# *STEREO IMPACT*

**PR Numbers: 1xxx=UCB, 2xxx=Caltech/JPL, 3xxx=UMd, 4xxx=GSFC/SEP, 5xxx=GSFC/Mag, 6xxx=CESR, 7xxx=Keil, 8xxx=ESTEC, 9xxx=MPAe**

| | |
|---|---|
| **Assembly :** HET Detectors | **SubAssembly :** |
| **Component/Part Number:** | **Serial Number:** |
| **Originator:** von Rosenvinge | **Organization:** GSFC |
| **Phone :** 301-286-6721 | **Email : tycho@milkyway.gsfc.nasa.gov** |

**Failure Occurred During (Check one √)**

**X** Functional test ☐ Qualification test ☐ S/C Integration ☐ Launch operations

**Environment when failure occurred:**

X Ambient ☐ Vibration ☐ Shock ☐ Acoustic
☐ Thermal ☐ Vacuum ☐ Thermal-Vacuum ☐ EMI/EMC

## Problem Description

During the accelerator test at MSU, it was noted that a large number of events were being improperly tagged as penetrating events and that a number of events were being flagged as invalid by the processing algorithms in the flight software.

## Analyses Performed to Determine Cause

There are 2 types of crosstalk conditions – H1 Detector Crosstalk and the PHASIC Crosstalk. See attached for a complete description.

HI Detector Crosstalk

The channels affected by the H1 Detector Cross talk are H1i and H1o. The cause of the crosstalk is the stray capacitance between H1i and H1o detector elements and the crosstalk between PHASIC post-amp channels. As a result, The unpulsed channel will read out a pulse height if the crosstalk pulse exceeds its threshold. The crosstalk pulse will cause an early arrival of the CLG pulse, which will corrupt the good pulse height by 0.2-0.5%.

PHASIC Crosstalk

The channels affected by the PHASIC Crosstalk are H2, H3, H4, H5, H6. The cause of the PHASIC crosstalk is the crosstalk between the PHASIC post-amp channels. As a result, the crosstalk pulse height will be less than or equal to the offset, and thus easily recognizable. For the worst-case scenario, H6 could have a crosstalk pulse height of 4 bins after offset correction.

Since the crosstalk itself cannot be eliminated without changing the physical structure the resolution to this issue was found in software.

## Corrective Action/ Resolution

☐ Rework **X** Repair (Software) ☐ Use As Is ☐ Scrap

A new software processing algorithm was designed and coded to detect the two types of cross-talk conditions and to allow the events to be properly tagged and processed. Testing was conducted using various command scripts to simulate the cross-talk events using the stimulus pulser. A final test of the software will be performed at a beam test on the HET ETU. This test is scheduled for March 2006. Update: The beam test was completed the first week of May 2006. The various types of crosstalk events were simulated during the beam test and was handled properly by the new processor algorithm. The software version tested at Michigan State was HETv2.4.

# *STEREO IMPACT*

**Date Action Taken**:_____5/1/2006_________ **Retest Results**:__Success!________
**Corrective Action Required/Performed on other Units** ☐ Serial Number(s): _n/a______

| **Closure Approvals** |
|---|

| | | |
|---|---|---|
| Subsystem Lead: | __________________________ | Date:_____________ |
| IMPACT Project Manager: | __________________________ | Date _____________ |
| IMPACT QA: | __________________________ | Date:_____________ |
| NASA IMPACT Instrument Manager: | __________________________ | Date:_____________ |

**By Larry Ryan**
**10/19/04**

**Overview**

Electronic crosstalk has been observed and characterized in the HET subsystem (comprising the HET telescope and electronics board). Crosstalk occurs in two separate regions of HET: 1) the H1 detector and 2) the PHASIC readout chips. In both cases, the crosstalk is capable of triggering quiet channels during cosmic ray events, thus corrupting the pulse-height and rate data. In addition, the PHASIC crosstalk (but not detector crosstalk) can occur for on-board stimulus events.

At the end of this write-up is a table summarizing the crosstalk analysis.

**Crosstalk in the H1 Detector**

When the HET was tested with real particles at the accelerator at Michigan State University in July 2004, we observed many instances when incoming particles triggered both the inner and outer rings of H1 (H1i and H1o). While this is expected to occur occasionally due to the physical structure of the H1 detector, we observed a far higher incidence of H1i / H1o coincident triggers than expected. Subsequent analysis of the data showed a linear relationship between the H1i and H1o pulse heights, in which one pulse height would generally be 0.23% the height of the other. This was a strong indicator of electronic crosstalk between H1i and H1o due to stray capacitance between the detectors.

At Goddard I probed for the crosstalk by pulsing (with a voltage pulser and charge-terminating capacitor) one detector output (H1i or H1o) with the H1 detector installed and biased. I determined that over the range of input energies for which the crosstalk is observable (exceeds threshold) the pulse-height relationship between the unpulsed channel and the pulsed channel is indeed 0.23%. This was true when I pulsed H1i and observed H1o, and vice-versa.

The full-scale input for H1i and H1o is about 2000 MeV. A full-scale pulse in H1i or H1o will therefore trigger an apparent 4.6 MeV pulse in the other channel. This is considerably higher than the 200 keV threshold of H1i and H1o. Furthermore, an input of 87 MeV or greater in H1i or H1o will trigger the threshold of the other channel.

In order to verify that the crosstalk path was stray capacitance between H1i and H1o, and to determine the approximate amount of capacitance present, I set up a simple electronic simulation. I found that with a simulated stray capacitance of 5 pF, the simulated H1i and H1o preamplifier output waveforms (pulse height and shape) very closely matched the actual preamplifier output pulses observed on an oscilloscope. So I would estimate that the stray capacitance between H1i and H1o is approximately 5 pF. It should be noted that with the H1 detector disconnected from the board, there is no observable crosstalk between H1i and H1o. Therefore, the 5 pF of stray capacitance must be present in the detector itself (or the detector mount), and not in the board. Care was taken in the board layout to minimize any stray capacitance between detector traces.

Because the crosstalk path is capacitive, the incoming pulse is differentiated when crossing over to the unpulsed channel. Therefore, the unpulsed preamplifier output peaks considerably more quickly than the pulsed preamplifier output (100 ns vs. 400 ns). This early peaking propagates through the shaping amplifier, with the end result being that the “rundown” signal (which is effectively a peak-detect) for the unpulsed channel arrives several hundred nanoseconds before the rundown signal for the pulsed channel. The rundowns of all seven HET channels are OR-ed together (RNDN-OR) to generate an overall trigger to the MISC. Once triggered, the MISC counts down the “coincidence-resolving time,” then asserts the CLG (close linear gate) signal. When asserted CLG effectively cuts off the shaped pulse, causes it to return immediately to the baseline. If the shaped pulse has not reached its peak when CLG is asserted, then a false peak will be created as the pulse stops its rise and returns to baseline. Since an H1 crosstalk event will cause RNDN-OR to arrive early, there is the possibility that CLG will be asserted before the pulsed channel’s shaping pulse reaches its peak, thus corrupting its pulse height. In fact, this is exactly what happens with the flight system as it is currently set up. We currently have the coincidence-resolving time set to “2”, which equates to about 550 ns. During crosstalk events, CLG arrives very close to the peak of the desired pulse, slightly corrupting it (by approximately 0.2% to 0.5%). Also, there is jitter in the timing of the CLG arrival relative to the pulse peak due to its being synchronized to the system clock, and this jitter effectively causes noise (uncertainty) in the pulse height. The coincidence-resolving time can be increased or decreased by steps of 156 ns (one clock tick). Increasing it by one clock tick would alleviate the problem of the desired pulse being corrupted during H1 crosstalk events. Unfortunately, however, doing so would worsen the other form of crosstalk, which will be discussed next.

**Crosstalk in the PHASIC Chip**

The PHASIC detector readout chip exhibits crosstalk in its “Post-Amp” stage. Any one channel receiving a large enough pulse can crosstalk to any other enabled channel within a PHASIC, and if several channels receive large pulses, the crosstalk into unpulsed channels will be larger. The crosstalk mechanism results in an inverted signal in the Post-Amp stage of the unpulsed channels. This signal is bipolar, and the subsequent shaping stages only respond to the positive-going lobe (the second lobe) of the pulse. Therefore, the shaped crosstalk pulse peaks considerably later than the desired pulse. As a result, the crosstalk pulse gets cut off by the arrival of CLG (described above). However, with the coincidence-resolving time setting we are currently using, the crosstalk pulse can and does occasionally trigger the threshold, causing a false pulse-height to be read out. This has been observed both in laboratory testing (with external pulsers and the internal stim pulser) and at accelerator testing at MSU. For reasons not fully understood, the crosstalk pulse height will generally be less than or equal to the offset; that is, when the offset is subtracted, the final pulse height value will be negative or zero. Therefore, such a pulse height can be recognized as being due to crosstalk. However, I have seen a case in which the crosstalk pulse height in H6 exceeds the offset by as much as 4 ADC bins. In that instance, it is more difficult to determine from the pulse height data whether the H6 pulse height is due to actual energy deposited in H6, or to crosstalk. I will describe that situation more fully later.

While the crosstalk equation is monotonic, it does have an interesting property that I will describe. The high-gain channel has about 20 times the gain of the low-channel. Therefore, an incoming event that has an energy greater than 5% of full-scale will saturate the high-gain channel. As incoming energies increase, the high-gain channel goes into harder saturation. At an input of about 25% of full-scale (and above), the shape of the high-gain channel shaped pulse changes abruptly. Its rise time speeds up, and it reaches its saturated peak faster. This results in its rundown signal arriving about 500 ns earlier, which causes CLG to arrive 500 ns earlier. This early arrival of CLG cuts off the crosstalk pulse before it can even begin. Therefore, if any HET channel receives an incoming energy greater than 25% of full-scale, there will effectively be no PHASIC-induced crosstalk. Of course, if the coincidence-resolving time, which is set in the flight software, were to be increased, then we might see crosstalk even for energies greater than 25% of full-scale. I have not tested this condition.

I have tested specifically to see how much energy in H1i will cause PHASIC-induced crosstalk in H1o, and vice-versa. I find that energies of 100 MeV to 500 MeV in the one channel can cause a crosstalk pulse-height to be read out in the other channel. (Full-scale on H1i and H1o is 2000 MeV.) However, PHASIC-induced crosstalk between H1i and H1o will not occur for particles in flight, because it will be cut off by the early arrival of the CLG pulse due to detector-induced crosstalk in H1. PHASIC-induced crosstalk between H1i and H1o can only occur for stimulus pulses, since these pulses don't trigger detector-induced crosstalk.

An H2 energy of 100 MeV to 500 MeV can cause a crosstalk pulse height in any of H3-H6. By extension, we can say that it would require about 200 MeV to 1000 MeV in H3, H4, or H5 to crosstalk into any other unpulsed channel among H2-H6. I say that such energies *can* cause crosstalk pulses, not that they *will* cause crosstalk pulses, because they only do so sometimes. As a result, it is possible to get an event that includes H2, H4, and H5, for example, when only H2 was really hit. This should not be flagged as an invalid event just because it does not include H3, since H4 and H5 are not real detector pulses.

The crosstalk effect is cumulative with channels being pulsed. That is, if more than one channel is hit, the unpulsed channels will exhibit more crosstalk than if only one channel is hit. I have tested the scenario in which H2 through H5 are all hit with the same energy, to see what energy is required in order to trigger a crosstalk pulse in H6. I find that if H2 is hit with 20 MeV and H3, H4, and H5 are hit with 40 MeV each, the H6 channel will occasionally be triggered, though the pulse-height will be less than the offset, and therefore easily recognizable as crosstalk. However, if H2 is hit with 500 MeV and H3, H4, and H5 with 1000 MeV each, the H6 crosstalk pulse will occasionally be as high as 4 counts above the offset, as mentioned above, making it more difficult to determine that the event was stopping and not penetrating. Above those energies in H2-H6, the CLG pulse comes 500 ns sooner, and the H6 crosstalk is cut off and does not exceed the threshold.

I have tested several specific event types to characterize the expected PHASIC-induced crosstalk in H2-H6. In the following table, I assume that all offsets have been increased by 1 from the offset value originally calculated using a least-squares linear fit of the INL data. Increasing the offsets by 1 is advantageous because it provides a better fit for very small pulses, and it pushes more crosstalk pulses below the offset.

| Condition | Result |
|---|---|
| H2-H5 pulse heights all within the High Gain channel. | H6 crosstalk pulse heights (if present at all) will never exceed the offset. |
| One of H2-H5 pulse heights at ~25% of full-scale (in the Low Gain channel) and the rest at the top of the High Gain channel. | H6 crosstalk pulse heights range from offset-2 to offset+1 (fewer than 0.2% of crosstalk pulses at offset+1). |
| Two of H2-H5 pulse heights at ~25% of full-scale (in the Low Gain channel) and the rest at the top of the High Gain channel. | H6 crosstalk pulse heights range from offset-1 to offset+2. |

| | |
|---|---|
| All of H2-H5 pulse heights at ~25% of full-scale (in the Low Gain channel) – worst case scenario for crosstalk into H6. | H6 crosstalk pulse heights range from offset+1 to offset+4. |
| Any H2-H5 pulse height combinations that fall on the stopping Carbon track. | H6 crosstalk pulse heights (if present at all) will never exceed the offset. Crosstalk in the stopping Carbon track will actually be rare, due to H1 detector crosstalk causing an early arrival of CLG, cutting off the crosstalk pulse. (Most of the Carbon track lies above 87 MeV in H1, the threshold for detector crosstalk.) |
| Any H2-H5 pulse height combinations that fall on the stopping Helium tracks. | H6 crosstalk pulse heights (if present at all) will never exceed the offset. Fewer than 1% of the highest energy stopping Helium pulses in H2-H5 cause crosstalk pulse heights in H6. |

The PHASIC-induced crosstalk can be alleviated somewhat by reducing the coincidence-resolving time, which causes CLG to arrive earlier and cut off the crosstalk pulse. For example, reducing it from "2" to "1" (one clock tick) causes the H6 pulse height in the worst-case scenario above to drop below the offset and causes most of the crosstalk pulses to be eliminated entirely. However, reducing the coincidence-resolving time would worsen the H1 detector crosstalk, as described above. And it also would have a detrimental impact on all pulse heights above 25% of full-scale, which I will describe in the next section.

**Effect of Reduced Coincidence-Resolving Time on Large Pulses**

As described above, pulse heights above 25% of low-gain full-scale cause the high-gain channel's "rundown" signal to arrive about 500 ns earlier. This causes the CLG pulse to arrive earlier as well. At the current coincidence-resolving time setting of "2", all of the pulses reach their peaks before the arrival of CLG, even in the case of its early arrival due to a large pulse (> 25% FS) in any channel. However, if the coincidence-resolving time is reduced by one clock-tick to "1", the pulses will not have fully reached their peak when CLG arrives early due to a large pulse. This will cause all pulse heights to be corrupted by 0.2% to 0.5%, with noise added due to jitter in the exact arrival time of CLG relative to the pulse peak (since CLG is synchronized to the system clock). Therefore it is probably not desirable to reduce the coincidence-resolving time from the current setting.

**Summary**

| | **H1 Detector Crosstalk** | **PHASIC Crosstalk** |
|---|---|---|
| **Channels Affected** | H1i and H1o | H2, H3, H4, H5, H6 (also H1i and H1o, but only for stim pulses, not for cosmic ray events) |
| **Cause** | Stray capacitance between H1i and H1o detector elements | Crosstalk between PHASIC post-amp channels |
| **Description** | 0.23% (-53 dB)<br>87 MeV or greater in H1i will trigger Hio and vice-versa.<br>Full-scale input to H1i will cause 4.6 MeV pulse height in H1o and vice-versa. | 100-500 MeV in H1i can trigger H1o and vice-versa (stim pulses only).<br>100-500 MeV in H2 can trigger H3, H4, H5, or H6.<br>200-1000 MeV in H3, H4, or H5 can trigger any of H2-H6.<br>20-500 MeV in H2, plus 40-1000 MeV in H3, H4, and H5 can trigger |

| | | |
|---|---|---|
| | | H6. |
| **Result** | The unpulsed channel will read out a pulse height if the crosstalk pulse exceeds its threshold.<br><br>The crosstalk pulse will cause an early arrival of the CLG pulse, which will corrupt the good pulse height by 0.2-0.5%. | Generally, the crosstalk pulse height will be less than or equal to the offset, and thus easily recognizable.<br><br>For the worst-case scenario, H6 could have a crosstalk pulse height of 4 bins after offset correction. |
| **Mitigation** | The crosstalk itself cannot be eliminated except by changing the physical structure of the H1 detector.<br><br>Increasing the coincidence-resolving time will eliminate the corruption of good events due to the early arrival of CLG. However this would worsen the PHASIC-induced crosstalk. | Crosstalk pulse heights can be recognized by the software due to their zero or negative offset-corrected pulse height.<br><br>Decreasing the coincidence-resolving time will eliminate the H6 worst-case scenario described above. However, this would worsen the detector-induced crosstalk. |
| **Made Worse By** | Decreasing the coincidence-resolving time (does not actually affect the crosstalk, but only the corruption of good events). | Increasing the coincidence-resolving time. |