The Status of Astronomical Control Systems

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OVRO

Astronomical Control System Status

- 10 years ago radio control systems were much more sophisticated than optical. Why?
  - Single pixel detectors (but some baselines)
  - Electrical engineering heritage
- Optical systems now have the lead
  - Sloan Digital Sky Survey
  - VLT
  - Gemini
- Our product is images (stacks of them)
- Astronomers are our consumers

The Future

- Where is the Barry Clark for the MMA?
  - He's now an undergrad who has:
    - Played Ninetendo, Quake, & Doom ad infinitem
    - Always had 50 channels of cable and a VCR
    - Had a personal web site since high school
  - When she is a new postdoc being shown the control system for the $400M MMA, what will she think???
- Today's students have grown up with a visual environment radically different than previous generations

Our Charge

- What used to be our private technology is now in the family room of middle America!
- Expectations about what a control system can do and how it interacts with humans are rapidly changing
- The migration of computer technology and the Internet into everyday life and the advances in optical astronomical control systems has raised the bar for our systems

Implications

- Staffing levels will need to be increased
- Developers will need to learn to work as part of larger teams
- More code reuse needed to increase efficiency

Java Realtime Monitoring Windows for the Caltech Millimeter Array

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The Monitoring Problem

- Realtime and archive aspects (separable)
- Quantity of monitor points and data
- Sampling rate
- Reatime feedback for control
- Satisfy operator/astronomer/engineer
- Availability (computer platform, location)
- Monitoring can dominate the monitor/control user interface design

Realtime Monitoring Wish List

- Easy to create operator screens
- Fault notification
- Variable sample rate
- Plot time series
- Visualize correlations
- Hard copy
- Data capture to file
- Cross platform

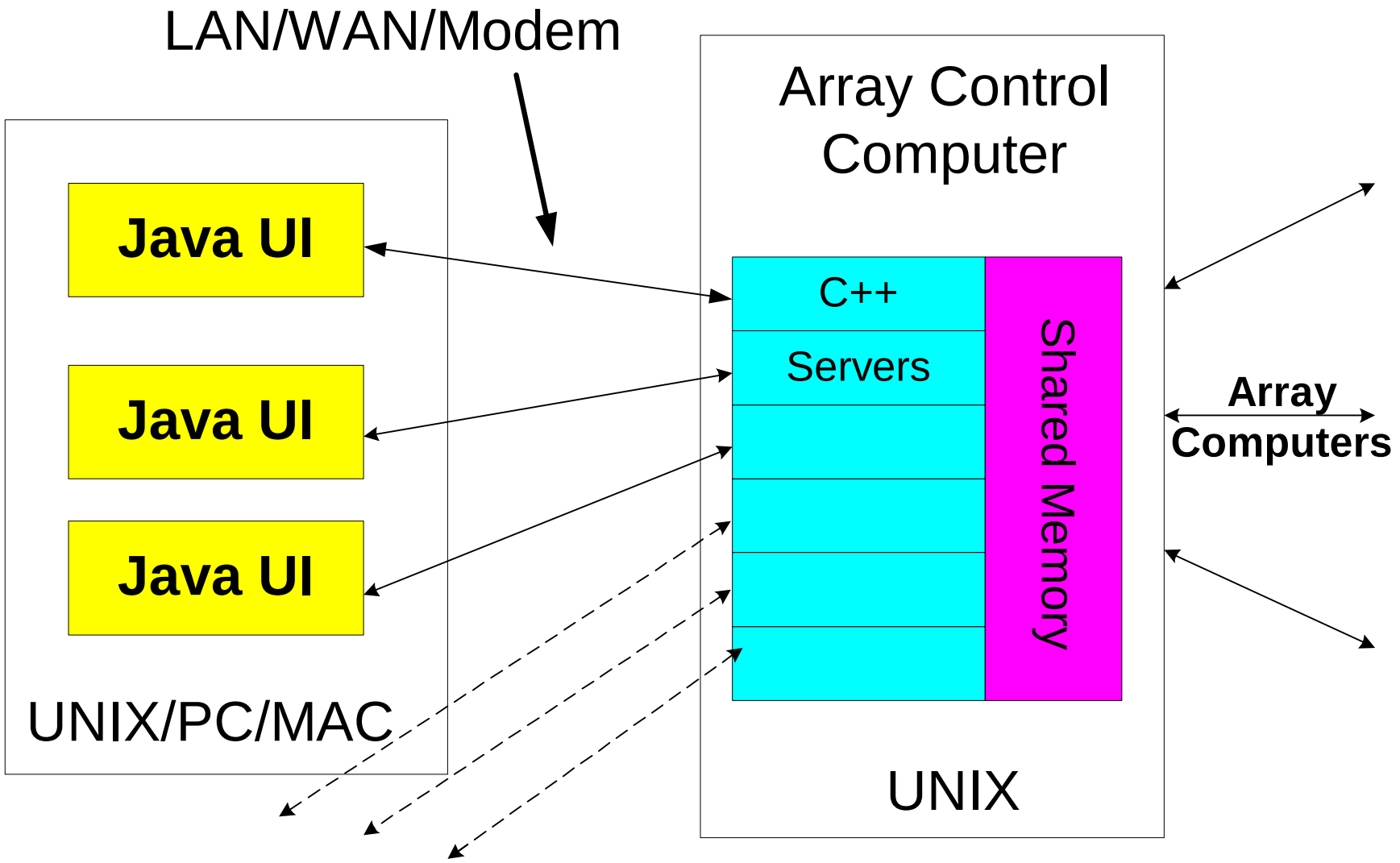
Caltech Millimeter Wave Array

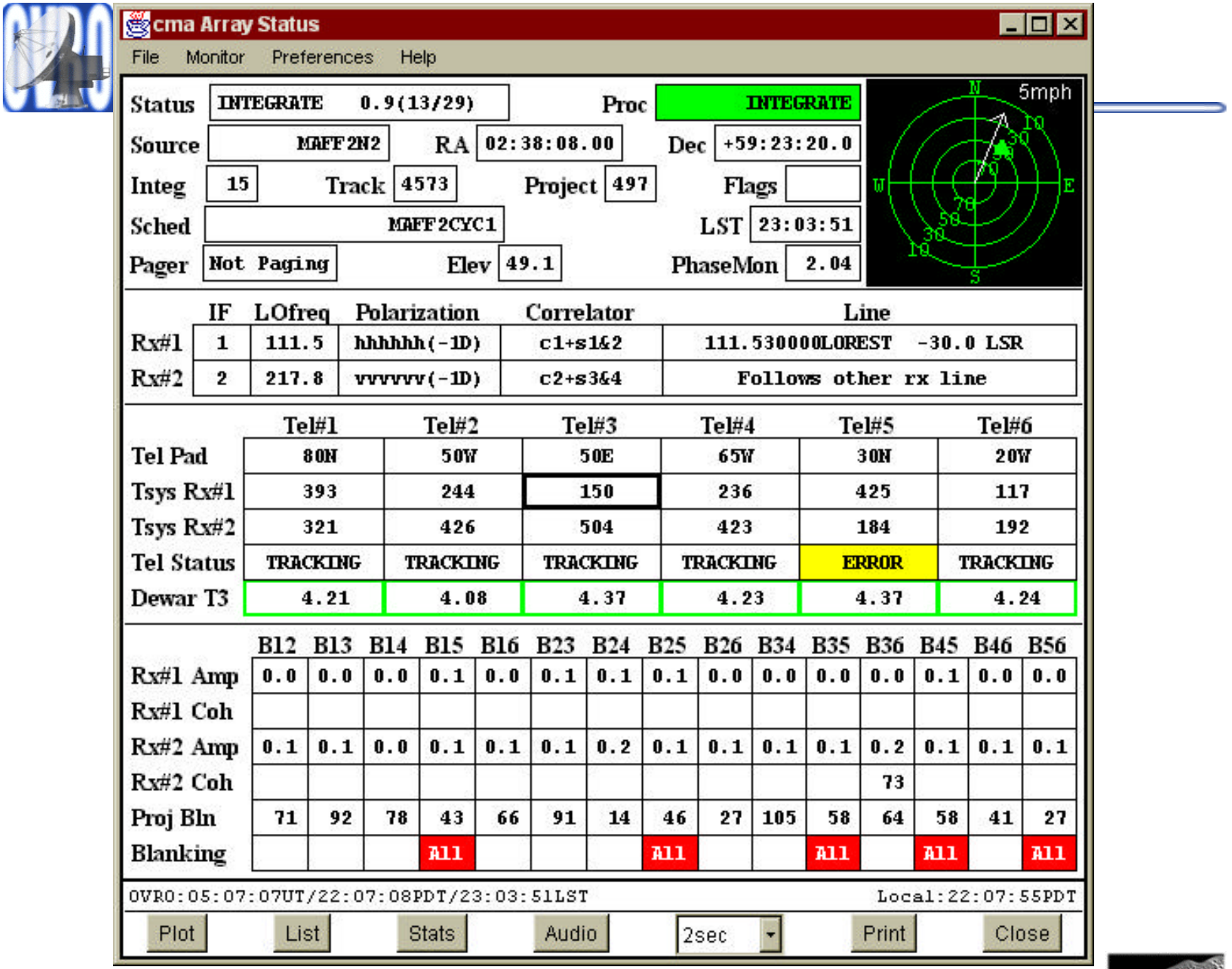
- 6 telescopes, 10 meters in diameter
  - Simultaneous dual receivers (1mm & 3mm)
  - 4GHz IF bandwidth
  - 2x1GHz continuum correlator
  - 4 band 512MHz digital correlator
- No operators - postdocs/faculty/students
- Developers are onsite

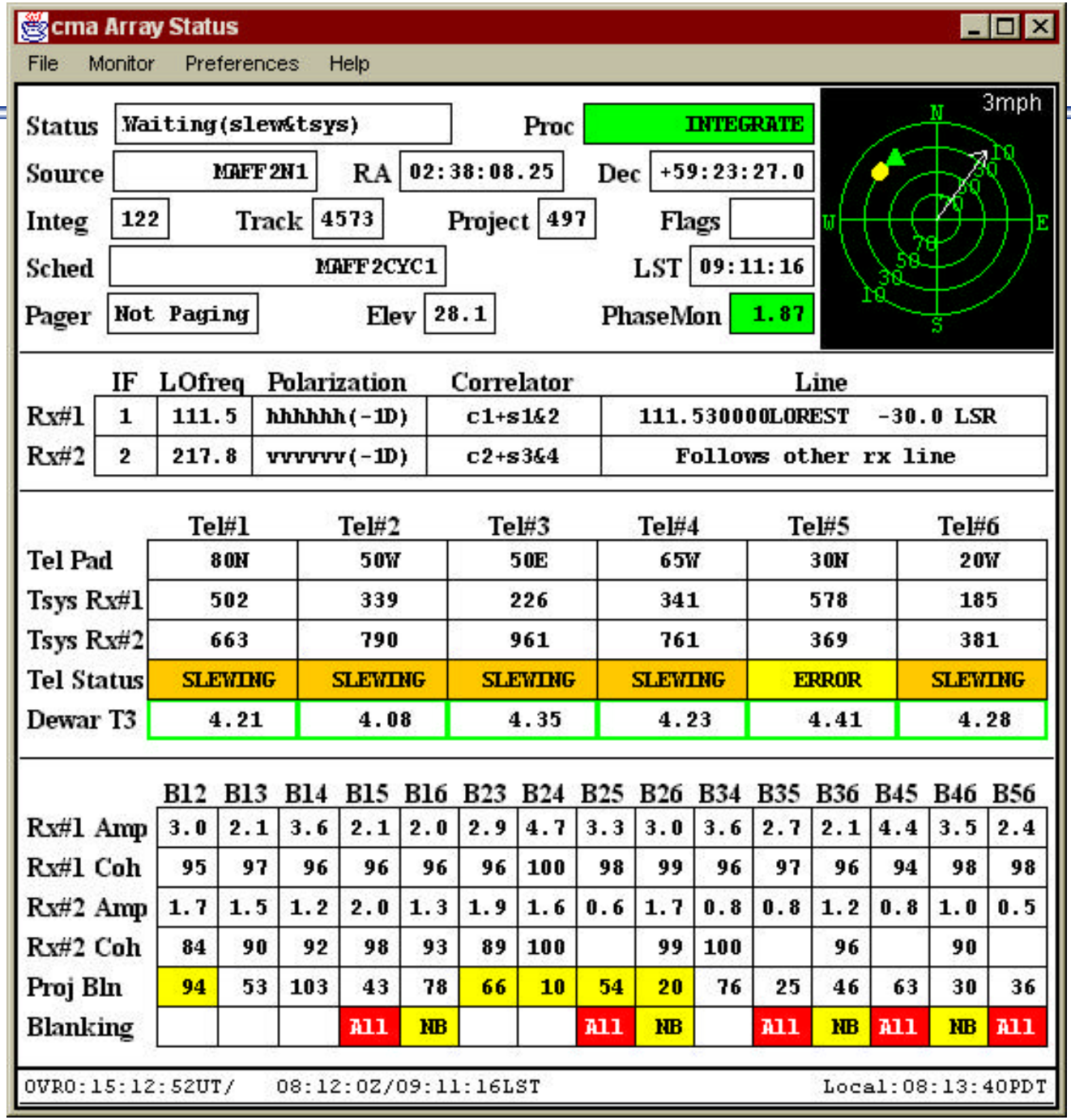
OVRO Monitoring Requirements

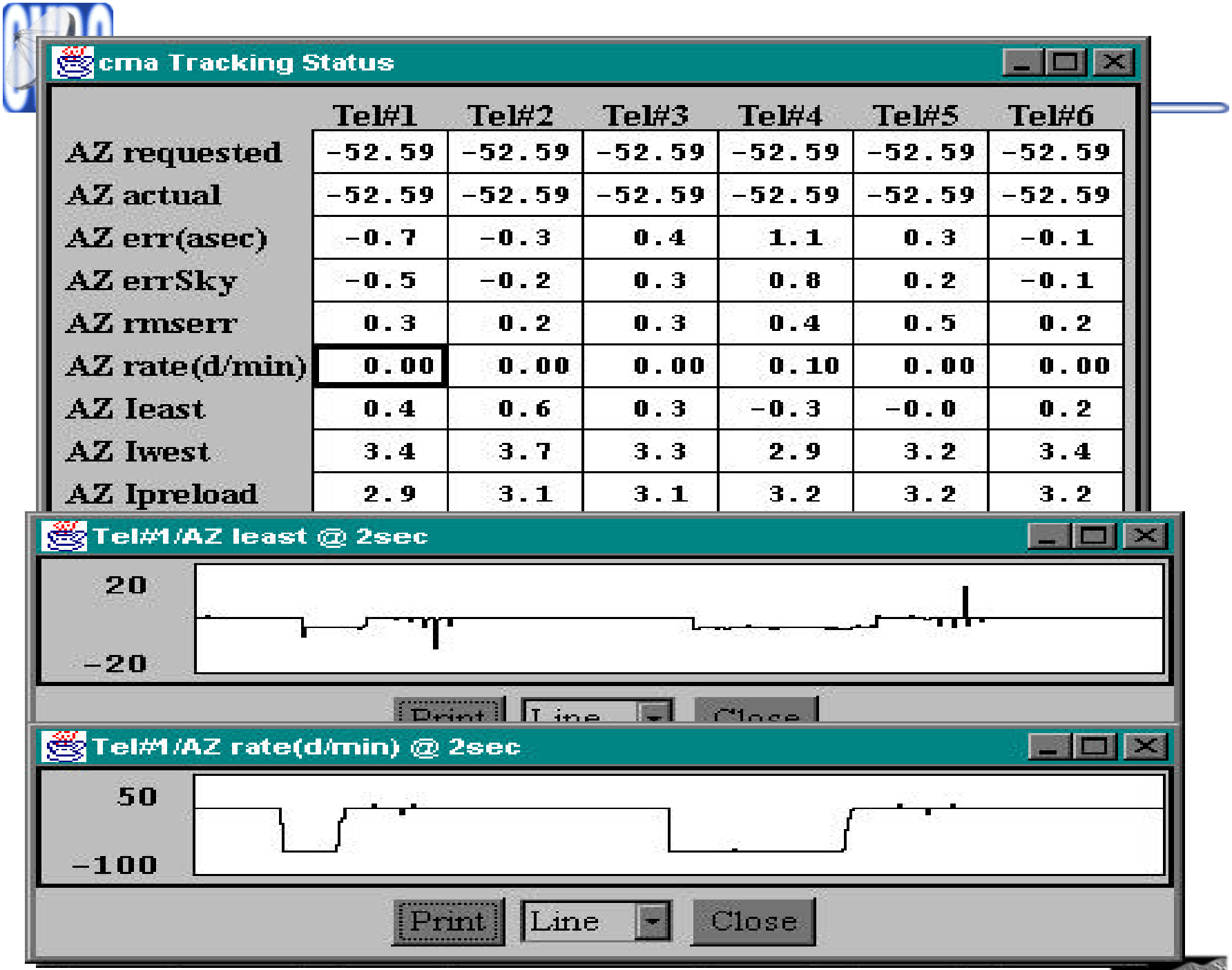
- User Interface
  - Color, audio, and plotting capabilities
  - Parallel access - many simultaneous users
  - Multiple platforms: Solaris, Win32, Mac, OS/2
  - Low bandwidth - run over modem
  - Control integrated with monitoring
  - Security for control
- Simple system
  - Modest computing hardware requirements
  - Limited programming resources

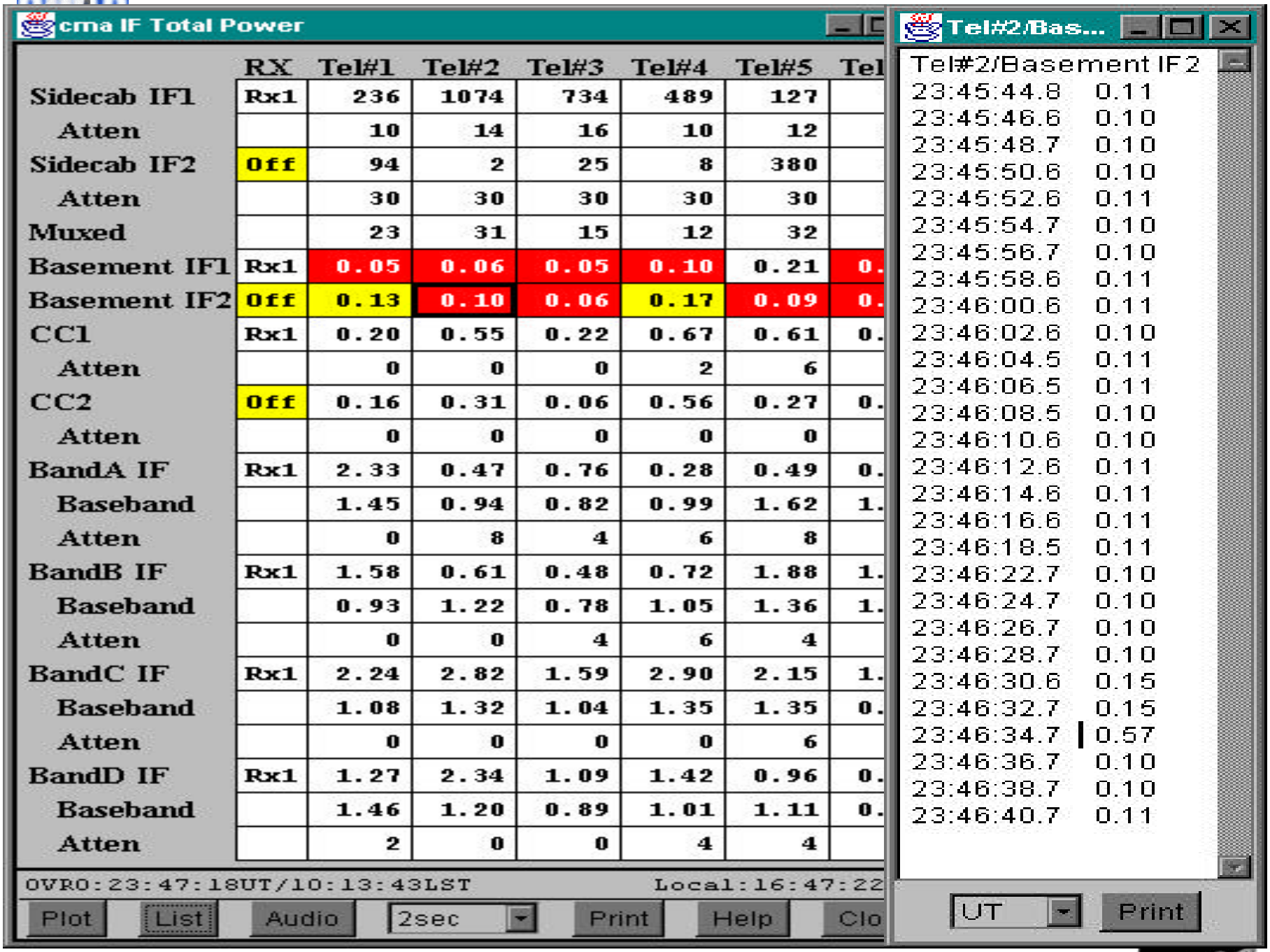
Realtime Monitoring Architecture

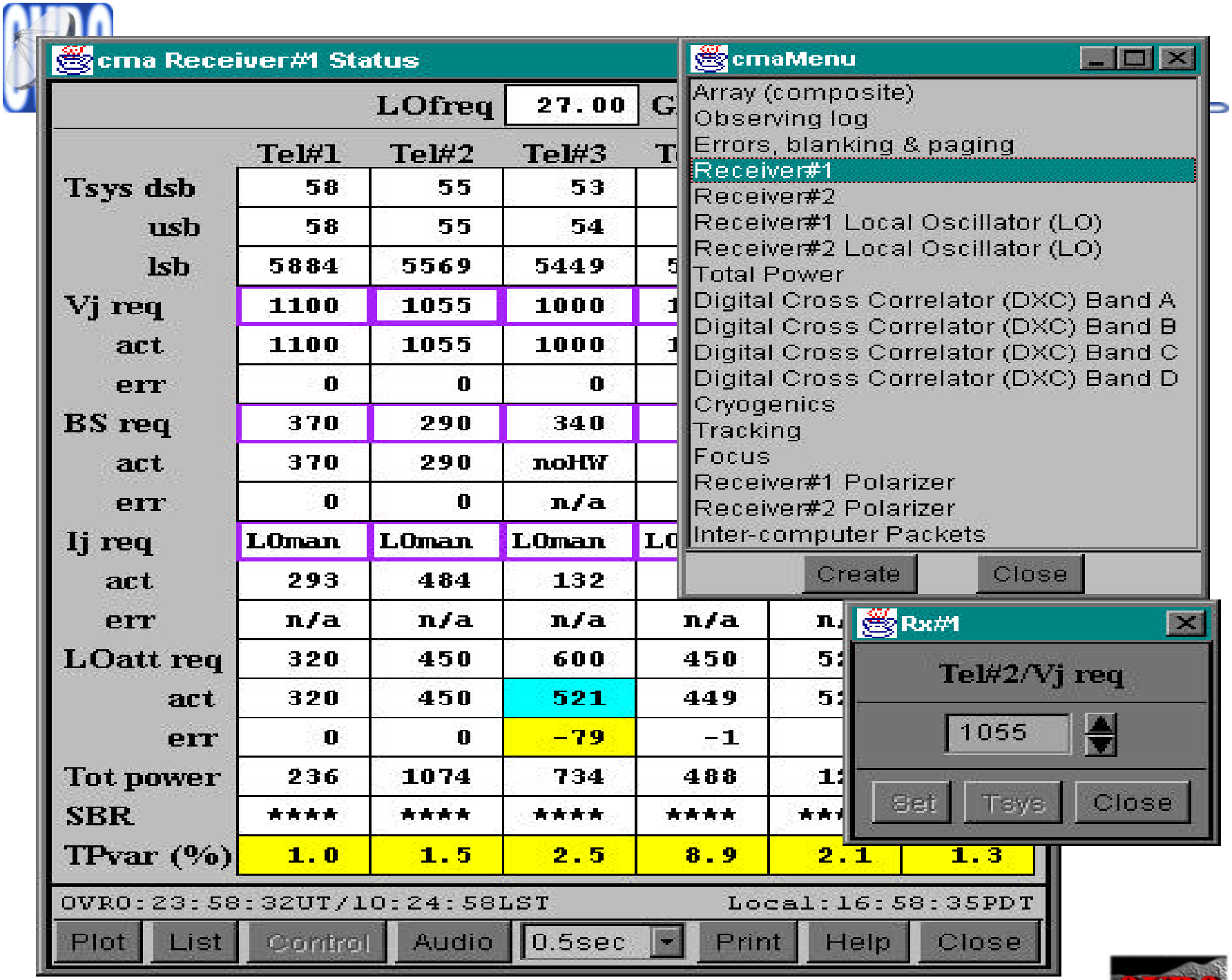


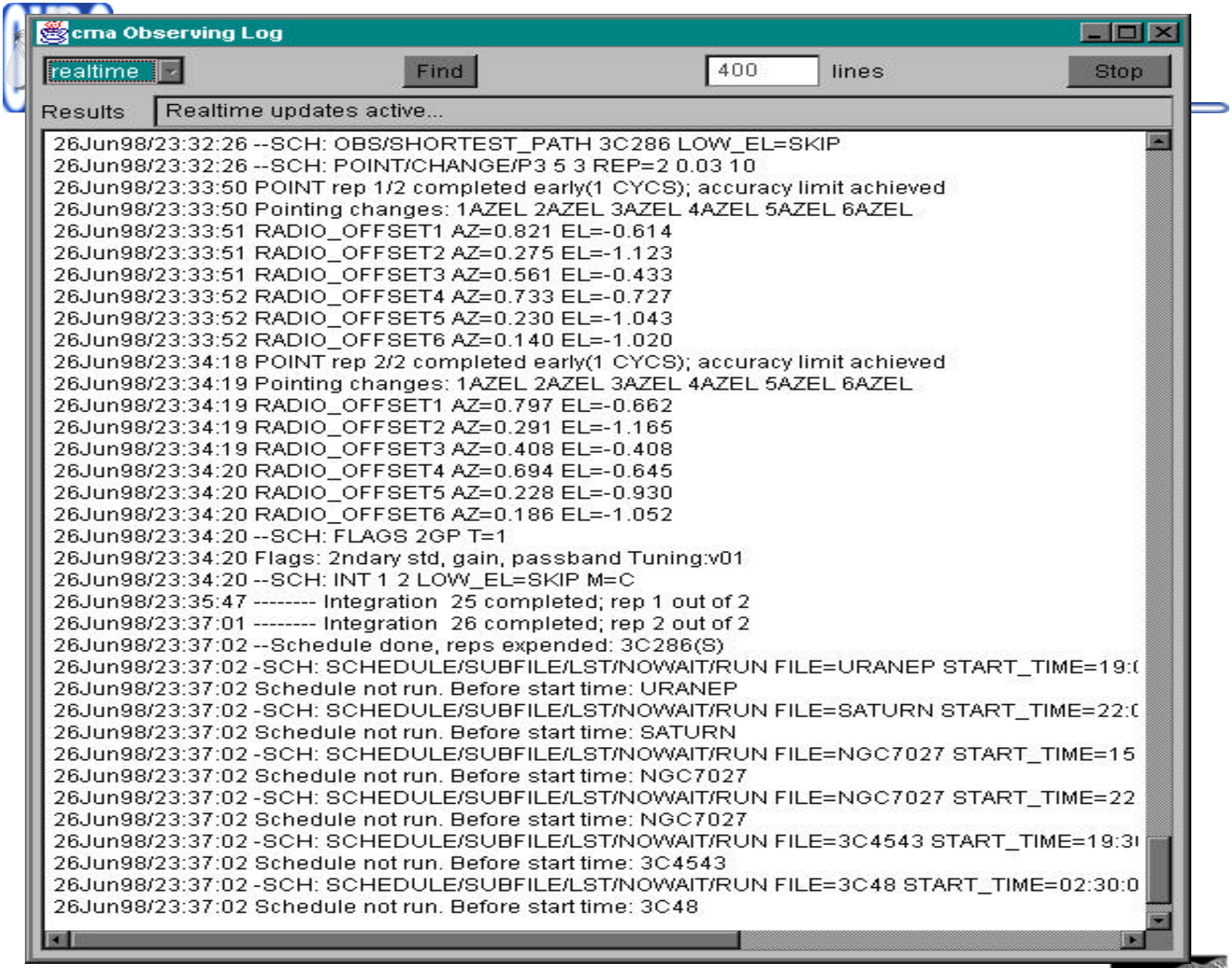

cma Array Status
File Monitor Preferences Help
Status INTEGRATE 0.9(13/29)
Proc INTEGRATE
Source MAFF2N2
RA 02:38:08.00
Dec +59:23:20.0
Integ 15
Track 4573
Project 497
Flags
Sched MAFF2CYC1
LST 23:03:51
Pager Not Paging
Elev 49.1
PhaseMon 2.04
5mph
N
E
S
W
IF LOfreq Polarization Correlator Line
Rx#1 1 111.5 hhhhhh(-1D) c1+s1&2 111.530000LOREST -30.0 LSR
Rx#2 2 217.8 vvvvvv(-1D) c2+s3&4 Follows other rx line
Tel#1 Tel#2 Tel#3 Tel#4 Tel#5 Tel#6
Tel Pad 80N 50W 50E 65W 30N 20W
Tsys Rx#1 393 244 150 236 425 117
Tsys Rx#2 321 426 504 423 184 192
Tel Status TRACKING TRACKING TRACKING TRACKING ERROR TRACKING
Dewar T3 4.21 4.08 4.37 4.23 4.37 4.24
B12 B13 B14 B15 B16 B23 B24 B25 B26 B34 B35 B36 B45 B46 B56
Rx#1 Amp 0.0 0.0 0.0 0.1 0.0 0.1 0.1 0.1 0.0 0.0 0.0 0.0 0.1 0.0 0.0
Rx#1 Coh
Rx#2 Amp 0.1 0.1 0.0 0.1 0.1 0.1 0.2 0.1 0.1 0.1 0.1 0.2 0.1 0.1 0.1
Rx#2 Coh 73
Proj Bln 71 92 78 43 66 91 14 46 27 105 58 64 58 41 27
Blanking All All All All All
OVRO:05:07:07UT/22:07:08PDT/23:03:51LST
Local:22:07:55PDT
Plot List Stats Audio 2sec Print Close

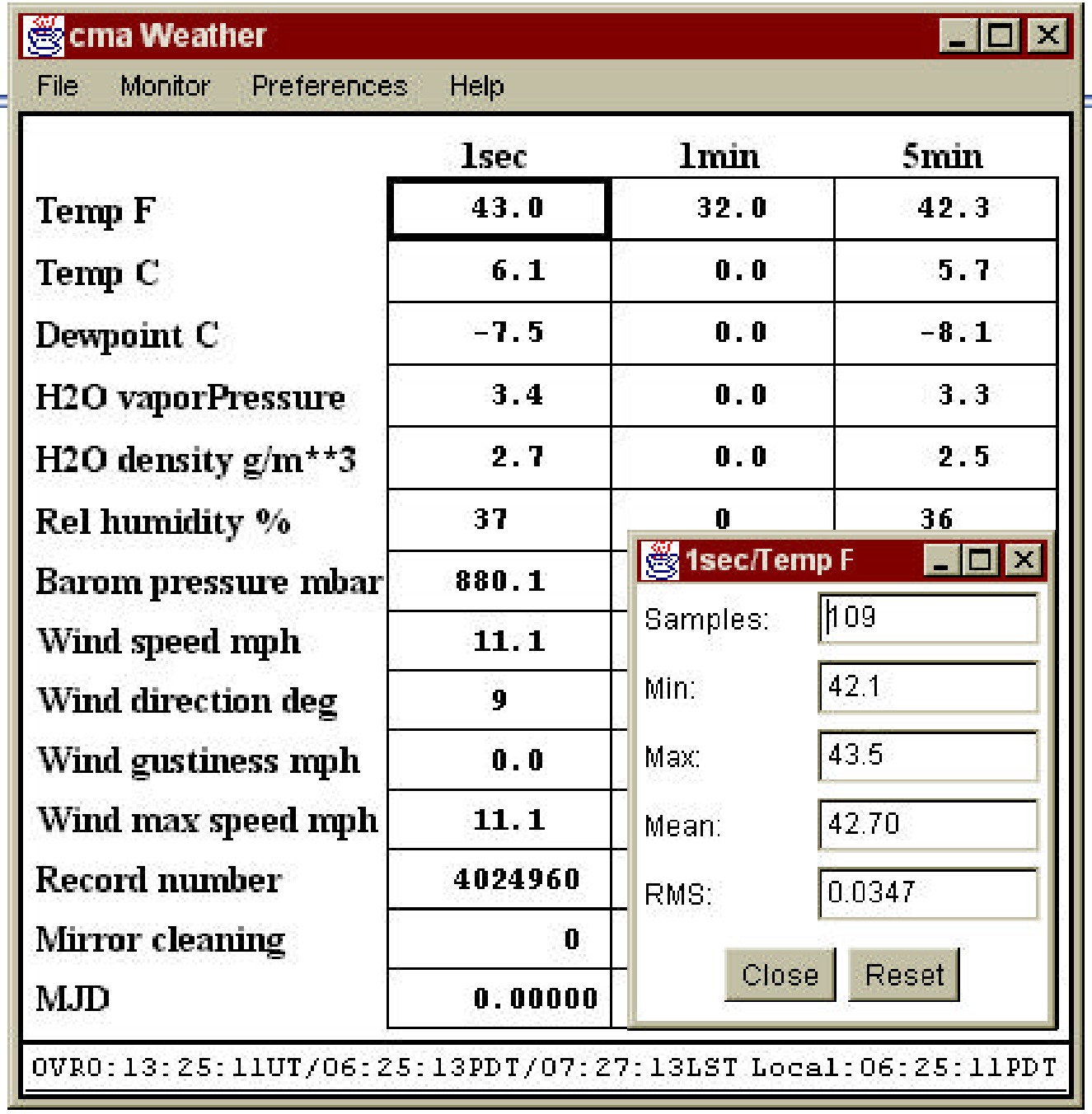

cma Array Status
File Monitor Preferences Help
Status Waiting(slew&tsys)
Proc INTEGRATE
Source MAFF2N1
RA 02:38:08.25
Dec +59:23:27.0
Integ 122
Track 4573
Project 497
Flags
Sched MAFF2CYC1
LST 09:11:16
Pager Not Paging
Elev 28.1
PhaseMon 1.87
3mph
N
W
E
S
10
30
50
70
90
IF LOfreq Polarization Correlator Line
Rx#1 1 111.5 hhhhhh(-1D) c1+s1&2 111.530000LOREST -30.0 LSR
Rx#2 2 217.8 vvvvvv(-1D) c2+s3&4 Follows other rx line
Tel#1 Tel#2 Tel#3 Tel#4 Tel#5 Tel#6
Tel Pad 80N 50W 50E 65W 30N 20W
Tsys Rx#1 502 339 226 341 578 185
Tsys Rx#2 663 790 961 761 369 381
Tel Status SLEWING SLEWING SLEWING SLEWING ERROR SLEWING
Dewar T3 4.21 4.08 4.35 4.23 4.41 4.28
B12 B13 B14 B15 B16 B23 B24 B25 B26 B34 B35 B36 B45 B46 B56
Rx#1 Amp 3.0 2.1 3.6 2.1 2.0 2.9 4.7 3.3 3.0 3.6 2.7 2.1 4.4 3.5 2.4
Rx#1 Coh 95 97 96 96 96 96 100 98 99 96 97 96 94 98 98
Rx#2 Amp 1.7 1.5 1.2 2.0 1.3 1.9 1.6 0.6 1.7 0.8 0.8 1.2 0.8 1.0 0.5
Rx#2 Coh 84 90 92 98 93 89 100 99 100 96 90
Proj Bln 94 53 103 43 78 66 10 54 20 76 25 46 63 30 36
Blanking All NB All NB All NB All NB All NB All
OVRO:15:12:52UT/ 08:12:0Z/09:11:16LST Local:08:13:40PDT

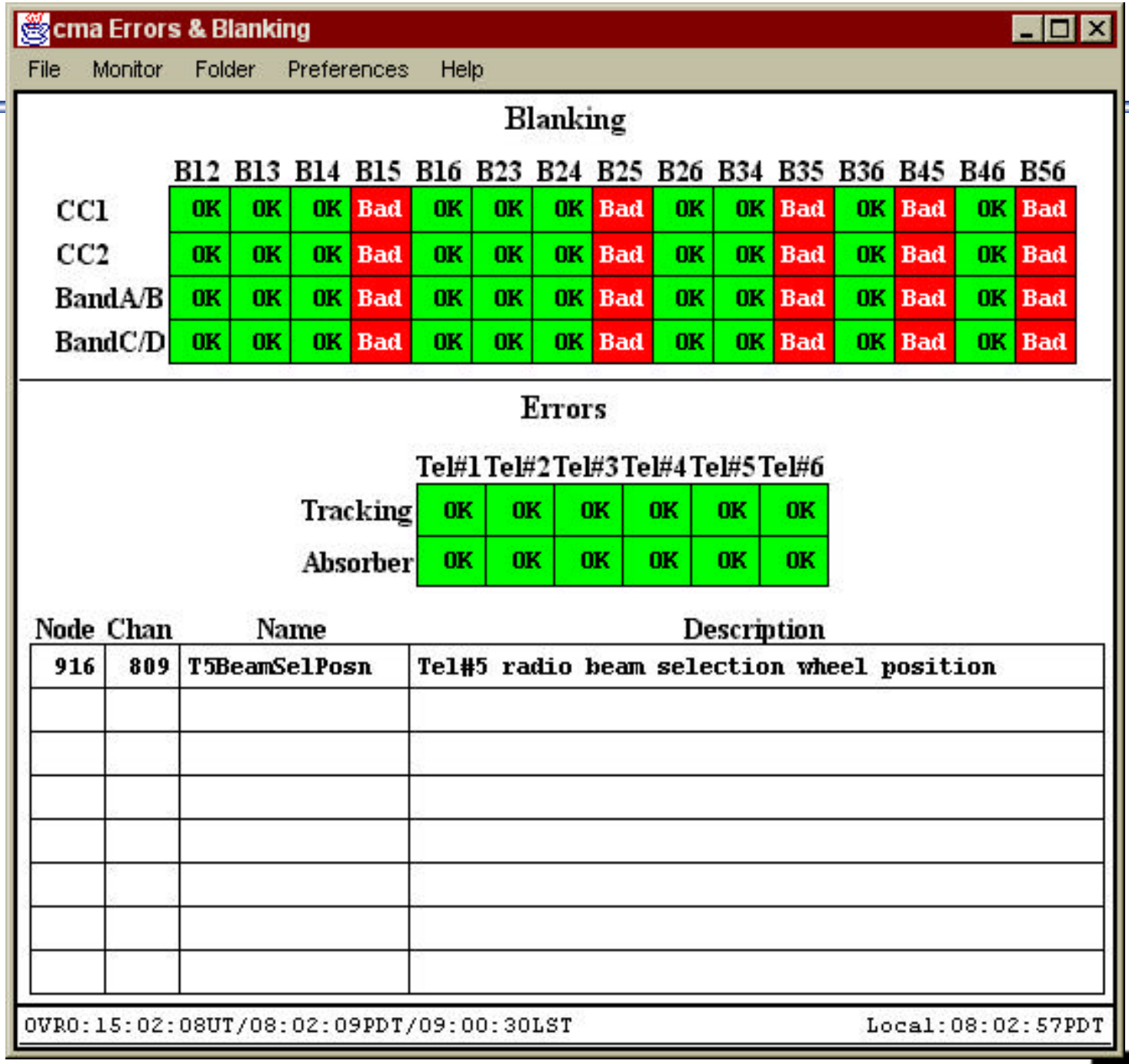

cma Tracking Status
Tel#1 Tel#2 Tel#3 Tel#4 Tel#5 Tel#6
AZ requested -52.59 -52.59 -52.59 -52.59 -52.59 -52.59
AZ actual -52.59 -52.59 -52.59 -52.59 -52.59 -52.59
AZ err(asec) -0.7 -0.3 0.4 1.1 0.3 -0.1
AZ errSky -0.5 -0.2 0.3 0.8 0.2 -0.1
AZ rmserr 0.3 0.2 0.3 0.4 0.5 0.2
AZ rate(d/min) 0.00 0.00 0.00 0.10 0.00 0.00
AZ least 0.4 0.6 0.3 -0.3 -0.0 0.2
AZ lwest 3.4 3.7 3.3 2.9 3.2 3.4
AZ lpreload 2.9 3.1 3.1 3.2 3.2 3.2
Tel#1/AZ least @ 2sec
20
-20
Tel#1/AZ rate(d/min) @ 2sec
50
-100
Print
Line
Close


cma IF Total Power
RX Tel#1 Tel#2 Tel#3 Tel#4 Tel#5 Tel
Sidecab IF1 Rx1 236 1074 734 489 127
Atten 10 14 16 10 12
Sidecab IF2 Off 94 2 25 8 380
Atten 30 30 30 30 30
Muxed 23 31 15 12 32
Basement IF1 Rx1 0.05 0.06 0.05 0.10 0.21 0.
Basement IF2 Off 0.13 0.10 0.06 0.17 0.09 0.
CC1 Rx1 0.20 0.55 0.22 0.67 0.61 0.
Atten 0 0 0 2 6
CC2 Off 0.16 0.31 0.06 0.56 0.27 0.
Atten 0 0 0 0 0
BandA IF Rx1 2.33 0.47 0.76 0.28 0.49 0.
Baseband 1.45 0.94 0.82 0.99 1.62 1.
Atten 0 8 4 6 8
BandB IF Rx1 1.58 0.61 0.48 0.72 1.88 1.
Baseband 0.93 1.22 0.78 1.05 1.36 1.
Atten 0 0 4 6 4
BandC IF Rx1 2.24 2.82 1.59 2.90 2.15 1.
Baseband 1.08 1.32 1.04 1.35 1.35 0.
Atten 0 0 0 0 6
BandD IF Rx1 1.27 2.34 1.09 1.42 0.96 0.
Baseband 1.46 1.20 0.89 1.01 1.11 0.
Atten 2 0 0 4 4
OVRO:23:47:18UT/10:13:43LST Local:16:47:22
Plot List Audio 2sec Print Help Clo
Tel#2/Bas...
Tel#2/Basement IF2
23:45:44.8 0.11
23:45:46.6 0.10
23:45:48.7 0.10
23:45:50.6 0.10
23:45:52.6 0.11
23:45:54.7 0.10
23:45:56.7 0.10
23:45:58.6 0.11
23:46:00.6 0.11
23:46:02.6 0.10
23:46:04.5 0.11
23:46:06.5 0.11
23:46:08.5 0.10
23:46:10.6 0.10
23:46:12.6 0.11
23:46:14.6 0.11
23:46:16.6 0.11
23:46:18.5 0.11
23:46:22.7 0.10
23:46:24.7 0.10
23:46:26.7 0.10
23:46:28.7 0.10
23:46:30.6 0.15
23:46:32.7 0.15
23:46:34.7 0.57
23:46:36.7 0.10
23:46:38.7 0.10
23:46:40.7 0.11
UT Print


cma Receiver#1 Status
LOfreq 27.00
Tel#1 Tel#2 Tel#3
Tsys dsb 58 55 53
usb 58 55 54
lsb 5884 5569 5449
Vj req 1100 1055 1000
act 1100 1055 1000
err 0 0 0
BS req 370 290 340
act 370 290 noHW
err 0 0 n/a
Ij req LOman LOman LOman
act 293 484 132
err n/a n/a n/a n/a
LOatt req 320 450 600 450
act 320 450 521 449
err 0 0 -79 -1
Tot power 236 1074 734 488
SBR **** **** **** ****
TPvar (%) 1.0 1.5 2.5 8.9 2.1 1.3
OVRO:23:58:32UT/10:24:58LST Local:16:58:35PDT
Plot List Control Audio 0.5sec Print Help Close
cmaMenu
Array (composite)
Observing log
Errors, blanking & paging
Receiver#1
Receiver#2
Receiver#1 Local Oscillator (LO)
Receiver#2 Local Oscillator (LO)
Total Power
Digital Cross Correlator (DXC) Band A
Digital Cross Correlator (DXC) Band B
Digital Cross Correlator (DXC) Band C
Digital Cross Correlator (DXC) Band D
Cryogenics
Tracking
Focus
Receiver#1 Polarizer
Receiver#2 Polarizer
Inter-computer Packets
Create Close
Rx#1
Tel#2/Vj req
1055
Set Tsys Close


cma Observing Log
realtime
Find
400
lines
Stop
Results
Realtime updates active...
26Jun98/23:32:26 --SCH: OBS/SHORTEST_PATH 3C286 LOW_EL=SKIP
26Jun98/23:32:26 --SCH: POINT/CHANGE/P3 5 3 REP=2 0.03 10
26Jun98/23:33:50 POINT rep 1/2 completed early(1 CYCS); accuracy limit achieved
26Jun98/23:33:50 Pointing changes: 1AZEL 2AZEL 3AZEL 4AZEL 5AZEL 6AZEL
26Jun98/23:33:51 RADIO_OFFSET1 AZ=0.821 EL=-0.614
26Jun98/23:33:51 RADIO_OFFSET2 AZ=0.275 EL=-1.123
26Jun98/23:33:51 RADIO_OFFSET3 AZ=0.561 EL=-0.433
26Jun98/23:33:52 RADIO_OFFSET4 AZ=0.733 EL=-0.727
26Jun98/23:33:52 RADIO_OFFSET5 AZ=0.230 EL=-1.043
26Jun98/23:33:52 RADIO_OFFSET6 AZ=0.140 EL=-1.020
26Jun98/23:34:18 POINT rep 2/2 completed early(1 CYCS); accuracy limit achieved
26Jun98/23:34:19 Pointing changes: 1AZEL 2AZEL 3AZEL 4AZEL 5AZEL 6AZEL
26Jun98/23:34:19 RADIO_OFFSET1 AZ=0.797 EL=-0.662
26Jun98/23:34:19 RADIO_OFFSET2 AZ=0.291 EL=-1.165
26Jun98/23:34:19 RADIO_OFFSET3 AZ=0.408 EL=-0.408
26Jun98/23:34:20 RADIO_OFFSET4 AZ=0.694 EL=-0.645
26Jun98/23:34:20 RADIO_OFFSET5 AZ=0.228 EL=-0.930
26Jun98/23:34:20 RADIO_OFFSET6 AZ=0.186 EL=-1.052
26Jun98/23:34:20 --SCH: FLAGS 2GP T=1
26Jun98/23:34:20 Flags: 2ndary std, gain, passband Tuning:v01
26Jun98/23:34:20 --SCH: INT 1 2 LOW_EL=SKIP M=C
26Jun98/23:35:47 -------- Integration 25 completed; rep 1 out of 2
26Jun98/23:37:01 -------- Integration 26 completed; rep 2 out of 2
26Jun98/23:37:02 --Schedule done, reps expended: 3C286(S)
26Jun98/23:37:02 -SCH: SCHEDULE/SUBFILE/LST/NOWAIT/RUN FILE=URANEP START_TIME=19:(
26Jun98/23:37:02 Schedule not run. Before start time: URANEP
26Jun98/23:37:02 -SCH: SCHEDULE/SUBFILE/LST/NOWAIT/RUN FILE=SATURN START_TIME=22:(
26Jun98/23:37:02 Schedule not run. Before start time: SATURN
26Jun98/23:37:02 -SCH: SCHEDULE/SUBFILE/LST/NOWAIT/RUN FILE=NGC7027 START_TIME=15
26Jun98/23:37:02 Schedule not run. Before start time: NGC7027
26Jun98/23:37:02 -SCH: SCHEDULE/SUBFILE/LST/NOWAIT/RUN FILE=NGC7027 START_TIME=22
26Jun98/23:37:02 Schedule not run. Before start time: NGC7027
26Jun98/23:37:02 -SCH: SCHEDULE/SUBFILE/LST/NOWAIT/RUN FILE=3C4543 START_TIME=19:3
26Jun98/23:37:02 Schedule not run. Before start time: 3C4543
26Jun98/23:37:02 -SCH: SCHEDULE/SUBFILE/LST/NOWAIT/RUN FILE=3C48 START_TIME=02:30:0
26Jun98/23:37:02 Schedule not run. Before start time: 3C48


cma Weather
File
Monitor
Preferences
Help
1sec
1min
5min
Temp F
43.0
32.0
42.3
Temp C
6.1
0.0
5.7
Dewpoint C
-7.5
0.0
-8.1
H2O vaporPressure
3.4
0.0
3.3
H2O density g/m**3
2.7
0.0
2.5
Rel humidity %
37
0
36
Barom pressure mbar
880.1
Wind speed mph
11.1
Wind direction deg
9
Wind gustiness mph
0.0
Wind max speed mph
11.1
Record number
4024960
Mirror cleaning
0
MJD
0.00000
1sec/Temp F
Samples:
109
Min:
42.1
Max:
43.5
Mean:
42.70
RMS:
0.0347
Close
Reset
OVRO:13:25:11UT/06:25:13PDT/07:27:13LST Local:06:25:11PDT


cma Errors & Blanking
File
Monitor
Folder
Preferences
Help
Blanking
B12 B13 B14 B15 B16 B23 B24 B25 B26 B34 B35 B36 B45 B46 B56
CC1 OK OK OK Bad OK OK OK Bad OK OK Bad OK Bad OK Bad
CC2 OK OK OK Bad OK OK OK Bad OK OK Bad OK Bad OK Bad
BandA/B OK OK OK Bad OK OK OK Bad OK OK Bad OK Bad OK Bad
BandC/D OK OK OK Bad OK OK OK Bad OK OK Bad OK Bad OK Bad
Errors
Tel#1 Tel#2 Tel#3 Tel#4 Tel#5 Tel#6
Tracking OK OK OK OK OK OK
Absorber OK OK OK OK OK OK
Node Chan Name Description
916 809 T5BeamSelPosn Tel#5 radio beam selection wheel position
OVRO:15:02:08UT/08:02:09PDT/09:00:30LST
Local:08:02:57PDT

Realtime Data Cells

- Background color used to represent item status
- Compact menu for advanced features
  - Plotting versus time
  - Text listing, including save to file
  - Statistics (mean, rms, max, min)
  - Optional audio alert
  - Optional control widget launch
- Built-in history of last 200 values
  - Realtime plots seeded with values from memory

Java Clients

- All realtime monitor windows run one generic Java client
- Unique setup and refresh driven from server
- Clients manage presentation & history
- Approximately 50 classes
- Approximately 22,000 lines code
- Uses JDK 1.1
- Can be run as application or applet
- Total size of classes ~700KB

UNIX C++ Servers

- Run as UNIX “services”
- One instance of server program for each instance of client window
- Unique server program for each type of client window
- Base server classes ~1500 lines
- Each server program 1 to 5 pages code making heavy use of base classes
- Gets data from shared memory

Resources

- Java Client
  - Size
    - No windows: 8.5 MB
    - Each additional window: 1.6MB
  - CPU <1% per window on P-150 or UltraSparc 1/140
- C++ Server
  - Size 0.9 to 1.3MB each
  - CPU: 0.3% UltraSparc 1/170
- Bandwidth
  - Approx 0.1 KBytes/second per window
  - Compression factor: 5 to 10 typical

Monitor Window Portability

- Need only port C++ server base classes for realtime monitor windows
- Java clients run unmodified
- Port to Solaris is trivial if shared memory exists with live data
- Custom window design and creation is straightforward using base classes

Lessons Learned

- Distributed parallel access is very powerful
- Generic plotting function very useful
- Using a table for display and as a menu saves screen space and complexity
- Shared memory simplifies programming
  Works well with one writer, many readers

And More Lessons Learned

- Advantages of C++ servers
  - Performance
  - Trivial access to shared memory structures
- Java applet versus application
  - Applet security restricts printing and file writes
  - Larger programs give slow applet download
  - But users love the browser applet model
- Limit Java target platforms to reduce support
- Use compression to handle network bandwidth limitations

Java Observations

- Very nice language, many good features
- Still evolving
- Hype is ~12 months ahead of implementation
- Performance can be an issue
- There are cross platform issues, particularly on new features
- Browsers
  - Lag in implementation of latest language features
  - Future fairly fuzzy
  - Users love browser interface