The Control System for the Caltech Millimeter Array

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OVRO

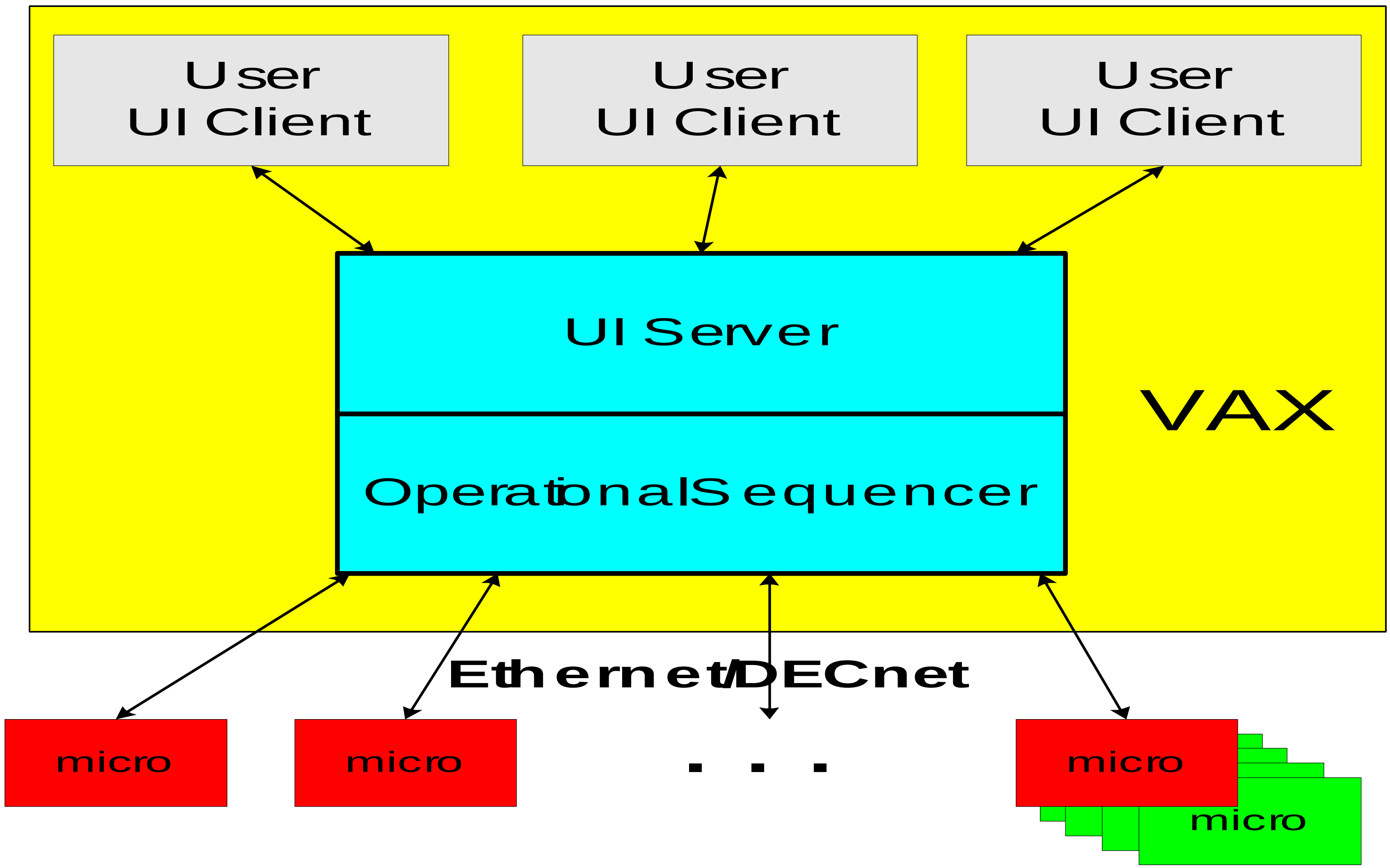
Caltech Millimeter Wave Array

- 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

Requirements

- Remote Operation
  - On site/home/Pasadena/anywhere
- Multiple simultaneous users
  - Collaboration
  - Trouble shooting
  - Teaching
- User Interface
  - Strong instrument diagnostic capabilities
  - Flexible use of screen real estate

System Architecture 1989-1995



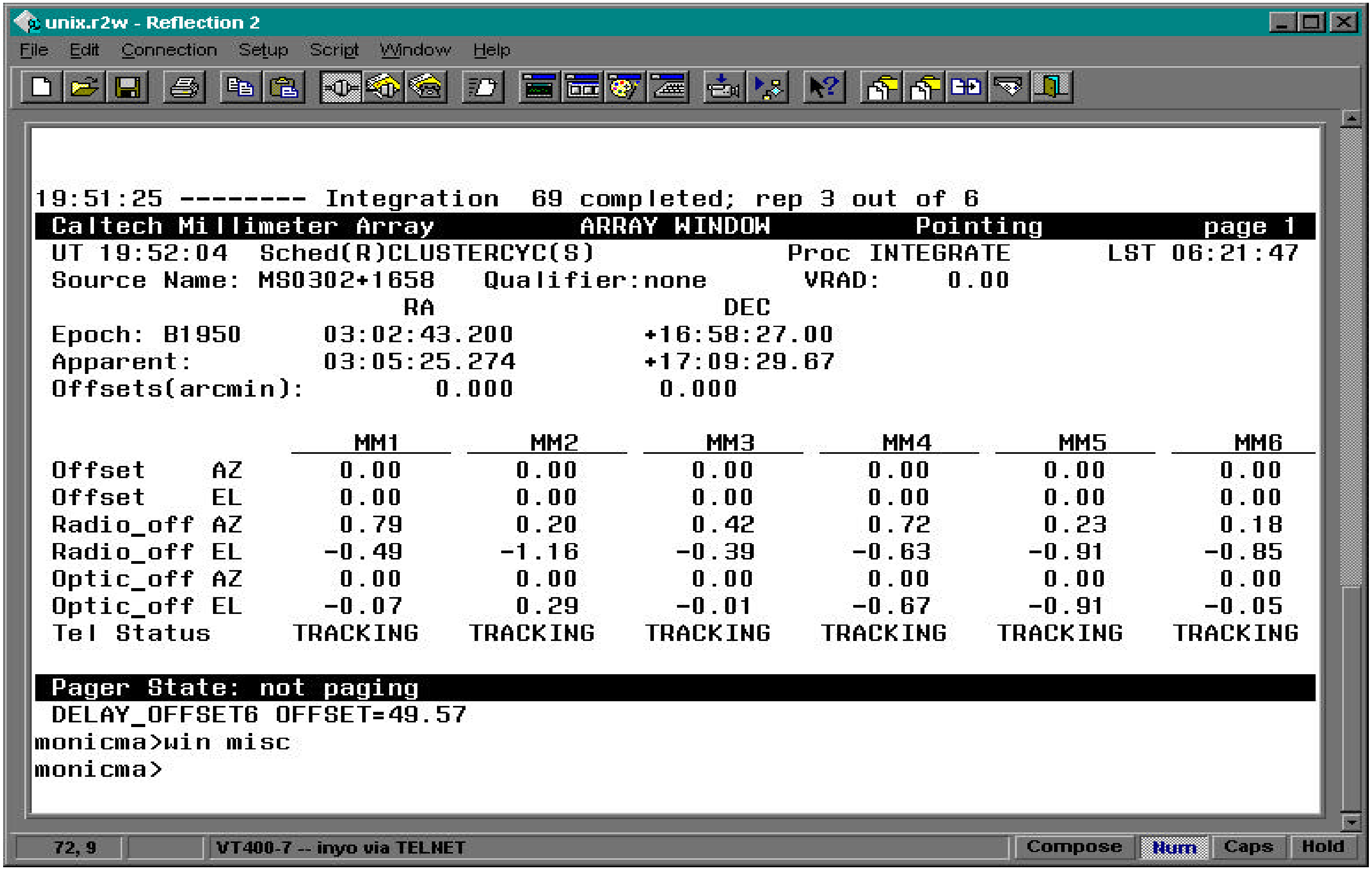
Distributed Computers

Control Function	Location	Type	OS	Num	Rqd
Master	Control Bldg	VaxStation	VMS	1	Y
Ant & Rx	Ant	μVax	VaxELN RTOS	6	Y
Water Line Mon	Ant	P-133	WinNT/LabView	6	N
Dig Cor Dcvrt	Control Bldg	μVax	VaxELN RTOS	1	Y
Ana Cor/Delay/ Lobe Rotators	Control Bldg	μVax	VaxELN RTOS	1	Y
Dig Cor Bln	Dig Cor	68030	PSOS	15	Y
Weather Station	Control Bldg	P-133	WinNT	1	N
Phase Monitor	Control Bldg	80486	DOS	1	N
Database Server	Control Bldg	Usparc336 (4)	Solaris	1	Y

Total Processors: 33

Required Processors: 25

VT100 Based Observing Window



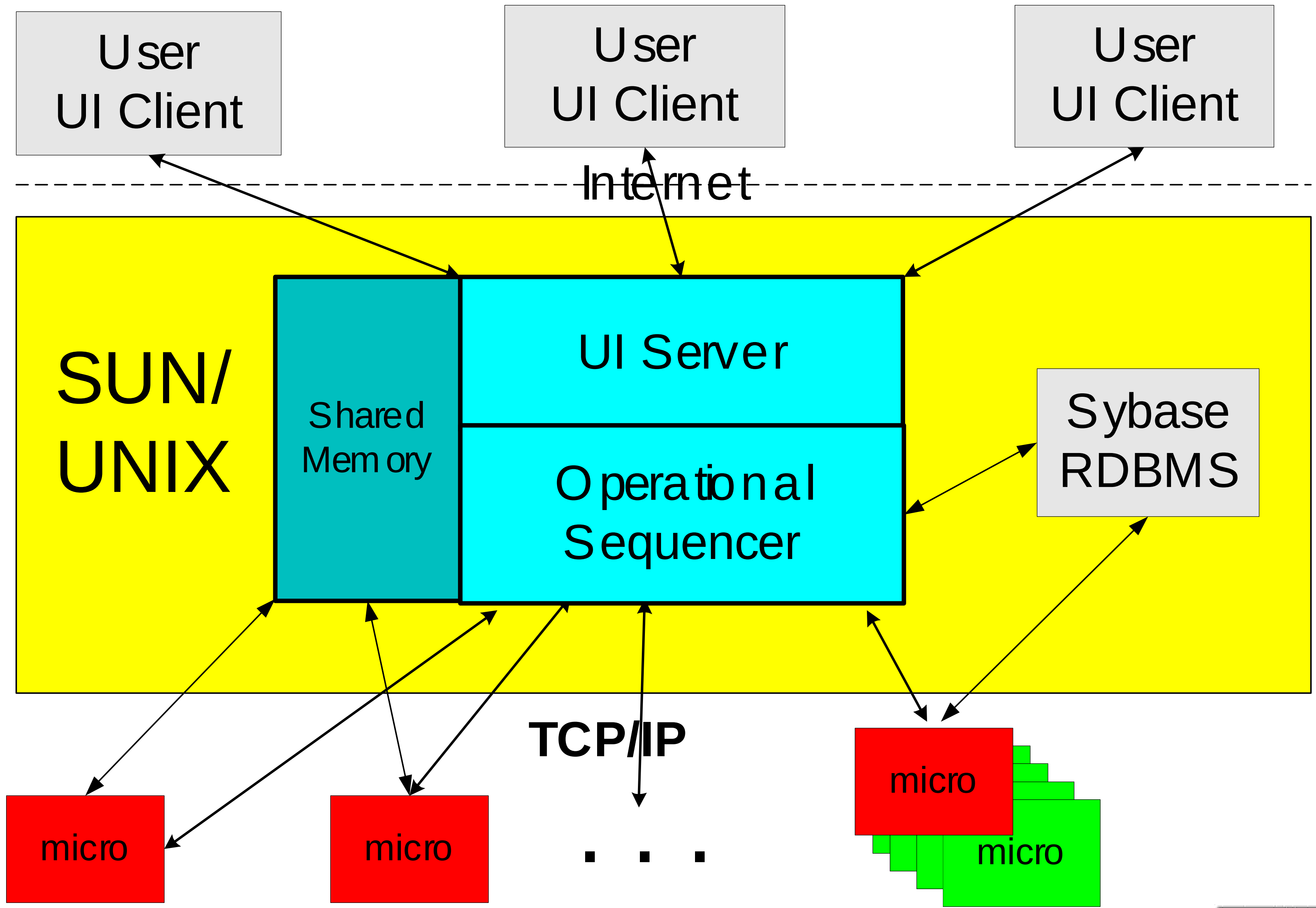
System Upgrade (`96→now)

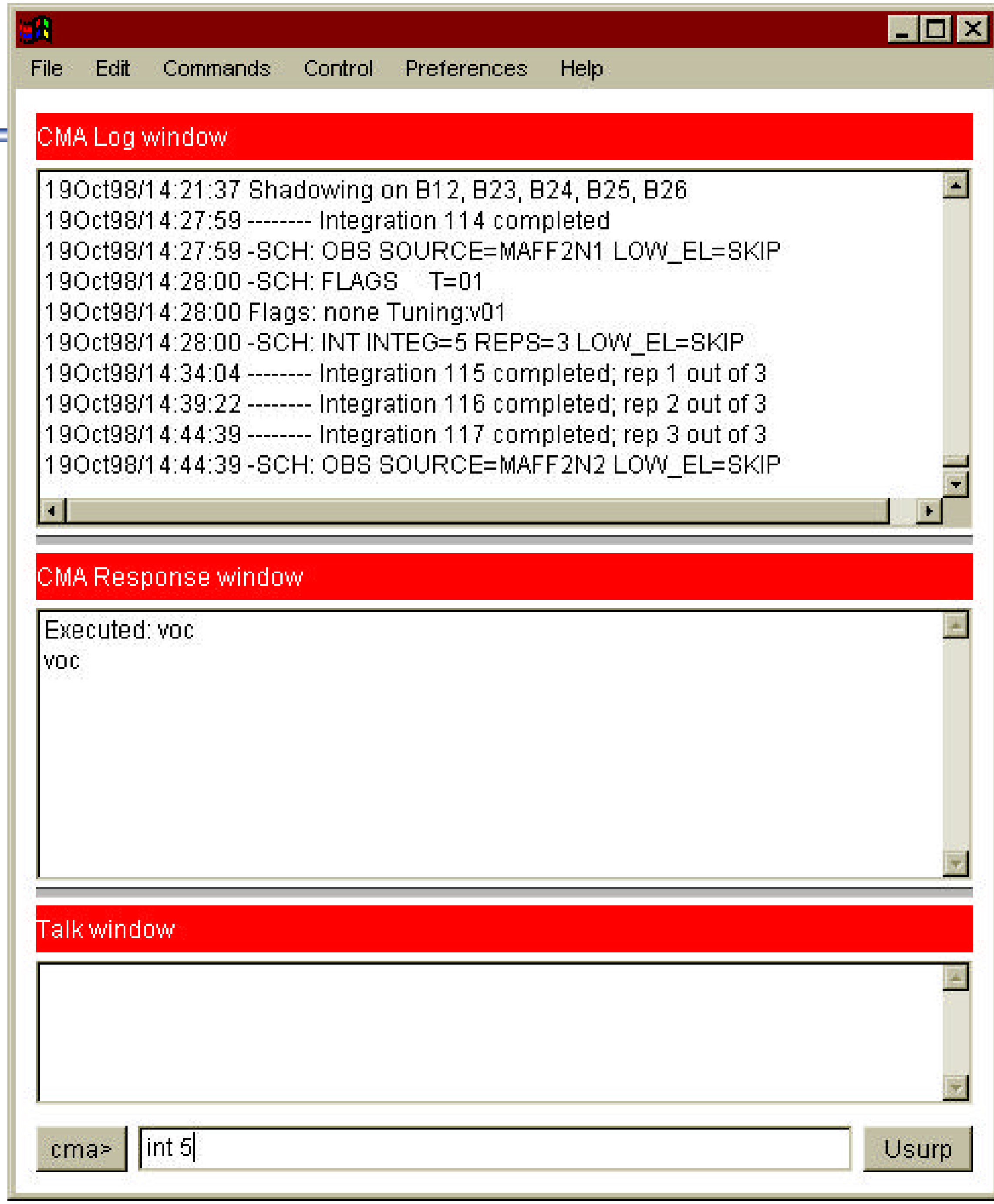
- Why?
  - Instrument bigger and more complicated, need better UI for monitoring and control
  - Need to migrate to better programming environment, from Vax to Unix
  - Need to retire obsolete hardware (Vax)
- Incremental upgrade, preserving existing realtime hardware and software components
- Separate monitoring from control
- Do monitoring first
- Monitoring about 60% complete

Upgrade Design Constraints

- Graphical UI with color and plotting capability
- Run over modem bandwidth
- Parallel access by users
- Multiple platorms for UI
  - Solaris, Win32, Mac, OS2
- Simple system
  - Modest computing hardware requirements
  - Limited programming resources (3-4 programmer years)

Future System Architecture




File Edit Commands Control Preferences Help
CMA Log window
19Oct98/14:21:37 Shadowing on B12, B23, B24, B25, B26
19Oct98/14:27:59 -------- Integration 114 completed
19Oct98/14:27:59 -SCH: OBS SOURCE=MAFF2N1 LOW_EL=SKIP
19Oct98/14:28:00 -SCH: FLAGS T=01
19Oct98/14:28:00 Flags: none Tuning:v01
19Oct98/14:28:00 -SCH: INT INTEG=5 REPS=3 LOW_EL=SKIP
19Oct98/14:34:04 -------- Integration 115 completed; rep 1 out of 3
19Oct98/14:39:22 -------- Integration 116 completed; rep 2 out of 3
19Oct98/14:44:39 -------- Integration 117 completed; rep 3 out of 3
19Oct98/14:44:39 -SCH: OBS SOURCE=MAFF2N2 LOW_EL=SKIP
CMA Response window
Executed: voc
voc
Talk window
cma>
int 5
Usurp

Distributed Computing

- Master/slave hierarchy connected with Ethernet
- Soft-realtime at top, hard realtime at bottom
- Hard realtime
  - Antenna pointing every 500 msec
  - Phase and delay control every 6.25 msec
  - Data collection, demodulation, and integration every 6.25 msec
- Soft realtime requirements emphasize
  - Data collection efficiency
  - Response to user input

Distributed Computing II

- Although recording of data is not synchronized between backends (spectrometers), time of data is rigorously recorded
- Direct wires used where Ethernet won't work
  - 3 per antenna (2 ← ant, 1→ ant)
- Real time machines have time synchronized with hardwired 1 pulse per minute
- Newer machines synched with NTP to GPS on the local network

Interprocessor Communication

- Ethernet (10Mbps)
- ASCII commands (DECnet)
  - Fully acknowledged protocol (ACK/NACK)
  - Synchronous execution of commands
- Data from backends to master (DECnet)
  - Binary structures (Vax specific)
  - Monitor data to Unix
    - Structures sent in a network independent format
    - UDP

Noteworthy Features

- Parallel access for control and monitoring
- Error system for fault detection
- Powerful peakup routine
- RDBMS for data in realtime

Error System

- Full representation of all (~1200) monitoring points and their interdependencies
- Directed Acyclic Graph (DAG)
- Reconfigurable for hardware changes
- Capabilities:
  - Pinpoint root cause of problems for log & display
  - Determines which data are affected by a fault and removes it
  - Integrated with a paging system

Peakup Routine (POINT)

- Takes data at 3 half power points around nominal source position
- Uses relative amplitudes per baseline, so resolved sources (planets) can be used
- Simultaneous binning at different SNR levels to give snr/(number sample) tradeoffs
- Takes many measurements so results have statistical significance
- Automatically quits when has accurate solution
- Changes offsets as required to improve SNR

RDBMS

- Store all data (visibilities and header) directly into Sybase commercial RDBMS
- Data integrity, backup, and selection features automatically come with a DBMS
- DBMS maintenance is an issue
- Data rate ~6GB/year

Lessons Learned

- Parallel access from any location very useful Home access helps maintain instrument
- Expose as much of the instrument as possible
- Monitoring is key to troubleshooting
- System for isolating faults very useful, but reconfiguration is tricky
- Simulation mode for individual pieces of hardware useful during construction phase
- Commercial DBMS works fine for realtime data

Distributed Computing Lessons

- No disks on embedded processors
- Need quick load time for embedded processors
- Saving and restoring state of instrument is very important issue
- Must have a way to trigger reboots remotely
- Staging of reboots can be tricky
- Distributed computing is good because
  - Allows parallel development
  - Puts processing power and IO devices where needed