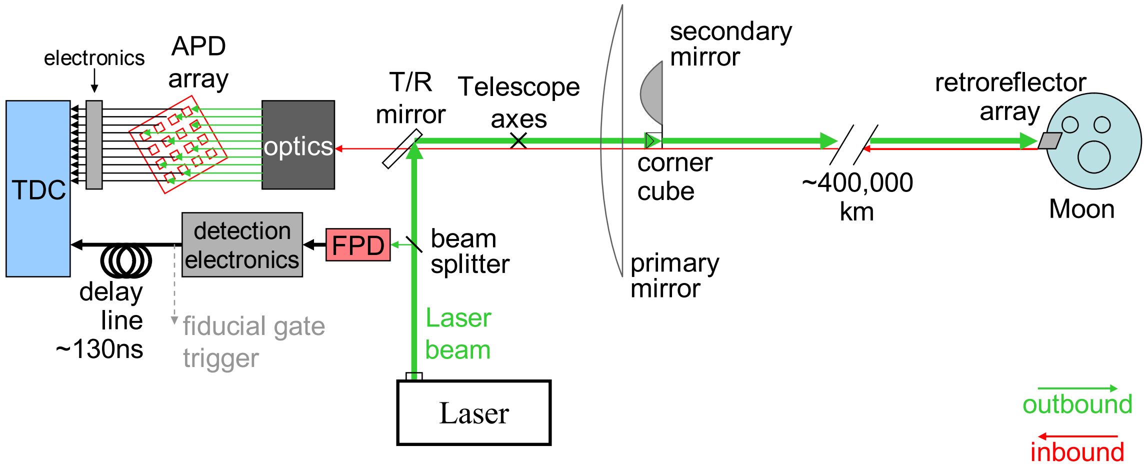
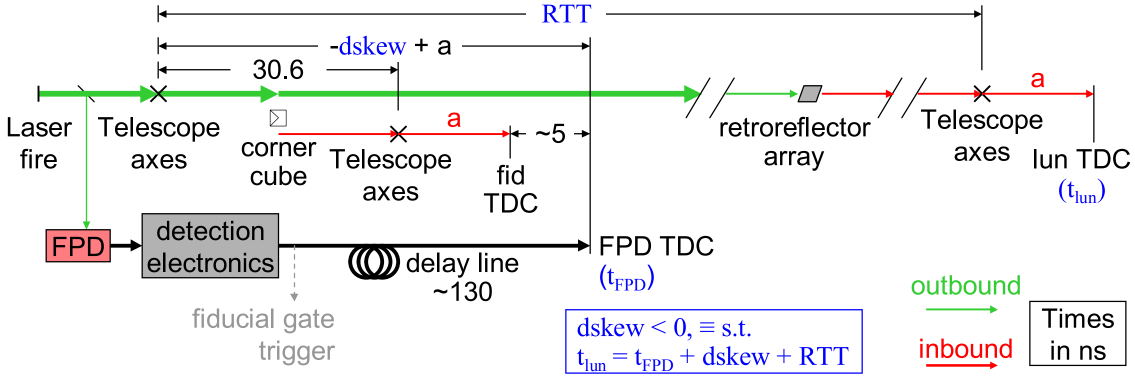
# APOLLO System Notes

Last saved by Eric L. Michelsen



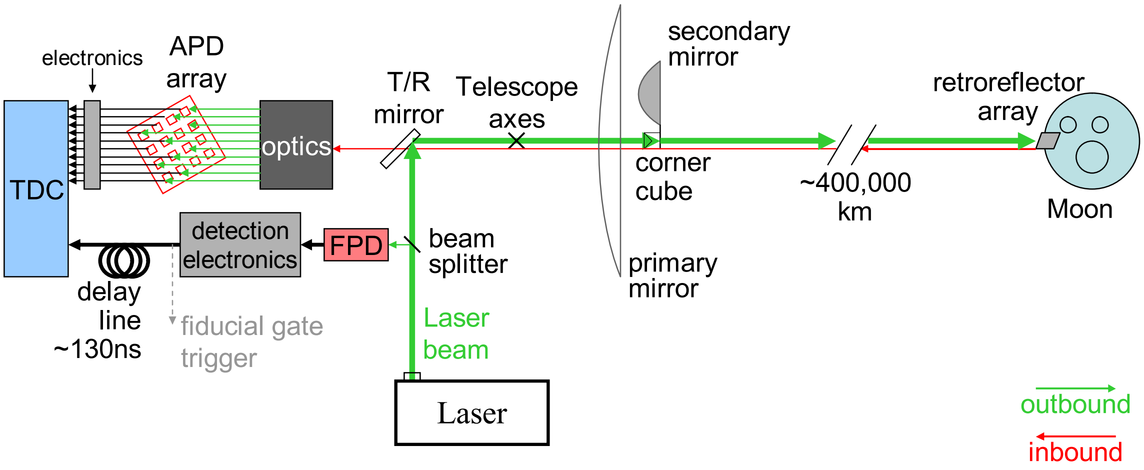


# Contents

# 1 Miscellaneous

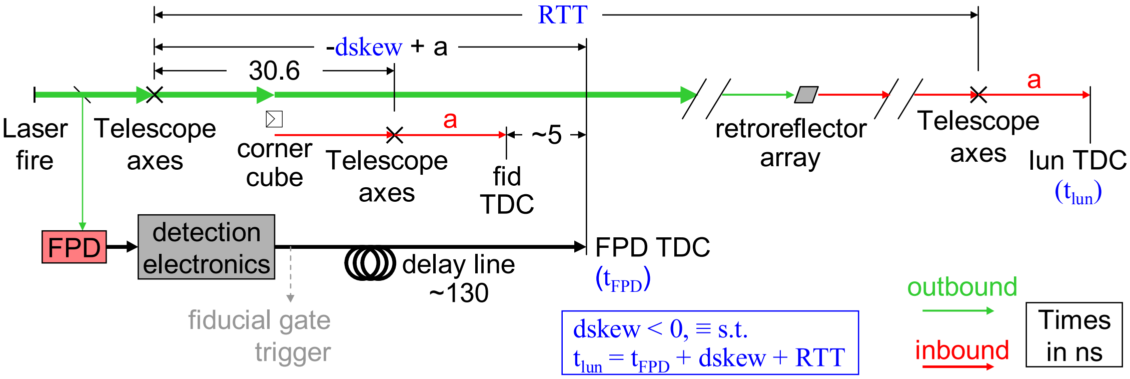
These are notes collected from various people and media (email, phone conferences, manuals, ...) over a long time. I (Eric Michelsen) have organized them into this document for easier reference, and a permanent record.

## Overview of APOLLO System



Schematic overview of APOLLO: Lunar Laser Ranging

Above is a simplified schematic overview of the key aspects of the APOLLO measurement. It leads to the following timing diagram:



Timeline of APOLLO measurement events

We can ignore the time delay 'a', because it is the same for fiducial and lunar paths, and cancels. In effect, then, 'dskew' is the time (negative) to add to the FPD time to get the time the outbound beam was crossing the telescope axes (ignoring delay 'a'). This pseudo-crossing time is the reference point to which housctl adds the predicted RTT to find the expected return time.

## General References

APOLLO home page: http://physics.ucsd.edu/~tmurphy/apollo/apollo.html

APOLLO observing manual:
http://cfa-www.harvard.edu/~jbattat/apollo/docs/observingManual/observingManual.pdf

APOLLO documentation: http://physics.ucsd.edu/~tmurphy/apollo/doc/ (not linked from home page).

APOLLO data sheets: http://cfa-www.harvard.edu/~jbattat/apollo/datasheets/

APOLLO highlights: http://physics.ucsd.edu/~tmurphy/apollo/highlights.html

APOLLO svn: svn://svn.apo.nmsu.edu/Apollo/

Russell has written a first draft manual on how to write an Instrument Control Computer. It is available at: http://rowen.astro.washington.edu/ICCManual/. This should be served at APO, once Craig Loomis has a chance to review it. P.S. Craig: the statement that Reply ID is obsolete and should not be supported by new instruments may be controversial. Other than that, I think it's mostly a matter of fact checking and filling out some details to come up with the final version.

Here are some example command sets that are simple and possibly worth emulating:

- DIS <http://tycho.apo.nmsu.edu:81/DIS/DIS_Commands.html>

- expose and tlamps: see links from <http://tycho.apo.nmsu.edu:81/MC2/>

> From: James Battat
> Sent: Thursday, March 16, 2006 10:39
> I've updated my tui install notes, available at:
> http://www.cfa.harvard.edu/~jbattat/apollo/TUIInstallNotes.txt
> Also, I've updated the notes in the .zip file that includes all necessary
> install files for a TUI install on windows:
> http://www.cfa.harvard.edu/~jbattat/apollo/TUIInstallation.zip

Info about TUI (APO's telescope user interface) can be found here: http://www.astro.washington.edu/rowen/TUIHelp. To get a copy of the program, read "Installation". (This is a copy of the html help built into TUI).

The hub tries to do very little other than authorize users and route commands. Authentication and some of the scripts are documented at http://tycho.apo.nmsu.edu:81/MC2/, and in particular, the link Authentication. The expose info is a bit outdated (especially since it is being overhauled right now).

The TCC is the Telescope Control Computer. It also lives at APO in the computer room. See http://www.apo.nmsu.edu/Telescopes/TCC/TCC.html for info on the commands and expected replies.

Lantronix Terminal Server Manual http://www.lantronix.com/pdf/ets_ref.pdf

From C.D.: virtual serial port software: Here is a link to the site where I downloaded the virtual port: http://www.hw-group.com/products/hw_vsp/index_en.html

**Fun Stuff:** http://moon.google.com for a google maps-like view of our moon, james

## Publicity

From James Battat: I've been compiling a list of public press articles that have featured APOLLO. If you know of some that you would like to add to the list, let me know and I will post them:

http://www.cfa.harvard.edu/~jbattat/apollo/docs/popularPress/

## Interesting Numbers

Target accuracy: 1 mm

Corresponding round-trip time accuracy: $2 \times \dfrac{.001 \text{ m}}{3.00 \times 10^8 \text{ m/s}} = 6.7 \text{ ps}$

Maximum range rate (at low elevation): $\approx 400$ m/s

Time dilation @ 400 m/s: $\gamma - 1 = \dfrac{1}{\sqrt{1-\beta^2}} - 1 \approx \dfrac{\beta^2}{2} = 0.89 \times 10^{-12}$

Time discrepancy due to time dilation @ 400 m/s: $\left(2.5\text{ s}\right)\left(.89 \times 10^{-12}\right) = 2.2\text{ ps}$

Target response rate: 0.1 photons/detector/pulse

Round-trip attenuation: ~$10^{18}$ / detector

Utah box thermal conductivity 2W / C (from 100W heater duty cycles, and times when heater failed)

Average difference between ND fiducial and diffused fiducial: 20 ps

$\sigma_{ND} \approx$ 135 ps, $\sigma_{diff} \approx$ 120 ps (why smaller??)

diffused intensity ≈ 1.7(ND intensity)

### *Telescope*

The APO telescope is Az-El. Some specs:

| | |
|---|---|
| Primary mirror | 3.5 m |
| Tracking speed | 2 deg/s |
| Max elevation | ~80 deg |

NA? f? focal length? See APO web site.

RTT from telescope axes to corner-cube: 30.6 ns

```
From: Tom Murphy
Sent: Monday, September 04, 2006 13:18
To: Eric L. Michelsen
Cc: 'Tom Murphy'; 'Hoyle C.D.'; 'Battat James'
Subject: RE: telescope reports

Yes, good point.  Typical focus moves are 50 to 100 microns for us (from
our practical experience).

> At one time, we estimated focus variations of 0.3 mm.  Since we've said
> that we'd like to account for any error ~0.1 mm or bigger (since
> there are quite a few of these), it seems that we need the focus
> moves to achieve our goal of 1 mm.
> ------------------
> Eric L. Michelsen
```

### *System Engineering*

| | |
|---|---|
| Utah heat conductivity | ~2 W/C |
| Utah heater | ~106W<br>(400W?<br>) |
| Noren fans | 25 W/C each |
| Noren fans power consumption | 12 W each |
| GPS clock | 20W |

### PCB Trace Impedance

http://www.fl-eng.com/specs/diffz.htm: The stripline and microstrip references on this web page may be reversed below. See National Semi for definitive reference.

**Stripline?? Differential Ended Impedance Approximation for FR-4 PCBs**

*Zdiff = 2*Zo[1-.347*exp(-2.9*S/H)]*

Where: S=Spacing between traces and H=Height above plane

**MicroStrip?? Differential Ended Impedance Approximation for FR-4 PCBs**

*Zdiff = 2*Zo[1-.48*exp(-.96*S/H)]*

Where: S=Spacing between traces and H=Height above plane

### Fibers In Utah Box

- Trigger Marx bank: 1064 nm
- Split off a pre-trigger to reset pulse energy measurement, and alert ACM to laser fire

### CCD Pixels

```
From: Tom Murphy
Sent: Monday, August 08, 2005 16:01
To: Eric Michelsen; Adam Orin
Subject: CCD scale
```

Incidentally, I made a check of the CCD pixel scale. Theoretically, a magnigication factor of 176.5 into a 100 mm lens, falling on 14.8 micron pixels would translate to 5.78 pixels per arcsecond, or 0.173 arcsec per pixel.

In practice, I marked on the screen (with sharpie) the position a star went to on a 5 arcsec commanded offset. Later in the lab, I measured the separation between this point and the sharpie'd crosshair to be 28.4 pixels. This gives a scale of 5.69 pix/arcsec, or 0.176 arcsec/pix.

Excellent agreement. Nice confirmation that our optics deliver what we expect...

## Lunar Prediction

Prediction of the lunar position to within a few meters is necessary for APOLLO to set its time window to catch the return light pulse. The prediction relies on a knowledge of the earth orientation parameters (EOP). The prediction software includes a Python program to retrieve the EOPs:

```
From: ... On Behalf Of Tom Murphy
Sent: Wednesday, June 27, 2012 21:08
To: core
Subject: [Apollo_core] leap-ready & more
```

I prepared APOLLO for the next leap second today.

While I was at it, I looked at the earth orientation problems of the past months, and discovered to my shock that the series we have traditionally retrieved for EOP (earth orient. params) is running about a month out of date. Used to, the updates were every Tuesday and Friday. So we were never too many days out of reckoning. I had a linear interpolation/extrapolation routine based on the last two entries to make us less sensitive to few-day-old data. But this wasn't working so well over a month lever arm (that's why we've seen more erratic predskews of late).

So I switched modes entirely, now using a series called gpsrapid.out (available here: http://www.iers.org/IERS/EN/DataProducts/EarthOrientationData/eop.html?__nnn=true)

This goes back to May 1992, and a bit into the future with predictions (far better than a linear extrapolation!). Updated weekly, we will always be covered in the prediction part now. It's a much better solution for us, and we no longer have to worry about year boundaries like we did in the old series (new year --> new file from scratch; had to piece two together --automatically--before).

I did extensive testing of the changes, verifying proper leap second behavior as well as proper use of the new EOP data. I checked across machines and across old/new regimes. Picosecond differences.

The new mkpoly is on houston, and its use should be transparent to the user (no change). The EOP stuff now comes from get_iers.py instead of get_eopc.py. Embedded in the code is an alternate website for the same data, in case one goes down (just change comments to enable alternate).

### JPL Lunar Prediction

```
From: Tom Murphy
Sent: Thursday, November 03, 2005 10:07
To: Williams Jim; Boggs Dale; G. Slava
Cc: Murphy Tom; Michelsen Eric; Orin Adam; Battat James
Subject: APOLLO normal points
```

The following normal points span three nights, on two reflectors. The analysis/reduction is not yet mature, but I would say I trust the results to maybe the 100-200 ps level. Meanwhile, this may be good enough for site coordinate determination--at least longitude and radius.

The reflector-to-reflector prediction offset is very small (well less than 1 ns), so the DE403 libration model seems perfectly good. Our prefit comparisons always showed offsets (semi-static) between the reflectors. This now appears to be coming from the prefit model, as both prediction and observation on our end are in good agreement (at least between A11 and A15), while the prediction vs. prefit showed 15 ns offsets between these two.

```
From: Tom Murphy [mailto:tmurphy@physics.ucsd.edu]
Sent: Thursday, November 03, 2005 14:46
To: Williams Jim; Boggs Dale; G. Slava
Cc: Michelsen Eric; Orin Adam; Battat James
Subject: meteorologically-correct
```

Here are the normal points again with the appropriate (measured) surface conditions properly entered:

```
5120051019 955468560424248130190320893706 10 55  4045 14C 72743  8369 5320A 249A
512005101910 740596936324823037334200370610 51  4200 18C 72742  8170 5320A 268A
51200510191015352293881248204889477560706 10 29  5570 12C 72735  8365 5320A 248A
51200510191058356819640248741819821593706 10 85  3253 35C 72749  7373 5320A 251A
5120051020 4503487062912523424371548837061040 6  1488127C 72778  7146 5320A 249A
5120051020 5 1378036233252234855111113706103 28  1656 93C 72785  7046 5320A 321A
5120051020 5 7 56581426252182949598353706104 48  1417165C 72785  7046 5320A 247A
5120051020 5134178422252521214481281937061044 1  1428174C 72782  6847 5320A 249A
5120051020 5181195283212520802926448837061067 7  1152246C 72779  6748 5320A 247A
5120051020 528345442789251877794995330706 10 51  4200 24C 72777  6250 5320A 247A
5120051020 5482971446712518215265252137061019 2  2165 83C 72775  6548 5320A 249A
5120051020 5542966923512517743218298037061047 5  1376191C 72770  6249 5320A 247A
5120051021 840343549625254839135039803706 10 46  4423 22C 73040  8633 5320A 252A
5120051021 9 2382316048254800966594643706103 91  1517181C 73041  7249 5320A 576A
```

```
From: Tom Murphy
Sent: Monday, August 08, 2005 15:33
To: Jim Williams
Cc: Dale Boggs; Tom Murphy; Eric Michelsen; Adam Orin
Subject: prediction check
```

Could you check that our prediction program is producing reasonable results for the following two points 5 minutes apart in time? The simulated normal points are:

```
512005 724112500000000023851292170070 3XXXXX  8  4000 50A 83044 20033 5320A 300A
```

```
512005 72411300000000000238550004095093XXXXX  8  4000 50A 83044 20033 5320A 300A
```

Hopefully this doesn't wrap in translation, but if so, all spaces are single after the 4000, and spaces on either side of the solitary 8 are double.

I left our station ID as XXXXX. We ought to now establish the APO station. Its coordinates (supposedly to few-meter precision) are:

```
#define P           6374.69650  // rho: radius from center
of earth in km
#define LAT         32.780361   // geodetic latitude
#define LON         254.179583  // longitude
#define HEIGHT      2.788       // height above geoid in km
```

While you're messing around with coordinates, now may be an opportune time to define reflector 1 as the moon center in such a way that normal points will be processed appropriately for purposes of prediction verification.

As a verification, we are using UTC times in the normal point. I have used the "old" normal point format, but should we migrate to the new format? As an optimistic caution, a 3-position field for the number of photons won't cut it for us if we meet our expectations of a few thousand photons in a 5-10 minute period. I know: you'll believe it when you see it...

```
From: Jim Williams
Sent: Monday, August 08, 2005 16:40
To: Tom Murphy
Cc: Dale Boggs; Tom Murphy; Eric Michelsen; Adam Orin
Subject: Re: prediction check
```

We do not use geodetic latitude for range computations. We use geocentric latitude, longitude and radius. Geodetic latitutde is useful if you are computing elevation and azimuth.

Reflector 1 is nominally Lunokhod 1, but we have no observations.

We use the old normal point format in our fitting program, but can convert the CSTG format. The CSTG format has four digits for number of photons, but the signal to noise ratio is a field that can saturate easily (at 9.9) and the normal point length is coarse.

## Gravimeter

The gravimeter will have its own independent data recorder off site. No need to bother houston/ICC with this. What is its recording mechanism?? Computer readable?

## Harvard Site Information

Good docs on Apollo system: http://www.cfa.harvard.edu/~jbattat/apollo/

## UW Site Information

| | |
|---|---|
| C.D. Hoyle | hoyle@npl.washington.edu |
| Eric Adelberger | eric@npl.washington.edu |
| Russell Owen, software engineer | owen@astro.washington.edu |

Russell’s computer: rowen.astro.washington.edu = 128.95.99.44.

Erik Swanson maintains the oft-used APOLLO_core mailing list. Russell Owen maintains the much-less-used APOLLO mailing list.

## San Diego Site Information

grlab firewall outside IP parameters: grlab.ucsd.edu = 132.239.146.224/225.225.225.0

| | | |
|---|---|---|
| linksys | 192.l68.1.1/255.255.255.0 | |
| houston1 | 192.168.1.2 | |
| houston | 192.168.1.3 | |
| grprinter | 192.168.1.4 | (labhp printer) |
| o-scope | 192.168.1.6 | |
| grcad | 192.168.1.7 | |
| | 192.168.1.9 | free |
| grlab | 192.168.1.10 | |
| grlab(#2) | 192.168.1.11 | (now free?) |
| gdot | 192.168.1.12 | |
| Lantronix Terminal Server | | 192.168.1.233, MAC: 00-80-A3-01-2E-2D |

| | |
|---|---|
| Default gateway | 132.239.146.1 |
| DNS1 | 128.54.16.2 |
| DNS2 | 132.239.1.52 |

* Inbound requests to Port 9100 are configured to go to 'grprinter'.

* All other inbound requests are configured to go to grlab.

Adam's environmental log: http://physics.ucsd.edu/~aorin/logpage/
Tom Gasaway, software engineer tgasaway@ucsd.edu

UCSD dynamic IP adresses: see Logins document.

**Phone conferencing** (the UCSD phone system only handles a 3-way option). We will each dial into:

```
866-424-4283              and enter pass-code:
9473976#                  (pound key at end).
```

If the moderator (Tom Murphy, typically) is not punched in, you will be on hold until this happens. If the moderator has to leave, the all/conversation continues. The charge (to UCSD: no charge for callers) is $0.33 per minute per caller, just so you know. Therefore I encourage people on the same campus to use the same phone when possible.

```
From: Tom Murphy
Sent: Monday, April 23, 2007 13:28
To: APOLLO Core
Subject: [Apollo_core] Audience Invitation - Tom Murphy - 9473976 (fwd)
1-800-CONFERENCE(R)
```

Please forward this e-mail to all meeting members participating in the conference noted below.

```
Company:            UCSD-University of California San Diego
Host:               Tom Murphy
Meeting Title:      Apollo

To Join Audio Conference
Primary Dial-In:    1 (866) 424-4283
Alternate Dial-In:  1 (630) 827-6657
Passcode:           9473976#

To Join Web Conference
IMPORTANT: PLEASE REVIEW PRIOR TO THE WEB CONFERENCE
```

To ensure your computer is properly updated, log on as if you were to start the meeting, per the instructions noted below. Prior to logging into the meeting, ensure popup blocker is turned off on your browser.

```
> Dial the audio conference dial-in number noted above and enter the
passcode as prompted.
> Click on this meeting URL:
   http://web.meetme.net/r.aspx?p=2&a=70541771384193
> On the Meeting Center page, enter your name and e-mail address.
> Click on the "Sign-in" button.
> Accept the Terms and Conditions and click "Join" to enter your
conference.
> Should your computer require any updates to accommodate web
conferencing, an additional message will be displayed.  Follow the
instructions to prepare your computer for the meeting.  These updates
should take 5 to 10 minutes to complete.
```

IF THE ABOVE URL DOES NOT ALLOW YOU TO JOIN THE WEB CONFERENCE, PLEASE FOLLOW THE PROCEDURE NOTED BELOW.

```
> Copy and paste the following URL in your web browser:
   http://web.meetme.net/audience
> Copy and paste the Meeting Key.
   70541771384193
> Click on the "Sign-in" button
> On the Meeting Center page, enter your name and e-mail address.
> Click on the "Sign-in" button.
> Accept the Terms and Conditions and click "Join" to enter your
conference.
```

PLEASE NOTE: Once your web conference has ended, please make certain to log out of the meeting.

As a courtesy to others and to improve sound quality, please mute your phone when not speaking.

You will be on hold with music until the host opens the conference call.

TOUCH-TONE COMMANDS:

Please use the list of touch-tone commands below to help facilitate your audio conference:

```
Press ** for a menu of touch tone commands.
Press *0 to speak to an operator (once the host has joined).
Press *6 to mute your own line.
Press #6 to unmute your own line.
```

Should you have any questions or require additional assistance, please contact one of our conferencing specialists at (800) 266-3373.

## APO Site Information

Dome telephone extension: x130 Fax: 505.434.5555

Apollo IP addresses at APO:

| | |
|---|---|
| 192.41.211.231 | WTI IP power switch |
| .232 | Houston |
| .233 | Terminal Server apollo3.apo.nmsu.edu |
| .234 | Cocoa |
| .235 | Laser Interlock AB (Allen-Bradley) computer |
| NTP server: | utc-time.apo.nmsu.edu, tai-time.apo.nmsu.edu |

tycho.apo.nmsu.edu [192.41.211.98] user “apollo”, pwd [see list]

Making X11 applications work locally: run X-server, then

```
export DISPLAY=a.b.c.d:0.0,      where a.b.c.d = your IP address
```

**Running disconnected processes:** `nohup cmd &`

When I was at APO with my laptop:

```
ipconfig/all
        DNS Suffix Search List. . . . . . : apo.nmsu.edu
Ethernet adapter Local Area Connection:
        Connection-specific DNS Suffix  . : apo.nmsu.edu
        Dhcp Enabled. . . . . . . . . . . : Yes
        IP Address. . . . . . . . . . . . : 192.41.211.247
        Subnet Mask . . . . . . . . . . . : 255.255.255.0
        Default Gateway . . . . . . . . . : 192.41.211.1
        DHCP Server . . . . . . . . . . . : 192.41.211.10
        DNS Servers . . . . . . . . . . . : 192.41.211.10
                                            192.41.211.11
        Lease Obtained. . . . . . . . . . : Monday, June 27, 2005 14:18:59
        Lease Expires . . . . . . . . . . : Monday, June 27, 2005 14:48:59
```

## Lantronix Terminal Server Configuration

We have an ETS/16 with flash ROM. Our APO term server MAC address is 00-80-A3-01-A2-95. It takes 1:50 (110 sec) to boot. Our UCSD lab server is 00-80-A3-01-2E-2D. The UCSD lab server boot screen looks like this:

```
Lantronix ETS16 Initialization
Flash Rom Version 2.2  (June 10, 1993)
Ethernet Address: 00-80-a3-01-2e-2d      Internet Address 192.168.1.233

Flash Version:    V3.5/3(971202)

Request BOOTP: no valid reply received.
Request RARP:  no valid reply received.

Checking 5 sections from flash:
    From address 0x20004 to 0x80000, 1329 bytes) ->
    From address 0x20549 to 0x807f8, 72 bytes) ->
    From address 0x205a5 to 0x480000, 145293 bytes) -> ++++++
    From address 0x43d46 to 0x4b2914, 24388 bytes) -> +
    From address 0x49c9e to 0x280000, 179603 bytes) -> +++++++++
Loaded 511580 bytes.

Load Completed - Boot in Progress

%% Lantronix ETS16
%% Ethernet Address: 00-80-a3-01-2e-2d      Internet Address 192.168.1.233
```

If the Ethernet link is down when the terminal server powers on, it won't boot. Even if the network later comes up, it stays stuck. This is an insane "feature," which forces us to put it on a programmable power outlet so we can re-cycle it when the network is up. What state is DTR in?? Perhaps we can fix this by removing the BOOTP and RARP requests during boot, which we don't need.

For 8-bit clean non-IAC (non-NVT) connections from Ethernet to a port, use (installation guide p 8-29, [bizarrely under "printing"]; ETS/EPS reference manual, p 8-15 "Unix/RTEL Host Setup").

```
telnet 192.168.1.233 30nn
```

where nn is the port number, and 192.168.1.233 is the terminal server IP address. Use ports 20nn for Telnet IAC sessions.

**Configuring the Terminal Server**: the manual is vague on many of these issues, so here's the scoop: Usernames are arbitrary; you make one up each time you log in. (This is very different from computers, which have a list of authorized users.)

Command line editing is bizarre and counterintuitive: Use a VT-100 terminal (or emulator). I've used Linux minicom, but it intercept ^A (ctl-A), so that's somewhat disruptive.

| | |
|---|---|
| ^X | deletes 1 char at the cursor, but obliterates 2 chars, so it messes up the display |
| ^R | redisplays the command line, thus fixing the screw-up of ^X |
| BS (^H) | jumps to beginning of line |
| ^E | jumps to end of line |
| left-arrow | moves cursor left (you can then use ^X to erase a char) |
| right-arrow | moves cursor right |

| | |
|---|---|
| up-arrow | recalls previous command in history |
| down-arrow | recalls next command in history |

So far as I can tell, there is no simple backspace function that erases the previous character.

Some of the network features don't work as the manual says. Serial port 1 is set aside for system configuration, so you don't need the network. You can use this to configure network parameters:

```
Username> x             this is arbitrary
Local_1> set priv       enable privileges (super-user)
Password>               [see list]
Local_1>> help set server                             this is handy
Local_1>> set server ipaddress 192.168.1.233          double >> indicates privileged session
Local_1>> set server mask 255.255.255.128             only needed if not default
Local_1>> set server gateway 192.168.1.1
Local_1>> set server nameserver 128.54.16.2           not really needed
Local_1>> set server domain ucsd.edu                  not really needed
Local_1>> save server                                 save in non-volatile
memory
Local_1>> logout
```

Then you can telnet to the Term Server. Here's a sample session:

```
>telnet 192.41.211.233
Lantronix ETS16 Version V3.3/6(960214)
Type HELP at the 'Local_18> ' prompt for assistance.
Username> x             this is arbitrary
Local_18> set priv      enable privileges (super-user)
Password>               [see list]
Local_18>>              double >> indicates a privileged session
:
Local_18>> logout
Exiting the Lantronix ETS16
```

We have data sessions on ports 1-8, for chillers, and programmable resistors (PRs). The PRs have local echo, and so does the term server, so it's important to disable the server's command prompt on those ports (set access remote).

```
Local_18>> help set port                              this is handy
Local_18>> define port 1 access dynamic               allow port 1 serial administration
Local_18>> define port 2-8 access remote
Local_18>> define port 1-8 dtrwait disable            not really needed
Local_18>> define port all flow none
Local_18>> define port all speed 9600
Local_18>> define port all modem none
: set all other port parameters: 8N1, telnet service, etc.
```

We use DTR on ports 9-16 to control hardware. When used this way, the port cannot also be used for serial data, because any time a session is active on a port, the ETS sets DTR high, regardless of configuration. To control DTR, Houston software configures ports with the DTRWAIT option, which makes DTR go low when there is no session active. The software configures it without DTRWAIT to make DTR go high. However, new configuration takes effect only after a session closes. After changing the configuration, the software must establish and then close a data session to the port, which causes the new configuration to take effect. To allow sessions to be established from the Ethernet side to the serial ports, a port must be configured for ACCESS DYNAMIC or ACCESS REMOTE:

```
Local_18>> help set port                              this is handy
Local_18>> define port 9-16 access dynamic
Local_18>> show port 9
Port 9 : Username:                      Physical Port 9 (Idle)
   Char Size/Stop Bits:         8/1     Input Speed:                 9600
   Flow Ctrl:                  None     Output Speed:                9600
   Parity:                     None     Modem Control:               None

   Access:                  Dynamic     Local Switch:                None
   Backward:                   None     Port Name:                 Port_9
```

```
      Break Ctrl:                Local    Session Limit:                  4
      Forward:                    None    Terminal Type:             Soft()

      Preferred Services:        (Lat)
                              (Telnet)
      Authorized Groups : 0
      (Current)  Groups : 0

      Characteristics:  Autoprompt  Broadcast  Loss Notify  Verify
                        Remote Conf  Telnet Pad  Dtrwait
```

### Lantronix Port Status

View a port's status with "`show port` *n*". The connection status is in parentheses after the "physical port" number; this is an idle port (which can accept a TCP connection):

```
   Local_18>> show port 4
   Port 4 : Username:                     Physical Port 4 (Idle)

      Char Size/Stop Bits:         8/1    Input Speed:                 9600
      Flow Ctrl:                  None    Output Speed:                9600
      Parity:                     None    Modem Control:               None

      Access:                  Dynamic    Local Switch:                None
      Backward:                   None    Port Name:                 Port_4
      Break Ctrl:                Local    Session Limit:                  4
      Forward:                    None    Terminal Type:             Soft()

      Preferred Services:        (Lat)
                              (Telnet)

      Authorized Groups : 0
      (Current)  Groups : 0

      Characteristics:  Autoprompt  Broadcast  Loss Notify  Verify
                        Remote Conf  Telnet Pad  Dtrwait
```

When the port has a connection, its status is "Job Service":

```
   Local_18>> show port 4

   Port 4 : Username:                     Physical Port 4 (Job Service)
   ...
```

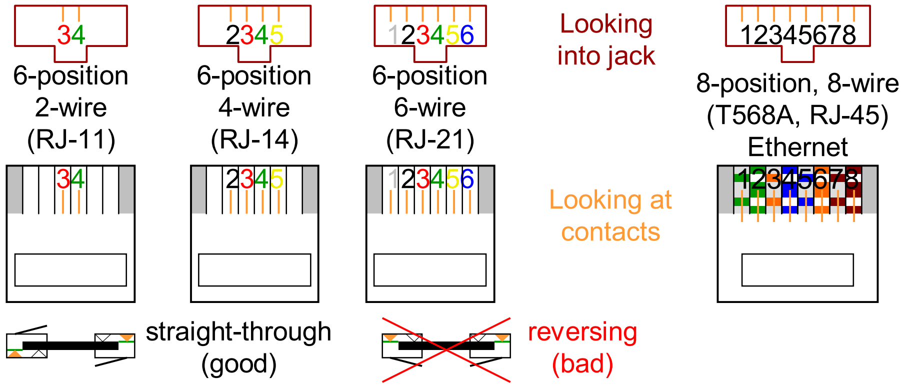
### Lantronix Connector Wiring

The Lantronix claims to have 16 "DTE" (Data Terminal Equipment) EIA-232 ports, in a 6-position modular jack. However, the ports are actually pretty symmetric, and can be configured and/or wired to look like either a DTE or a DCE (Data Communication Equipment). Each NESLAB chiller has a proper 9-pin DCE socket. It requires only 3 pins (Rx, Tx, and Gnd) and does not use RTS/CTS flow control. However, Eric M. wired the modular-to-9-pin adaptors to include RTS/CTS capability, so they would be general and could work on most equipment with DCE interfaces:

Lantronix to RS-574 adaptor:

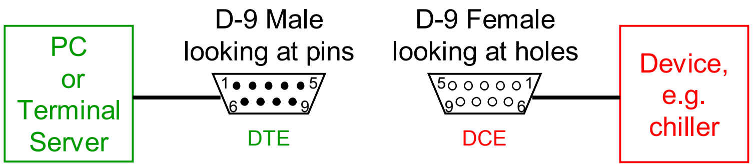
| Male 6-Position Modular Plug Pin # | Signal Name | Signal Description | Male DB-9 RS-574 Pin # |
|---|---|---|---|
| | CD | Carrier Detect | 1 |
| 5 | RXD | Receive Data | 2 |
| 2 | TXD | Transmit Data | 3 |
| | DTR | Data Terminal Ready | 4 |
| 3 TxG<br>4 RxG | GND | Signal Ground / Common | 5 |
| | DSR | Data Set Ready | 6 |
| 1 | RTS | Request To Send | 7 |
| 6 | CTS | Clear To Send | 8 |
| | RI | Ring Indicator | 9 |

We have to crimp pins 3 & 4 together under a new pin to connect the 2 Lantronix grounds to the one EIA-574 ground.



## How To Make an EIA-232 Interface (Important!)

Computers are DTEs (Data Terminal Equipment). External modems are DCEs (Data Communication Equipment). The important point is that a DTE plugs into a DCE with a simple straight through cable (no crossovers, null-modem, etc. needed). The terminal server (TS) can be a limited version of either, but you should make it a DTE, to be like a PC, and to be compatible with other stuff like our chillers.



The NESLAB chillers did it right: their interface is a female D9 connector, with DCE wiring. That means it plugs directly into a PC, or a terminal server port wired as a DTE. It requires only 3 pins (Rx, Tx, and Gnd) and does not use RTS/CTS flow control.

| **Signal Name** | **Signal Description** | **Signal Direction** | **DB-9 RS-574 Pin #** |
|---|---|---|---|
| CD | Carrier Detect | **DTE ← DCE** | **1** |
| RXD | Receive Data | **DTE ← DCE** | **2** |
| TXD | Transmit Data | **DTE → DCE** | **3** |
| DTR | Data Terminal Ready | **DTE → DCE** | **4** |
| GND | Signal Ground / Common | | **5** |
| DSR | Data Set Ready | **DTE ← DCE** | **6** |
| RTS | Request To Send | **DTE → DCE** | **7** |
| CTS | Clear To Send | **DTE ← DCE** | **8** |
| RI | Ring Indicator | **DTE ← DCE** | **9** |

If you need the PC/TS to activate a control line, use DTR. The TS requires DTR be active during a data session. It can be configured to have DTR always on, or have it drop when there is no data session. If we use a TS port, be aware of this constraint: DTR is always high when data can be communicated. For example, reset lines should be active on DTR low, and inactive on DTR high. Then we can control reset (outside of a data connection). PCs have two control line outputs (DTR and RTS), and they have no data-connection restriction, but designing for the TS gives us maximum flexibility.

### *Data Protocol*

Default communication parameters should be the most common choice: 9600 bps, 8 data bits, no parity, 1 stop bit, commonly known as 9600 8N1.

For simple interfaces, it is easiest to use pure printable ASCII characters, and no flow control. Since most terminal servers, and simple computer software, read ASCII terminated by CR (carriage return, 0x0D), a simple protocol uses CR as a record terminator. For example, I recommend the aviation transponder receiver use a protocol with the following record format:

| **Byte Offset** | **Description** | **ASCII Value** | **Hex Value** |
|---|---|---|---|
| 0 | Version identifier | ‘0’ | 30 |
| 1 | A digit | ‘0’ - ‘7’ | 30 - 37 |
| 2 | B digit | ‘0’ - ‘7’ | 30 - 37 |
| 3 | C digit | ‘0’ - ‘7’ | 30 - 37 |
| 4 | D digit | ‘0’ - ‘7’ | 30 - 37 |
| 5 | Status: 6 bits mapped to printable ASCII | ‘ ‘ - ‘_’ (underscore) | 20 - 5F |
| 6 | Checksum hex low digit | ‘0’ - ‘9’, ‘A’ - ‘F’ | 30 - 39, 41 - 46 |
| 7 | Checksum hex low digit | ‘0’ - ‘9’, ‘A’ - ‘F’ | 30 - 39, 41 - 46 |
| 8 | Carriage return | <CR> | 0D |

A 6-bit binary value can be encoded as a single printable ASCII character, by adding 0x20 (ASCII ‘ ‘) to it. The binary value can be recovered by masking the low-order 6 bits. 7 or 8 bit values require more encoding. Two-digit ASCII hex is a simple encoding for 8 bits.

The checksum is the 8-bit mod 256 arithmetic sum of all the bytes preceding it. It is encoded as 2 ASCII hex digits. Alternatively, we could use a 6-bit checksum, and encode it in a single printable character.

A sample record might be, in ASCII:

04321*24<CR>

Interpreted as:

| Byte Offset | Description | ASCII Value | Hex Value |
|---|---|---|---|
| 0 | Version identifier | ‘0’ | 30 |
| 1 | A digit | ‘4’ | 34 |
| 2 | B digit | ‘3’ | 33 |
| 3 | C digit | ‘2’ | 32 |
| 4 | D digit | ‘1’ | 31 |
| 5 | Status: 6 bits mapped to printable ASCII | ‘*’ mapping to binary 101010 | 2A |
| 6 | Checksum hex low digit | ‘2’ | 32 |
| 7 | Checksum hex low digit | ‘4’ | 34 |
| 8 | Carriage return | <CR> | 0D |

## SPI Is Not RS-232

RS-232 (properly called EIA-232) specifies voltages, etc. It supports both line-protocols: asynchronous and synchronous. Most interface specifications work similarly: one set of electrical specs support both asynchronous and synchronous. There is another protocol layer built on top of synchronous interfaces, and this appears to be SPI in this case.

I only had time to look briefly at the data sheet. I don't know exactly what SPI is, but I have used a similar (if not identical) interface for serial EEPROMs. In the "write" direction, I think we can make a simple async-to-sync converter out of little more than an RC delay. The "read" direction may be a little harder, but I'm not sure.

## IP Power Switch

Note our firmware version is not the newest (see display below). The serial port is a standard 9-pin DTE (man 13369 Rev C, p. Apx-1 with a confusing diagram). We don’t use the serial port.

Houston software uses telnet to control the box. The box has an “automated” mode, but it bypasses all the password security, and isn’t very helpful anyway, so we don’t use it. When you telnet in, you see this:

```
Internet Power Switch v1.10d    Site ID: (undefined)

Plug | Name              | Password          | Status   | Boot/Seq. Delay |
-----+-------------------+-------------------+----------+-----------------+
 1   | (undefined)       | (undefined)       |   ON     |      1/2 Secs   |
 2   | (undefined)       | (undefined)       |   ON     |      1/2 Secs   |
 3   | (undefined)       | (undefined)       |   ON     |      1/2 Secs   |
 4   | (undefined)       | (undefined)       |   ON     |      1/2 Secs   |
-----+-------------------+-------------------+----------+-----------------+
"/H" for help.
IPS>
```

Commands are case insensitive. Houston avoids confirmation prompts with the “,y” option (man p6.5). A typical session from Houston looks like this:

```
/ON 1,Y          turn on plug 1, without confirmation
/X,Y             exit now, without confirmation
```

The ASCII configuration file is totally cryptic, and as of 6/29/2005, ours looks like this:

```
\L-00,00,""
```

```
\L-00,01,""
\L-00,02,""
\L-00,03,"ATE0M0Q1&C1&D2S0=1"
\L-00,04,0,5,1,0,1,0,1,1,0,0,1
\L-01,00,"192.41.211.231","255.255.255.0","192.41.211.1"
\L-01,01,1460
\L-01,10,"0.0.0.0",1
\L-01,11,"0.0.0.0",1
\L-01,12,"0.0.0.0",1
\L-01,13,"0.0.0.0",1
\L-01,14,"0.0.0.0",1
\L-02,00,1,80
\L-03,00,1,23
\L-10,00,""
\L-10,01,""
\L-10,02,0
\L-11,00,""
\L-11,01,""
\L-11,02,0
\L-12,00,""
\L-12,01,""
\L-12,02,0
\L-13,00,""
\L-13,01,""
\L-13,02,0
\G-00
```

If our configuration ever gets corrupted, you can upload this to the box (see manual).

## RG174 vs RG58 Signal Degradation

```
From: Tom Murphy
Sent: Friday, November 18, 2005 16:16
```

James and I looked yesterday at why the RG174 cable wasn't working. We looked on the scope and saw that the NIM signal was getting through, but degraded. The original signal is 1 V, < 1ns rise time. The signal after the RG58 is 850 mV, 1.5 ns rise time. The signal after the RG174 is 600 mV and a 3 ns rise, and much crummier looking. So its high-frequency response is killing the fast edge and eating away the signal.

## Windows Shortcuts for SSH

```
On Thu, 16 Mar 2006, Eric L. Michelsen wrote:
```

Instead of making a batch file, make a shortcut with

```
    sshclient -u aorin -h grlab.ucsd.edu
```

as its command. Then there's no CMD.

## Satellite Strike Probability

```
From: Tom Murphy [mailto:tmurphy@physics.ucsd.edu]
Sent: Tuesday, January 25, 2005 17:44
To: Eric Adelberger; Erik Swanson; C.D. Hoyle; James Battat;
Chris Stubbs; Eric Michelsen; Adam Orin; Eric Williams
Cc: Tom Murphy
Subject: satellite strike probability
```

I thought you all may be interested to learn the results of some quick numbers I ran on the chances of illuminating a satellite with our laser beam. Bottom line: 3 parts in 1 billion per satellite per 30-minute run, translating to about 0.3% chance of hitting any of the 10,000 catalogued low-earth-orbit bodies in one year of 100 runs. But only 7% of satellites are operational (most are softball-sized debris), so only 0.2% chance in 10 year lifetime. Not so bad, as numbers go. This excludes analysis of geostationary satellites, which I will have to treat separately sometime.

The analysis assumed a 1-arcsecond beam starting at 3.5 m. Also assumed point-like satellites. This isn't too unfair if what we really care about is illuminating an optical sensor. Who cares if we hit a solar panel: we're giving them a few extra mJ of energy! I took an average satellite altitude of 800 km: most cluster between 600 to 1000 km. The probability of illumination grows (slowly) as a function of altitude, since satellites move more slowly through a larger beam. I assumed satellites to be uniformly (isotropically) distributed around the earth, on average.

Below about 6 earth radii, satellites can zip right through center of beam without getting hit if timed right. At low altitude, the chance of getting hit is only 1.3%, even if crossing right through beam path.

On the whole, these aren't scary numbers, though they will mean absolutely nothing to Space Command. Nonetheless, it's good for us to appreciate a realistic risk.

# 2 Support Software

## APOLLO Computer Administration

### General

You should log all administrative changes in “/changelog” (in the root directory).

| APO | UCSD Lab | |
|---|---|---|
| houston | houston1 | Computers houston, houston1 are identical hardware/software. |
| | grlab, gdot | grlab & gdot are almost identical software |
| cocoa | | Runs the environmental monitor, and VLC server |

### Linux Local Machine Firewall

/etc/hosts.allow takes priority over hosts.deny. See VLC section for allowing an SSH session to cocoa:.

Somewhere /etc/firestarter/* comes into play, as well. It looks like this (for firestarter 0.9.3):

```
-rw-r--r--  1 root root     0 May  3  2004 blocked-hosts
-rw-r--r--  1 root root     0 May  3  2004 blocked-ports
-rwx------  1 root root 19507 Sep  7  2005 firewall.sh
-rw-r--r--  1 root root     0 May  3  2004 forward
-rw-r--r--  1 root root   961 Nov 23 21:36 non-routables
-rw-r--r--  1 root root    20 Aug 11  2005 open-ports
-rw-r--r--  1 root root     0 May  3  2004 stealthed-ports
-rw-r--r--  1 root root    70 Aug 11  2005 trusted-hosts
-rwxrwx---  1 root root     0 May  3  2004 user-post
-rwxrwx---  1 root root     0 May  3  2004 user-pre
```

The firestarter home page is www.fs-security.com. You can edit “non-routables” with vi (and probably the other files as well). Then enter:

```
/usr/sbin/firestarter -p                (stops the firewall)
Firewall stopped, network traffic is now flowing freely
/usr/sbin/firestarter -s                (starts the firewall)
Firewall started
```

> You must type the path ‘/usr/sbin/’ on the ‘firestarter’ command; otherwise you get no error (and no other response), but it doesn’t work. I don’t know why.

See www.iana.org/assignments/ipv4-address-space for IP address assignments.

What is /etc/firestarter/trusted-hosts for? It doesn’t allow those hosts to connect to the machine.

### Cocoa Information

In the `/etc/rc.d/rc.local` starup script, we have the following auto-start on bootup:

```
echo "Selecting PVR channel 1 (STV)"
/usr/bin/ivtvctl -p 1

echo "Starting VLC stream"
/usr/bin/vlc --no-audio --ttl=64 pvr:// :pvr-device=/dev/video0 --sout
'#transcode{vcodec=mp4v,vb=128,scale=.5}:standard{access=http,mux=ts,url=:8
080}' &

echo "Setting DISPLAY to 0:1 (virtual frame buffer)"
export DISPLAY=0:1

echo "Starting ICC"
/usr/local/bin/python /home/apollo/icc/ApolloICC/ApolloICC.py &
```

```
echo "Starting htmlmonitor.py"
/usr/local/bin/python /home/environment/htmlmonitor.py &
```

We could add the interlock monitor to this list.

## ICC

On cocoa: see `/etc/rc.local` for where ICC code is located.

Apollo ICC understands these commands: launch, test filename [interval in s], status, raw cmd-string

**Running ICC on cocoa:** can be run from any directory, and stays running even after you log out:

```
export DISPLAY=0:1
/usr/local/bin/python /home/apollo/icc/ApolloICC/ApolloICC.py
```

which tells you where it sits physically. This can be executed by typing (at $ prompt):

```
$ /home/tmurphy/icc
```

**(Old)** Running ICC on houston:

```
python2.4 /home/apollo/icc/ro/ApolloICC/ApolloICC.py.
```

Python1.5 won't do.

**To stop ICC:** just kill it. "ps -auxw | grep apollo" should show it.

**Telling hub where apollo ICC is:** Edit a file on "hven", file `Nubs/apollo.py` (it's obvious what to edit).

**Running ICC on another computer:** Fix "hven", and run as above. On our backup cocoa: built by Fritz S, python is in `/usr/bin/python`, rather than that given above.

## VLC

Runs on cocoa:

```
vlc --no-audio --ttl=64 pvr:// :pvr-device=/dev/video0 --sout
'#transcode{vcodec=mp4v,vb=128,scale=.5}:standard{access=http,mux=ts,url=:8
080}' &
```

which can be executed by typing (at $ prompt):

```
$ sh < ~tmurphy/vlc_cmd
```

To see which video source is selected:

```
ivtvctl -P
```

Choose the one you want with

| | |
|---|---|
| `ivtvctl -p 1` | composite video from STV |
| `ivtvctl -p 4` | S-Video from small camera aimed at GPS clock |

### *Running VLC Through an SSH Tunnel*

From Tom Murphy, on 11/14/2007, 18:46:

We have verified the VLC feed from a number of previously unsecured locations:

- My laptop on UCSD wireless network
- Eric's laptop on UCSD wireless network (at least ssh trick worked)
- CD's work computer
- My laptop from home

We put the IP address we want to allow into the /etc/hosts.allow file on cocoa.

From the client machine, the command line (the external cocoa name is “cocoa-p”, internal is “cocoa”):

```
ssh2 username@cocoa-p.apo.nmsu.edu -L 8080:cocoa.apo.nmsu.edu:8080
```

from either a unix-like prompt or a dos shell prompt will connect you to cocoa and “port-forward” the 8080 port on cocoa to the local 8080 port. Then you run VLC and point it to:

http://localhost:8080 or http://127.0.0.1:8080

### VLC Server Restarting

From James Battat:

For the vlc command to work, you must set the DISPLAY environment variable to enable a virtual X-session. If you do not do this step, you will see an error like:

```
  VLC media player 0.8.4a Janus
The application '.' lost its connection to the display localhost:10.0;
most likely the X server was shut down or you killed/destroyed the
application.
```

In bash, you can add the following to the .bash_profile file (or type it at the command line):

```
export DISPLAY=0:1
```

In tcsh, you can type:

```
setenv DISPLAY 0:1
```

or put it in the .cshrc file.

In Tom's cocoa home directory, /home/tmurphy, there is a file called vlc_cmd that contains the messy command to start the vlc server. As root, run

```
export DISPLAY=0:1
sh < vlc_cmd
```

to execute its contents.

**To kill a VLC server** that appears to be failing, look for the VLC process ID, and kill it:

```
ps aux | grep vlc                get the process id and then kill that process
root      6113 14.6  2.8 144676 29676 ?        Sl   12:14  77:38 vlc --no-
audio --ttl=64 pvr:// :pvr-device=/dev/video0 --sout
#transcode{vcodec=mp4v,vb=128,scale=.5}:standard{access=http,mux=ts,url=:80
80}
eric     22566  0.0  0.0   3752   684 pts/1    R+   21:06   0:00 grep vlc
kill 6113                        kill <process_id_number>
```

## TUI

**Starting TUI**: Double click the TUI Icon on the Windows desktop. This opens 6-10 windows. In this notation, the window name you need to select is given in square brackets: [window_name]. Choose [Status] TUI, Connect: program za01.

**connect hub to ICC**: In [Apollo], Main tab, click [startnubs].

Old manual mode: In TUI log window (not message window): `hub startNubs apollo` (reads the file hven:Nubs/apollo.py, described below).

To receive apollo data: click [Listen]

Old manual mode `hub listen addActors apollo`

To stop receiving apollo data: `hub listen delActors apollo`

**connect ICC to Houston**: click [ConnDev]

manual mode: `apollo launch`

### TUI Installation Notes that May Be Out of Date

I'm reproducing a snapshot of the TUI installation instructions here, for easy reference, but

To install TUI, check out the latest installation instructions from SVN and follow them.

They are at svn://svn.apo.nmsu.edu/Apollo/TUI/trunk/Main/Installing APOLLO TUI.doc.

As of Revised 8/4/2009 by Eric L. Michelsen, they were these:

## Installing APOLLO TUI (ATUI) on Windows in 10 or more Steps

## Note that there are two step #8s.

C.D. Hoyle

November 10th, 2007

Tom Murphy's notes from 2007/12/01 in green; 2007/12/20 in red

Notes: Completed this procedure (minus SVN) on UCSD computer in < 70 minutes on 2007/12/20, but still sharp from 2007/12/01 exercise on APO laptop…

ELM 8/4/09: Took me 1:45 with Python25 already installed, and with pyfits error.

The following steps will install the APOLLO TUI from scratch on a windows machine. This installation is valid for the following versions:

- Python 2.5
- Hippodraw 1.21.3
- TUI 1.4.1

The whole process should take about 1-1½ hr.

**0. Only do this if you are upgrading versions of Hippodraw and/or Python:** Remove old versions of Hippodraw and Python using the Control Panel's Add/Remove Programs utility. You don't have to bother with Python extras like numeric packages, PIL, etc.: just the main Python2.X.

**1.** If not already installed, install Python 2.5 for Windows x86 with the .msi file from

http://www.python.org/download/releases/2.5.1/

You may want to put downloads in C:\APOLLO\Software as an archive of sorts. You may also want to create bookmarks to all these sites in a "software updates" folder.

Let this install in its default location: C:\Python25\

1a. Once python is installed, use the Windows Explorer to allow command line operation. This is done by choosing Tools: Folder Options: File Types; select .PY type, then hit Advanced. Making sure "open" is highlighted, Edit this entry. The Application should be: "C:\Python25\python.exe" "%1" %* Note that quotes do not appear around the %*. Use DDE with Application: Python and Topic: System.

**2.** Download Python MegaWidgets (PMW) from http://sourceforge.net/projects/pmw/. You may need a program such as Winzip to extract the files, and you may need to change the compressed folder extension to .tgz. Unpack into the Python directory, yielding "c:\Python25\Pmw.1.3.2", or similar. Inside, you should see a src directory, within which is a setup.py and a Pmw folder. From a DOS command prompt, change into the src directory and type setup.py install. This will only work if command line arguments have been associated with .PY files in the manner described above. The result will be an installation of Pmw in the canonical place: C:\Python25\Lib\site-packages (rather than just C:\Python25).

Test installation by starting Python (e.g., clicking python.exe in Python25 directory brings up window), and type:

`import Pmw` (case sensitive)

If it returns a prompt with no errors, then installation is fine.

**3.** Install Hippodraw 1.21.3 using the information here: http://www.slac.stanford.edu/grp/ek/hippodraw/install_notes.html. Note that the code publisher is not verified, so you have to say "yes" to Windows asking if you really want to do this, since the code could contain malware.

- I have let it stay in the default Program Files location without problems; just modify path accordingly in next step
- In addition to \Hippodraw\, also add \Hippodraw\examples\ to your PYTHONPATH environment variable as discussed on the installation page. Note the PYTHONPATH only needs to be defined in the User block, not the system block. Access the path settings via: right click on My Computer; Properties: Advanced: Environment Variables. The entry should look like: C:\Program Files\Hippodraw;C:\Program Files\Hippodraw\examples
- On another system, the environment variables were accessed through Control Panel → Performance/Maintenance → System → Advanced

**4.** Install TUI 1.4.1 for windows in \Python25\ as directed here:

http://www.apo.nmsu.edu/35m_operations/TUI/Installation.html

- You must actually start under the "Installing on Unix" section. Scroll down and follow all steps from "Download and install numpy" through "Download and install Snack Sound Toolkit."
- For numpy, the msi file (for python2.5) works with no fuss: check import numpy from python prompt to verify
- For pyfits, extract to Python25\, which creates pyfits subdirectory. From DOS command prompt, cd to pyfits directory and type: setup.py install (which will place pyfits appropriately in site-packages). Try "import pyfits" to verify.

ELM 8/4/09: I get this error when I try to install pyfits for Windows:

```
C:\Python25\pyfits-2.1.1>setup.py install
running install
running build
running build_py
creating build
creating build\lib.win32-2.5
creating build\lib.win32-2.5\pyfits
copying lib\NA_pyfits.py -> build\lib.win32-2.5\pyfits
copying lib\NP_pyfits.py -> build\lib.win32-2.5\pyfits
copying lib\rec.py -> build\lib.win32-2.5\pyfits
copying lib\svn_version.py -> build\lib.win32-2.5\pyfits
copying lib\__init__.py -> build\lib.win32-2.5\pyfits
running build_ext
No module named msvccompiler in numpy.distutils; trying from distutils
error: Python was built with Visual Studio 2003;
extensions must be built with a compiler than can generate compatible
binaries.
Visual Studio 2003 was not found on this system. If you have Cygwin
installed,
you can try compiling with MingW32, by passing "-c mingw32" to setup.py.
```

- The Python Imaging Library (PIL; .exe file) auto-installs with no fuss: just pick the one for the appropriate python version. Check with "import PIL". Installs by default to C:\Python2X. As with HippoDraw, the code publisher is not verified, so you have to say "yes" to Windows asking if you really want to do this, since the code could contain malware.
- The matplotlib package (version 0.91.1) caused some trouble, though this was not immediately apparent: only when trying to import pylab did I see the problem. I reverted to

version 0.90.1 (.exe variety for python2.5) and this auto-install worked fine. Check with import pylab. Installs by default to C:\Python2X.

- For the last step, be sure to download Snack for Python, the README describes the installation procedure best. I picked the binary release for Windows with Python 2.3 (worried about incompatibility, but it worked), installing into C:\Python25\Snack. You must specify a subdirectory to unpack to: type in C:\Python25\Snack. If you stop at Python25, this directory gets annoyingly cluttered! The README file instructs you to copy (or move) the tksnack.py file to Python2X\Lib\, and the snacklib folder to Python2X\tcl. Click on some of the examples (e.g., generator.py) to make sure they run without error (and generate sound).
- Now skip to the "Installing on Windows" section and follow all steps. It's a good idea to put XPA in the DS9 directory, but the web page instructions are backwards: the web should say "tell the installer to use ...\ds9\ instead of ...\xpa\".
- Put the resulting unzipped folder (for me C:\Python25\TUI_1.4.1_Windows\) in your PYTHONPATH directory list. I let TUI go to the nominal \Program Files\ location, and found that I did not need it in the PYTHONPATH.
- Create a shortcut to TUI.exe on the Desktop and run TUI to see if it works (the APOLLO windows may not come up at this point – don't worry!)

**5.** If not already installed, download and install Tortoise http://tortoisesvn.net/downloads

**6.** Connect to the APOLLO svn server svn://svn.apo.nmsu.edu/Apollo/ and "checkout" /TUI/trunk/ to a local directory such as C:\Apollo\. This is the latest ATUI code in two subfolders "Main" and "Lunar Pointer."

**7.** Create a directory (if not already there)

C:\Documents and Settings\<your user name>\Application Data\TUIAdditions\Apollo\

and add it to your PYTHONPATH directory list. I find this addition to be unnecessary.

**8a.** Copy all of the files and folders in the "Main" subfolder from step 6 into the directory created in step 7 (but do not copy the .svn directory if shown). Also copy all of the .py files from "Lunar Pointer" to this same directory (again ignore .svn folder). Copy the entire ephem folder (in "Lunar Pointer") into C:\Apollo\ so it becomes

C:\Apollo\ephem\ (the absolute path is important here, so make sure you do this! We may want to fix this so ephem doesn't sit off in some unusual spot, but sits with all the other stuff? If the path is right, the program should find moon_pos.py.)

**8b.** In ...\TUIAdditions\Apollo\ , copy pathStuff_example.py to pathStuff.py

**9.** In pathStuff.py, edit the paths to point to the appropriate locations as described within. Note the comments on format! If you put hippodraw in \Program Files\, you need to change the defaults in pathStuff.py. Instead of the third sys.path entry pointing to C:\Python25, have it point to C:\Python25\Lib\site-packages. This will not only get Pmw, but pyfits, numpy, matplotlib, and other auto-installed stuff.

**10.** Run TUI again and make sure that both Hippodraw and the ATUI tabbed window

appear.

### Troubleshooting

- Check TUI.exe.log to help troubleshoot problems.
- Make sure all required directories are in PYTHONPATH. Mine looks like this:

  C:\Python24\Hippodraw\;C:\Python24\Hippodraw\examples\; C:\Python24\TUI_1.3_Windows;C:\Documents and Settings\All Users\Application Data\TUIAdditions;C:\Documents and Settings\cdh33\Application Data\TUIAdditions\APOLLO

The ApolloLaptop only seems to need: C:\Python25\Hippodraw and C:\Python25\Hippodraw\examples, though I ran fine without the latter, even.

- Delete old versions of TUI and Hippodraw

## TUI and HippoDraw on Mac Os X

Mac has its own issues for installing HippoDraw and TUI/ATUI. No one has gotten ATUI to work on MAC yet. Here are first-cut notes on both from Tom Murphy, which might be a start, even though it didn't work in the end. The notes could be polished up. The formatting has extra linefeeds, but Eric M didn't want to spend time cleaning it up when they are likely to change after James B uses them.

> **From:** C.D. Hoyle
> **Sent:** Tuesday, July 22, 2008 12:25
> **To:** Tom Murphy
> **Cc:** James Battat; Eric L. Michelsen; Russet McMillan
> **Subject:** Re: hippodraw on mac os x
> My guess is that the problem with ATUI is path related. I am more than happy to help debug this.

### *HippoDraw on Mac OS X*

```
first, try Qt 4.1.4

cd ~/system/qt-mac-opensource-4.1.4
configure -therad -qt-gif failed: no -thread
configure -qt-gif

edit .bash_profile according to INSTALL instructions

make  [2:12PM - 4:45PM!]
make install --> /usr/local/Trolltech/Qt-4.1.4

boost (1.33.1) appears to be already installed
pyfits (1.1.b2) ditto

in ~/system/hippo_build:

../HippoDraw-1.19.1/configure --with-qt4-dir=/usr/local/Trolltech/Qt-
4.1.4
make
fail: no libQtCore.dylib (Test, yes; Core, no)

in Qt 4 directory:
make uninstall

unpack qt-mac-free-3.3.6 in /Developer and rename to qt/
follow INSTALL directions
./configure -thread -qt-gif
make [6:04PM - 7:11PM]

unpack boost 1.33.1 anew
./configure --with-python=/usr/local/bin/python2.4
make [7:21PM - 7:55PM]
failed 6 targets, updated 825 targets
not all boost libraries built properly
make install

back to hippo
../HippoDraw-1.19.1/configure (no args)
did not find python2.4 (but did find 2.3)
```

```
ln -sf /usr/local/bin/python2.4 /usr/bin
configure
make  [8:33PM - 8:49PM fail]

try 1.17.4 version
some error in boost
make  [8:57 - 9:17 fail] ld can't locate file for -lboost_python-
gcc_1_33_1
hippo website provided clue:
configure --with-Qt-dir=/Developer/qt --with-boost-libname=boost_python-
1_33_1
no complaints this time about boost
make  [9:25PM - 9:44PM] success!
make install
doxygen Doxyfile fail: command not found (documentation error)

in python:
import hippo
some error in dylibs:
Reference from /usr/local/lib/libssl.0.9.7.dylib
Expected in /usr/lib/libcrypto.0.9.7.dylib

install MacPython2.4.3
pylab, numpy, scipy, Tkinter still load
same error loading hippo

suspect need to have python built with same version of gcc.
Certainly old python was built with gcc 3.3

get python2.4.3 source
configure
make  [10:30PM - 10:38PM]
make install
put 3 MB binary in /usr/local/bin (cf. 39 kB binary in framework tree)
can't find old modules

revert to MacPython2.4.3
see that it was built with:
[GCC 4.0.1 (Apple Computer, Inc. build 5250)] on darwin

so okay: my gcc:
gcc version 4.0.1 (Apple Computer, Inc. build 5250)

Try remake of hippo now that gcc vers. of python good, in case python
used
in make

same error on import hippo (both python and pythonw)

in hippo_build:
make macapp
had to copy some missing files from 1.19.1 tree to same loc in 1.17.4
tree:
icon & some qt/app files
now app works (in hippo_build/qt/app)

retry hippo 1.19.1 w/ same config arguments (this time in
~/system/hippo/)
configure --with-Qt-dir=/Developer/qt --with-boost-libname=boost_python-
1_33_1
```

```
make (successful)
same import error!

delete old Hippo in python site-packages tree, also axe hippo.pth
log of hippo make install hints that python libraries stuffed in:
/usr/local/lib/python2.4/site-packages/Hippodraw (incl. hippo.pth)
not usual
/Library/Frameworks/Python.framework/Versions/2.4/lib/python2.4/site-
packages

so in usual place (above), make hippo.pth that simply says:
/usr/local/lib/python2.4/site-packages/Hippodraw

now works!! both as clickable app (make macapp works straight out for
1.19.1)
and as python import
tried examples in HippoDraw-1.19.1/examples
pythonw -i displays.py, for example


3/02/2007: installed python2.5, and wanting hippo to work with this.

Just putting hippo.pth into site-packages is not good enough.  Version
conflict and python dumps.  So cleared out system/hippo directory, and
ran:

../HippoDraw-1.19.1/configure --with-python=/usr/local/bin/python2.4
--with-Qt-dir=/Developer/qt --with-boost-libname=boost_python-1_33_1
make [17:34 - 17:58]

oops: meant to say python2.5!!  That was the whole point...  May need to
re-do boost with 2.5 also...  actually, the with-python business is not
a
proper flag in hippo configure: it's a boost flag.

make clean in boost_1_33_1
./configure --with-python=/usr/local/bin/python2.5
make [18:12 - 19:06] (on battery; interrupted by end of bus ride for 8
minutes)
failed 10 targets, updated 817 targets
not all boost libraries built properly

clear out hippo/ directory

ln -sf /usr/local/bin/python2.5 /usr/bin/python

../HippoDraw-1.19.1/configure --with-Qt-dir=/Developer/qt
--with-boost-libname=boost_python-1_33_1
make [19:15 - 19:37]
make install
make macapp
can run app in hippo/qt/app/
but can't import hippo into python2.5.  When I try, I get
Fatal Python error: Interpreter not initialized (version mismatch?)
Abort trap
and python quits

try getting python2.5 source
./configure
make
```

```
make install
import hippo --> same problem

revert to mac-packaged Python2.5 (at least all supplemental stuff
already
intact and working)

try make clean and re-make boost, just in case.  Flying blind.

12/29/2007
get 1.21.3 source, unpack to /system/HippoDraw-1.21.3

make hippo1.21 directory for dirty work
ln -sf /usr/local/bin/python2.5 /usr/bin/python

../HippoDraw-1.21.3/configure --with-Qt-dir=/Developer/qt --with-boost-
libname=boost_python-1_33_1
[1:47-1:50]
make [1:52-2:02] fail in Transform section: wcs errors
make clean
try configure --without-wcslib (also --without-WCSLIB), but ignores!

go back to boost, cause I notice trying to use python2.4

in boost_1_33_1
as root:
make clean
./configure --with-python=/usr/local/bin/python2.5
make [2:20-2:57]
failed to update 10 targets; skipped 4; updated 817; Not all Boost
libraries built properly
make install
...failed updating 10 targets...
...skipped 16 targets...
...updated 70 targets...
Not all Boost libraries built properly.

in hippo1.21

../HippoDraw-1.21.3/configure --with-Qt-dir=/Developer/qt --with-boost-
libname=boost_python-1_33_1 --without-wcslib
still identifying python2.4
ah: /Library/Frameworks/Python.framework/Versions/Current is set to 2.4
re-do configure (same as above): found 2.5
make [3:15-3:23] same wcs error

get latest wcslib-4.3; follow hippo instructions:
touch C/wcsulex.l
touch C/wcswtrn.l
try make from top directory
make [3:32-3:34] success
make install error
cd C
make install (works)

make again in hippo1.21 (no make clean--hopefully saves TIME)
make [3:35-3:38]
got past transforms, but fail /usr/bin/libtool: internal link edit
command failed
try: ranlib /usr/local/lib/libwcs.a
```

```
make
same failure
ld: /usr/local/lib/libwcs.a(wcs.o) has local relocation entries in non-writable section (__TEXT,__text)
rm /usr/local/lib/libwcs*
rm -rf /usr/local/include/wcslib*

hippo1.21
make clean
../HippoDraw-1.21.3/configure --with-Qt-dir=/Developer/qt --with-boost-libname=boost_python-1_33_1 --without-wcslib
this time wcs explicitly NOT included in configure output
make [3:47-4:10] success!
make install
doxygen error
make macapp
app (in hippo1.21/qt/app/) runs on click
>>> import hippo
Fatal Python error: Interpreter not initialized (version mismatch?)
Abort trap
after all this--same PROBLEM!

notice that boost stuff in /usr/local/lib/ is not from today;
try boost_1_34_1 to get fresh start
./configure --with-python=/usr/local/bin/python2.5 --with-libraries=python
The last flag is said to save 200MB of disk space, and considerable time
based on config output, thinking it used 2.4 before, despite flag.  I
think this because it looked much like the hippo config, where it used
the Current link to identify the python version.  This could explain
version mismatch error.
make [4:46-5:06]
...updated 237 targets...
(good sign)
make install
...updated 4055 targets...

in hippo1.21

make clean
../HippoDraw-1.21.3/configure --with-Qt-dir=/Developer/qt --with-boost-libname=boost_python-1_34_1
make [5:22-5:48] (CPU also busy on NYT sudoku) success!
make install - usual doxygen error
make macapp (app runs)
import hippo --> segmentation fault!  Argh!
trail is cold...

trying Qt4.3.3
./configure -R/usr/local/lib
[7:35-8:12]
don't know if -R option is necessary: following Hippo suggestions for Qt3
make [8:12-12:32!!]
make install --> /usr/local/Trolltech/Qt-4.3.3/ [also slow!]

in hippo1.21

make clean
```

```
../HippoDraw-1.21.3/configure --with-qt4-dir=/usr/local/Trolltech/Qt-
4.3.3 --with-boost-libname=boost_python-1_34_1
checking for Qt... yes:
    QT_CXXFLAGS=-I/Developer/qt/include -DQT_THREAD_SUPPORT
    QT_DIR=/Developer/qt
    QT_LIBS=-L/Developer/qt/lib -lqt-mt -R/Developer/qt/lib
    QT_UIC=/Developer/qt/bin/uic
    QT_MOC=/Developer/qt/bin/moc
checking correct functioning of Qt installation... success
configure: checking QT4 install
checking for /usr/local/Trolltech/Qt-
4.3.3/include/QtGui/QAbstractButton... yes
checking for /usr/local/Trolltech/Qt-4.3.3/lib/libQtCore.dylib... no
configure: WARNING: Qt4 not found

2007-12-30

back to qt
make confclean
./configure -qt-gif -no-framework -universal -sdk
/Developer/SDKs/MacOSX10.4u.sdk -release
[10:31-11:28] competing CPU with LAtimes sudoku
make
[11:29-12:46]
lipo: can't open input file: /var/tmp//ccmmur8d.out (No such file or
directory)
make[2]: *** [.obj/release-shared/qpnghandler.o] Error 1
make[1]: *** [release] Error 2
make: *** [sub-gui-make_default-ordered] Error 2
problem in qpnghandler
./configure -qt-gif -no-framework -universal -sdk
/Developer/SDKs/MacOSX10.4u.sdk -release -no-libpng
[1:25-2:22]
make
[2:27-4:35 (sleep); 5:31-1:56AM!!!] successful
rm -rf /usr/local/Trolltech/Qt-4.3.3/
make install
[9:54-10:01]
now chock full of dylibs in /usr/local/Trolltech/Qt-4.3.3/lib (none
before)

in hippo1.21
make clean
../HippoDraw-1.21.3/configure --with-qt4-dir=/usr/local/Trolltech/Qt-
4.3.3 --with-boost-libname=boost_python-1_34_1
Qt4 deemed useful; still finding Qt3 in /Developer/qt
make [10:06-abort]
using boost_1_33_1 lib!
cd /usr/locl/lib
rm *boost*33*
cd ...../hippo1.21
make clean
make
[10:11-abort]
still see -I/usr/local/include/boost-1_33_1
from /usr/locl/include, remove old boost dirs
make clean
../HippoDraw-1.21.3/configure --with-qt4-dir=/usr/local/Trolltech/Qt-
4.3.3 --with-boost-libname=boost_python-1_34_1
still see ref to 1_33_1 in config output
```

```
back to boost_1_34_1 and make install (looking to see
/usr/include/boost/python.hpp) ...found 9058 targets...
in hippo1.21
make clean
../HippoDraw-1.21.3/configure --with-qt4-dir=/usr/local/Trolltech/Qt-
4.3.3 --with-boost-libname=boost_python-1_34_1 --with-boost-
version=1_34_1 --with-boost-root=/usr/local --with-boost-
include=/usr/local/include/boost-1_34_1
make
[10:32-? ( < 11:12)] success
getting the boost picture this time!; confirm using Trolltech/Qt-4.3.3
root# rm -rf /usr/local/lib/python2.5/site-packages/HippoDraw/
make install [doxygen prob]
make macapp [runs]
import hippo works!!!!!!!
pythonw -i displays.py  [also works]

2008-01-01

still fails in connection with TUI:
tuilog says no module named hippo
running /Application/TUI.app/Contents/MacOS/python starts interactive
python shell; notice it's 2.5.1
.mojo:APOLLO$ /Applications/TUI.app/Contents/MacOS/python
.Python 2.5.1 (r251:54869, Apr 18 2007, 22:08:04)
.[GCC 4.0.1 (Apple Computer, Inc. build 5367)] on darwin
import hippo leads to same version mismatch statement I saw before;
abort trap
.Fatal Python error: Interpreter not initialized (version mismatch?)
.Abort trap

the MacPython installation is just 2.5
getting dmg of 2.5.1 from python.org;
hope it installs over macpython version smoothly...
ReadMe.txt in dmg suggests it *is* MacPython and will install in
/Applications/MacPython 2.5/
select upgrade installation type

now python enters 2.5.1 interactive
.mojo:APOLLO$ python
.Python 2.5.1 (r251:54869, Apr 18 2007, 22:08:04)
.[GCC 4.0.1 (Apple Computer, Inc. build 5367)] on darwin
SAME EXACT BUILD, etc.: good sign
got numpy, pylab, Pmw, Tkinter, pyfits, PIL, Numeric, numarray
import hippo works
still fails in TUI-started python shell

back to boost 1_34_1
make clean
./configure --with-python=/usr/local/bin/python2.5 --with-
libraries=python
[9:27-9:27]
make
[9:36-9:55]
...updated 237 targets...
make install
...found 9058 targets...
...updating 12 targets...

back in hippo1.21
```

```
../HippoDraw-1.21.3/configure --with-qt4-dir=/usr/local/Trolltech/Qt-
4.3.3 --with-boost-libname=boost_python-1_34_1 --with-boost-
version=1_34_1 --with-boost-root=/usr/local --with-boost-
include=/usr/local/include/boost-1_34_1
make
[10:00-10:26]
make install [doxygen prob]
make macapp
import hippo [works]
pythonw -i displays.py  [also works]
TUI hippo same problem! argh!

tried moving hippo to /Lirary/Frameworks...site-packages/ place; no diff
```

### *TUI on Mac OS X*

```
in svn/Apollo/TUI: svn update

check Tcl/Tk versions in /usr/lib: 8.4 check
try insalling snack 2.2.10
in unix/
configure with flags pointing to Tcl/Tk framework dirs,
edit Makefile to point at Headers
as instructed in mac/README
make fails:
ranlib problem
ranlib /Library/Frameworks/Tcl.frameworks/Versions/8.4/libtclstub8.4.a
ranlib /Library/Frameworks/Tk.frameworks/Versions/8.4/libtkstub8.4.a
make (success)
make test (some failures, but heard something)
make install

python imaging library (PIL)
in ~/system/Imaging-1.15.1

python2.4 setup.py build_ext -i
 TKINTER   ok
 JPEG      ok
 ZLIB      ok
 FREETYPE2 ok

python2.4 selftest.py  --> 55 tests passed
python2.4 setup.py install

pyfits 1.1.b2
python setup.py install

py2app-0.2.5
python setup.py bdist_mpkg --open
error copying doc tree
(then python setup.py install?)
```

Note for python2.5, I had to additionally install:

```
* Numeric
* numarray
* Pmw
```

which presumably were already in place when the above notes for python2.4 were made.

verify ds9 works (launches X11): view fits file

TUI app in dock ignores TUIAdditions (in ~/Library/Application Support/)

in TUI source directory (~/Library/Application Support/TUI_1.2_Source)

pythonw runtui.py

change pathStuff.py in additions to point to ~/system/HippoDraw-1.19.1/

load_hippo.py in 1.19.1/examples important

must not only customize pathStuff.py

but also command call (popen) in moonWdg.py

```
module            called by
ApolloModel HippoWdg
ApolloWindow      --
HippoWdg    ApolloWindow
laserKeypad HippoWdg
moonWdg           HippoWdg
stv         HippoWdg
pathStuff   HippoWdg,ApolloWindow,laserKeypad,stv
```

Now a summary from an e-mail to C.D. and Russell:

I have finally gotten around to upgrading my mac OS to 10.4, which means I now have claen gcc and associated libraries, which enabled me to build Qt and HippoDraw. It was not without some pain, but I now have hippo running on my mac (both as clickable application and as python-callable).

The main hurdle over, I am now trying to get TUI and TUIAdditions to work properly. I've been running TUI for some time now as the mac binary without APOLLO support.

Apparently, this binary did not look for the TUIAdditions (perhaps there is a way to get it to do so: I didn't check thoroughly). I had the source around, so I decided to try this route. I updated my builds/installations of the various dependencies (snack, pyfits, PIL, etc.). With TUIAdditions in the appropriate place and the latest APOLLO TUI version (modified here and there for mac paths etc.), I get problems.

First, and probably not important, I always get the error:

```
Could not initialize snack: invalid command name
"snack::setUseOldObjAPI"
```

whether I use APOLLO additions or not. Not worried about it, and haven't checked my snack installation carefully.

The behavior is: hippo brings up its two windows, following the second line (of three total) in load_hippo.py:

```
import hippo
app = hippo.HDApp()
canvas = app.canvas ()
```

then hangs. It never gets to the third line.

I tried running some of the examples packaged with the hippo dist. that use the exact same load_hippo.py (from same directory/file, in fact), and this works fine. I moved an example python script from the examples to TUIAdittions and used pathStuff.py in exactly the way HippoWdg.py, etc. uses it to point at the examples directory where load_hippo.py sits. This worked. In other words, hippo is fine, running python code from the TUIAdditions directory with appropriate path pointers is fine.

After experimentation just running HippoWdg.py on its own (pythonw HippoWdg.py), and at first encountering the same hang, I found that if I move the following four lines to the top of the HippoWdg.py file, it no longer hangs:

```
import pathStuff
pathStuff.apolloWindowPaths()
from load_hippo import app, canvas
from hippo import *
```

All the other imports (RO, TUI, etc.) now happen after this. The first two lines simply have the effect of putting the examples directory where load_hippo.py sits into sys.path. But the striking thing here is that order is important. When I use this "new order" and run TUI itself, I still get the same hang. So no hang on its own, but hang (in same old place in load_hippo) when TUI presumably imports bunches of stuff first. I would suspect a namespace conflict, but

A) this would presumably be reported, and

B) if not, we still could not explain why there is no such conflict on the windows machines where this package runs. I suppose there still could be some path issue somewhere.

That's the main problem, and I would appreciate suggestions for how to probe this further.

Now a couple other tidbits that may be irrelevant given the main problem, but are certainly a little worrisome. The second one is definitely for Russell only, but the first may be relevant to both (or certainly Russell may have seen similar Tk behaviors and have insights).

So I get over the hang problem when I run HippoWdg.py on its own. But it's still intermittent and problematic after this.

Sometimes it crashes with a Segmentation fault and sometimes it crashes with Bus error after drawing the canvas, opening the tk window, but before populating said window. Sometimes it gets all the way to drawing the window (minus boxes for user-settable text fields). If it gets this far, I don't get the interactive python prompt (I run pythonw with -i flag: on hippo distribution example, after drawing is complete, I get an interactive prompt). I also can't manipulate any of the buttons/tabs/etc. I can't even move the window as a whole on the screen. So it seems like it gets stuck. Could be related to the user-input text fields, which fail to show up.

If I run moonWdg.py, this seems to work fine and I can manipulate the window: both the buttons (with correct behavior) and moving the whole thing on the screen. But I still don't get the prompt (maybe because Tk loop is running, and this is not important). Anyway, it's encouraging in other respects.

If I run ApolloWindow, this brings up the two hippo windows, does not draw anything on the canvas, I get no Tk window, and the interactive prompt appears. In other words, it thinks it's done and is happy. But given that ApolloWindow is the only one that doesn't get imported by another *.py in TUIAdditions, and it itself imports HippoWdg, I would expect this to do everything HippoWdg does and more. But no Tk stuff.

And a postscript: if I move load_hippo.py to TUIAdditions and remove path references to ~/system/HippoDraw-1.19.1/, same behavior, but I saw one Bus error again.

## moon_pos.py

From email:

```
From: Tom Murphy [mailto:tmurphy@physics.ucsd.edu]
Sent: Saturday, July 04, 2009 18:52
To: Russet McMillan
Cc: Tom Murphy; Eric L. Michelsen; C.D. Hoyle
Subject: Re: UTC-TAI time?
```

The input to moon_pos.py is in UTC, but is merely a “serving suggestion.” The UTC is converted to TDT for the calculation, which has a fixed offset from TAI of 32.184 seconds (don’t ask!). Since the TCC works on TAI, we serve out a track command tied to TAI. The UTC input merely established a “nowish” time for which you’d like a track command. In fact, the computer time is used, which can be even minutes off and we’re still fine. One second hurts nothing in this context.

## SVN (SubVersioN)

```
From: Russell E Owen
Sent: Monday, September 12, 2005 13:48
To: apollollr@u.washington.edu
Subject: [LLR] svn repository
```

Fritz has set up the svn repository. It is available at: svn://svn.apo.nmsu.edu/Apollo , and it consists of 3 sub-projects:

```
Houston
ICC
TUI   (meaning the TUI additions used to run Apollo)
```

Each project has the traditional svn layout:

| | |
|---|---|
| trunk | Regular main-line development |
| branches | Branches off main line, when updating an old version |
| tags | Named important versions for easier human reading |

Warning: always check out the TRUNK of each project you are working on. Do NOT check out the whole project (it’s too big)!

...Each of you will have your own username and password. This apparently helps keep track of who is doing what to what (at the cost of some clutter). I'm happy to collate them and send them on to Fritz (and also happy to have anyone else do it).

The subversion project: <http://subversion.tigris.org/> This includes links to clients.

The manual is here (and is very readable): <http://svnbook.red-bean.com/>

For those familiar with CVS but not svn, please check out "The Top Ten Subversion Tips for CVS Users": <http://www.onlamp.com/pub/a/onlamp/2004/08/19/subversiontips.html>. It will save you a lot of grief.

The svn command-line client (available at the subversion site) is quite easy to use and the obvious place to start.

There are also some excellent GUI clients (many of which rely on the command-line client under the hood). I personally prefer the command-line client for most things, but prefer a GUI for tagging releases and browsing logs.

### SVN Tips

```
rm -Rf * .svn                [wipe out current directory, including SVN private data]
svn co svn://svn.apo.nmsu.edu/Apollo/Houston/trunk .     [check out]
svn list -v
    497 eric          10096 Jul 28 16:20 Makefile
    497 eric                Jul 28 16:20 include/
    497 eric                Jul 28 16:20 src/
svn status|grep -v ^M            [show everything except simple modifications]
A      src/utility/pr_util.c
A      src/utility/apfile_lib.c
?      src/pwr_meter/pwr_cli.c
?      src/pwr_meter/pwr_restart.c
A      src/pwr_meter
A      src/stv
!      src/stv/stvadam.c
A      src/stv/stv_lib.c
svn list -v
```

```
        498 eric          12146 Jul 30 10:22 Makefile
        498 eric                Jul 30 10:22 include/
        498 eric                Jul 30 10:22 src/
    svn log
    ------------------------------------------------------------------------
    r497 | eric | 2008-07-28 16:20:05 -0700 (Mon, 28 Jul 2008) | 1 line

    First SVN version from 2005-10-20 tar
    ------------------------------------------------------------------------
    r1 | fstauffer | 2005-09-12 12:39:40 -0700 (Mon, 12 Sep 2005) | 1 line

    initial version
    ------------------------------------------------------------------------
```

The following is good for creating the working directory for old source code so it can be checked into SVN:

```
    cp -prv new/* working_dir/
```

[copy old source files over checked out SVN files]

## Zaber Motor Controls

```
    From: Tom Murphy
    Sent: Wednesday, May 09, 2007 12:19
    To: Eric Michelsen
    Subject: zaber additions
```

I added a zaber/ subdirectory to grlab's apollo/src, and also added a target/rule for zabercom to the Makefile. I don't think such changes affect you: as I understand it grlab is the master, and these items do not need to be propagated elsewhere. But I thought I would let you know of my activity in case it matters to you.

The zaber stuff is the motor actuation control for moving the microscope objective in front of the APD array in the lab.

## Handy Unix Stuff

Examples of handy Unix commands.

| | |
|---|---|
| `uname -a` | displays complete unix version |
| `df` | displays all filesystems, and what they're connected to: |

```
    [eric@grlab eric]$ df
    Filesystem           1K-blocks      Used Available Use% Mounted on
    /dev/hda1              8096152    680988   7003904   9% /
    none                    517936         0    517936   0% /dev/shm
    /dev/hda4             96165100   2351340  88928796   3% /home
    /dev/hda2             10088552   4888896   4687184  52% /usr
    houston1:/home        96719024    335760  91470192   1% /houston1
    gdot:/home            77418240  15236128  58249408  21% /gdot
```

To see a complete directory size:

```
    du 2007 -s
    2034772 2007
    du -sh 2009
    1.7G    2009
```

human readable

Find a file from the given directory down:

```
    find -name "*.ps"
    ./src/calib/cal_tdc.ps
    ./src/calib/selfjit.ps
    ./src/acm/acm.ps
    ./src/tdc/tdc_c.ps
    ./src/tdc/tdc_h.ps
    ./src/gps_clock/gps_clock_c.ps
```

```
     locate tv1
    /home/eric/src/test/stv1.c
    /home/eric/tv1
    /home/eric/test/src/test/stv1.c
    locate -r ".*tdc$"
    /home/apollo/data/2005/051209/051209-131430.tdc
    /home/apollo/data/2005/051209/051209-170100.tdc

    tar -xvf /gdot/eric/grlab070929-000101.tar          [extract tar file to current directory]
    tar -xvzf /gdot/eric/grlab071028-000101.tar         [extract compressed tar file to cur dir]
    tar -cvzf stuff.tar Makefile src include predict    [create compressed tar file to cur dir]
    less backupgr
    cd /grlab/apollo
    tar -cvzf /home/eric/grlab`date +%y%m%d-%H%M%S`.tar Makefile src include
    predictq
    cd ~
    ls -l
    rm -v `find -name "*.ps"`                  [wipe out all *.ps files in directory tree]
```

Prepend first the day directory, then the year directory, to each line in the ‘run_names.txt’ file:

```
    sed 's!^......!&/&!' run_names.txt >temp
    sed 's!^..!20&/&!' temp >run_names_d.txt
```

or in one step:

```
    sed -e 's!^......!&/&!' -e 's!^..!20&/&!' run_names.txt >run_names_d.txt
```

**Calendar:** Unix/mac has a nice tool to see a calendar in day number:

```
    cal -j
       September 2009
Sun Mon Tue Wed Thu Fri Sat
        244 245 246 247 248
249 250 251 252 253 254 255
256 257 258 259 260 261 262
263 264 265 266 267 268 269
270 271 272 273
```

```
    From: Tom Murphy
    Sent: Saturday, July 31, 2004 8:24
    To: Eric Michelsen
    Subject: services/ports
```

You can get a more-or-less complete list of linux service ports at /etc/services on the machine in question. I also found a command: nmap (run with options -sS -O <IPaddress>) that looks at open ports by sequentially trying to connect to each one. My machine at home, for instance, only puts out 22: ssh, 111: sunrpc, and 6000: X11. I understand the first and last: ssh and X go together so you can run remote graphics. Don’t know right off why sunrpc is running—but it’s not on the “bad” list of vulnerable ports.

Output looks like:

```
    > nmap -O -sS 24.152.182.63

    Starting nmap V. 3.00 ( www.insecure.org/nmap/ )
    Interesting ports on user-0c9hdhv.cable.mindspring.com (24.152.182.63):
    (The 1598 ports scanned but not shown below are in state: closed)
    Port       State       Service
    22/tcp     open        ssh
    111/tcp    open        sunrpc
    6000/tcp   open        X11
    Remote operating system guess: Linux Kernel 2.4.0 - 2.5.20
    Uptime 5.890 days (since Sun Jul 25 11:07:55 2004)

    Nmap run completed -- 1 IP address (1 host up) scanned in 7 seconds
```

My desktop machine at work is more active:

```
(The 1578 ports scanned but not shown below are in state: closed)
Port       State       Service
15/tcp     filtered    netstat
22/tcp     open        ssh
25/tcp     filtered    smtp
53/tcp     filtered    domain
69/tcp     filtered    tftp
111/tcp    filtered    sunrpc
135/tcp    filtered    loc-srv
136/tcp    filtered    profile
137/tcp    filtered    netbios-ns
138/tcp    filtered    netbios-dgm
139/tcp    filtered    netbios-ssn
445/tcp    filtered    microsoft-ds
515/tcp    filtered    printer
530/tcp    filtered    courier
593/tcp    filtered    http-rpc-epmap
600/tcp    filtered    ipcserver
730/tcp    open        netviewdm2
1433/tcp   filtered    ms-sql-s
1434/tcp   filtered    ms-sql-m
1524/tcp   filtered    ingreslock
5000/tcp   filtered    UPnP
6000/tcp   open        X11
32771/tcp  open        sometimes-rpc5
Remote operating system guess: Linux Kernel 2.4.0 - 2.5.20
Uptime 123.894 days (since Mon Mar 29 10:10:44 2004)

Nmap run completed -- 1 IP address (1 host up) scanned in 16 seconds

I have to look at what filtered means.  More things outright open, though.
```

## Python

### Versions

Starting Python gives you its version:

```
>python
Python 2.5.2 (r252:60911, Feb 21 2008, 13:11:45) [MSC v.1310 32 bit
(Intel)] on win32
```

Check package versions like this:

```
>>> import numpy
>>> numpy.__version__
'1.0.4'
```

### Starting Points

Simple examples of code are often the most useful way to get started with a new language. Two common uses for Python are simple text filters, and graphing, so here are two very simple Python scripts for them:

**Simple Text Filter**

**Simple Plot**

### PyLab

The various numerical and scientific packages are a mess, as of 6/09. We use NumPy, SciPy, and MatPlotLib. Alternatively, you may be able to use a combination of all 3 called “PyLab”.

As of 6/09, there is an effort to replace “numpy+scipy+ipython+matplotlib” with PyLab [www.scipy.org/PyLab]. We can’t know now what will become of this. There is a PyLab “super-pak” download, which says it automatically include NumPy, but as of 6/09, it did not properly include NumPy. Eric M (and Rebecca S) successfully downloaded NumPy separately afterwards. Excerpts from [www.scipy.org/PyLab]:

“At the moment, the current combination of Python, **NumPy**, **SciPy**, **Matplotlib, and IPython** provide a compelling environment for numerical analysis and computation.

PyLab should be the name of the entire suite, and I feel strongly that the correct way to import the entire core PyLab API should be via

```
    from pylab import *
```

This should include the core parts of numpy, scipy, and matplotlib. A rough equivalent would be:

```
    from pylab import *
    from numpy import *
    from scipy import *
```

”

Currently, with Python 2.5.2, Eric M can import PyLab as above.

## *Numpy*

Numpy and Scipy are closely related, but separate, packages for numerical and scientific computing. Note that as of 6/09, there is an effort to replace “numpy+scipy+ipython+matplotlib” with PyLab [www.scipy.org/PyLab]. Until then, you can use them separately. Numpy is a prerequisite for Scipy.

Numpy has some documentation at http://numpy.scipy.org//numpydoc/numdoc.htm and PDF at http://numpy.scipy.org//numpy.pdf .

Both NumPy and SciPy are poorly documented at www.scipy.org/Documentation. The web site doesn’t even list the subpackages, so here’s an excerpt from the built-in help:

```
>>> import numpy       # for help, can’t use ‘from numpy import *’
>>> numpy.__version__
'1.0.4'
>>> help(numpy)
Help on package numpy: NAME   numpy

FILE      c:\python25\lib\site-packages\numpy\__init__.py
...
    Available subpackages
    ---------------------
    core      --- Defines a multi-dimensional array and useful procedures
                  for Numerical computation.
    lib       --- Basic functions used by several sub-packages and useful
                  to have in the main name-space.
    random    --- Core Random Tools
    linalg    --- Core Linear Algebra Tools
    fft       --- Core FFT routines
    testing   --- Numpy testing tools

      These packages require explicit import
    f2py      --- Fortran to Python Interface Generator.
    distutils --- Enhancements to distutils with support for
                  Fortran compilers support and more.

    Global symbols from subpackages
    -------------------------------
    core    --> *
    lib     --> *
    testing --> NumpyTest

    Utility tools
    -------------
      test        --- Run numpy unittests
      pkgload     --- Load numpy packages
      show_config --- Show numpy build configuration
      dual        --- Overwrite certain functions with high-performance
Scipy tools
      matlib      --- Make everything matrices.
      __version__ --- Numpy version string

PACKAGE CONTENTS
    __config__
    _import_tools
    add_newdocs
    core (package)
    ctypeslib
    distutils (package)
    dual
    f2py (package)
    fft (package)
    lib (package)
    linalg (package)
    matlib
    numarray (package)
    oldnumeric (package)
    random (package)
    setup
    testing (package)
    version
```

### SciPy

The scientific Python package is poorly documented (www.scipy.org/Documentation). You can’t even easily find a list of subpackages, so here is an excerpt, as of v0.6.0 ~6/2008. Note that scipy uses the ‘numpy’ namespace.

```
import scipy     # for help, can’t use ‘from scipy import *’
>>> scipy.__version__
'0.6.0'
help(scipy):
Help on package scipy: NAME      scipy

FILE      c:\python25\lib\site-packages\scipy\__init__.py

      numpy name space

    Available subpackages
    ---------------------
    ndimage          --- n-dimensional image package [*]
    stats            --- Statistical Functions [*]
    signal           --- Signal Processing Tools [*]
    lib              --- Python wrappers to external libraries [*]
    linalg           --- Linear algebra routines [*]
    linsolve         --- Linear Solvers [*]
    misc             --- Various utilities that don't have another home.
    sparse           --- Sparse matrix [*]
    interpolate      --- Interpolation Tools [*]
    optimize         --- Optimization Tools [*]
    cluster          --- Vector Quantization / Kmeans [*]
    linsolve.umfpack --- Interface to the UMFPACK library. [*]
    fftpack          --- Discrete Fourier Transform algorithms [*]
    odr              --- Orthogonal Distance Regression [*]
    io               --- Data input and output [*]
    maxentropy       --- Routines for fitting maximum entropy models [*]
    integrate        --- Integration routines [*]
    lib.lapack       --- Wrappers to LAPACK library [*]
    special          --- Airy Functions [*]
    lib.blas         --- Wrappers to BLAS library [*]
```

```
      [*] - using a package requires explicit import (see pkgload)

    Global symbols from subpackages
    -------------------------------
    stats   --> find_repeats
    misc    --> info, factorial, factorial2, factorialk, comb, who, lena,
                central_diff_weights, derivative, pade, source
    umfpack --> UmfpackContext
    fftpack --> fft, fftn, fft2, ifft, ifft2, ifftn, fftshift, ifftshift,
                fftfreq

    Utility tools
    -------------
      test        --- Run scipy unittests
      pkgload     --- Load scipy packages
      show_config --- Show scipy build configuration
      show_numpy_config --- Show numpy build configuration
      __version__ --- Scipy version string
      __numpy_version__ --- Numpy version string

    Environment variables
    ---------------------
      SCIPY_IMPORT_VERBOSE --- pkgload verbose flag, default is 0.

PACKAGE CONTENTS
    __config__
    __svn_version__
    cluster (package)
    fftpack (package)
    integrate (package)
    interpolate (package)
    io (package)
    lib (package)
    linalg (package)
    linsolve (package)
    maxentropy (package)
    misc (package)
    ndimage (package)
    odr (package)
    optimize (package)
    sandbox (package)
    setup
    signal (package)
    sparse (package)
    special (package)
    stats (package)
    stsci (package)
    version
    weave (package)
```

### SciPy.Stats

Scipy includes a subpackage for statistics, scipy.stats. Here's an excerpt of its help, from the scipy version 0.6.0. I've omitted the extensive list of 81 continuous and 10 discrete probability distributions, since they are long and of limited use. You can get them from Python, as below, if you want:

```
Help on package scipy.stats in scipy:      NAME   scipy.stats

FILE      c:\python25\lib\site-packages\scipy\stats\__init__.py

    Statistical Functions
    =====================
    This module contains a large number of probability distributions as
    well as a growing library of statistical functions.

    Each included distribution is an instance of the class rv_continous.
...omitted for brevity
```

```
Statistical Functions (adapted from Gary Strangman)
gmean           --  _
hmean           --  _
mean            --  _
cmedian         --  _
median          --  _
mode            --  _
tmean           --  _
tvar            --  _
tmin            --  _
tmax            --  _
tstd            --  _
tsem            --  _
moment          --  _
variation       --  _
skew            --  _
kurtosis        --  _
describe        --  _
skewtest        --  _
kurtosistest    --  _
normaltest      --  _

itemfreq            -- _
scoreatpercentile   -- _
percentileofscore   -- _
histogram2   -- _
histogram   -- _
cumfreq   -- _
relfreq   -- _

obrientransform    -- _
samplevar    -- _
samplestd    -- _
signaltonoise    -- _
bayes_mvs   -- _
var    -- _
std    -- _
stderr    -- _
sem    -- _
z    -- _
zs    -- _
zmap    -- _

threshold    -- _
trimboth    -- _
trim1    -- _
cov    -- _
corrcoef    -- _

f_oneway    -- _
paired    -- _
pearsonr    -- _
spearmanr    -- _
pointbiserialr    -- _
kendalltau    -- _
linregress    -- _

ttest_1samp    -- _
ttest_ind    -- _
ttest_rel    -- _
kstest    -- _
chisquare    -- _
ks_2samp    -- _
meanwhitneyu    -- _
tiecorrect    -- _
ranksums    -- _
```

```
        wilcoxon    -- _
        kruskal    -- _
        friedmanchisquare     -- _

        ansari    -- _
        bartlett    -- _
        levene    -- _
        shapiro    -- _
        anderson    -- _
        binom_test    -- _
        fligner    -- _
        mood    -- _
        oneway    -- _

        glm    -- _
        anova  -- _

        Plot-tests

        probplot    -- _
        ppcc_max    -- _
        ppcc_plot    -- _

        For many more stat related functions install the software R and the
        interface package rpy.

    PACKAGE CONTENTS
        _support
        distributions
        futil
        info
        kde
        morestats
        mvn
        rv
        setup
        statlib
        stats
```

# 3 APOLLO System Maintenance

## Aligning Fiducials to APD

```
From: Russet McMillan
Sent: Tuesday, October 02, 2007 0:35
To: apollo_core@u.washington.edu
Subject: [Apollo_core] clouded out again
```

Earlier in the evening, however, Tom and I did some tests of the six-lobed pattern seen on the fiducial returns as a function of polarization. We confirmed that, as expected, the central lobe is polarized 90 deg from the six outer lobes -- so Tom's previous speculation about the nature of those lobes and the power going into them is upheld.

```
From: Tom Murphy
Sent: Thursday, September 20, 2007 19:19
To: APOLLO Core
Subject: [Apollo_core] stormed out

Today I/we:
...
```

* tried to measure beam profile with calibrated photodiode at exit aperture (but can't handle high-power pulsed laser, it seems)

* found that we can pump up the STV exposure time and see the six-lobe pattern on the STV when the TR is in dark position! So now I know for sure why the APD sees this pattern, but the STV never did: the TR dielectric coating is passing P-polarization preferentially, and the surrounding lobes are P.

```
* recognized that this mode of looking at fiducial returns will let us
align to the APD position directly (since the TR is in the fire position)
without having to offset 2 arcseconds.
```

# 4 Hardware Information

## Houston

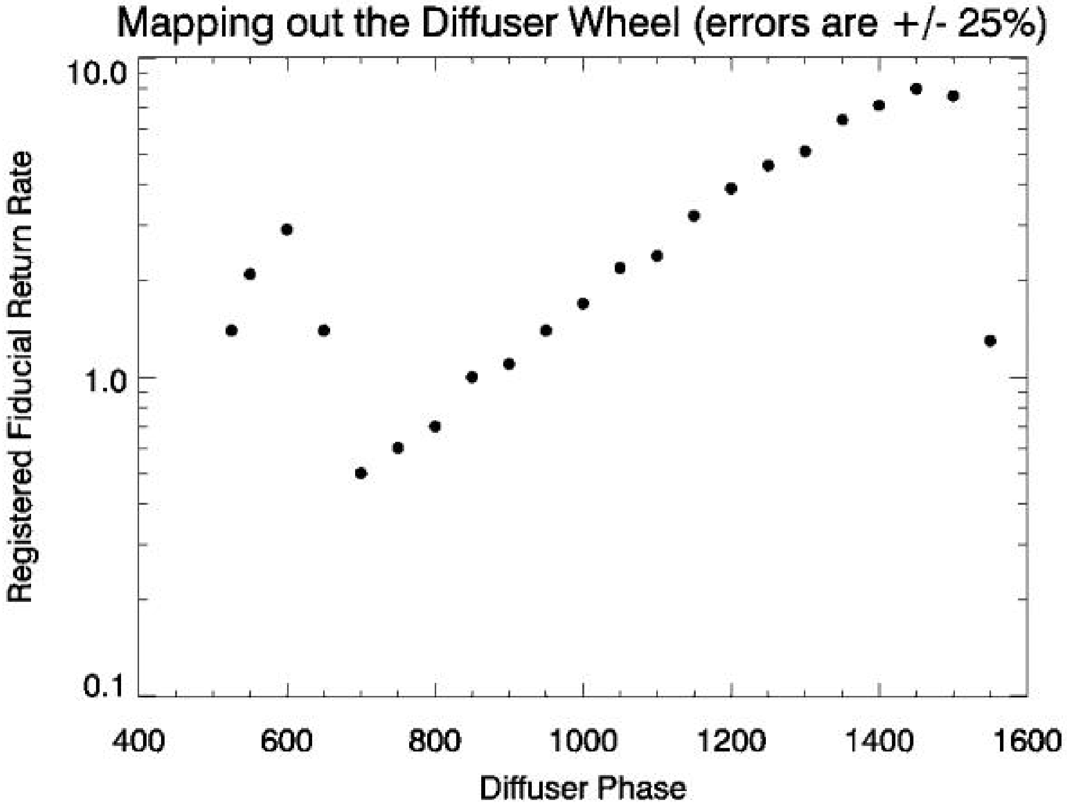
### CAMAC

We are at the mercy of the crummy CAMAC driver, which does not allow timeouts on waiting for CAMAC interrupts. If the CAMAC does not interrupt, housctl will hang waiting for it, and there is nothing we can do about it. A better CAMAC driver would allow housctl to set a timeout on the wait for interrupts (say, 40 ms), which would allow housctl to keep functioning even on CAMAC failure, or other hardware or software errors that lead to no interrupt. Perhaps a newer version of the driver has this feature, which is usually standard on any driver.

**TDCs:** We have two TDCs, informally called TDC1 and TDC2. We're currently (12/2006) using TDC2, which we think is the one with the RTD temperature sensors.

### Diffuser Wheel

From http://www.cfa.harvard.edu/~jbattat/apollo/docs/diffuser/



The edge of the diffuser quadrant is around ~680, so that's why the results go bad there.

### Tiltmeter

http://www.cfa.harvard.edu/~jbattat/apollo/docs/tiltmeter/ the calibration is:

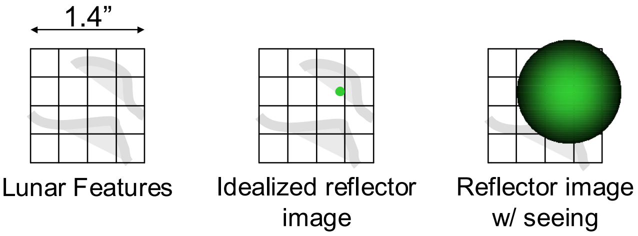
$$V = 2536.9 - 737.4\cos\theta \text{ mV} \quad \Rightarrow \quad \theta = \cos^{-1}\left(\frac{2536.9 - V}{737.4}\right)$$

### Terminal Server

```
Local_19> show version
ETS16 Version V3.3/6(960214)  Platform: 1b
```

## Optics

**Images on Lenslet**



Lunar Features

Idealized reflector image

Reflector image w/ seeing

```
From:  Tom Murphy
Sent: Monday, May 09, 2005 12:02
To: apollollr@u.washington.edu
Subject: [LLR] Helpful webpage
```

Eric Williams has put together a description and pictures of the APOLLO optical train that I have places on the APOLLO website. Check it out at: http://physics.ucsd.edu/~tmurphy/apollo/optics_bench.html

This will give you all a feel for the geometry, available space, etc. I will point out some additional things:

* at upper left in the top drawing, between the laser enclosure and the red mirror mount, is the fast photodiode mount that will hold a beamsplitter (seen as 45-degree score) and the photodiode at top, allowing some light to pass to the pulse-energy measurement photodiode that will be located somewhere below the blue beam.

* the optics mounts in the receiver allow adjustment in the two dimensions transverse to the beam (the important ones for alignment). For axial motion, we can use nudgers, seen mounted to the rail in the lower picture.

* all that you see here is realized in metal and glass, aside from this photodiode mount just mentioned. We also have yet to make a CCD mount (it's just floating in this SolidWorks rendition).

## Band Pass Filter

The optical bandpass filter is in the path to the APDs. It blocks most stray light, mostly from lunar background, from hitting the APDs. Without it, the background noise would be overwhelming. The original BPF had a transmission at 532 nm of only about 35%.

```
From: Tom Murphy
Sent: Thursday, May 17, 2007 10:35
To: APOLLO Core
Subject: [Apollo_core] new bandpass filter
```

I just ordered the new bandpass filter, which will improve our throughput from about 0.35 to 0.999 (2.85 x improvement), while admitting effectively 2.1 nm of wavelength as opposed to 0.95 nm in the current filter (2.2 x more light). We will get a detailed transmission curve for our particular piece of glass. Cost: $590.

There are a few ways to look at the gain this provides. We should consider both dark and full moon scenarios, as well as criteria for evaluating the gain (e.g., visibility vs. signal to noise of the spike).

For illumination, I've looked at two cases: full moon and dark. Right now, we get 0.15 photons per gate (across all elements and all 100 ns TDC window) in dark, and 0.60 photons per gate at full moon. These numbers become 0.15 and 1.14 with the new filter.

We currently form our histogram by taking the last 200 lunar gate events. This takes a variable amount of time depending on the background rate. At full moon, this currently takes about 330 shots, or 17 seconds for a complete refresh. In the dark, it takes about 1300 shots (65 sec) for a full refresh. In the absence of signal, this makes for an average noise background of 2.0 hits per bin (100 1-ns bins for 200 photons). Using Poisson statistics, there will typically be one bin with 5-6 photons, but almost never anything over 8. We typically regard a 10 or higher as a real signal--and are usually right. In our current implementation of constant photon number instead of constant shot number, the update time of the histogram is highly variable. This is perhaps something we ought to rethink (or have options to go either way).

So the two ways to look at signal are: how much does it pop up out of the grass of background (visibility); and what is the statistical signal-to-noise of the signal spike itself. For visibility, we simply want to know when the signal exceeds 10 counts (so signal is 8, on top of background of 2). For SNR of the spike, we want s/sqrt(s+b), where s is signal count, and b is background count. I think for the purpose of finding and identifying the signal, visibility is the best guide.

OLD FILTER

| condition | N(200) | s(0.01) | s(0.02) | s(0.04) | r(0.01) | r(0.02) | r(0.04) |
|---|---|---|---|---|---|---|---|
| dark | 1333 | 13.3 | 26.6 | 53 | 3.4 | 5.0 | 7.1 |
| full | 333 | 3.3 | 6.7 | 13.3 | 1.4 | 2.3 | 3.4 |

Here, N is the number of shots corresponding to 200 APD events, and the signal (s) and snr (r) are evaluated at three average lunar return rates, constituting the low end of what we know we can detect. Visibility would require s > 8 (so s + b > 10), and snr would want r > 3 for believability. Both happen at about the same place: < 0.01 in the dark, and about 0.03 at full.

NEW FILTER

| condition | N(200) | s(0.01) | s(0.02) | s(0.04) | r(0.01) | r(0.02) | r(0.04) |
|---|---|---|---|---|---|---|---|
| dark | 1333 | 38 | 76 | 152 | 6.0 | 8.6 | 12.2 |
| full | 175 | 5.0 | 10 | 20 | 1.9 | 2.9 | 4.3 |

Here, I am using the same signal return rates (treating conditions as the same: the same number of photons are returning to the telescope), but boosting the detected signal by 99.9/35 = 2.85. Now the signal becomes visible in worse conditions in both dark and full scenarios.

In the dark case, the background is unchanged by the filter width, so the gain in visibility is 2.85. At full, the gain is 2.85/(2.1/0.95) = 1.29, or about 30% better. Effectively, we reach our 200-photon wrap count sooner by the ratio of bandpass, which cuts our signal accordingly. The snr approach shows a similar gain that is maintained at full moon.

Sometimes the signal is split between 2 bins. In this case, both filters are affected similarly, so the comparative analysis only needs deal with one case.

Eric Adelberger and I briefly discussed an ability to flip between new and old filters (in case the full moon turned out to be worse in the new filter), but it looks like this won't be necessary.

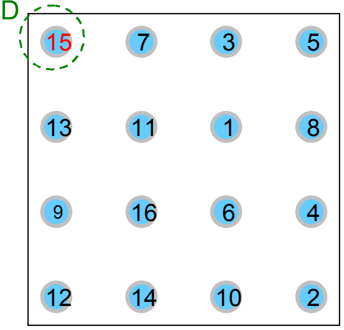
## APD and Motherboard

Motherboard APD wires:

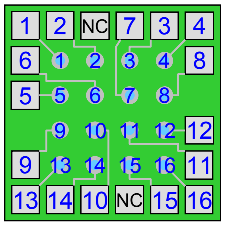
| **Motherboard / TDC Channel** | **APD #** | **Mboard 1 Cable length (in)** | **Mboard 2 Cable length (in)** |
|---|---|---|---|
| 1 | 7 | 7 | 7.5 |
| 2 | 16 | 5 | 7.5 |
| 3 | 3 | 5 | 6.5 |
| 4 | 12 | 5 | 6.5 |
| 5 | 4 | 5.5 | 6.25 |
| 6 | 11 | 7 | 7.5 |
| 7 | 2 | 7 | 7.5 |
| 8 | 8 | 8.25 | 8.5 |

| | | | |
|---|---|---|---|
| 9 | 9 | 5 | 5.75 |
| 10 | 15 | 5.5 | 8 |
| 11 | 6 | 6 | 7 |
| 12 | 13 | ?? | 5.75 |
| 13 | 5 | 3.25 | 5.75 |
| 14 | 14 | 5.75 | 7 |
| 15 | 1 | 5.75 | 6.25 |
| 16 | 10 | 7.75 | 5.75 |

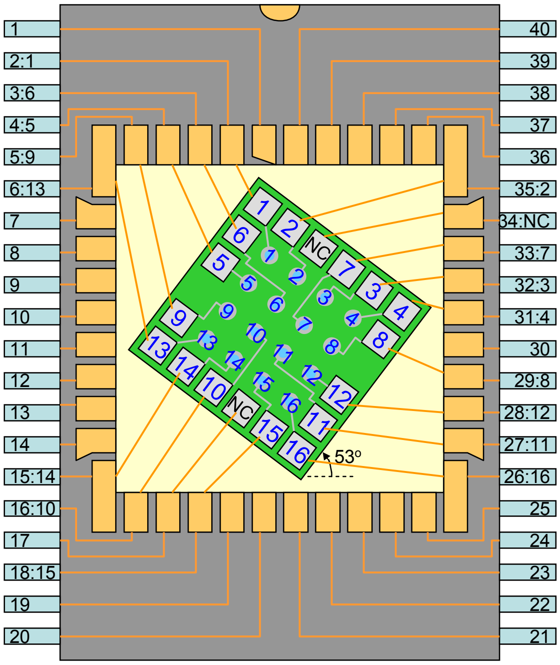
TDC Ch15 used for FPD



TDC Channels



anode connection



From: Tom Murphy
Sent: Friday, January 06, 2006 12:04
To: aull@ll.mit.edu
Cc: Orin Adam; Michelsen Eric
Subject: 4x4 pinout

For redundancy, here is the pinout list:

| Pin | APD |
|---|---|
| 2 | 1 |
| 3 | 6 |
| 4 | 5 |
| 5 | 9 |
| 6 | 13 |
| 15 | 14 |
| 16 | 10 |
| 18 | 15 |
| 26 | 16 |
| 27 | 11 |
| 28 | 12 |
| 29 | 8 |
| 31 | 4 |
| 32 | 3 |
| 33 | 7 |
| 35 | 2 |

You have in the past connected pin 17 to the isolated pad between APD 10 and 15 pads, and pin 34 to the NC pad between APD 2 and 7. I don't know if this served any purpose.

In the event that we end up wanting to use a newly packaged device in our telescope system, in order to use our lenslet with the package, it would be advantageous to orient the silicon block the same way as it is in our current device. I have measured this angle to be 53 degrees in our current package, so that the 16-pad is farther from the wall nearest the 13-pad (left in the figure), and the 1-pad is closer to the 13-wall. The drawing is precisely at 45-degrees, BTW. Even getting within 5 degrees of the 53 degree target helps.

## Powering Devices

As of 6/30/2005, we have

IP1 UPS Houston  
IP2 UPS flow meter box  
IP3 UPS Temperature adaptor box  
IP4 UPS Laser power meter (bolometer)

From: Tom Murphy  
Sent: Wednesday, April 27, 2005 10:06  
To: apollollr@u.washington.edu  
Subject: [LLR] powering equipment

Here is a list of the devices that need AC power in the APOLLO setup, and how they are powered. The circuit numbers refer to switchable relays that we can control from Houston. Please look this over and let me know if I have forgotten any devices, or if you spot anything wrong with the scheme. We will work in the near term to assign power consumption numbers to each item. A key to abbreviations appears at bottom.

| circ. # | equipment | loc. | when on |
|---|---|---|---|
| 1 | APD Power supply | CAB | WU, OP, testing |
| 1 | Photodiodes/9327 supply | CAB | WU, OP |
| 2 | CAMAC crate | Utah | WU, OP, testing |
| 2 | Booster power supply | CAB | WU, OP, testing |
| 3 | diffuser motor power supply | CAB | OP, testing |
| 3 | T/R motor power supply | CAB | OP |
| 4 | STV CCD camera controller | CAB | OP |
| 4 | New Focus optics actuators | CAB | OP |
| 5 | Utah box heater | Utah | random (thermal control) |
| 6 | Noren heat exch. fans | Utah | random (thermal control) |
| 7 | Plenum fan banks | ILE | random (thermal control) |
| 8 | ILE exhaust fan | ILE | random (thermal control) |
| 9 | Passive Utah cooling pump | ILE | random (thermal control) |
| 9 | Passive Utah heat exch. fans | ILE | random (thermal control) |
| IP1 UPS | Houston | CAB | always |
| IP2 UPS | flow meter box | CAB | whenever a pump is on |
| IP3 UPS | M33 chiller relay | CAB/ILE | WU, OP, CD |
| IP4 UPS | M75 chiller relay | CAB/ILE | WU, OP, CD |
| UPS | XL-DC clock | Utah | always |
| UPS | RTD Signal conditioner | CAB | always |
| UTIL | Laser Power Meter | CAB | always (with battery backup) |
| UTIL | Cabinet circulation fan | ILE | always |

WU: warm-up  
OP: operation  
CD: cool-down  
Utah: laser thermal enclosure  
CAB: phone-booth cabinet  
ILE: intermediate level enclosure (or vicinity)  
IP#: IP switch in cabinet (4 outlets)  
UPS: uninterruptible power supply  
UTIL: utility power

From Tmurphy, 5/23/2005:

The UW relay boxes are each 4-outlet units, and there are 4 such boxes. Labeling these boxes 1, 2, 3, 4 and the outlets on each a, b, c, d, we can lay out a map designating who is where, and which signals control each. Box 1 is in the Utah laser enclosure Box 2 is in the phone-booth/cabinet Box 3 is in the phone-booth/cabinet Box 4 is in the intermediate level enclosure (ILE)

On the terminal server (located in the ILE), ports 1-8 are reserved for communications. Ports 9-16 are usable for relay switching (this division is arbitrary).

The IP power switch is plugged into the UPS.

The devices controlled by the NI-DAQ on houston are as follows:

| bit # | box/outlet | equipment | max pwr |
|---|---|---|---|
| 0 | 2a | APD Power supply | |
| 0 | 2b | Photodiodes/9327 supply | |
| 1 | 1a | CAMAC crate | 175 |
| 1 | 2c | Booster power supply | 35 |
| 2 | 3a | T/R motor power supply | 65 |
| 2 | 3b | diffuser motor pwr sup. | |
| 3 | 3c | STV CCD camera ctrl | 25 |
| 3 | 3d | NF optics actuators | 35 |
| 4 | 1b | Utah box heater | 110 |
| 5 | 1c | Noren Lower fan | |
| 6 | 1d | Noren Upper fan | |

The devices controlled by the terminal server are:

| port # | box/outlet | equipment | max pwr |
|---|---|---|---|
| 9 | 4a | Plenum fan banks | |
| 10 | 4b | ILE exhaust fan | |
| 11 | 4c | Aux. cooling pump & fans | |
| 12 | 4d | Cabinet circulation fan | |
| 13 | -- | Laser keyswitch relay | <1 |
| 14 | -- | Laser 208 V 3-phase (3 relays) | 2500 |

The devices supported on the UPS-fed IP switch are:

| port# | equipment | max pwr |
|---|---|---|
| 0 | houston | 150 |
| 1 | flowmeter box | |
| 2 | undesignated | |
| 3 | undesignated | |

Then there are some devices left always powered:

| type | equipment | max pwr |
|---|---|---|
| UPS | XL-DC clock | 25 |
| UPS | RTD Signal conditioner | |
| UPS | Interlock box & shutter | |
| utility | Laser Power Meter | 3 |
| utility | ILE heater (own thermostat) | 420 |
| 220V | M33 Chiller (RS-232 activated) | 1500 |
| 220V | M75 Chiller (RS-232 activated) | 2000 |

## XL-DC GPS Clock

Model 151-602-949

We have the Disciplined Quartz Oscillator Option, *not* the Disciplined High Stability Quartz Oscillator Option. To meet its published specs, the day/night temperature variation must be < ~5 C [Manual Rev G p17-3].

## TR Motor

Silvermax (I think Silvermax 23 -ELM 11/2006) (www.qcontrol.com) is now discontinued. Internal encoder at 4000/rev. Our logic provides 1000/rev (was 2000/rev at first) to the software.

## Laser

From: Russet McMillan
Sent: Tuesday, October 02, 2007 0:35
To: apollo_core@u.washington.edu
Subject: [Apollo_core] clouded out again

The only other notable thing was that Tom got a power of 2.15 W after only 15 minutes of flashing. This [might be] because the telescope was at high altitude []. Most of my laser power measurements made on nights when we run are made at an altitude near that of the moon; although I do adjust the [2nd] harmonic generator to give peak power depending on the altitude, it seems the best we can get might be lower at low altitude regardless of the SHG. It's encouraging to know the laser isn't really losing power rapidly after the service visit(s), but unfortunate that laser power seems to be lower at altitudes where we're more likely to observe.

**Continuum Leopard (SS-20)**

http://www.photonic.solutions.zen.co.uk/downloads/acrobat/continuum/CNleopard.pdf

| | |
|---|---|
| Wavelength: | 532 nm |
| Pulse duration: | ~120 +/- 20 ps |
| Pulse energy | ~115 mJ |
| Pulse rate: | 20 pulse/s |
| Average light output power: | 2.3 W |
| Photons per pulse: | $\sim 10^{17}$ |

~1 µs variation in shot time from trigger pulse.

From: Tom Murphy
Sent: Tuesday, August 28, 2007 22:07
To: APOLLO Core
Subject: [Apollo_core] laser tip-top

Vlad has finished his work on the laser for this trip, and I am very pleased with what he has done. Details will come later (sleep must come first), but I'll give you the punch-line(s).

We get 2.3 W with 57% conversion efficiency (good: means short pulses, and better than prev. 50% typ). This is with the oscillator threshold at 1390 V (compare to previous 1600+), and the amplifier at 1500 V (down from 1600 V), all with the newer, less aggressive saturable absorber. I wouldn't have thought it possible. But our laser was aligned with a care and attention to detail that has been lacking in other service visits. Vlad did a heck of a job--in the pre-Katrina sense of the phrase.

We still have some RF intermittency problems, now traced to the RF generator itself. Vlad would not have been able to do anything about that on this trip anyhow, and suggests that we try to borrow another driver from Continuum to further isolate the problem.

Aside from this, we've never had a laser in such good shape. More later...

On Tuesday 8/28/2007, Tom wrote

A more aggressive saturable absorber holds off lasing for longer, so more energy builds up in the rod as the flash persists. When the laser does swing into action, it has more energy to play with. The SA becomes essentially transparent once there is enough light. The new SA becomes transparent sooner. It was as a result of the newer SA that we had to drive the amplifier harder to make up for diminished pulse energy out of the oscillator. Amplifier alignment could also play some role here.

From: Tom Murphy
Sent: Friday, September 29, 2006 18:29
To: APOLLO Core
Subject: [Apollo_core] laser works

The laser guys have left, and I believe we have a stable laser now.

The new saturable absorber is less aggressive, which means that it becomes transmissive at lower laser energy. This means that instead of rasing lasing threshold by 400 volts, the new one is more like 230.

So now we have the headroom to tune the AOML to its maximum modulation and still achieve lasing at a reasonable voltage. For perspective, when we (Chris, James and I) played with this last November, the lowest threshold we could get with the S.A. out and the AOML properly tuned was 1330 V, meaning a threshold with the S.A. of 1730, and an operating voltage (40 above threshold) of 1770. This is practically off-scale for these lamps, and 1700 is considered the hardest you want to drive them. So we had no choice but to accept a non-maximized tuning of the AOML, translating to instability.

In the current setup, threshold is 1620 V, and rock steady so far as we can tell so far. Doubling efficiency is good (50%), meaning that our pulse is short.

The only negative is that the new S.A. produces a weaker oscillator output (the AOML is tuned to reject more light--thus better pulse shaping, and the lasing is initiated sooner in the flashlamp cycle so at lower energy). The amplifier output is proportional to oscillator output (I wasn't sure about this before), so the total power is less. UNLESS we crank the amplifier harder. From the factory, the amp was at 1370V; on installation, it was about 1400V; recently, we've been at 1440-1450V. Now, we would need to be at 1620V to get the nominal 2.3 W out. We may opt to do this. I learned that these flashlamps are no different from the others in terms of how hard you can push them. 1600 is uneasy, and 1700 is the max to be considered.

What are the downsides to pumping hard?

* reduced lamp lifetime (do we care?)

* different thermal state of rod, so lensing more severe, leading to beam convergence and possibly disastrous focusing.

The last point (along with persistent warnings from laser guy not to push any harder than we were at 1530 V) did give me pause. But Russet and I did a check of power vs. voltage, and simultaneously measured the outgoing beam radius using the shear plate (fantastic device!). At 1530 V, we had 1.60 W of green (3.45 W IR), and absolutley no divergence/convergence that I could detect. At 1600 V, we had 2.13 W (4.36 IR), and about 20-degree fringes on the shear plate, translating to a radius of curvature of 100 m. Once expanded through the telescope, this translates to 0.1 arcsec of angle. At 1560 V, we had 1.85 W green (3.92 IR) and about half the convergence.

Interestingly, the change in convergence when going from 1600 V to 1560 V was almost immediate.

We also sent the beam across the dome (collimated) to take burns to look at far field beam quality/divergence. The burns near Utah and at the dome wall are practically identical (23 feet of travel), with less than a millimeter of difference on the 12 mm beam--confirming the conclusion from the shear plate.

So I think I'll crank the amplifier a little harder before I leave so we get our full energy out. Doesn't seem to be a real issue with beam convergence.

Also, Russet loaded the new TUI additions onto the APOLLO laptop, and we successfully ran the laser from it. I'm not sure the COOLDOWN button did anything, but I need to look at this again.

```
From: Tom Murphy
Sent: Friday, December 08, 2006 12:53
To: APOLLO Core
Subject: [Apollo_core] happy laser
```

New flashlamps in the amplifier have given us a 1.95W laser. Up from 1.45W with old lamps. They had about 15 million shots. So we should ignore the 25 million shot expectation, and replace ours around 10M or so. They're cheaper than the trip out here (even from S.D.). So now we have reasonable power *and* what I think will be an even more stable laser. I think the laser jocks last time detuned a bit off of best oscillator performance to squeeze more light out (since we were straining to get close to spec with the modifications). It's my belief that we're better off now than we were after the September visit.

But of course time will tell.

```
From: Tom Murphy
Sent: Friday, September 29, 2006 20:40
To: Eric L. Michelsen
Subject: RE: [Apollo_core] laser news
```

The GaAs is in the oscillator cavity, and becomes absortive when it gets too much incident optical (photon) density--almost the exact opposite to the saturable absorber. The result is clamping the intensity, which shortens pulse width and makes a flat spot in the pulse train for more stable pulse slicing (they're all the same height).

No idea what the physics is. But I know it's oriented at the Brewster angle, for what that's worth.

```
From: Tom Murphy
Sent: Tuesday, September 26, 2006 18:26
To: APOLLO Core
Subject: [Apollo_core] laser news

In the half-day of laser work this afternoon, we found that:
* the GaAs wafer had damage (possibly from day one?)
```

## Laser Safety

Originally from Erik Swanson’s email, modified by the subsequent conference call. Goals:

- System of interlocks must allow control room disabling, dome disabling, and some bypass mechanisms for engineering work.
- Must allow for engineers to work on laser with motor kill switch engages.

The laser interlock system works with our interlock shutter inside the laser box, in the Utah box. The interlock shutter moves in front of the laser output aperture on the side of the laser box.

```
From: swanson
Sent: Wednesday, September 26, 2007 10:45
To: 'Russet McMillan'; apollo_core@u.washington.edu
Subject: RE: [Apollo_core] returns! and some problems
```

I checked the interlock code and even though the IR camera is bypassed if it is up and running and doesn't detect something in its field of view (ie. is A-OK) the light will be on solid.

The other problem with telescope stop could be related to your engineering shutdown. I get the "telescope stop" signal from a panel on the intermediate level (A set of relay contacts). Could this have been removed for any reason?

From: Erik Swanson Sent: Friday, May 13, 2005 9:09 AM

Here is an initial set of objects and signals for a Laser security system:

### Control Room Box (inputs):

Operator Enable OK (perhaps a key switch)
Collision imminent (defeatable with override)
Other Inputs: Audio, FAA feed… (defeatable with override) ?

### Control Room Box (outputs):

Forwards inputs via Fiber to Telescope. Transmission of information acts as a <Comm OK> keep-alive.

**Telescope Silo Box (inputs) – Logic to open shutter is here**

All Control Room inputs from fiber

Aircraft Avoidance System OK (missing pulse on Heartbeat Tc -> frame rate) (defeatable with override)

Dome Stairway Door Closed

Dome stairway door opening sets an interlock bit which the operator (or dome engineers?) must explicitly reset

Telescope motor kill-switch (STOP button) transition sets an interlock bit which dome engineers may override

Utah Box Open (defeatable with override)

Local Override (overrides ONLY those things listed as defeatable.)

Spotter Switches (defeatable with override)

Houston Enable ? (defeatable with override)

**Telescope Silo Box (outputs)**

Open Shutter (AND of Inputs or Override)

Status changes to HUB

CAMAC, RS232, or TCP/IP ??

```
    have closed
From: swanson    Sent: Tuesday, April 10, 2007 11:11
To: 'James Battat'; 'Russet McMillan'
Cc: apollo_core@u.washington.edu
Subject: RE: [Apollo_core] interlocks broken
```

There are two things in the ILE. 1- Allen Bradley (AB) rack and 2- Silver box with black connectors for the cables to the outside world. The Fiber optics are powered from the AB rack. One thing to check is the AB computers web page for what it thinks about the status of the system. You'll need the IP address which hopefully Tom or Eric can come up with. The shutter system's status is under I believe something like "USER1" which has a link on the home page. I would also like access to this IP from Seattle but that will take some help from Fritz.

In the control room there is another silver box similar to the one in the ILE which also must be powered as well as a fiber optic transceiver box. I built the system such that if there is a fault in the fiber optic circuit between control and dome you should be able to operate the shutter from the remote console by itself.

Later: The AB rack's modules have lights showing to some extent what is going on. Check for some activity here including power. Do check the fuse on the silver box it should come out although I also remember the "push and turn" operation was a bit problematic.

### *Laser Interlock Log*

The digested interlock changelog status can be viewed online at: http://cocoa.apo.nmsu.edu/interlock/interlockChangelog.log

From James Battat 4/24/2007:

I've started the interlock status checker in motion on cocoa. This version actually polls the allen bradley webpage data in real time and tracks any changes to the interlock bits. It is running in:

cocoa: /home/environment/interlock

The python code is called: trackInterlockChanges.py

and the digested interlock status gets saved in: interlockChangelog.log

The python code relies on two other libraries (in the same directory):

```
  AllenBradley.py
  AllenBradleyHTMLParser.py
```

Running "top" on cocoa shows that vlc (the video server) consumes about 15% of cocoa's cpu. My interlock status checker takes less than 1%. For now, I will leave it running even when not ranging, just to see if it can run for long periods. Eventually though, this process should be started and stopped with ranging sessions (perhaps with warmup and cooldown).

### *Safety Issue: When Is Agreement to Lase Terminated?*

```
From: Eric L. Michelsen
Sent: Tuesday, June 20, 2006 10:34
To: 'apollo_core@u.washington.edu'
Subject: Laser safety
```

I agree that the laser should never fire without positive operator directive.

(Note that in this night's case, and all other known cases, the laser did not lase at all. Only the flashlamps flashed. It would have required several other operator actions to actually get the laser to send a beam out of the box.)

The unanswered question about firing the laser is "When is the operator agreement-to-lase terminated?" In other words, what events require ANOTHER operator confirmation?

The normal case is obvious: successful completion of the laser operation (e.g., RUN or FIDLUN) terminates the operator agreement-to-lase. Another lasing requires another operator action.

The difficulty is the case where the intended operation fails. For example, the operator commands FIDLUN, but due to some failure, the laser does not lase, even though the hardware is asking it to. Now the operator must poke around to find the problem, and try to fix it. If the operator finds some issue, and fixes it, the laser might start lasing. This behavior is pretty much required to allow the operator to diagnose and fix a problem.

However, a potential risk is this scenario:

1. the operator agrees to lase
2. lasing fails but the agreement-to-lase is still valid
3. it takes so long to find the problem that operators forget the command-to-lase and agreement-to-lase are still pending
4. someone pokes around some more, fixes the problem, and the still-valid agreement-to-lase starts the laser lasing, surprising the operators.

If we deem the above risk substantial, then we must identify specific, unambiguous criteria for terminating the agreement-to-lase. Keep in mind that the software does not always have an easy way to tell if the lasing command succeeded or failed.

A somewhat similar situation arises with the space-command blockages. We chose to allow short blockages to be covered under the existing agreement-to-lase. Long blockages (>~2 min) abort the RUN, and hence abort the agreement-to-lase.

## Solid State Relays

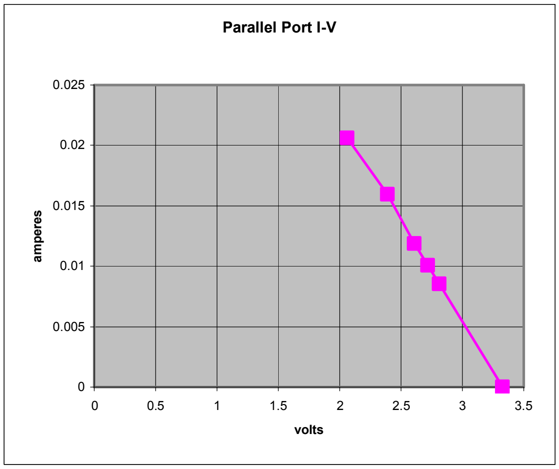
Crydom, probably model D2425D. Requires 4V to operate. Draws 13 mA @ 5V. This is highly annoying, since they can’t be driven from TTL. So we have “converter” boxes which accept 8 TTL inputs, and drive up to 16 relays. The boxes also provide jumper selectable controls, so a given input can drive an arbitrary set of outputs. Most boxes accept a DB-9 input, but one of them accepts a standard DB-25 with parallel port wiring.

## Parallel Port

Drive capability. Notice that the open circuit voltage is insufficient to drive the solid-state relays.

| Volts | Ohms | Amps |
|---|---|---|
| 2.06 | 100 | 0.0206 |
| 2.39 | 150 | 0.015933 |
| 2.61 | 220 | 0.011864 |
| 2.72 | 270 | 0.010074 |
| 2.81 | 330 | 0.008515 |
| 3.33 | infinite | 0 |

The Houston parallel port can give us another 8 digital controls, suitable for power control. In particular, it would allow us to get the critical environmental controls off the less-reliable Ethernet and terminal server. Currently, a network failure results in loss of some environmental controls (laser freezing circulation, ILE & DI pump for DI anti-exhaust, passive propylene-glycol Utah cooling, e.g.). [The laser would require 3 pins in parallel to drive the 3 solid state relays (SSRs) for its 3-phase power.] This would eliminate the need for the TS as a power control device, but we'd still need it for serial I/O for the chillers and digipots.



Note that with a tiny bit of external logic, we could expand the parallel port to hundreds of digital outputs, with tons of current drive on each. Slightly more logic (but worth it) to make the expansion I/Os readable.

The M33 (and M75) chiller is also on the TS, but the parallel port can't replace that.

## Zaber

5/9/2007 Tom added a zaber/ subdirectory to grlab's apollo/src, and also added a target/rule for zabercom to the Makefile. The zaber stuff is the motor actuation control for moving the microscope objective in front of the APD array in the lab.

# 5 Data And Data Reduction

## APOLLO Raw Data

### APOLLO Raw Data Directory Structure

Run files:

```
houston:/home/apollo/data
    run.last, cal.last, log.last, ... etc.
    2006/yymmdd
            *.run, *.cal, *.drk, *.flt, etc.
    2007/yymmdd
```

Polynomials (and some normal points):

```
/home/apollo/ephem/predict/
    yymmdd/      (e.g. 060514 for May 14, 2006)
or  yyyy-mm-dd/
or  yyyymmdd
```

#### Backing Up Data From Houston to Cocoa

`rsync`, according to its website, essentially tracks changes on a remote disk and updates your local copy accordingly, only transferring the missing info. James B thinks it's used a lot in mirroring websites. It's free and will take care of the unix/linux platforms.

```
From: Tom Murphy
Sent: Friday, February 22, 2008 11:39
To: James Battat; Eric Michelsen
Subject: rsync on cocoa
```

I now have rsync running on cocoa as a cron job. I checked out its performance on syncing the old stuff (mostly didn't need to do anything, but I **had** missed a few bits here and there in my manual copying). I was pleased with its behavior and verified its incremental update performance.

The cron runs at 20:29 UTC each day, about 30 min after the log roll-over. The timing is arbitrary, since it will get a partial log file no matter what, and complete it the next day. But might as well grab a recently completed chunk...

For reference, the cron line is:

```
29 20 * * *     /usr/bin/rsync -av
--exclude-from=/home/apollo/data/exclude_list /houston/apollo/data/
/home/apollo/data/ >> /home/apollo/data/cron_report 2>&1
```

performing a verbose "archive" (preserves date, ownership, permission) copy, minus the contents of exclude_list:

- *.last
- nohup.out
- fidtests
- rename_list

and appending the verbose output (and any errors) to cron_report in the cocoa data directory.

I verified proper operation of the cron job before setting the time to 20:29 daily.

#### Tar-ing Data on Cocoa for Transport Elsewhere

To list contents of a tar file

```
tar -tf archive        or          tar --list -f archive
```

To create a compressed tar file of directory 2009/:

```
tar -czvfdata2009 2009
```

To see a complete directory size:

```
du -s 2009
1696380 2009
```

## APOLLO Data Reduction

### Installation & Operation

```
From: James Battat [mailto:jbattat@cfa.harvard.edu]
Sent: Monday, November 19, 2007 11:55
To: Tom Murphy
Cc: Eric Michelsen
Subject: Re: NP reduction installation
```

I've put up some notes on the python data reduction installation at:

http://www.cfa.harvard.edu/~jbattat/apollo/docs/dataReduction/installation.html

Tom, I noticed that mkcal.py was not in the repository, so there was no way to make the .tdc file from the .cal file. I added mkcal.py to the repository.

I successfully ran one run from last night through the analysis (071119-004237.run, and 071119-004323.cal). I detail this process as a specific example at the end of the instructions.

#### np_master options

--yavg=x ns, offset of prediction to help find signal on weak runs

--slope=x ns/day, slope error in prediction to help find signal with bad predictions

--echo=x ns, offset of weak pulse relative to strong one

--tdc=filename for missing TDC calibration files *.tdc

#### APOLLO Reduced Data

The old "run_names" (without ".txt" extension) is obsolete. The new `cocoa:/home/apollo/reduced/run_names.txt` lists all the *.run files that we attempt to reduce as :

```
...
080719-072108.run  3 XX 0
080719-072134.run  3  a 1000
080719-072246.run  3  b 1000
080719-072419.run  3  c 1000
080719-073057.run  3  d 1000
080719-073305.run  3  e 5000
080723-103931.run  3  a 1000
080723-104042.run  3  b 1000
080723-104336.run  3  c 1000
080726-110734.run -1 XX 1000
080728-111955.run  3  a 10000
080728-112907.run  0  b 5000
080730-153324.run -1 DY 500
080730-153514.run -1 DY 5000
080730-232309.run -1 XX 0
...
```

The fields are original file name, reflector, short name or status, # shots. Reflector -1 is for testing, and not real data. The status codes are XX = invalid (-1 reflector used for testing, < 1000 shots, etc.), DY = daytime, FR = .

(4/29/2010 the following file doesn't seem to exist anymore.)
`cocoa:/home/apollo/reduced/runlist` gives a 1-line summary of each run's reduction, as:

```
...
071220/071220-005005.run  7000  2  Y  e  698 (535: )
```

```
071220/071220-005658.run  7000  0  Y  f  826 (613: )
071221/071221-061929.run 10000  3  Y  a 8937 (1846: 70)
071221/071221-062939.run 15000  0  Y  b 1180 (689: )
071221/071221-065522.run  5000  0  Y  e  195 (162: 2)
071227/071227-072610.run 10000  3  Y  a 3435 (1813: 32)
071227/071227-073555.run 10000  2  Y  b 1469 (1037)
071227/071227-082120.run  3000  3  Y  g  229 (186)
080101/080101-130508.run 15000  3  ?  a    6
080101/080101-131756.run 15000  3  Y  b  147
080101/080101-133152.run 15000  3  Y  c  331
...
```

The columns are filename, shots attempted, reflector, successful NP (Y or N), yield = detections w/in 2ns window minus background average, and (net) = yield after threshold imposed. The number after ":" is how many ps RTT is reduced by including all shots with detections (regardless of 'threshold').

Since 9/24/2008, reduced files are in `cocoa:/home/apollo/reduced/pipeline/....` Older reduced files are in `cocoa:/home/apollo/reduced/master/....` Reduced files from a run have names like:

```
080512h.r0.s05000.t01.y1089.n661_pretty.png
080428a.r3.s15000.t01.y1215.n959_pretty.png
080414a.r3.s10000.t01.y1946.n1274_pretty.png
080319d.r3.s14677.t01.y1768.n1188_pretty.png
080218h.r3.s03000.t01.y2269.n713_pretty.png
080218b.r3.s10000.t01.y8457.n2442_pretty.png
080211c.r3.s10000.t01.y6064.n2086_pretty.png
```

The names have date, shorthand, reflector, shots, thresh, yield, net, and then a suffix and extension indicating the contents of the file.

### Data Reduction Directory Structure

TBS

Run 060618 is split into two NPs, because the laser stopped double pulsing in the middle.

### APOLLO Data Reduction on Windows XP

From Eric M. 9/5/2008. Most of this is also valid on Unix.

```
C:\apollo\svn\data_reduction>
>type ..\..\reduced\master\test.cfg
:default --threshold=1 --noplot=1 --pretty=1 --target=master
071227-075537.run
071227-080611.run
071227-081547.run
071227-082120.run
>set APOLLO_DATA_DIR=\apollo\data
>set APOLLO_REDUCED_DIR=\apollo\reduced
>batchConfigInterpreter.py ..\..\reduced\master\test.cfg >test.bat
>type test.bat
mkcal.py 071227-075532.cal 071227-075532.tdc
np_master.py 071227-075537.run --threshold=1 --noplot=1 --pretty=1 --
target=master --tdc=071227-075532.tdc
mkcal.py 071227-080606.cal 071227-080606.tdc
np_master.py 071227-080611.run --threshold=1 --noplot=1 --pretty=1 --
target=master --tdc=071227-080606.tdc
mkcal.py 071227-081542.cal 071227-081542.tdc
np_master.py 071227-081547.run --threshold=1 --noplot=1 --pretty=1 --
target=master --tdc=071227-081542.tdc
mkcal.py 071227-082114.cal 071227-082114.tdc
np_master.py 071227-082120.run --threshold=1 --noplot=1 --pretty=1 --
target=master --tdc=071227-082114.tdc
```

I got this error on batchRun 9/5/2008:

```
>batchRun.py test.bat
mkcal.py 071227-075532.cal 071227-075532.tdc
np_master.py 071227-075537.run --threshold=1 --noplot=1 --pretty=1 --
target=master --tdc=071227-075532.tdc
Traceback (most recent call last):
  File "C:\apollo\svn\data_reduction\batchRun.py", line 389, in <module>
batchExecute(batchFile)
  File "C:\apollo\svn\data_reduction\batchRun.py", line 228, in
batchExecute
    bundle_dir = os.path.join(target,'new_bundles')
UnboundLocalError: local variable 'target' referenced before assignment
```

### *APOLLO Data Reduction/Normal Point Archive*

```
From: Tom Murphy
Sent: Friday, May 09, 2008 13:30
To: APOLLO Core
Subject: APOLLO normal points are public
```

Yesterday I sent the following e-mail to all the LLR analysts I know of, and Cc'd APOLLO core, though it was withheld from delivery because the recipient list was too large (looked like SPAM). In trying to work an open collaborative agreement with JPL (or Mueller or others), we will likely be far more effective if we ourselves have demonstrated openness. We run some risk of being shut out, but at this point we stand to lose more from being protectionist.

Dear LLR-interested scientists,

APOLLO normal point data is now available on the APOLLO website:

http://physics.ucsd.edu/~tmurphy/apollo/norm_pts.html

We acknowledge that we were slow in making our data available. We have a complex apparatus, and the new high-signal regime brings with it a fresh set of data reduction challenges. We are not 100% of the way to achieving all of our data reduction goals, but as time passes it becomes more urgent that we release what we **do** have. We expect to evolve our data reduction in significant ways in the near future, so will treat our website as an archive for reduction products, each time presenting a complete set of newly reduced normal points.

Part of our delay had to do with establishing confidence in the data quality, in which the JPL group has been invaluable. We don't have all the answers yet (at the sub-centimeter level it becomes hard to separate data errors from incomplete model), but maybe the rest of you can contribute meaningfully to our progress.

We ask that those using APOLLO data extend an invitation for us in APOLLO to participate in any scientific analyses in a collaborative way. We are eager to learn and primarily driven by tests gravitational physics. We may not always have direct interest in the specific enterprise, or something to contribute more than the data itself (important piece!), but we would appreciate the courtesy of an invitation in any case.

Our goal is to format our normal points according to the new ILRS standard, and make our data available on the ILRS website (even so, we will still need to evolve our data as we improve our reduction scheme). Until then, we wanted to provide access to our data in its present form.

We are eager to see results/residuals/solutions concerning our data, so please keep us informed.

### Retrieving Data

```
From: James Battat
Sent: Thursday, November 08, 2007 15:49
To: apollo_core@u.washington.edu
Subject: [Apollo_core] The APOLLO database (preliminary)
```

Some thoughts about the APOLLO database and trawler that we discussed on the last phone-con.

Essentially, we want to be able to get tabulated ASCII data that satisfies some arbitrary query criteria (e.g. give me all observations on Apollo 15 taken after July, 2007 that were successful). Here, "observations" are the normal point data (time, reflector, range, uncertainty, etc), the auxiliary data (atmospheric pressure, elevation angle, lunar phase, etc) and also data-model residuals (from e.g. JPL). I'm sure that there are other things that could go into the database, but I even having this would go a long way to begin with.

As Tom mentioned, our database must be fluid as the normal points can change (if our reduction style changes) as can the residuals provided by JPL (there are infinite ways in which this can change even for a given set of normal points). Because the size of our data set is so small, we can afford to build a database on the fly and then query it. That's good.

We then need a way to tie together data from three (and possibly more) sources:

1. normal point data
2. auxiliary data
3. residual data (e.g. from JPL)
4. telescope time allocation data (when we ranged and whether we succeeded or not)

1 & 2 are intimately linked already. We generate both simultaneously when we make a normal point from a .run file. So that's easy. 3 is a separate file that Jim e-mails to us (sometimes with different formats than others) 4 is a separate file that is currently maintained by Tom.

In relational database language, 1,2 and 3 could be a single table and 4 could be a separate table.

So we need tools that:

  * generate a database on the fly

    - the database may or may not have sources 1, 2, 3 and 4 at any given time

  * map JPL residuals to APOLLO normal points

  * allow for queries of the database

It seems to me that harnessing pre-built database tools and especially query handling would be a *good* thing. To this end, I have constructed a very rudimentary version of a data trawler on my local machine. It does the following:

  * searches for all normal point observation data under a specified directory on your local machine (recursively).

    -OR- accepts a list of normal points observation filenames to include

  * Reads the data (JD, range, uncertainty, RA, DEC, etc) for each observation.

  * Stores this information in a relational database.

  * Responds to user queries in the standard SQL format, e.g. the query:

```
select * from APOLLO WHERE (HOUR_ANGLE < 50 AND JD > 2454250)
```

returns:

```
     JD         | DEC        | HOUR_ANGLE | RA            ...
================================================   ...
2454256.96308 | -21.41427 | 4.793071   | 309.628006   ...
```

The entire toolkit is built in Python and is therefore cross-platform. I have made use of a small, free python add-on called gadfly which handles database generation and querying.

You can use your favorite plotting program to generate plots (or pylab could be used directly from within python). There are, however, several missing pieces in my implementation. For example, no provision to merge our normal point observation data with the JPL residuals yet exists. I have not yet worried about preserving full precision, e.g. the JD is truncated, but that's easy to fix, etc. At this point the code is a sort of proof-of-concept and in that respect it's a success. But there is much more to be done to make it a useful tool for the collaboration.

## Historical Normal Point Archive

All the normal points ever made by all measuring stations till around 9/2006 are in

`jpl_pts.np` which I converted to `jpl_spaced.np`

It has these points from these stations:

```
0 71110   3451
1  1910   9177
2 56610    694
3 71111    275
4 71112   2628
5  4610     11
6 70610     19
```

## Normal Point Format

```
From: Eric L. Michelsen
Sent: Friday, November 10, 2006 15:50
To: 'APOLLO Core '
Subject: [Apollo_core] data file format
```

The JPL normal point format is an old format designed for FORTRN and punch cards. It is illegible and hard to parse. I'll soon post the C-language normal point utility library on grlab, but I think we should move away (no, *run* away) from normal point format. I already have converted the JPL grand-unified normal point file into a spaced-out version that's much easier to read and parse, which I'll also soon post. The normal point library reads and writes this much-more-useful format as well. In fact, you can convert a file between the two formats with a simple loop to read in one format, and write the other.

I'm not sure what utilities we're making now, but I think we should be designing any new utilities to use the better spaced-out format. We should use the awkward normal point format for only one purpose: to communicate with JPL.

```
Subject: Re: predictions
From:    Jim Williams
Date:    Wed, August 11, 2004 7:48 pm
To:      Tom Murphy
```

The best thing is to make the predictions look like normal point observations and we can put them through our reduction program. There are old and new formats. We still use the old, but can convert new to old so use either one. Here is an example of the old format from McDonald.

```
511999 5 610 4 40767686262685932813873711112  5   940 59  79694 10531 5320a 726A
511999 5 61023538433538262566695438743711112  9   925137  79719 10531 5320a 786A
511999 5 61150154533141262322709004100711112  3  2144221  79794 10032 5320a 416A
511999 5 61223316528334262354403695733711112 14  1334  4  79794  9832 5320a1295A
511999 5 7 955560385950260242333953603711112  4  2082126  79719 15328 5320a 718A
511999 5 71020145355119260007674855263711112 15  1007684  79744 15328 5320a1057A
511999 5 71140394916535259470555752163371112 30   674709  79744 14929 5320a1059A
511999 5 71159 89790508259275255086082711112 11  1219  7  79744 14629 5320a1222A
511999 5 71333129734845259381947281273711112 30   745 73  79894 17125 5320a 813A
511999 521 21337296324824828907608377071112 14   973645  79869 26014 5320a 531A
511999 525 24046542847626183666150063371112  4  1111 67  79944 18974 5320a 703A
511999 525 25054557308726183153382269371112 14  1648 43  79969 18974 5320a 645A
511999 525 31159510619326184258299546371112 12  1143165  79994 19173 5320a1405A
511999 526 05440392004526492840396808371112  8  1990  8  79919 26321 5320a1714A
511999 526 254 69587360264132949656693711112  7  1064 42  79969 22326 5320a1156A
511999 527 31318907789626586069334643371112 14  1084 48  80044 20432 5320a 624A
511999 527 32640815132226569951070568271112  7  1244 49  80044 20334 5320a 403A
  yyyyMMddhhmmSSssssss-RTT-mu  n  p-RStaidNnnUUUUuuSnrQPPPPppTTTtHHWavelVSpanD
```

The 5 is invariant, 1 is laser color (?) virtually invariant, followed by year (4 digits), month (2), day (2), hr (2), min (2), sec (9.7), round-trip time in UTC sec (14.13), a 1 digit reflector ID (0 Tranquility, 2 Fra Mauro, 3 Hadley, 4 is Lunokhod 2), 71112 identifies the 3rd McDonald site with an old scheme, # photons (3), normal point uncertainty (6.1 in psec (corrected from 6.2)), SNR (3.1?), data quality of A, B, C, D (a1), pressure in mbar (6.2), temp C (4.1), humidity % (2), wavelength in angstroms (5), data version (1), span in seconds of normal point (4), detector (?) (a1).

The time is UTC of transmit, not TDT. Time of flight is UTC sec.

Please keep in time sequence. Otherwise our program comes to a shuddering halt.

Here is an OCA example

```
5120020901022051289985725664686656631301910008003553032 087540+13858 5320a0486
5120020901023258485242425649573454653301910008002933034 087529+13858 5320a0458
```

Sample FORTRAN read (corrected to f6.1 for uncertainty):

```
       read(1,50,end=150) iyr, mon, iday, ihr, min, sec, rndtrp, irfl,
      c          istns, nph, unc, sn, qual, press, temp, humid, wave,
      c          fv, ispan
    50 format( bz, 2x, i4, 4i2, f9.7, f14.13, i1, i5, i3, f6.4, f3.1,a1,
      c          f6.1, f4.1, f2.0, f5.1, a1, i4 )
```

I think that the CSTG format is on the ILRS website. It is a two line format.

At least one day should have a span of several hours. If some is dense we can check for jitter. Have at least a few points through a month. You can turn the atmospheric model on and off with the pressure field.

McD would be easier since we do not have an Apache Point ID in our program. Here are the coordinates for the McD 2.7 m (ID 71110): R=6,374,664.867 m, E long=921520.8111 arc sec, geocentric lat 109811.6529 arc sec.

You can use moon center, any of the reflector IDs, but warn us so we will remember to change the input! Here is Apollo 11: X=1591999.50 m, Y=690623.90 m, Z=21004.53 m. Actually this and station coordinates are for DE336. Do you use DE403 or 405 or ?

```
Adapted From: Tom Murphy
Sent: Thursday, September 07, 2006 13:04
To: Eric Michelsen
Subject: normal points
```

You can retrieve all historical normal points at:

```
anonymous ftp: cddis.gsfc.nasa.gov
```

in pub/slr/data/npt/moon/YYYY, where YYYY is 4-digit year (1969-2006)

you'll see files like moon.XXXX, which contains line pairs like:

```
000010300224708024195320-000183200000001972463106214131
076770886519671341796049000062208026296805800140220600
```

See: http://ilrs.gsfc.nasa.gov/products_formats_procedures/normal_point/np_format_intro.html

for info on normal point format, and in particular:
http://ilrs.gsfc.nasa.gov/products_formats_procedures/normal_point/np_format.html

The above record breaks out as follows:

```
000010300224708024195320-000183200000001972463106214131

0000103         satellite (103 = moon)
00              year of century
224             DOY
7080            cdp pad ID
```

```
24              cdp #
19              cdp #
5320            wavelength
-0001832        calib delay
000000          calib delay shift
0197            sys RMS
2               normal point window
4               epoch time scale
6               system cal method
3               sys change
1               sys config
0621            pass rms (ps)
4               data quality
13              checksum
1               format revision #

076770886519671341796049000062208026296805800140220600

076770886519    time: microseconds from 0:00 UTC
671341796049    r.t. travel in ps (ad 2.0 seconds for moon!!)
0000622         bin RMS
08026           pressure, 0.1 mB
2968            T (0.1 K)
058             R.H. %
0014            # photons
0               release #
2               integer part of delay in sec
2               normal point window mapping (units of 5 minutes)
06              SNR in units of 0.1
00              checksum (optional)
```

So of relevance to our quest to understand response, you want to keep track of station number (7080), target (103 = A15?; 100 = A11?), # of photons (14), window mapping (2 * 5 = 10 minutes).

So this example is 14 photons in 10 minutes (6,000 shots) for a rate of 0.0023 on Apollo 15 with station 7080.

The integer time window (5 min increments) introduces a *lot* of noise to the estimate, but this is what we're stuck with.

```
From: Tom Murphy
Sent: Thursday, September 07, 2006 13:17
To: Eric Michelsen
Subject: site ID
```

possible lunar IDs

```
7080 = McD
7845 = OCA (France)
7941 = Matera
7210 = Haleakala
8834 = Wettzell (Germany)
```

Also pay attention to the four digits following the site ID, as these may change (7080 has at least two existences), and maybe also the system change indicator to keep major changes separate.

```
From: Tom Murphy
Sent: Friday, September 08, 2006 10:19
To: Eric Michelsen
Subject: NP extraction
```

When you extract the data we want from the np record, here's what it might look like:

```
708024193  2000  224  103  14  2
```

where the first chunk is full station ID (8 digit) plus the change digit, the second is year number (last two digits available in record), third is DOY, fourth is target num, fifth is # photons, 6th is time interval indicator.

## Long Term Historical Return Rates

We're looking for indications of the integrity (or degradation) of the reflectors, by watching the return intensities over the years. Examination of returns vs. time over 35 years show no clear trend from two different stations. Here are the total NPs from JPLs complete file of all NPs ever submitted:

```
     0 71110   3451
     1  1910   9177
     2 56610    694
     3 71111    275
     4 71112   2628
     5  4610     11
     6 70610     19
```

```
Station  1910, npts = 7784, start, end: 18.757088, 35.601275
7620 points.  0 low, 164 high
    0     2
 0.31    49 ******
 0.62   188 *********************
 0.94   381 *******************************************
  1.2   492 ********************************************************
  1.6   561 ****************************************************************
  1.9   563 ****************************************************************
  2.2   493 ********************************************************
  2.5   491 ********************************************************
  2.8   429 *************************************************
  3.1   369 ******************************************
  3.4   308 ***********************************
  3.8   286 *********************************
  4.1   225 **************************
  4.4   266 ******************************
  4.7   204 ***********************
    5   180 ********************
  5.3   162 ******************
  5.6   156 ******************
  5.9   167 *******************
  6.2   126 **************
  6.6   130 ***************
  6.9   102 ************
  7.2    80 *********
  7.5   110 *************
  7.8    85 **********
  8.1    73 ********
  8.4    66 ********
  8.8    79 *********
  9.1    66 ********
  9.4    51 ******
  9.7    61 *******
   10    45 *****
   10    54 ******
   11    41 *****
   11    43 *****
   11    42 *****
   12    36 ****
   12    24 ***
   12    24 ***
   12    23 ***
   13    21 **
   13    23 ***
   13    25 ***
   14    16 **
   14    16 **
   14    17 **
   15    11 *
   15     9 *
   15    13 *
   16    18 **
   16    16 **
   16    15 **
   17    16 **
   17     7 *
   17     4
   18    12 *
   18    12 *
   18    11 *
   18     4
   19     8 *
   19     3
   19     2
   20     8 *
7620 points.  0 low, 164 high
```

```
    1988   69  2.67  1.47  0.81  8.35
    1989  329  3.77  3.33  0.46 26.75
    1990  573  3.55  2.95  0.42 25.14
    1991  407  3.33  2.73  0.75 27.96
    1992  358  3.96  4.01  0.38 34.31
    1993  512  3.27  2.32  0.28 16.36
    1994  587  4.62  4.25  0.55 40.20
    1995  575  4.49  5.38  0.61 58.01
    1996  609  5.71  5.00  0.54 38.83
    1997  577  7.64  4.78  0.76 36.56
    1998  338  7.18  6.67  0.67 56.01
    1999  661  9.49  6.84  1.14 39.04
    2000  826  4.85  4.44  0.66 41.42
    2001  285  2.73  1.43  0.64 10.07
    2002  174  3.14  2.96  0.85 21.20
    2003  185  2.49  1.69  0.40 10.56
    2004  426  3.83  4.49  0.24 36.48
    2005  293  2.83  2.13  0.40 16.40

    1988 2.816 +++++++++++++++++++
    1989 3.971 +++++++++++++++++++++++++++
    1990 3.738 +++++++++++++++++++++++++
    1991 3.510 ++++++++++++++++++++++++
    1992 4.173 ++++++++++++++++++++++++++++
    1993 3.444 +++++++++++++++++++++++
    1994 4.866 +++++++++++++++++++++++++++++++++
    1995 4.735 ++++++++++++++++++++++++++++++++
    1996 6.020 +++++++++++++++++++++++++++++++++++++++++
    1997 8.047 +++++++++++++++++++++++++++++++++++++++++++++++++++++++
    1998 7.560 +++++++++++++++++++++++++++++++++++++++++++++++++++
    199910.000 ++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
    2000 5.113 +++++++++++++++++++++++++++++++++++
    2001 2.876 ++++++++++++++++++++
    2002 3.306 ++++++++++++++++++++++
    2003 2.627 ++++++++++++++++++
    2004 4.031 +++++++++++++++++++++++++++
    2005 2.980 ++++++++++++++++++++
```

Counting only top-5 NPs each year, to (we hope) reduce effect of long-term weather trends:

```
    1988     5   6.29  1.30   5.22  8.35
    1989     5  20.45  5.26  14.23 26.75
    1990     5  20.76  3.75  15.97 25.14
    1991     5  19.62  5.69  13.44 27.96
    1992     5  25.24  5.87  18.47 34.31
    1993     5  12.58  2.18  10.76 16.36
    1994     5  32.06  5.10  26.29 40.20
    1995     5  49.30  8.23  38.92 58.01
    1996     5  33.82  3.20  30.10 38.83
    1997     5  28.37  5.97  23.63 36.56
    1998     5  45.24 13.14  25.10 56.01
    1999     5  36.96  2.80  32.11 39.04
    2000     5  32.23  6.64  26.46 41.42
    2001     5   8.06  1.33   6.70 10.07
    2002     5  16.28  3.51  12.27 21.20
    2003     5   8.06  1.43   7.12 10.56
    2004     5  32.03  6.45  21.04 36.48
    2005     5  13.33  2.39  10.08 16.40
    1988 1.276 +++++++++
    1989 4.148 ++++++++++++++++++++++++++++
    1990 4.211 +++++++++++++++++++++++++++++
    1991 3.980 +++++++++++++++++++++++++++
    1992 5.120 +++++++++++++++++++++++++++++++++++
    1993 2.551 +++++++++++++++++
    1994 6.503 ++++++++++++++++++++++++++++++++++++++++++++
    199510.000 ++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
    1996 6.861 +++++++++++++++++++++++++++++++++++++++++++++++
    1997 5.755 +++++++++++++++++++++++++++++++++++++++
    1998 9.177 ++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
    1999 7.497 +++++++++++++++++++++++++++++++++++++++++++++++++++
    2000 6.537 ++++++++++++++++++++++++++++++++++++++++++++
    2001 1.635 +++++++++++
    2002 3.301 ++++++++++++++++++++++
    2003 1.636 +++++++++++
    2004 6.497 ++++++++++++++++++++++++++++++++++++++++++++
    2005 2.703 ++++++++++++++++++

    71112
    2588 points.  0 low, 0 high
```

Counting only top-5 NPs each year, to (we hope) reduce effect of long-term weather trends:

```
1988     5    0.81  0.41    0.50  1.48
1989     5    0.70  0.13    0.58  0.92
1990     5    3.87  2.30    2.30  7.90
1991     5    3.65  0.80    2.75  4.40
1992     5    3.72  1.33    2.74  6.00
1993     5    3.71  0.57    2.95  4.43
1994     5    4.79  0.50    4.29  5.56
1995     5    8.11  1.81    6.39 10.80
1996     5    7.86  2.18    6.00 10.95
1997     5    4.10  0.66    3.48  5.10
1998     5    3.92  0.85    3.20  5.34
1999     5    4.70  0.89    3.95  6.23
2000     5    2.05  0.05    2.00  2.11
2001     5    1.75  0.12    1.60  1.87
2002     5    1.73  0.64    1.20  2.80
2003     5    1.29  0.13    1.14  1.47
2004     5    0.83  0.18    0.64  1.12
2005     5    1.26  0.10    1.20  1.43
2006   5   0.33  0.22   0.17  0.72
1988 1.002 +++++++
1989 0.864 ++++++
1990 4.777 ++++++++++++++++++++++++++++++++
1991 4.495 +++++++++++++++++++++++++++++++
1992 4.590 +++++++++++++++++++++++++++++++
1993 4.574 +++++++++++++++++++++++++++++++
1994 5.903 ++++++++++++++++++++++++++++++++++++++++
199510.000 ++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
1996 9.694 ++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
1997 5.057 ++++++++++++++++++++++++++++++++++
1998 4.838 +++++++++++++++++++++++++++++++++
1999 5.798 +++++++++++++++++++++++++++++++++++++++
2000 2.528 +++++++++++++++++
2001 2.163 +++++++++++++++
2002 2.130 ++++++++++++++
2003 1.590 +++++++++++
2004 1.026 +++++++
2005 1.550 +++++++++++
2006 0.413 +++
```

## Apollo Run Simulator

The simulator documentation is now maintained separately by Eric Michelsen.

## Data Reduction Anomalies

```
From: Tom Murphy [mailto:tmurphy@physics.ucsd.edu]
Sent: Sunday, June 03, 2007 17:50
To: Michelsen Eric; Battat James
Cc: Hoyle C.D.
Subject: data reduction anomalies
```

In reducing the last month of data today, I have the following notes:

1) After 070522, the first GPS trigger time nicely corresponds to the first fiducial (shot 1, not the first shot = -1 fid). This is very nice: saves pesky hand-editing!

2) As expected, the new feature for getting the GPS DAC stats mid-run (which is important and good) results in some missed fids. They look like laser dropouts (1 fid missing):

```
missing 1 fids, prior to shot 383
missing 1 fids, prior to shot 583
missing 1 fids, prior to shot 783
missing 1 fids, prior to shot 983
missing 1 fids, prior to shot 1384
```

But the pattern is obvious: every 200 shots one fid goes missing.

3) A new problem crops up on occasion. Don't know what to make of it yet, but it's always at the very end of a run.

```
******** WARNING *************
Number of dTWS-dFRC errors detected: 4
TWS-FRC Error: at shot 14997: 2*dfrc, dtws, twsfrcerr =
 266627604, 3498516, 63129088
TWS-FRC Error: at shot 14998: 2*dfrc, dtws, twsfrcerr =
 266627610, 3498522, 63129088
TWS-FRC Error: at shot 14999: 2*dfrc, dtws, twsfrcerr =
 266627616, 3498528, 63129088
TWS-FRC Error: at shot 15000: 2*dfrc, dtws, twsfrcerr =
 266627622, 3498534, 63129088
******************************
```

4) A weird problem prevented one of the run files from being processed by the analysis software. It turns out that the gps0 record after fid shot 2202 in 070529-062657.run had an extra (^A) character in the DOY:

```
gps0 gpstrig="^A149:06:28:49.00677"; cpserr=0
```

Don't know where this came from, but it messed things up. This could be a one-time error.

## Solar System Model for LLR

Around 6/21/2007, James G. Williams wrote:

Dear Sergei

Our LLR formulation and code predates the IERS Conventions, but chapter 11 of the 2003 Conventions appears to be compatible and is attached.

In our computer program which calculates the model time delay, the computation of the time delay is done in solar system barycentric (SSB) coordinates and then times are transformed to the ranging station. This is convenient because the integration of the ephemeris is in the SSB frame and we can avoid moving and accelerating coordinate frames for the positions of the centers of solar system bodies.

To the SSB radius vector from the center of the earth to the center of the moon, we add the vector from the center of the moon to the retroreflector and subtract the vector from the center of earth to the ranging station. While the radius of the station is constant in the geocentric frame, and similarly the moon centered retroreflector radius is constant, those radius vectors have to be transformed for the motion of the earth and moon. For the Lorentz contraction we use -(R.V)V/2c^2 where R is the body centered station or retroreflector vector and V is the earth or moon velocity vector with respect to the SSB. So that correction amounts to about 3 cm for the earth and 1/4 that for the moon. We also apply a scale correction to the earth and moon centered radii which depends on the potential/c^2.

After we get the distance between the ranging station and retroreflector, we divide by c. There is both an up leg and down leg to the computation. We start at transmit time, go up to the moon, and come back down to receive. To start, we have to transform the transmit time from station to TDB. After getting the range in the SSB frame, the gravitational time delays are added in and then we transform the SSB receive time back to the station time. Then the model time delay is compared to the observed time delay for the fit.

We had a publication on LLR relativistic computation in a proceedings many years ago, but that was so long ago that I don't think that I have a copy handy. Skip Newhall prepared it and he has left.

## Atmospheric Effects

From James Battat, 10/18/2007:
http://www.cfa.harvard.edu/~jbattat/apollo/docs/atmosphere/atmosphericModels.ps

Comparison of the old Marini-Murray model (1973) with the new Mendes-Pavlis et al. model (2002, 2004). Executive summary:

- zenith delays agree at the mm level for a typical APO atmosphere
- Above 40 degrees elevation, the total delay agrees to within 2 mm.
- Of this difference, <0.6 mm is attributable to the mapping function
- Over typical APO atmospheric pressures, the zenith delay differences range from 0.95 to 1.01 mm.

## JPL Solutions and Fits

```
From: James Battat
Sent: Wednesday, November 14, 2007 11:32
To: James G. Williams
Cc: Nicolas Rambaux; Dale Boggs; APOLLO Core; Slava Turyshev
Subject: question on reported uncertainties
```

Your recent gravitational physics solutions have prompted the following questions. Hopefully you can shed some light on these for me:

* Are these parameters the result of an iterative solution or a single linear least-squares-based adjustment?

* Are the reported uncertainties simply the 1-sigma standard errors reported by the least-squares solution, or are they scaled by some factor?

* The N-dimentional error hyper-ellipsoid for the N fit parameters (and lower dimensional projections) can be constructed from the covariance matrix. It seems that a 1-d parameter constraint (central value and uncertainty) implicitly assumes some "prior" knowledge on the other parameters. Are the uncertainties simply the square root of the diagonal elements of the covariance matrix, or are the off-diagonal (covariance) terms involved somehow?

* How does one verify the linear-regime approximation and ensure that one is not falling into a local minima? In your opinion, would there be a benefit to computing residuals and chi-squares on a sensibly chosen grid of parameter values to identify optimal parameter values?

James Battat

# 6 Observing Notes

## Choosing Reflectors

From: Tom Murphy
Sent: Monday, November 05, 2007 9:50
To: APOLLO Core
Subject: reflector procedures

Fantastic news on the Lunokhod record run! As we get to know its performance better, we should establish some guidelines on what reflectors to observe and when, based on conditions and performance on a given night. We consistently see Apollo 15 about 3 times better than Apollo 11/14 (with variability, of course). This morning L2 was 18% the Apollo 15 rate, suggesting about a factor of two lower than A11/A14. Previous work on L2 indicated a return about 1/4 of the A11/A14 rate. The tighter return beam makes this more sensitive to libration, which may play a role in our observed differences--though this could also be ordinary variation and small number statistics.

We tend to be able to find signals if they have peak performances during the run of around 0.05 photons per pulse or so. Therefore if A15 (which we always do first) exceeds 0.15, we are likely to find A11/A14. Since it is easier to find a second reflector having acquired the first, we can perhaps reduce our threshold a bit to 0.12: If A15 exceeds 0.12, we have the green light to search for others. For L2, let's use the more generous assumption (for now) that it is twice as bad as A11/14 if it's in the dark, so A15 must be > 0.25, OR A11/14 over about 0.1. After that we try to fill in a uniform sampling of the smaller reflectors: roughly equal A11/14, and L2 whenever we can get it. This rationale would put priority on L2 over A11/14 when conditions are favorable to acquire it. This is effectively what happened this morning: good A15 signal; L2 in dark; time for one run only; L2 gets the time.

When possible, it is good to get another A15 run at the end to help nail down earth orientation. The longer the baseline the better.

On crummy nights when we barely hold on to A15, we get something useful out of a sequence of many measurements on A15: it lets us check our data scatter and make sure it is consistent with estimated error.

On superb nights when we get strong signal on all viable reflectors, the remaining time can be usefully spent on A15, which accomplishes several goals: earth orientation determination; additional runs to look at scatter (this time in strong signal regime); beam profile exploration. For the last, this is an opportunity to both peak the RX and map out the beam footprint on the moon, establishing FWHM of our beam. For this, with return centered on APD, move any RX axis off about 1 arcsec and spend 30 seconds or so at positions separated by 0.25 arcsec, moving through center. On these very good nights, it becomes important to know our beam so we can continue to get at reflector health issues.

It also seems from last night like we may need to routinely enlarge our pointing raster when reference craters are far away on the limb.

## TUI Controls

The “beam offset” buttons on TUI issue ‘`vmove`’ or ‘`rxx`’/’`rxy`’ commands, and then compensating telescope motions, to effect the equivalent of moving the return beam without (significantly) changing the pointing.

### *TUI Slowness*

From: Tom Murphy
Sent: Monday, November 05, 2007 10:03
To: Battat James; Michelsen Eric; Hoyle C.D.; Russet McMillan
Cc: Murphy Tom; fstauffer@apo.nmsu.edu
Subject: CPU vs. internet

I want to collectively put together experiences that tell us whether our TUI lag problems are CPU or internet. Please contribute your relevant experiences, adding to this thread. The ultimate result will be an e-mail chain that has a jumbled collection of observations we can then synthesize. I suspect Eric has the most quantitative information.

prepend each with what you think this clue points to:

```
[CPU] : CPU's fault
[net] : network slowness fault
[CPU & net] : both at fault
[CPU | net] : either, favoring CPU as explanation
[net | CPU] : either, favoring network
[?] : seems relevant, but don't know who to blame
```

My observations:

[net | CPU] : variable phenomenon sometimes no lag; sometimes 10%; sometimes worse

[CPU] : TUI text update slow; Hippodraw more up to speed; redraw of TUI after changing tabs very slow

[CPU] : lag performance unchanged based on whether streaming video is n; the stream should take more bandwidth than fids/luns; video does not lag/stall

[CPU | net] : when lagging, outbound messages immediate, echo and incoming messages delayed according to lag

From James:

[CPU | net] APOLLO TUI text lags behind hippodraw plots. The Fiducial Record number text grows by about 10 counts per second.

[CPU] I also notice that GUI update in APOLLO window is very slow during runs. If I click on the TUI task bar and drag it around, it seems to force the GUI update to be a priority and I get a redraw. When I release the task bar, the updates often stop (e.g. Fiducial Number is unchanged).

[CPU] VLC stream is up-to-date even when TUI is not (as Tom mentioned above)

[CPU | net] I have horrible delays whether working at home or from the much faster network on campus.

[CPU | net] : unlike Tom's comment above, I find that when lagging, interaction with the Message GUI is also delayed. Typed words do not appear locally for some time, and then after I send a string to Message, it does not appear in the transcript for quite some time. At the end of the run, I get a stream of queued messages that dump out all at once.

[CPU] A look at my WinXP system monitor shows that TUI consistently consumes 99% of the CPU during runs.

[?] On Saturday morning, my TUI updates lagged behind reality by 10-15 minutes, but the messages lagged less. In other words, there was a relative lag between the Message tool and the APOLLO TUI.

[?] It is essentially impossible for me to watch the APOLLO TUI windows and be able to communicate via Message simultaneously. I now log into TUI but do not "Listen" on the APOLLO stream. At least this way I can message with Russet in real-time. I can also view the video stream.

[?] Computer specs for the laptop that I use to watch observations: 1.5 GHz Pentium M, 512MB RAM, WinXP

[?] How difficult would it be to try sending data less often to TUI? e.g. 5 Hz instead of 20 Hz?

From CD: My observations:

[CPU:net] My laptop (same specs as James') has horrible lags from home, I have not tried it on the fast campus network

[CPU:net] Very little lag on campus (2 GHz, 2 GB RAM), but any lags I do see are similar to those mentioned by Tom

[?] I would like to try my laptop from campus next lunation to compare

From Russett:

[CPU] My laptop (Macintel, 2Ghz, 1GB RAM, running TUI under Parallels) could not keep up while running on NMSU campus. Have not yet tried under BootCamp, nor this laptop at APO. APOLLO laptop keeps up fine from NMSU campus.

[CPU] Similar symptoms that others have mentioned, but I would see the stats in the TUI window (e.g. number of fids) jump suddenly instead of maintaining a regular update rate.

[CPU & net] Lag gets worse for longer runs; some eavesdroppers can catch up between short runs, but fall further behind for runs >5K.

## Laser Operations

```
From: Tom Murphy [mailto:tmurphy@physics.ucsd.edu]
Sent: Saturday, November 07, 2009 10:31
To: Russet McMillan
Cc: Michelsen Eric; Gasaway Tom
Subject: Re: [Apollo_core] good signal between clouds
```

[lasercal, like run, fidlun, relies] on the laser to lase, so the shutter has to be open. I think we've never automated this, because we want a human to think about whether we should be letting the laser go. For lasercal, it is important to note that the laser will come out of the scope if: 1) the interlock shutter is open; 2) the eyelid/[tertiary mirror] is configured; 3) the TR is in dark position; 4) amp delay digipot in high power mode. Defeating any of these four will prevent danger to people or airplanes. Usually RUN leaves TR clear, so this is protection enough. But be careful all the same...

### *Laser Adjustment*

```
From: Russet McMillan
Sent: Sunday, October 08, 2006 1:24
To: apollo_core@u.washington.edu
Subject: [Apollo_core] bad weather
```

... The oscillator threshold was just a little lower tonight (1640), so we were able to operate at 1680 V. Still not as stable as advertised, though.

... I also noticed (Tom said this isn't new) that the peak power came from different SHG positions when the telescope was at different altitudes. This maybe means the SHG should be peaked up at an altitude similar to the one we'll be observing at.

## RX Beam Optimization

```
From: Tom Murphy
Sent: Friday, October 19, 2007 17:17
To: Eric Michelsen; James Battat; C.D. Hoyle
Cc: Russet McMillan; Tom Murphy
Subject: RX beam optimization
```

I want to lobby for efforts to optimize the RX positioning as soon as conditions are favorable. (Last night wasn't so good for this).

Getting the RX offset is as important as pointing the telescope right in terms of getting good signal. We have now two methods for setting the origin: the TR clear method with approximately-compensated offset to account for TR wobble; and the TR dark method looking at the (faintly visible, high background) central lobe and 6-lobe pattern. The latter at least has no TR wobble offset, but visibility (centroiding by eye) is worse.

I can imagine each of these methods having 0.5 (or even 1.0) arcsec errors: the TR clear via not *really* knowing where the offset spot should be (have often had confusing disagreements between in-dome determination and moon-optimized position); the TR dark method due to confusing and less visible pattern. Both rely on knowing exactly the APD position on the STV.

So they should both be considered approximate and the real story needs to come from on-moon performance in stable seeing conditions. It is possible that the reason we didn't get signal on 10/4 in good seeing conditions was this RX offset business. Good seeing makes this offset more critical. It has not been adequately moon-optimized since summer shutdown was over--and I don't think we've got it dialed in yet.

It can be burdensome to mess with RX, but we must do so to get our system in shape. Part of the burden is the imperfectly compensated hysteresis of the RX motion (open loop--leads to walk), part is the 3 second hiatus of lun data, part is that the telescope pointing may drift during the exercise and confuse the result.

The better and more stable the seeing, the more productive the tuning will be. Ideally, one finds the signal first, optimizes telescope pointing, then commences RX beam moves (which moves scope, compensating with RX to keep the APD pointing the same). The faster the better too, in my opinion: telescope has less chance to drift, and looking for big changes:

imagine a BIG signal sitting out there if you just run across the right parameters (my ever-present wishful thinking). Natural fluctuations and drifts *do* complicate this picture, though.

I have on occasion seen us actually *find* the signal via RX moves when pointing rasters fail. So if good seeing and no signal, try this.

Here's the way I'd like to try it: If you ever get a good signal, the APD hitgrid is meaningful (> 0.2 photons/shot, let's say). Also in this case it's clear that the beam is hitting the reflector. See if you sense an offset in the APD hitgrid, and use RX Optics offsets in the APD reference frame (TUI selections) to KEEP THE BEAM where it is (not moving telescope), but adjust the RX mirror to better center signal on APD. Once this is good, you may swith to RX Beam offset to keep the APD where it is while sweeping the beam around.

Probably 0.5 arcsec RX beam moves are most productive for roughing in. 0.25 only after you've located the optimal spot via 0.5.

It would be useful once we trust the on-moon optimization to re-check the positions of the fiducial pattern in both TR dark and TR clear modes. To the extent we can calibrate these, the easier things become in the future. But as always, both STV methods rely on precise understanding of the APD position.