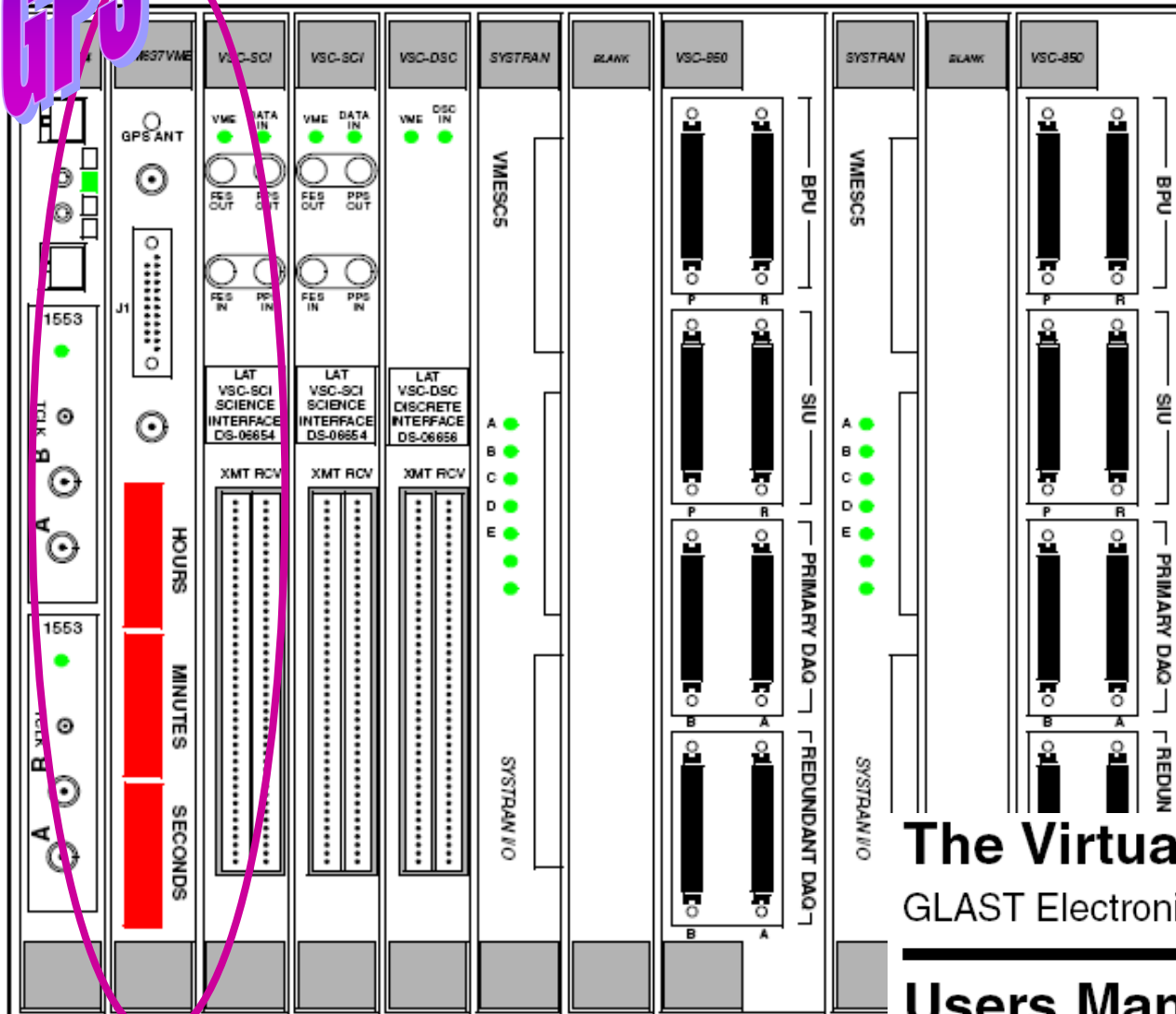


Absolute LAT Timing

GPS

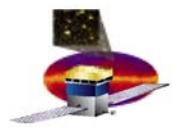


David Smith
CENBG/In2p3/CNRS
Bordeaux, France

The Virtual Spacecraft (VSC)

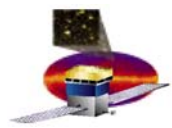
GLAST Electronics group

Users Manual



Motivation

- For pulsar studies, bad event absolute time stamps would be nearly as bad a disaster as gyroscope failures. Many missions have had issues, including recent ones.
- I set out to compare the timestamps at the very end of the hardware+software chain with some independent measure, if possible, and with anything at all for starters.
- This talk:
 - A. plausible dates using NRL FSW muons.
 - B. Current events
 - C. Future prospects



Example of “real life” timing problem

THE ASTROPHYSICAL JOURNAL, 568:226–231, 2002 March 20

- While reading up on PSR J0205+6449 I came across this:

THE ASTROPHYSICAL JOURNAL, 566:1039–1044, 2002 February 20

IS THE COMPACT SOURCE AT THE CENTER OF CASSIOPEIA A PULSED?

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Harvard-Smithsonian Center for Astrophysics, Cambridge, MA 02138; ssm@head-cfa.harvard.edu

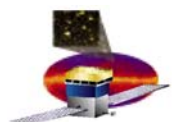
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Received 2001 June 28; accepted 2001 October 22

ABSTRACT

A 50 ks observation of the supernova remnant Cas A was taken, using the *Chandra X-Ray Observatory* High-Resolution Camera (HRC) to search for periodic signals from the compact source located near the center. Using the HRC-S in imaging mode, problems with correctly assigning times to events were overcome, allowing the period search to be extended to higher frequencies than possible with previous observations. In an extensive analysis of the HRC data, several possible candidate signals are found

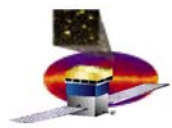


CHANDRA pulsar timing problems, cont'd

1.1. *Problems with HRC-I Timing*

Using the *Chandra X-Ray Observatory* and the HRC, we obtained a 50 ks observation of Cas A specifically to search for pulsations from the compact source detected near the center of the remnant. This observation (OBSID 01505) was taken using the HRC-I on 1999 December 20. It was subsequently found that the HRC has a wiring error that incorrectly assigns event times such that the assigned time is that for the previous event trigger (Murray 2000; Seward 2000).¹ If every event trigger resulted in an event in the telemetry, this error could be easily corrected by simply shifting event times by one event during ground processing. However, because of telemetry limitations ($184 \text{ events s}^{-1}$) and onboard event screening, not all event triggers necessarily result in an event entering the telemetry stream. Therefore, determining true event times is not always possible and under normal HRC operating conditions cannot be done for a significant fraction of the events.

In order to evaluate the effect of the HRC timing error on our ability to detect pulsations, we developed a high-fidelity software simulation of the detector and telemetry system. Simulations for this observation (OBSID 01505) show that if no attempt is made to correct the timing error, or if the only correction made is to shift the telemetered time for each event by one event, then a sinusoidal pulse signal with $< 20\%$ modulation amplitude or with a period of less than 20 ms will be undetectable (similar to the conclusions of Chakrabarty et al. 2001).

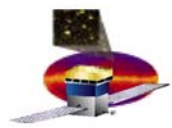


CHANDRA pulsar timing solution

1.2. *Solution using HRC-S in Imaging Mode*

Fortunately, the HRC-S can be operated in a “special” mode where all event triggers result in events that are included in the telemetry. In this mode, only the central microchannel plate segment is able to initiate an event trigger. This restriction reduces the background by about a factor of 3 from the normal HRC-S rate (i.e., total event rate goes from ~ 250 to ~ 90 counts s^{-1}) and therefore allows onboard event screening to be turned off. All event triggers are processed as valid events and fitted within the telemetry limit of 184 counts s^{-1} . This mode is designated the HRC-S (Imaging) Mode. It is now available for all observers and was used to reobserve those AO-1 and AO-2 targets requiring the high time resolution of the HRC, including our Cas A observation.

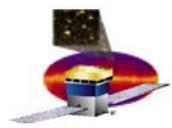
They recovered, but apparently with some loss of pulsed sensitivity...



LAT pulsar timing tests

- Ongoing discussions with Eric Grove and a growing list of experts.
- From Pat Hascall, 17 April: “LAT 13x tests performed at SLAC to demonstrate the 10uS timestamp requirement (Level 3 req’t 5.2.11). Tests described in LAT-MD-02730. (The accuracy of the 1PPS signal is a spacecraft requirement). Test results will be analysed and documented in LAT-TD-xxxxx*.”
- Gregg Thayer prepared the tests. See for example run 77005274, “intSeApp_e2e_LAT-13x_0.17hr”, from 2006-05-24 19:53.

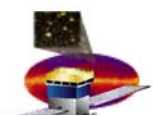
* yesterday I asked Pat if xxxxx exists and who’s writing it, and he said “you are!”.



Real ~~GPS~~ timestamps in real data

-
- FSW (=Flight Software) gets GPS absolute time stamp for individual triggers from the VSC (virtual space craft, see next slide).
 - Except that, at present, it gets it from a highly reliable internet time source at power up, and then counts forward in time using a computer clock, because of some thorny VSC+FSW issues. Hence, timestamps drift over time.
 - The elements for building MET (=Mission Elapsed Time, that is, seconds since 2001 January 1, the input to gtbary, the first step towards calculating pulsar spin phase) are “TimeTone at PPS” and “50 ns ticks since last PPS” and appear in the digi.root and SvacNtuple.root files.

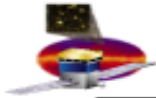




How to build MET from raw data

Slide 9 of Anders Borgland's talk,

http://www-glast.slac.stanford.edu/IntegrationTest/SVAC/Instrument_Analysis/Meetings/05262006/SVAC.pdf



ISOC/SVAC

Instrument Analysis Meeting, May 26, 2006

Time Tones

- We receive a time tone from the GPS every second: 1-PPS
- Can be used to make an event time stamp!
- For every event:
 - Information about the current and previous time tone
 - Can correct for drift in the system clock i.e. The Time Tone is our absolute time!
- Example:
 - Event time stamp in seconds:

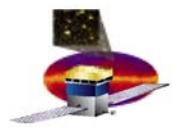
$$\text{TimeStamp} = \text{ContextLsfTimeTimeToneCurrentSeconds} + \left[\frac{\text{ContextLsfTimeTimeTicks}}{\text{ContextLsfTimeTimeToneCurrentGemTimeTicks} - \text{ContextLsfTimeTimeTonePreviousGemTimeTicks}} \right]$$

Number of seconds since Epoch start 01.01.2001 of last 1-PPS

Number of system clock ticks (50 ns) since last time tone for this event

Number of system clock ticks between last two 1-PPS

All the **ContextLsf....** are SVAC ntuple variables!



Timestamps in SVAC & Merit Tuples

- I followed Anders' recipe, using a recent muon run from NRL, 77005390. Generated *plausible* METs. Learned lotsa nifty little details.
- Continue down the software chain? There used to be a .fits file from the pipeline, I wrongly thought it was like the .fits we used in DC2.

But a) it was the MeritTuple with a .fits wrapper, and b) it's gone since the switch from Latte to FSW.

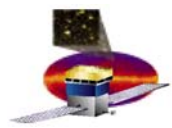
- So I looked at EvtElapsedTime in the MeritTuple. It's sort of within a second of the SVAC-derived time: (here, 10 of first 10,000 events, at ~440 Hz).

```
int diff = TTCGemTimeTicks-TTPGemTimeTicks ;    if (TTPGemTimeTicks>TTCGemTimeTicks) diff = TTCGemTimeTicks+(33554432-TTPGemTimeTicks) ;  
float fraction=TTCTTicks/(float)diff ;           Expect TTCTSecs+TTicks/Diff to equal EvtElapsedTime
```

EvtID	TTCTSecs	TTicks/diff	EvtElapsedTime
3695052	170449260	1.064380	170449261.065369
3696052	170449263	1.620004	170449263.226898
3697052	170449265	0.450713	170449265.435852
3698052	170449267	0.951812	170449267.623566
3699052	170449269	1.489436	170449269.799530
3700052	170449271	0.367067	170449272.023560
3701052	170449274	0.968614	170449274.353455
3702052	170449276	1.543594	170449276.554779
3703052	170449278	0.355703	170449278.734436
3704052	170449280	0.830439	170449280.823669

E-mailed with Anders & Heather about this. To me, seems that Merit value should be replaced by $TTCTSecs+TTicks/diff$ (Anders' recipe) but they concluded something different that I didn't understand.

Nota bene – Joanne Bogaert selects rdb calibration files using these event times.



(What does “plausible” mean?)

- Run 77005390 started at 2006-05-27 18:59:38, according to IA runs database.
- MET (=Mission Elapsed Time is seconds since 2001 January 1) .

<78>smith:borlin57.cenbg.in2p3.fr% /bin/date -u --date="1 Jan 01 00:00" '+%s' → 978307200

<79>smith:borlin57.cenbg.in2p3.fr% /bin/date -u --date="27 May 06 18:59:38" '+%s' → 1148756378

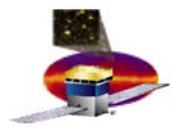
Difference is 170,449,178 (MET of begin run).

SVAC recipe shows 170,449,260 82 second difference “plausible”

EvtID	TTCTSecs	TTCTTicks	TTCGemTTix	TTPGemTTix	diff	TTicks/diff
3695052	170449260	21287574	2918647	16473104	19999975	1.064380
3696052	170449263	32400049	29364140	9364165	19999975	1.620004
3697052	170449265	9014258	2255226	15809683	19999975	0.450713

The 20 MHz scaler counts 19999975 times per second instead of counting 20000000. Fine.

TTicks/diff would, naively, never be more than 1 but apparently some PPS's get lost, which is also fine.



(A glance at the status words)

NEXT: quick look at the many status variable...

"FlyWheeling" always zero for the above.

if (TTCincomplete!=0 || TTPincomplete!=0) nHOLA++ ; ten thousand times! Always 65536.

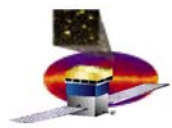
```
printf(" Current flags: %d %d %d %d %d \n",CFlagsValid, CMissingGps, CMissingCpuPps,  
      CMissingLatPps, CMissingTimeTone) ; Ditto "Previous"
```

For all 10 events sampled from 10,000 events, here's what you get:

Current flags: 1 1 0 0 0

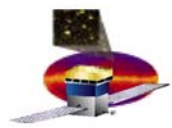
Previous flags: 1 1 0 0 0

Anders says: features known from the digi reports, and under investigation.



Current events (downstream)

- As stated: ultimate goal is to check the absolute time stamp at the very end of the SC+LAT+FSW+Pipeline chain against a more-or-less GLAST independent reference time.
- So I enquired to Julie & Seth about plans for the DC2-like .fits files to exist with real data.
- She said: currently discussions at GSFC, including e.g. choice of time standards (how to deal with leap seconds, etc).
- A suggestion: as part of the DC3-like “service challenges”, process LAT ground cosmics all the way through MOC and ISOC to the .fits files data servers. Include LAT orientation during muon runs (e.g. the orbital elements of NRL...) so that (RA,dec) as well as MET are filled as realistically as possible.
- Then perform pulsar searches on atmospheric gammas (and muons?) -- good way to stress all software.
 - *First one to see pulsed muons from Cyg-X3 looses!*

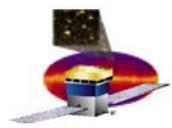


Current events (upstream)

- [Intermediate goal – verify that TimeStamp downstream of LAT+FSW+pipeline is still precisely correlated with original TimeStamp.]
- Eric Grove told me that data from the VSC comes in a CCSDS* file, part of which becomes the Science Stream and hence our digi.root and SVAC files.
- It further contains info from “upstream” of the LAT, e.g. space craft attitude and position and the TimeTone of the most recent PPS.
- Bryson Lee confirmed, and thought he could provide me with some ascii dumps. Then we a) learned that it's not really GPS and that b) what are you going to learn by comparing 440 Hz with asynchronous 1 PPS anyway? This task is temporarily adrift...

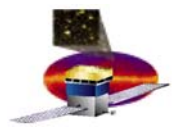
* See ccsds.org

The Consultative Committee for Space Data Systems
The Official Web Site



Future prospects

- The current “internet time at power-on followed by freewheeling” will be upgraded, to either use the (now unused) GPS that is in the VSC VME crate, hopefully before the LAT leaves NRL, or by the GPS on the real space craft once the LAT is in Arizona.
- **What seems groovy to me:** at NRL, use a muon telescope to trigger an external GPS (see next slide) while LAT triggers on cosmix, and then perform offline analysis of the independent data streams. Like “if TKR track points at paddles then compare our time and LAT time”.
- Or do that after integration with spacecraft, to *really* get the whole shbang? Both is better.
- Quandry:
 - on the one hand, waiting is appealing – the VSC+FSW folks are progressing, and CERN is looming.
 - On the other hand, access will be even harder once the LAT leaves NRL.
- Or just trust 10 uS verification, and SpaceCraft absolute time verification?



An independent, external muon timestamp?

- The VME GPS that Denis Dumora and I used to see the Crab optical pulsar with CELESTE is in our basement. We got PMTs, NIM logic, etc. If this task is deemed critical and no one else is available to do it, we could get it working again and bring it to NRL, but then we'd be (mostly) absent from CERN.

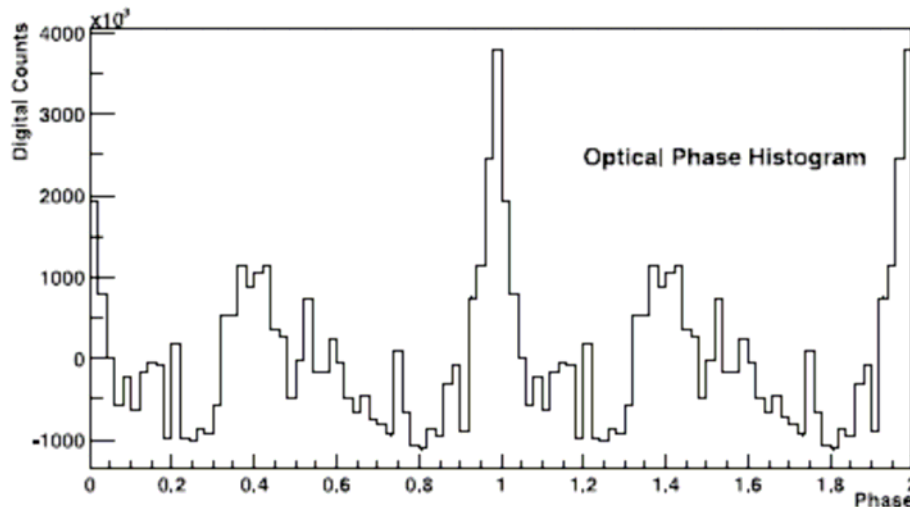


FIG. 16.—Phase histogram for the optical Crab data

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MEASUREMENT OF THE CRAB FLUX ABOVE 60 GeV WITH THE CELESTE CERENKOV TELESCOPE

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