

## **E10/S3 Hardware Pulsar Injections**

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**(impossible without Peter Shawhan, Teviet  
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Riles, Graham Woan)**

# Pulsar Hardware Injections

- Provide end-to-end validation of search code:
  - » Gain confidence about tricky things like floating point dynamic range in filtering process.
  - » Helps algorithm/code developers in testing.
  - » Provide a fixed point of reference to return to.
  - » Convince community that we can **really** detect signals.

- Differences between **S2** and **S3** injections

	<u>S2</u>	<u>S3</u>
<b>Duration:</b>	~10 hours	entire run
<b>Mechanism:</b>	Data files + Peter S.	'on the fly'
<b>Number:</b>	2	10 (or more)

# How was it done?

- The pulgroup (MAP, Xavier) had developed and validated a standalone program (**makefakedata**) for pulsar generation.
- Built around LAL routines (Cutler: barycentering, Creighton: inject, Chin: beam pattern).
- This program has previously been used:
  - » in S1 analysis for Monte-Carlo testing
  - » in S2, to make fake signals, and for software injection testing
- Major shortcoming for our purposes: pulsar parameters ( $f$ ,  $df/dt$ , ...) were defined at instant of first sample produced, not at arbitrary Solar System Barycenter (SSB) time. Made it hard to restart code.

# First: modified **makefakedata**

- Additional command line arguments:
    - » -G to specify GPS time to start making data
    - » -S to specify SSB fiducial time at which parameters are defined
    - » -b write raw binary output (with magic value 1234.5) to stdout
- ```
makefakedata_v2 -i Pulsar.0 -I LHO -S 751680013 -b -G 761234567
```
- Small “internal” fixes:
    - » increase range of internal interpolation table (cured starting zeros)
    - » set heterodyning reference time in terms of SSB fiducial time.
  - Better error messages (use errno, print PID, time ...)
  - Poor performance under solaris. After some profiling, replaced sin() and cos() calls with sincos(&s, &c) from libsunmath

# A typical pulsar parameter file

## Pulsar.0

```
20.0          Tsft in seconds.  Lenth of time chunks made internally
300000       nTsft: the number of chunks made. Enough for > 2 months
0.0          Frequency of to start with
8192.0       Frequency band (sets sample rate)
0.0          Sigma (std of noise).  When 0, only signal present.
1.0          Aplus  (units: CONTROL signal)
0.0          Across (units: CONTROL signal)
0.0          psi
1.5          phi0   (radians: incorporates calibration phase)
1279.123456789012  f0 frequency
0.3766960246  lattitude in radians (declination delta)
5.1471621319  longitude in radians (right ascension alpha)
0            Number of spindown parameters (in this case, zero)
```

# Second: wrote s3inject

- The s3inject program:

```
./s3inject -n 5 -G 751680013
```

- » Reads 5 files called in.0 to in.4. Each contains a command line, like:

```
./makefakedata -i Pulsar.0 -I LHO -S 751680013 -b
```

- » Uses popen(3) to fork(2) and exec(2) the specified programs, appending the additional command-line -G argument to specify GPS time

- » Reads data from each pipe, summing values for next second

- » Calls SIStrAppend() to send data to online injection system (Peter Shawhan did this part.)

- Careful tuning of stdio stream buffers and calls to flush, so that s3inject doesn't block waiting for next data set.

- Framework general enough to accommodate SB injection also.

- Actuator amplitude/phase response included in A+/Ax amplitudes and initial phase.

# Validation

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- I checked that I could reproduce S2 hardware injection signals from both fake pulsars, at start and end of 12 hour injection period, at both H[12] and L1.
- Nevertheless Peter Shawhan found a problem when making long injection stretches:
  - » Spurious harmonics
  - » Turned out to be overflowing float in inject package, shifting phase in jumps rather than smoothly
  - » Fixed by Teviet

# Pulsars being injected

- Why 10 ‘random’ pulsars?
  - » Signal amplitudes chosen to cover the range from virtually undetectable in 60 days to SNR of hundreds in 60 days.
  - » If some are near strong lines or instrumental artifacts, others will still be visible
  - » Graham Woan in charge of choosing parameter sets. 1-5 are “public” and “6-10” are ‘private’.
- May add 11<sup>th</sup> pulsar (GEO requires  $\cos i = 0$ )
- Dedicated machines (one per each instrument):
  - » h1injection, h2injection, l1injection
- Running as we speak....



# 'top' run on h1injection

load averages: 2.59, 2.73, 2.75

22:44:32

103 processes: 102 sleeping, 1 on cpu

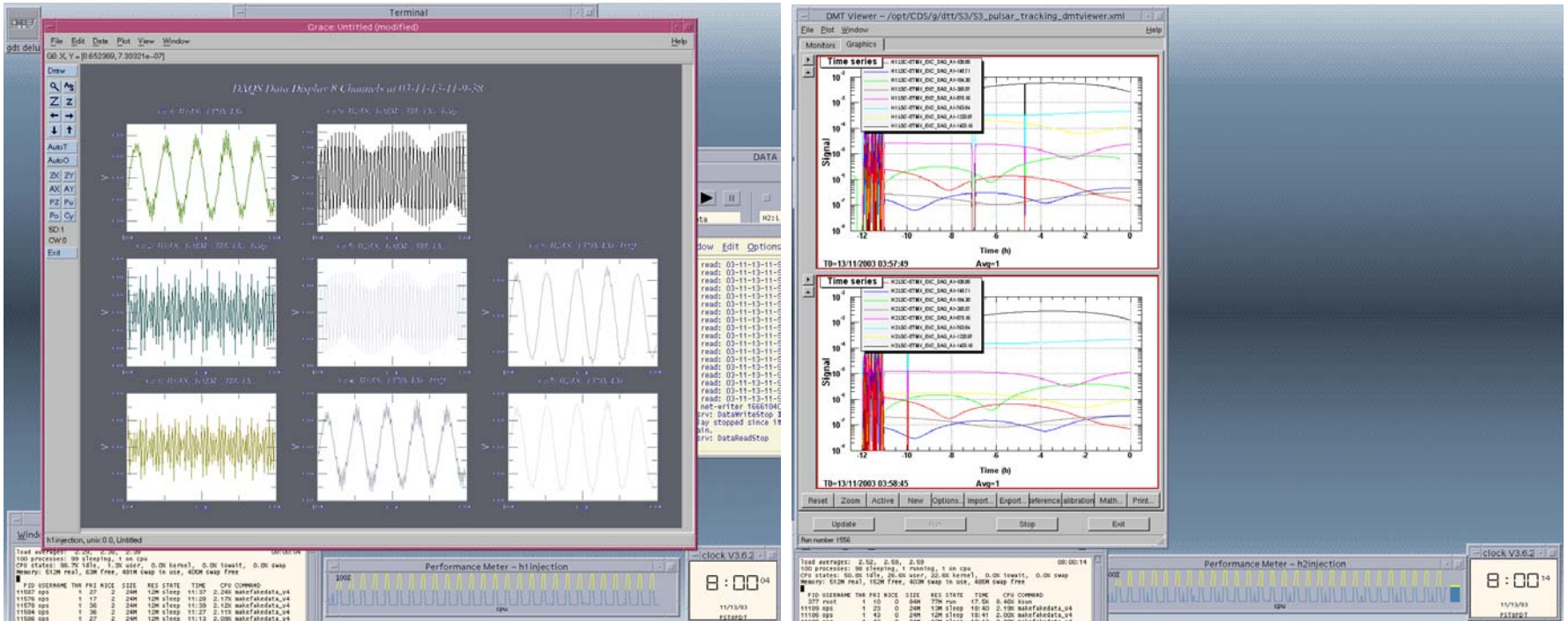
CPU states: 90.7% idle, 8.6% user, 0.7% kernel, 0.0% iowait, 0.0% swap

Memory: 512M real, 70M free, 475M swap in use, 412M swap free

| PID   | USERNAME | THR | PRI | NICE | SIZE | RES | STATE | TIME | CPU   | COMMAND         |
|-------|----------|-----|-----|------|------|-----|-------|------|-------|-----------------|
| 11331 | ops      | 1   | 32  | 0    | 24M  | 12M | sleep | 3:02 | 2.19% | makefakedata_v4 |
| 11334 | ops      | 1   | 33  | 0    | 24M  | 12M | sleep | 3:03 | 2.15% | makefakedata_v4 |
| 11333 | ops      | 1   | 52  | 0    | 24M  | 12M | sleep | 2:59 | 2.07% | makefakedata_v4 |
| 11324 | ops      | 1   | 43  | 0    | 24M  | 12M | sleep | 3:05 | 2.03% | makefakedata_v4 |
| 11321 | ops      | 1   | 43  | 0    | 24M  | 12M | sleep | 3:03 | 1.99% | makefakedata_v4 |
| 11322 | ops      | 1   | 43  | 0    | 24M  | 12M | sleep | 2:58 | 1.97% | makefakedata_v4 |
| 11330 | ops      | 1   | 43  | 0    | 24M  | 12M | sleep | 2:57 | 1.93% | makefakedata_v4 |
| 11323 | ops      | 1   | 43  | 0    | 24M  | 12M | sleep | 2:56 | 1.92% | makefakedata_v4 |
| 11320 | ops      | 1   | 33  | 0    | 24M  | 12M | sleep | 2:58 | 1.88% | makefakedata_v4 |
| 11329 | ops      | 1   | 33  | 0    | 24M  | 12M | sleep | 2:54 | 1.84% | makefakedata_v4 |
| 11313 | ops      | 5   | 58  | 0    | 18M  | 17M | sleep | 1:48 | 1.48% | s3inject3       |

# Watch the signals.....

- <http://blue.ligo-wa.caltech.edu/screencapture/h1injection.gif>
- <http://blue.ligo-wa.caltech.edu/screencapture/h2injection.gif>



# What next?

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- We may turn off the 'loudest pulsars'. Stan is worried about unexpected side effects (eg, nonlinearities, upconversion)
- Will add 11<sup>th</sup> pulsar when GEO is ready to coordinate
- Need to check that sign of calibration phase correctly incorporated