The Control System for the Caltech Millimeter Array

Steve Scott
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

User UI Client
User UI Client
User UI Client

UI Server

Operational Sequencer

Ethernet/DECnet

VAX

micro
micro
micro
micro
## Distributed Computers

<table>
<thead>
<tr>
<th>Control Function</th>
<th>Location</th>
<th>Type</th>
<th>OS</th>
<th>Num</th>
<th>Rqd</th>
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<tr>
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<td>VMS</td>
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<td>µVax</td>
<td>VaxELN RTOS</td>
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<td>Ant</td>
<td>P-133</td>
<td>WinNT/LabView</td>
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Total Processors: 33  
Required Processors: 25
VT100 Based Observing Window

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### Caltech Millimeter Array

**From:** OT 19:52:04  Sched(R)CLUSTERCYC(S)  
**Proc:** INTEGRATE  
**LST:** 06:21:47

**Source Name:** MS0302+1650  
**Qualifier:** none  
**VRAD:** 0.00

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**Tel Status:** TRACKING  TRACKING  TRACKING  TRACKING  TRACKING  TRACKING

**Pager State:** not paging

**DELAY_OFFSET6 OFFSET=49.57**

**monicma>win misc**

**monicma>**
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 platforms for UI
  - Solaris, Win32, Mac, OS2
- Simple system
  - Modest computing hardware requirements
  - Limited programming resources
    (3-4 programmer years)
Future System Architecture

- User UI Client
- User UI Client
- User UI Client

Internet

SUN/UNIX

Shared Memory

UI Server

Operational Sequencer

Sybase RDBMS

TCP/IP

micro

micro

micro
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