New ITF Observations for the IUE Prime Cameras

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1 Motivation

The intensity transfer function (ITF) is the fundamental calibration involved in transforming the raw camera data (data numbers, or DN) into astronomically meaningful quantities. The ITF is applied to the DN value of each pixel in the camera image to convert the reading to linearized flux numbers (FN). The relation between DN and FN differs from pixel to pixel, so the ITF must be defined on a pixel-by-pixel basis for the entire image formed by 768x768 pixels. The ITF is constructed from a series of carefully obtained UV-flood lamp exposures. The last set of ITFs were taken on September 24–28, 1984 for the LWP and on January 30 to February 2, 1985 for the SWP camera. The SWP ITF (epoch 1985) was never implemented in the current version of IUESIPS.

The current LWP ITF has been known for some time to be inadequate especially for the images taken after 1985. Several attempts were made to adjust the ITF empirically, with limited improvements. Recent LWP nulls taken during December 1991 and January 1992 show a better spatial match to the fixed-pattern noise in the background regions of flux standard star images than does the existing null level of the LWP ITF (epoch 1984), resulting in a decrease in the mean pixel shifts between the nulls and the flux standard images. A new ITF determination has been considered desirable, but was not attempted before due to the sizeable amount of spacecraft time required ($\sim$ 6-9 days) and the suspicious health of the UV lamps.

The need for a new SWP ITF was considered secondary; however, recent camera behavior suggested that it would be advisable to acquire a more up to date ITF. Consequently, a recent Three-Agencies agreement recommended to take the SWP ITF as an alternative in case of repeated failures of the LW UV-flood lamp or if four or more days were left after finishing the LWP ITF. Since the latter occurred, a complete SWP ITF was recently acquired and related details are reported here. Table 1 is a description of the S/C time used for the observations.

2 The LWP ITF

2.1 THDA

The LWP ITF observations were started at GSFC on Monday, April 27 during the second half of the US1 shift, and continued almost uninterrupted until the US2 shift on May 2, 1992. A few additional observations were made on May 6, after the SWP ITF was finished.

Table 1: Total S/C Observing Time Used

Shift	ITF Obs.	Std. Stars[1]
US1[2]	8.5	
US2	9.0	1.5
VILSPA	7.5[3]	
TOTAL	25.0	1.5

The first shift was immediately following the monitoring of the AGN target NGC 3783 which was at beta=42. The initial ITF attitude chosen was at beta=49. Since this ITF had a strong THDA constraint of 9.5 (± 1 deg), the current THDA at that moment, ignoring the recent past thermal history of the S/C, was judged to be appropriate for future shifts. UV-floods were initiated and continued during the US2 shifts. A forced parenthesis of about 4 hours was made during the peak of the background radiation during this and most of the other US2 shifts. The background radiation, as is discussed later, was low during the whole week of the ITF observations. The UV-flood sequence was restarted just prior to the VILSPA shift. The main problem faced at this point was achieving the desired THDA value rather than making the lamps fire, which worked better than expected at that point.

Since the THDA of 9.5 is certainly on the "high" side for the cameras when pointing in the middle β range, especially when the S/C is close to apogee (summer months), than at the original beta of 49, the THDA started to slide down. This was aggravated during the second day (Tuesday) by the telemetry problems due to line anomalies with the Wallops Tracking Station. During the subsequent US2 shift drastic measures had to be taken to raise the THDA of the LWP camera. Maneuvering to a higher β and exposing on standard stars did not seem to change the thermal configuration fast enough for the time allowed during the constraint of one shift. We resorted to the least advised tool, which is to use the deck heater where the lamp resides. This seemed to slowly change the THDA to the desired temperature, after which the UV-flood sequence was restarted before the VILSPA shift. The ESA shifts were highly productive and a large portion of the usable images were taken there.

During the third day of the observations a thermally stable S/C was achieved; the THDA values were around 9.8 for the LWP and 9.2 for the SWP camera. This equilibrium took place at $\beta=55\,^\circ$ while pointing at the star HD 109867 (V=6.30, SpT=B0Ib), which happened to have the same β angle throughout the week of observations. This equilibrium was also a strong function of the camera activity. The maneuvers during the US2 were restricted to a narrow β range in order to avoid any thermal upset of the Scientific Instrument. On the average, individual ITF images were acquired every 45-55 minutes. A total of 86 images were taken with THDAs between the telemetry values of 9.2 and 9.8, which is 65% of the total UV-flood images taken. Moreover, there were a few images taken at extreme THDA values of 10.2 (18) and 6.8 (1), which is illustrated in Figure 1.

[1] These are PHCAL standard stars used to bracket the ITF observations.

[2] The US1 shifts were interrupted twice on May 1 and 5 to carry out the AGN monitoring program of NGC 3783.

[3] There was a Lunar shadow on May 3 during the VILSPA shift. The last shift on May 6, was partially dedicated to the ITF.

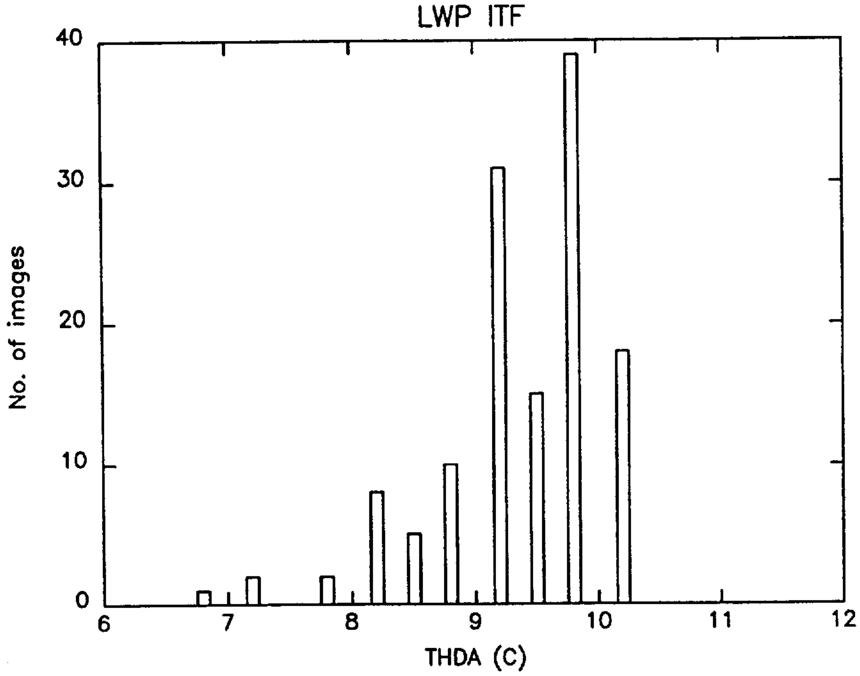

Figure 1: Histograms of the No. of LWP ITF images against THDA

2.2 Lamp Behavior

In terms of degradation and reliability, the LW UV-flood lamp was found to be in good working condition. Previous camera baseline exposures were used to estimate the integration time for the first exposure meter image; this value had to be *decreased* to reach the desired exposure DN levels. During the second full day of activities, the lamp misfired for the first time, which was remarkable in itself, since more than 40 UV-flood exposures had already been obtained. As the lamp got hotter, there were more failures. Many of the lamp failures which did occur were resistant to the successful technique employed during the previous ITF. In all cases, several attempts were made using the same calling parameters of the UVITF procedure; however, only in a few cases did the lamp fire successfully, and a new approach was devised to face these failures. Since it was noticed that the lamp was slightly hotter than the "cold" temperature entered in the procedure, a new "cold" temperature was entered with the same value as the current temperature or, if that attempt failed, 5 telemetry units lower in the RAW(AS3CH31) parameter (see Figures 2 and 3 for thermistor lamp behavior during a successful firing). This successfully took care of all the recurrent failures of the lamp. Care was exercised not to use a raw value less than 50 (equivalent to 36 °C). Therefore, as long as the lamp fired, the value of RAW(AS3CH31) was kept at the same number. The lamp failures of last two days of this ITF were all single failures and there was no need to change anything in the calling of the UVITF procedure. The largest value of RAW(AS3CH31) used for the thermistor lamp was 66, which is equivalent to 28 °C.

2.3 Exposure Levels

The continuous on-line monitoring of the DN levels of the exposure meter (80%) at 9 boxes distributed throughout the camera faceplate suggested the modification of the 100% exposure time on several occasions. This number is important because all the different ITF

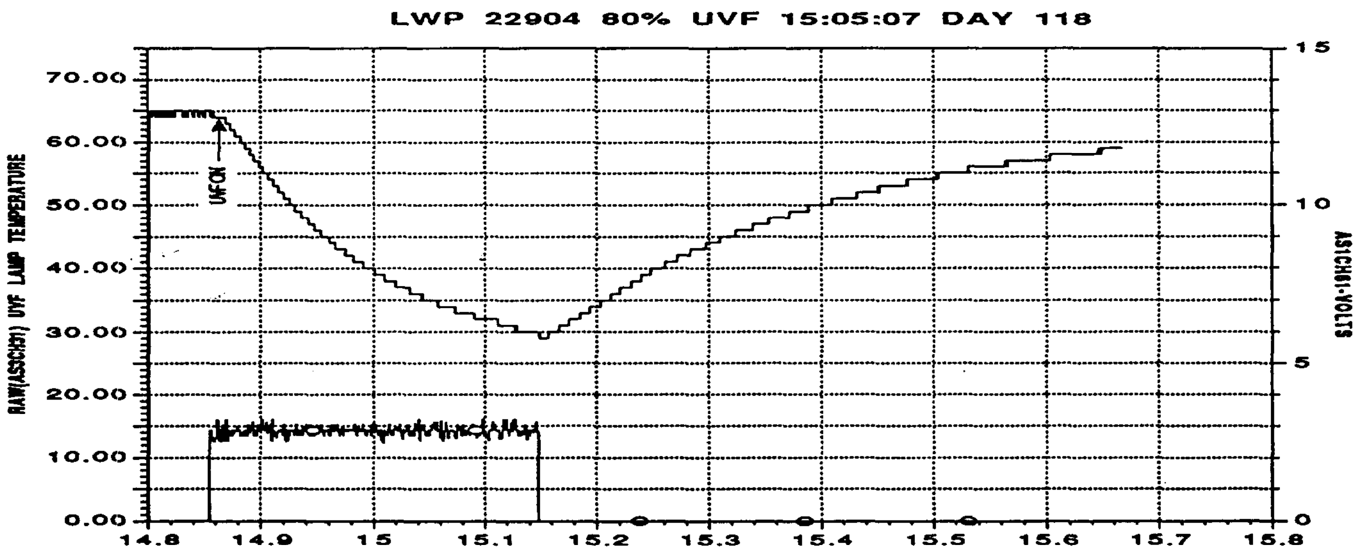

Figure 2: Thermal behavior of the LW UV-flood lamp for a successful firing

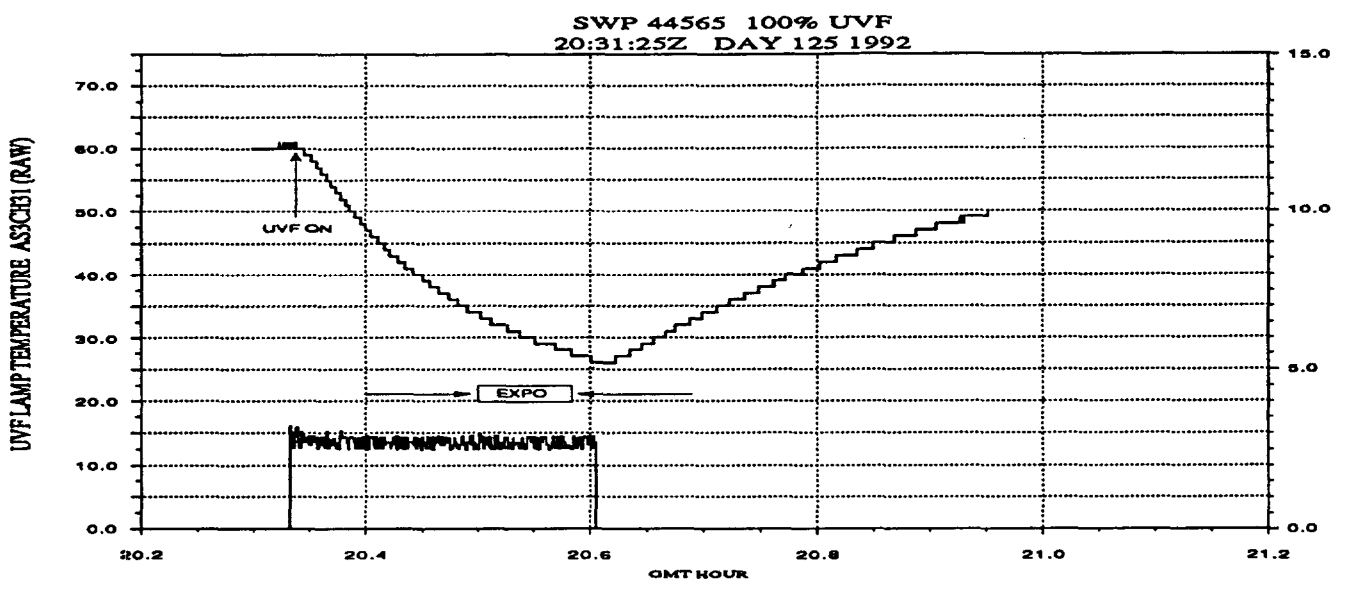

Figure 3: Thermal behavior of the SW UV-flood lamp for a successful firing

Table 2: UV-Flood Lamp Degradation

Lamp	U100A(1) (sec)	U100A(3) (sec)	day (UT) 1992
LW	280		118.63
	261		118.67
	271		120.60
	277		121.02
	296		121.55
	317		122.35
	345		122.87
	366		123.31
	390		123.70
	413		127.39
SW		238	123.91
		293	123.94
		260	124.39
		270	124.82
		285	125.49
		294	125.86
		315	126.55
Total	58.2%	32.4%	

levels are relative to this exposure time, according to the UVITF procedure. The number determined by the previous camera baseline exposures was 280 seconds. Nevertheless, this number proved to be slightly higher and the actual value used for the beginning of the UV-flood sequence was 261 s which was later modified to 271, 277, 296, 317, 345, 366, and 390 s. The latest observations taken on May 6, after the SWP ITF, demanded an even higher value of UV100A(1) equal to 413 s (see Table 2). For future UV-flood exposures, this implies that the 280% level will be at least 19 min long. After the initial two days' continuous usage of the lamps a rapid degradation became evident; however, this was not beyond the original predicted degradation based on the previous camera baseline exposures. Degradation during the subsequent days was severe, reaching an average value of 5–10% per day. A summary of the UV-flood exposures taken in this camera is listed in Table 3, and displayed, along with the associated nulls, in Figure 4.

3 The SWP ITF

After a very careful assessment by the ITF Task members of the risks, advantages and disadvantages of taking a SWP ITF, it was finally decided on May 2 to proceed with the emergency plans as described in the appendix of the LWP ITF instructions. For the next four days, until May 6, 112 UV-flood images were taken in this camera. The first exposure for this ITF was a 100% (exposure meter) taken during US2 on May 2. By then, the whole S/C had reached thermal equilibrium (β=55°) centered around the THDA desired for each

Table 3: UV-Flood exposures (% levels)

	20	40	60	80	100	130	160	200	240	280	340
SWP	8	8	6	6	24	6	7	6	6	6	6
	20	40	60	80	100	120	140	170	200	240	280
LWP	10	8	8	34	9	7	8	9	8	7	6

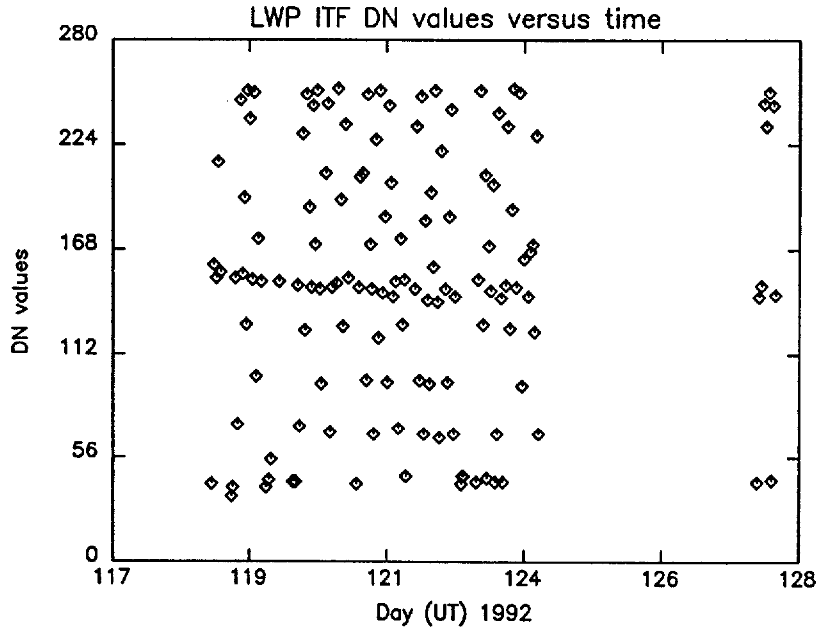

Figure 4: DN values of all the UV-flood and Null LWP images against UT time

camera. Since the mean desired THDA was also centered at 9.5 degrees, no changes in S/C pointing were necessary and in almost all the US2 shifts no maneuvers were necessary since the background radiation was estimated to be low. In Table 4 we include a list of the total number of exposures taken for each ITF, including lamp failures and the number of images taken on B stars during the US2 shifts.

3.1 THDA

This ITF greatly benefited from a very thermally stable S/C. The mean THDA of the SWP ITF (Epoch 1985) was 9.293. The mean THDA for all SWP images from 1978 until mid-1988 is $\sim$ 9.5–9.8. From this information, it was decided that the ideal THDA would be 9.5$\pm$1.0 degrees. From previous experience, it was known that in this ITF it is more critical to maintain a stable temperature in order to ensure geometric consistency. This was certainly achieved; of a total of 112 UV-flood images, 44 were at THDA=9.5 and 84 between 9.2 and 9.5 degrees. The minimum THDA was 8.5 for 5 images; consequently all the SWP images were within a degree of 9.5 (see Figure 5).

Table 4: Summary of the Observations

Camera	Nulls	UV-Flood	Total	Lamp Failures	B Stars
SWP	23	89	112	0	7
LWP	18	115	133	27	7
			245	27	14

3.2 Lamp Behavior

The SW UV-flood lamp was known to be very reliable and no failures were encountered during this ITF. This is consistent with prior behavior, as no lamp failures were reported during the previous SWP ITF (epoch 1985) either. Nevertheless, we experienced non-linear degradation during this ITF as was experienced previously (Imhoff 1985, internal memorandum).

In the first two days, the values of the reference exposure (100%=exposure meter) had to be adjusted three times according to the somewhat unpredictable DN levels of the exposure meter.

3.3 Exposure Levels

Based on the analysis of the 80% and 60% SWP camera baseline exposures taken between 1987 and 1991, an initial value of U100A(3)=238 s was predicted. This value proved to be low and after the first 100% test exposure it was increased to 293 s. After the following 8 UV-flood images the same value was estimated to be too high for the current output of the lamp and it was decreased to 260 s. From this point on, the lamp continued to show its non-linearity; however, the subsequent adjustments of the reference exposure were only in the sense that the number was increased four more times, finishing at 315 s (see Table 2). For future UV-flood images this implies that the 340% exposure will be at least 18 minutes long. The non-linearity characteristic of the lamp produced a spread of the meter exposures of about 30 DN or 23% of the mean exposure level. The total number of UV-flood images acquired in this camera is listed in Table 3, and displayed, along with the associated nulls, in Figure 6.

4 Background Radiation

The previous ITFs were taken using strict guidelines regarding the amount of radiation which could be tolerated. This step is necessary since excess radiation from particles around the Van Allen belts will fog the entire camera faceplate in the same manner as the UV-flood lamps. Since the loss of the IUE particle flux monitor (FPM) in 1991, we have had no real-time knowledge of the level of this radiation. But we do have a independent method of predicting the maximum FPM level for a single day. Information from the Geostationary Orbiting Earth Satellite (GOES) is used to predict the peak radiation levels which IUE will experience during the US2 shifts. The GOES-7 measures the flux of electrons in the atmosphere; the peak one-hour reading from this satellite correlates very well with IUE peak FPM.

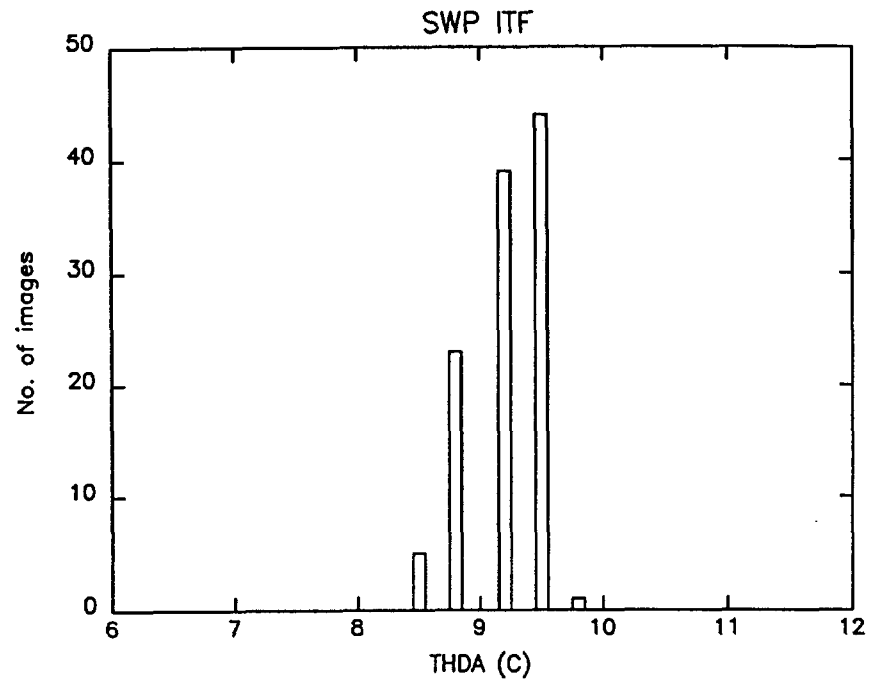

Figure 5: Histograms of the No. of SWP ITF images against THDA

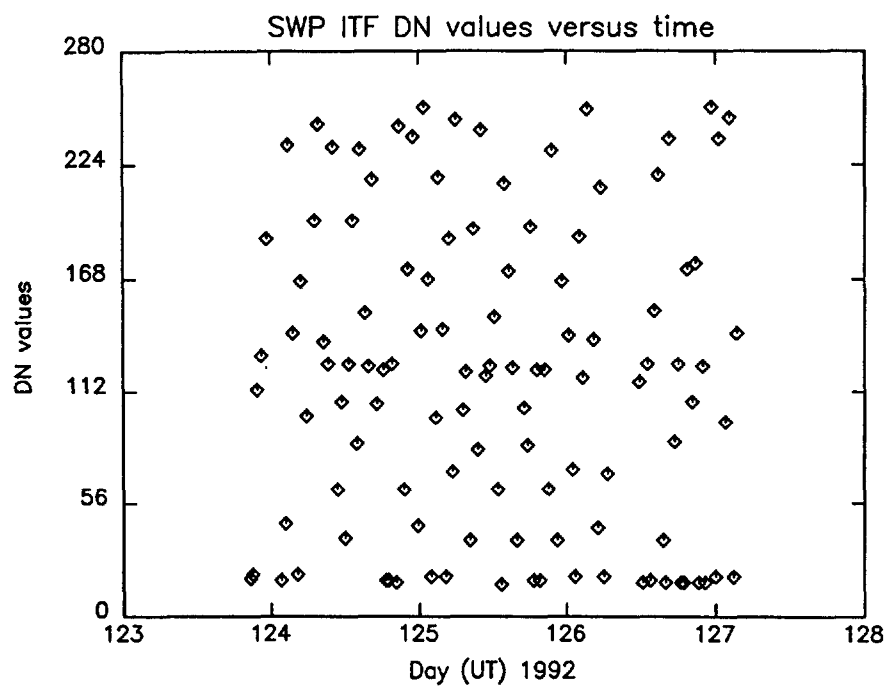

Figure 6: DN values of all the UV-flood and Null SWP images against UT time

Table 5: Background Radiation during the ITF Observations

Date	Daily Electron Peak (GOES-7)	Predicted Maximum FPM (IUE)
April 26	200	1.9
April 27	120	1.7
April 28	45	1.3
April 29	55	1.3
April 30	31	1.1
May 1	36	1.2
May 2	37	1.2
May 3	35	1.2
May 4	46	1.3
May 5	29	1.1

In Table 5 we present the GOES-7 data for the days in which the ITFs for both cameras were obtained. The last column gives the worst-case prediction for the maximum US2 FPM. The GOES flux units are: electrons/cm^2/second/ steradian and the IUE FPM units are in volts. We point out that the FPM estimates shown in Table 5 are probably higher than what was actually present, since it is the worst-case prediction. The actual peak was probably about a half-volt lower.

5 Highlights and Summary

The task of taking two ITFs during a 9-day period demanded a significant effort and continuous coordination with VILSPA. At GSFC a planning task force was organized after the Three-Agency recommended taking the LWP ITF in November 1991. This task force was formed by calibration personnel and several task leaders that oversee related observatory tasks, such as scheduling, processing, operations, etc. The input from senior staff members, who were in charge of taking previous ITFs, was crucial to the success of this effort. The coordination and exchange of information and data with VILSPA was intense and several means of communications were employed (e-mail, FAX, voice). For all the GSFC shifts, 17.5 in total, a calibration task member was present to conduct the observations. This proved to be very beneficial since a large number of decisions were immediately taken after confronting operation or lamp anomalies. In addition, the newly remodeled IUE Telescope Operation Control room has new EDSs (Experiment Display System, now called TOCS) that allowed us to perform on-line measurements on the raw images. Due to this quick feedback, several modifications were carried out, especially the one related to the changes in exposure time of the exposure meter. In Figures 7 and 8, the mean DN at the center are shown for all the ITF images taken for all 12 levels in both prime cameras. In summary, we list some of the highlights and achievements of the ITF observations.

- Good coordination between VILSPA/SERC and GSFC (e-mail, FAX, voice) Example: the SWP ITF was decided, planned, executed and partially analyzed in two weeks.

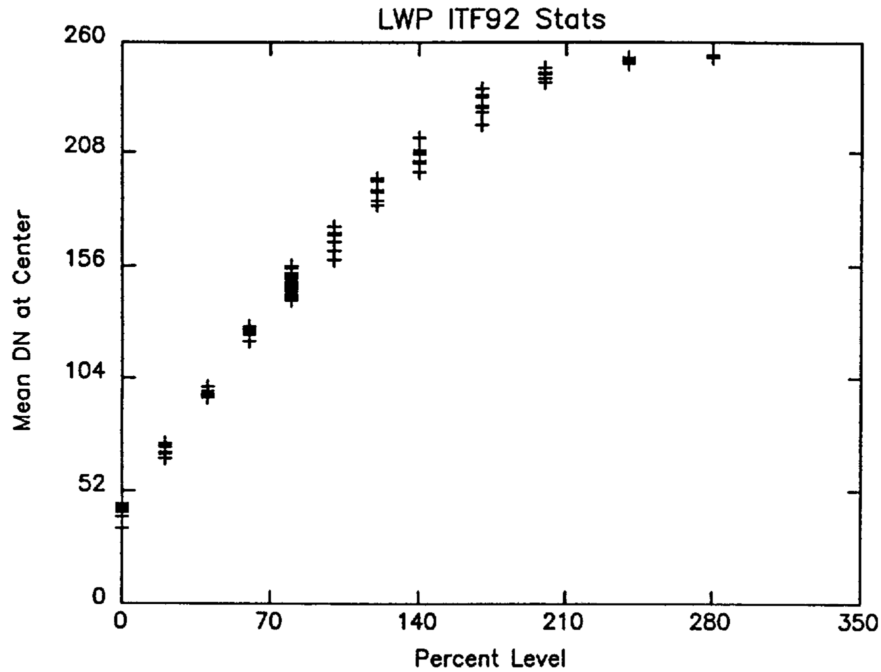

Figure 7: Mean DN for all LWP ITF images against exposure level

- The new approach of adjusting the database exposure time (reference=100%) in real-time proved to be very efficient and safe.
- Both ITFs had the same THDA requirement (9.5 C). This severe restriction of a narrow range of THDA values was overcome by planning + trials (equilibrium: β=55).
- Immediate analysis of the raw images was possible due to the new EDS (TOCS) in the operations control room.
- The immediate availability of VILSPA ITF raw images through the network was highly beneficial.
- Further quality checks (e.g., cross-correlation) were carried out soon enough to properly assess the need for retaking images.
- No measurable background radiation was detected during the ITF observations (estimated mean US2 peak FPM=1.2 V).
- From the original values of the reference exposures, the 100% level for the LW lamp is 2 times longer (i.e., 280%: 19 min) and 1.7 times longer for the SW lamp (i.e., 340%: 18 min).
- Complete and promising SWP and LWP ITFs were acquired.

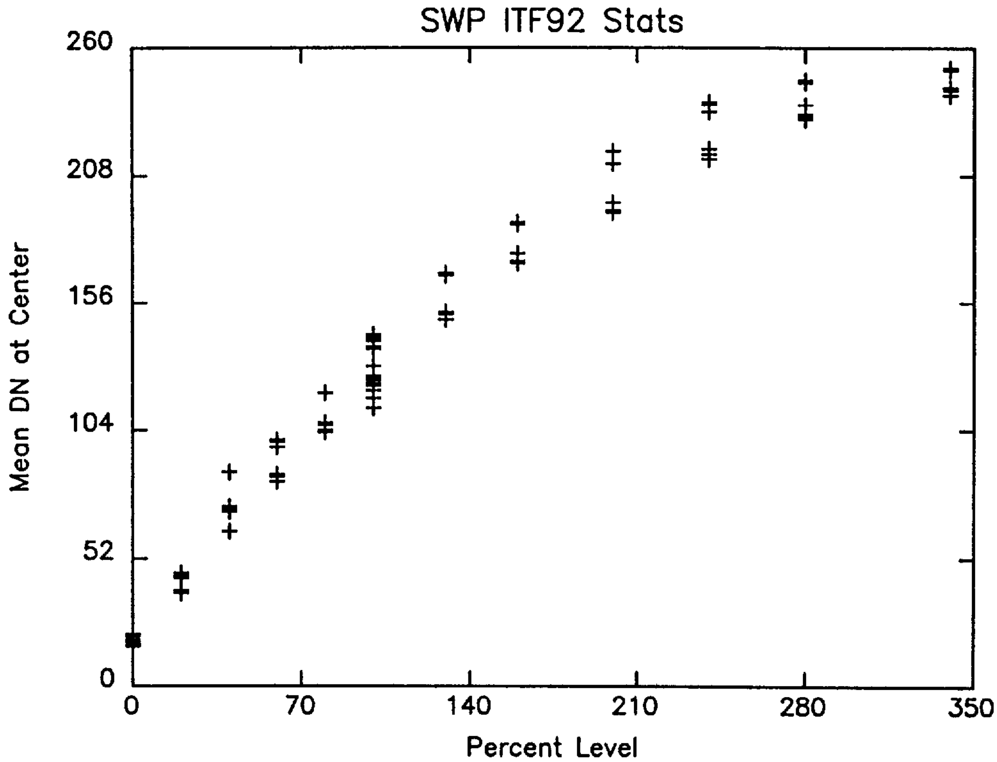

Figure 8: Mean DN for all SWP ITF images against exposure level