NASA SLR MCP PMT Upgrade

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ABSTRACT

Currently, the NASA SLR Network uses the International Telephone and Telegraph (ITT) F4129F Microchannel Plate (MCP) Photomultiplier Tube (PMT). Originally purchased between1985 and 1989, the ITT MCP PMTs were installed throughout the NASA SLR network beginning in 1986. Replacing the Amperex XP2233B PMT, the ITT MCP PMT, coupled with the Tennelec 454 Constant Fraction Discriminator (CFD), greatly enhanced the resolution and accuracy of the NASA SLR Network. After 15 years, the original ITT MCP PMTs have long since lived their useful life. As the original PMTs failed, they were replaced with the spares. Now, these supplementary units are beginning to fail. Efforts to find a suitable replacement for the ITT MCP PMT were begun three years ago, with the first unit being delivered in June of 2002. While the initial purchase of the new MCP PMTs was in progress, investigative efforts continued in an effort to find other manufactures that would meet the needs of the SLR Network. This poster paper will cover the laboratory verification, testing and calibration of the new MCP PMTs for the SLR Network as well as cover the field testing of a developmental MCP PMT from a separate manufacturer.

PHOTEK 318 SA SPECIAL MICROCHANNEL PLATE PHOTOMULTIPLIER TUBE

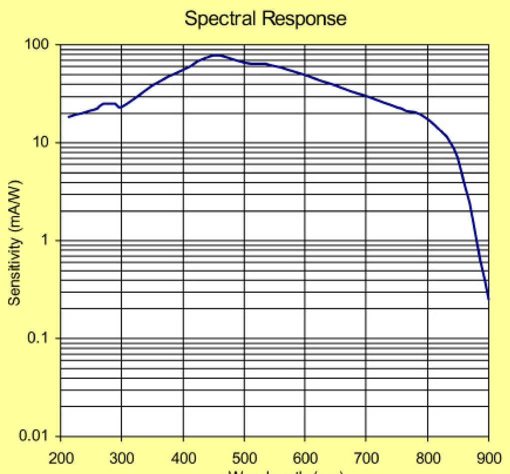
Test Data Summary

20 June 2002

DeviceType	Input Window	Cathode	Anode
PMT318	FS	S20	Single

SerialNo: 42020531 Customer: Photek Inc. (NASA)
PhotekRef: 20002-1 Specification No: SP18AS01 Issue 3 7th January 2002

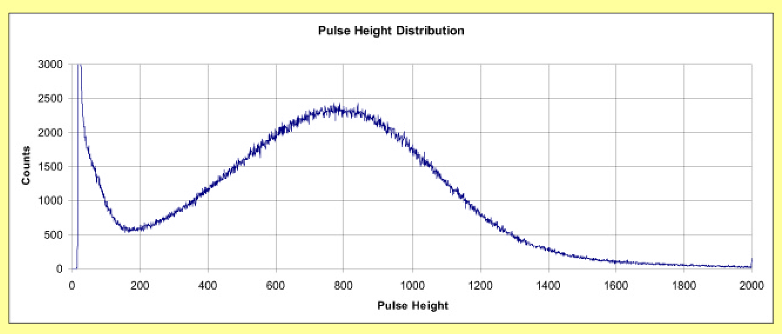
Spectral Response



Sensitivity: 336 μA/lm

	mA/W	%QE
214nm	18.8	10.89
254nm	22	10.74
270nm	25	11.48
290nm	25	10.69
300nm	23	9.51
350nm	38	13.46
400nm	56	17.36
450nm	77	21.22
500nm	66	16.37
532nm	57	13.29
550nm	61	13.75
650nm	39	7.44
750nm	23	3.80
800nm	17.4	2.70
850nm	7.1	1.04
900nm	0.25	0.03

Electron Gain : 1.00E+07 Rise Time: 250ps Soak Test: OK



Maximum Operating Voltage -3.3kV

PVR = 4:1 FWHM = 95% Dark Noise < 50kcps.

Test Background:

Various oscilloscopes were used in an effort to show the best representation of the signal under test, and to give the end user a good feel for the expected in system "look" of these signals. The CSA 8000 oscilloscope was used in the lab to make precise measurements for this acceptance testing. The 2467B oscilloscope was used to document what station operators would see with this PMT installed in the tracking environment.

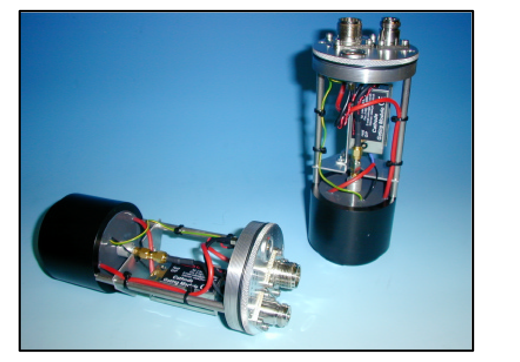
Additionally, the exact interface cabling that is to be used in the tracking system was utilized as part of the laboratory test configuration.

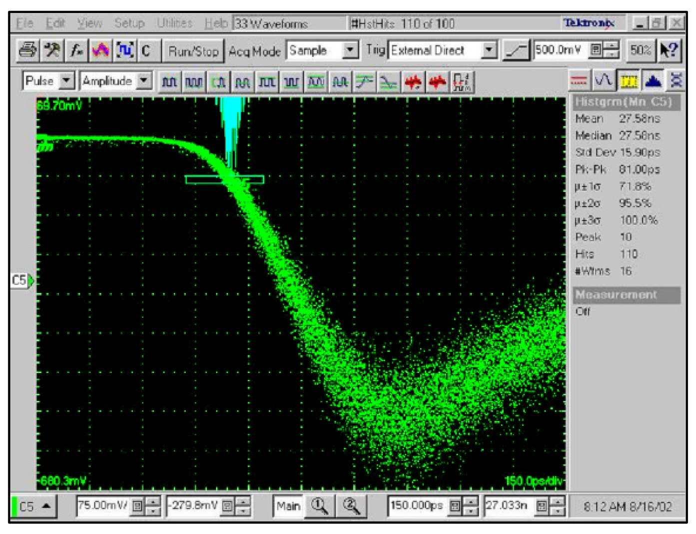
Test Equipment Used:

1. Opto Electronics PLS20 Pulsed Diode Laser Wavelength: 785 nm, +/- 10 nm
   Peak Power: > 30 mW
2. HP 2467B Oscilloscope 400 MHz, four channel
3. SRS DG535 Digital Delay/Pulse Generator
4. SRS PS350 High Voltage Power Supply
5. Tektronix CSA 8000 Communications Signal Analyzer 80E02 Sampling Module, 12.5 GHz, two channel

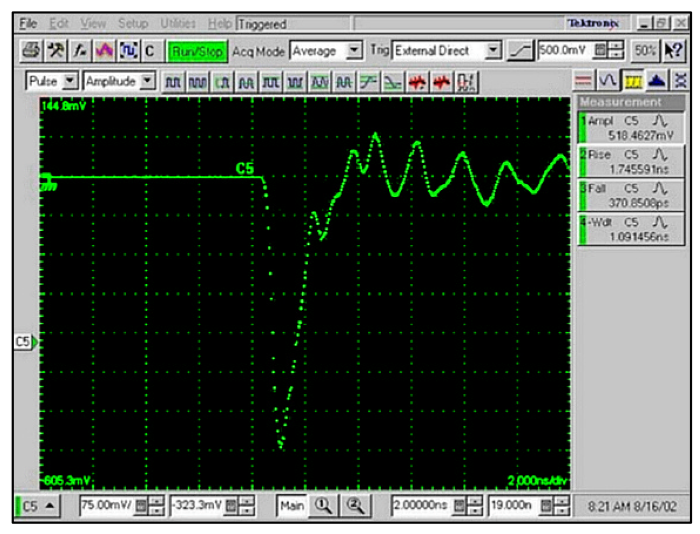
NSLR Laboratory Data Summary

	Specification	Measured / Verified	Pass / Fail
Active Area Stages:	3	3 (Manufacturers Data Sheet)	**Pass**
Active Area Diameter:	18 mm	18.4 mm Lab Measurement	**Pass**
QE-Minimum @ 532 nm:	13%	13.29% (Manufacturers Data Sheet)	**Pass**
Gain Minimum:	1 X 10e+07	1 X 10e+07 (Manufacturers Data Sheet)	**Pass**
Risetime Minimum:	250 pS	339.48 pS * Lab Measurement	**Pass (Exception)**
Risetime Maximum:	350 pS	370.85 pS ** Lab Measurement	**Pass (Exception)**
Risetime Target:	300 pS	339.48 pS * Lab Measurement	**Pass (Exception)**
Jitter (Single PE Level):	100 pS	63 pS Lab Measurement	**Pass**
Dark Count @ 22 Degrees C:	10e+05 cps	<50e+03 (Manufacturers Data Sheet)	**Pass**
Peak to Valley Ratio:	2:1	4:1 (Manufacturers Data Sheet)	**Pass**
Width of Pulse Height Distribution:	160%	? (Manufacturers Data Sheet)	**Pass (Exception)**
Gating:	Internal	Internal Observed	**Pass**
Gating Type:	TTL	TTL Lab Measurement	**Pass**
Gating Max. Rep. Rate:	10,000 Hz	3 Hz to 11 KHz *** Lab Measurement	**Pass**
Gating Pulse Width Range:	80nS to 10 uS	75 nS to 20uS **** Lab Measurement	**Pass**
High Voltage Bias Supply Operating Voltage:	External @ -3,600 VDC	External @ -3,300 VDC (Maximum Voltage per Manufacturers Data Sheet)	**Pass (Exception)**



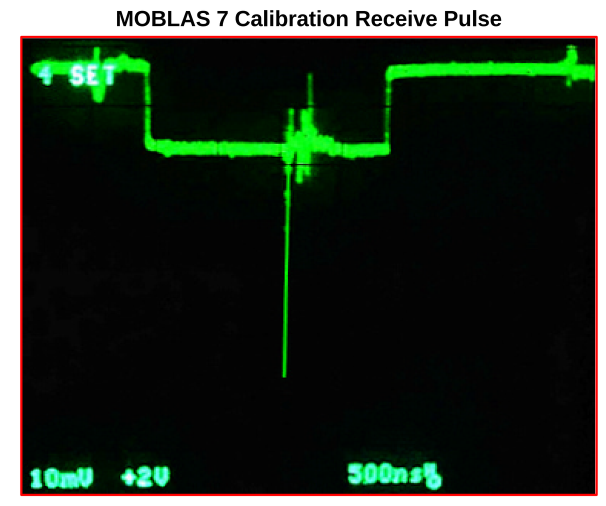


Single Photon Jitter Measurement - 81 picoseconds



Pulse Rise Time Measurement - 370 picoseconds

MOBLAS 7 Calibration Receive Pulse



4 microsecond Range Gate
2 microsecond Window/Window

BURLE 85104 DEVELOPMENTAL MICROCHANNEL PLATE PHOTOMULTIPLIER TUBE

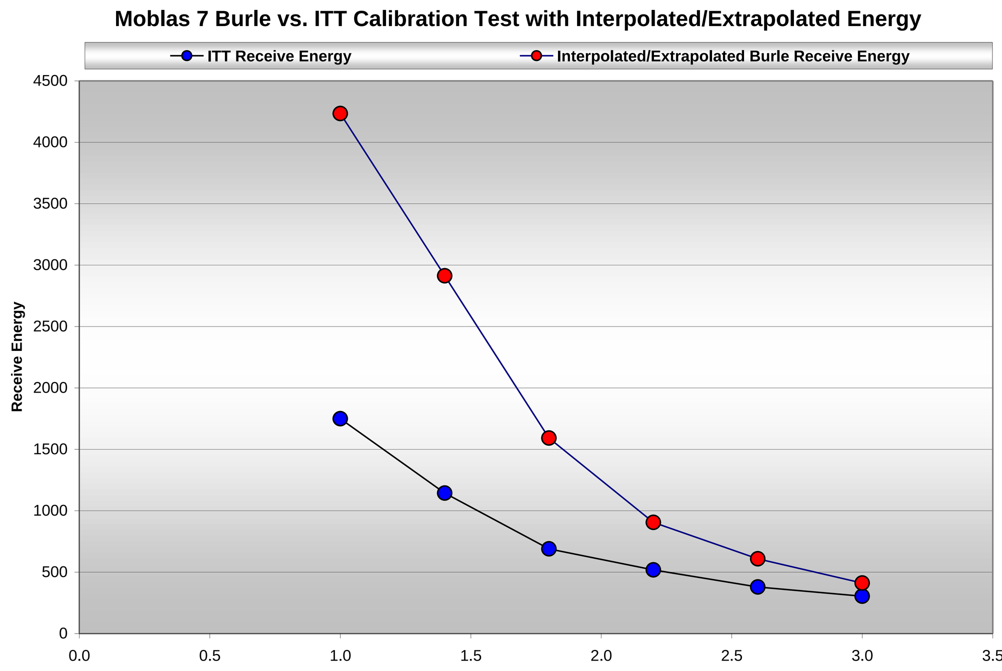
Power Supply and Socket Assembly

Burle 85104 Developmental MCP

Test #	Day of Year	Time (hh:mm:ss) GMT (-5 Local) Start	Stop	Total	MCP Type	Calibration or Satellite	HSLR Mode Amp or Non-Amp	Transmit Obs	Receive Observations Received	Rejected	Accepted	Rec/Xmit Ratio	RMS (mm)	Elevation Start	Stop	Total Angle	MCP Voltage	Gain	Notes	File Name
1	352	22:21:08	22:22:12	0:01:04	ITT	Calibration (Bin 1)	Non-Amp		208	1	207		5.40				-3600	5.00E+06	3.0 ND, -20mV Receive Amplitude	S87y01d352t2221#TT
1	352	22:22:26	22:23:15	0:00:49	ITT	Calibration (Bin 2)	Non-Amp		236	2	234		4.90				-3600	5.00E+06	2.6 ND, -80mV Receive Amplitude	S87y01d352t2222#TT
1	352	22:23:27	22:24:12	0:00:45	ITT	Calibration (Bin 3)	Non-Amp		216	1	215		4.70				-3600	5.00E+06	2.2 ND, -140mV Receive Amplitude	S87y01d352t2223#TT
1	352	22:24:24	22:25:09	0:00:45	ITT	Calibration (Bin 4)	Non-Amp		218	2	216		4.60				-3600	5.00E+06	1.8 ND, -250mV Receive Amplitude	S87y01d352t2224#TT
1	352	22:25:23	22:26:23	0:01:00	ITT	Calibration (Bin 5)	Non-Amp		226	2	224		5.60				-3600	5.00E+06	1.4 ND, -400mV Receive Amplitude	S87y01d352t2225#TT
1	352	22:26:18	22:27:05	0:00:47	ITT	Calibration (Bin 6)	Non-Amp		225	0	225		5.80				-3600	5.00E+06	1.0 ND, -600mV Receive Amplitude	S87y01d352t2226#TT
2	352	22:54:08	22:55:08	0:01:00	Burle	Calibration (Bin 1)	Non-Amp		207	4	203		9.70				-4200	5.92E+06	3.5 ND, -20mV Receive Amplitude	S87y01d352t2254#TT
2	352	22:55:56	22:56:40	0:00:44	Burle	Calibration (Bin 2)	Non-Amp		213	1	212		7.40				-4200	5.92E+06	3.1 ND, -45mV Receive Amplitude	S87y01d352t2255#TT
2	352	22:57:38	22:58:26	0:00:48	Burle	Calibration (Bin 3)	Non-Amp		241	1	240		6.70				-4200	5.92E+06	2.7 ND, -100mV Receive Amplitude	S87y01d352t2257#TT
2	352	22:59:33	23:00:17	0:00:44	Burle	Calibration (Bin 4)	Non-Amp		218	0	218		7.30				-4200	5.92E+06	2.3 ND, -200mV Receive Amplitude	S87y01d352t2259#TT
2	352	23:01:01	23:01:52	0:00:51	Burle	Calibration (Bin 5)	Non-Amp		255	3	252		8.50				-4200	5.92E+06	1.9 ND, -350mV Receive Amplitude	S87y01d352t2301#TT
2	352	23:03:36	23:04:20	0:00:44	Burle	Calibration (Bin 6)	Non-Amp		222	2	220		12.90				-4200	5.92E+06	1.5 ND, -600mV Receive Amplitude	S87y01d352t2303#TT
3	352	?			Burle	Calibration	Non-Amp		1155	3	1152		6.50				-4200	5.92E+06	2.7 ND, No post-cal due to next satellite pass	
3	352	23:29:30	23:35:29	0:05:59	Burle	Ajisai	Non-Amp	1795	797	33	764	42.6%	15.90	20.00º	47.43º	27.43º	-4200	5.92E+06	2.7 ND, PCA 48 Degrees	S87y01d352t2329#1500
4	353	1:46:41	1:56:00	0:09:19	ITT	GPS35	Amp	2795	656	656	0	0.0%	N/A	39.57º	40.64º	01.07º	-3600	5.00E+06	Clear Sky, No data processed	S87y01d353t0146#3535
5	353	2:10:42	2:32:45	0:22:03	Burle	GPS35	Amp	6615	288	288	0	0.0%	N/A	41.13º	39.47º	01.66º	-4200	5.92E+06	Clear Sky, No data processed	S87y01d353t0210#3535
6	355	1:33:00			Burle	Calibration	Amp		510	13	497		13.20				-4200	5.92E+06	3.5 ND, 4 PPS, Daylight Filter Out	
6	355	1:46:47	1:55:31	0:08:44	Burle	Etalon 1	Amp	2620	230	20	210	8.0%	25.90	51.82º	56.57º	04.75º	-4200	5.92E+06	Clear Sky, At 40 degrees added Daylight Filter because of a noise problem.	S87y01d355t0146#0525
6	355	1:56:00			Burle	Calibration	Amp		619	20	599		12.00				-4200	5.92E+06	3.1 ND, 4 PPS, Daylight Filter Out	
7	355	2:58:00			ITT	Calibration	Amp		520	10	510		9.00				-3600	5.00E+06	2.6 ND, 4 PPS, Daylight Filter Out	
7	355	2:59:08	3:09:54	0:10:46	ITT	Etalon 1	Amp	3230	465	18	447	13.8%	24.92	74.57º	71.78º	02.79º	-3600	5.00E+06	Daylight Filter In for whole pass, PCA 70 degrees, Lots of noise	S87y01d355t0259#0525
7	355	3:12:00			ITT	Calibration	Amp		774	15	759		8.20				-3600	5.00E+06	2.7 ND, 5 PPS (In a hurry for next pass), Daylight Filter Out	
8	355	3:38:00			ITT	Calibration	Non-Amp		1032	7	1025		4.80				-3600	5.00E+06	1.3 ND, 4 PPS, Daylight Filter In	
8	355	3:47:26	4:02:00	0:14:34	ITT	Etalon 2	Non-Amp	4370	81	1	80	1.8%	17.05	55.43º	57.23º	01.80º	-3600	5.00E+06	Clear Sky, Daylight Filter Out, Not enough signal amplitude to trigger system	S87y01d355t0347#4146
8	355	4:03:36	4:18:24	0:14:48	ITT	Etalon 2	Amp	4440	808	22	786	17.7%	26.25	57.56º	61.38º	03.82º	-3600	5.00E+06	Clear Sky, Daylight Filter In	S87y01d355t0403#4146
8	355	4:23:07	4:37:53	0:14:46	Burle	Etalon 2	Amp	4430	1080	36	1044	23.6%	28.15	62.03º	61.82º	00.21º	-4200	5.92E+06	Clear Sky, Daylight Filter In, HSLR Amp overload light illuminated, .8 ND dialed in, no effect	S87y01d355t0423#4146
8	355	4:40:21	4:54:58	0:14:37	Burle	Etalon 2	Non-Amp	4385	190	101	89	2.0%	23.28	61.40º	57.87º	03.53º	-4200	5.92E+06	Clear Sky, Daylight Filter Out	S87y01d355t0440#4146
8	355	4:58:00			Burle	Calibration	Non-Amp		1031	2	1029		7.50				-4200	5.92E+06	4 PPS, Daylight Filter Out	

Table 1

Moblas 7 Burle vs. ITT Calibration Test with Interpolated/Extrapolated Energy

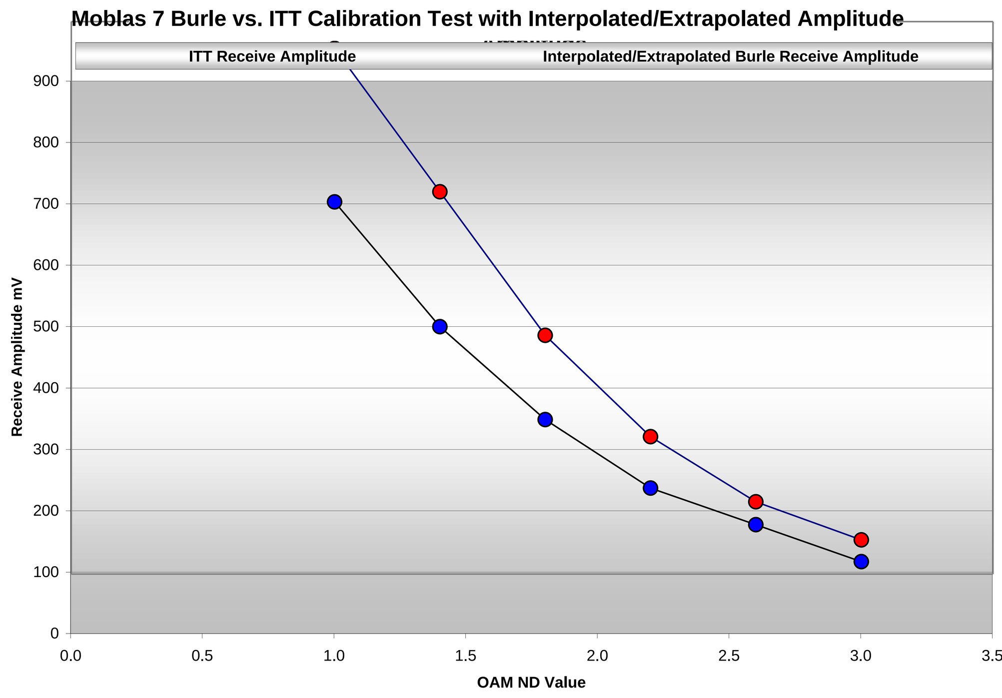


Ground Calibrations

The Burle 85104 used in this test is an ungated, gallium-arsenide photodcathode MCP PMT. With a quantum efficiency of ~30% and a gain of 5.9 X 10^6, the Burle 85104 is a developmental unit that was lent to NASA in order to better understand the needs of the SLR community. Ground calibrations were first performed with the ITT MCP, and then with the Burle MCP. The tests were conducted by first attenuating the receive signal to the point where a return from the ground calibration target was received at a rate of about 1 to 2 times per second. The MOBLAS 7 system normally operates at a 5 hertz rate. The attenuation value of the neutral density (ND) filter was noted and ~200 returns were recorded. Each set of 200 returns was called a calibration bin for test purposes. Then, the optical attenuation was decreased by 0.4, using the MOBLAS Optical Attenuation Mechanism (OAM), and an additional 200 returns were recorded. 6 data sets, or calibration bins, were obtained first with the ITT MCP, then the Burle MCP was installed and the test repeated.

Table 1 includes the data summary results from all of the Burle MCP tests over a two day period. To obtain a better understanding of the differences in receive signal strength for each MCP, the Transmit Energy was normalized by adding a bias to each individual Transmit Energy value to make all the Transmit Energies values equal. The same bias value for the accompanying Receive Energy record was then added. To better visualize the expected receive energy data for identical OAM ND values for both the ITT MCP and the Burle MCP, data points were linearly interpolated and extrapolated for the Burle MCP receive energy. The plot to the left shows the interpolated and extrapolated transmit and receive energies used to equalize the OAM ND attenuation values between the Burle and ITT MCP data. Since the MOBLAS Receive Energy system essentially makes a relative measurement of the power within the receive pulse, it is expected that a wider receive pulse would produce a greater Receive Energy for a given amplitude. To account for this, the Receive Amplitude was manually recorded for each data set. This was accomplished by observing the Receive Amplitude on an oscilloscope and noting average Receive Amplitude. If the Receive Amplitude is normalized for the fluctuations in Transmit Energy and plotted against the OAM ND value, then we have the results as shown in the plot to the left and below. As expected, the Burle MCP provides a greater Receive Amplitude at a given ND value as compared to the ITT MCP.

Moblas 7 Burle vs. ITT Calibration Test with Interpolated/Extrapolated Amplitude



Satellite Tracking

As shown in Table 1, Test #3, the Ajisai satellite was tracked using the Burle MCP and with the Receive System configured in the Non-Amp mode. The receive pulse, as viewed on the monitoring oscilloscope, was of greater width than the output pulse normally seen from the ITT MCP. Next, the GPS 35 satellite was attempted using both the Burle and ITT MCPs with the system configured in the Non-Amp mode. However, as indicated in Table 1, Test #4 and #5, no data was recorded. It was noted by the station operator that he was unable to observe a receive signal in the monitoring oscilloscope. Many times the station operator is able to observe the receive signal in the monitoring oscilloscope, but the signal amplitude in not sufficient to meet the receive system threshold requirement. Hence, the system does not register a data record.

Since the operator was not able to observe the returns from the GPS 35 satellite in the Non-Amp mode, it was decide to attempt an Etalon 1 satellite because of the greater optical link. This was done with the hope of obtaining a receive signal in the Non-Amp mode so that a comparison could be made between the Non-Amp and Amp modes with both the ITT and Burle MCP. In Test #7, the Etalon 1 satellite was observed, however, the pass had to be terminated early in order to observe a higher priority satellite. In Test #8, the Etalon 1 satellite was again tracked, but this time, in all four modes of operation; ITT MCP in the Non-Amp and Amp modes, the Burle MCP in the Amp and Non-Amp modes. The sky was very clear with no clouds or haze. Additionally, the elevation angles of the telescope were similar for all four modes. Though this was only one test, there appears to be a definite increase in data quantity between the Burle and ITT MCPs. Concentrating on the column labeled Receiver Observations Accepted in Table 1, the data indicates about a 10 to 1 increase in data yield between the Amp and Non-Amp modes for the ITT MCP and about a 12 to 1 increase for the Burle MCP. In the Non-Amp mode, the number of Burle MCP receive observations accepted was similar to the number collected with ITT MCP. In the Amp Mode, the number of Burle MCP receive observations accepted was about 33% greater than those of the ITT MCP. In order to minimize the effects from the amount of atmosphere the transmitted and received energy traveled through, data was collected as close to PCA as possible. As seen in Table 1, the Non-Amp and Amp data from the ITT MCP was collected close to the same elevation angles as the Non-Amp and Amp data from the Burle MCP. It should be noted that the receive amplitude achieved with the Burle MCP while in the Amp Mode, exceeded the maximum limit of the MOBLAS 7 receive electronics. As a result, the receive electronics switched to the bypass mode for the particular return that exceeded the maximum limit, and the receive observation is not recorded. The bypass feature is present to eliminate damage to the MOBLAS 7 receive electronics. All Burle MCP tests were concluded at the end of this pass and the MOBLAS 7 was returned to normal configuration.