PRELIMINARY ANALYSIS OF DATA FROM SRI INTERNATIONAL TRANSIENT PULSE MONITOR ON BOARD P78-2 SCATHA SATELLITE

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To further the understanding of the phenomena associated with electrostatic charging of satellites, the U.S. Air Force and N.A.S.A. have undertaken a joint program called "Satellite Charging at the High Altitudes" (SCATHA). The program addresses a problem of great concern to agencies which operate satellites, the occurence of electrostatic discharges thought capable of causing various undesirable effects including deleterious transients in electronic circuits on satellites (see Ref. 1). The program's P78-2 satellite carries instruments on a nearly geosynchronous orbit to monitor the high altitude plasma environment and to study the effects of the interaction of this environment with the orbiting satellite. One of these instruments is the SRI Transient Pulse Monitor (TPM) which detects and characterizes the transient electromagnetic signals induced in selected circuits inside the P78-2 (Ref. 2, 3). As a transient detector, the TPM serves several purposes: it records the occurence of transient signals, it indicates the number of transients observed, and it gives the peak amplitude of the largest transient during each second's interval. In recording the times of transient occurrences, the TPM alerts investigators to periods during which environmental factors could have caused electrical upsets within the spacecraft. By measuring the intensity and amplitude characteristics of the transients induced in the internal circuitry, the TPM empirically indicates the kinds of electric transients to which spacecraft systems may be subjected.

The TPM detects and characterizes all transients induced in four selected circuits within the P78-2 including transients generated by switching of internal electrical circuits of the spacecraft and by electrostatic discharging on the outside of the craft. In general, most of the early data from the TPM contain pulses associated with internal electrical activity. The data also contain evidence of electrostatic charging on the surface of the P78-2. A very significant finding from analysis of early data is that periods of external discharging do not necessarily coincide with periods in which high potentials are measured on the satellite's surface.

TPM OPERATION

The TPM, described in References 2 and 3, has four sensors which run from various locations inside the satellite to a processing unit. Two sensors measure the transient signals induced in a pair of specially installed wires which run in an internal Faraday cage containing the command distribution wires. One of these instrumented wires is terminated with a high impedance (High-Z channel), the other with a low impedance (Low-Z channel). The other two sensors measure the signals induced in two selected wires of the regular spacecraft circuitry. The first wire connects the solar array to the power conditioning unit (Array channel). The second wire is the "single point" ground lead from the power conditioning unit (Ground channel) (see Figure 1). The TPM processing unit monitors the four sensors continuously and during each second indicates the negative and positive peak pulse amplitudes of the pulses that occur within that one-second interval. It also indicates the integral of the observed transient signal over the one second interval, and counts the number of times the signal exceeds a preset threshold during the second. For a more detailed description of TPM operation see References 4 and 5.

DATA ANALYSIS

In orbit, the TPM records a large number of transient pulses every day. Transients generated by internal electrical operation account for the majority of these pulses. As examples, a clocking pulse produces periodic glitches on the High-Z and Low-Z channels; automatic switching on the power conditioning unit causes random pulses on the Array and Ground channels; and, responses to certain commands issued from ground stations to the satellite cause noise pulses on various monitored channels. In the data analysis so far it has not been possible to devise a scheme for unequivocally identifying and eliminating all of the random transients that power conditioning activity induces in the Array and Ground sensors.

However, a method has been found to identify and eliminate the internally generated pulses observed on the High-Z and Low-Z sensors (see Ref. 6). Two traits characterize the pulses which remain after this elimination: they appear simultaneously on at least the High-Z and Low-Z peak amplitude sensors, and they are electrically bipolar on these two channels. Since no identifiable internal transients cause pulses of this type, it has been concluded that the pulses result from electrostatic discharges on the spacecraft. The fact that several of these TPM discharge detections have coincided with discharges measured by the SC1-8B transient detector on the exterior of the P78-2 supports the validity of the internal-pulse elimination technique and the claim that the selected pulses do, in fact, result from electrostatic discharges on the exterior of the satellite.

In comparing the TPM results to other transient discharge data, it is interesting to note that the 1973 predecessor to the TPM on another geosynchronous satellite (see Refs. 2 and 7) recorded a diurnal distribution of discharge transients very similar to the distribution seen by the TPM on the P78-2. Figure 2 shows the diurnal distribution of external transient pulse occurences from about forty days of TPM data. The distribution in both eclipse and non-eclipse orbits demonstrates a tendency for discharges to occur in the night time hours (satellite Local Time), especially after midnight. Although discharges measured on the 1973 satellite were measured on the vehicle's exterior, they show the same diurnal grouping of pulses in the midnight period. From the data analyzed so far, the TPM senses a daily average of two or three pulses attributable to discharges.

On several days in 1979 there were short periods in which large numbers of discharges occured. On days 118, 119, and 120 the periods of high discharge activity coincided with or followed shortly after satellite eclipse periods. However, other highly active days, such as days 136, 140, and 146, were after the Spring, 1979 eclipse season. Figure 3 shows the TPM data record of the early part of the first command session of day 146 on which several discharges took place. The Figure shows all five channels of data generated by each of the four sensors the TPM monitors for forty minutes of time. Above the TPM data at the top of the Figure are five rows of ticks indicating issuance of control commands to the satellite and showing unedited SC1-8 transient detector responses; the regular ticks below the TPM data are minute marks in earth time. The very top row of ticks shows the times that commands were issued from a ground station. Each of the other top four rows presents the output of one of the four sensors associated with the SC1-8 transient detector. From top to bottom, these are a sensor on a digital command line, on a harness wire, looped around the command distribution wires (there are no ticks for this row in this particular example), and at the end of a two meter boom (see Ref. 8). A tick on one of these rows corresponds to a non-zero datum at that time for one of the four sensors.* As with the TPM, many of the SC1-8 pulses correspond to internal electrical switching.

Under the five rows of ticks are three lines of data for each TPM sensor (twelve lines total). The top line of each set of three lines indicates the peak amplitude of the largest pulse during each second's interval for both positive and negative signals; the next line down gives the integral value of the positive and the negative pulses over a second's period; and, the bottom line shows the number of times the preset threshold was exceeded during the same second. The scales for each channel are shown on the left. The High-Z and Low-Z sensors measure induced voltages on the internal command wires and the Array and Ground sensors measure the currents induced in loops around the wires they monitor. Hence the peak amplitude scales are in volts and amperes and their integrals are in volt-microseconds and ampere-microseconds, respectively. Beneath the data are minute and ten-minute ticks in earth time, as well as the beginning and ending times of the plot in both Universal Time (UT) and satellite Local Time.

The nine small bipolar pulses labeled one through nine in Figure 3 starting at about 0:42 UT on the High- and Low-Z peak channels indicate external electrostatic discharges occurring late in the first hour of the day. Four of the pulses measured by the TPM on day 146, the second, third, seventh and ninth pulses, occured simultaneously with pulses recorded by the SC1-8B. The second and seventh pulses occured when the SC1-8 was monitoring its outside sensor. These are two of the pulses which both the TPM and the SC1-8 have identified independently as resulting from external discharging. It should be noted that, because the electric coupling from the exterior of the satellite through the frame to the sensors is not known at this time, it is not possible to estimate the amplitude of the discharges these pulses represent. They do give some idea of the magnitudes and rates of occurrence of the electrical transients observed in a well-shielded portion of this particular vehicle during a period of frequent electrostatic discharge. Usually the High-Z sensor measures up to one-half volt and the Low-Z sensor measures up to five volt peaks during discharging activity. Background activity in Figure 3 typifies the conditions observed in periods of normal satellite operation. In spite of the large number of pulses attributed to external discharges on day 146, it is interesting to note that the potentials measured on the spacecraft were only in the few hundred volt range on this day.

On day 43, which was one of the year 1979's quietest days geomagnetically, the TPM recorded two pulses (see Table 1). This Table is a raw data tabulation of the puse amplitudes observed on each sensor by the TPM and the time when the pulses occurred. In the 1973 satellite data, a strong correlation between geomagnetic activity and the frequency of discharges was observed (Ref. 7), but it was also found that discharges occurred even on undisturbed days. The TPM data for day 43 again shows that discharges do occur on "quiet" days.

Day 120, the last day of P78-2's spring eclipse season for 1979, has the longest sustained period of discharges seen by the TPM in the data analyzed so far (see Table 2). The pulses on Day 120 fall into two main clusters. The first cluster occurs just after the penumbral eclipse at midnight Local Time and the other after about three in the morning Local Time. This second cluster seems to correspond with a satellite charging event, but again the charging was only in the several hundred volt range.

In contrast, when the potentials measured on the satellite on day 114 reached the several kilovolts level, the TPM recorded no discharges. On most other days when large potentials were measured, the TPM, with few exceptions, also indicated little activity. One exception was day 113 on which the TPM measured discharges at about the same time the spacecraft was at a potential of one kilovolt. Generally, though, discharge activity is no more likely during periods of high measured satellite frame potentials than it is during periods of low measured potentials.

The relation of transients recorded by the TPM to spacecraft spin orientation has not been established definitely. Some of the data suggest that pulses of like amplitudes might be occuring with a periodicity corresponding approximately to the

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* It should be noted that, unlike the TPM, the SC1-8 system does not continuously monitor all of its sensors. Instead the processing electronics is periodically switched from sensor to sensor. Thus the same pulse is never indicated on more than one SC1-8 channel.

one minute spin period of P78-2. If this is true, it would indicate that some of the discharge activity could be associated with specific spacecraft geometries and positions relative to the flux of photons from the sun. A more thorough analysis of the discharges and the spin orientations is needed before this relationship can be validated. Over the span of several active discharge periods, however, no general spin dependency has been observed. This is a departure from the general correlation of spin orientation and discharge occurrence observed by the SRI pulse counting instrument flown in 1973 (see Ref. 7).

CONCLUSIONS

On the average, the TPM observes two to three pulses per day which can be attributed to discharges on the exterior of the P78-2 space vehicle. The discharges tend to occur in spurts, with an hour or two of discharging activity followed by several days of quiet. Generally, the pulses occur in the late night and morning periods. So far there has been little correlation between the potentials measured on the satellite frame and discharge activity. This indicates that the charging processes that lead to high frame potentials are not necessarily the ones that lead to the generation of discharges. In addition, TPM data analyzed thus far seems devoid of the general correlation between spin orientation and discharge occurence which had been observed in 1973 on another high altitude satellite. This suggests that spacecraft discharge activity depends in large part upon the design and construction of each individual craft.

The TPM operating on the P78-2 satellite is adding to the understanding of the electrostatic discharge phenomenon on high altitude spacecraft. As a piggyback instrument it represents a cost effective manner of gathering empirical discharge data. From the data analyzed so far, the TPM has shown the times of occurence and amplitudes of electrical transients caused by electrostatic discharges on the P78-2 satellite, a well shielded space vehicle. The data also appear to indicate that certain characteristics of the discharges may be different from one craft to the next. Generating and analyzing more data of the general kind produced by the TPM on satellites of different geometries and constructions will help to provide spacecraft engineers with the information needed to design satellites to withstand electric system upsets caused by electrostatic discharges.

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Table 1
TPM Pulse List

Day 043 1100-1500 UT

Universal Time Sec	Universal Time HH.MMSS	Local Time Approx. Dec. Hr.	Peak Amplitude Channels: +LO Z/-LO Z (V)	+HI Z/-HI Z (V)	+ARRAY/-ARRAY (A)	+GRND/-GRND (A)
44425	12.2025	4.432	0.094/0.106	0.792/0.792	below	below
44968	12.2918	4.583	0.186/0.201	2.457/1.622	threshold	threshold

Table 2

Day 120 0500-1100 UT

18184	5.0304	23.427	0.123/0.081	1.293/1.155		
18413	5.0653	23.484	0.811/0.781	5.227/5.637		
20953	5.4913	.118	0.304/0.252	4.168/2.752		
21267	5.5427	.196	0.271/0.225	3.722/2.650		
21405	5.5645	.230	0.084/0.056	1.343/0.921		
21662	6.0102	.293	0.179/0.143	2.194/1.817		
22091	6.0811	.392	0.282/0.160	3.081/1.293		
23025	6.2345	.607	0.304/0.252	4.013/3.081		
23720	6.3520	.766	0.304/0.233	3.865/2.650		
23942	6.3902	.817	0.216/0.216	2.551/1.959		
24448	6.4728	.933	0.396/0.242	3.451/1.749	below	below
24641	6.5041	.978	0.242/0.186	1.886/0.956	threshold	threshold
25027	6.5707	1.066	0.304/0.225	2.752/1.343		
25481	7.0441	1.167	0.304/0.235	2.752/1.395		
26838	7.2718	1.458	0.340/0.233	3.081/1.448		
35123	9.4523	3.153	0.282/0.193	2.551/1.245		
35495	9.5135	3.226	0.293/0.186	2.650/1.343		
36246	10.0406	3.374	0.326/0.201	3.081/1.448		
39279	10.5439	3.964	0.143/0.093	1.562/0.887		
40428	11.1348	4.189	0.396/0.206	3.584/1.504	0.000/0.004	

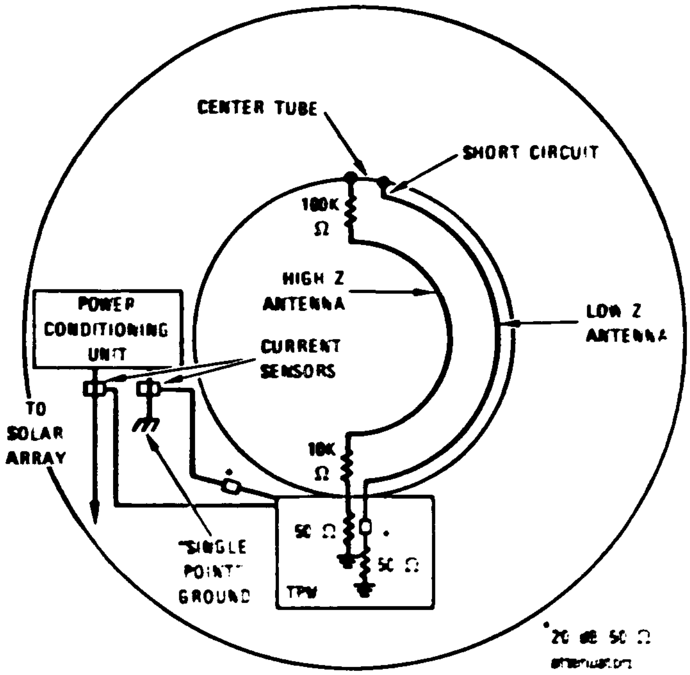

FIGURE 1 TPM SENSOR LOCATIONS ON P78-2

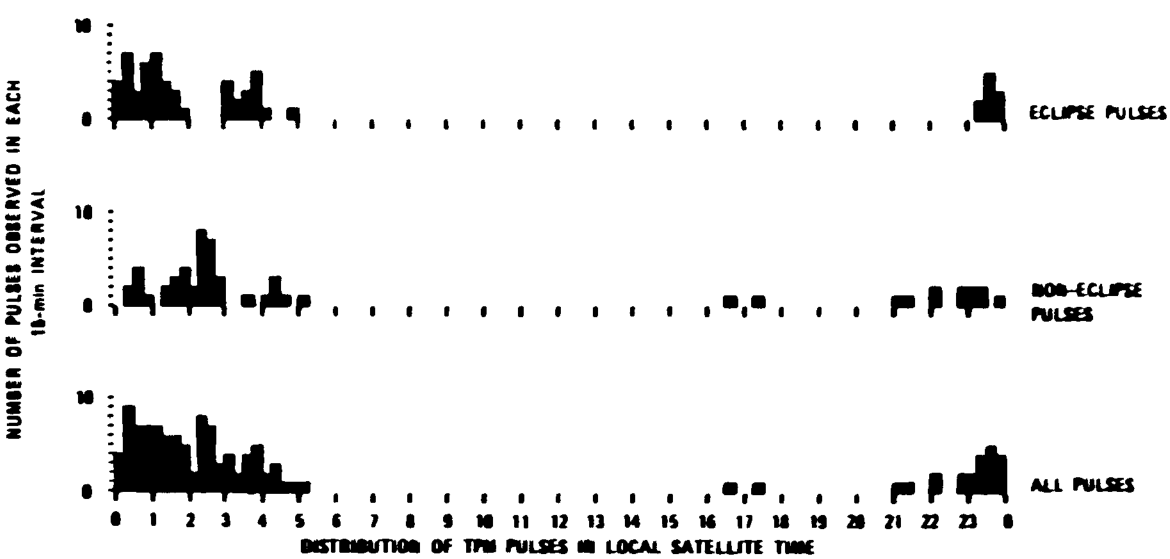

FIGURE 2 DISTRIBUTION OF PULSES OBSERVED BY THE SRI TPM

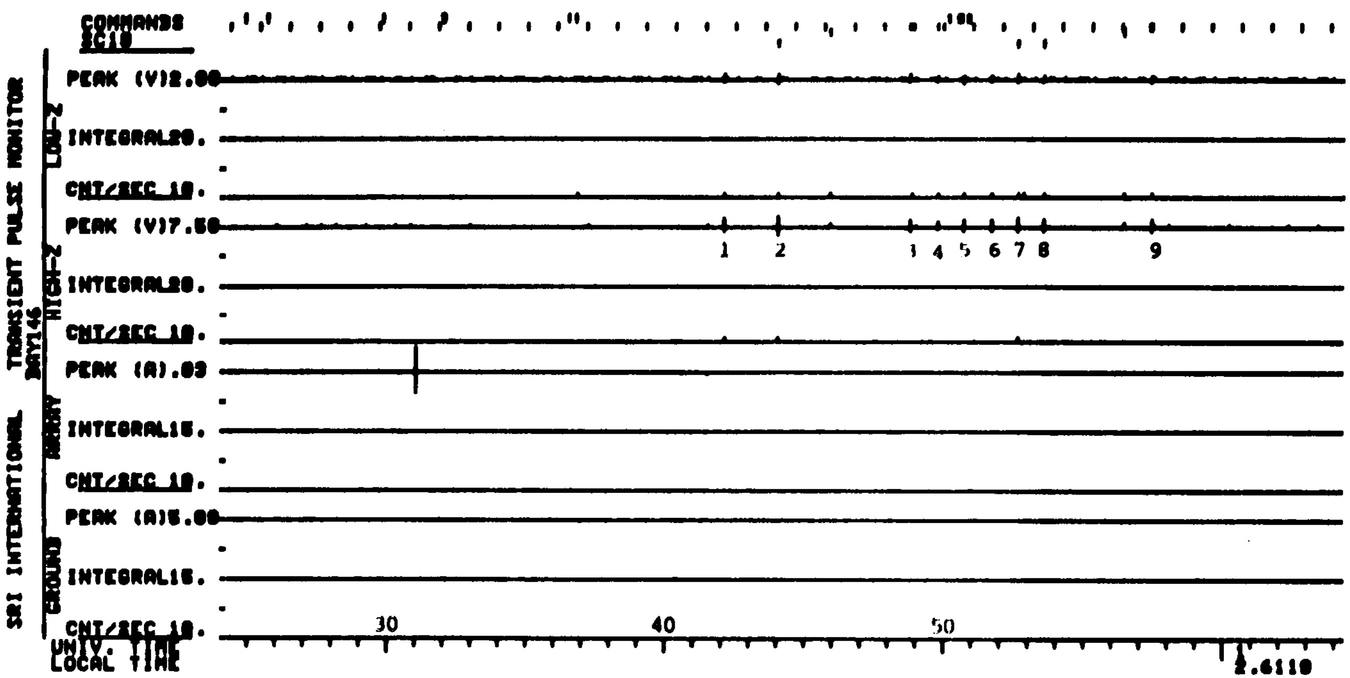

FIGURE 3 TPM DATA DAY 146, 0:24:23 1:04:23 UNIVERSAL TIME