATNESS NEGATIVE
MEANS	PF*	603	698	95	12	16	7.0	12.9[b]
	PF**	603	696	93	12	16	6.7	12.0[b]
	F	603	697	94	12	15	7.6[b]	11.1[b]
	1	603	701	97	15	26	9.0[b]	13.3[b]
	2*	607	710	103	14	30	7.9[b]	18.0[b]
	2**	607	710	103	14	29	7.8[b]	16.8[b]
	3	606	705	100	14	31	7.2	17.2[b]
STANDARD DEVIATIONS	PF*	0.7	4.7	4.8	0.5	1.9	1.4	2.5
	PF**	0.8	0.8	0.6	0.5	1.4	1.5	1.4
	F	0.4	0.6	0.5	0.4	0.9	1.2	3.0
	1	3.5	2.2	2.8	1.7	3.4	3.4	2.8
	2*	0.6	0.8	1.0	1.2	3.6	1.1	4.5
	2**	0.6	0.9	1.1	1.2	1.0	1.2	3.8
	3	0.9	1.2	0.8	0.8	2.0	2.0	4.8

*WITH OUTLIER CHANNEL INCLUDED
**WITH OUTLIER CHANNEL EXCLUDED

a — NO FILTER SPECIFICATION
b — FAILS TO MEET FILTER SPECIFICATION

BOXES INDICATE CHARACTERISTICS WHERE DIFFERENCES BETWEEN PF OR F AND ALL PREVIOUS SCANNERS (1,2,3) WERE GREATER THAN DIFFERENCES BETWEEN TWO SETS OF PF MEASUREMENTS.

Band 3 (700 to 800 nm) Spectral Characterization by Means and Standard Deviations: MSS-1, 2, 3, PF and F

	SCANNER	BAND EDGE (nm) LOWER	BAND EDGE (nm) UPPER	WIDTH* (nm)	SLOPE INTERVAL (nm) LOWER	SLOPE INTERVAL (nm) UPPER	SPECTRAL FLATNESS POSITIVE	SPECTRAL FLATNESS NEGATIVE
MEANS	PF	701	813[b]	112	15	15	13.2[b]	12.8[b]
	F	704	814[b]	110	16	14	12.6[b]	9.6[b]
	1	694	800	105	19	35	7.2[b]	7.4[b]
	2	697	802	106	16	34	8.4[b]	7.9[b]
	3	693	793	100	19	32	9.9[b]	22.2[b]
STANDARD DEVIATIONS	PF	0.7	0.9	1.1	0.3		2.9*	2.9*
	F	0.3	0.2	0.3	1.0		1.1*	0.8*
	1	0.9	1.0	0.9	2.0	3.8	3.2	2.9
	2	1.1	2.3	2.1	0.6	2.7	3.0	1.9
	3	1.8	1.6	0.8	1.4	1.1	2.7	3.4

*PF, F DIFFERENCE EXCEEDS DIFFERENCE BETWEEN TWO SETS OF PF MEASUREMENTS

a — NO FILTER SPECIFICATION

b — FAILS TO MEET FILTER SPECIFICATION

BOXES INDICATE CHARACTERISTICS WHERE DIFFERENCES BETWEEN PF OR F AND ALL PREVIOUS SCANNERS (1,2,3) WERE GREATER THAN DIFFERENCES BETWEEN TWO SETS OF PF MEASUREMENTS.

Band 4 (800 to 1100 nm) Spectral Characterization by Means and Standard Deviations: MSS-1, 2, 3, PF and F

	SCANNER	BAND EDGE (nm) LOWER	BAND EDGE (nm) UPPER	WIDTH* (nm)	SLOPE INTERVAL (nm) LOWER	SLOPE INTERVAL (nm) UPPER[a]	SPECTRAL FLATNESS POSITIVE	SPECTRAL FLATNESS NEGATIVE
MEANS	PF	808	1023	215	23	110	29.8[b]	53.7[b]
	F	809	1036	227	23	101	23.0[b]	50.8[b]
	1	810	989	179	22	120	46.0[b]	74.5[b]
	2	807	990	183	23	118	45.4[b]	75.9[b]
	3	812[b]	979	167	24	108	56.4[b]	80.7[b]
STANDARD DEVIATIONS	PF	0.5	14.9	14.6	0.2	9.2	6.8	6.8*
	F	0.1	12.5	12.5	0.4	9.9	6.0	4.1*
	1	1.2	3.5	3.7	2.1	7.2	2.3	3.1
	2	2.0	4.0	5.3	0.8	2.7	4.7	1.1
	3	0.9	7.9	7.6	1.0	3.0	11.7	2.4

*PF, F DIFFERENCE EXCEEDS DIFFERENCE BETWEEN TWO SETS OF PF MEASUREMENTS
BOXES INDICATE CHARACTERISTICS WHERE DIFFERENCES BETWEEN PF OR F AND ALL PREVIOUS SCANNERS (1,2,3) WERE GREATER THAN DIFFERENCES BETWEEN TWO SETS OF PF MEASUREMENTS.
a — NO FILTER SPECIFICATION
b — FAILS TO MEET FILTER SPECIFICATION

Simulated MSS Band Mean Outputs to Soybean and Soil Targets: MSS-1, 2, 3, PF and F

TARGET	SENSOR SYSTEM	MEANS[a] (DIGITAL MSS COUNTS) BAND 1[b]	BAND 2[b]	BAND 3[b]	BAND 4[b]
SOYBEANS	LS4-PF	19.36	14.89 (14.76)[c]	80.82*	45.80
	LS4-F	19.25	14.72	82.81*	45.39
	LS1	19.46 (19.55)[c]	15.43	76.95	47.14
	LS2	19.58	16.24 (16.13)[c]	78.58	47.24
	LS3	19.77	15.36	73.93	47.55
SOIL	LS4-PF	28.39	34.75[d]	41.02	18.61
	LS4-F	28.39	34.75	41.05	18.48
	LS1	28.32[d]	34.73	41.04	19.02
	LS2	28.34	34.66[d]	41.05	19.07
	LS3	28.33	34.66	41.10	19.15

a — AT SATELLITE SENSOR RESPONSE, NADIR—LOOKING FOR 40° SOLAR ZENITH ANGLE AND 20 km VISIBILITY; UNITS ARE SIMULATED NON-TRUNCATED MSS DIGITAL COUNTS WITH MAXIMUM SPECIFIED RADIANCE SCALED TO 127.99 FOR BANDS 1, 2, 3 AND 63.99 FOR BAND 4.

b — LANDSAT-4 BANDS 1, 2, 3 AND 4 CORRESPOND TO BANDS 4, 5, 6 AND 7, RESPECTIVELY ON PREVIOUS LANDSATS.

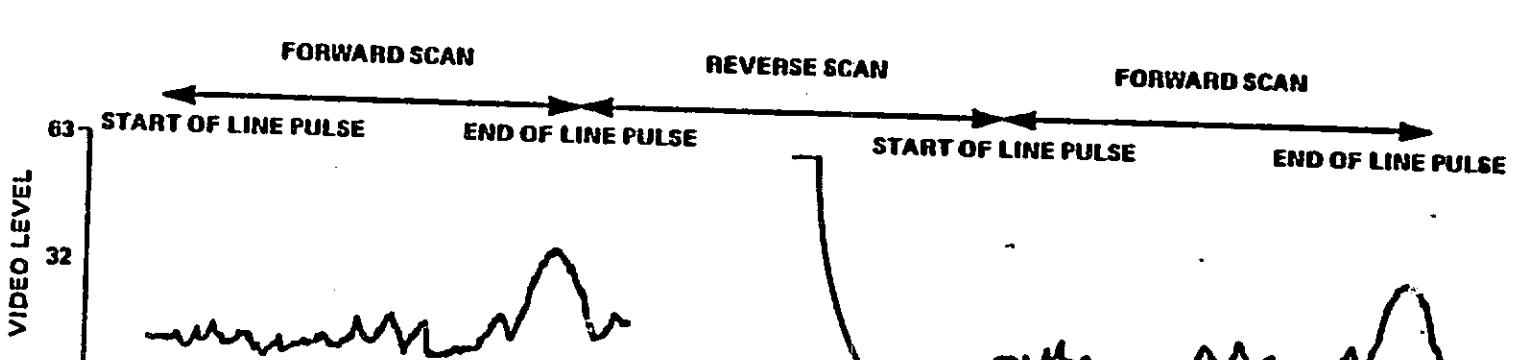
c — MEAN IN PARENTHESES IS WITH OUTLIER CHANNEL EXCLUDED

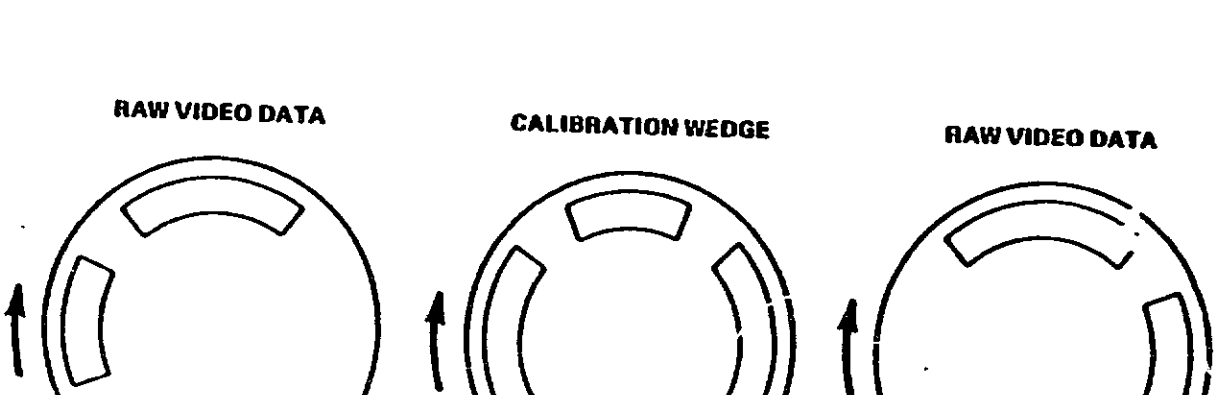
d — EXCLUSION OF OUTLIER DID NOT CHANGE BAND MEAN

*PF, F DIFFERENCE EXCEEDS: (1) DIFFERENCE BETWEEN SIMULATIONS RUN WITH EACH SET OF PF MEASUREMENTS SEPARATELY AND (2) 0.30 DIGITAL COUNTS

BOXES INDICATE BANDS WHERE OUTPUT DIFFERENCES BETWEEN PF OR F AND ALL PREVIOUS SCANNERS (1,2,3) EXCEED: (1) AND (2) AS ABOVE.

MSS Data Acquisition





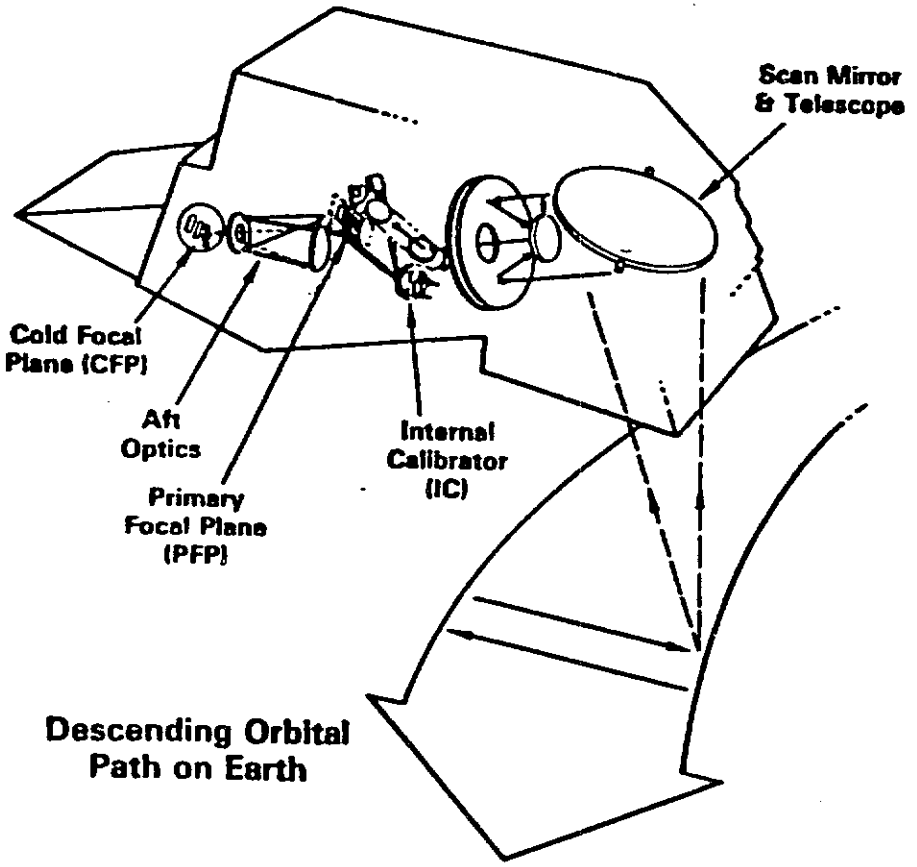
NOTE: CALIBRATION DATA ARE ACQUIRED IN ALTERNATE MIRPOR SWEEPS.

LANDSAT-D' MSS COHERENT NOISE

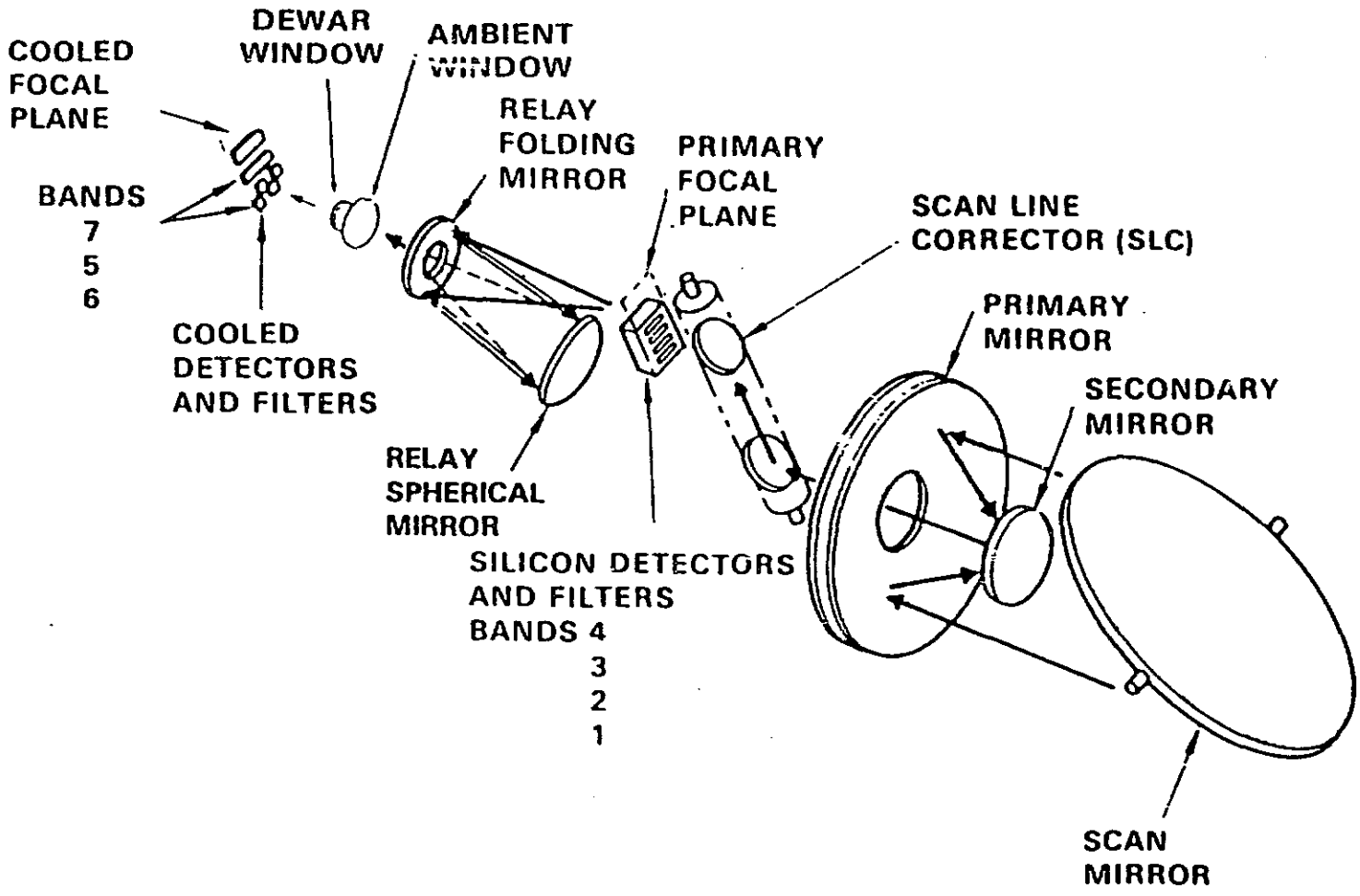
Before Adding RC Filters			After Adding RC Filters		
Component No.	Frequency (KHz)	Adjusted Peak Value	Component No.	Adjusted Peak Value	Filtered Value Baseline Value
26.5	16.24	0.056	30.0	0.058	1.04
(158.6	97.20	0.013)	154.5	0.044	(3.38)*
211.5	129.6	0.052	215.0	0.056	1.08
343.5	210.5	0.061	339.6	0.039	0.64
370.0	226.8	0.357	369.6	0.230	0.64
396.4	242.9	0.258	399.8	0.227	0.88
528.6	323.9	0.036	524.4	0.042	1.17
(581.4	356.3	0.016)	584.6	0.107	(6.70)*
713.4	437.2	0.059	709.0	0.051	0.86
740.3	453.7	0.074	739.2	0.054	0.73
766.4	469.7	0.136	769.4	0.113	0.83
898.4	550.6	0.062	894.0	0.044	0.71
951.3	583.0	0.080	954.0	0.069	0.86
1136.3	696.4	0.097	1139.0	0.069	0.71
1267.6	776.9	0.057	1263.5	0.045	0.79
1321.3	809.8	0.074	1324.0	0.067	0.90
2035.3	1247.4	0.065	2033.0	0.031	0.48

*low baseline value

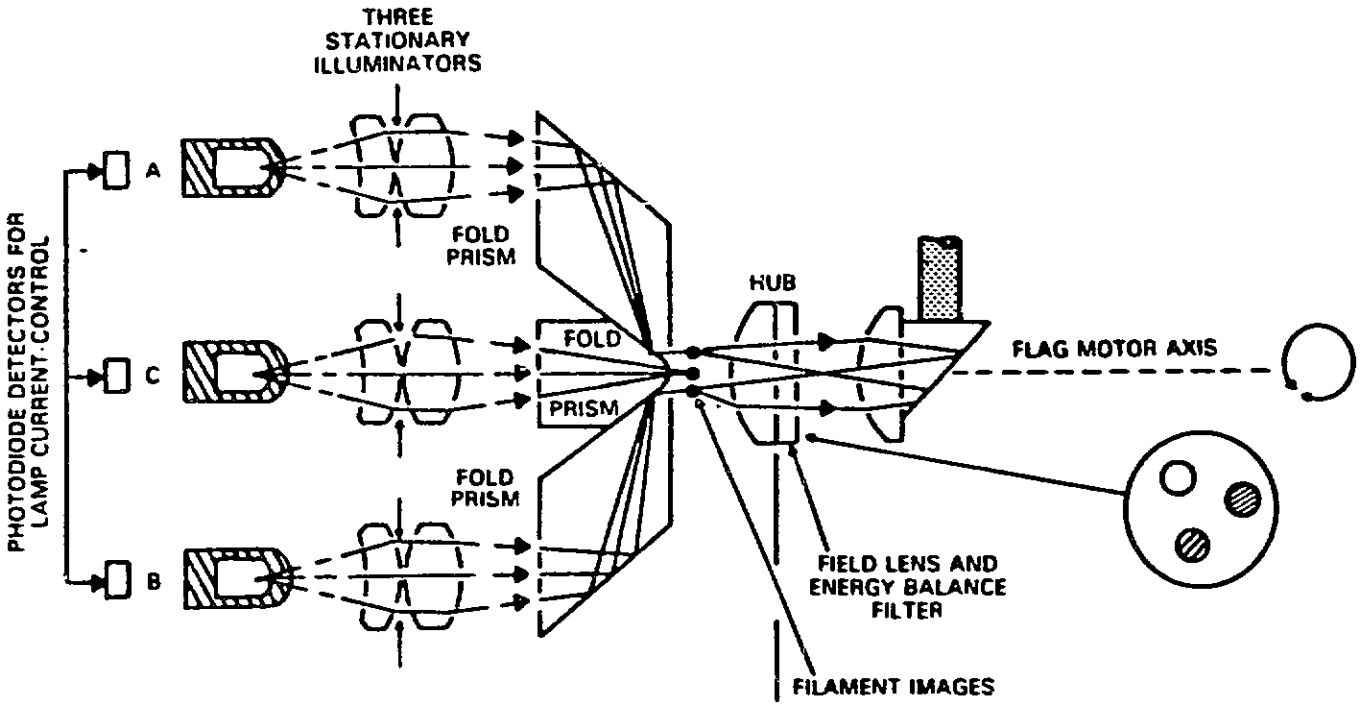
Landsat-4 Thematic Mapper (TM) Optical Path



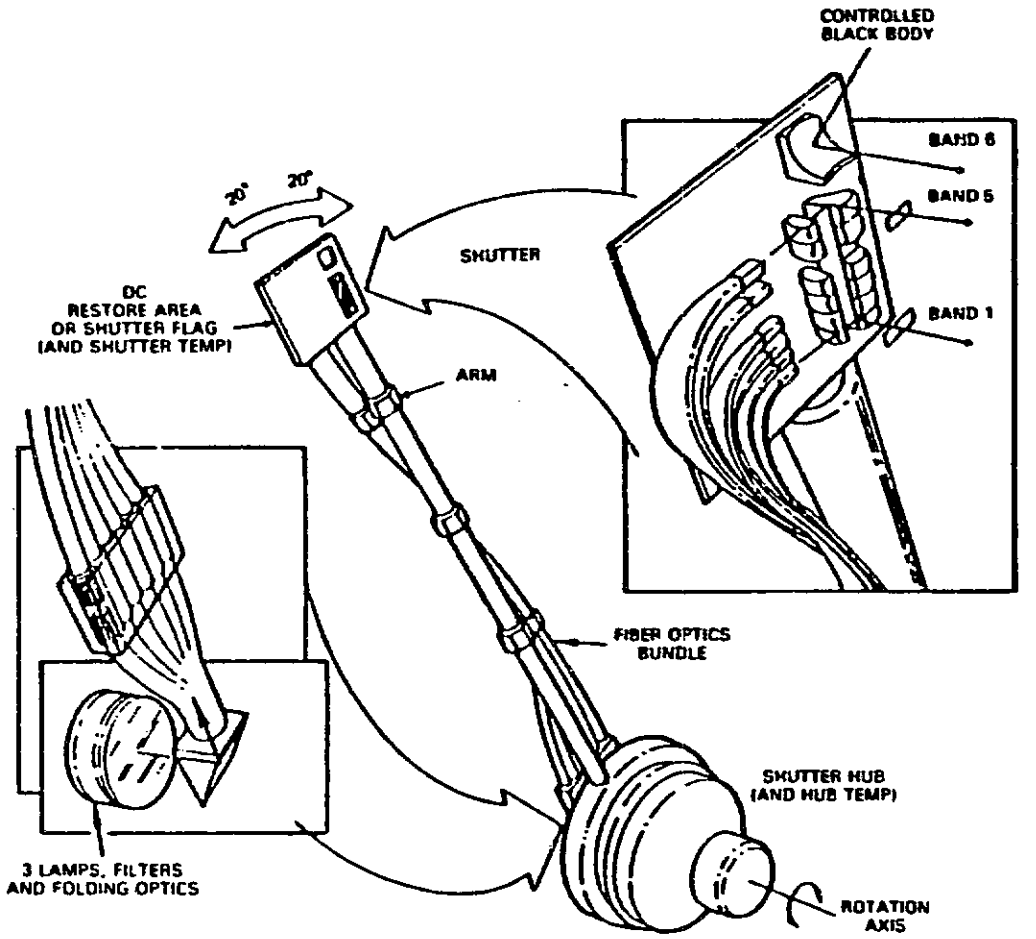
Thematic Mapper Optical System (Modified Hughes Schematic).



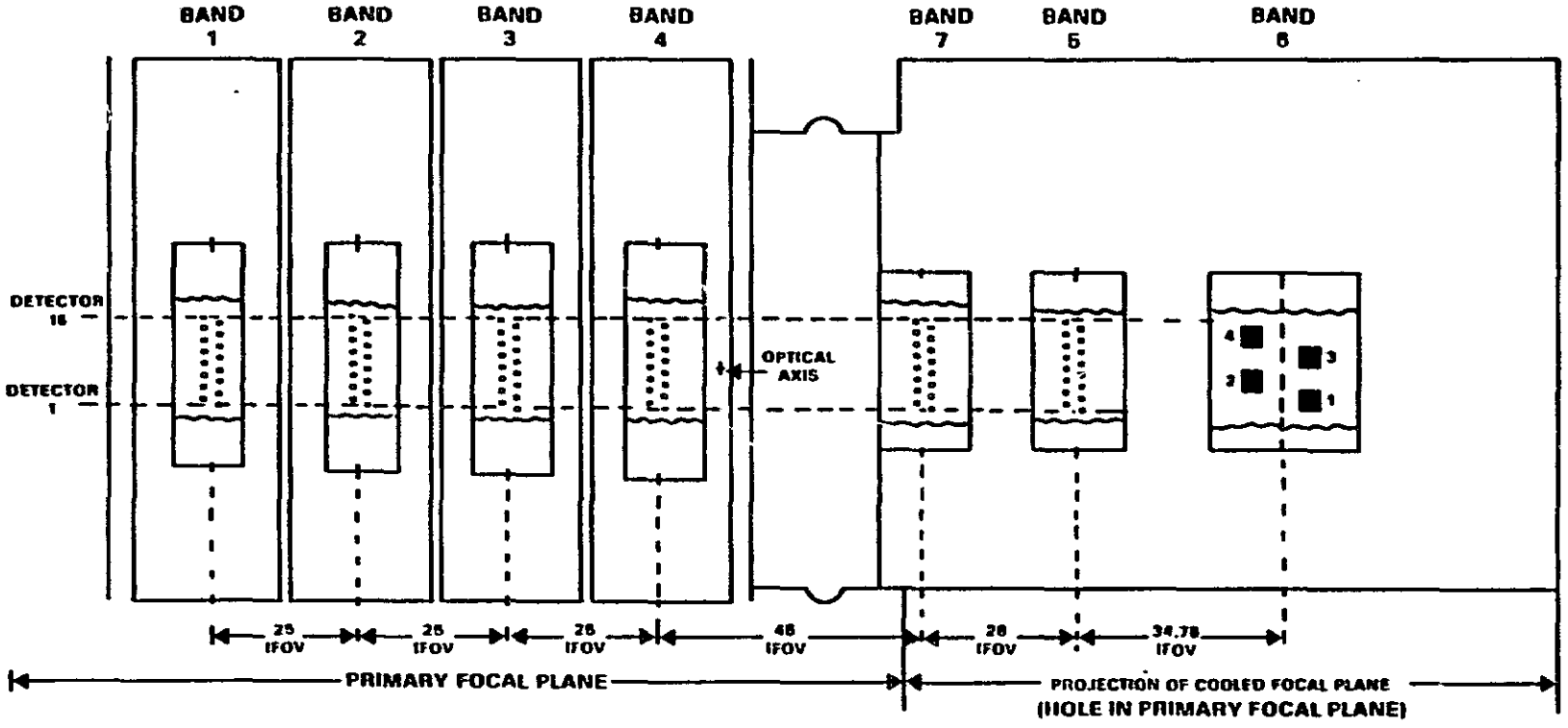
LANDSAT-4 THEMATIC MAPPER INTERNAL CALIBRATION
THREE LAMP OPTICS



LANDSAT-4 THEMATIC MAPPER INTERNAL CALIBRATION TRANSFER OPTICS



Landsat-4 TM/PF Focal Planes



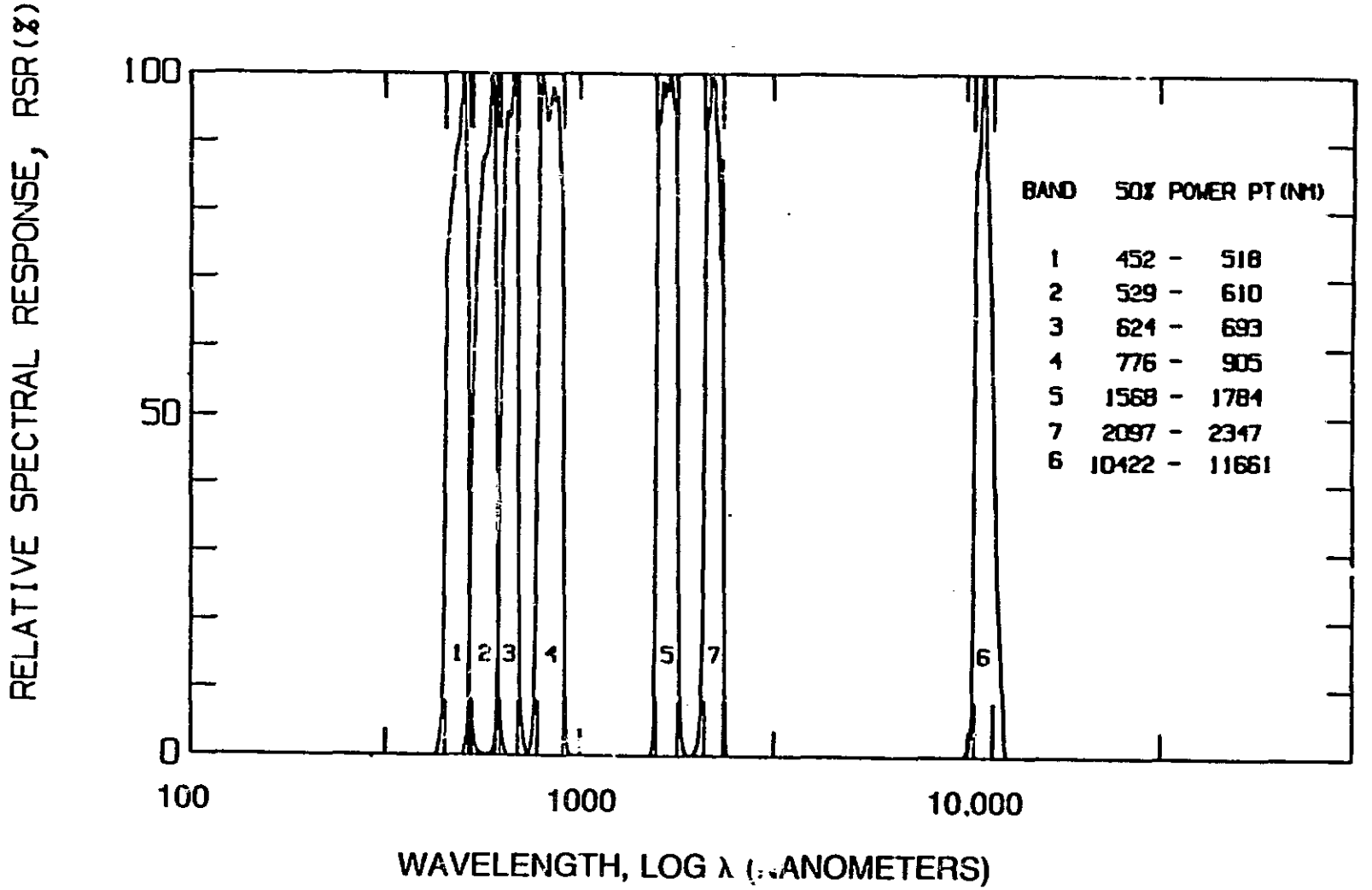
Landsat-4 TM/PF Spectral Characteristics

OBSERVED BAND LOCATIONS AND DIFFERENCES FROM SPECIFICATION

Band	Lower Band Edge at Half Maximum (nm)	Upper Band Edge at Half Maximum (nm)	Bandwidth at Half Maximum (nm)
1	452	518	66
2	529	610	81
3	624	693	69
4	776	905	129
5	1568	1784*	216
7	2097	2347	250
6 (μm)	10.422	11.661*	1.239

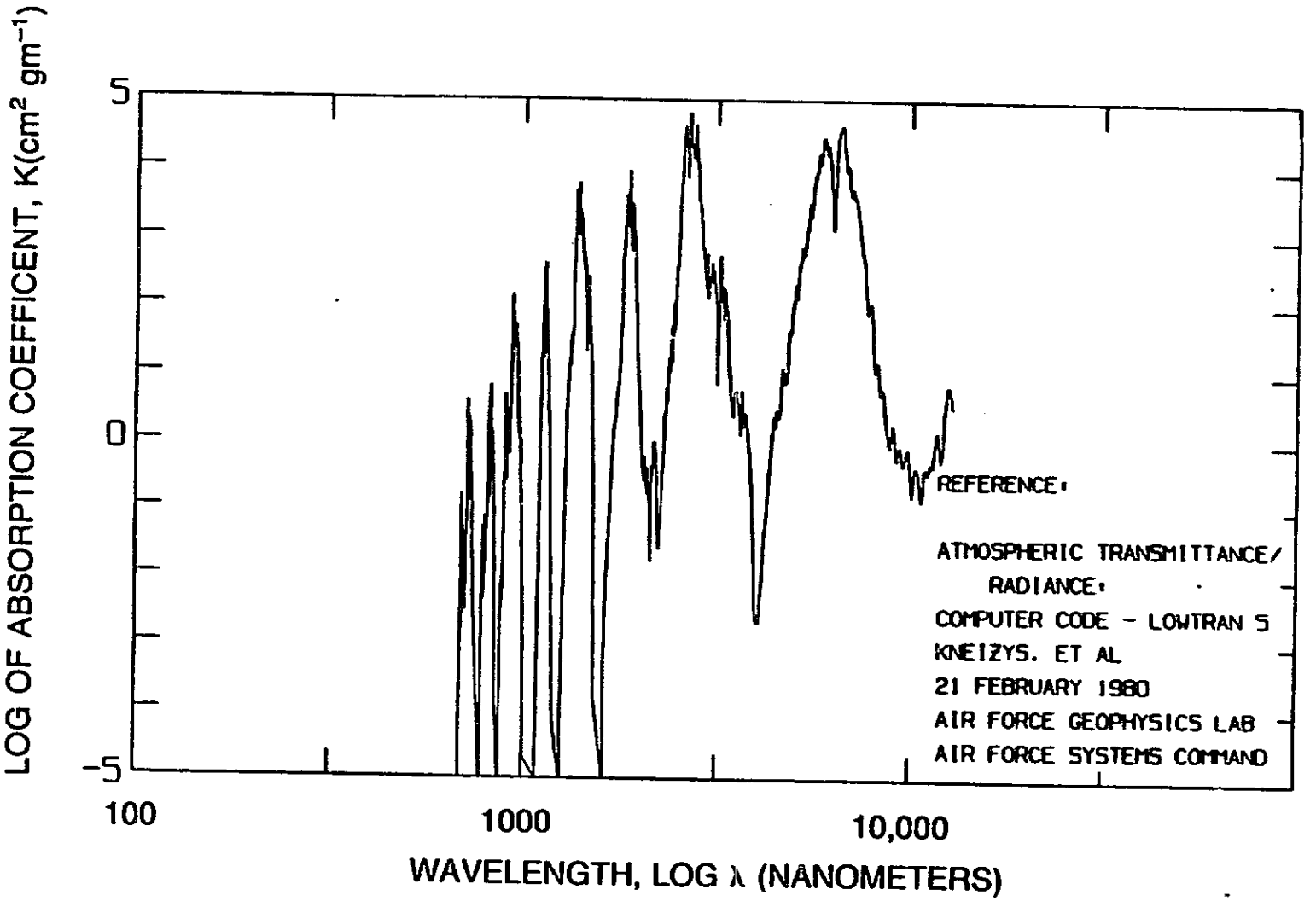
*Out of Specification Characteristics

TM Bands
Landsat-4 Thematic Mapper

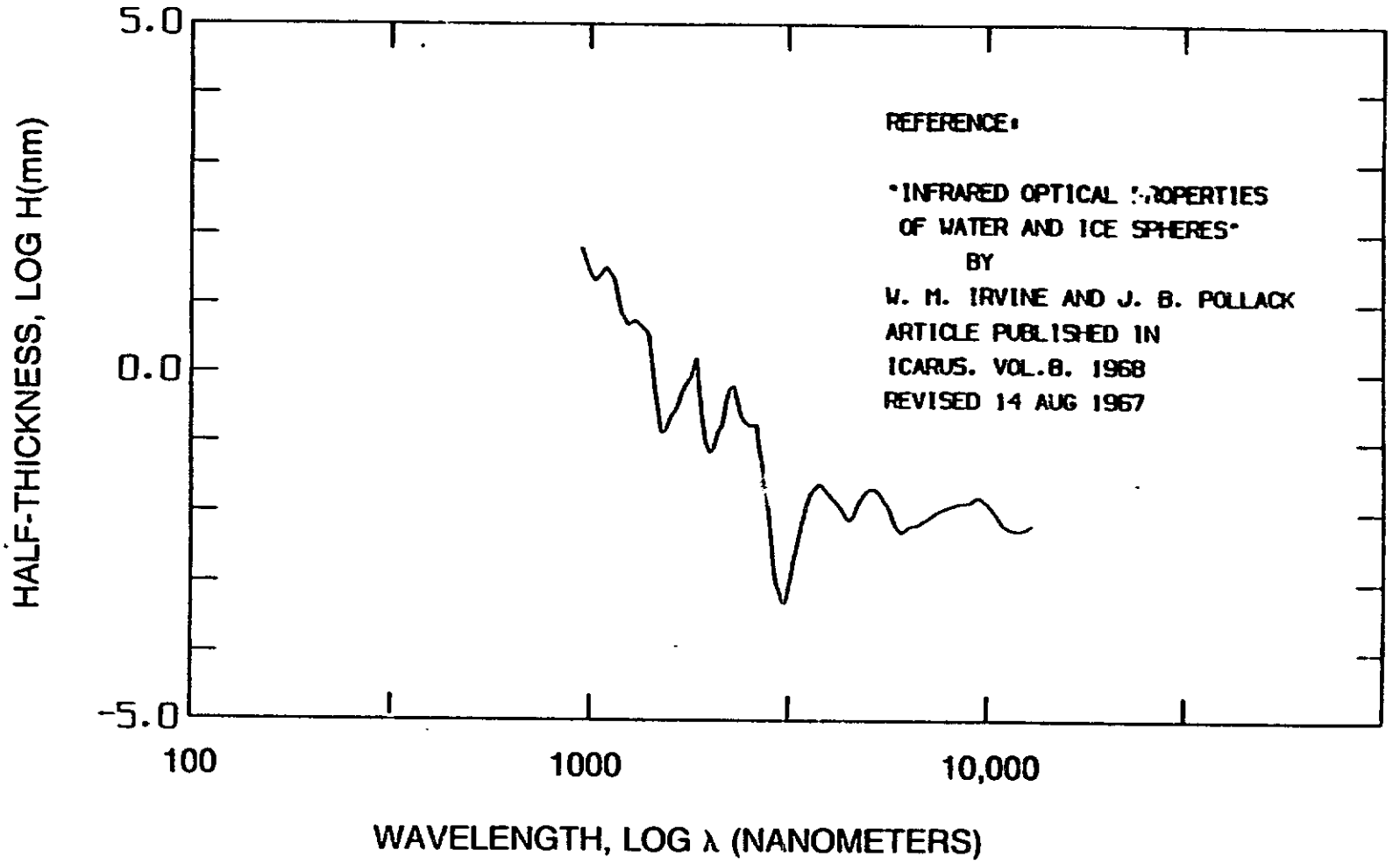


SEPT 83

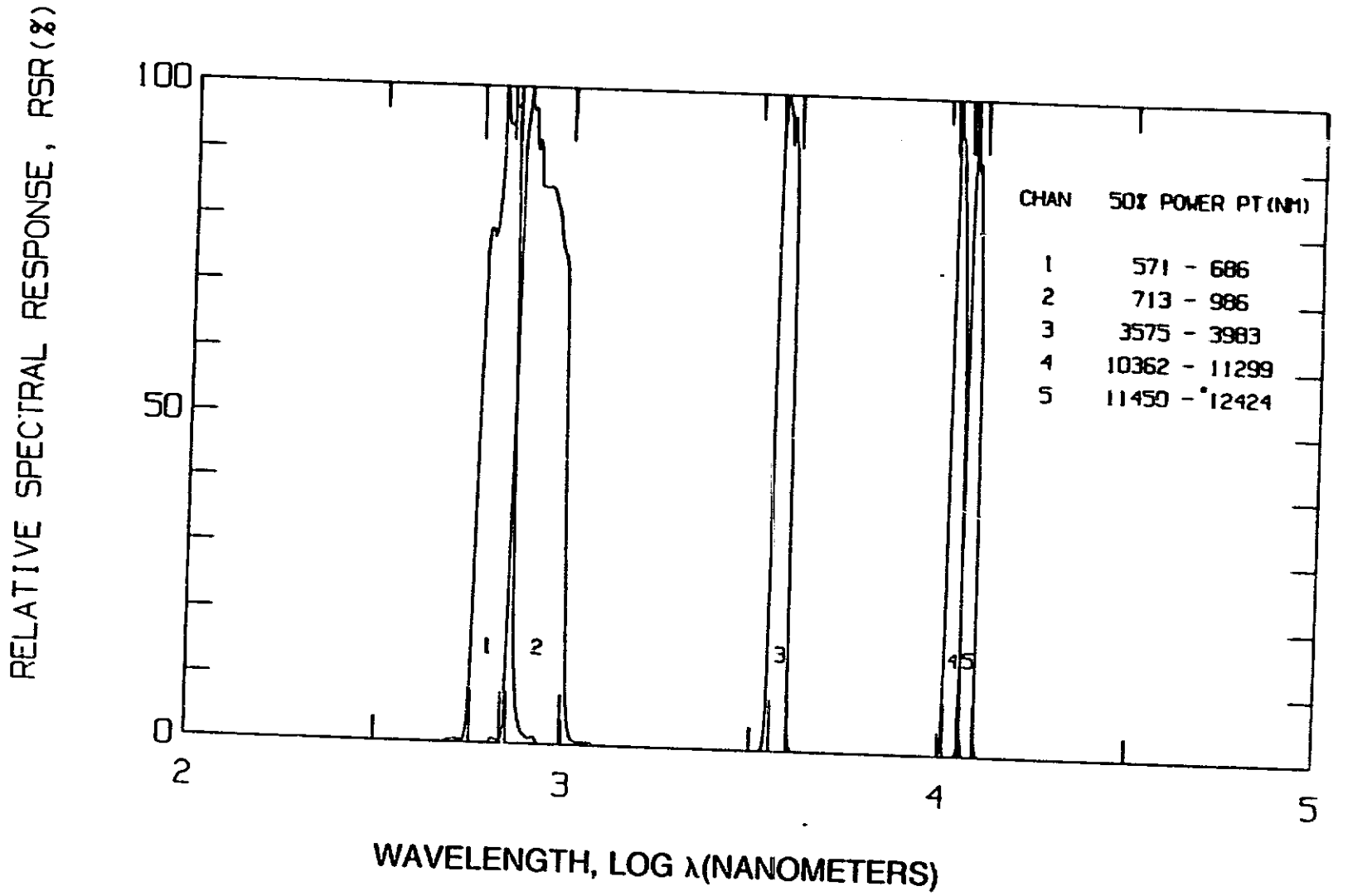
Water Vapor Absorption Coefficients



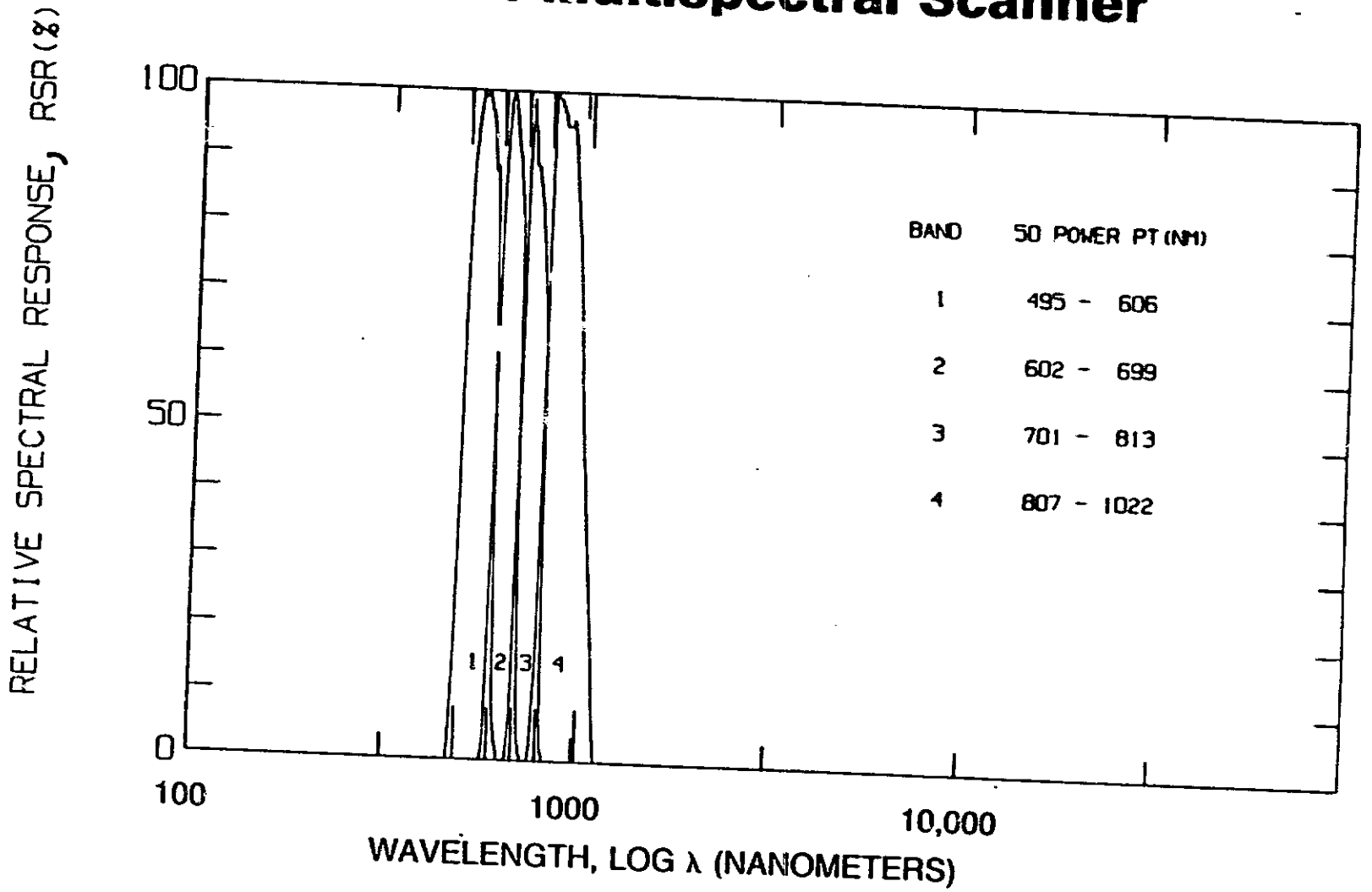
Ice (Solid Water) Half-Thickness



AVHRR Bands
NOAA-7 Advanced Very High Resolution Radiometer



MSS Bands
Landsat-4 Multispectral Scanner



Band 5 Characteristics on Landsat TM

SPECTRAL PARAMETER	SPECIFICATION	PROTOFLIGHT	FLIGHT
LOWER BAND EDGE (nm)	1550 ± 20	1568	1567
UPPER BAND EDGE (nm)	1750 ± 20	1784 *	1784 *
LOWER BAND EDGE SLOPE (nm) 5% TO 75%	50 (MAX)	32	33
UPPER BAND EDGE SLOPE (nm) 75% TO 5%	50 (MAX)	42	43
FLATNESS (%)	75 (MIN)	84	84

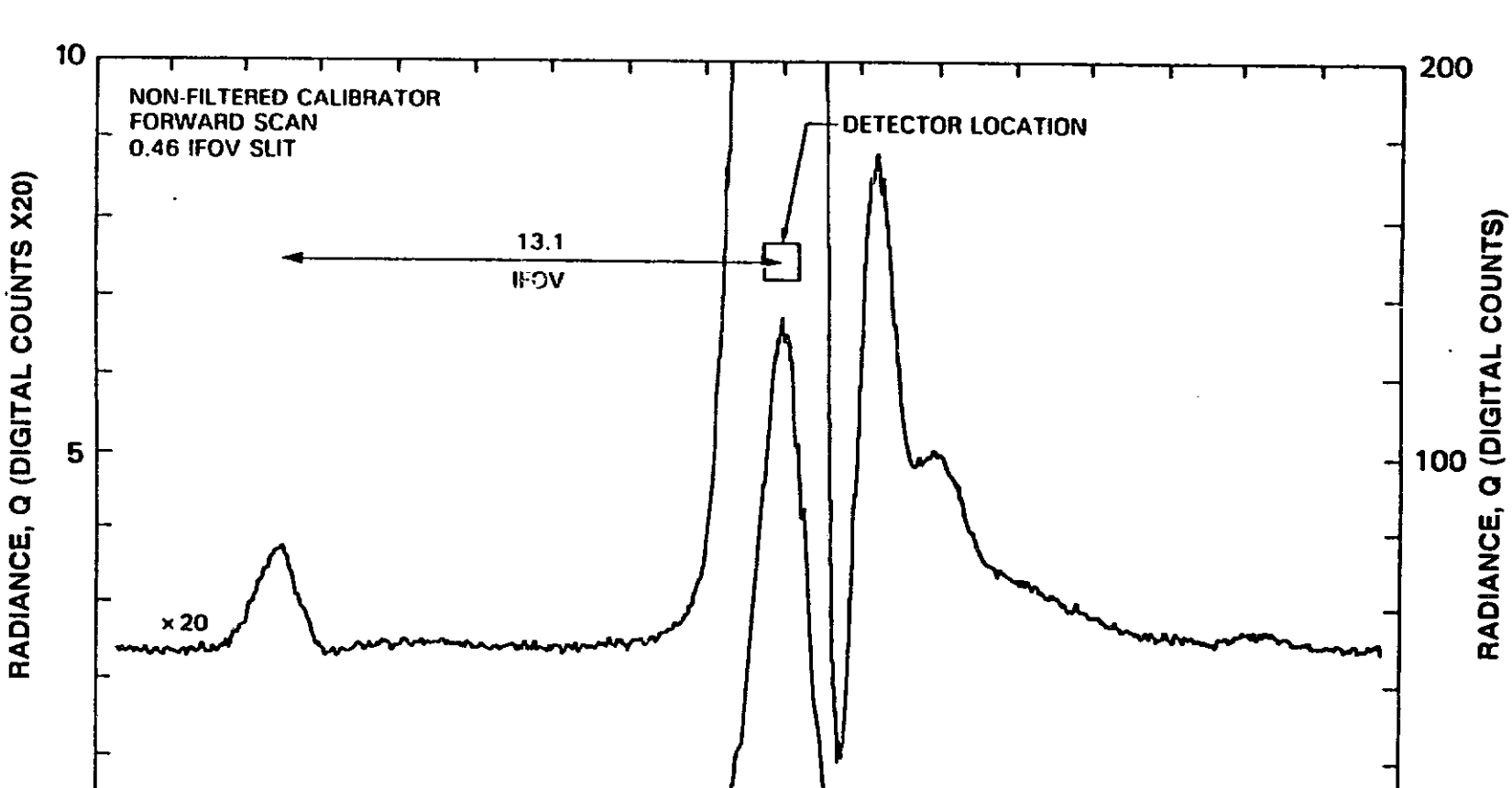
* OUT OF SPECIFICATION

Band 6 Characteristics on Landsat TM

SPECTRAL PARAMETER	SPECIFICATION	PROTOFLIGHT	FLIGHT
LOWER BAND EDGE (μm)	10.4 ± 0.1	10.42	10.45
UPPER BAND EDGE (μm)	12.5 ± 0.1	[11.66] •	12.43
LOWER BAND EDGE SLOPE (μm) 5% TO 75%	0.3 (MAX)	0.25	[0.34] •
UPPER BAND EDGE SLOPE (μm) 75% TO 5%	0.3 (MAX)	[1.01] •	0.26
FLATNESS (%)	75	[67] •	78

•OUT OF SPECIFICATION

Light Leak in Band 1
Landsat-D′ TM/F Line Spread Function



TM Integrated Out-of-Band Responses in Relation to Specifications

OUT-OF-BAND RESPONSES

BAND	CALCULATED FROM FILTER TRANSMISSION (%)	SPECIFICATION
1	1.64%	5 (MAX)
2	1.30%	5 (MAX)
3	2.87%	5 (MAX)
4	0.78%*	5 (MAX)
5	0.79%	5 (MAX)
7	1.25%	5 (MAX)
6	0.81%*	5 (MAX)

*DETECTOR RSR AND SOLAR IRRADIANCE CONSIDERED IN CALCULATION

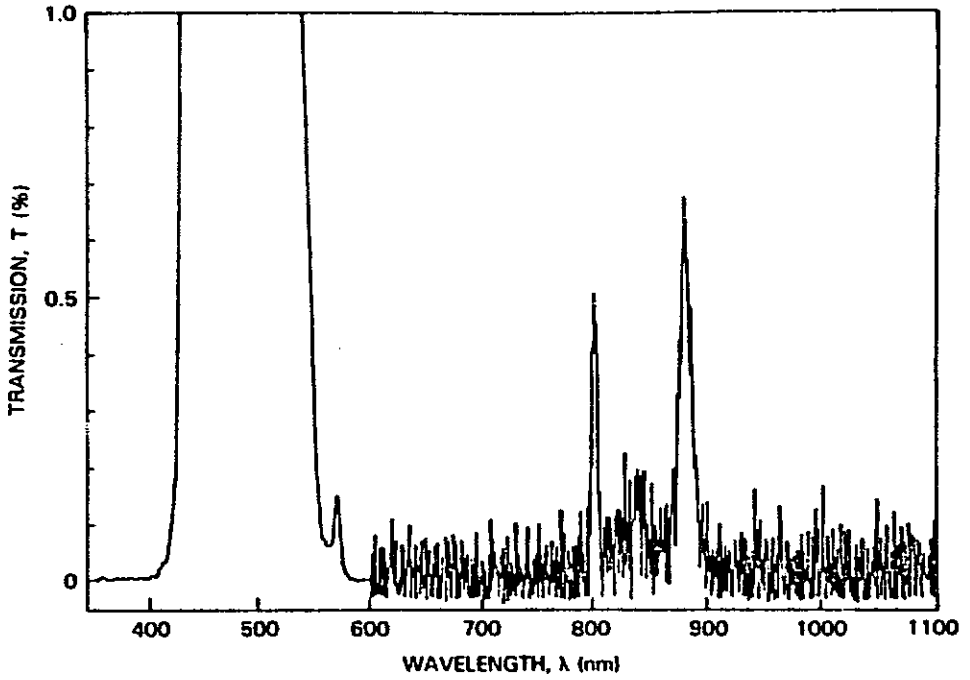
TM/F Peak Responses to Filtered Slit Light Source

BAND IN WHICH OUTPUT MEASURED	SOURCE LIGHT FILTER (BAND #)			
	1	2	3	4
1	120.0	6.6	0.0	1.2
2	2.7	82.0	1.2	0.2
3	<0.2	1.5	105.0	0.2
4	~0.2	~0.2	<0.1	115.0

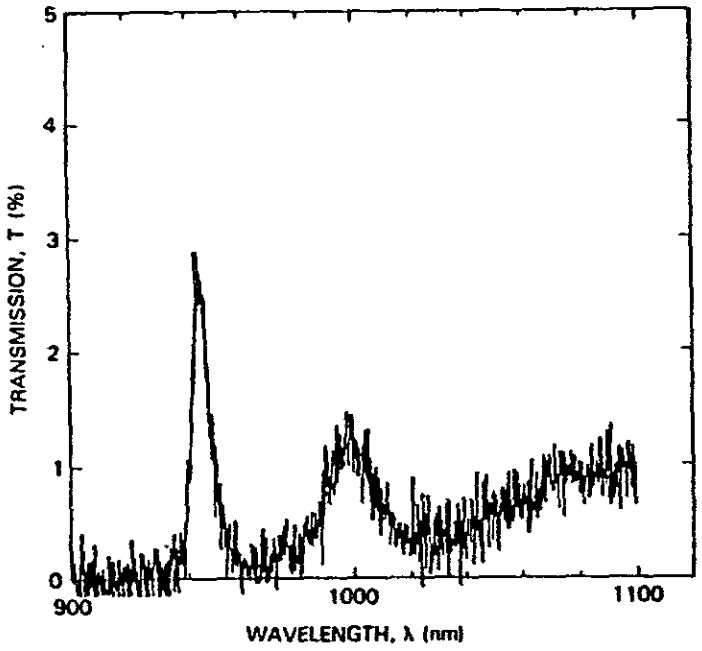
Principal TM/F Primary Focal Plane Light Leaks (Magnitudes > 0.2 MUX with MTF Slit Source)

HALF-BAND	LEAK POSITION RELATIVE TO CENTRAL MAX (IFOV'S)	LEAK AMPLITUDE (MUX)	LEAK AMPLITUDE (% PEAK RESPONSE)
1–ODD	−13.1	1.3	1.10
1 – EVEN	−15.6	0.45	0.37
	14.7	0.20	0.16
2 – ODD	−12.0	0.20	0.18
2 – EVEN	–	–	–
3 – ODD	−12.0	0.30	0.27
	12.3	0.90	0.80
3 – EVEN	−14.8	0.25	0.21
	9.7	0.30	0.26
4 – ODD	−11.7	0.30	0.24
	12.6	0.20	0.16
4 – EVEN	−14.0	0.60	0.53
	−7.4	0.30	0.26
	10.1	0.20	0.18

Band 1 Out-of-Band Filter Transmission Landsat-4 TM



Out of-Band Filter Transmission Band 3 on Landsat TM



Radiometric Characterization of Sensors

Absolute Accuracy
L-4 TM/PF
Pre-Launch Calibration

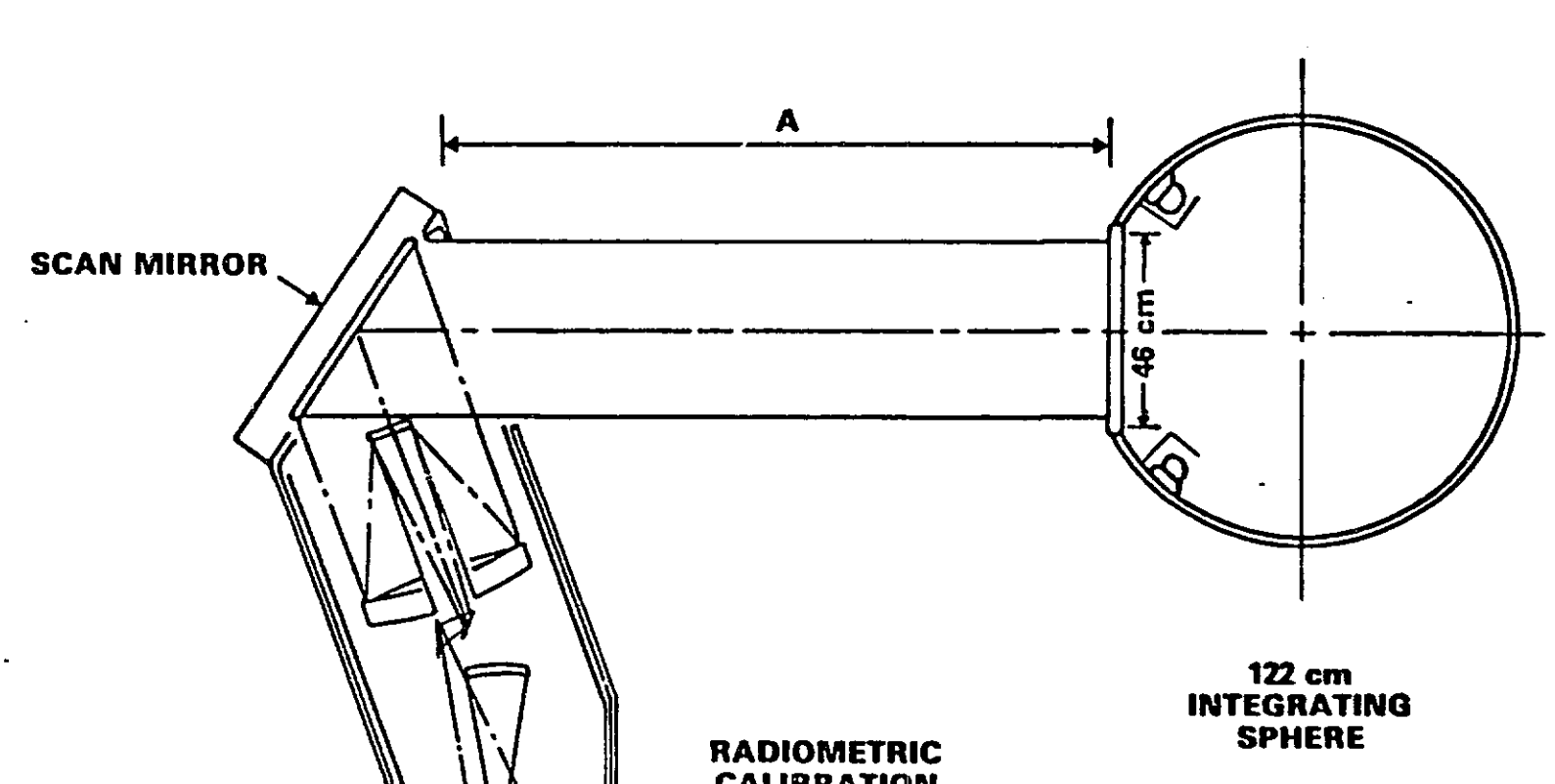
96 Reflective Channels (Bands 1,2,3,4,5 and 7)

- Gains and Offsets from Integrating Sphere
- Radiances and Offsets from Integrating Sphere

4 Emissive Channels (B and 6, Thermal)

- Gain and Offset from External Calibrator at Fixed Temperature of Cold Focal Phase
- Radiance of 3 Internal Black Body Temperatures

PLACEMENT OF THE TM AND THE IS(122) ILLUSTRATING THE NEED FOR GOOD ALIGNMENT WHEN THE DISTANCE OF A IS LARGE



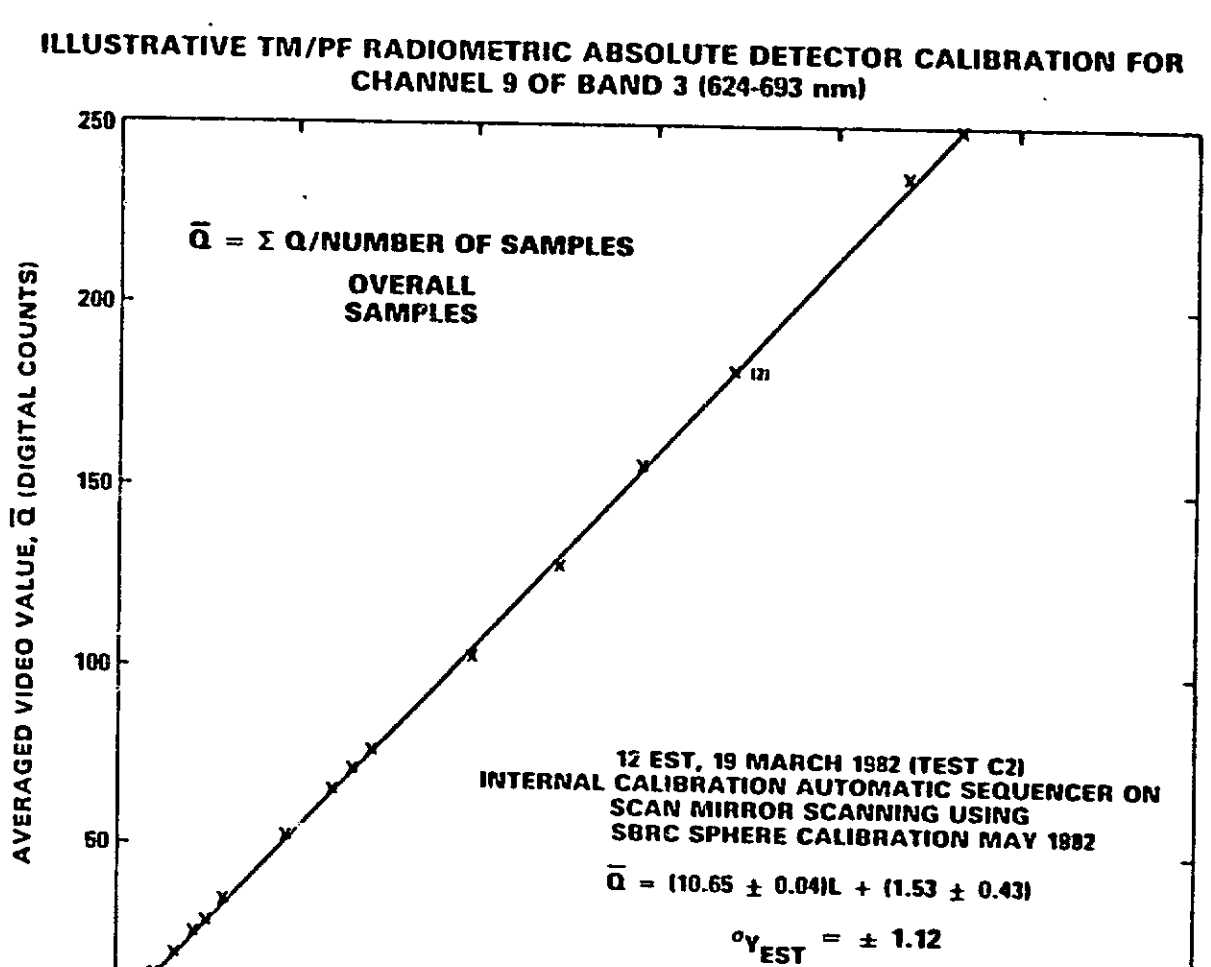
122cm Integrating Sphere Lamp Configurations by Radiance Level Landsat TM

TEST SEQUENCE I			TEST SEQUENCE II		
SEQUENCE NUMBER[b]	LAMP CONFIGURATION[a]	NOMINAL LAMP POWER (W)	SEQUENCE NUMBER[b]	LAMP CONFIGURATION[a]	NOMINAL LAMP POWER (W)
1(1)	624[c]	1500	1(6)	224	700
2(2)	524	1300	2(7)	214	600
3(3)	424	1100	3(9)	114	400
4(4)	324	900	4(13)	014	200
5(5)	224	700	5(17)	004[c]	100
6(8)	124	500	6(18)	003	75
7(10)	024[c]	300	7(19)	002	50
8(11)	023	275	(20)	001	25
9(12)	022	250			
10(14)	012	150			
11(15)	011	125			
12(16)	010	100			

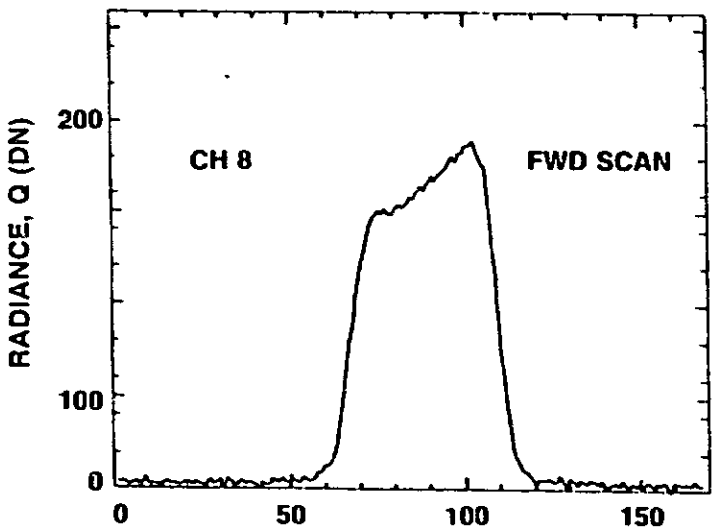
[a]ABC WHERE A = NUMBER OF 200-W LAMPS, B = NUMBER OF 100-W LAMPS, AND C = NUMBER OF 25-W LAMPS. LAMPS 1 THROUGH 6 ARE 200 W EACH, 7 AND 8 ARE 100 W EACH, AND 9 THROUGH 12 ARE 25 W EACH.

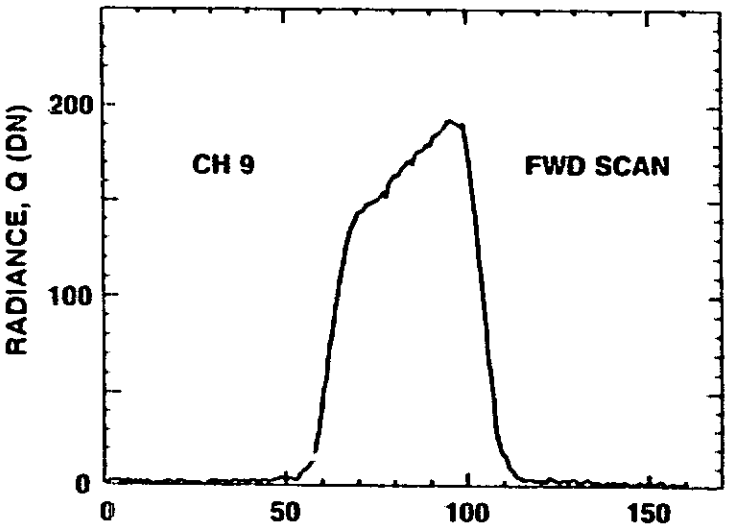
[b]NUMBER IN PARENTHESES IS RANK OF SEQUENCE LEVEL FROM 1 (BRIGHTEST) TO 20 (FAINTEST) FOR ALL 20 TEST LEVELS.

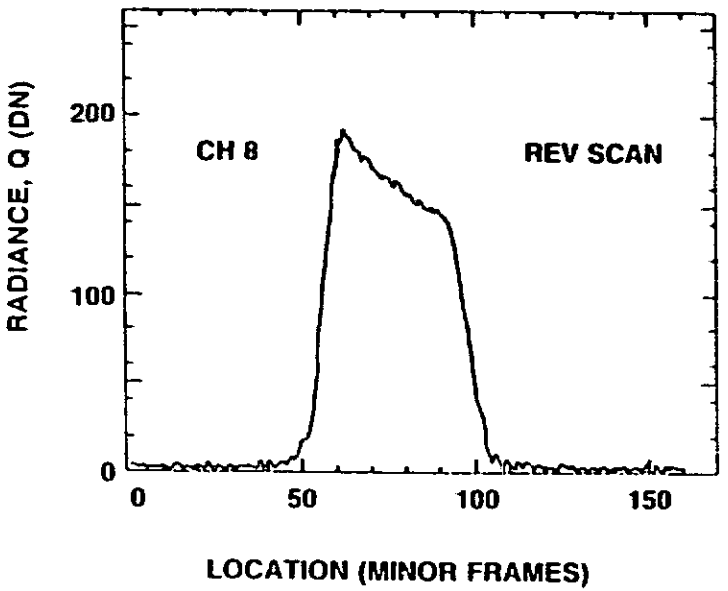
[c] MOST SYMETRIC DISTRIBUTION OF LIGHTS IN SPHERE


ILLUSTRATIVE TM/PF RADIOMETRIC ABSOLUTE DETECTOR CALIBRATION FOR CHANNEL 9 OF BAND 3 (624-693 nm)
$\bar{Q}$ = Σ Q/NUMBER OF SAMPLES
OVERALL SAMPLES
12 EST, 19 MARCH 1982 (TEST C2)
INTERNAL CALIBRATION AUTOMATIC SEQUENCER ON SCAN MIRROR SCANNING USING SBRC SPHERE CALIBRATION MAY 1982
$\bar{Q}$ = (10.65 ± 0.04)L + (1.53 ± 0.43)
$^{o}Y_{EST}$ = ± 1.12
AVERAGED VIDEO VALUE, $\bar{Q}$ (DIGITAL COUNTS)
250
200
150
100
50
0
5
10
15
20
25
30
INTEGRATING SPHERE SPECTRAL RADIANCE, Lλ
(MILLIWATTS PER SQUARE CENTIMETER PER STERADIAN PER MICROMETER)

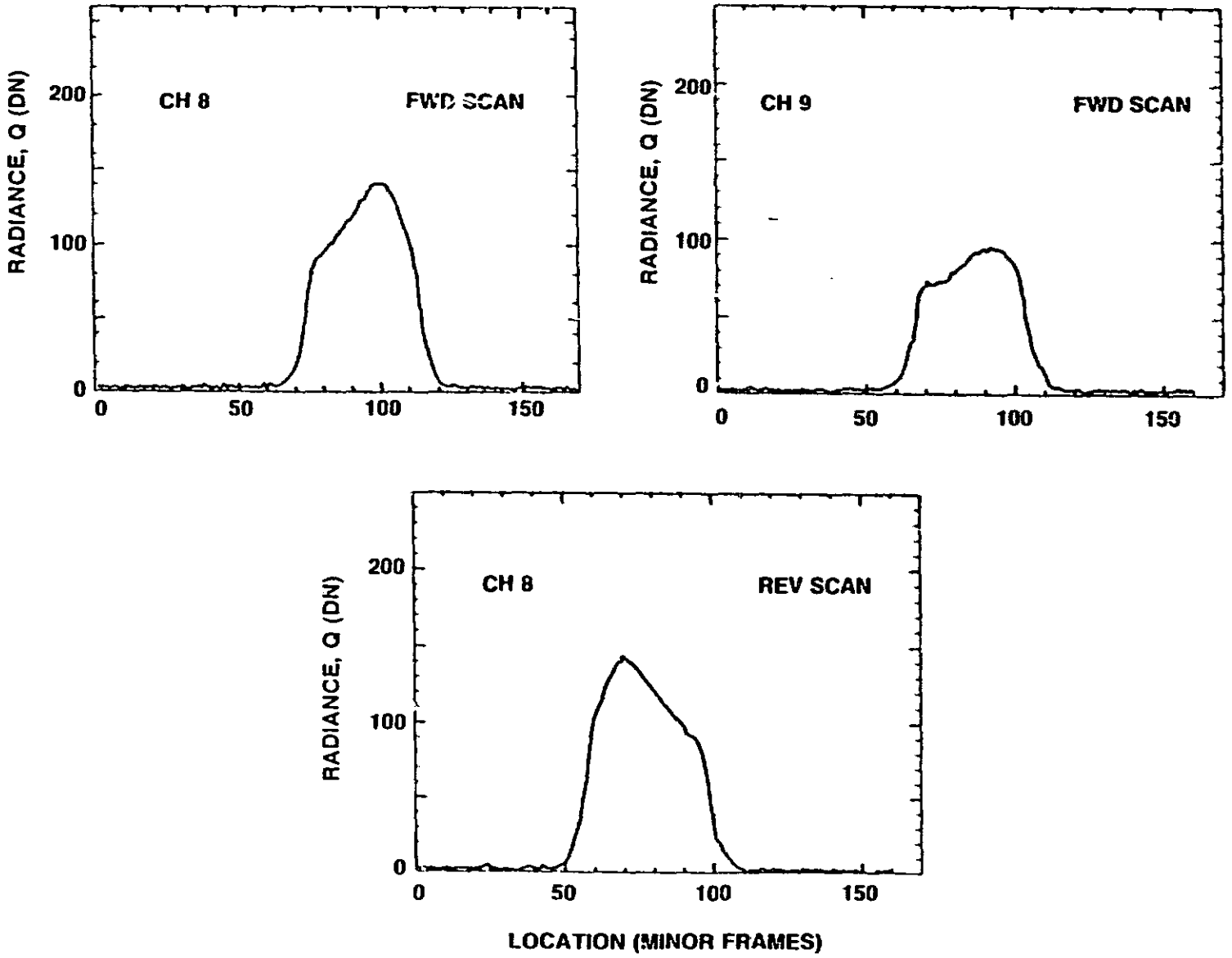
Band 1 Internal Calibrator Pulse Shapes
Landsat-4 TM/PF (9 Mar 82, Vacuum)



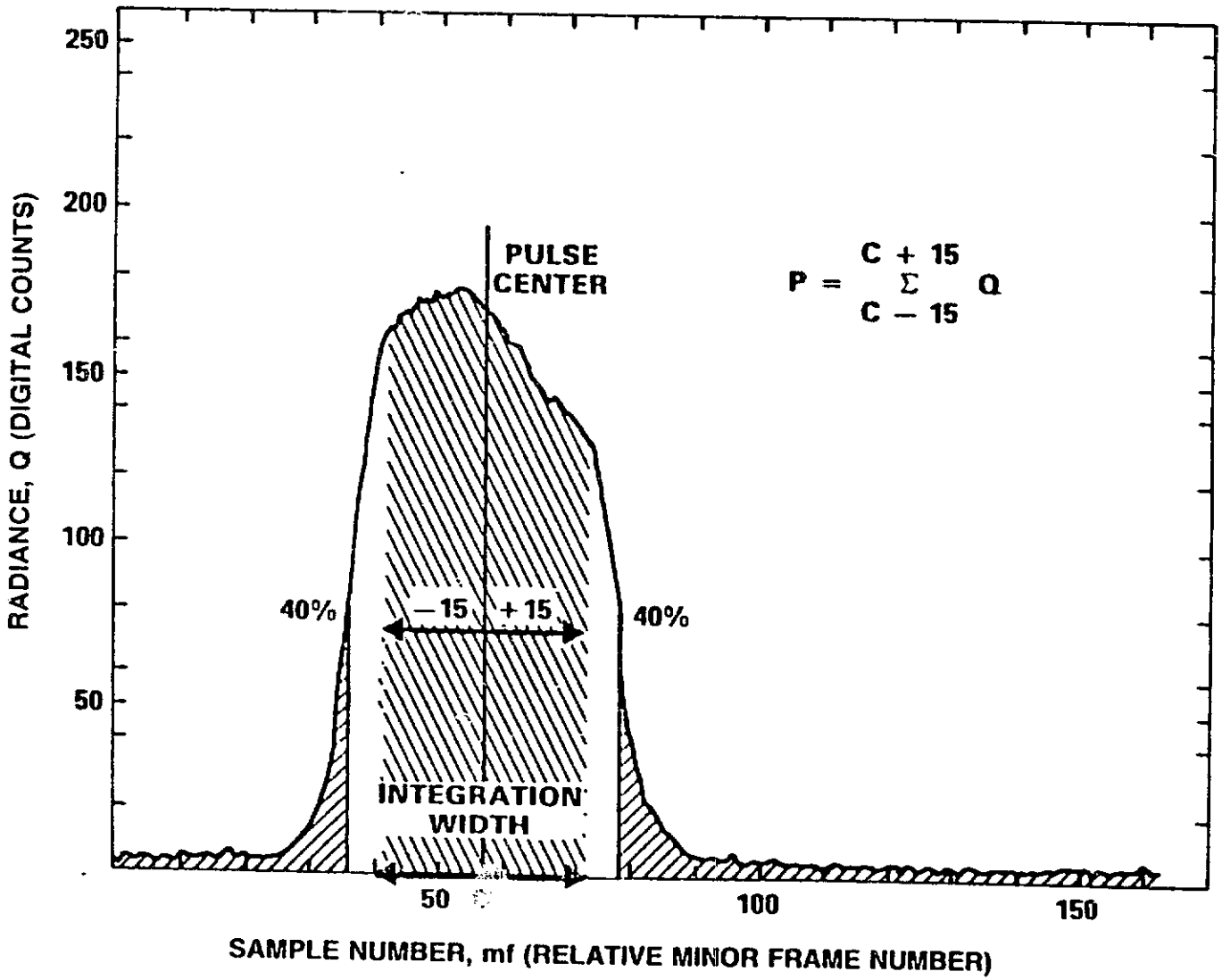




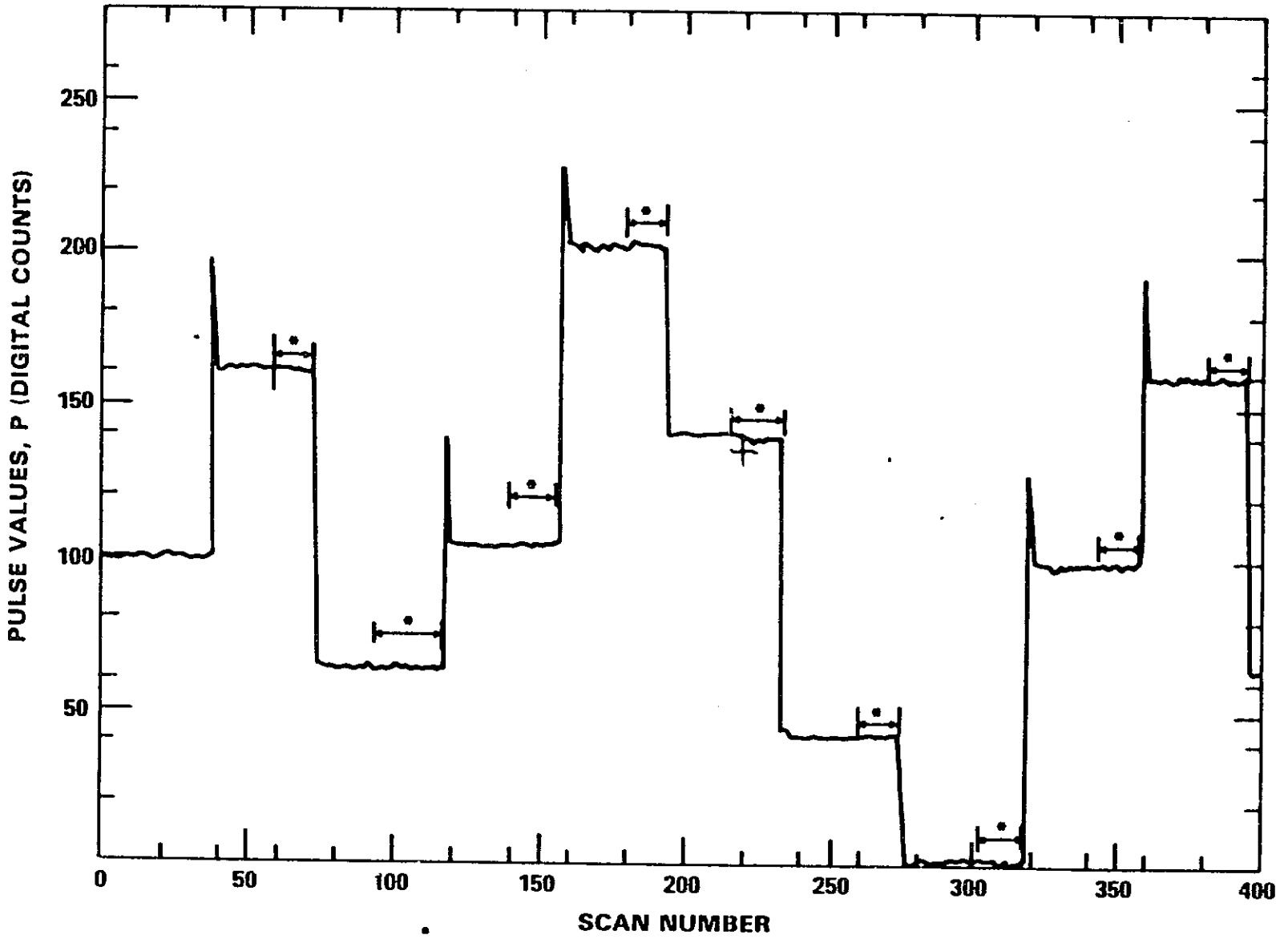
Band 5 Internal Calibrator Pulse Shapes
Landsat-4 TM/PF (9 Mar 82, Vacuum)



Radiometric Calibration – TM Landsat-4
"Hughes Algorithm"



POSTLAUNCH RADIOMETRIC CALIBRATION — TM LANDSAT-4
TM1 CHANNEL 9



* PULSE VALUES USED IN COMPUTING PULSE AVERAGE, $\bar{P}$, IN THE SCROUNGE SYSTEM.

Pre-Launch Absolute Radiometric Calibration of Landsat TM by Channel

$$Q \equiv G * L_\lambda + O$$

$$L_\lambda = \frac{Q - O}{G}$$

Q is Raw Radiance Value in Digital Numbers (DN)

O is Offset in DN

L_λ is Spectral Radiance in (m W cm^{-2} st^{-1} μm^{-1})

G is Gain in DN $\div$ (m W cm^{-2} st^{-1} μm^{-1})

POST-LAUNCH RADIOMETRIC CALIBRATION OF LANDSAT TM TO UNIFORM GAIN AND OFFSET FOR EACH CHANNEL WITHIN A BAND

BAND NUMBER	RMIN (AT Q = Ø DN)	RMAX (AT Q = 255 DN)
	$(MWCM^{-2}ST^{-1}\mu M^{-1})$	$(MWCM^{-2}ST^{-1}\mu M^{-1})$
1	-0.152	15.842
2	-0.284	30.817
3	-0.117	23.463
4	-0.151	22.432
5	-0.037	3.242
7	-0.015	1.700

N.B. RMIN IS THE LARGEST MINIMUM RADIANCE OBSERVED IN THE BAND.
RMAX IS THE SMALLEST MAXIMUM RADIANCE OBSERVED IN THE BAND.
KG = GAIN AFTER CALIBRATION = 255/(RMAX-RMIN)
KO = OFFSET AFTER CALIBRATION = 255 - (KG*RMAX)

RELATIVE RADIOMETRIC PRECISION

LANDSAT-4 THEMATIC MAPPER

PRE-LAUNCH SIGNAL-TO-NOISE RATIO (SNR)*

AT MINIMUM SATURATION LEVEL RADIANCE (Q = 243DN)

BAND	SPECIFIED SNR	OBSERVED SNR
1	85	152
2	170	281
3	143	235
4	240	341
5	75	180
7	45	175

*$SNR = \frac{Q}{\sigma_Q}$

Landsat-4 TM/PF Band 1 for Nominal Correction of In-Orbit Without Internal Calibration Pre-Launch Radiometric Calibration Parameters

CHAN	GAIN G	OFFSET O	SNR		SPECTRAL RADIANCE, L_λ			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	$Q = G*L_\lambda + O$
3	15.929	2.65	51	157	−0.166	15.089	15.842	$L_\lambda = \frac{Q-O}{G}$
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	Q IN DN (DIGITAL NUMBER)
6	15.734	2.51	51	160	−0.160	15.285	16.048	O IN DN
7	15.685	2.68	53	165	−0.165	15.327	16.092	L_λ IN $(MW CM^{-2} ST^{-1} \mu M^{-1})$
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	G IN DN $\div (MW CM^{-2} ST^{-1} \mu M^{-1})$
10	15.859	2.47	49	155	−0.156	15.166	15.923	
11	15.686	2.63	50	160	−0.161	15.330	16.095	$SNR = \frac{Q}{\sigma_Q}$
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	
SPECIFIED VALUE OF SNR			32	85				
SNR COMPUTED AT SPECTRAL RADIANCE			4.00	14.29	[AT 0 COUNTS]	[AT 243 COUNTS]	[AT 255 COUNTS]	

LSR ≡ Specified Lower Scene Radiance

MSL ≡ Specified Minimum Saturation Level Radiance

Landsat-4 TM/PF Band 1
Average, Standard Deviation and Coefficient of Variation for Radiometric Calibration Parameters

	GAIN G	OFFSET O	SNR		SPECTRAL RADIANCE, L_λ		
			LSR	MSL	MIN	MSL	MAX
			at L_λ = 4.00	at L_λ = 14.29	at Q = 000	at Q = 243	at Q = 255
MEAN:							
ODD CHAN	15.757	2.67	51	161	−0.170	15.252	16.014
EVEN CHAN	15.811	2.49	45	144	−0.158	15.212	15.971
ALL CHAN	15.784	2.58	48	152	−0.164	15.232	15.992
SIGMA:							
ODD CHAN	± 0.096	± 0.21	± 3	± 8	± 0.014	± 0.090	± 0.094
EVEN CHAN	± 0.071	± 0.10	± 4	± 13	± 0.006	± 0.068	± 0.071
ALL CHAN	± 0.086	± 0.18	± 5	± 13	± 0.012	± 0.079	± 0.083
COEF. VAR. (%):							
ODD CHAN	± 0.61 %	± 7.9 %	± 6 %	± 5 %	± 8.2 %	± 0.6 %	± 0.6 %
EVEN CHAN	± 0.45 %	± 4.0 %	± 29 %	± 9 %	± 3.8 %	± 0.4 %	± 0.4 %
ALL CHAN	± 0.54 %	± 7.0 %	± 10 %	± 9 %	± 7.3 %	± 0.5 %	± 0.5 %

Landsat-4 TM/PF Band 2 for Nominal Correction of In-Orbit Without Internal Calibration Pre-Launch 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	
2	8.117	2.33	24.	179.	−0.287	29.648	31.127	NOISY
3	8.014	2.41	53.	298.	−0.301	30.021	31.519	
4	8.144	2.44	40.	151.	−0.300	29.538	31.011	SLOW RESPO. SE (MTF)
5	8.198	2.43	59.	293.	−0.297	29.353	30.817	
6	8.183	2.54	61.	302.	−0.311	29.384	30.851	$Q \equiv G * L_\lambda + O$
7	8.057	2.32	51.	303.	−0.288	29.873	31.363	
8	8.079	2.62	51.	317.	−0.312	29.768	31.253	$L_\lambda = \frac{Q-O}{G}$
9	8.075	2.39	53.	308.	−0.296	28.797	31.283	
10	8.093	2.35	53.	298.	−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	8.185	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			L_λ= 3.00	L_λ= 29.12	[AT Q= 0]	[AT Q= 243]	[AT Q= 255]	
SPECIFIED VALUE OF SNR			35.	170.				

Landsat-4 TM/PF Band 2
Average, Standard Deviation and Coefficient of Variation for Radiometric Calibration Parameters

CHAN	GAIN G	OFFSET O	SNR		SPECTRAL RADIANCE, $L_\lambda = \frac{Q-O}{G}$		
			LSR (at L_λ = 3.00)	MSL (at L_λ = 29.12)	MIN (at Q = 000)	MSL (at Q = 243)	MAX (at Q = 255)
MEAN:							
ODD	8.104	2.45	55	295	−0.30	26.68	31.17
EVEN	8.094	2.43	50	267	−0.30	29.72	31.20
ALL	8.098	2.44	52	281	−0.30	29.20	31.18
SIGMA:							
ODD	± 0.080	± 0.22	± 3	± 10	± 0.02	± 0.30	± 0.31
EVEN	± 0.070	± 0.08	± 12	± 65	± 0.01	± 0.25	± 0.26
ALL	± 0.072	± 0.16	± 9	± 47	± 0.01	± 0.27	± 0.29
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

TM/PF Band 3 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.				

Landsat-4 TM/PF Band 3
Average, Standard Deviation and Coefficient of Variation for Radiometric Calibration Parameters

CHAN	GAIN	OFFSET	SNR		RADIANCES		
			LSR	MSL	MIN	MSL	MAX
MEAN:							
ODD	10.654	1.61	46	228	−0.151	22.65	23.78
EVEN	10.583	1.55	46	241	−0.147	22.81	23.94
ALL	10.618	1.58	46	235	−0.149	22.73	23.86
SIGMA:							
ODD	± 0.084	± 0.28	± 2	± 16	± 0.025	± 0.19	± 0.19
EVEN	± 0.064	± 0.08	± 2	± 10	± 0.007	± 0.13	± 0.14
ALL	± 0.081	± 0.20	± 2	± 14	± 0.018	± 0.18	± 0.19
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 %

Landsat TM/PF Band 4 Radiometric 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.	308.	−0.179	22.286	23.395	
3	11.018	1.96	70.	360.	−0.178	21.876	22.865	
4	10.831	1.82	76.	310.	−0.168	22.267	23.374	
5	10.812	1.75	69.	348.	−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	10.880	1.89	84.	304.	−0.174	22.201	23.308	
10	11.291	1.73	63.	358.	−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				
SPECIFIED VALUE OF SNR			32.	240.	(AT 0 COUNTS)	(AT 243 COUNTS)	(AT 255 COUNTS)	

Landsat-4 TM/PF Band 4
Average, Standard Deviation and Coefficient of Variation for Radiometric Calibration Parameters

CHAN	GAIN G	OFFSET O	SNR		SPECTRAL RADIANCE, L_λ		
			LSR	MSL	MIN	MSL	MAX
MEAN:							
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
SIGMA:							
ODD	± 0.117	± 0.29	± 7	± 28	± 0.027	± 0.242	± 0.254
EVEN	± 0.154	± 0.10	± 7	± 29	± 0.011	± 0.299	± 0.313
ALL	± 0.134	± 0.22	± 7	± 30	± 0.020	± 0.268	± 0.280
COEF. VAR. (%):							
ODD	± 1.08	±14.9	±10	± 8	± 15.0	± 1.1	± 1.1
EVEN	± 1.41	± 5.4	±10	± 9	± 6.2	± 1.4	± 1.4
ALL	± 1.23	±11.5	±10	± 9	± 11.4	± 1.2	± 1.2

TM/PF BAND 5 DERIVED RADIOMETRIC CALIBRATION PARAMETERS

CHAN	GAIN	OFFSET	SNR		RADIANCES			COMMENTS
			LSR	MSL	MIN	MSL	MAX	
1	76.569	3.28	42.	184.	−0.043	3.131	3.288	
2	76.830	2.94	43.	198.	−0.038	3.125	3.281	
3	—	—	—	—	—	—	—	DEAD DETECTOR
4	77.898	2.85	43.	182.	−0.037	3.091	3.245	
5	76.806	3.00	37.	172.	−0.039	3.125	3.281	
6	76.888	3.03	36.	190.	−0.039	3.121	3.277	
7	77.412	3.01	33.	166.	−0.039	3.100	3.255	
8	77.168	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	77.765	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.				

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

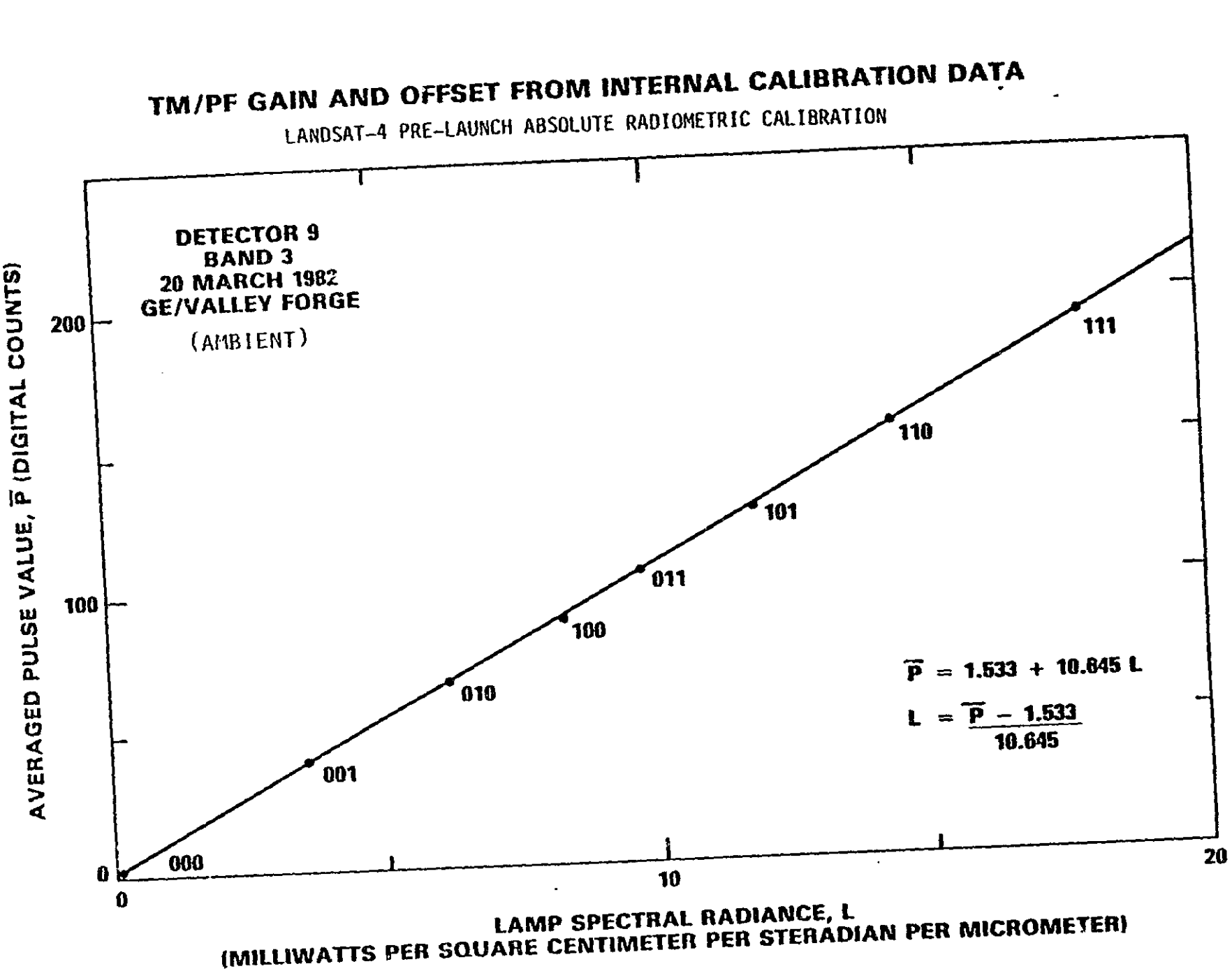
TM/PF BAND 7 DERIVED RADIOMETRIC CALIBRATION PARAMETERS

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	148.770	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	148.698	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	148.976	2.31	28.	185.	−0.016	1.638	1.719	
12	147.933	2.49	27.	171.	−0.017	1.628	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	1.618	1.700	
SNR COMPUTED AT SPECTRAL RADIANCE			0.17	1.59	[AT 0 COUNTS]	[AT 243 COUNTS]	[AT 255 COUNTS]	
SPECIFIED VALUE OF SNR			5.	46.				

381-BA/AB(11*)
JLB/D02/83

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	28	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


TM/PF GAIN AND OFFSET FROM INTERNAL CALIBRATION DATA
LANDSAT-4 PRE-LAUNCH ABSOLUTE RADIOMETRIC CALIBRATION
DETECTOR 9
BAND 3
20 MARCH 1982
GE/VALLEY FORGE
(AMBIENT)
AVERAGED PULSE VALUE, $\overline{P}$ (DIGITAL COUNTS)
200
100
0
000
001
010
011
100
101
110
111
$\overline{P} = 1.533 + 10.645\ L$
$L = \frac{\overline{P} - 1.533}{10.645}$
0
10
20
LAMP SPECTRAL RADIANCE, L
(MILLIWATTS PER SQUARE CENTIMETER PER STERADIAN PER MICROMETER)

Estimated Absolute Radiometric Calibration Accuracy for the Landsat Thematic Mapper Sensor Reflective Bands

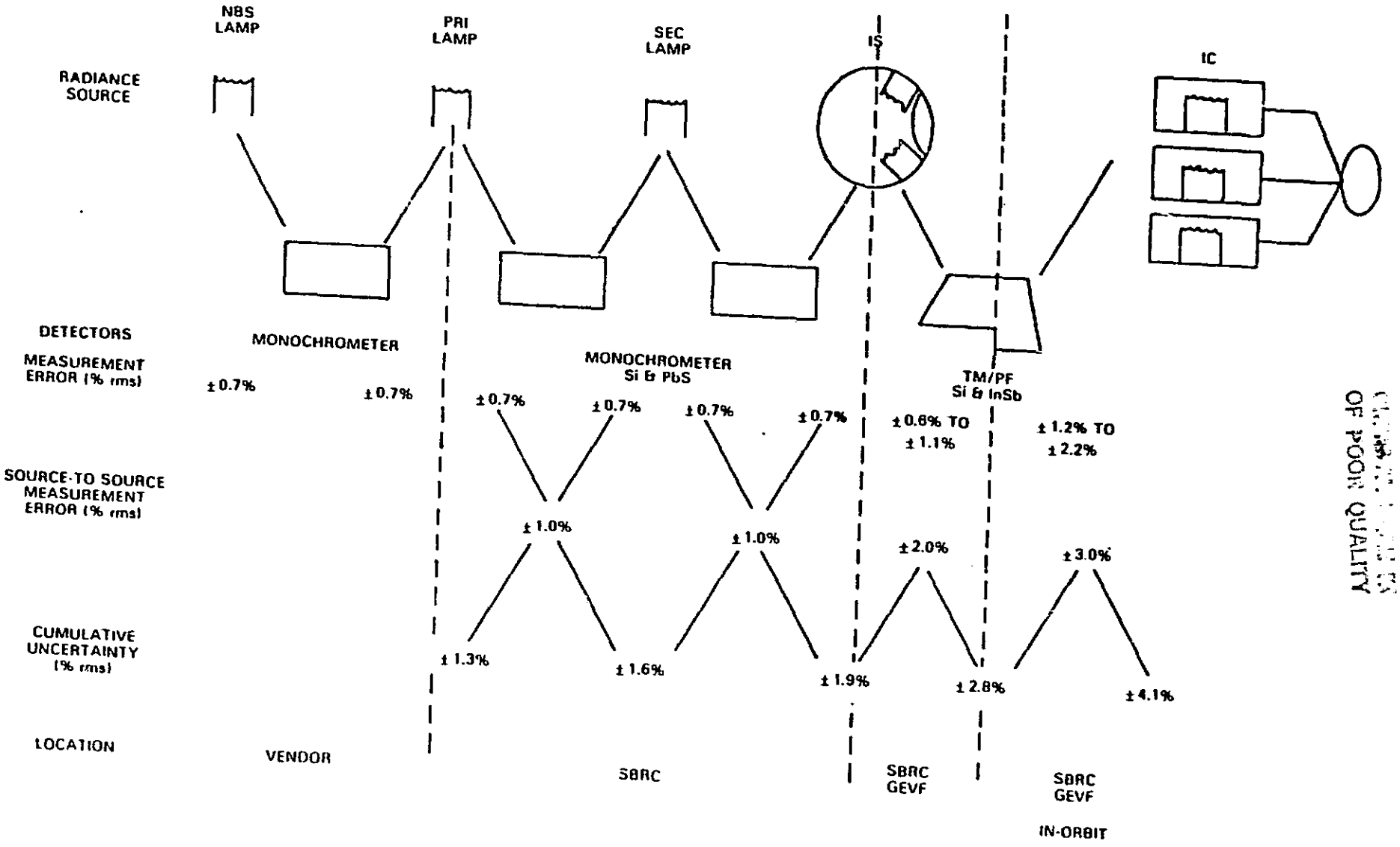


ILLUSTRATION OF "VACUUM SHIFT" FOR LANDSAT-4 TM/PF

BAND 1

Channels	Internal Lamp Configuration	IC Pulse, $P = -15^{\sum_{15} Q}$ Ambient 4/27/82 (DN)	IC Pulse, $P = -15^{\sum_{15} Q}$ Vacuum 3/9/82 (DN)	ΔP AMB - VAC (DN)	$\Delta P\%$ $\left(\frac{AMB - VAC}{VAC}\right) 100$ (%)
OPD	001	48.52	46.27	2.25	4.86
	010	70.45	68.51	1.94	2.84
	100	107.95	106.68	1.27	1.19
EVEN	001	45.90	44.40	1.50	3.39
	010	66.14	65.14	1.00	1.54
	100	105.25	105.32	-0.07	-0.07

$\Delta P\%(ODD) = 7.31 - .0589\ PVAC$

$\Delta P(ODD) = .0731\ PVAC - 5.89 \times 10^{-4}\ PVAC^2$

$PAMB(ODD) = PVAC\ [1.0731 - 0.000589\ PVAC]$

$\Delta P(\%)(EVEN) = 5.53 - 0.054\ PVAC$

$\Delta P(EVEN) = .0553\ PVAC - 5.45 \times 10^{-4}\ PVAC^2$

$PAMB(EVEN) = PVAC\ [1.0553 - .000545\ PVAC]$

CORRELATION OF "VACUUM SHIFT" WITH 3IC PULSE VALUES
LANDSAT 4 TM PRELAUNCH
(27 APRIL 1982 AMBIENT - 9 MARCH 1982 VACUUM)

BAND	AVERAGE SHIFT (DN)	AVERAGE SHIFT (%)	LINEAR CORRELATION	COMMENT
1 ODD	1.8	3.0	-0.98	CORRELATION WITH % SHIFT
EVEN	.8	1.6	-0.98	" " " "
2 ODD	1.4	2.3	-0.91	" " " "
EVEN	-1.0	-1.2	-0.80	" " " "
3 ODD	-2.0	-2.4	-1.00	" " " "
EVEN	-1.6	-1.7	-0.95	" " " "
4 ODD	-2.6	-2.8	- .95	" " " "
EVEN	-4.1	-4.5	- .79	" " " "
5 ODD	1.3	3.3	+1.00	CORRELATION WITH DN SHIFT
EVEN	2.1	4.3	+0.97	" " " "
7 ODD	1.9	4.3		
EVEN	.3	.8		

BARKER/BALL 83 GSFC

Pre-Launch Radiometric Calibration – TM/PF Landsat-4

COMPARISON OF AMBIENT AND VACUUM PULSE VALUES FOR SINGLE LAMP STATES (DIGITAL COUNTS)

BAND[a]	LAMP 100			LAMP 010			LAMP 001		
	VAC[b]	VAC[c]	AMB[d]	VAC[b]	VAC[c]	AMB[d]	VAC[b]	VAC[c]	AMB[d]
1O	106.69	106.67	107.95	68.54	68.47	70.45	46.32	46.22	48.52
1E	105.39	105.25	105.25	65.20	65.08	66.14	44.47	44.32	45.90
2O	99.45	99.15	100.53	78.75	78.40	79.45	45.40	45.23	47.40
2E	93.27	93.02	91.28	66.98	66.71	65.27	41.10	40.95	41.34
3O	94.36	94.01	89.95	69.07	68.76	67.21	40.13	39.95	39.91
3E	96.11	95.75	91.94	71.85	71.52	70.87	42.58	42.38	42.48
4O	96.01	95.89	91.61	98.92	98.68	96.43	47.00	46.94	46.74
4E	102.69	102.53	97.93	95.05	94.85	88.64	51.63	51.58	50.37
5O	44.96	44.87	46.23	41.30	41.19	42.70	24.23	24.14	25.01
5E	64.[illegible]	64.59	67.30	57.57	57.49	59.74	32.83	32.74	34.39
7O	57.19	57.10	59.21	45.08	44.95	47.24	32.34	32.27	33.75
7E	58.20	58.18	57.44	55.24	55.22	56.18	34.93	34.87	35.62

NOTES:

[a]O = ODD DETECTORS; E = EVEN DECTORS.

[b]VACUUM, MARCH 9, 1982, 12:43 P.M.

[c]VACUUM, MARCH 9, 1982, 12:48 P.M.

[d]AMBIENT, APRIL 27, 1982, 1:33 P.M.

Pre-Launch Radiometric Calibration – TM Landsat-4 Ambient Gain Changes (ppt) Relative to March 9, 1982, Vacuum

$$\Delta G\ (PPT) \equiv 1000\ [(GAMB - GVAC) \div GVAC]$$

BAND[a]	DATE				RANGE (%)
	JANUARY 13, 82[b]	FEBRUARY 26, 82[b]	MARCH 12, 82[c]	MARCH 23, 82[b]	AM
1O	28.63	31.38	21.62 Low	30.88	+ .8
1E	15.75	17.25	8.00 Low	16.63	+ 3.1
2O	25.12	26.25	19.75 Low	24.38	- 1.4
2E	−9.40	−4.20	−13.90 Low	−10.90	+ 2.6
3O	−23.50	−23.50	−50.00 Low	−18.25	- 5.0
3E	−18.63	−18.63	−46.25 Low	−15.00	- 1.5
4O	−15.00	−15.00	−30.75 Low	−10.13	- 4.7
4E	−27.38	−27.38	−47.00 Low	−27.00	- 1.7

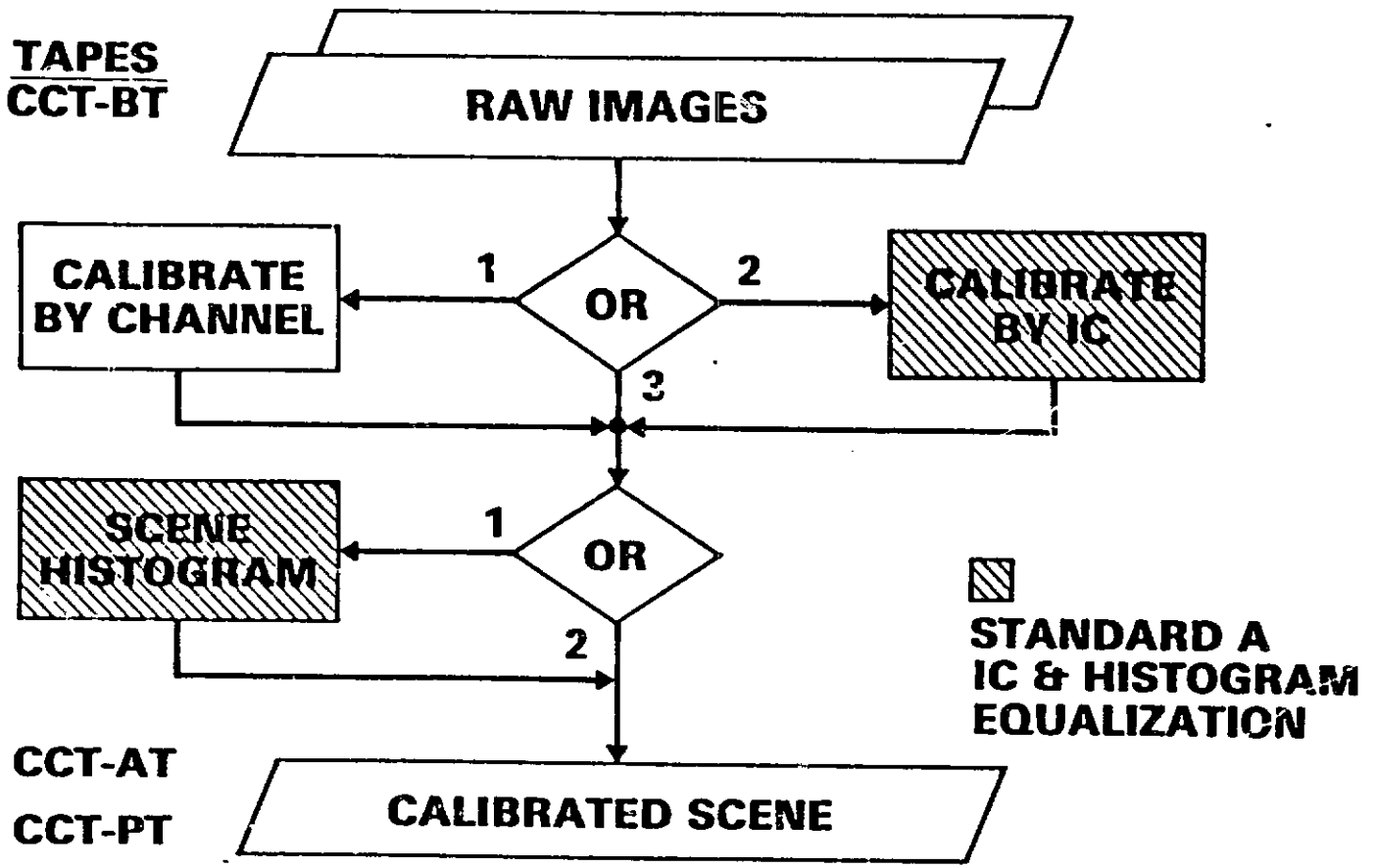
[a] O = ODD DETECTORS; E = EVEN DETECTORS.

[b] CAL SHUTTER FLAG TEMPERATURE, 10.11 C°.

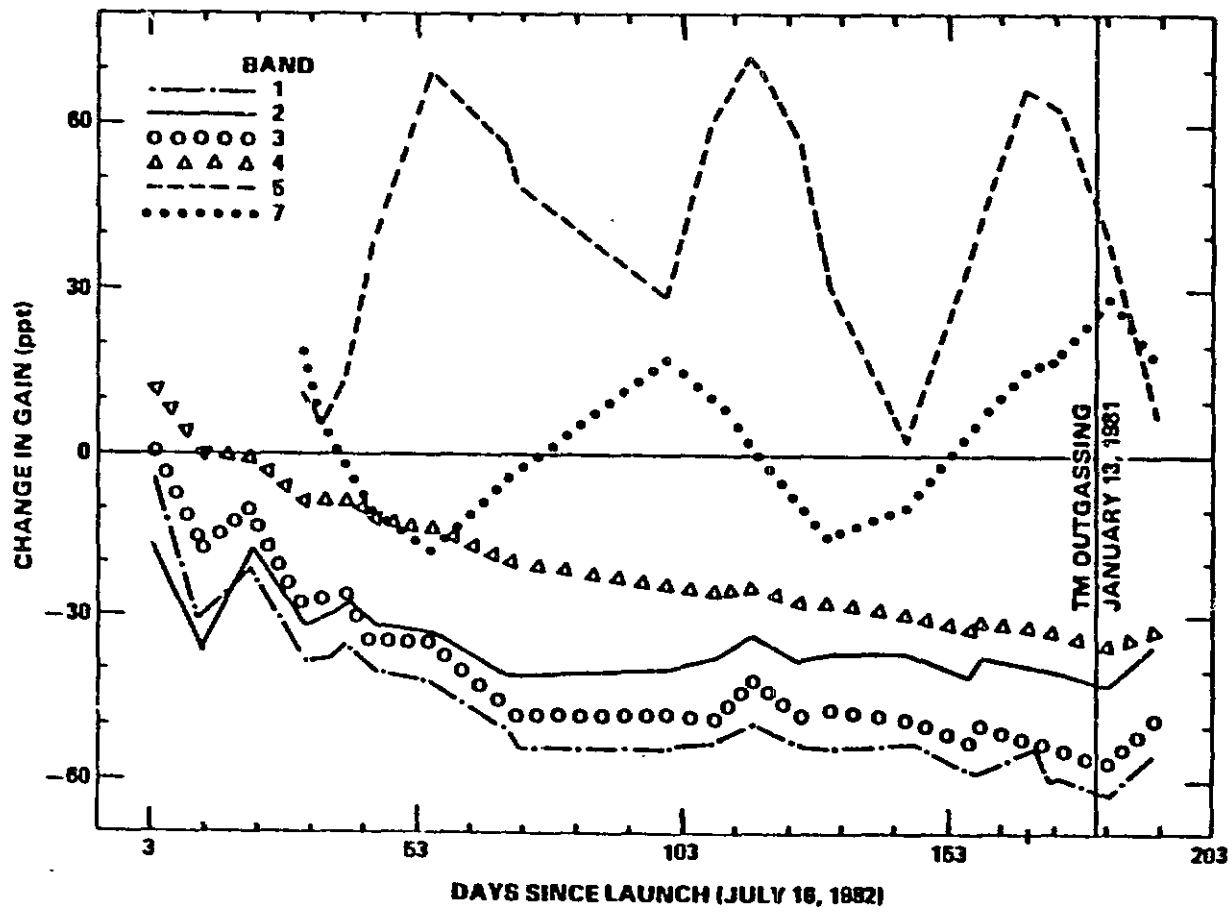
[c] CAL SHUTTER FLAG TEMPERATURE, 22.85 C°, SAME AS VACUUM RUN ON MARCH 9, 1982.

LANDSAT-4 TM RADIOMETRY

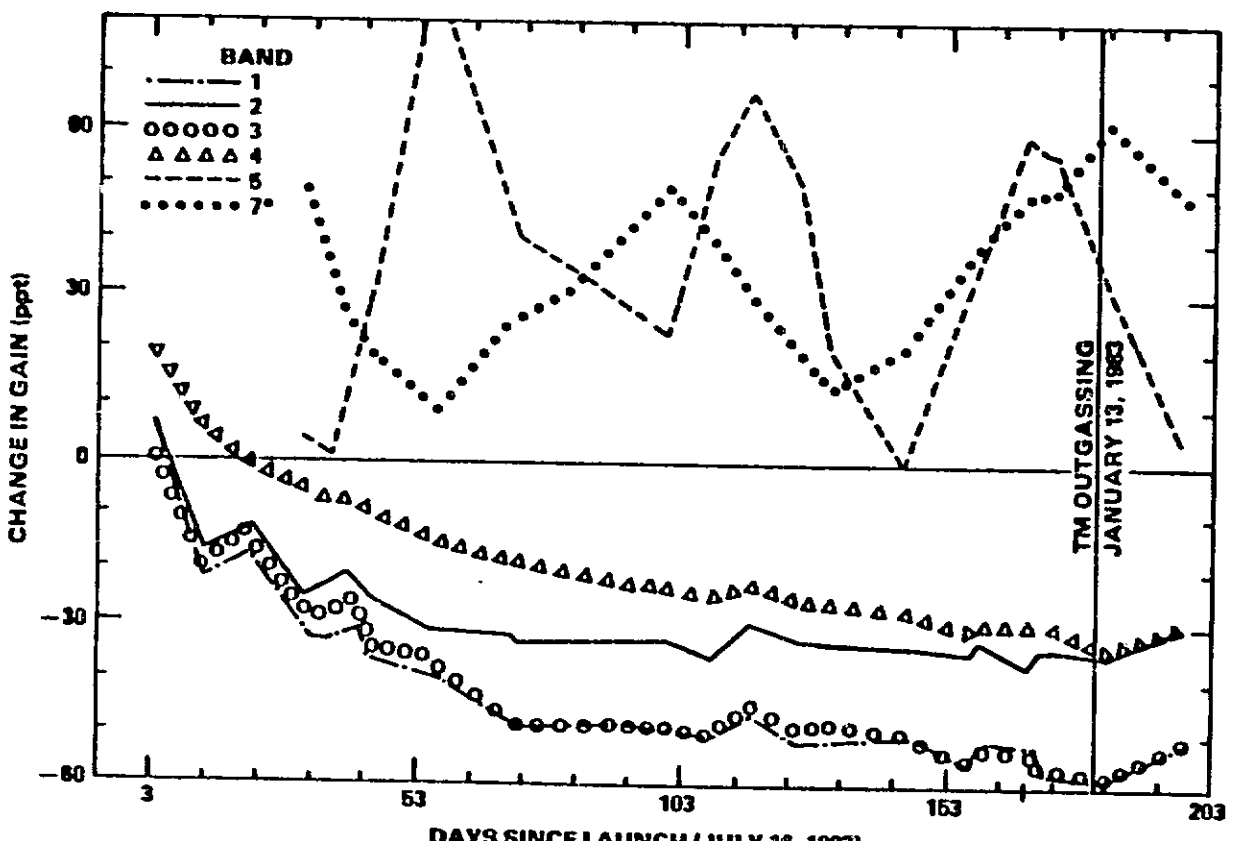
SCROUNGE-ERA
GROUND PROCESSING OPTIONS



POSTLAUNCH RADIOMETRIC CALIBRATION—TM LANDSAT-4
CHANGE IN GAIN (ppt) EVEN DETECTORS RELATIVE TO MARCH 9, 1982

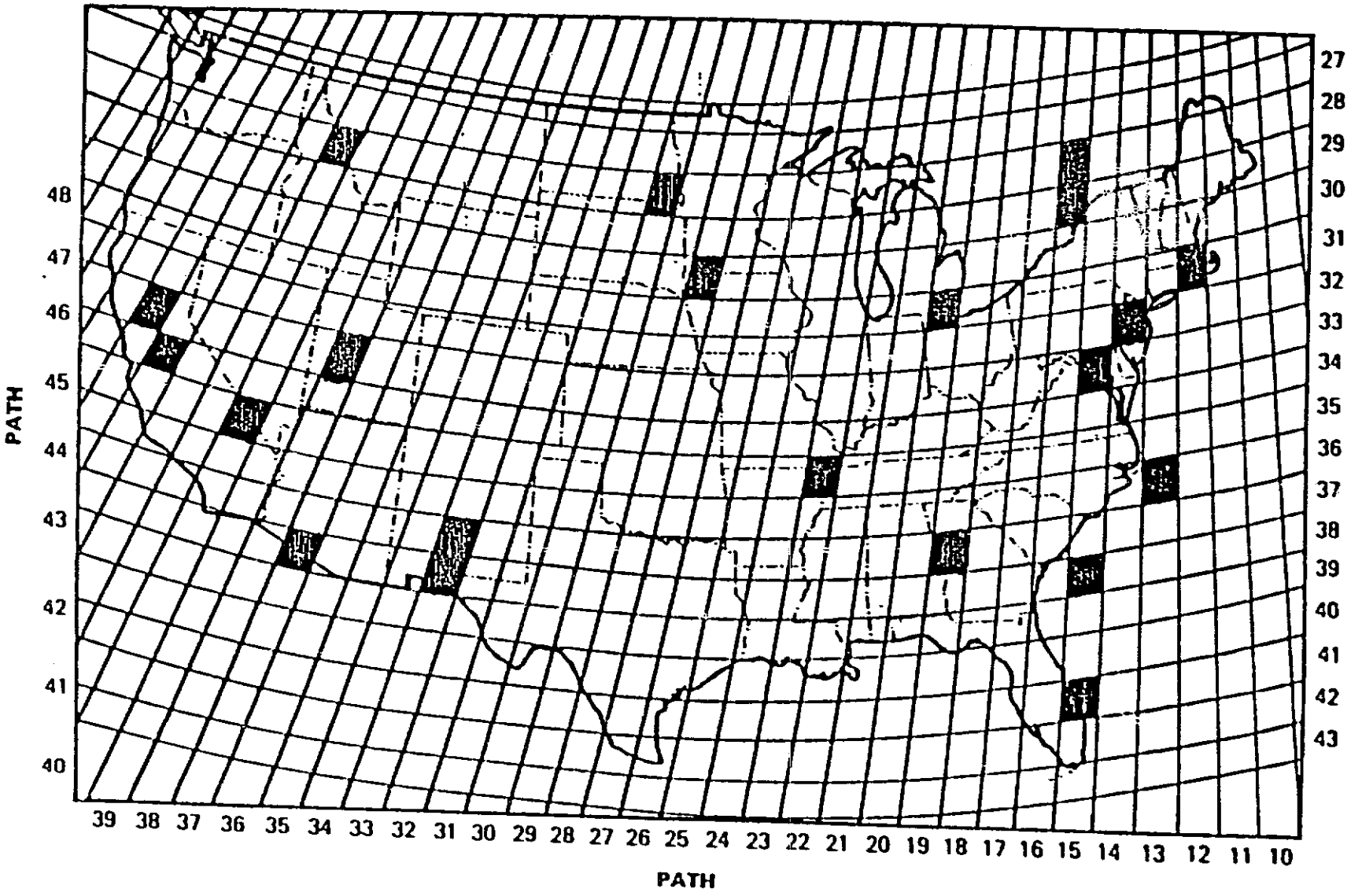


POSTLAUNCH RADIOMETRIC CALIBRATION—TM LANDSAT-4
CHANGE IN GAIN (ppt) ODD DETECTORS RELATIVE TO MARCH 9, 1982



*INCLUDES BAND 7, CHANNEL 7

The U.S. With WRS Path/Row Scenes Indicated



LANDSAT-4 TM SCENE IDENTIFICATION

ACQUISITION DATE	SCENE ID	WRS PATH/ROW	AREA
20 JUL 82	40004-15401	020/031	DETROIT, MICHIGAN
29 JUL 82	40011-31525	015/033	WASHINGTON, D.C.
AUG 82	40022-15061	014/032	NEW YORK/PHILADELPHIA
17 AUG 82	40032-15425	020/031	TOLEDO, OHIO
22 AUG 82	40037-16031	023/035	NORTHEAST ARKANSAS
25 AUG 82	40040-16321	028/030	FT. DODGE, IOWA
30 AUG 82	40045-15151	015/038	ATLANTIC OCEAN
10 SEP 82	40056-14541	012/031	BOSTON, MASSACHUSETTS
24 SEP 82	40070-16442	030/028	FORMAN, NORTH DAKOTA
26 SEP 82	40072-16325	028/030	NORTHWEST IOWA
27 SEP 82	40073-15400	019/037	ATLANTA, GEORGIA
24 OCT 82	40100-15182	016/028	OTTAWA, CANADA
24 OCT 82	40100-15184	016/029	KINGSTON, CANADA
2 NOV 82	40109-16140	015/033	WASHINGTON, D.C.
9 NOV 82	40116-18350	048/025	VANCOUVER, BRITISH COLUMBIA
17 NOV 82	40124-17495	040/035	DEATH VALLEY, CALIFORNIA
24 NOV 82	40131-17533	041/028	MT. HAMILTON, MONTANA
8 DEC 82	40145-18082	043/034	MODESTO, CALIFORNIA
20 DEC 82	40157-15174	015/041	FT. PIERCE, FLORIDA
22 DEC 82	40159-15032	013/036	CAPE HATTERAS, NORTH CAROLINA
31 DEC 82	40168-18141	044/033	SACRAMENTO, CALIFORNIA
3 JAN 83	40171-	033/037	WHITE SANDS, NEW MEXICO
3 JAN 83	40171-	033/038	WHITE SANDS, NEW MEXICO
6 JAN 83	40174-17372	038/033	MARYSVILLE, UTAH
15 JAN 83	40183-17332	037/038	LUKEVILLE, ARIZONA
29 JAN 83	40197-02267	112/211	WEST WASHINGTON, D.C., PM

TRAPP Software Program
(TM Radiative and Algorithmic Performance Program)

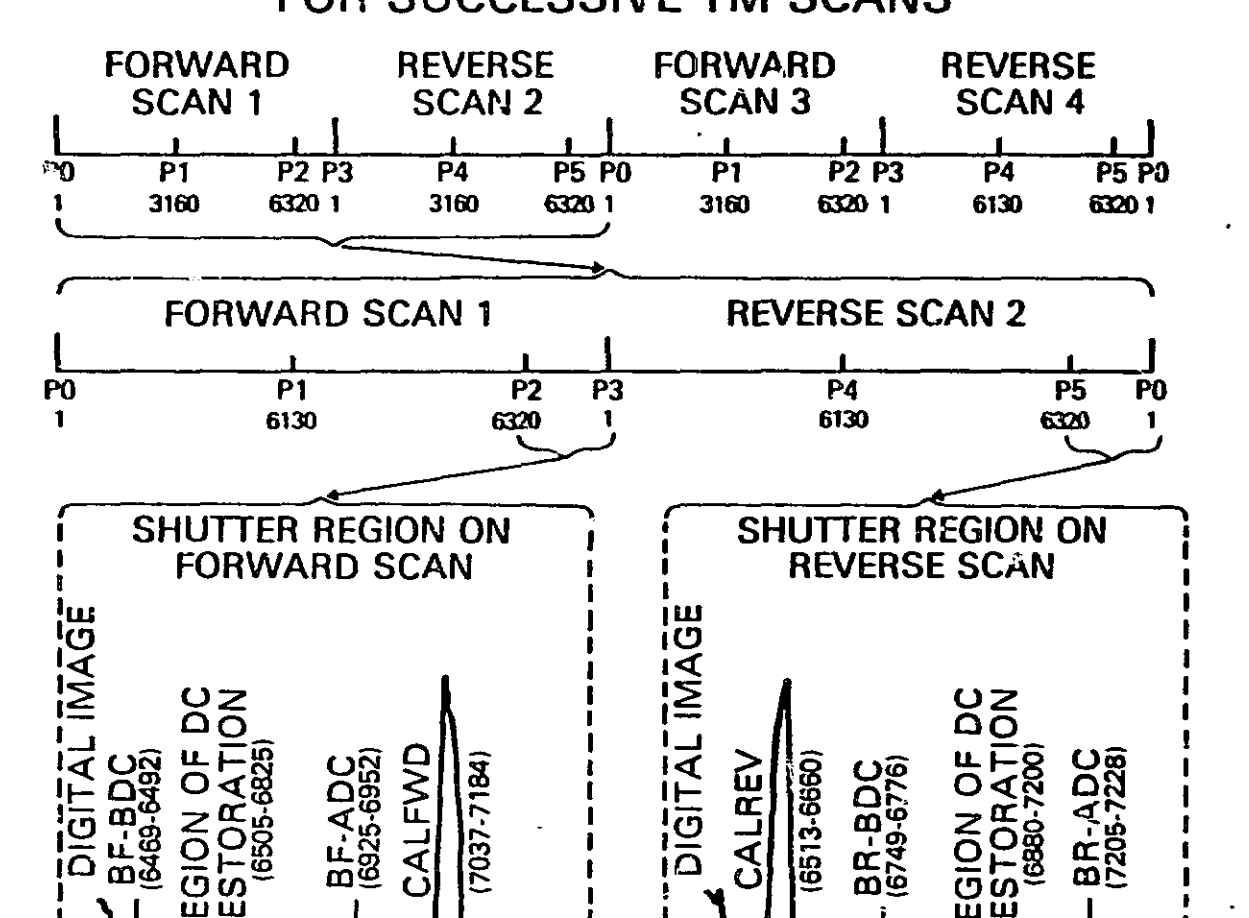
Input (TM Digital Imagery and Raw Calibration Data)

- L-4 Pre-Launch CCTs (BRU Tapes)
- L-4 In-Orbit CCT-BT, CCT-ADDS
- L-D Pre-Launch CCTs (BRU Tapes)

Output (Approx. 200 Page Xerox Book Characterizing an Image)

- Sensor Information (TM Configuration and housekeeping Info)
- Geometric (Bench Mark Matrices (Som, UTM); Nominal CH Locations, EOS, SOS, High Frequency Matrices)
- Radiometric Information
  - 5 to 8 Window Samples of Raw Collects (Video, Background, and Cal)
  - Intermediate Sample Products
    - 4 Channels, All Scans
    - C & Pulse Locations of 2 Scans for All Channels
    - Pulse for 6 Detectors, All Scans
    - All Detectors, 8 Scans
  - Midscan
  - Background
  - Calibration (All 8 Levels, Checks)
  - Histograms All Bands (All and Video Only)
  - Gain, Offsets
  - RLUTs

DIGITAL MINOR FRAME LOCATIONS FOR SUCCESSIVE TM SCANS



Landsat-4 TM (Scounge-Era 1982-1983)

BACKGROUND COLLECT WINDOWS

PERIOD	FIRST COLLECT		SECOND COLLECT	
	FORWARD SCAN (MINOR FRAMES)	REVERSE SCAN (MINOR FRAMES)	FORWARD SCAN (MINOR FRAMES)	REVERSE SCAN MINOR FRAMES)
LAUNCH TO MAY 83	6543 (52)	7089 (52)	—	—
MAY 83 TO END	6469 (24)	6749 (28)	6925 (28)	7205 (24)

IN-ORBIT 148-mf CALIBRATION COLLECT WINDOWS

PERIOD	FORWARD SCAN (mf)	REVERSE SCAN (mf)
LAUNCH TO DECEMBER 22, 1982	7009	6525
DECEMBER 22, 1982, TO PRESENT	7029	6517
PROPOSED COMPROMISE	7017	6525
PROPOSED CENTERED	7037	6513

Timing Locations on Main Shutter during Odd Numbered (Forward) Scans of Internal Calibrator (IC) on Landsat-4 Thematic Mapper and Scrounge-ERA (1982-1983) Ground Processing IC Collect Windows

Collect Window Label	Location From Start of Line (mf)	(msec)	Minor Frame Label	Description of Label	Method of Calculating Location (2)	
(1)	(2)	(3)				
	1	0.00	P0	SAM SOL (Scan Angle Monitor FWD Start)	DEF	Start of mf Counting in ADDS
	3160	30.37	P1	SAM Midpoint of Active FWD Scan	NOM	From Scan Mirror Frequency
	6320	60.74	P2	SAM EOL End of Active FWD Scan	NOM	From Scan Mirror Frequency
	6383	61.35	EOIF16	End of Image (FWD) for CH 16	CALC	SOSF16-16= SOSF1-70
	6399	61.50	SOSF16	Start of IC Shutter (FWD) for CH 16	CALC	SOSF1-[(CALF1-CALF16) =54]
	6407	61.58	SADDSF	Start of 824mf ADDS FWD "MAP1" Buffer	DEF	
	6437	61.87	EOIF1	End of Image (FWD) for CH 1	CALC	SOSF1-16
	6453	62.02	SOSF1	Start of Shutter (FWD) for CH 1	OBS	ADDS Comtal of 2 NOV 82 Data
BF-BDC	6469	62.17	SBFBDC	Start of 24mf ADDS FWD BKGD Before DC	CALC	(Multiple of 4) +1 of(MBFBDC-12)
BF-BDC	6479	62.27	MBFBDC	Middle of ADDS FWD BKGD Before DC	CALC	(SOSF1 + SODCF) / 2
BF-BDC	6492	62.39	EBFBDC	End of 24mf ADDS FWD BDGD Before DC	CALC	SBFBDC + 24-1
	6505	62.52	SODCF	Start of DC Restore Region for FWD Scan	CALC	1.023 msec (106mf) to SOSF16
	6825	65.60	EODCF	End of DC Restore Region for FWD Scan	CALC	3.075 msec (320mf) to SODCF
BF-ADC	6925	66.56	SBFADC	Start of 28mf ADDS FWD BKGD After DC	CALC	(Multiple of 4)+1 of(MBFADC-14)
BF-ADC	6938	66.68	MBFADC	Middle of ADDS FWD BKGD After DC	CALC	(CALF16-32+EODCF) / 2
BF-ADC	6952	66.82	EBFADC	End of 28mf ADDS FWD BKGD After DC	CALC	SBFADC + 28 - 1
CALFWD	7037	67.63	SCALF	Start of 148mf ADDS CAL FWD Collect	DEF	Starting 20 May 83
CALFWD	7084	68.08	CALF16	Center of CAL FWD Pulse for CH 16	OBS	TRAPP (4) for 2 NOV 82 Scene
CALFWD	7109	68.32	CALF9	Center of CAL FWD Pulse for CH 9	OBS	TRAPP (4) for 2 NOV 82 Scene
CALFWD	7111	68.34	MCALF	Middle of CAL FWD Region	CALC	(CALF16 + CALF1) / 2
CALFWD	7112	68.35	CALF8	Center of CAL FWD Pulse For CH 8	OBS	TRAPP (4) for 2 NOV 82 Scene
CALFWD	7138	68.60	CALF1	Center of CAL FWD Pulse for CH 1	OBS	TRAPP (4) for 2 NOV 82 Scene
CALFWD	7184	69.05	ECALF	End of 148mf ADDS CAL FWD Collect	CALC	SCALF + 148-1
	7182	69.03	EOSF16	End of IC Shutter (FWD) for CH 16	OBS	ADDS Comtal of 2 NOV 82 Data
	7198	69.18	SOIR16	Start of Image Before REV Scan for CH 1	CALC	EOSF16 + 16
	7230	69.49	EADDSF	End of 824mf ADDS FWD "MAP1" BUFFER	DEF	
	7236	69.55	EOSF1	End of Shutter (FWD) for CH 1	CALC	EOSF16 + 54
	7252	69.70	SOIR1	Start of Image Before REV Scan for CH 1	CALC	EOSF1 + 16
	7435	71.46	P3	SAM SOL (Scan Angle Monitor REV Start)	CALC	71.46 msec/.009611 msec/mf

MF LOCATIONS FOR ODD-NUMBERED (FORWARD) SCANS

(1) Collection of digital data for radiometric calibration of TM during the Scrounge-Era preprocessing by ADDS, 824mf (minor frames) of IC (Internal Calibrator) data are temporarily put in a buffer of a Macro Array Processor (MAP1). These calibration data are collected starting at minor frame 6407, which is close to the end of the scene video data and the beginning of shutter obscuration. 200 of the 824mf are sent on to a Vax computer for use in radiometric calibration.

For odd-numbered scans (forward sweeps of the TM scan mirror), these 200mf from the IC shutter are collected from three separate regions (windows). Labels and descriptions for the three collect windows from each forward scan are given below:

BF-BDC — This is a 24mf region of dark level background (BKG) taken on a forward scan before DC restoration begins. Prior to May 20, 1983, there was a single 52mf ADDS BKG collect window which started before DC restoration, at MF 6543.

BF-ADC — 28mf BKG taken after DC forward restoration ends.

CALFWD — This is a 148mf forward scan calibration (CAL) region containing the TM responses to light from the current configuration of the three IC lamps. Prior to December 22, 1982, the 148mf CAL collect window started at MF 7009. It then began at MF 7029 until May 20, 1983, when it was changed to MF 7037.

(2) MF (Minor Frame) locations were arrived at one of four ways:

DEF — By Definition

NOM — From nominal value of another variable

OBS — Observed from in-orbit digital data

CALC — Calculated from values of other MF locations and defined, nominal or observed relative differences

(3) MSEC (Milliseconds) locations were calculated from MF locations assuming a nominal 9.611 microseconds per minor frame.

(4) TRAPP is a TM Radiometric and Algorithmic Performance software program run on pre and postlaunch tapes at the LAS Facility.

Revised 25 MAY 83/JLB

Timing Locations on Main Shutter during Even Numbered(Reverse) Scans
of Internal Calibrator (IC) on Landsat-4 Thematic Mapper
and Scrounge-ERA (1982-1983) Ground Processing IC Collect Windows

Collect Window Label	Location From Start of Line (mf)	(msec)	Minor Frame Label	Description of Label	Method of Calculating Location (2)	
(1)	(2)	(3)				
	1	0.00	P3	SAM SOL (Scan Angle Monitor REV Start)	DEF	Start of mf Count
	3150	30.37	P4	SAM Midpoint of Active REV Scan	NOM	From Scan Mirror Frequency
	6320	60.74	P5	SAM EOL (End of Active REV Scan)	NOM	From Scan Mirror Frequency
	6407	61.58	SADDSR	Start of 824mf ADDS REV "MAP1" Buffer	DEF	
	6453	62.02	EOIR1	End of Image (REV) for CH 1	CALC	(SOSR1-12); also OBS Comtal
	6465	62.14	SOSR1	Start of IC Shutter (REV) for CH 1	OBS	ADDS Comtal of 2 NOV 82 Data
	6507	62.54	EOIR16	End of Image (REV) for CH 16	CALC	(SOSR16-12); also OBS Comtal
CALREV	6513	62.60	SCALR	Start of 148mf ADDS CAL REV Collect	DEF	Starting 20 MAY 83
CALREV	6519	62.65	SOSR16	Start of IC Shutter (REV) for CH 16	OBS	ADDS Comtal of 2 NOV 82 Data
CALREV	6560	63.05	CALR1	Center of CAL REV Pulse for CH 1	OBS	TRAPP (4) Data for 2 NOV 82 Scene
CALREV	6580	63.24	CALR8	Center of CAL REV Pulse for CH 8	OBS	TRAPP (4) Data for 2 NOV 82 Scene
CALREV	6587	63.31	MCALR	Middle of CAL REV Region	CALC	(CALR1 + CALR16) / 2
CALREV	6614	63.57	CALR16	Center of CAL REV Pulse for CH 16	OBS	TRAPP (4) Data for 2 NOV 82 Scene
CALREV	6660	64.01	ECALR	End of 148mf ADDS CAL REV Collect	CALC	SCALR + 148-1
BR-BDC	6749	64.86	SBRBDC	Start of 28mf ADDS REV BKGD Before DC	CALC	(Multiple of 4)+1 of (MBRBDC-14)
BR-BDC	6763	65.00	MBRBDC	Middle of REV BKGD Before DC	CALC	(CALR16 + 32 + SODCR) / 2
BR-BDC	6776	65.12	EBRBDC	End of 28mf ADDS REV BKGD Before DC	CALC	SBRBDC + 28-1
	6880	66.12	SODCR	Start of DC Restore Region for REV Scan	CALC	4.098msec (426mf) to EOSR16
	7200	69.20	EODCR	End of DC Restore Region for REV Scan	CALC	3.075msec (320mf) to SODCR
BR-ADC	7205	69.25	SBRADC	Start of 24mf ADDS REV BKGD After DC	CALC	EBRADC - 24 + 1
BR-ADC	7226	69.45	MBRADC	Middle of REV BKGD After DC	CALC	(EODCR + EOSR1) / 2
BR-ADC	7228	69.47	EBRADC	End of 24mf ADDS REV BKGD After DC	CALC	First Multiple of 4 below EADDSR
	7230	69.49	EADDSR	End of 824mf ADDS REV "MAP1" Buffer	DEF	
	7252	69.70	EOSR1	End of IC Shutter (REV) for CH 1	CALC	SOSR1 + 787
	7264	69.81	SOIF1	Start of Image Before FWD Scan for CH 1	CALC	EOSR1 + 12
	7306	70.22	EOSR16	End of IC Shutter (REV) for CH 16	CALC	SOSR16 + 787
	7318	70.33	SOIF16	Start of Image Before FWD Scan for CH 16	CALC	EOSR16 + 12
	7435	71.46	P0	SAM SOL (Scan Angle Monitor FWD Start)	CALC	71.46 msec/.009611 msec/mf

MF LOCATIONS FOR EVEN-NUMBERED (REVERSE) SCANS

(1) Collection of digital data for radiometric calibration of TM during the Scrounge-Era preprocessing by ADDS, 824mf (minor frames) of IC (Internal Calibrator) data are temporarily put in a buffer of a Macro Array Processor (MAP1). These calibration data are collected starting at minor frame 6407, which is close to the end of the scene video data and the beginning of shutter obscuration. 200 of the 824mf are sent on to a Vax computer for use in radiometric calibration.

For even-numbered scans (reverse sweeps of the TM scan mirror), these 200 mf from the IC shutter are collected from three separate regions (windows). Labels and descriptions for the three collect windows from each reverse scan are given below:

CALREV — This is a 148mf reverse scan calibration (CAL) region containing the TM responses to light from the current configuration of the three IC lamps. Prior to December 22, 1982, the 148mf CAL collect window started at MF 6525. It then began at MF 6517 intil May 20, 1983, when it was changed to MF 6513.

BR-BDC — This is a 28mf region of dark level background (BKG) taken on a reverse scan before DC restoration begins.

BR-ADC — 24mf BKG taken after DC reverse restoration ends. This is the same shutter location as the 24mf forward BKG. Prior to May 20, 1983, there was a single 52mf ADDS BKG collect window which started after DC restoration, at MF 7089.

(2) MF (Minor Frame) locations were arrived at one of four ways:

DEF — By definition

NOM — From nominal value of another variable

OBS — Observed from in-orbit digital data

CALC — Calculated from values of other MF locations and defined, nominal or observed relative differences.

(3) MSEC (milliseconds) locations were calculated from MF locations assuming a nominal 9.611 microseconds per minor frame.

(4) TRAPP is a TM Radiometric and Algorithmic Performance software program run on pre and postlaunch tapes at the LAS Facility.

Revised 25 May 83/JLB

RADIOMETRIC MODEL FOR CHARACTERIZING TM IMAGERY

CAUSE	LABEL	COMMENTS
DROOP	D	WITHIN SCAN
BRIGHT TARGET RECOVERY	B	WITHIN SCAN
CHANNEL CORRELATED NOISE		
TWO STATE	N	WITHIN LINE
FOUR STATE	N4	
COHERENT NOISE	C	WITHIN LINE

BARKER 83 GSFC

MODEL FOR STEADY-STATE CORRECTIONS IN TM IMAGERY

REGION OF IMAGE	LABEL	NOMINAL VALUE	CORRECTION	
			TWO-STATE NOISE	DROOP
FORWARD SCAN				
IMAGE-WEST	I0001F	QTA+Aw	N	
IMAGE-MID	I3088F	QTA	N	-DMF
IMAGE-EAST	I6176F	QTA+Ae	N	-D
REVERSE SCAN				
IMAGE-EAST	I0001R	QTA+Ae	N	-DSR
IMAGE-MID	I3088R	QTA	N	-DMR
IMAGE-WEST	I6176R	QTA+Aw	N	-D

BARKER 83 GSFC

MODEL FOR CORRECTIONS TO EXPECTED VALUES

IN TM CALIBRATION REGION

CALIBRATION REGION	NOMINAL VALUE	CORRECTION TO NOMINAL VALUE			
		TWO-STATE NOISE	DROOP	DROOP +NOISE	BRIGHT TARGET
FORWARD SCAN					
SHUTTER 1 BEFORE DC RESTORE	QB	N	-D	(N-D)	-B
SHUTTER 2 AFTER DC RESTORE	QB	N		N	
CAL PULSE	P	N		N	
REVERSE SCAN					
CAL PULSE	P	N	-D	(N-D)	-B
SHUTTER 1 BEFORE DC RESTORE	QB	N	-D	(N-D)	-B
SHUTTER 2 AFTER DC RESTORE	QB	N		N	

BARKER 83 GSFC

CHECK FOR "DROOP" IN LANDSAT 4 THEMATER MAPPER

CHANNEL 9 OF BOSTON SUBIMAGE (40056-14541, 10 SEP 82)

REGION	LABEL	EXPECTED (MODEL)	OBSERVED DIFFERENCES IN FORWARD AND REVERSE SCANS (DN)					
			BAND 1	BAND 2	BAND 3	BAND 4	BAND 5	BAND 7
IMAGE-EAST	QI6176F-QI0001R	-D+DSR	-.89	-.11	-.07	.08	.01	-.03
512 x 512								
SHUTTER								
BEFORE-AFTER 52mf	QBBF1-QBAR2	-D	-.63	-.03	-.01	.58	-.03	-.04
CAL PULSE								
ALL OFF	P000F-P000R	D	-.88	.20	.27	1.33	.02	.03
LOWEST	P001F-P001R	D	-.92	.33	.48	2.05	-.07	-.07
MIDDLE	P010F-P010R	D	-.30	-.30	.15	1.71	-.30	-.25
HIGHEST	P100F-P100R	D	-.92	.20	.52	2.18	-.09	.28

CHECK FOR BRIGHT TARGET RECOVERY IN L-4 TM

CHANNEL 9 OF WHITE SANDS SUBIMAGE WITH SNOW (3 JAN 83)

REGION	LABEL	EXPECTED (MODEL)	OBSERVED DIFFERENCES IN FORWARD AND REVERSE SCANS (DN)					
			BAND 1	BAND 2	BAND 3	BAND 4	BAND 5	BAND 7
IMAGE-MID	QI3088F-QI3088R	-(DMF-DMR)	-2.54	-1.00	-1.11	-.82	-1.89	-1.25
512 x 512								
SHUTTER								
BEFORE-AFTER	QBBF1-QBAR2	-(D+B)	-.13	-.10	.14	.04	-.04	.00
52 mf								
CAL. PULSE								
ALL OFF	P000F-P000R	(D+B)	3.50	1.21	1.84	1.14	.02	.00
LOWEST	P001F-P001R		2.89	1.22	1.40	1.46	-.07	.02
MIDDLE	P010F-P010R		3.52	1.20	1.73	1.56	-.22	-.21
HIGHEST	P100F-P100R		4.02	1.63	2.03	2.83	-.14	-.09

BARKER 83 GSFC

DEFINITION OF LABELS FOR STEADY-STATE OF LANDSAT TM BY CAUSE

CAUSE NAME	CAUSE SYMBOL	SELECTED* CONDITION LABEL: REF	D	B	N	DB	DBw	DBE	DN	DN4	DBN	DBwN	DBEN
DROOP	D	N	Y	N	N	Y	Y	Y	Y	Y	Y	Y	Y
BRIGHT TARGET		N	N		N				N	N			
TOTAL IMAGE	B			Y		Y					Y		
WEST ONLY	Bw						Y					Y	
EAST ONLY	BE							Y					Y
CHAN-CORR NOISE		N	N	N		N	N	N					
TWO-STATE	N				Y				Y		Y	Y	Y
FOUR-STATE	N4									Y			

*FOR THESE 3 CAUSES, THERE ARE 24 POSSIBLE CONDITIONS (STATES) OF TM

DEFINITIONS OF RAW RADIANCE DATA IN LANDSAT TM
LABELS FOR CALIBRATION REGION

FORWARD SCAN	LABEL	
BKG-BDC-FWD	BBF-1	SHUTTER REGION-1 BEFORE DARK CURRENT RESTORATION
BKG-ADC-FWD	BAF-2	SHUTTER REGION-2 AFTER DARK CURRENT RESTORATION
CAL-ADC-FWD	CAF	INTERNAL CALIBRATION (IC) PULSE REGION
REVERSE SCAN		
CAL-BDC-REV	CBR	INTERNAL CALIBRATION (IC) PULSE REGION
BKG-BDC-REV	BBR-1	SHUTTER REGION-1 BEFORE DARK CURRENT RESTORATION
BKG-ADC-REV	BAR-2	SHUTTER REGION-2 AFTER DARK CURRENT RESTORATION
DIFFERENCE (FWD-REV)		
BKG-BDC-DIF	BBD-1	FORWARD MINUS REVERSE DIFFERENCE FOR SHUTTER REGION 1
BKG-ADC-DIF	BAD-2	FORWARD MINUS REVERSE DIFFERENCE FOR SHUTTER REGION 2
CAL-DIF	CD	FORWARD MINUS REVERSE DIFFERENCE FOR IC PULSE REGION

EXPECTED RADIOMETRIC CORRECTIONS IN TM CALIBRATION REGION

Calibration Data Labels	Ref Value	N	D	Correction to Reference Value by Steady-State Condition: DN	B	DB	DBN	DBe	DBeN
Forward Scan									
BBF-1	QB	N	-D	(N-D)	-B	-(D+B)	(N-D-B)	-(D+B)	(N-D-B)
BAF-2	QB	N		N			N		N
CAF	P	N		N			N		N
Reverse Scan									
CBR	P	N	-D	(N-D)	-B	-(D+B)	(N-D-B)	-D	(N-D)
BBR-1	QB	N	-D	(N-D)	-B	-(D+B)	(N-D-B)	-D	(N-D)
BAR-2	QB	N		N			N		N
Difference (F-R)									
BBF1-BAR2	0		-D	-D	-B	-(D+B)	-(D+B)	-(D+B)	-(D+B)
BBD-1	0							-B	-B
BAD-2	0								
CD	0		D	D	B	(D+B)	(D+B)	D	D
Average									
BB-1	QB	N	-D	(N-D)	-B	-(D+B)	(N-D-B)	$(-D-\frac{B}{2})$	$(N-D-\frac{B}{2})$
BA-2	QB	N		N			N		N
C	P	N	$-\frac{D}{2}$	$(N-\frac{D}{2})$	$-\frac{B}{2}$	$-\frac{(D+B)}{2}$	$(N-\frac{D}{2}-\frac{B}{2})$	$-\frac{D}{2}$	$(N-\frac{D}{2})$

DEFINITIONS OF DATA IN LANDSAT TM
LABELS FOR RAW RADIANCE DIGITAL IMAGERY

FORWARD SCAN	LABEL	
IMAGE-WEST-FWD	I0001F	WESTERN-MOST DIGITAL PIXEL REGION NEAR SAMPLE 0001
IMAGE-MID-FWD	I3160F	MIDDLE DIGITAL PIXEL REGION NEAR SAMPLE 3160
IMAGE-EAST-FWD	I6320F	EASTERN-MOST DIGITAL PIXEL REGION NEAR SAMPLE 6320
REVERSE SCAN		
IMAGE-EAST-REV	I6320R	EASTERN-MOST PIXEL REGION NEAR REVERSED SAMPLE 6320
IMAGE-MID-REV	I3160R	MIDDLE PIXEL REGION NEAR REVERSED SAMPLE 3160
IMAGE-WEST-REV	I0001R	WESTERN-MOST PIXEL REGION NEAR REVERSED SAMPLE 0001
DIFFERENCE (FWD-REV)		
IMAGE-WEST-DIF	I0001D	FORWARD MINUS REVERSE DIFFERENCE FOR WESTERN-MOST REGION
IMAGE-MID-DIF	I3160D	FORWARD MINUS REVERSE DIFFERENCE FOR MIDDLE PIXEL REGION
IMAGE-EAST-DIF	I6230D	FORWARD MINUS REVERSE DIFFERENCE FOR EASTERN-MOST REGION

EXPECTED RADIOMETRIC CORRECTIONS IN TM IMAGERY

TM Scene Data Labels	Scene Ref	Correction to TM Scene Reference (By Steady-State Condition) N	D	DN	B	Bw	DBw
Forward							
10001F	QTA+Aw	N		N	"255"	"255"	"255"
13160F	QTA	N	-DF	(N-DF)	"255"	-B	(-B-DF)
16320F	QTA+Ae	N	-D	(N-D)	"255"		-D
Reverse							
16320R	QTA+Ae	N	-DSR	(N-DSR)	"255"		-DSR
13160R	QTA	N	-DR	(N-DR)	"255"		-DR
10001R	QTA+Aw	N	-D	(N-D)	"255"	"255"	"255"
Diff (F-R)							
10001D	0		D	D			
13160D	0		(DR-DF)	(DR-DF)		-B	(DR-DF-B)
16320D	0		(-D+DSR)	(-D+DSR)			(-D+DSR)
Average							
10001	QTA+Aw	N	$-\frac{D}{2}$	$(N-\frac{D}{2})$	"255"	"255"	"255"
13160	QTA	N	$(-\frac{DF}{2}-\frac{DR}{2})$	$(N-\frac{DF}{2}-\frac{DR}{2})$	"255"	$-\frac{B}{2}$	$(-\frac{B}{2}-\frac{DF}{2}-\frac{DR}{2})$
16320	QTA+Ae	N	$(-\frac{D}{2}-\frac{DSR}{2})$	$(N-\frac{D}{2}-\frac{DSR}{2})$	"255"		$(-\frac{D}{2}-\frac{DSR}{2})$

Speculative Radiometric Assignments

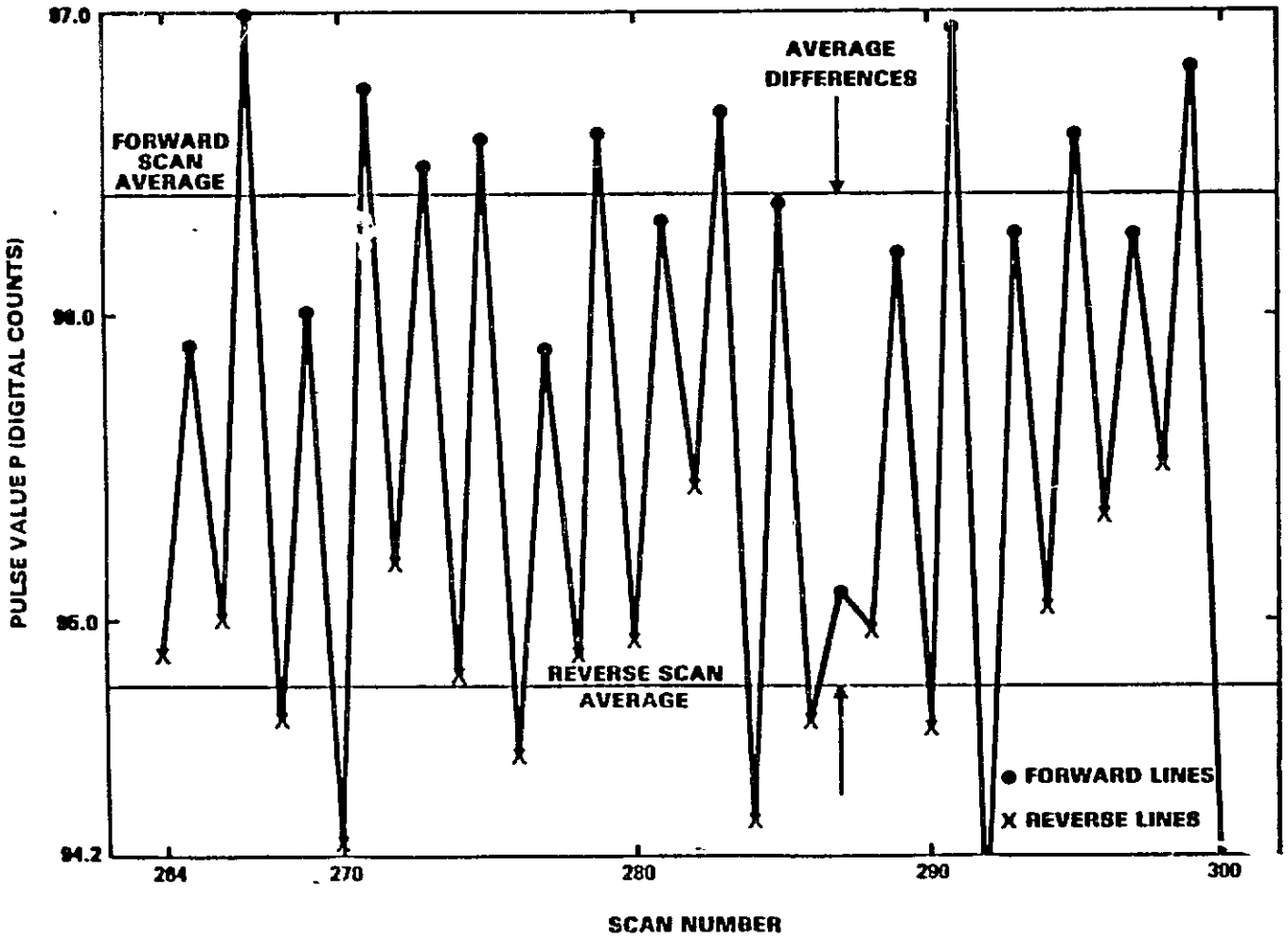
Landsat-4 TM/PF
Band 1 Channel 4

Cause	Label	Magnitude* (DN)
Droop	D	.4
Bright Target Recovery	B	1.0
Channel-Correlated Noise	N	2.0

* Based on Analysis of Shutter collects Before and After DC Restoration for Landsat Scene 40174-16011 WRS:P022R040 - 3 January 1983 Terrebonne Bay, LA with Clouds on Bottom and East

PRELAUNCH TM LANDSAT-4 RADIOMETRIC CALIBRATION

BETWEEN-LINE VARIABILITY OF IC PULSE
TM4, CHANNEL 9, LAMP 100, MARCH 5, 1982



P (CD)

FWD-REV =

DROOP

$\Delta = D = 1.7$

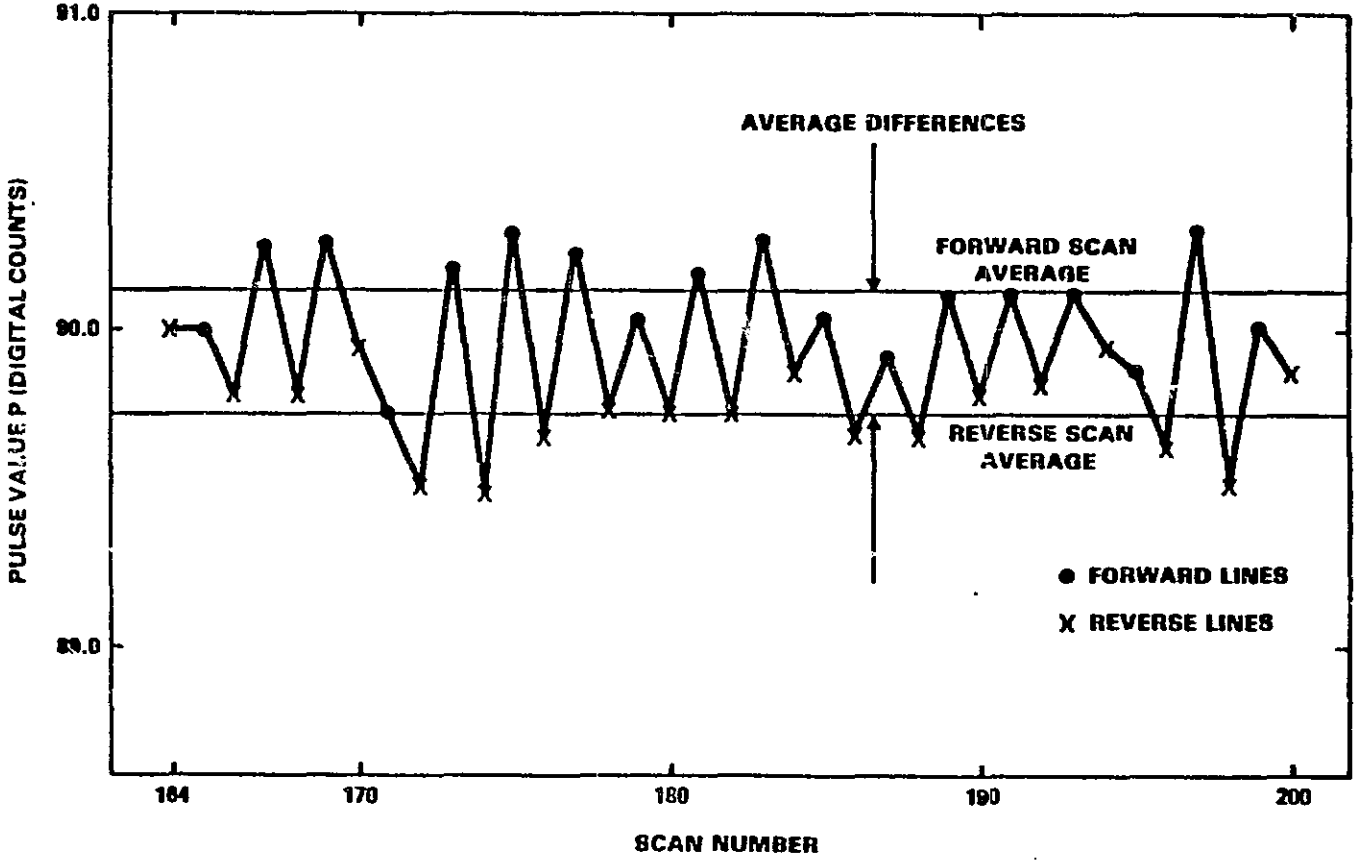
$D = 96.4$

-94.7

1.7

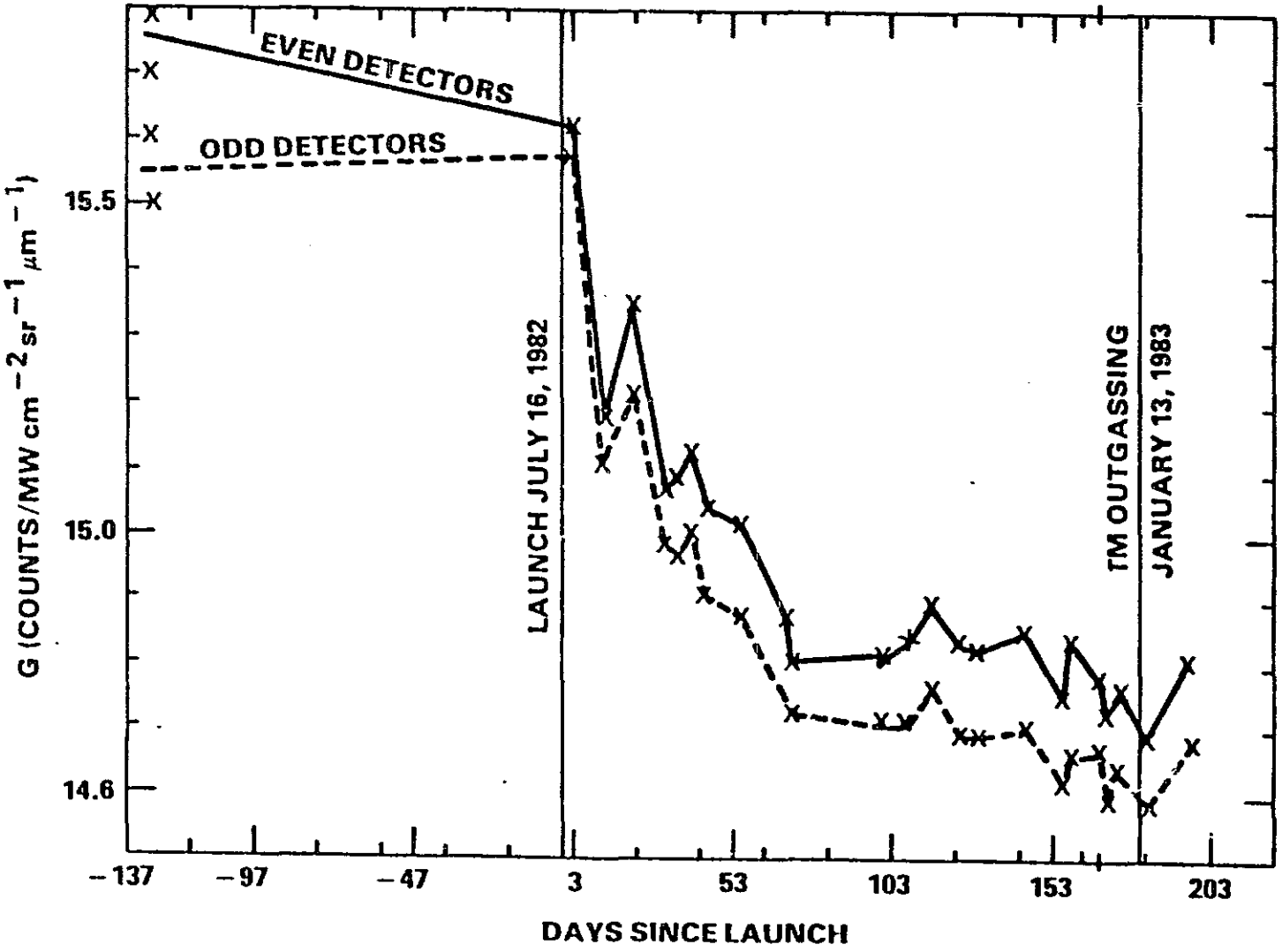
POSTLAUNCH TM LANDSAT-4 RADIOMETRIC CALIBRATION

BETWEEN-LINE VARIABILITY OF IC PULSE
TM4, CHANNEL 9, LAMP 100, D.C., NOVEMBER 2, 1982

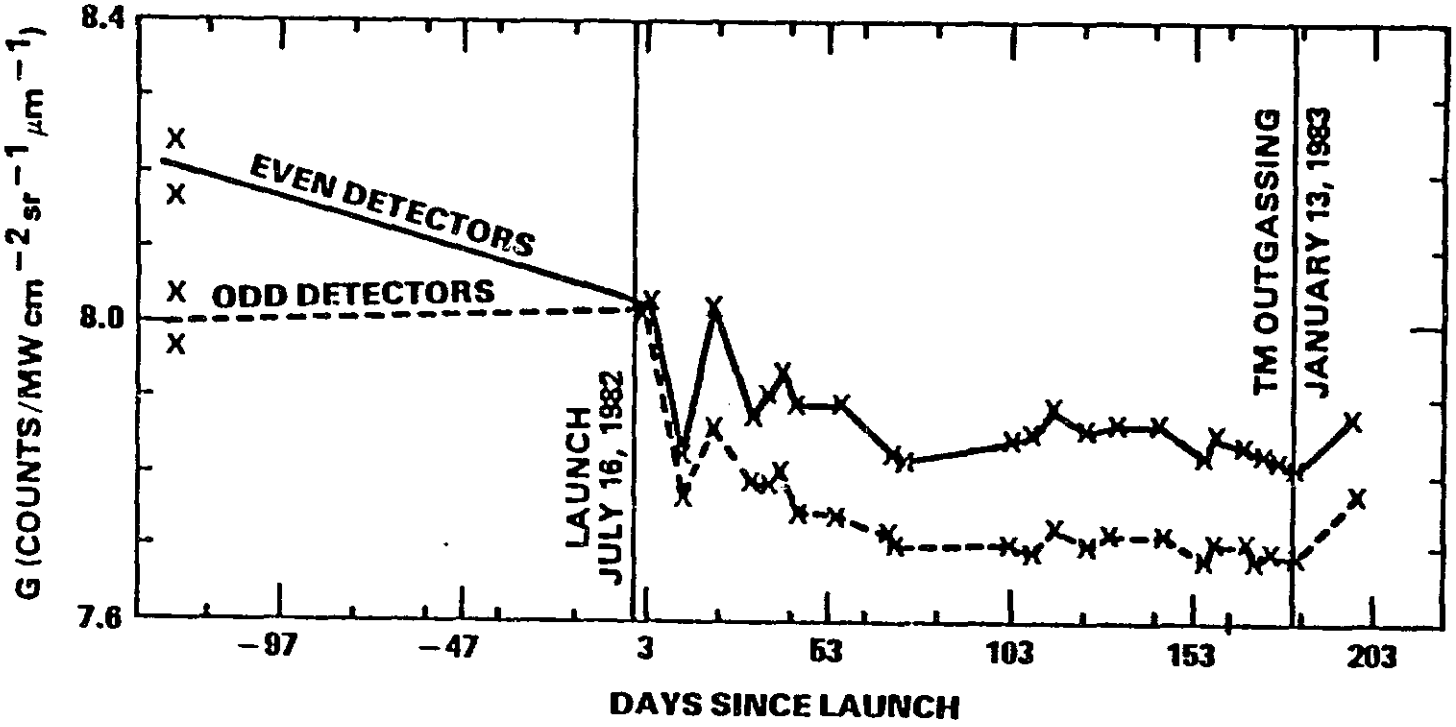


EXPECTED
DROOP
FWD-REV= D
Δ = 90.15
-89.9
.25

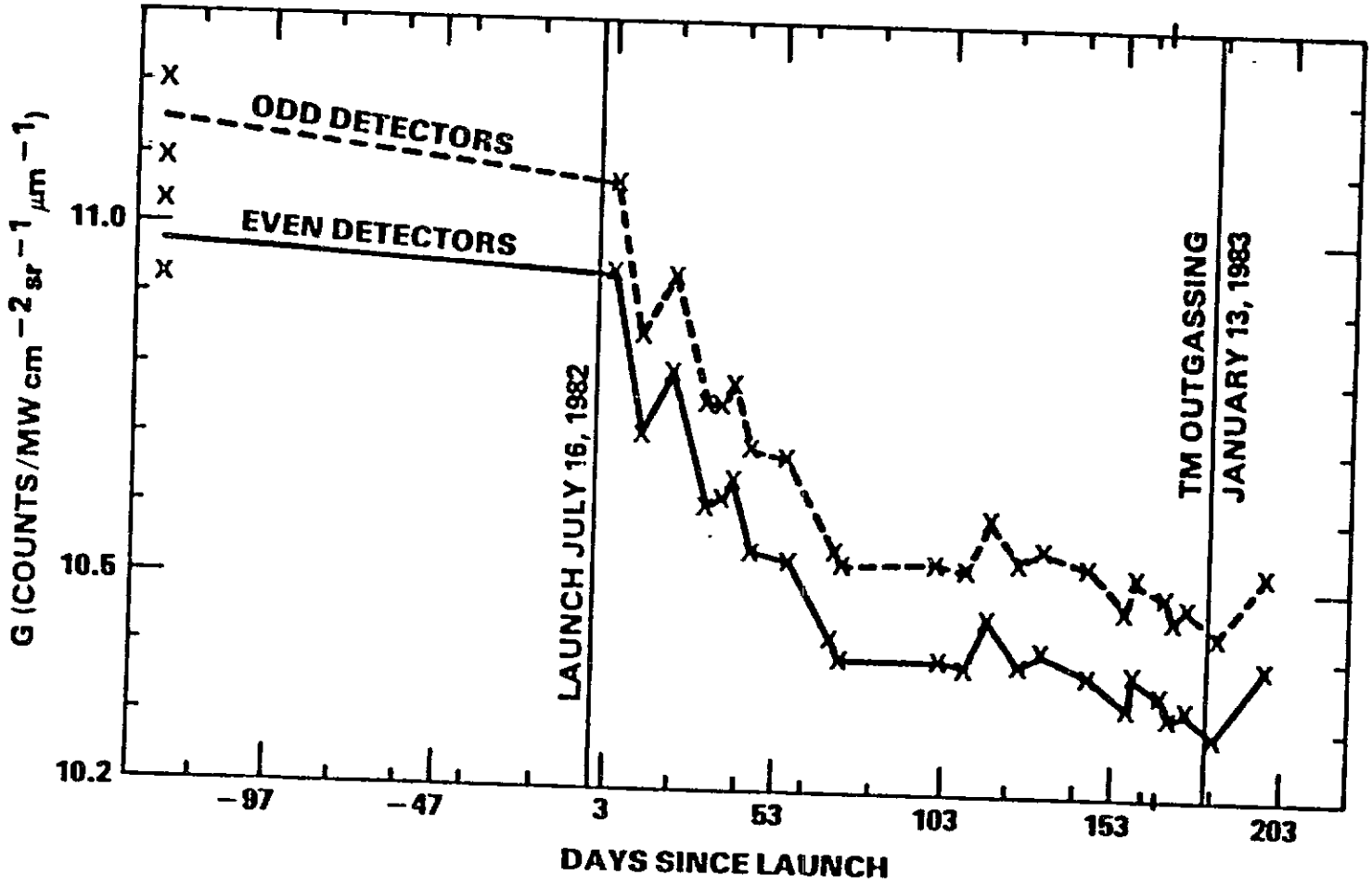
POSTLAUNCH RADIOMETRIC CALIBRATION—TM LANDSAT-4
TM1 GAIN IN COUNTS/SPECTRAL RADIANCE AS A FUNCTION OF TIME



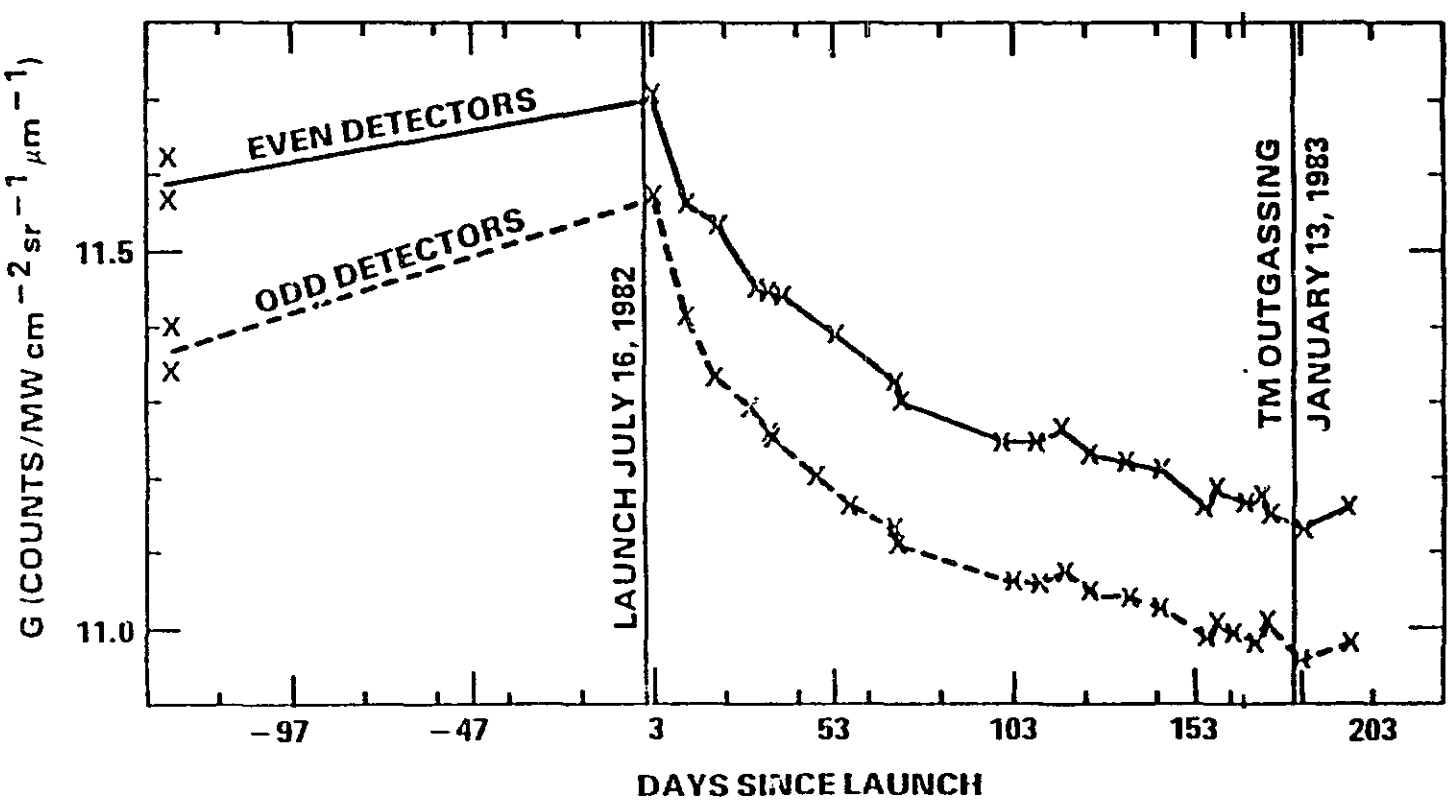
POSTLAUNCH RADIOMETRIC CALIBRATION—TM LANDSAT-4
TM2 GAIN IN COUNTS/SPECTRAL RADIANCE AS A FUNCTION OF TIME



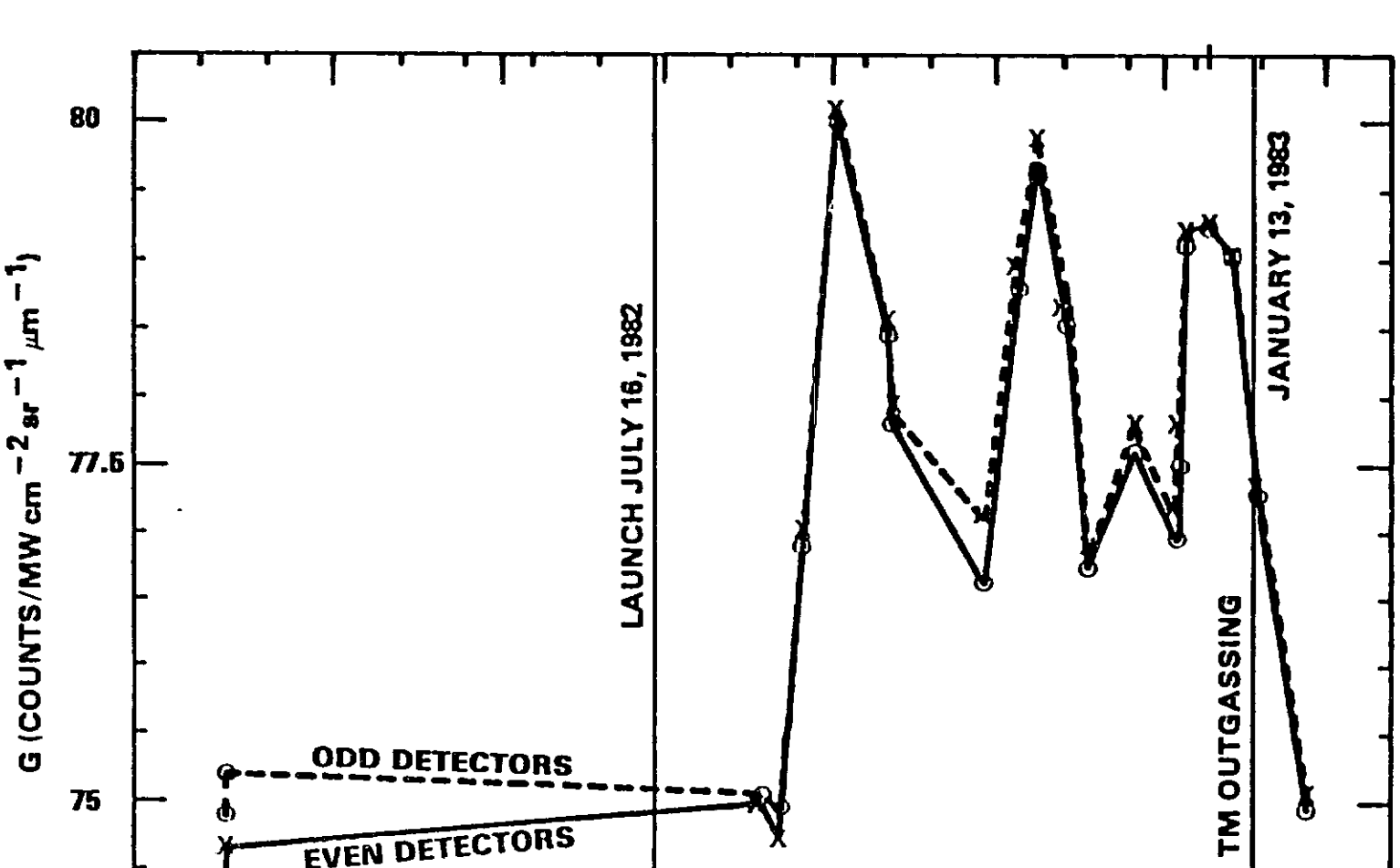
POSTLAUNCH RADIOMETRIC CALIBRATION—TM LANDSAT-4
TM3 GAIN IN COUNTS/SPECTRAL RADIANCE AS A FUNCTION OF TIME



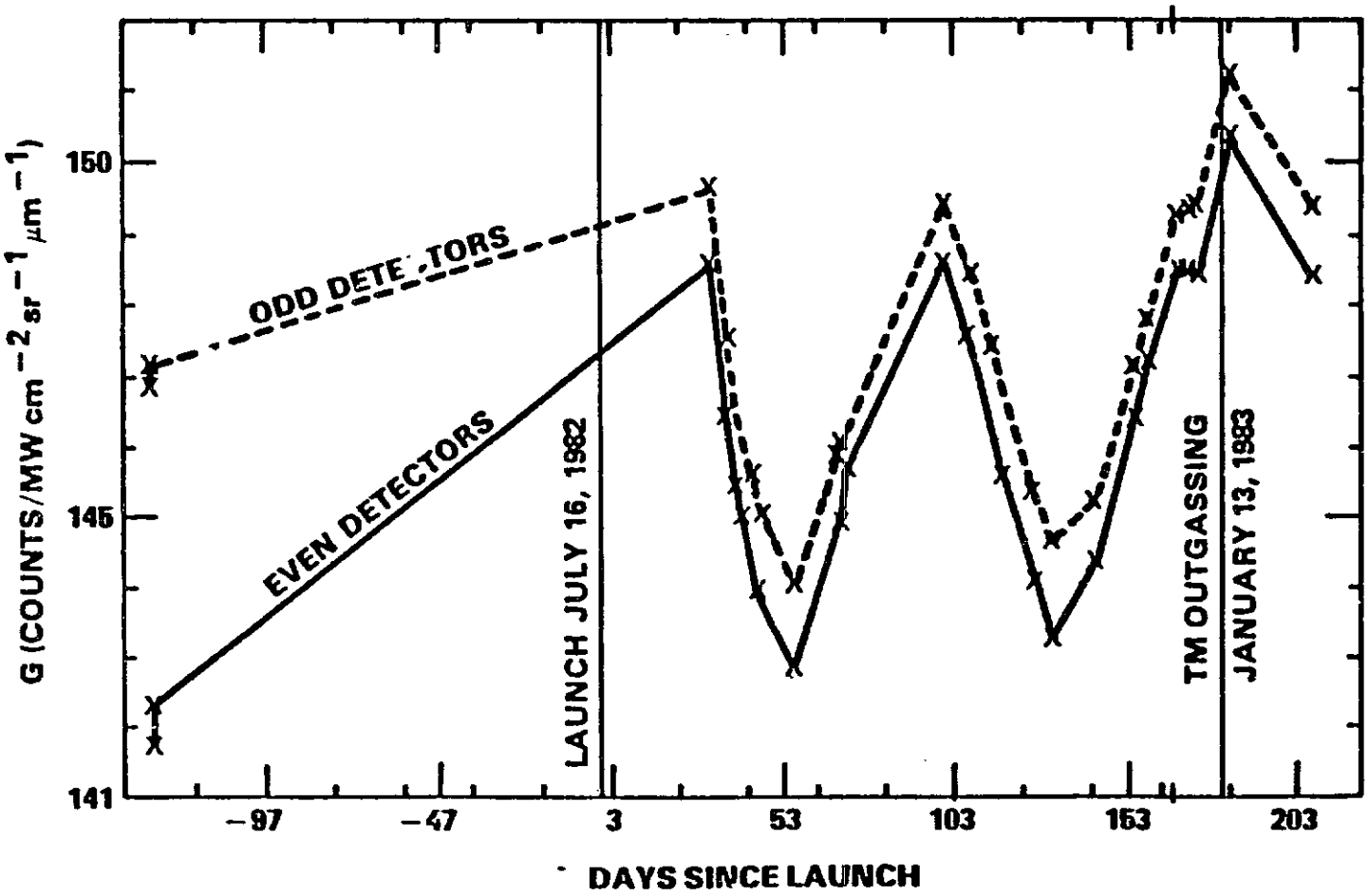
POSTLAUNCH RADIOMETRIC CALIBRATION—TM LANDSAT-4
TM4 GAIN IN COUNTS/SPECTRAL RADIANCE AS A FUNCTION OF TIME



POSTLAUNCH RADIOMETRIC CALIBRATION—TM LANDSAT-4
TM GAIN IN COUNTS/SPECTRAL RADIANCE AS A FUNCTION OF TIME



POSTLAUNCH RADIOMETRIC CALIBRATION—TM LANDSAT-4
TM7 GAIN IN COUNTS/SPECTRAL RADIANCE AS A FUNCTION OF TIME



PRELAUNCH LANDSAT-4 TM COHERENT NOISE (DIGITAL COUNTS)

CHANNEL NUMBER	PEAK-TO-PEAK COHERENT NOISE AT 32.7 KHz (COUNTS)					
	BAND 1	BAND 2	BAND 3	BAND 4	BAND 5	BAND 7
1	0.75					
2	0.69					
3	0.75					
4	—		0.23	0.22		
5	0.56		0.41		0.44	
6	1.06			0.31	0.50	
7	0.38					
8	0.72		0.63	0.47		
9	0.56					
10	0.69				0.44	
11	1.00					
12	0.25					
13	0.56			0.50		
14	0.50					
15	0.60				0.60	
16	1.00		0.53			

NOTES:

DATA MEASURED PEAK TO PEAK WITH BACKGROUND SUBTRACTED IN DIGITAL COUNTS.

DATA FROM FIRST REVERSE SCAN OF FLOODING LAMP DATA (52 SAMPLES PER CHANNEL) MARCH 9, 1982.

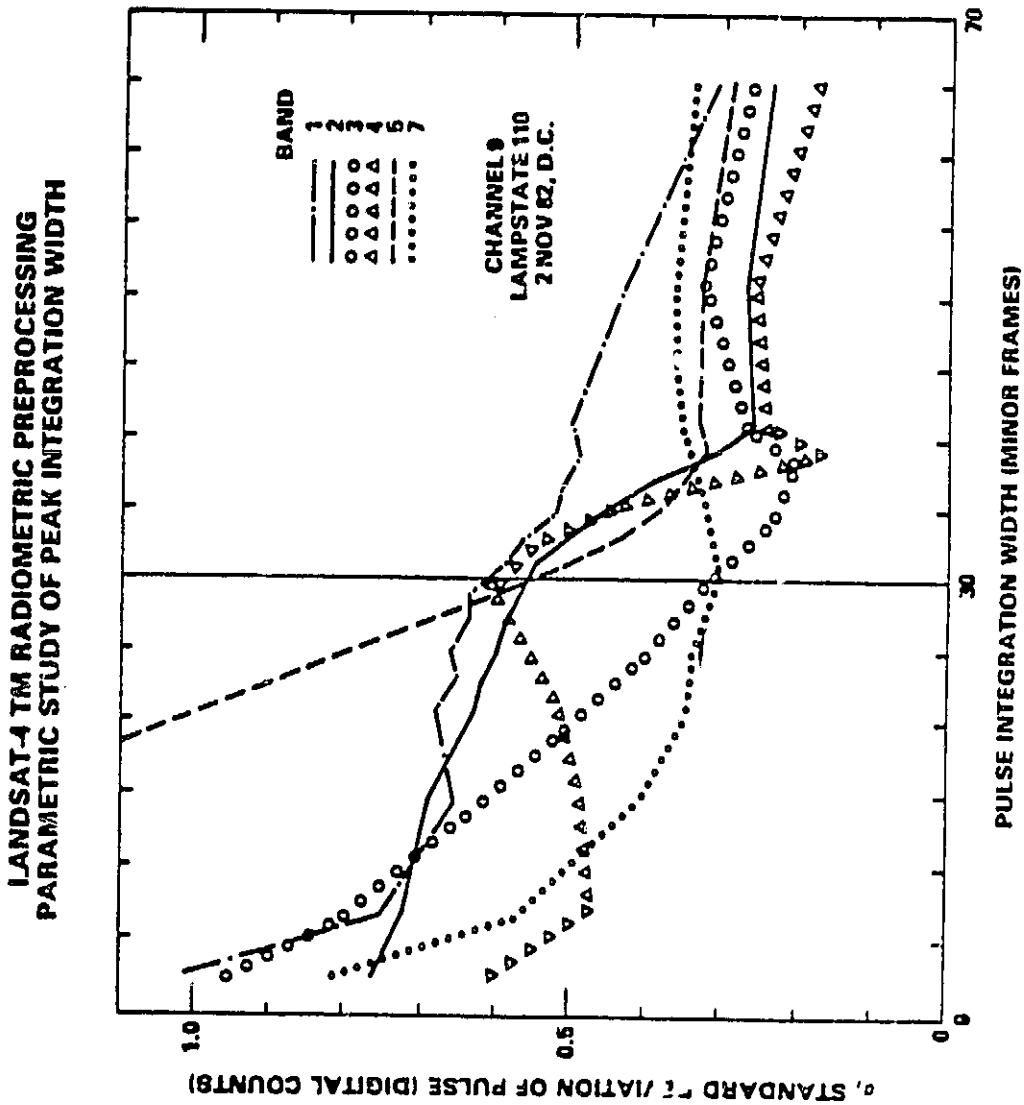
IN-ORBIT LANDSAT-4 TM RADIOMETRIC COHERENT NOISE (DIGITAL COUNTS)

Channel No.	Peak-to-Peak Coherent Noise at 32 KHZ (Counts)					
	Band 1	Band 2	Band 3	Band 4	Band 5	Band 7
1	.54	.08	.09	.28	.25	.16
2	.98	.13	.13	.39	.50	.28
3	.74	.07	.07	.42	—	.20
4	.03	.15	.86	.77	.19	.37
5	.83	.15	.20	.76	.33	.35
6	1.02	.16	.19	.49	.25	.21
7	.39	.10	.15	.58	.59	.46
8	.93	.00	.80	.70	.34	.29
9	.44	.08	.16	.43	.38	.25
10	.33	.14	.08	.35	.19	.28
11	.54	.13	.17	.37	.29	.18
12	.47	.13	.10	.35	.41	.31
13	.52	.05	.21	.43	.20	.26
14	.76	.00	.12	.28	.25	.34
15	.57	.06	.09	.34	.32	.18
16	1.43	.06	.35	.37	.49	.20

Data Measured Peak-to-Peak, With Background Subtracted, in Digital Counts
Data From Scene W023036 ID = 4__0037__16__033 (22 Aug 82) Memphis

POSTLAUNCH RADIOMETRIC CALIBRATION — TM LANDSAT-4
SACRAMENTO, CALIFORNIA DECEMBER 31, 1982
SUM (S_4) OF NET IC STATES (111-100-010-001)

		TM 1	TM 2	TM 3	TM 4	TM 5	TM 7
CHANNEL	1	−0.197	−0.481	−0.713	−3.034	−1.035	−1.689
	2	−0.039	−0.297	−0.563	−1.594	−0.792	−1.643
	3	−0.439	−0.854	−0.806	−2.598	—	−0.445
	4	−0.106	−0.100	−0.071	−1.644	0.153	−0.360
	5	−0.385	−1.220	−0.716	−2.333	0.019	−0.381
	6	0.005	−0.962	−0.436	−2.397	−0.051	−0.463
	7	0.085	−1.409	−0.697	−3.466	0.169	−0.005
	8	0.027	−0.829	−0.054	−1.469	0.108	−0.512
	9	−0.226	−1.068	−0.686	−1.972	−0.011	−0.345
	10	−0.156	−0.987	−0.379	−3.898	0.160	−0.468
	11	0.054	−1.420	−0.606	−2.117	−0.020	−0.409
	12	−0.144	−0.896	−0.685	−2.135	0.037	−0.554
	13	−0.100	−0.869	−0.631	−2.624	−0.206	−0.496
	14	−0.377	−1.087	−0.549	−2.686	0.018	−0.490
	15	−0.095	−1.392	−0.761	−0.836	−1.022	−1.522
	16	−0.010	−0.796	−0.311	−2.264	−1.008	−1.907
	MEANODD	−0.163	−1.089	−0.698	−2.373	−0.301	−0.859
	MEANEVN	−0.100	−0.727	−0.378	−2.248	−0.159	−0.800
	MEANALL	−0.132	−0.908	−0.538	−2.310	−0.226	−0.729
	MEANODD SD	0.188	0.337	0.065	0.787	0.509	0.604
	MEANEVN SD	0.131	0.324	0.225	0.781	0.464	0.609
	MEANALL SD	0.160	0.370	0.230	0.760	0.473	0.590

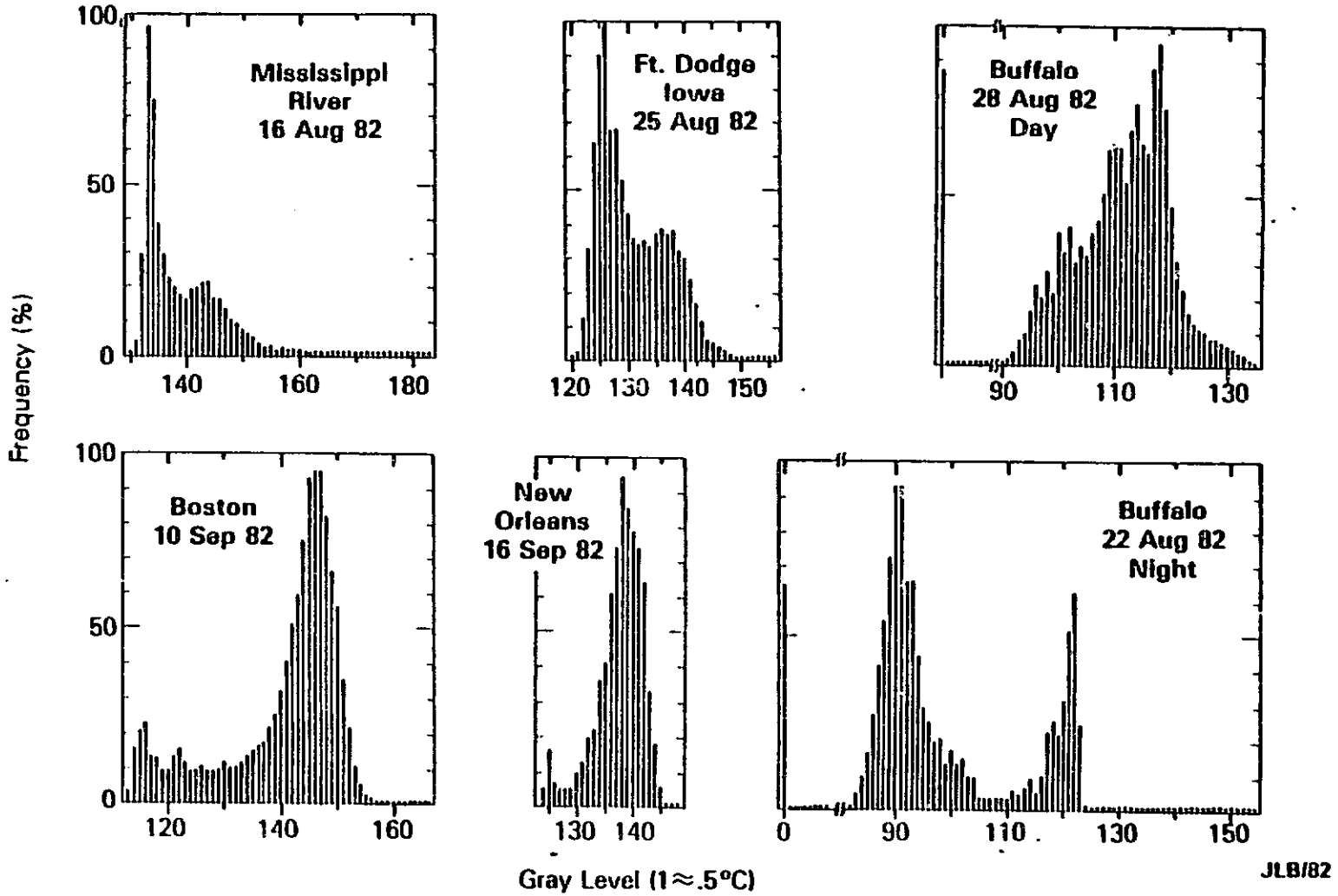


PERCENT IMPROVEMENT IN STANDARD DEVIATION OF INTERNAL CALIBRATION PULSE WITH PARAMETER CHANGES

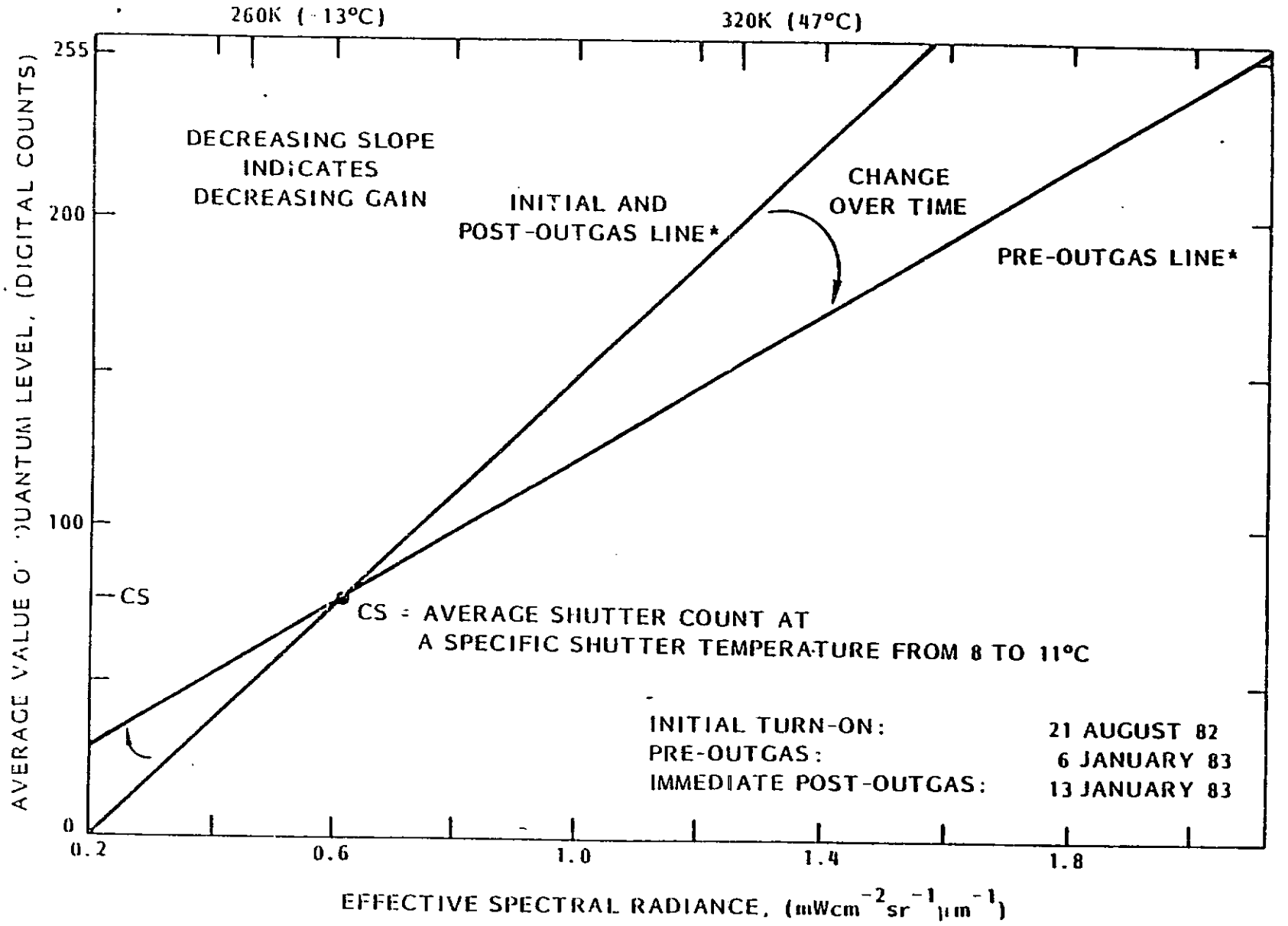
IC Lamp Configuration	ΔSDP% by Band L-4 TM/PF for ODD Channels					
	1	2	3	4	5	7
1 (1) 1	-69	65	-69	-14	53	3
1 (1) 0	[68]	[123]	4	[76]	14	3
1 0 1	49	-5	38	[360]	4	8
0 (1) 1	[136]	[147]	7	[107]	29	3
1 0 0	48	7	15	[284]	12	2
0 (1) 0	[122]	[124]	-9	[57]	24	26
0 0 1	- 9	0	18	29	20	13
0 0 0	3	1	-1	1	7	1

See Table 24, Barker, Abrams, Ball and Leung

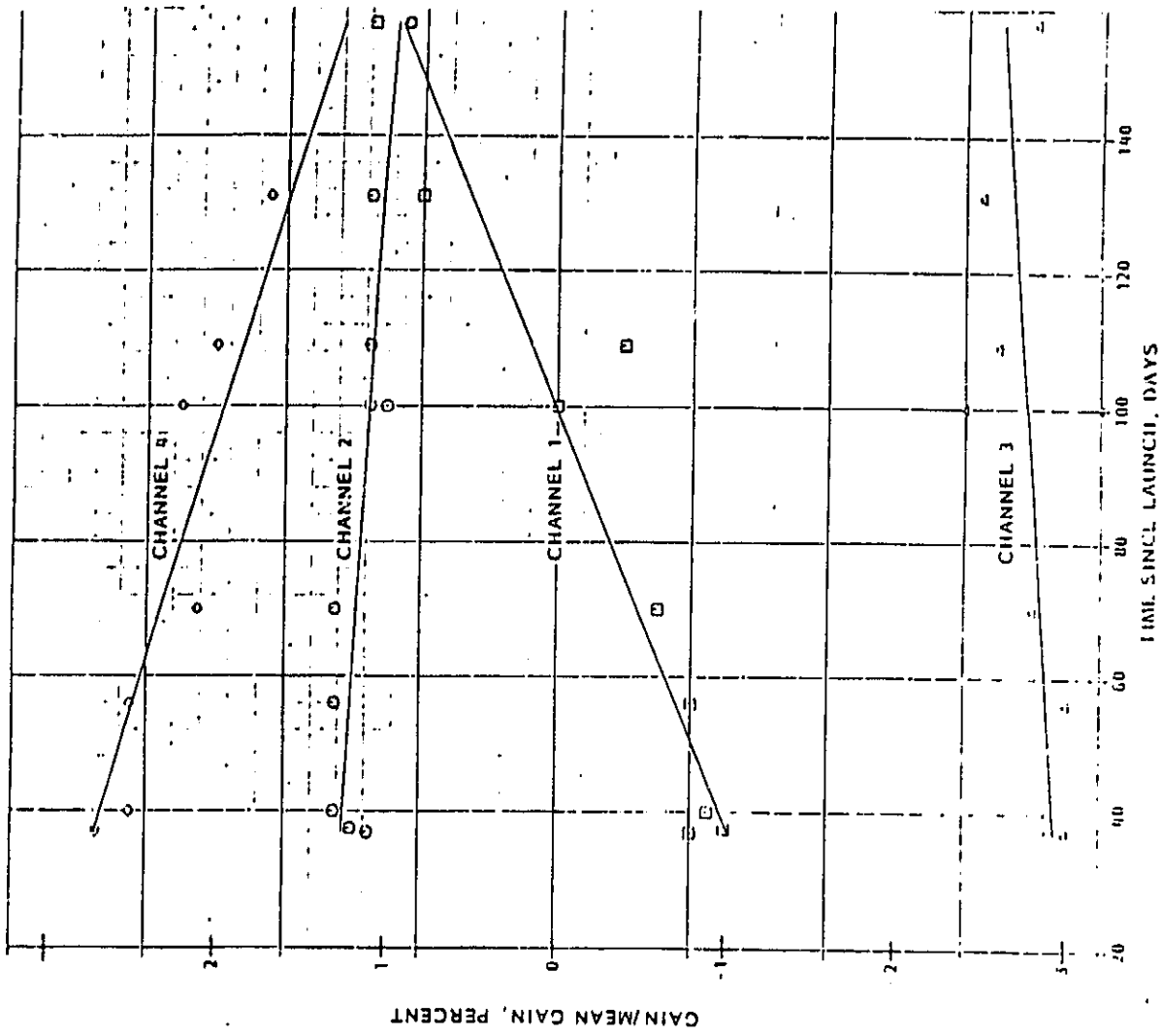
TM Thermal Band Histograms



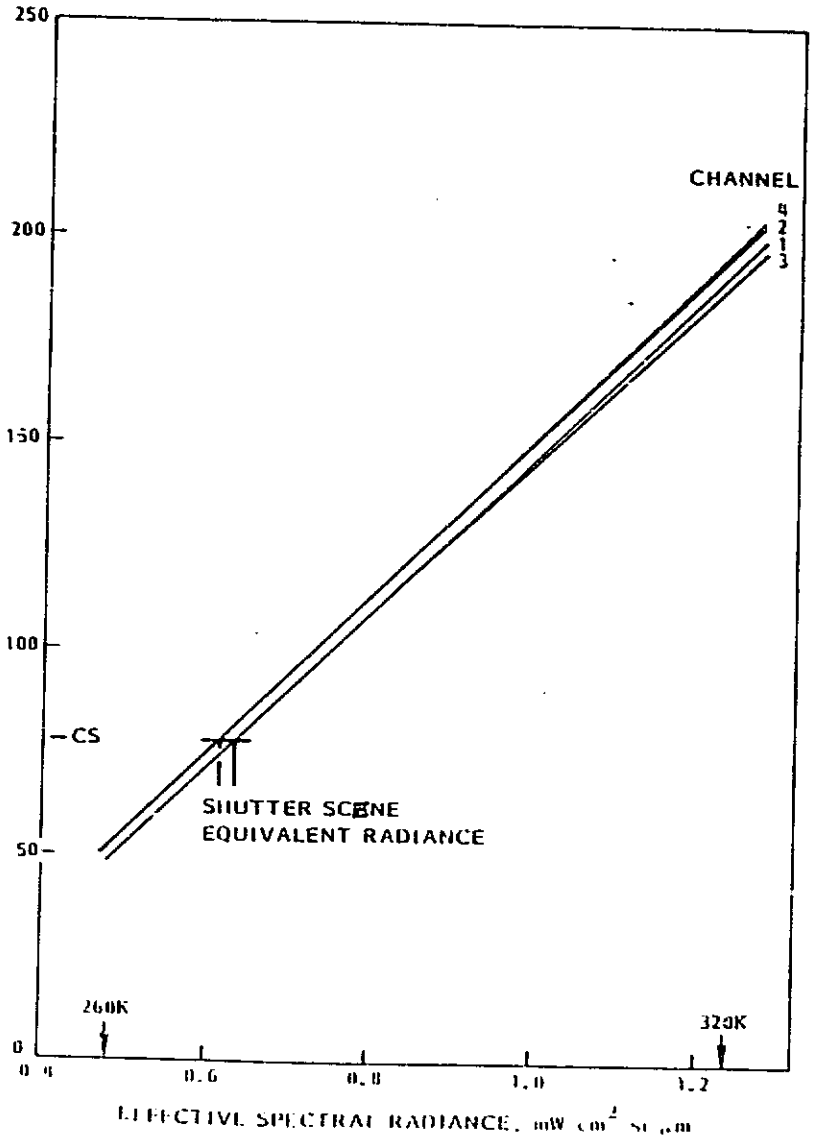
Thermal Band Gain Change with Time



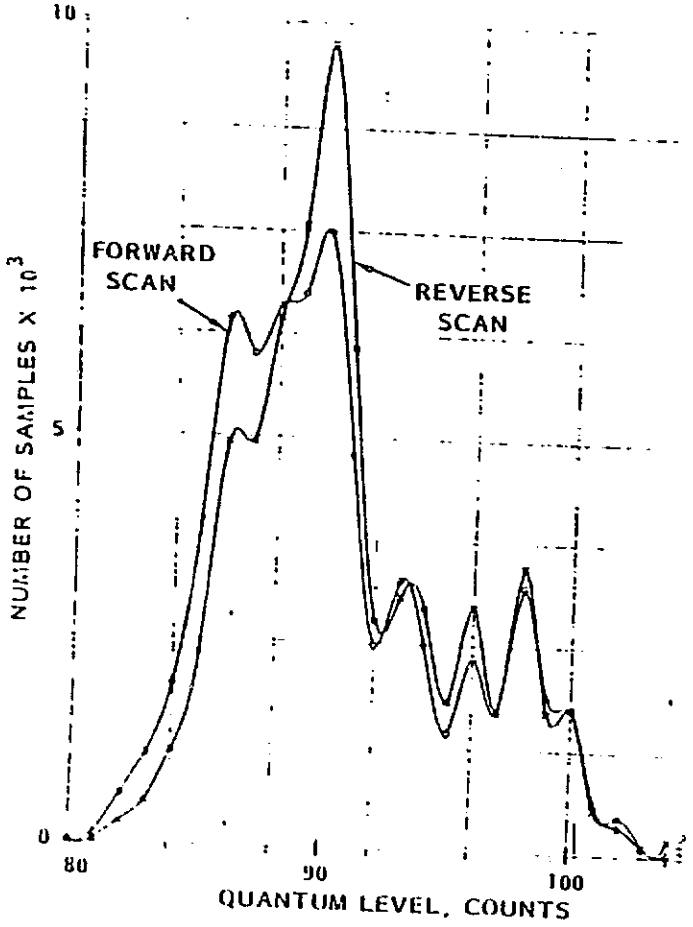
Relative Internal Gain Versus Time



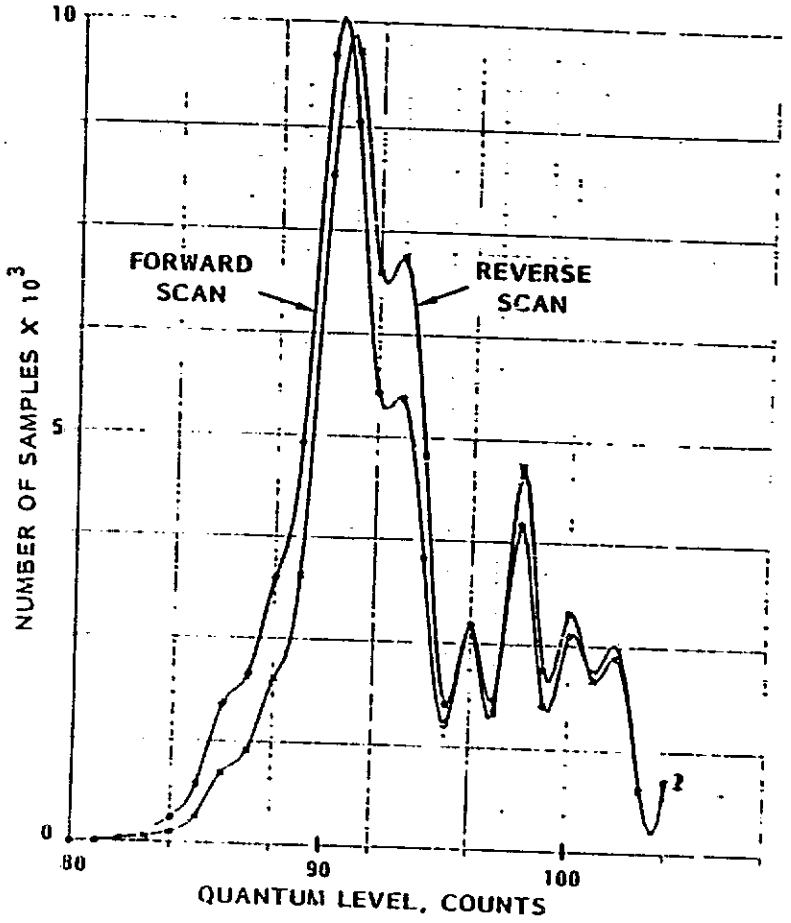
Thermal Band Output Versus Input Estimated from Calibration Data with Channel-to-Channel Adjustments from Buffaio Scene



Frequency Histogram, Banded Portion, Channel 1

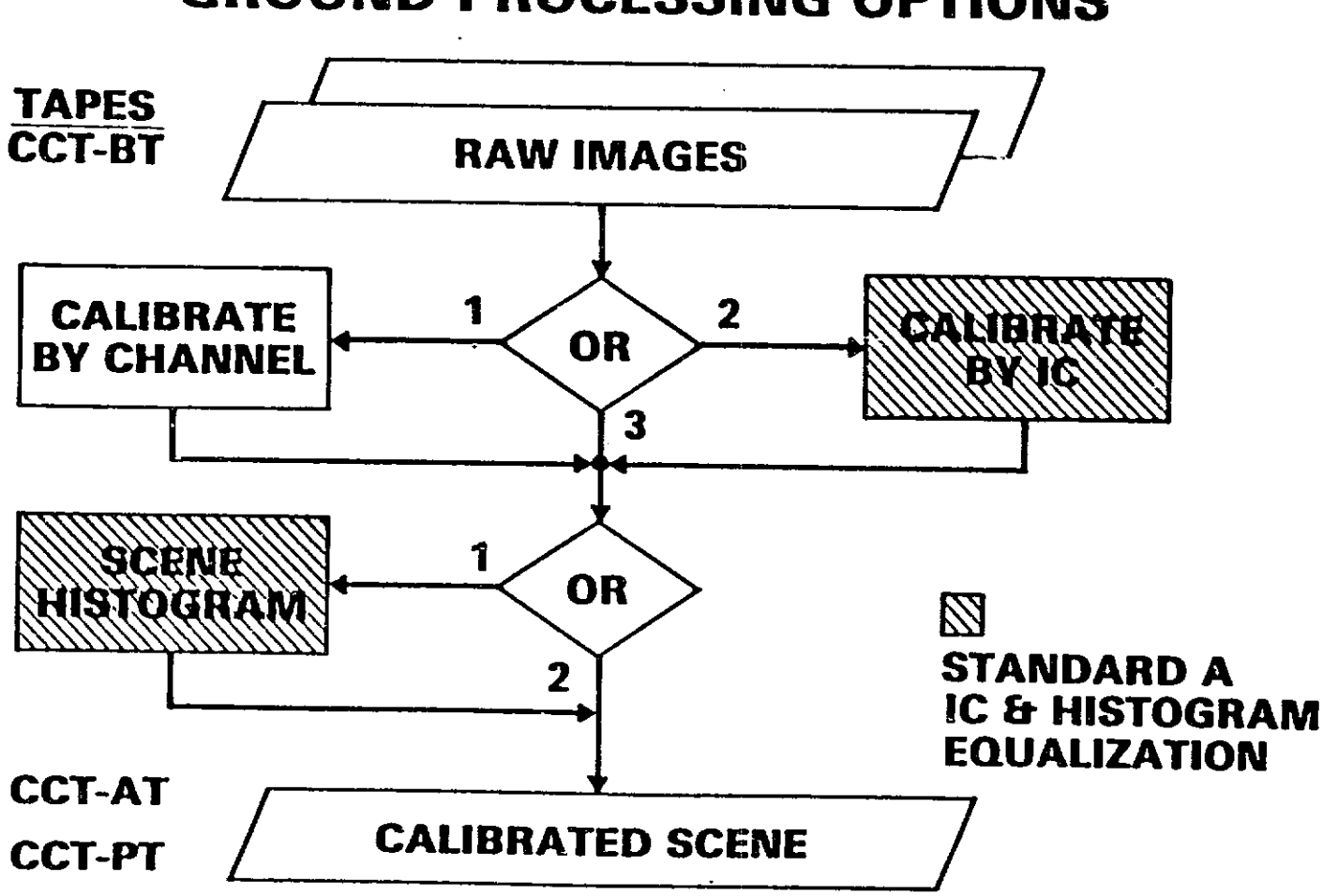


Frequency Histogram, Banded Portion, Channel 4



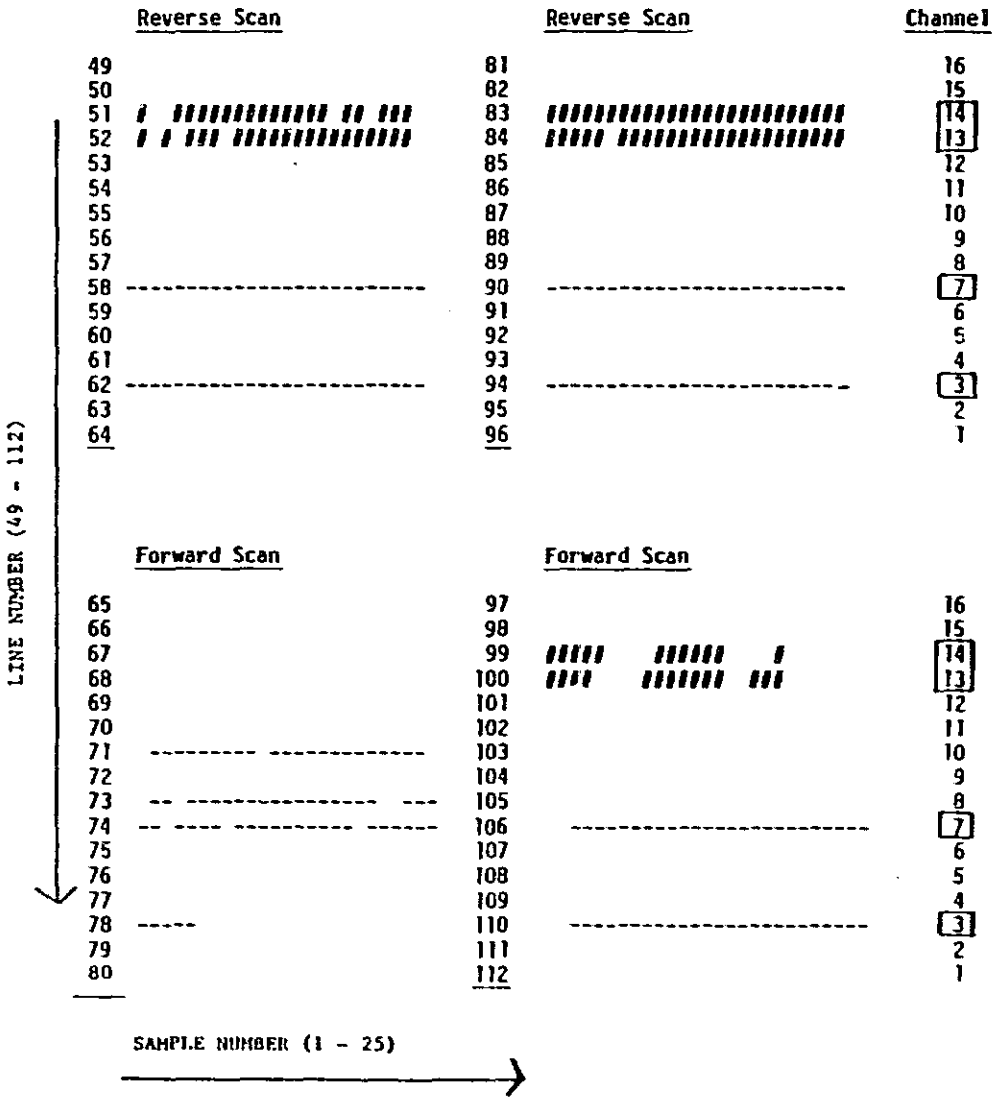
LANDSAT-4 TM RADIOMETRY

SCROUNGE-ERA
GROUND PROCESSING OPTIONS



DIFFERENCE IMAGE OF TWO CALIBRATED TM IMAGES OF BAND 2
NOMINAL PRE-LAUNCH VS INTERNAL CALIBRATOR

MEMPHIS TN (ID = 40037-16033) 22 AUG 1982 # = H
START LINE (SL) = 3001, START SAMPLE (SS) = 2001 - = -1 or -2



LANDSAT-4 TM — CCT-AT — NOMINAL CALIBRATION — BAND 2

MEMPHIS TN (ID = 40037-16033) 22 AUG 1882
START LINE (SL) = 3001, START SAMPLE (SS) = 2001
SCROUNGE ERA (1982-1983)

SAMPLE / LINE	641	642	643	644	645	646	647	648	649	650	651	652	653	654	655	656	657	658	659	660	661	662	663	664	665	
13	38	38	38	38	38	39	39	39	39	49	71	71	72	72	72	70	68	61	44	38	39	37	37	37	33	16
14	38	38	38	38	38	38	39	39	40	53	72	72	74	74	73	72	73	70	64	46	38	40	38	37	35	15
15	39	39	39	38	39	39	39	39	42	60	76	75	74	75	74	75	74	72	67	49	38	39	38	37	36	14
16	39	38	39	39	39	39	39	39	43	63	76	75	74	76	76	75	74	72	71	55	38	40	39	38	37	13
17	38	38	38	39	38	38	39	39	43	66	72	73	74	75	73	74	74	72	71	56	38	38	37	38	35	12
18	38	38	38	38	38	39	38	39	45	67	72	72	73	74	74	73	76	74	72	58	38	39	39	37	38	11
19	38	38	39	39	38	39	41	41	51	73	74	75	76	75	74	75	75	73	72	58	37	39	38	37	37	10
20	39	39	39	39	39	39	39	41	51	72	74	74	74	73	74	74	74	74	71	60	40	39	39	38	38	9
21	39	39	39	39	39	39	39	41	53	72	73	73	76	75	73	75	75	75	72	64	40	40	39	38	37	8
22	38	37	37	37	38	38	38	41	56	73	72	73	74	72	73	73	73	71	71	69	42	37	40	37	37	7
23	38	39	38	38	39	38	41	42	61	72	74	74	73	74	74	74	74	74	72	67	45	39	38	38	37	6
24	38	38	38	39	39	39	39	41	61	73	73	73	74	74	74	73	74	73	72	70	58	37	39	39	38	5 ←
25	38	38	38	38	39	39	39	41	61	73	73	73	74	74	74	73	74	73	72	70	58	37	39	39	38	4
26	39	39	39	39	39	39	39	45	67	72	73	72	74	74	73	74	75	73	73	70	60	39	39	38	36	3
27	39	38	41	38	40	41	42	42	68	69	72	73	74	73	77	76	75	75	74	75	61	46	41	42	39	2
28	40	39	39	40	40	39	41	43	66	73	74	73	76	76	77	77	77	77	76	74	52	39	42	40	39	1
29	27	27	28	28	27	27	27	27	27	28	28	28	28	27	28	28	29	28	28	29	31	38	38	38	38	16
30	27	27	26	27	27	26	27	27	27	27	27	27	28	27	28	27	29	29	28	28	29	29	29	28	38	15
31	28	29	28	27	27	27	28	28	30	28	28	28	28	28	28	29	30	29	29	30	32	31	31	29	38	14
32	27	30	27	27	27	27	27	28	30	30	31	28	28	28	28	28	28	28	28	30	30	31	31	31	38	13
33	28	28	27	27	27	27	27	27	27	28	28	27	27	28	28	29	28	28	29	30	28	30	30	32	38	12
34	27	28	27	27	27	28	28	27	28	29	28	28	29	28	28	30	30	30	30	30	30	31	30	31	38	11
35	28	28	28	28	27	28	28	28	30	28	28	28	28	29	27	28	29	30	30	28	29	31	32	31	41	10
36	27	28	28	27	28	30	28	28	28	28	29	30	28	28	28	28	30	28	28	31	31	31	35	42	43	9
37	28	28	28	28	28	30	29	29	29	30	30	28	28	28	28	29	30	29	30	33	30	34	40	48	48	8
38	26	27	27	27	27	28	28	27	28	27	27	27	28	28	27	28	29	31	30	27	34	43	43	44	46	7
39	27	28	29	27	28	30	29	28	27	29	27	29	28	29	27	29	30	33	37	43	47	45	46	47	46	6
40	28	27	27	29	29	30	29	30	29	29	28	28	29	29	30	33	35	38	42	45	48	45	42	41	44	5 ←
41	28	27	27	29	29	30	29	30	29	29	28	28	29	29	30	33	35	38	42	45	48	45	42	41	44	4
42	27	27	27	28	27	28	27	27	28	29	29	35	42	44	45	45	46	44	46	45	46	43	41	39	40	3
43	28	28	28	30	28	29	30	31	33	39	39	43	46	46	45	46	43	44	40	39	40	41	39	39	40	2
44	27	27	29	28	30	29	30	30	33	42	45	43	45	45	45	42	38	36	31	30	33	34	33	38	41	1
45	38	39	37	39	39	38	39	39	39	39	42	46	71	75	76	76	76	78	76	76	73	72	66	42	39	16
46	39	38	38	39	40	39	41	39	39	41	41	42	61	73	74	73	77	77	76	73	73	74	70	63	40	15
47	39	39	39	39	39	39	40	40	39	39	42	42	58	76	75	77	77	79	78	76	75	75	71	67	39	14
48	39	39	39	39	39	39	39	39	39	39	41	40	41	58	75	76	76	79	79	77	78	76	76	74	52	40	13
49	38	38	39	39	39	39	39	38	39	40	40	40	46	78	75	75	76	77	76	77	75	74	72	54	38	12
50	39	39	39	38	39	38	39	38	39	39	41	39	42	42	76	76	76	76	77	76	78	73	76	62	39	11
51	38	38	39	39	39	38	39	39	39	41	42	41	41	56	77	77	77	78	79	76	75	74	75	66	42	10
52	39	39	39	39	39	39	39	39	39	40	40	40	40	47	72	77	75	77	78	77	75	73	74	71	46	9
53	38	39	39	39	39	39	39	39	39	38	39	39	40	40	63	78	76	77	78	77	76	76	76	72	50	8
54	37	38	38	38	38	38	40	37	38	38	38	38	40	40	42	82	75	75	75	75	74	74	74	72	74	58	7
55	39	38	38	38	38	38	38	38	38	39	39	40	40	40	41	65	67	77	77	76	76	75	75	75	74	65	6
56	38	39	39	38	37	38	39	38	38	40	40	39	40	41	40	56	77	76	76	76	78	74	73	75	72	8 ←
57	38	39	39	38	37	38	39	38	38	40	40	39	40	41	40	54	77	76	76	76	75	74	73	75	72	4
58	40	38	37	39	39	38	38	39	40	39	39	39	39	39	41	61	75	76	75	76	76	75	74	75	73	3
59	39	40	38	38	38	40	39	40	39	38	39	40	38	41	40	61	63	78	72	77	75	76	77	75	73	2

SWEEP: FORWARD / REVERSE / FORWARD — CHANNEL

An example of TM data for spectral band 2 in CCT-AT format, unblocked. Note the duplication of DNs for channel 5 to replace defective data in channel 4. Note also the difference in DNs between forward and reverse scans resulting from the scan offset.

LANDSAT-4 TM — CCT-AT— IC BAND 2

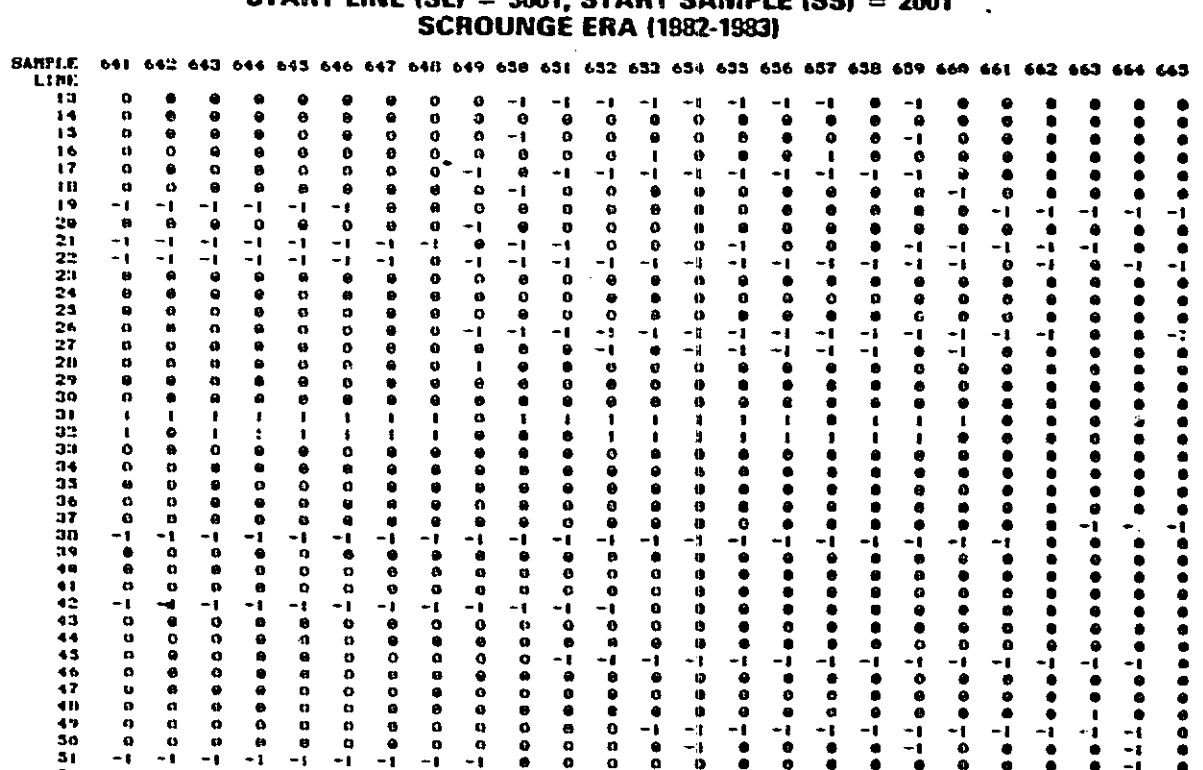
MEMPHIS TN (ID = 40037-16033) 22 AUG 1982
START LINE (SL) = 3001, START SAMPLE (SS) = 2001
SCROUNGE ERA (1982-1983)

SAMPLE LINE	641	642	643	644	645	646	647	648	649	650	651	652	653	654	655	656	657	658	659	660	661	662	663	664	665
13	38	38	38	38	38	39	39	39	39	38	72	72	73	73	73	71	69	61	46	38	39	37	37	37	33
14	38	38	38	38	38	38	39	39	40	53	72	72	74	74	73	72	73	70	66	46	38	40	38	37	36
15	39	39	39	38	39	39	39	39	42	61	76	78	74	75	74	75	74	72	68	49	38	39	38	37	36
16	39	38	39	39	39	39	39	39	43	63	76	78	73	76	76	78	73	72	71	85	38	40	39	38	37
17	38	38	38	39	38	38	39	39	44	66	73	76	75	76	74	78	75	73	72	86	38	38	37	38	33
18	38	38	38	38	38	39	38	39	45	68	72	72	76	74	74	73	75	74	72	39	38	39	39	37	38
19	39	39	40	40	39	40	41	41	51	73	74	75	76	75	74	75	73	73	72	38	38	40	39	38	38
20	39	39	39	39	39	39	39	41	52	72	74	74	74	73	74	74	74	74	71	68	40	39	39	38	38
21	40	40	40	40	40	40	40	42	55	73	74	75	76	75	74	75	75	75	73	65	41	41	40	38	37
22	39	38	38	38	39	39	39	41	57	74	73	74	75	73	74	74	74	72	72	70	42	38	40	38	38
23	38	39	38	38	39	38	41	42	61	72	74	74	73	74	74	74	74	74	72	67	45	39	38	38	37
24	38	38	38	39	39	39	39	41	61	73	73	73	74	74	74	73	74	73	72	70	38	37	39	39	38
25	38	38	38	39	39	39	39	41	61	73	73	73	74	74	74	73	74	73	72	70	50	37	39	39	38
26	39	39	39	39	39	39	39	45	60	73	74	73	75	75	74	75	76	74	74	71	51	37	39	39	37
27	39	38	41	38	40	41	42	42	60	69	72	76	74	76	78	77	76	76	74	76	61	46	41	42	39
28	40	39	39	40	40	39	41	43	65	73	74	75	76	76	77	77	77	77	76	74	62	39	42	40	39
29	27	27	28	28	27	27	27	27	27	28	28	28	28	28	27	28	28	29	28	28	29	31	38	38	38
30	27	27	26	27	27	26	27	27	27	27	27	27	28	27	28	27	29	29	28	28	29	29	29	38	38
31	27	28	27	26	26	26	27	27	38	27	27	27	27	27	27	28	38	27	28	28	38	32	31	31	39
32	26	38	26	26	26	26	26	27	38	38	31	27	27	27	27	27	27	27	27	38	38	31	31	31	38
33	28	28	27	27	27	27	27	27	28	28	27	27	28	28	29	28	28	29	38	28	28	38	38	32	38
34	27	28	27	27	27	28	28	27	28	29	28	28	29	28	28	38	38	28	38	38	28	38	38	31	38
35	28	28	28	28	27	28	28	28	38	28	28	28	28	29	27	28	29	38	38	28	29	31	32	31	41
36	27	28	28	37	28	38	38	28	28	28	28	29	38	28	28	28	38	28	28	31	31	31	35	42	43
37	28	28	28	28	28	38	29	29	29	38	38	28	28	28	28	29	38	29	38	33	38	34	41	46	46
38	27	28	28	28	28	29	29	28	29	28	28	28	29	29	28	29	37	32	31	28	38	43	45	46	46
39	27	28	29	27	28	38	29	28	27	29	27	29	28	29	27	29	38	33	33	37	43	47	45	46	47
40	28	27	27	29	29	38	29	38	29	29	28	28	29	29	38	33	35	38	42	45	45	45	42	41	44
41	28	27	27	29	29	38	29	38	29	29	28	28	29	29	38	33	35	38	42	45	45	45	42	41	44
42	28	28	28	29	28	29	28	28	29	38	38	36	42	44	48	48	44	44	46	48	46	43	41	39	40
43	28	38	28	38	28	29	38	31	33	39	39	43	46	46	48	48	43	44	48	39	48	41	39	39	40
44	27	27	29	28	38	29	38	38	33	42	48	48	48	48	48	42	38	34	31	38	33	34	35	38	41
45	38	39	37	39	39	38	39	39	39	39	43	47	72	76	77	77	77	79	77	77	76	73	67	43	39
46	39	38	38	39	48	38	41	39	39	41	41	42	61	78	74	75	77	77	76	75	78	74	78	45	40
47	39	39	39	39	39	39	48	48	39	39	42	42	58	76	78	77	77	79	78	76	75	78	71	47	39
48	39	39	39	39	39	39	39	39	39	41	40	41	58	78	76	76	79	79	77	78	76	76	73	82	50
49	38	38	39	39	39	39	39	38	39	40	48	48	47	71	76	76	77	78	77	78	76	78	73	35	38
50	39	39	39	38	39	38	39	38	39	39	41	39	42	63	76	76	76	76	78	76	75	73	74	63	39
51	39	39	48	48	48	39	48	48	48	61	42	41	41	56	77	77	77	78	79	76	75	74	75	67	42
52	39	39	39	39	39	39	39	39	39	48	48	48	48	47	72	77	78	77	78	77	78	73	74	71	46
53	38	48	48	48	48	48	48	48	38	48	48	41	41	44	64	78	76	77	78	77	76	78	73	73	50
54	38	39	39	39	39	48	38	39	39	39	39	48	48	42	53	76	76	76	76	78	78	73	73	75	59
55	39	38	38	38	38	38	38	38	39	39	48	48	48	41	45	67	78	78	76	74	78	78	73	74	63
56	38	39	39	38	37	38	39	38	38	48	48	39	48	41	48	56	77	76	76	74	75	74	73	75	72
57	38	39	39	38	37	38	39	38	38	48	48	39	48	41	48	56	77	76	76	76	73	76	73	78	72
58	48	38	39	39	39	38	38	39	48	39	39	39	39	39	41	41	66	77	76	77	75	76	78	76	74
59	49	48	38	38	38	48	39	48	39	38	39	48	38	41	48	41	45	63	78	72	78	76	77	78	76

An example of TM data for spectral band 2 in CCT-AT format, unblocked, internal calibration.

LANDSAT-4 TM – CCT-AT – NOMINAL MINUS IC – BAND 2

MEMPHIS TN (ID = 40037-16033) 22 AUG 1982
START LINE (SL) = 3001, START SAMPLE (SS) = 2001
SCROUNGE ERA (1982-1983)



AN EXAMPLE OF THE DIFFERENCE IMAGE BETWEEN TM DATA PROCESSED USING TWO DIFFERENT CALIBRATION OPTIONS.

BAND-AVERAGE COMPARISON OF DIFFERENT CALIBRATION METHODS

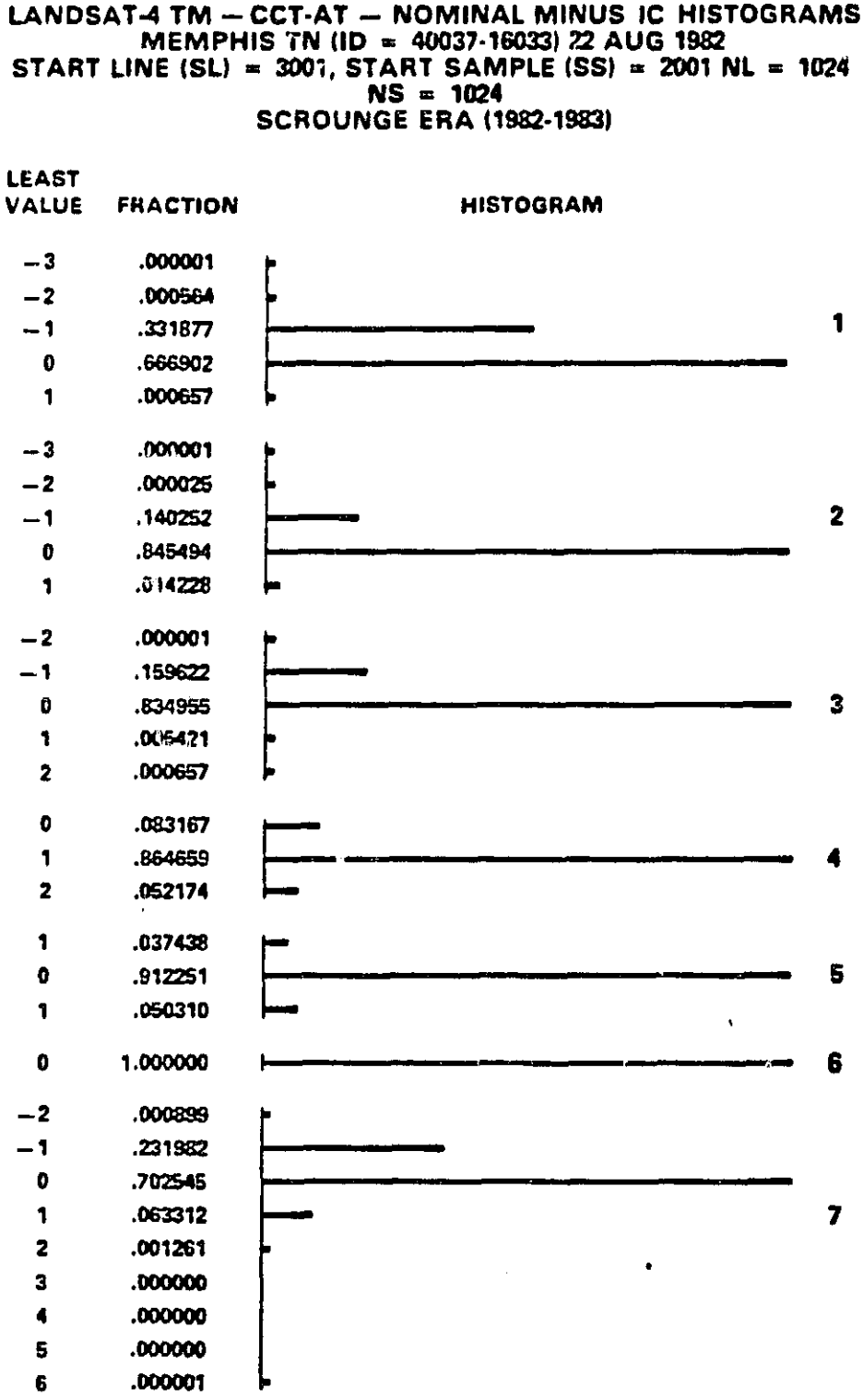
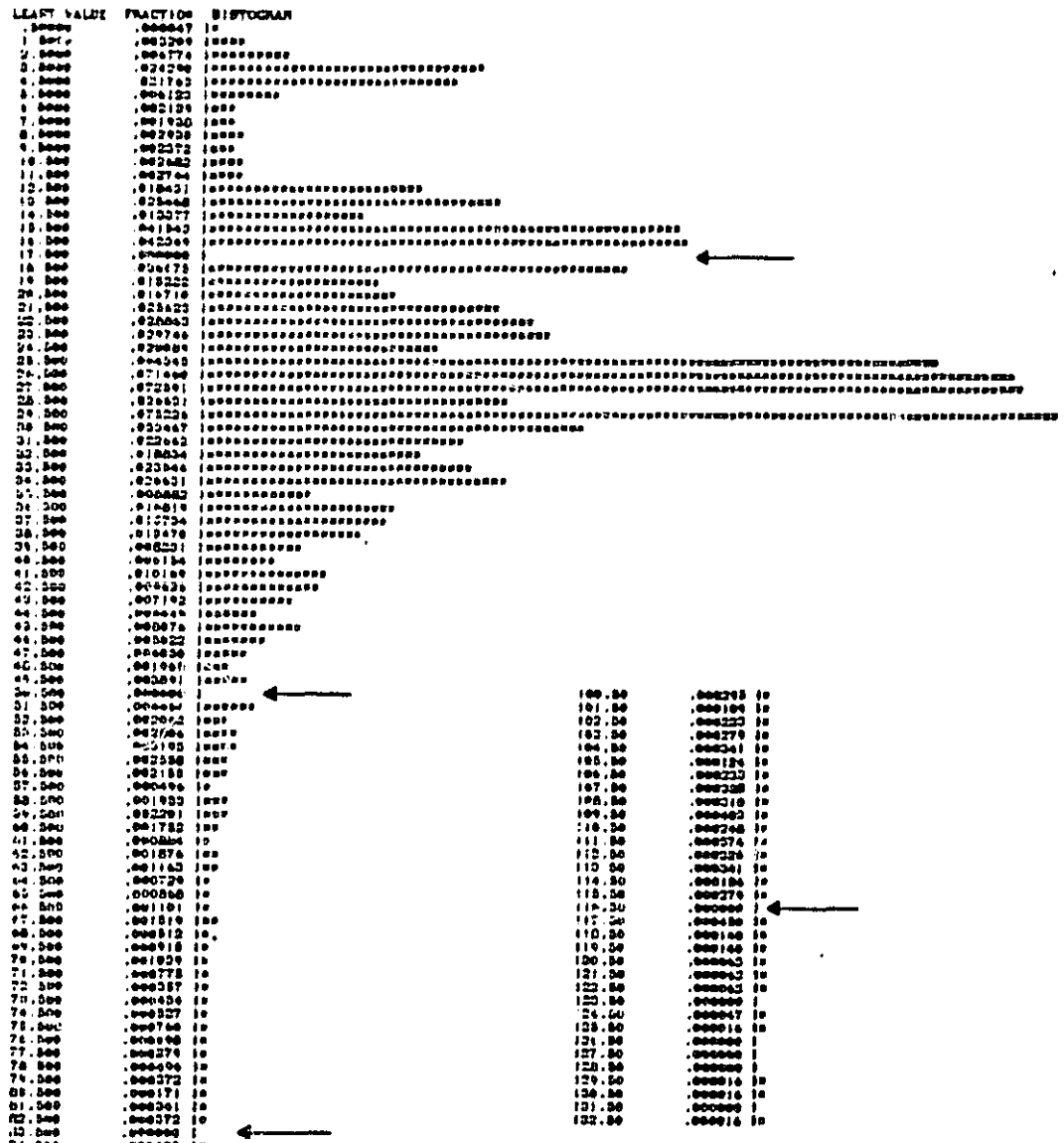


Figure 2-26. Histograms showing the frequency of differences between images produced by two different TM calibration options. Compare with Figures 2-22 to 2-25.

LANDSAT-4 TM – CCT-AT – EMPTY BINS CHANNEL 1 HISTOGRAM

MEMPHIS TN (ID = 40037-16033) 22 AUG 1982

SL = 3001 NL = 63
SS = 2001 NS = 1024

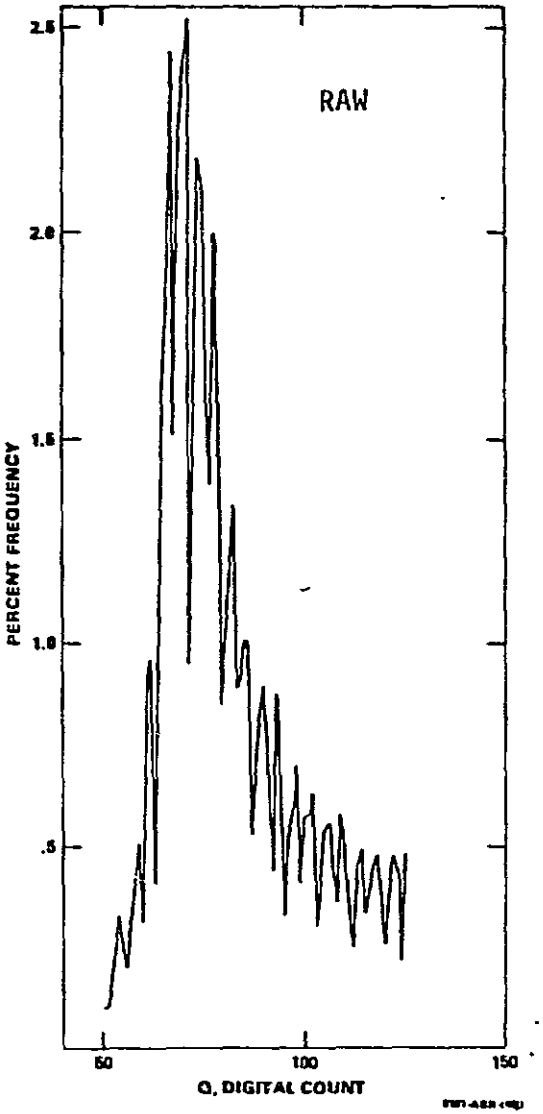


LANDSAT-4 THEMATIC MAPPER
CCT-AT EMPTY BINS

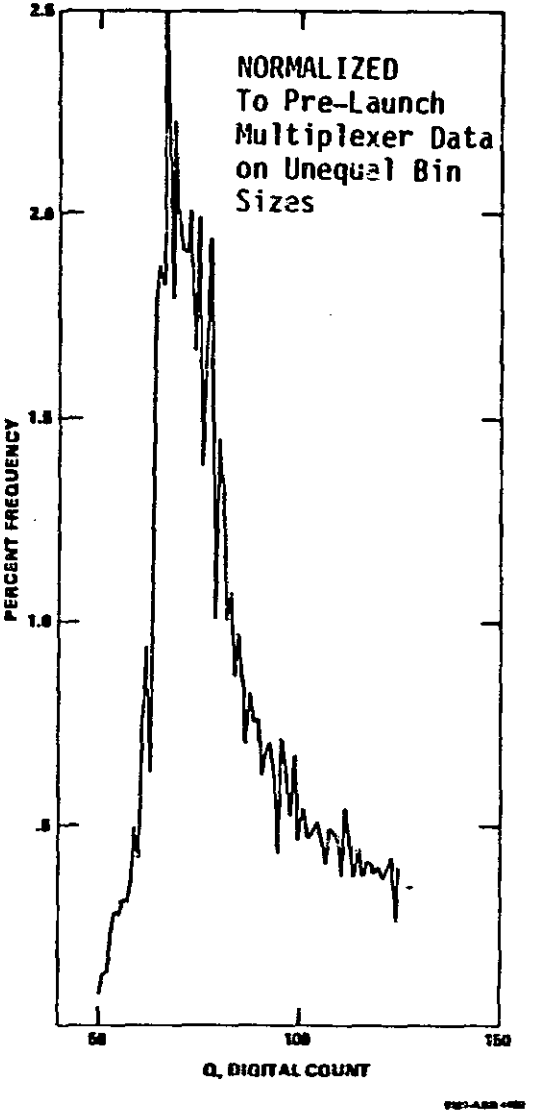
MEMPHIS TN (ID = 40037—16033) 22 AUG 1982
EXAMPLE USING DETECTOR1

BAND	OBSERVED EMPTY BINS	PERIOD
1	79, 132	53
2	29, 74	45
3	39, 94	55
4	39, 117	78
5	47, 99, 151	52
6	—	—
7	18, 51, 84, 117	33

POSTLAUNCH RADIOMETRIC CALIBRATION — LANDSAT-4
HISTOGRAM TM1, CHANNEL 1, NORMALIZED
WHITE SANDS, NEW MEXICO, JANUARY 3, 1983

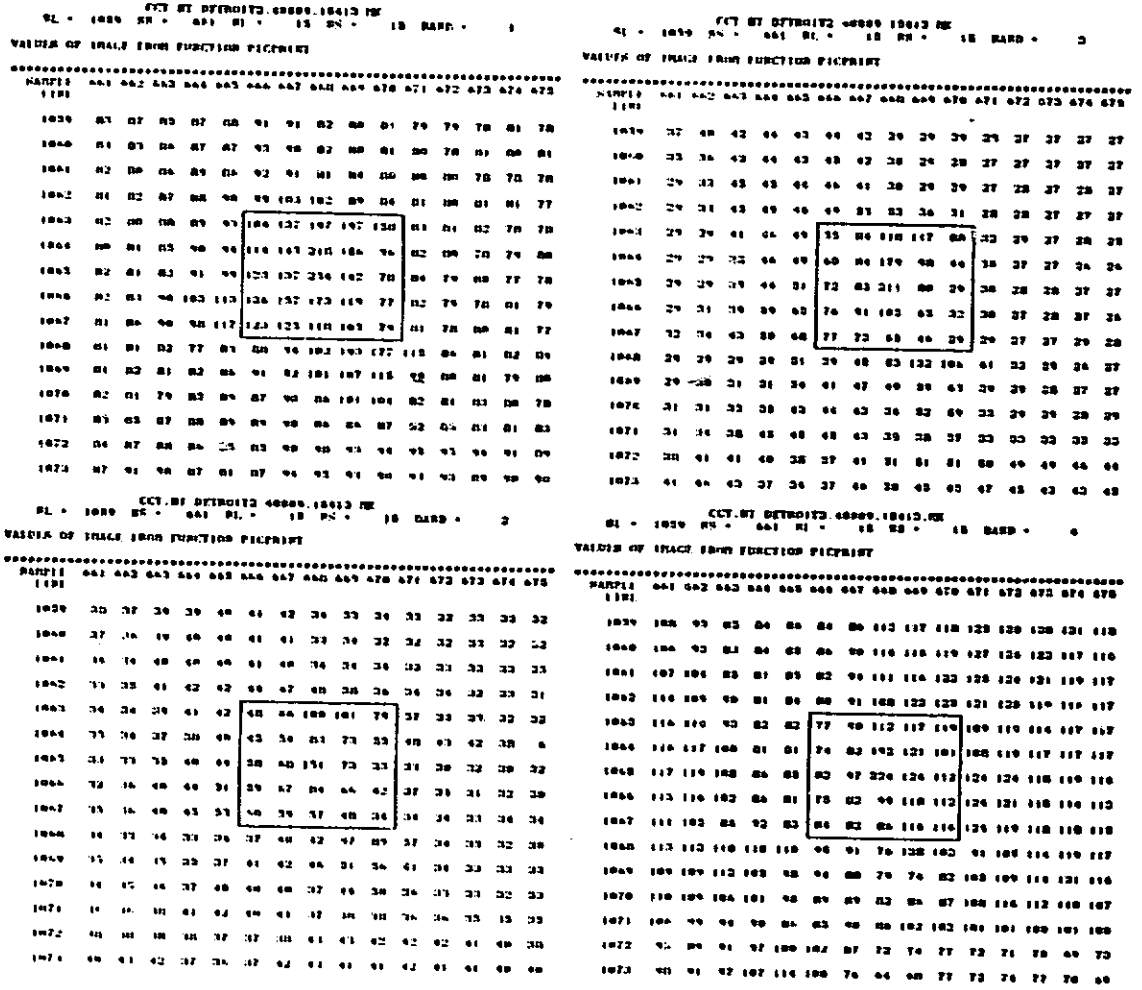


POSTLAUNCH RADIOMETRIC CALIBRATION — TM LANDSAT-4
HISTOGRAM TM1, CHANNEL 1, RAW DATA
WHITE SANDS, NEW MEXICO, JANUARY 3, 1983



LANDSAT-4 TM APPARENT SPECULAR REFLECTANCE

DETROIT 2 (ID = 40000 -16413) 26 JULY 1982
SL = 1 SS = 1601



An example of spectral reflectivity. The bright pixel is located at relative line number 1065 and sample number 668.

LANDSAT-4 TM-INTERBAND REGISTRATION

PFP

5 x 5 CELL

CCT-BT DETROIT 1

BAND	CENTER	
	l = 2870	s = 1788
1	3.092	2.958
2	3.123	2.933
3	3.155	2.911
4	3.016	3.191
B1—B4	0.076	—0.233

CCT-BT DETROIT 2

BAND	CENTER	
	l = 1065	s = 1768
1	3.088	2.901
2	3.096	2.887
3	3.163	2.767
4	2.946	3.250
B1—B4	0.142	—0.349

LANDSAT-4 TM — INTERBAND REGISTRATION — CCT-AT

MEMPHIS TN (ID = 40037-16033) 22 AUG 1982
APPARENT SPECULAR-REFLECTANCE PIXEL
LINE = 3342, SAMPLE = 2519

PRIMARY FOCAL PLANE **7 x 7 CELL** **COLD FOCAL PLANE**

BAND	CENTER	
	LINE	SAMPLE
1	3.898	3.887
2	3.999	3.954
3	3.821	3.946
4	4.272	4.034
1—4	−0.374	−0.147

BAND	CENTER	
	LINE	SAMPLE
5	4.077	4.166
7	3.939	4.215
5—7	0.138	−0.049
1—5	−0.179	−0.279