# LabVIEW: a Graphical Dataflow Language and Telescopes

*Silicon Valley*
*Forth Interest Group*

Sunnyvale, January 28, 2006

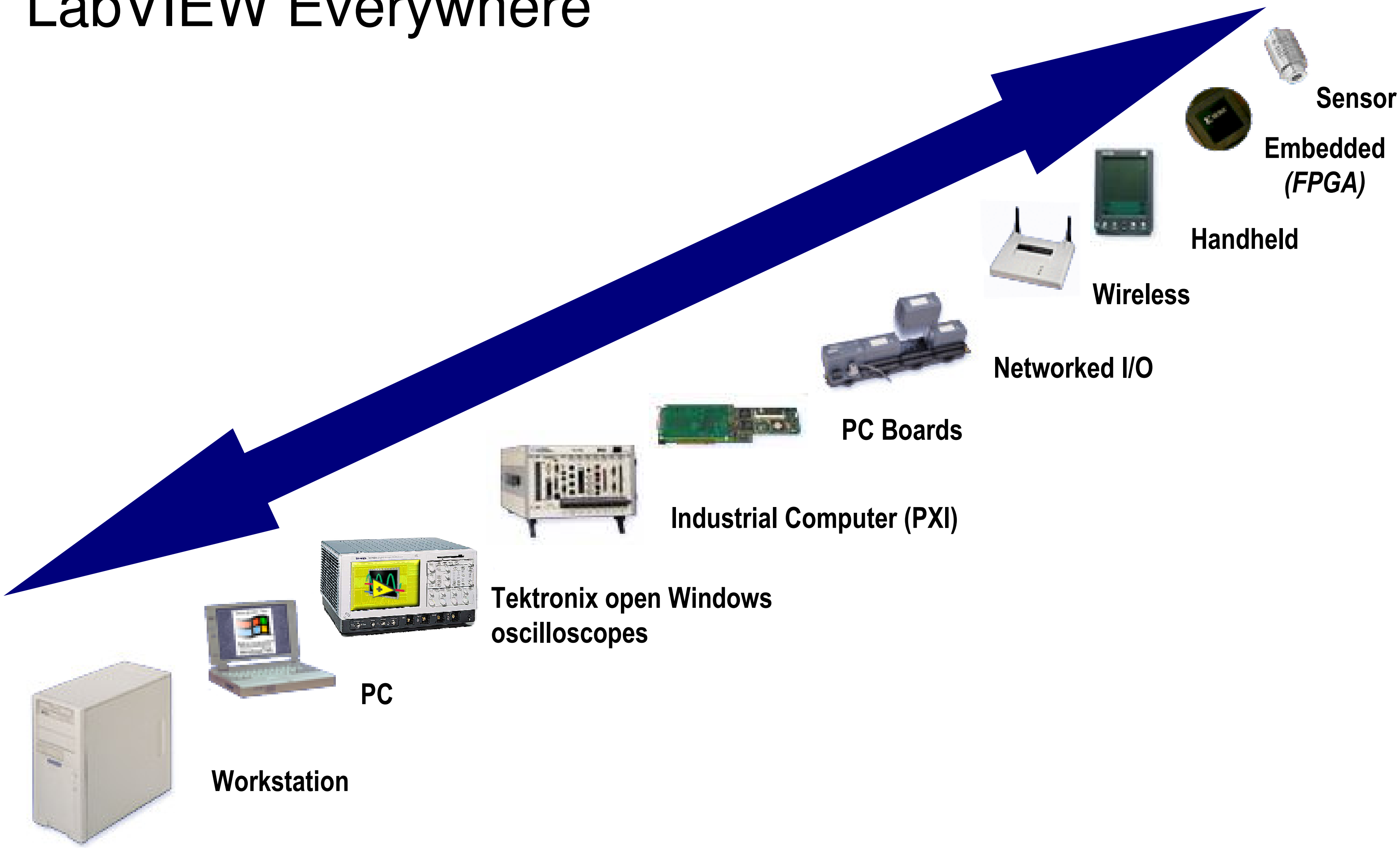
# Why?

- Do we only find problems after compiling?
- Do we only find missing functions after linking?
- Can’t we give hints to the environment about what can run independently?
- …

# LabVIEW: a graphical dataflow language

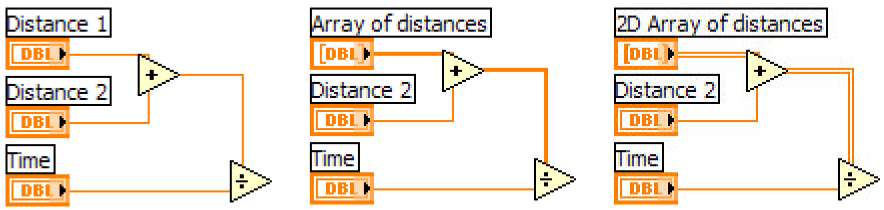
- Execution order determined by presence of data on input: different paradigm than text based procedural languages. In general: no sequential execution, no variables.
- Every subunit of code (a VI or “Virtual Instrument”) has its own user interface, “for free”. Great for testing.
- Requires more an “engineering thinking” than traditional “computer science” thinking.
- Dataflow languages lend themselves to parallel execution. Multithreaded execution becomes automatic without the user having to think much about it.
- Code is automatically compiled to machine language. Not interpreted so it’s (reasonably) fast (about ½ of C).
- Comes with large libraries of math & signal processing functions.
- In the real world: seldom the only development environment used so cooperation is paramount. There are interfaces to C/C++, .NET assemblies, DLL’s.
- Available on different operating systems: Windows family, Mac, Linux, Solaris. Code is platform independent and can be moved from one OS to another.
- Available for different hardware targets: PDA (Palm/WinCE), PXI, FPGA. Same code can be downloaded to different targets (but FPGA is limited to integer operations). Next version of Lego Mindstorm (NXT) is also LabVIEW based.

# LabVIEW Everywhere

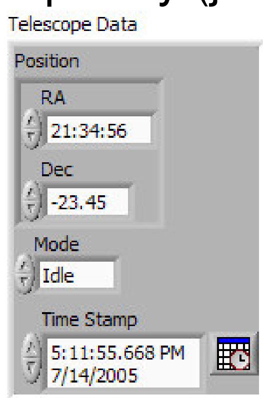


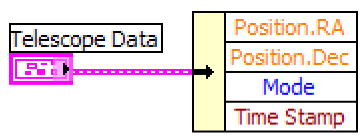
# LabVIEW: Data Capabilities

- Supported types: int (I8-I64), float, complex, boolean, enum, string, object reference, variant, time and N-dimensional arrays of those
- Functions are polymorphic: adapt to input wires. Greatly decreases required number of primitives.
- Wire color indicates type. Wire thickness indicates dimensionality.




- Primitive data types can be combined in user-defined structures, up to any complexity (just like C structs)

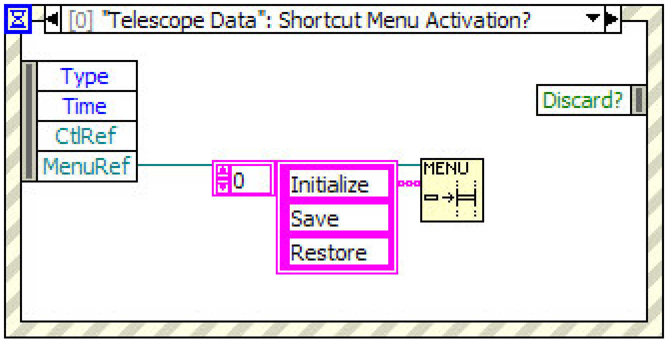


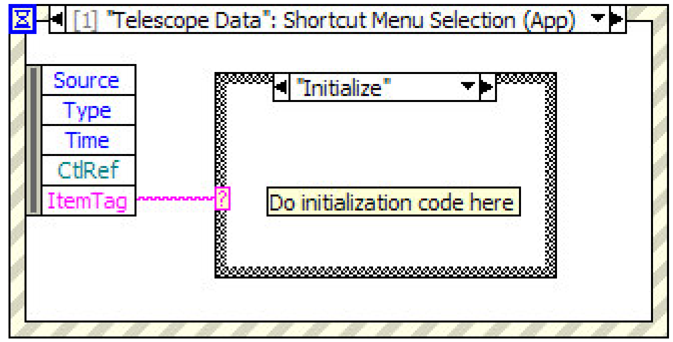




- Support for +/- Inf and NaN.

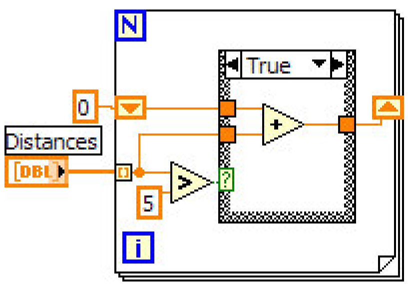
# LabVIEW: Programming Capabilities

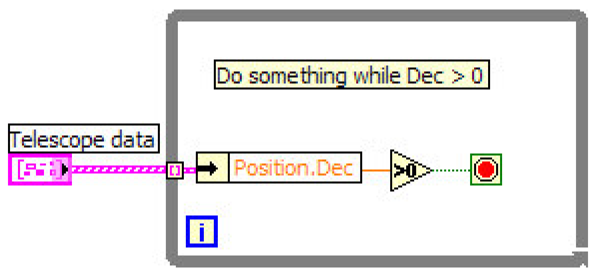
- Event handling: user defined or User Interface triggered

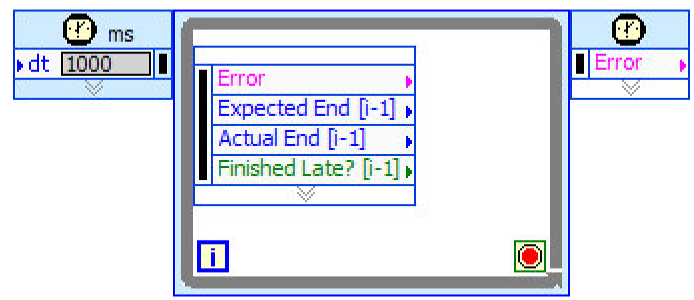



- For and While loops. “Sequence Structures” where order of execution is important. Timed Loops for rate based scheduling.



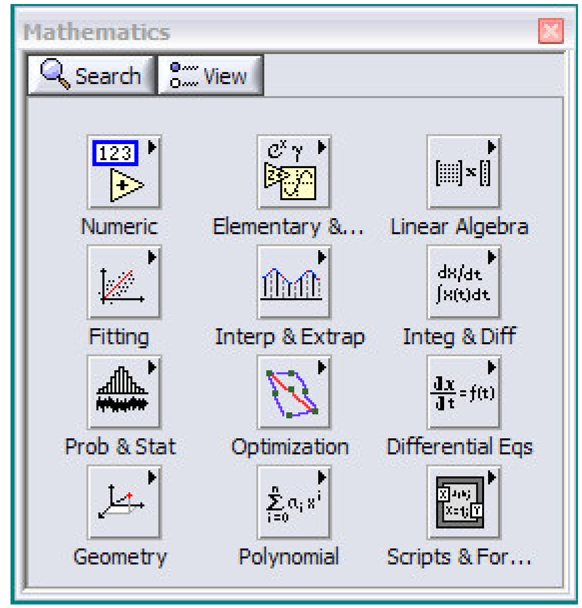




- Synchronization primitives: Queue, Rendezvous, Semaphore, Notifier.
- Unlimited hierarchy of VI’s.

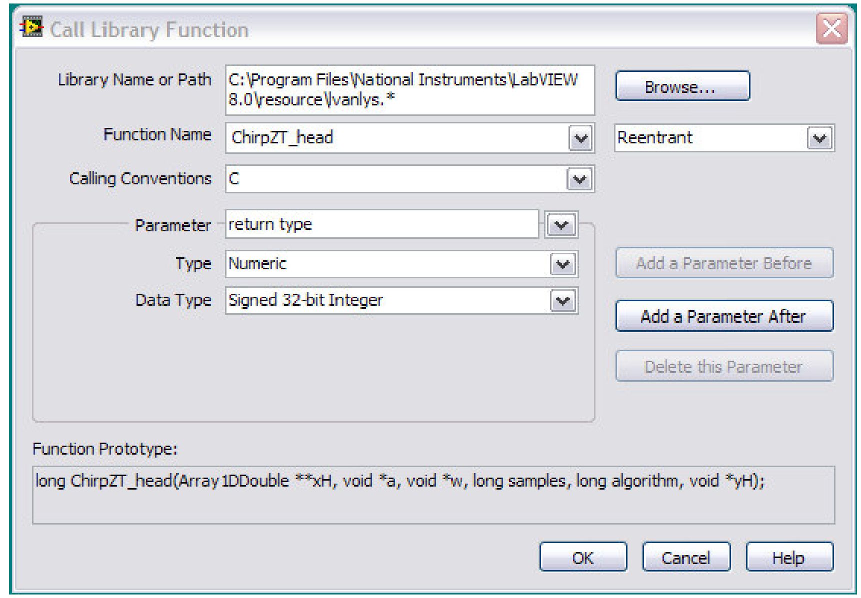
# LabVIEW: Math & Signal Processing Libraries

- Math
  - Linear Algebra
  - Optimization
  - Curve fitting, interpolation, extrapolation
  - Integration, differentiation, differential equations
  - Probability, Statistics
  - Elementary & Special functions (Gamma, Bessel,…)
  - N-dimensional array manipulation
  - Polynomial operations
- Signal Processing
  - Windows (Hamming, Flat top,…)
  - Spectral analysis
  - IIR & FIR filters (Butterworth, Chebychev,…)
  - Transforms (Laplace, Fourier, Z, wavelets,…)
  - Signal generation (chirp, noise,…)



# LabVIEW: Connectivity

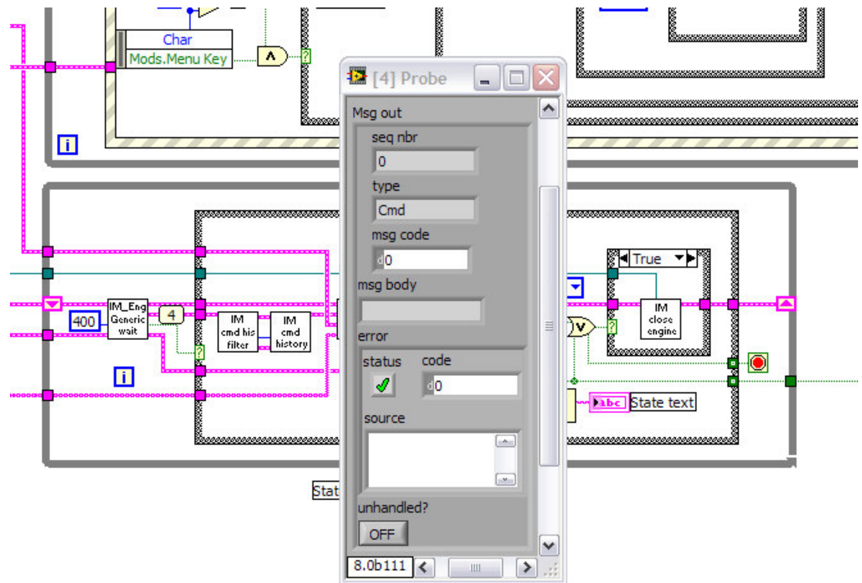
- Call Windows DLL or Unix Shared Libraries
- ActiveX server/client: control LabVIEW from other Windows programs
- Embed ActiveX components in display, including event handling
- Call .NET assemblies
- Drivers for serial, TCP, UDP, IRDA, Bluetooth, SMTP
- Formula nodes: C-syntax, Matlab, Xmath, IDL (RSI)




- Instrument I/O
  - Data acquisition boards (double-buffered, complex triggering, intra-board synchronization)
  - VISA (serial)
  - GPIB (with 1000's of drivers to other vendors instruments)
- Sound In/Out
- File I/O: binary, text, datalog (structured binary), XML support
- VI server for remote control – DataSockets for remote data

# LabVIEW: Productivity Improvements

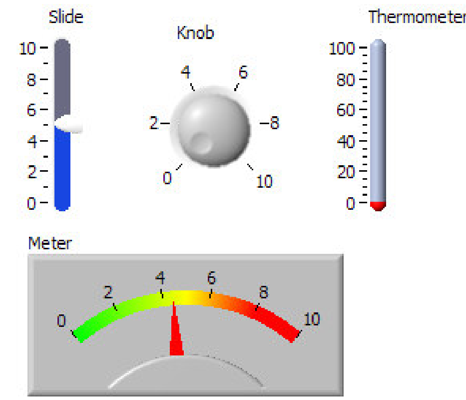
- Impossible to write syntactically incorrect code: wires “break”
- Immediate execute, invisible compile/link cycle
- No pointers, garbage collection, automatic memory allocation for all objects, variable size arrays => really hard to make code crash
- Debugging
  - Probes on wires
  - Single stepping
  - Breakpoints
  - User defined probes

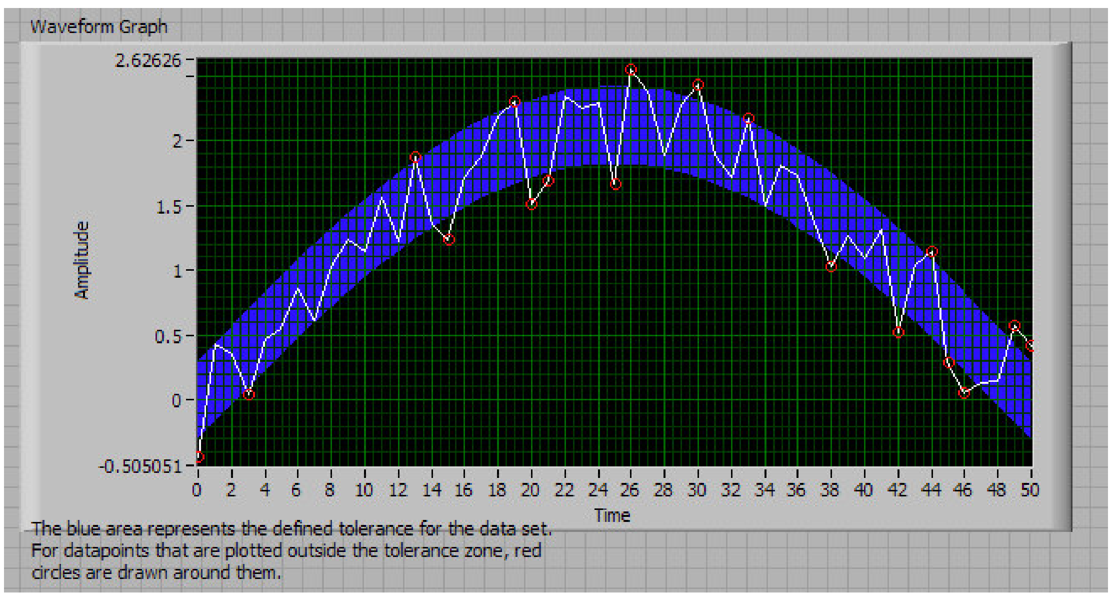


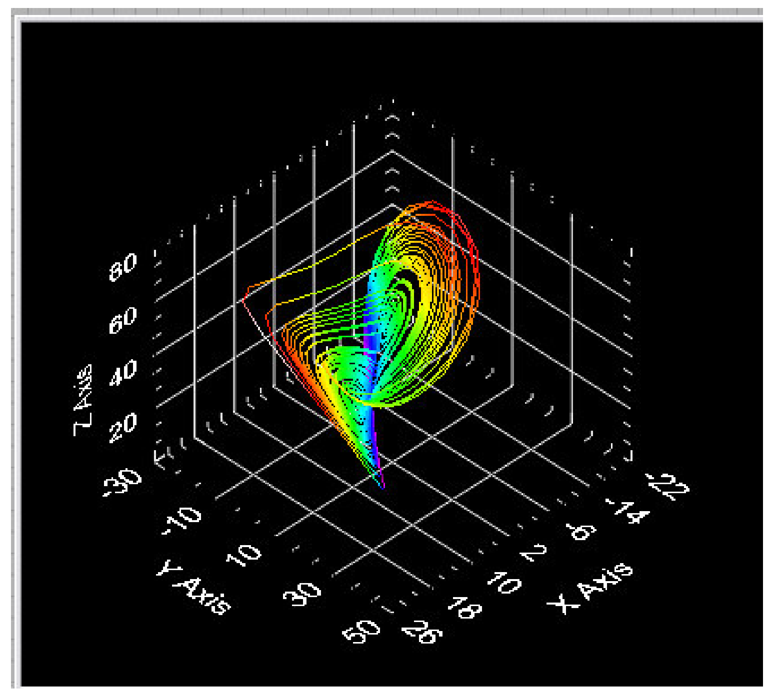

- Every piece of code (VI) has its own interface and can be tested without having to write a “main” function

# LabVIEW: User Interface elements

- Numerics
- Graphs
- Trees, listboxes, tables
- Tabs
- ActiveX container
- 3D
- For everything else: Drawing canvas (Picture control)



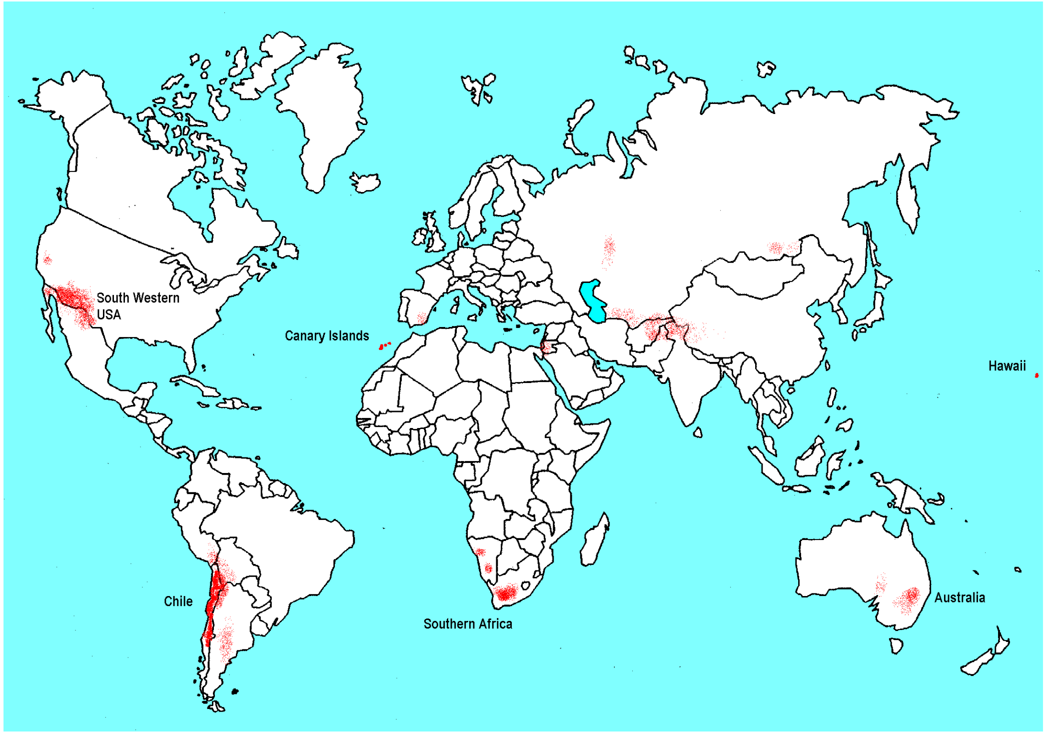



# LabVIEW: Final Comments

- It's a 4th generation language, specifically designed to tackle measurement and engineering problems. Don't do "computer science" stuff with it!
- Use it for:
  - Multi-threaded, multi-rate measurement and control problems
  - Simple and complex data acquisition, machine vision, motion control
  - Rich user interfaces
  - Rapid Prototyping
  - Environments where development cost and "time to market" is the most important factor (e.g. not for mass produced items)
- Do not use it for:
  - Device drivers, operating system stuff
  - Complex parsing (Yacc/Lex)
  - Word processors
  - Games…
- It's fun. Makes you think about the problem to solve and less about the syntax of a programming language.

# An Introduction to SALT

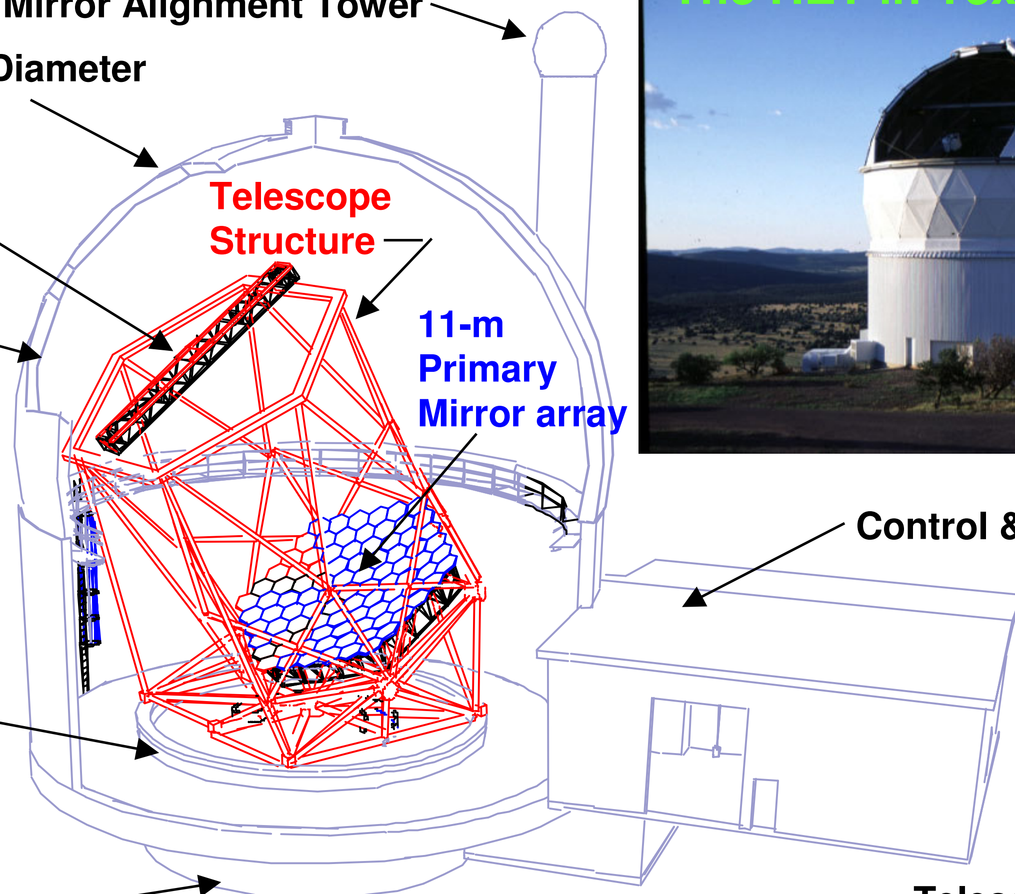


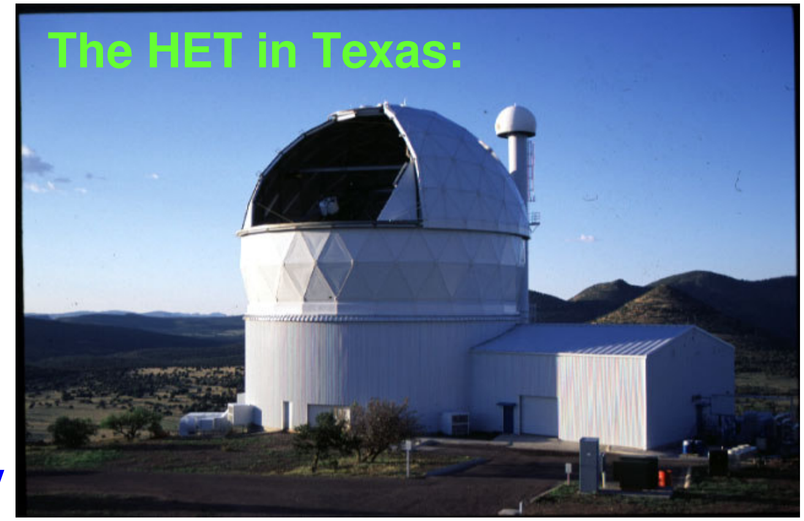

***General:***

- **SALT is a 10 metre class telescope built in South Africa.**
- **It is the largest single telescope in the Southern Hemisphere**
- **SALT is being built by an international consortium consisting of the following partners:**

  - South Africa (host institution: the South African Astronomical Observatory).
  - Poland (through the Nicholas Copernicus Astronomical Centre, Warsaw).
  - Rutgers University, New Jersey, USA.
  - Göttingen University, Germany.
  - The Hobby-Eberly Telescope Board (consisting of partners in the USA & Germany).
  - Carnegie Mellon University, Pittsburgh, Pennsylvania, USA.
  - University of Wisconsin, Madison, Wisconsin, USA.
  - New Zealand (founding institution: the University of Canterbury).

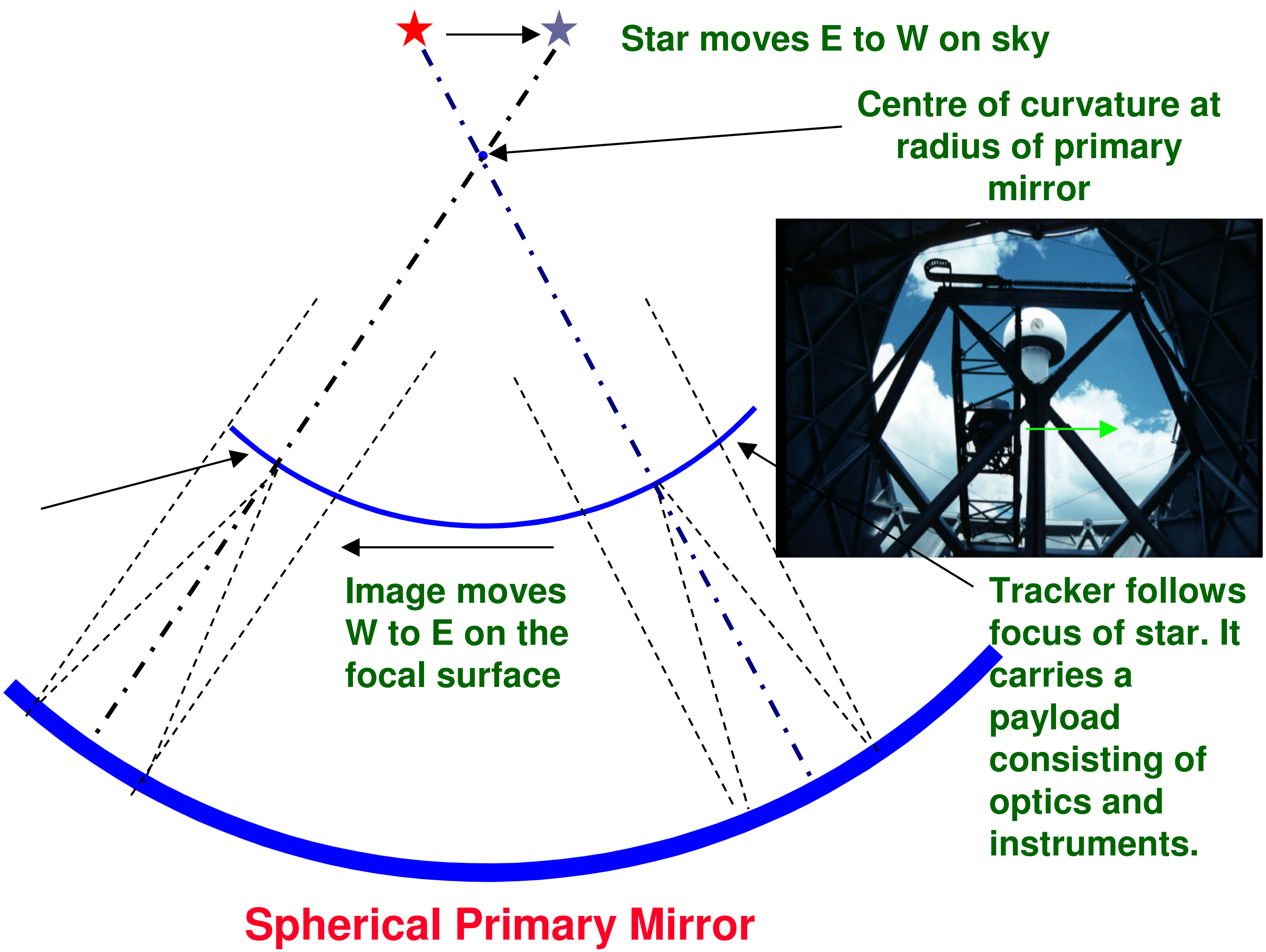
# A concept diagram of SALT



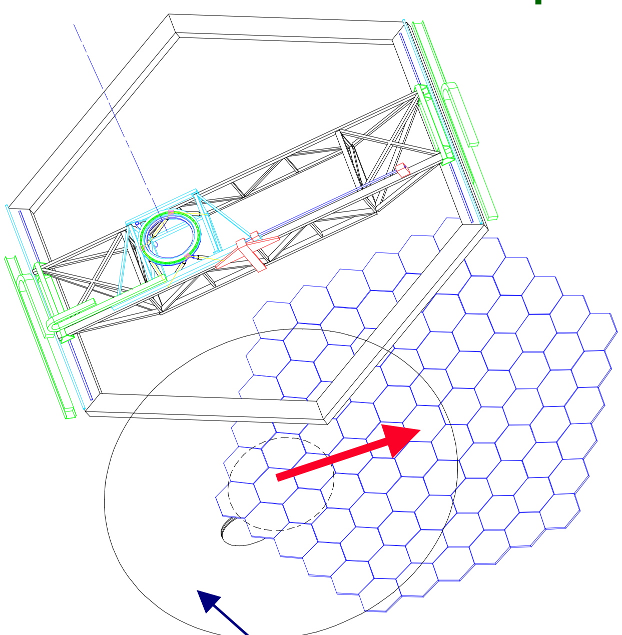

Telescope moves in azimuth only, not in altitude (fixed at 37 degrees from zenith)

# The Arecibo Concept:



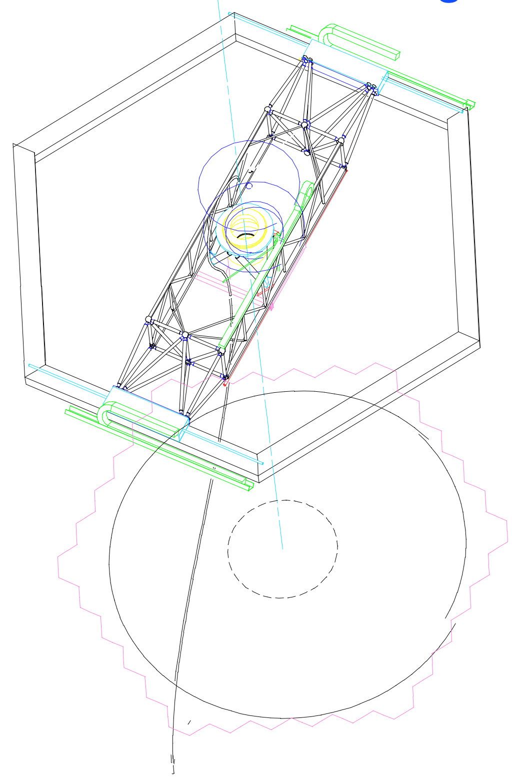
# How the telescope tracking works

Tracker off-centre
and pupil partially on primary
mirror array. At worst extreme,
still a 7 metre telescope!



Part of pupil off mirror is baffled
at exit pupil position

Tracker centred
and pupil centred on
primary mirror array. Full
9.2 metre collecting area.



# Primary Mirror Array

***Attributes:***

• **segmented array of 91 hexagons, each 1 meter wide (edge-to-edge) and 50 mm thick**

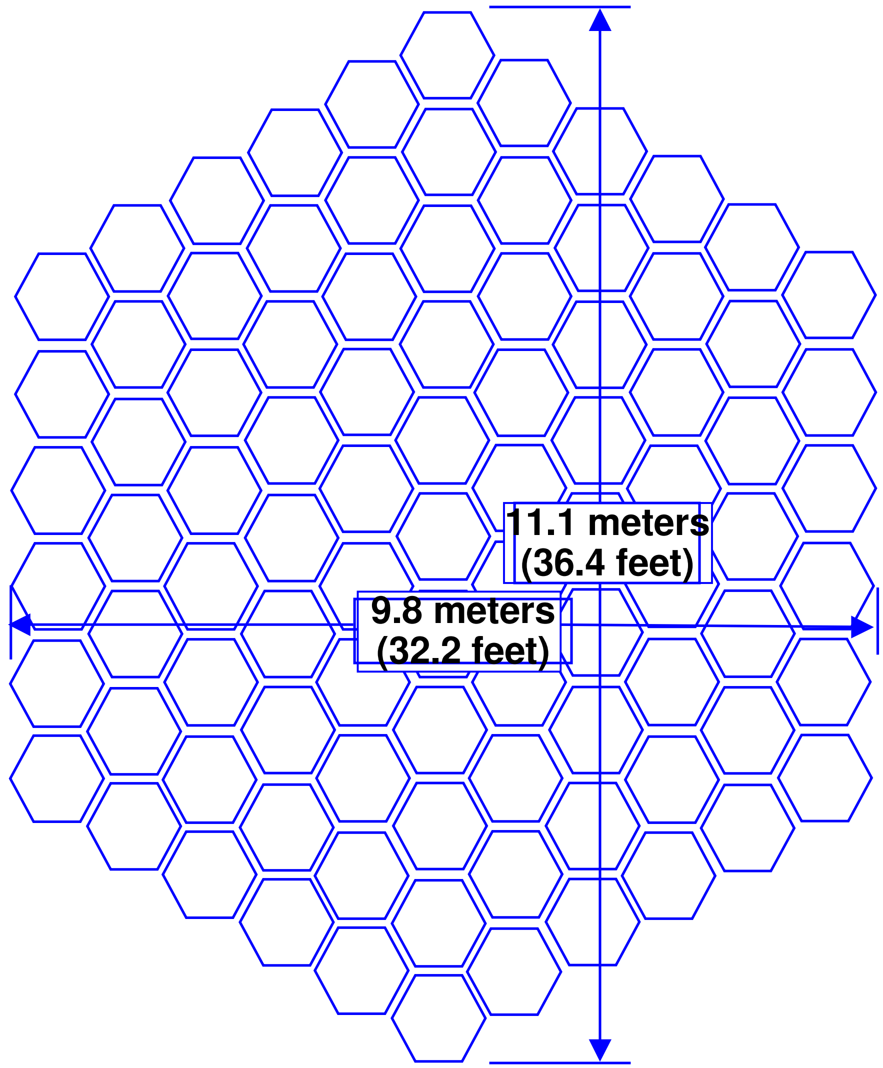
• **maximum mirror diameter:**
***11 m***

• **accuracy of mirror surface:**
***0.052 microns (1/10$^{th}$ wavelength of light***
(smooth to 5/100,000 $^{th}$ of a mm)

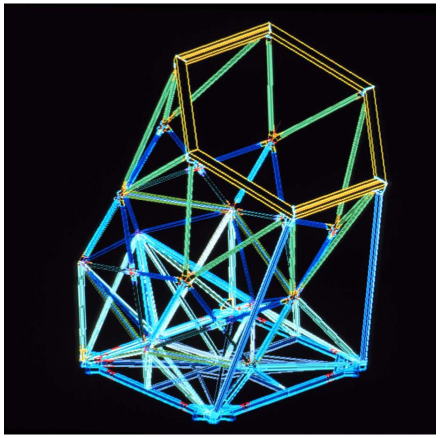
• **Field of view:**
***8 arcmin*** *(~1/4 size of Moon)*

• **Resolution:**
***0.25 – 0.5 arcsec***
*(size of quarter at 10 km)*

• **Mirror array supported on steel 'space frame' truss containing 1,747 struts and 383 nodes, precise to 4 mm over the entire truss.**

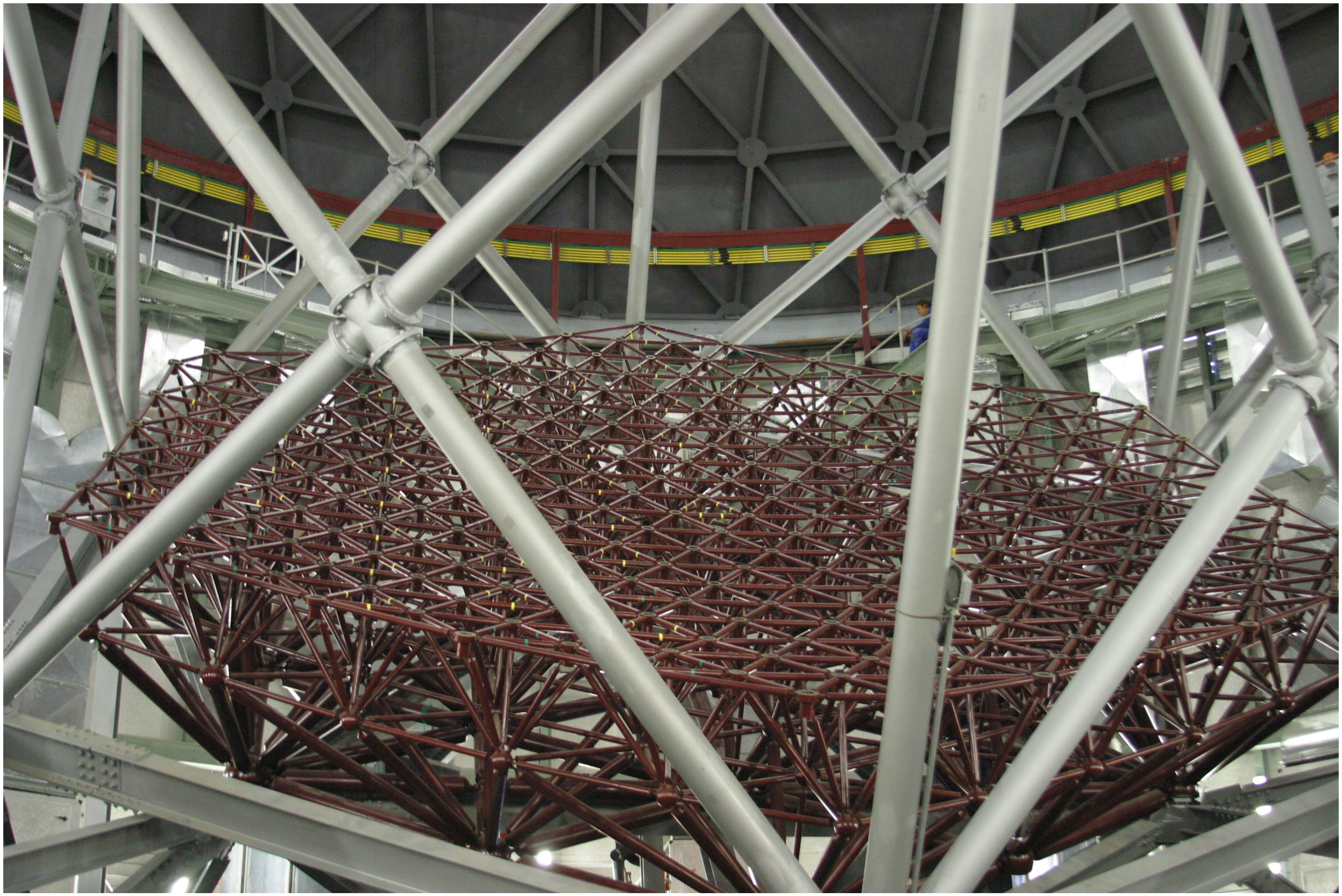


# Facts & Figures: telescope



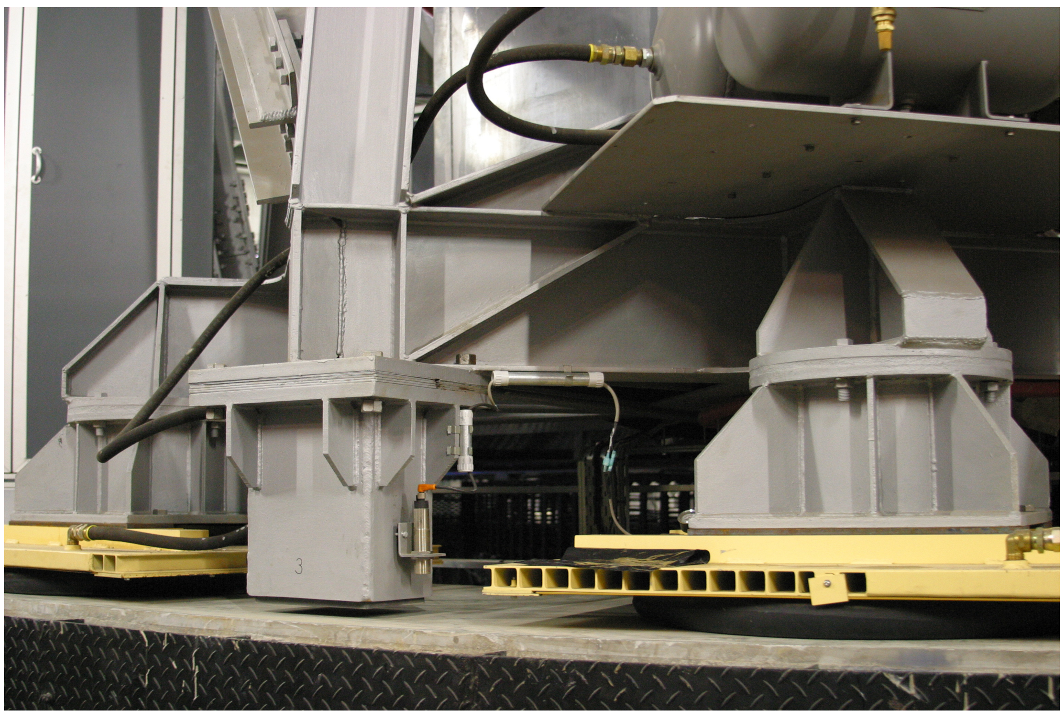
- Design: modified version of Hobby-Eberly Telescope.
- Telescope  length 13 meters, mirror array 11 $\times$ 10 meters.
- Mass of telescope: 82 tonnes.
- Light collecting area of array: 77.6 sq. meters
- Wavelength coverage: 340 nm to 2500 nm (ultraviolet to near infrared).
- Telescope rotates in azimuth on 8 air bearings to acquire targets, with a precision of 3 microns.  A tracker with 10 degrees of freedom then follows the target, as the Earth rotates, for up to ~2.5 hours.
- The telescope can be moved from one object to another in < 5 min.
- Optical fibers can relay light from several objects (10-20) in the field to instruments in the the basement.
- The tracker will consist of a Prime Focus Instrument Platform, consisting of an efficient imaging spectrograph capable of observing many objects at once.

# Mirror support trusses 3 years ago



Telescope building with alignment tower

Supported by air bearings during movement



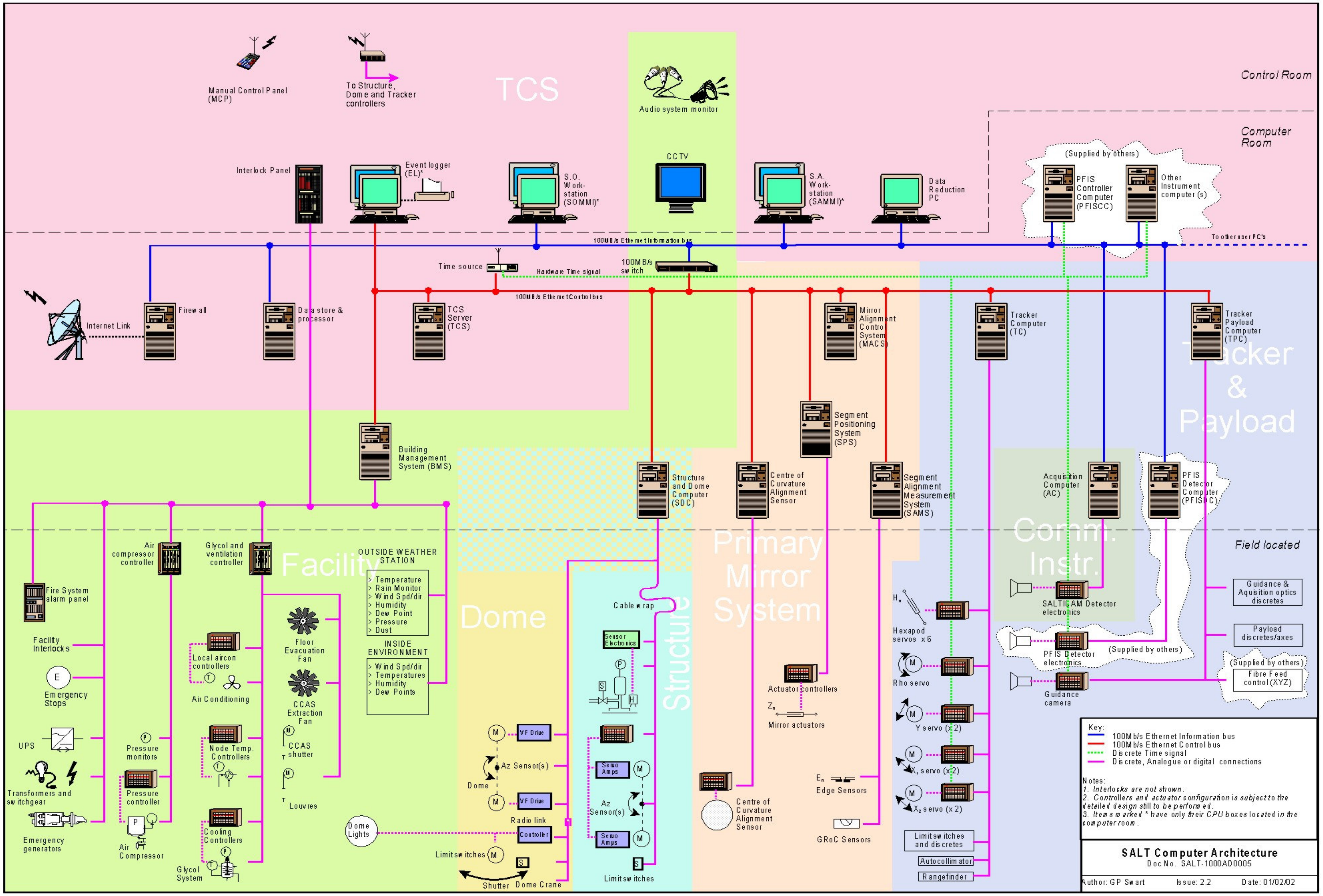
# Cost benefits analysis

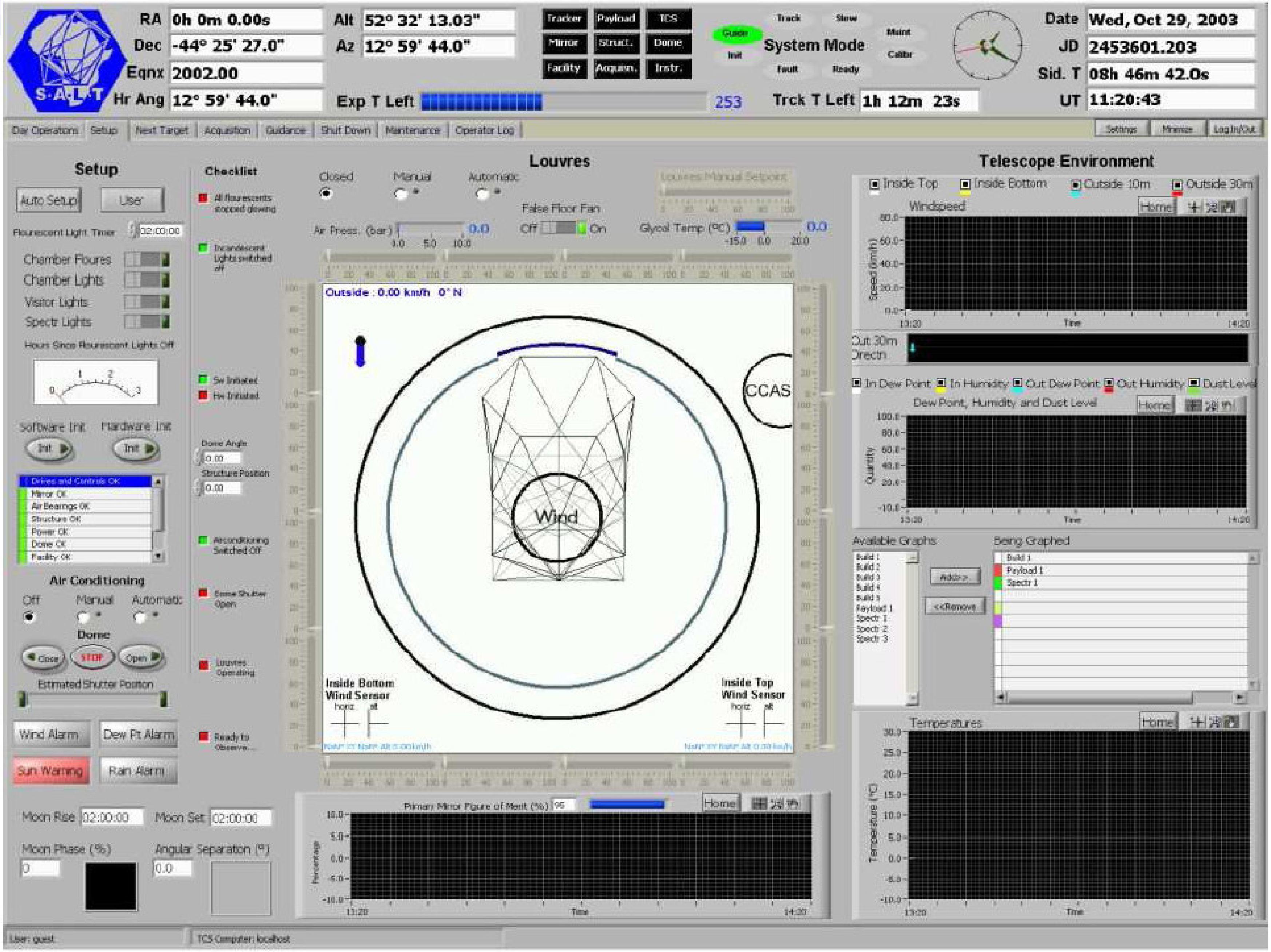
- Spherical mirror segments (not parabolic)
  - Easy to grind
  - Only one type of shape needed
  - Optical aberrations (coma) corrected by secondary
- Move in azimuth only
  - Much lighter telescope structure
  - Gravity constant on mirror, corrections much easier
- Mirror not phased (edge alignment in microns, not nanometers)

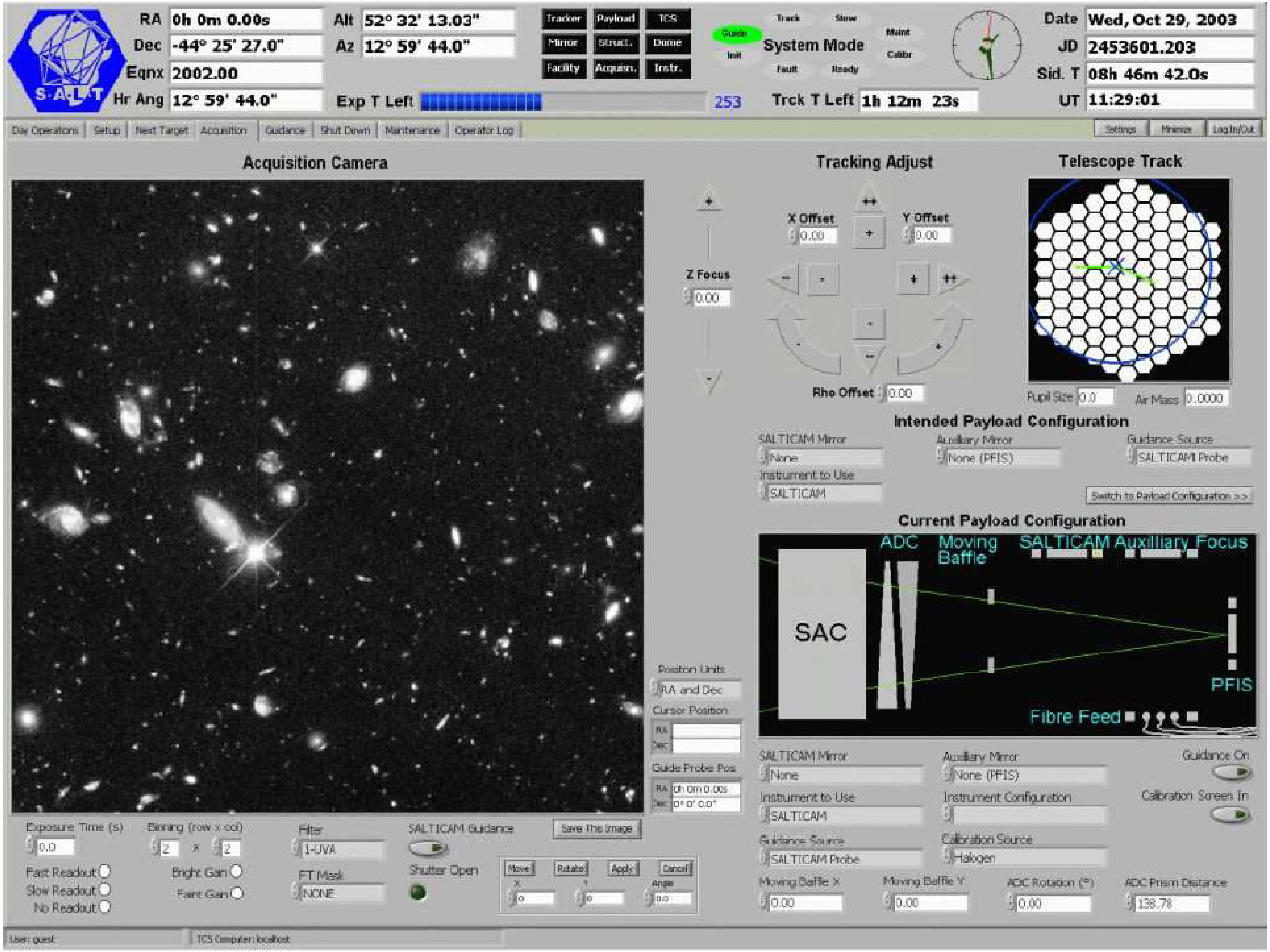
→ Only 70% of sky visible
Will never be able to use Adaptive Optics
Scheduling of time more cumbersome

But: 10% of cost of Keck!
Optimized for spectroscopy and UV

# Telescope Control System Architecture




S-A-L-T
RA 0h 0m 0.00s
Dec -44° 25' 27.0"
Eqnx 2002.00
Hr Ang 12° 59' 44.0"
Alt 52° 32' 13.03"
Az 12° 59' 44.0"
Exp T Left
253
Tracker
Payload
TCS
Mirror
Struct.
Dome
Facility
Acquisn.
Instr.
Guide
Track
Slew
Maint
Init
System Mode
Calibr
Fault
Ready
Trck T Left 1h 12m 23s
Date Wed, Oct 29, 2003
JD 2453601.203
Sid. T 08h 46m 42.0s
UT 11:20:43
Day Operations
Setup
Next Target
Acquisition
Guidance
Shut Down
Maintenance
Operator Log
Settings
Minimize
Log In/Out
Setup
Auto Setup
User
Checklist
Louvres
Closed
Manual
Automatic
False Floor Fan
Off
On
Air Press. (bar)
Glycol Temp (ºC)
Telescope Environment
Inside Top
Inside Bottom
Outside 10m
Outside 30m
Windspeed
Home
Outside : 0.00 km/h 0° N
CCAS
Wind
Inside Bottom Wind Sensor
Inside Top Wind Sensor
Chamber Floures
Chamber Lights
Visitor Lights
Spectr Lights
Software Init
Hardware Init
Drives and Controls OK
Mirror OK
Air Bearings OK
Structure OK
Power OK
Dome OK
Facility OK
Air Conditioning
Dome
Close
STOP
Open
Estimated Shutter Position
Wind Alarm
Dew Pt Alarm
Sun Warning
Rain Alarm
Moon Rise 02:00:00
Moon Set 02:00:00
Moon Phase (%)
Angular Separation (º)
Primary Mirror Figure of Merit (%)
In Dew Point
In Humidity
Out Dew Point
Out Humidity
Dust Level
Dew Point, Humidity and Dust Level
Available Graphs
Being Graphed
Add>>
<<Remove
Temperatures
Time
User: guest
TCS Computer: localhost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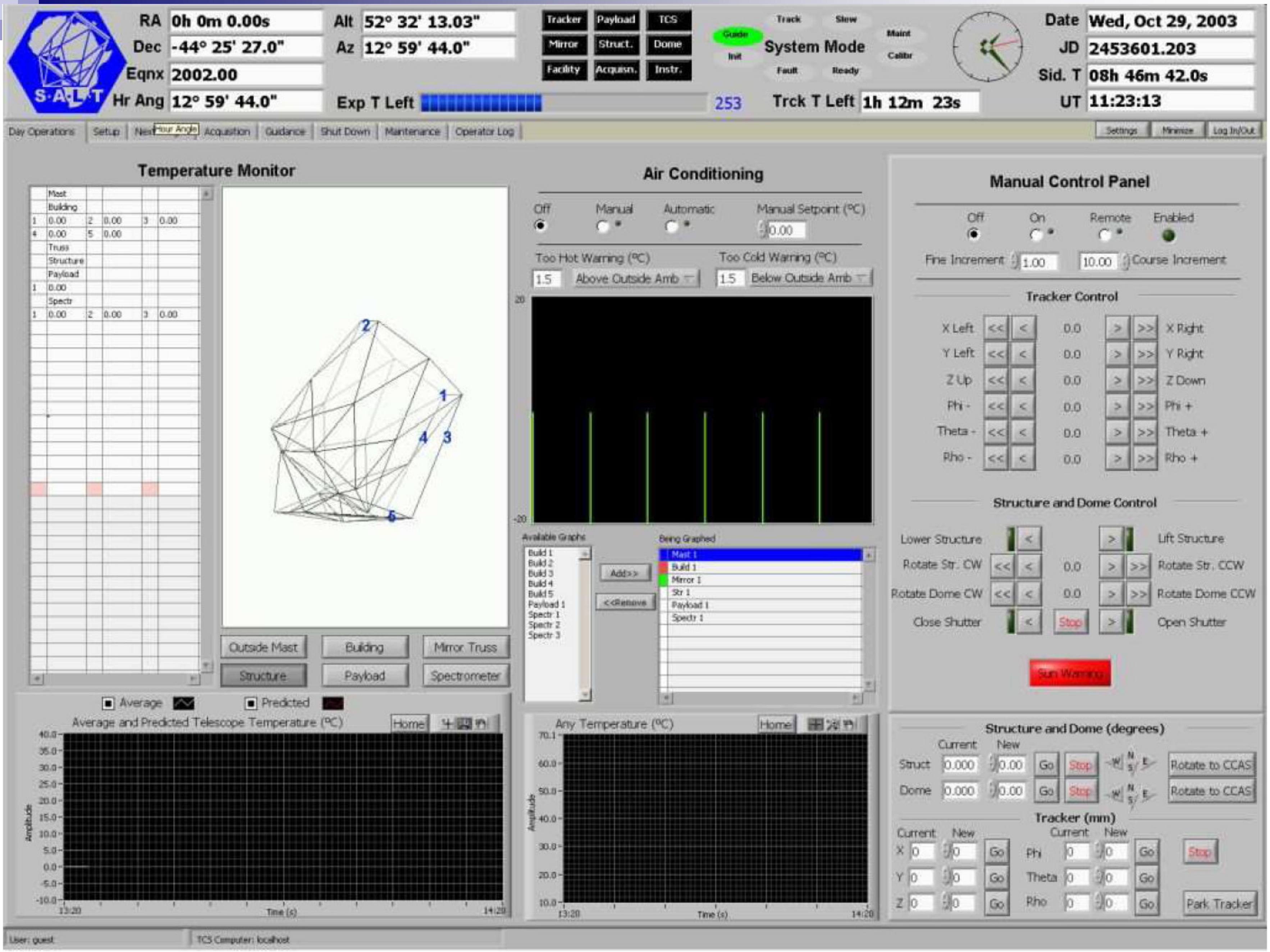
UT 11:29:01
Day Operations Setup Next Target Acquisition Guidance Shut Down Maintenance Operator Log
Settings Minimize Log In/Out
Acquisition Camera
Tracking Adjust
Telescope Track
X Offset 0.00
Y Offset 0.00
Z Focus 0.00
Rho Offset 0.00
Pupil Size 0.0
Air Mass 0.0000
Intended Payload Configuration
SALTICAM Mirror None
Auxiliary Mirror None (PFIS)
Guidance Source SALTICAM Probe
Instrument to Use SALTICAM
Switch to Payload Configuration >>
Current Payload Configuration
ADC
Moving Baffle
SALTICAM Auxiliary Focus
SAC
PFIS
Fibre Feed
Position Units RA and Dec
Cursor Position
RA
Dec
Guide Probe Pos
RA 0h 0m 0.00s
Dec 0° 0' 0.0"
SALTICAM Mirror None
Auxiliary Mirror None (PFIS)
Guidance On
Instrument to Use SALTICAM
Instrument Configuration
Calibration Screen In
Guidance Source SALTICAM Probe
Calibration Source Halogen
Moving Baffle X 0.00
Moving Baffle Y 0.00
ADC Rotation (°) 0.00
ADC Prism Distance 138.78
Exposure Time (s) 0.0
Binning (row x col) 2 x 2
Filter 1-UVA
SALTICAM Guidance
Save This Image
Fast Readout
Slow Readout
No Readout
Bright Gain
Faint Gain
FT Mask NONE
Shutter Open
Move Rotate Apply Cancel
X 0
Y 0
Angle 0.0
User: guest
TCS Computer: localhost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Day Operations Setup Acquistion Guidance Shut Down Maintenance Operator Log
Settings Minimize Log In/Out
Temperature Monitor
Mast Building Truss Structure Payload Spectr
Outside Mast Building Mirror Truss
Structure Payload Spectrometer
Average Predicted
Average and Predicted Telescope Temperature (ºC)
Amplitude
Time (s)
Air Conditioning
Off Manual Automatic Manual Setpoint (ºC)
Too Hot Warning (ºC) Too Cold Warning (ºC)
1.5 Above Outside Amb 1.5 Below Outside Amb
Available Graphs
Being Graphed
Add>> <<Remove
Any Temperature (ºC)
Manual Control Panel
Off On Remote Enabled
Fine Increment 1.00 10.00 Course Increment
Tracker Control
X Left X Right
Y Left Y Right
Z Up Z Down
Phi - Phi +
Theta - Theta +
Rho - Rho +
Structure and Dome Control
Lower Structure Lift Structure
Rotate Str. CW Rotate Str. CCW
Rotate Dome CW Rotate Dome CCW
Close Shutter Stop Open Shutter
Sun Warning
Structure and Dome (degrees)
Current New
Struct 0.000 0.00 Go Stop Rotate to CCAS
Dome 0.000 0.00 Go Stop Rotate to CCAS
Tracker (mm)
X Y Z Phi Theta Rho
Go Stop Park Tracker
User: guest
TCS Computer: localhost