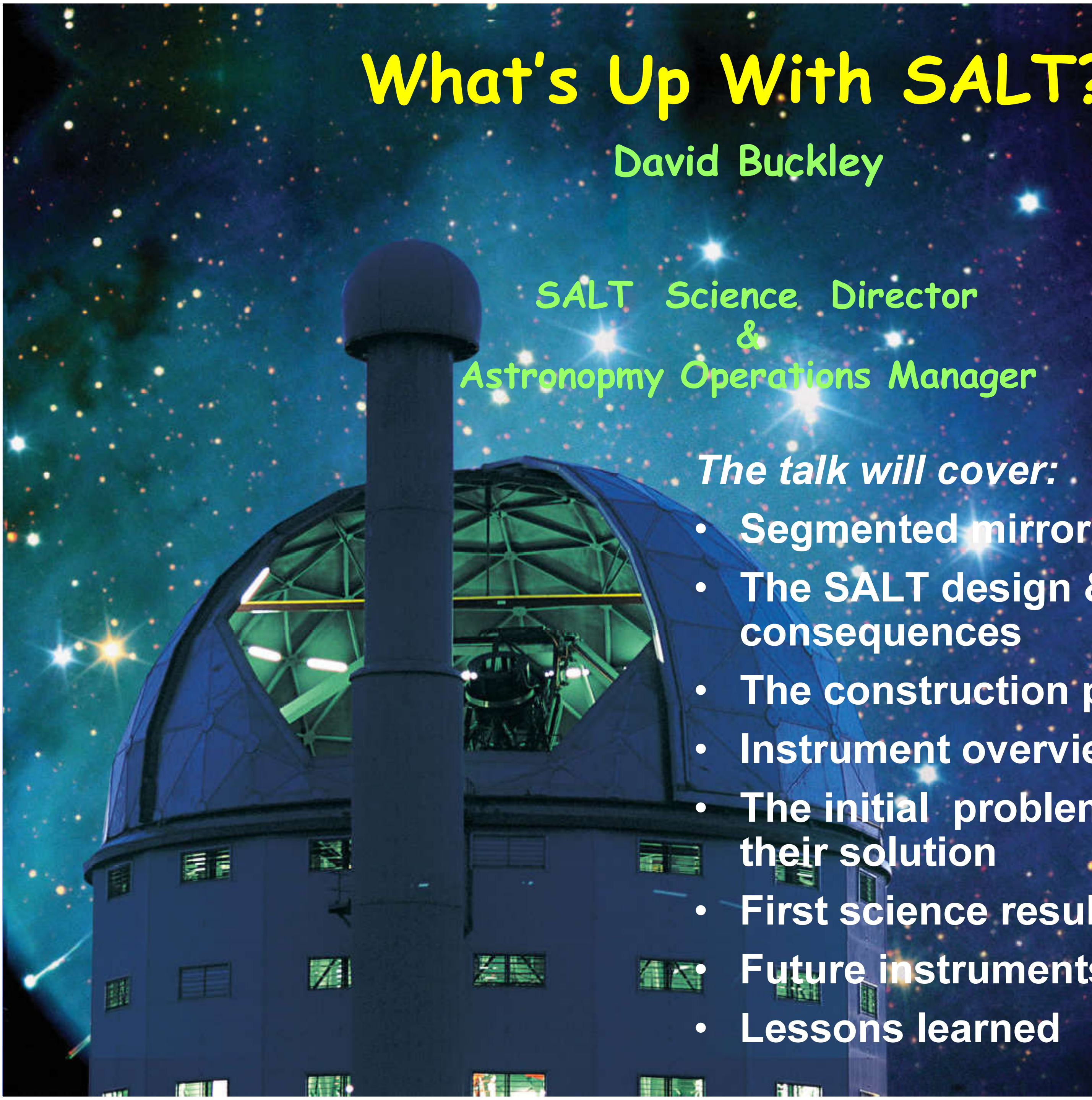
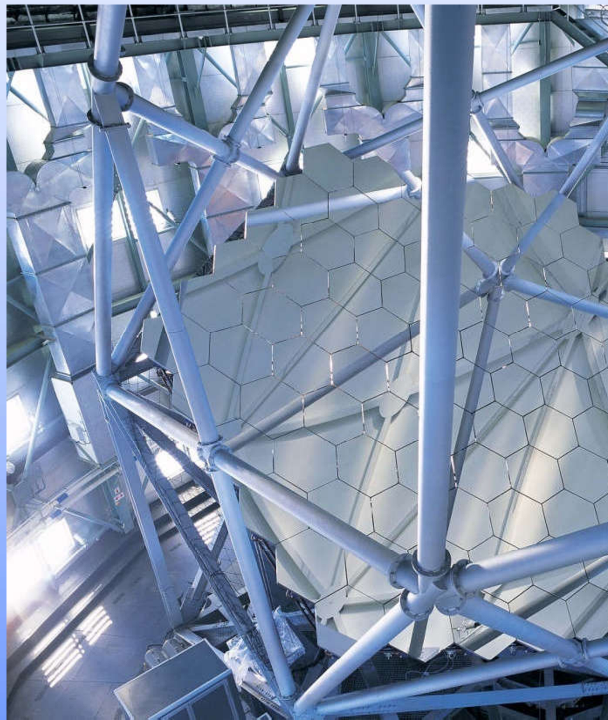

What's Up With SALT?
David Buckley
SALT Science Director
&
Astronopmy Operations Manager
The talk will cover:
• Segmented mirror
• The SALT design &
consequences
• The construction p
• Instrument overvie
• The initial problem
their solution
• First science resul
• Future instrument
• Lessons learned

Giant Steps in Telescope Desi

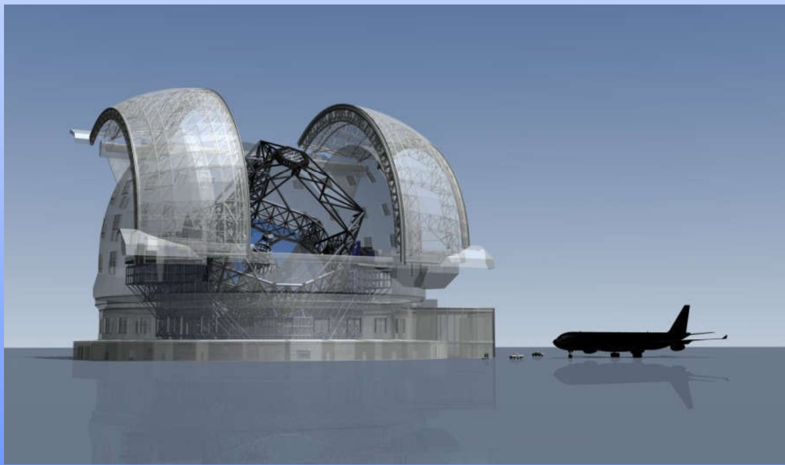
- Telescope invented ir
- First astronomical ob
  Galileo in July 1609
  - 37 mm diameter, f/2
  - largest now 10,000 m
    42,000)
  - ~70,000 times larger



SALT primary mirror array:

What Do Telescopes Do?

- They collect light (electromagnetic radiation)
- They form images of distant objects
- The images are analyzed by instruments
  - The human eye
  - Photographic plates/film
  - Digital detectors (e.g. CCDs)



Technology developments
Astronomy HUGELY!

- bigger & better teles
- more sensitive and cl

Left: Design concept for th
Extremely Large Telescope
cost ~€ 2B and take ~10 y
(Airbus A340 on same scale

Innovations in telescope mirro
(from the 1990's)

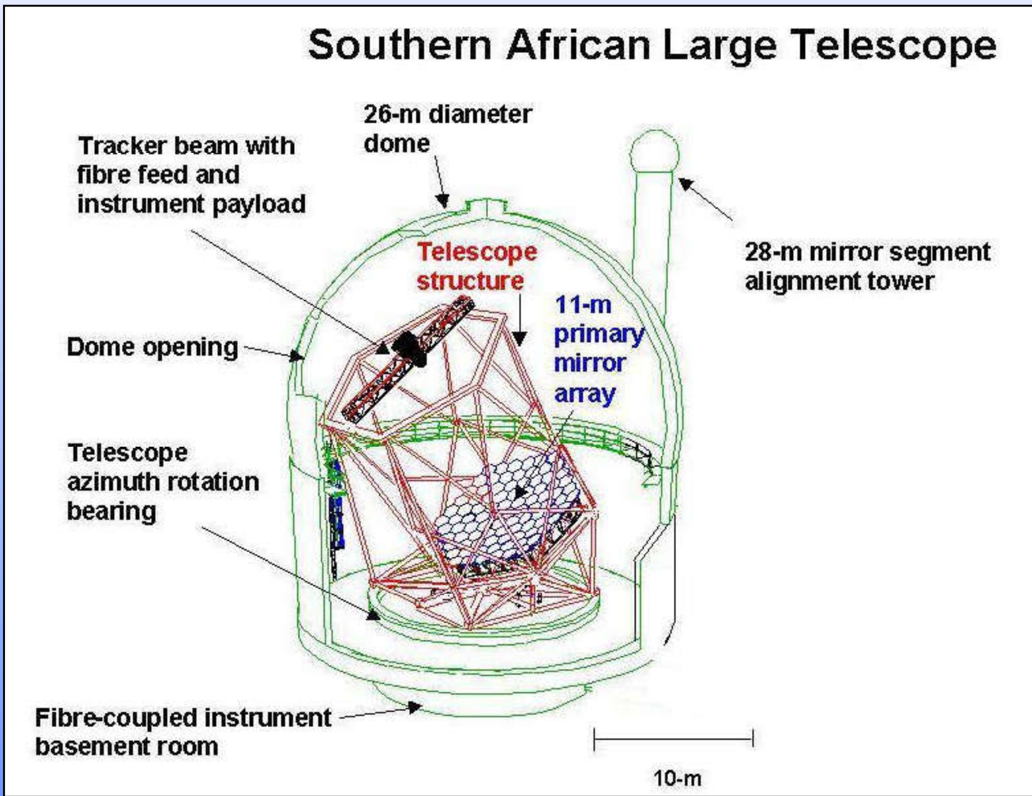
New innovations in telescope mirrors

- Meniscus mirrors (thin)
- Spun-cast mirrors (honeycomb)
- Segmented mirrors (e.g. SALT)

Innovative Telescope Mounts

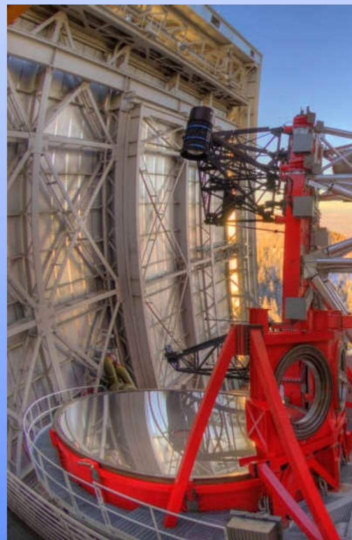
New types of mounts:

- Large Binocular Telescope (LBT)
  - Two co-aligned telescopes on a common mount
- SALT & HET
  - Tracking done with prime focus tracker



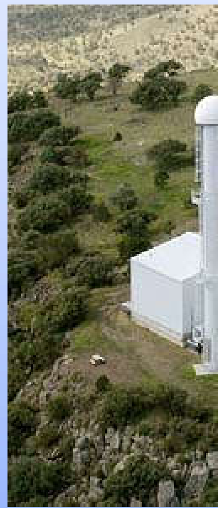
SALT (2005)

Twin 8.4



The "Big Five": Segmented M Telescopes

- Keck I (1993) & Keck II (1996): Hawaii, USA
- HET (1999): Texas, USA
- SALT (2005): South Africa
- GRANTECAN (2009:) Canary Islands, Spain



These telescopes have the largest light grasp

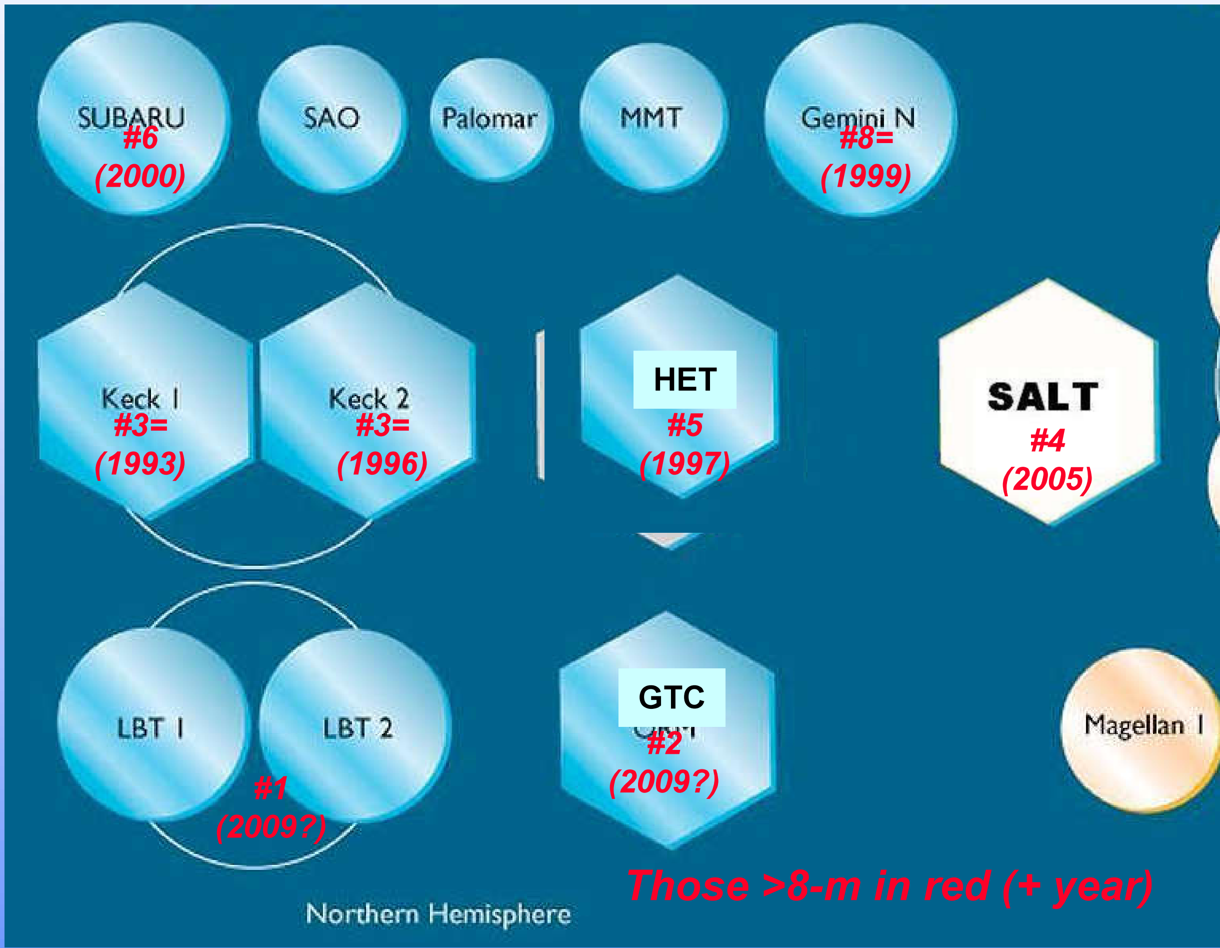
SALT is the only one in the southern hemisphere

Some also use *adaptive optics* to get sharper images, particularly at longer wavelengths (IR)

League Rankings of the Largest Telescope

Rankings:

1. LBT 2 x 8.4 m (≡ 12 m)
2. GTC 10.4 m
3. 2 x Keck 9.8 (≡ 14 m for interferometry)
4. SALT 10 m (unfilled pupil)
5. HET 9 m (unfille
6. Subaru 8.3 m
7. VLT 4 x 8.2 m (≡
8. Gemini 2 x 8.1 m

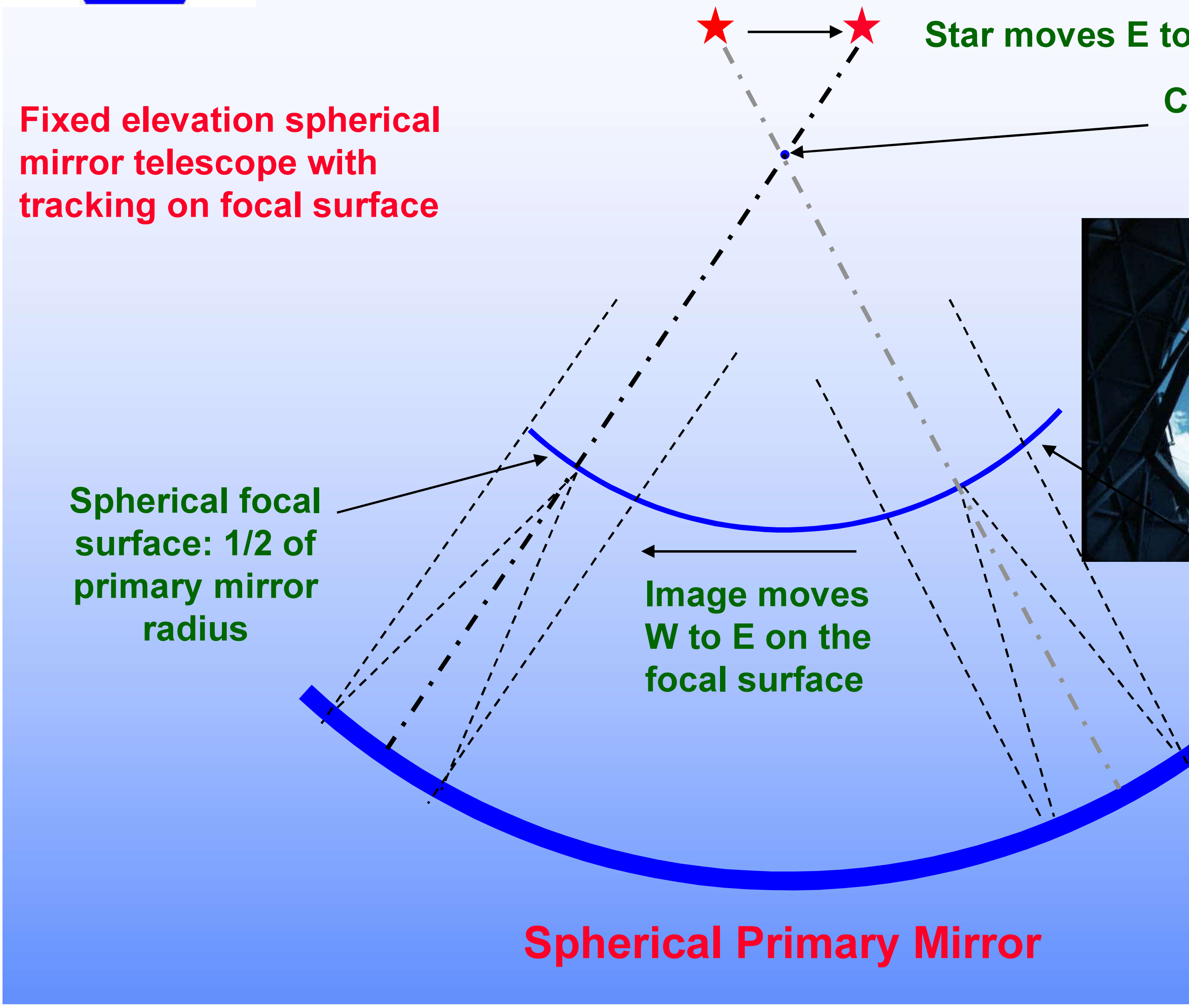


SALT: the southern hemisphere version of Hobby Eberly Telescope (HET) in Tex

SALT: A ‘fixed’ Altitude Teles

SALT is the optical analogue of the (zenith poi radio telescope, except its tilted to Z.D. = 37°

The Arecibo Tracking Concept: extended to optical telescopes



SALT: *A Tilted Arecibo-like Optical-IR Telesc… the Hobby-Eberly Telescope (HET)*

BASIC ATTRIBUTES

- PRIMARY MIRROR ARRAY
  - Spherical Figure
  - 91 identical hexagonal segments
  - Unphased (i.e. not diffraction limited 10-m, just 1-m)
  - Mirrors (*Sitall:* low expansion ceramic) supported on a steel structure
- TELESCOPE TILTED AT 37^o
  - Declination Coverage +10^o < δ < -75^o
  - Azimuth rotation for pointing only
- OBJECTS TRACKED OVER 12^o FOCAL SURFACE
  - Tracker executes all precision motions (6 d.o.f.)
  - Tracker contains Spherical Aberration Corrector (SAC) with 8 arcminute FoV (*Prime Focus*)
- IMAGE QUALITY
  - Telescope error budget of ~0.7 arc-second FWHM
  - Designed to be seeing limited (median = 0.9 arcsec)

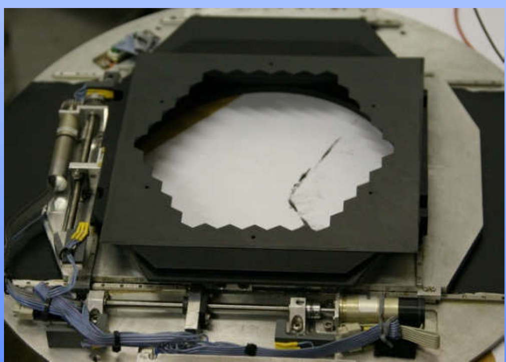
Peculiarities of SALT

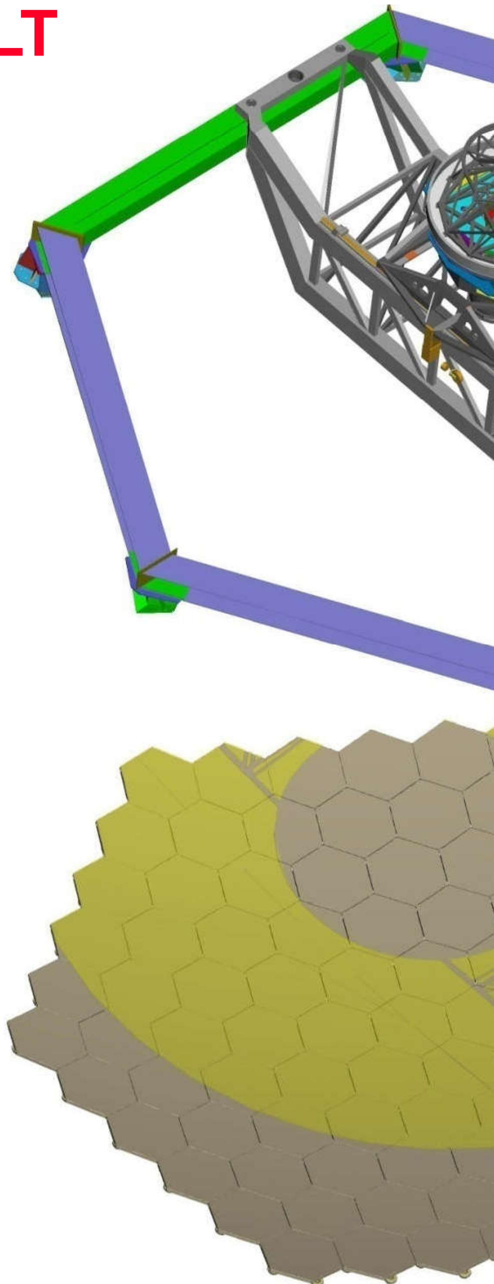
SALT/HET Tracking Principle

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

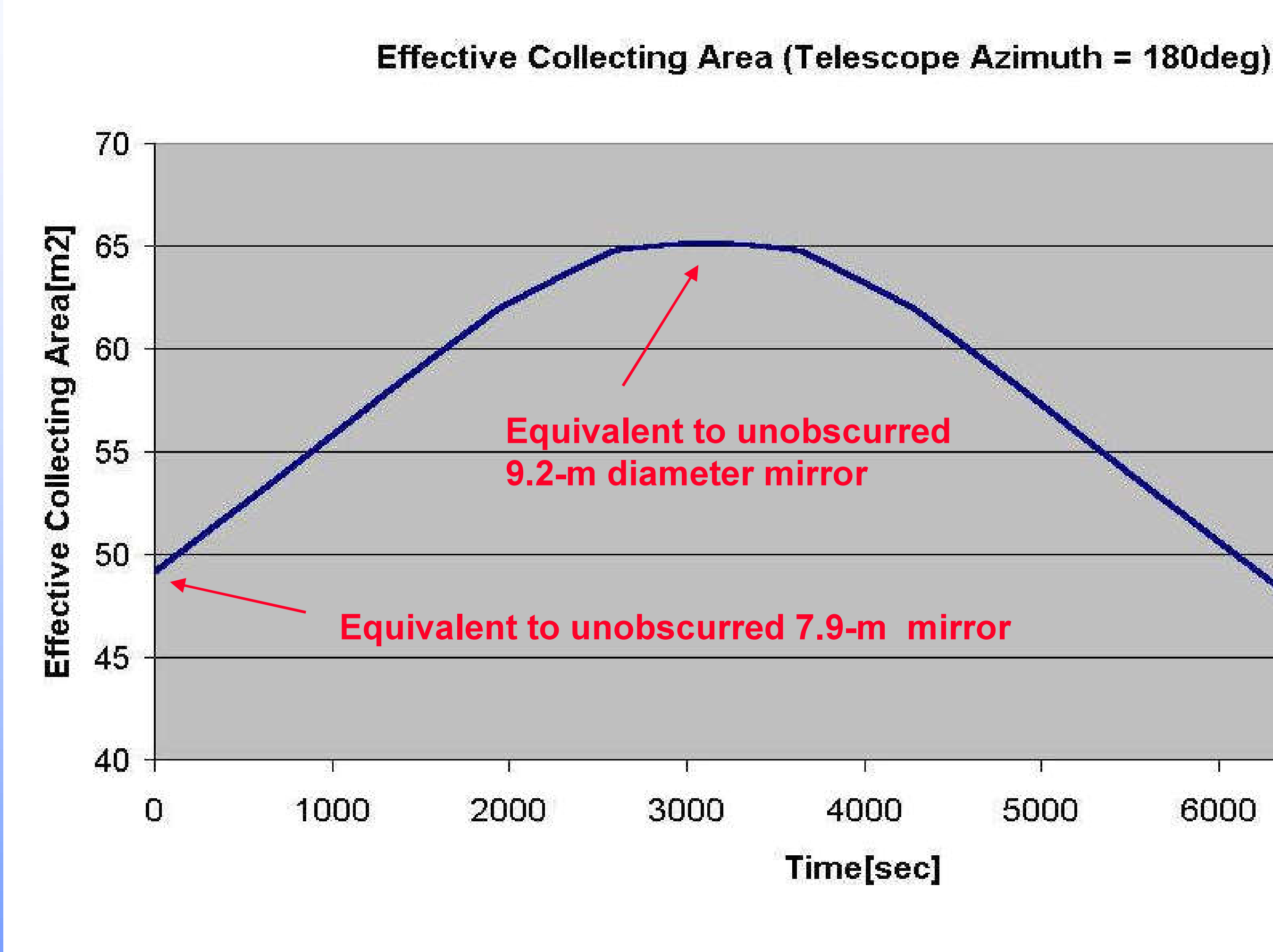
With tracker and 11-m pupil centred on primary mirror array and central obstruction (from SAC optics), equivalent to a 9 metre telescope.

Pupil is always underfilled
Pupil is baffled at exit pupil
- controls stray light
- used to simulate pupil for calibrations





SALT tracking characteristics



How SALT Observes: Restricted View

Annulus of visibility for SALT:

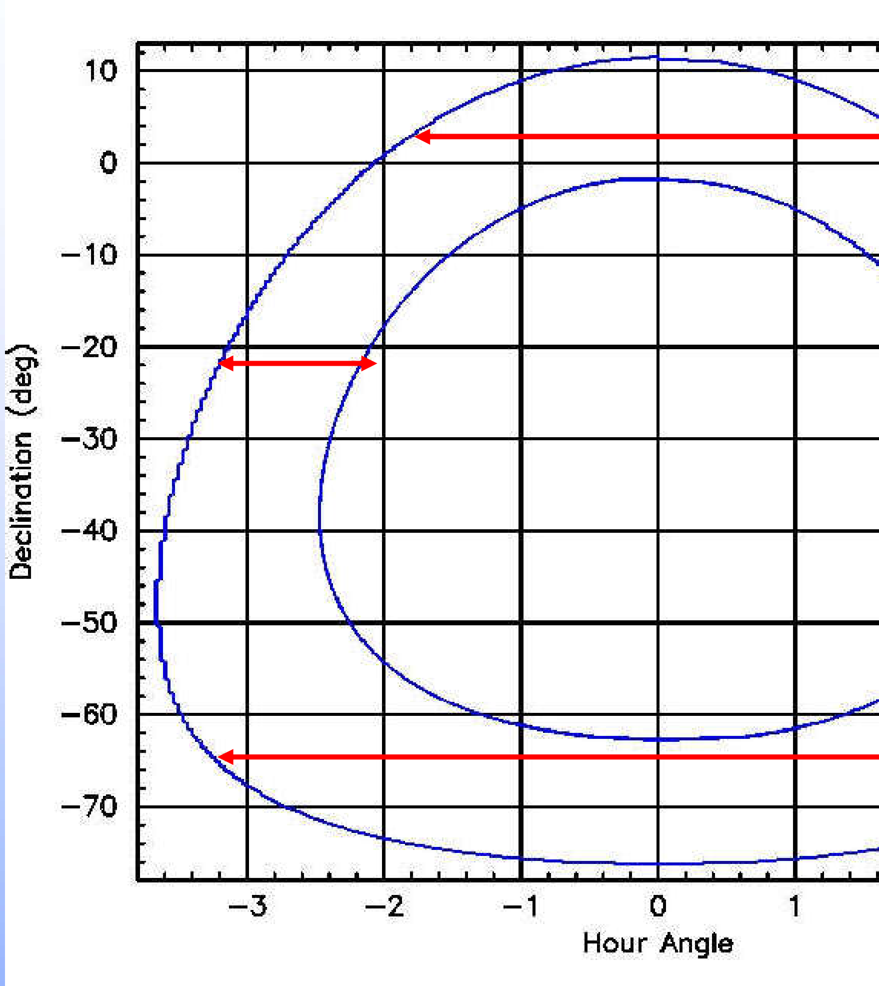
Annulus represents 12.5% of visible sky

Declination range: +10º to -75º

Observation time available = time taken to cross annulus

***But* tracker only has limited range ⇒**

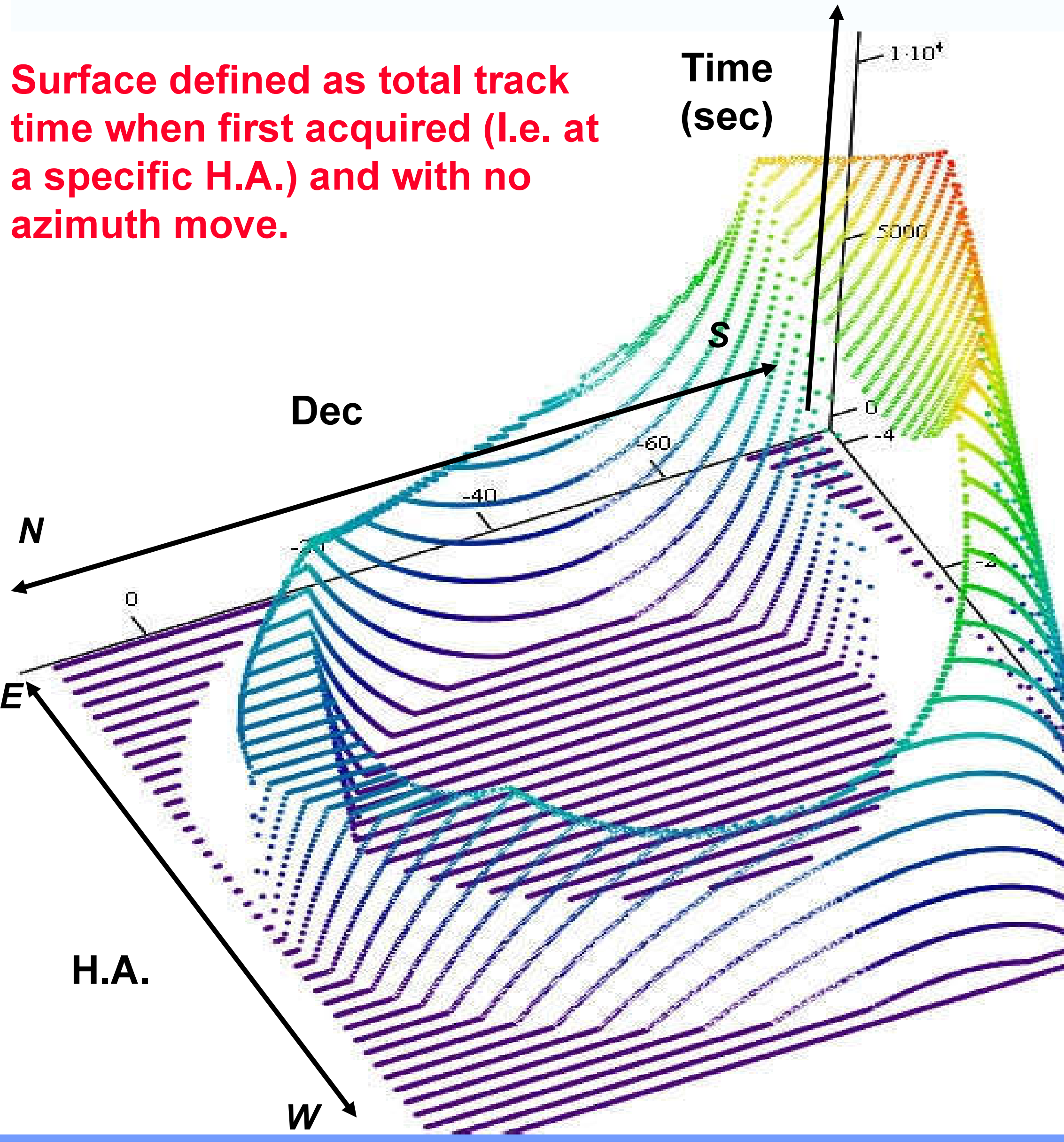
Additional azimuth moves needed to achieve full obs. time



Implies that all SALT observations have to be queue-sch

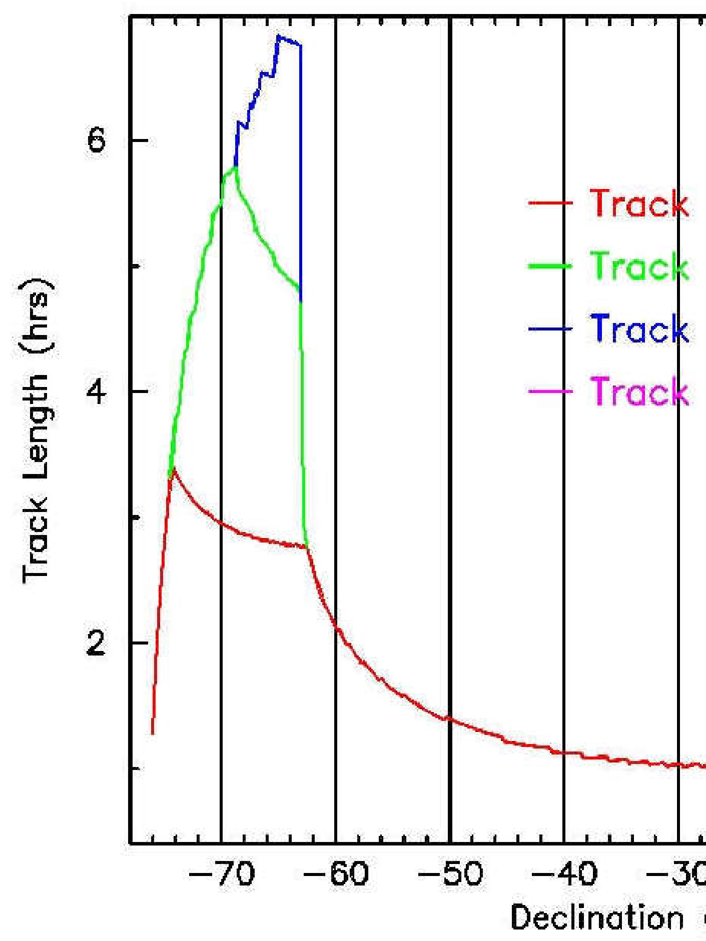
SALT Track Su

Surface defined as total track time when first acquired (I.e. at a specific H.A.) and with no azimuth move.

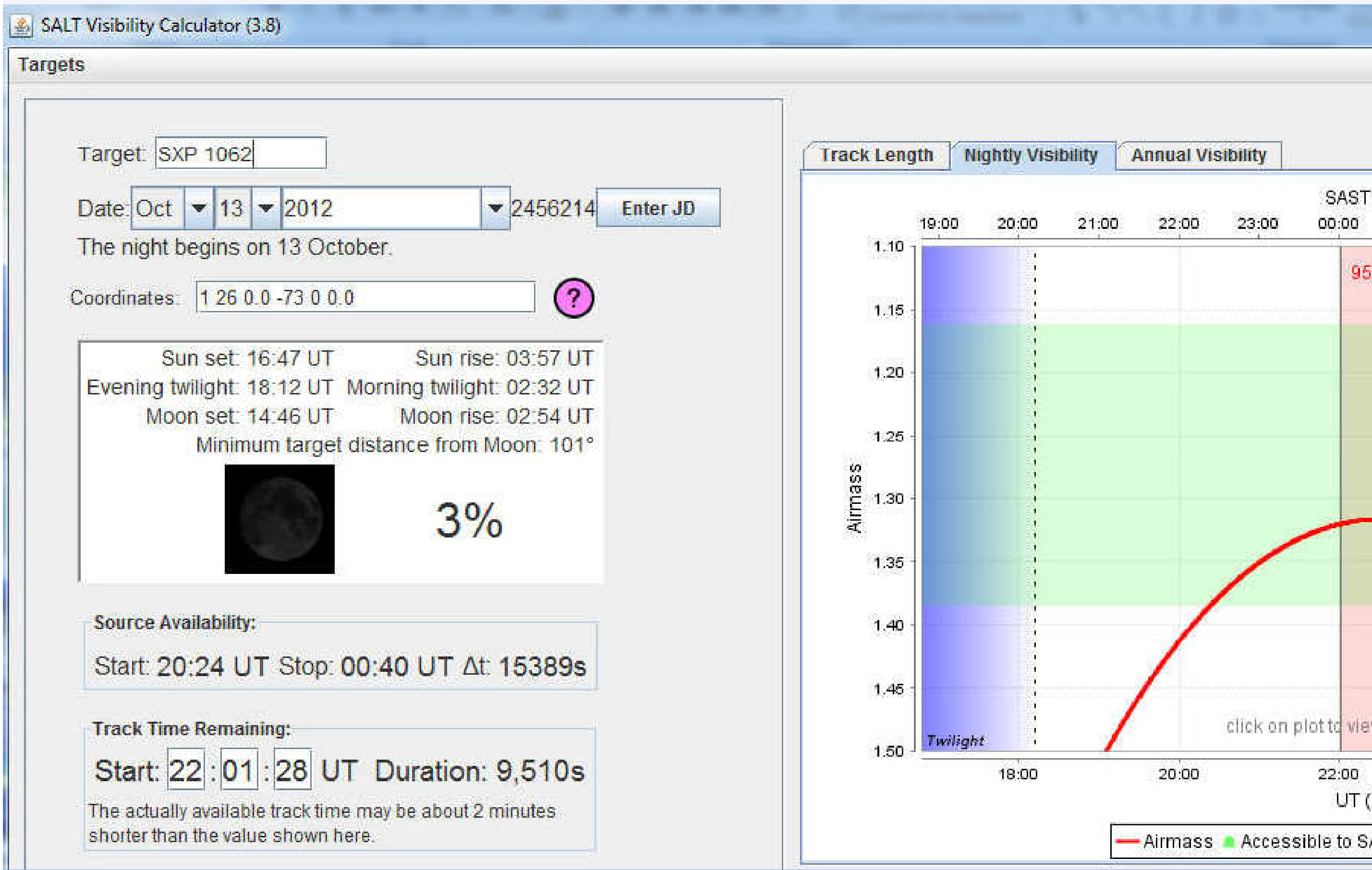


SALT Track Times

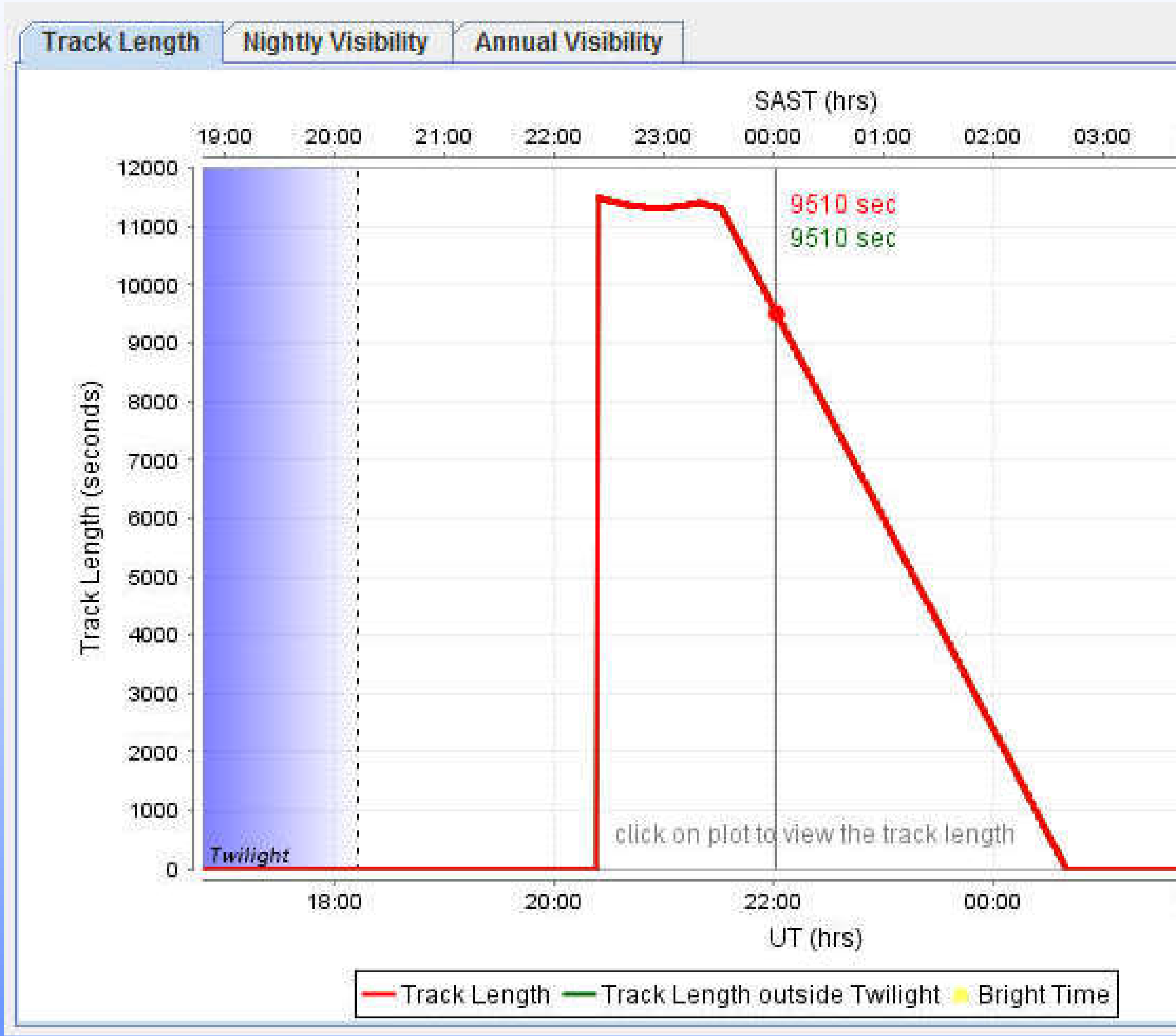
- **Observation times can be extended by successive azimuth moves for extreme Declinations**
- **Limited track lengths mean that ALL observations are queue-schedule**
- **Multiple observing programs with different instruments/modes can be done in one night**
- **Observing HAS to be efficient**
  - **Minimum instrument set-up time**
  - **Minimum slew and target acquisition time**
  - **Holistic Observation Control System**



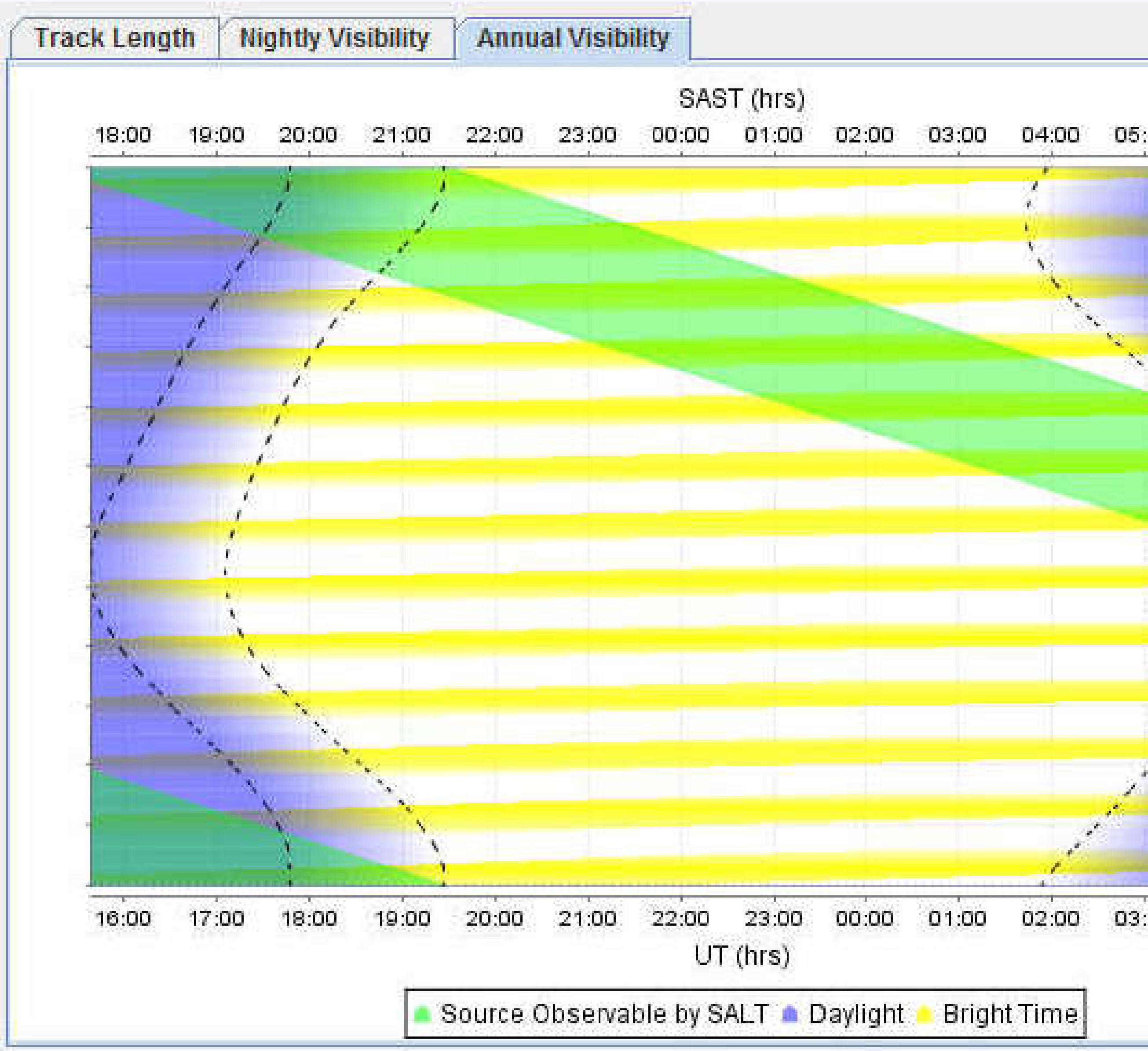
The SALT Visibility Tool: How to determine when a particular to SALT



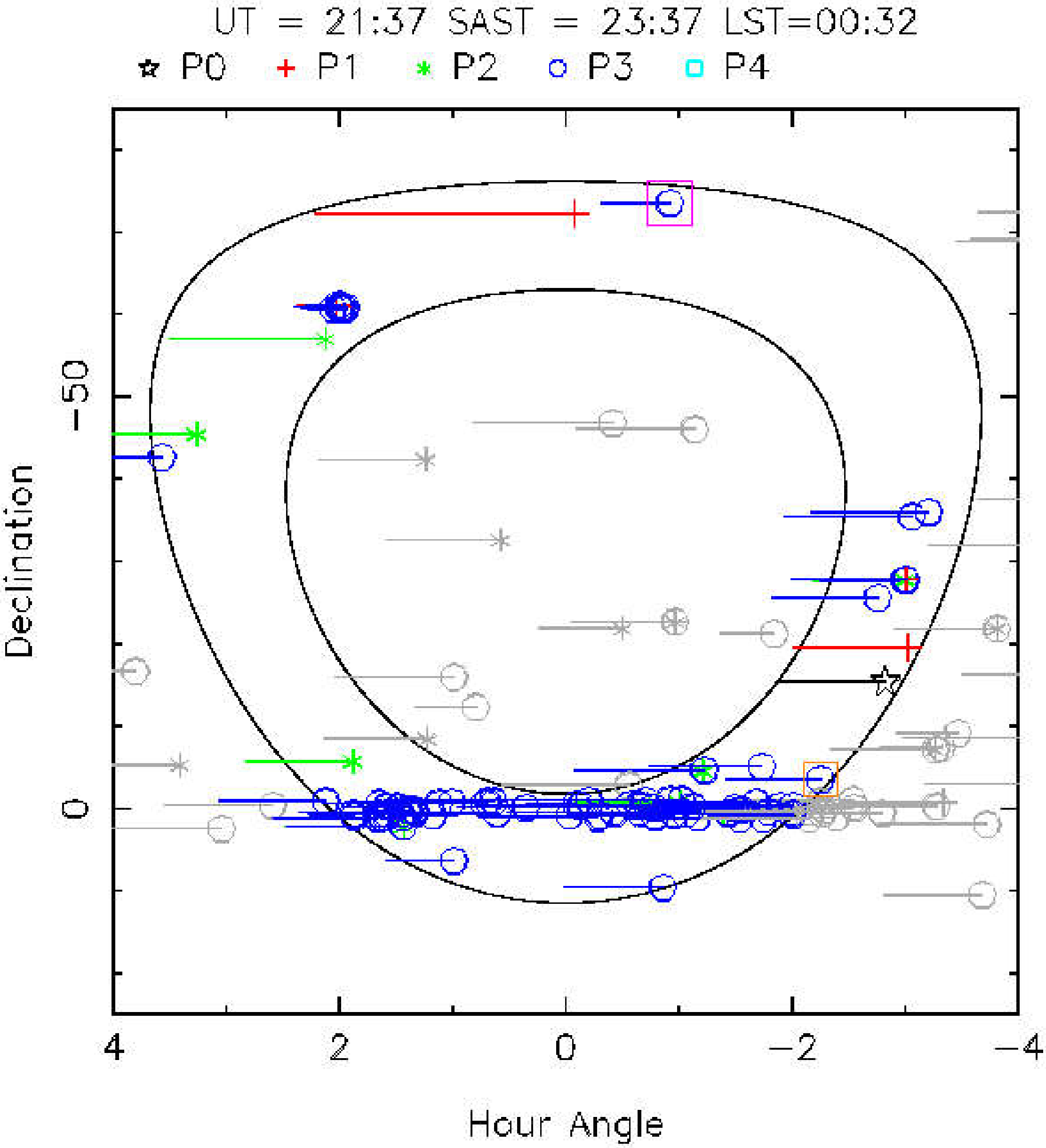
The SALT Visibility Tool:



The SALT Visibility Tool:



SALT Scheduling & Planning Tool:



SALT Efficiency

Comparisons of Time Breakdowns: other te

Because of the limited window, SALT has to b

Telescope	Bad weather	Technical problems	Engineering & Calibrations	Movin acquis overh
Keck I	16%	4%	11%	26%
VLT	12%	2%	5%	15%
Gemini	20%	3%	10%	15%
HET (original)	30%	6%	20%*	18%
SALT spec	25%	3%	7%*	15%

* Including mirror alignment

**Defined as shutter open plus CCD readout time

Design innovations for SALT

Because of the valuable lessons learnt from H.E.T., p engineering approach and improvements made pos technological advances and sourcing products glob benefited and is expected to have *greatly improved*

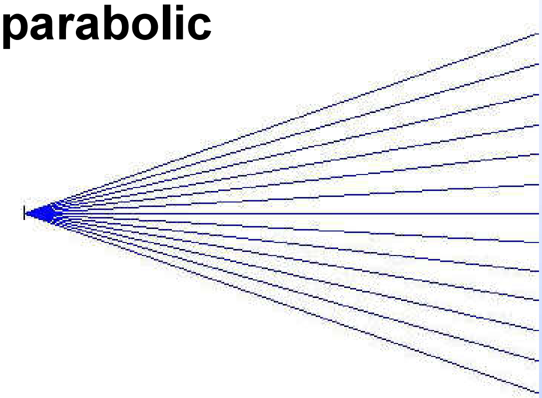
- **Improved optical design (the Spherical Aberration Corrector) by** ***delivering larger field, better image quality.***
- **Larger effective collecting area by increasing pupil size (11-m di** ***15% increase in light collecting power.***
- **More efficient protected silver-aluminium multi-layer coatings (L** ***much improved blue/UV performance (320 < λ < 450 nm).***
- **Holistic integrated payload design, increased mass budget (~10 carbon composites.** ***Enhanced capabilities, 4 foci, relatively easy***
- **Prime focus instruments (e.g. Wisconsin's *PFIS*) planned from th larger mass/volume envelope.** ***Very versatile instrument deliveri polarimetry, Fabry-Perot, high time resolution, VPH gratings).***
- **Different primary mirror segment alignment system (e.g. Shack- the use of capacitive edge sensors on the mirror segments will g** ***more stable, sharper, images.***
- **Use of natural ventilation (e.g. louvres) and aggressive attitude t lead to** ***better image quality.***
- **Used graphical programming language LabVIEW to do all telesc prototyping & development, quick to debug, easy to integrate, go**


SALT Performance Requiremer
Image quality: EE(50) ≤ 0.6"
Throughput: Optimised fo
Field of View: 8 arcmin diar
Pupil size: 11m (unfilled
Availability/Efficiency: >90%, >50%
Operating environment:
Normal: 0 to 20°C, ≤ 60
Marginal: -10 to 25°C, ≤ 7
Survival: -20 to 45°C, ≤ 2
Maximum acquisition time: 3 min
Normal acquisition time: ≤ 1 min for 9
Guide object ≤ 19th magni
Degradation of site seeing: ≤ 0.2"
Primary Mirror alignment:
Optical (tip & tilt): 0.05" (once pe
Edge sensing (tip & tilt): 0.06" (continu
Piston ±10μm
Global radius of curvature measurement & control
Not phased (growth path)
Three First Generation instruments: SALTICAM, F

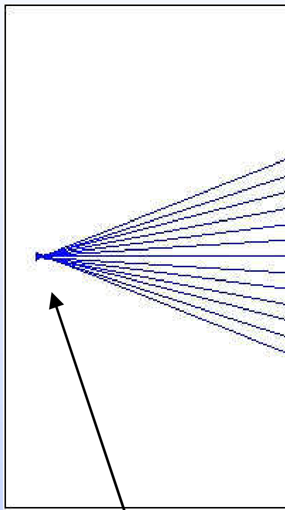
Spherical Aberration in the HET

Perfect image

If the primary were parabolic

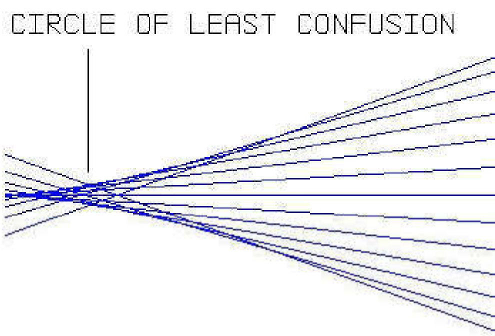


… BUT the primary is spherical



Prime Focus

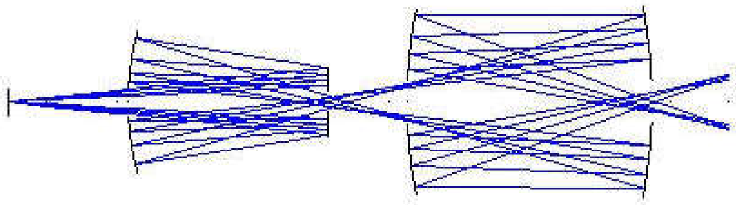
Very bad Image: ~10 arcmin, about 1/3 size of moon



Therefore both HE
employ a prime-fo
Aberration Correc

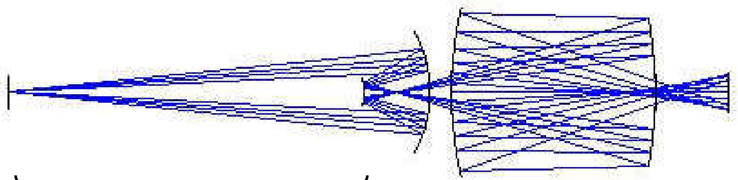
Spherical aberration correct
comparisons

HET SAC

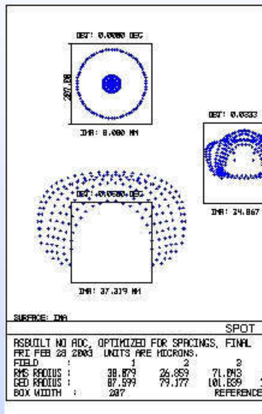


Focal Plane

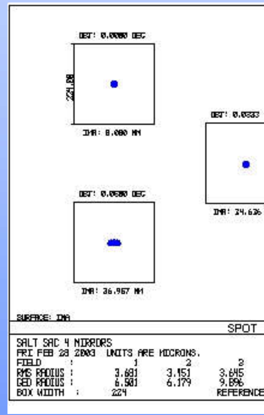
SALT SAC



Large back focal distance

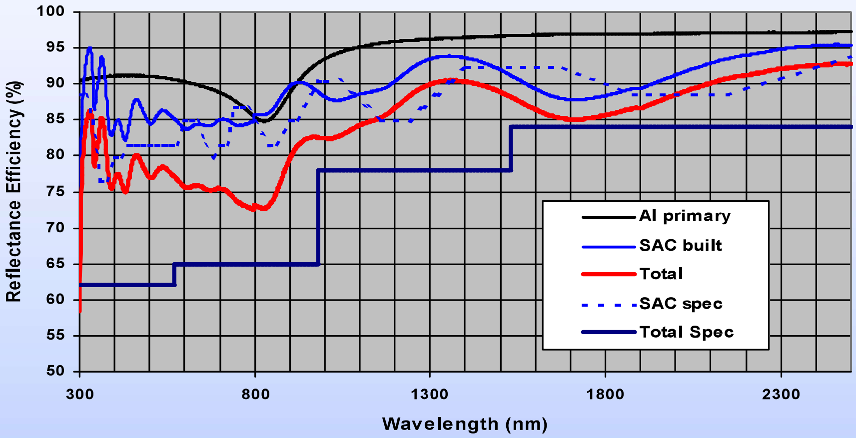


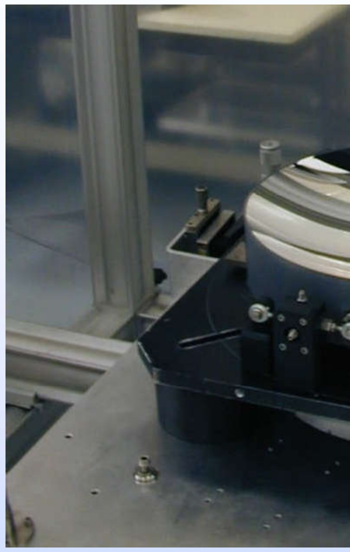
Spot

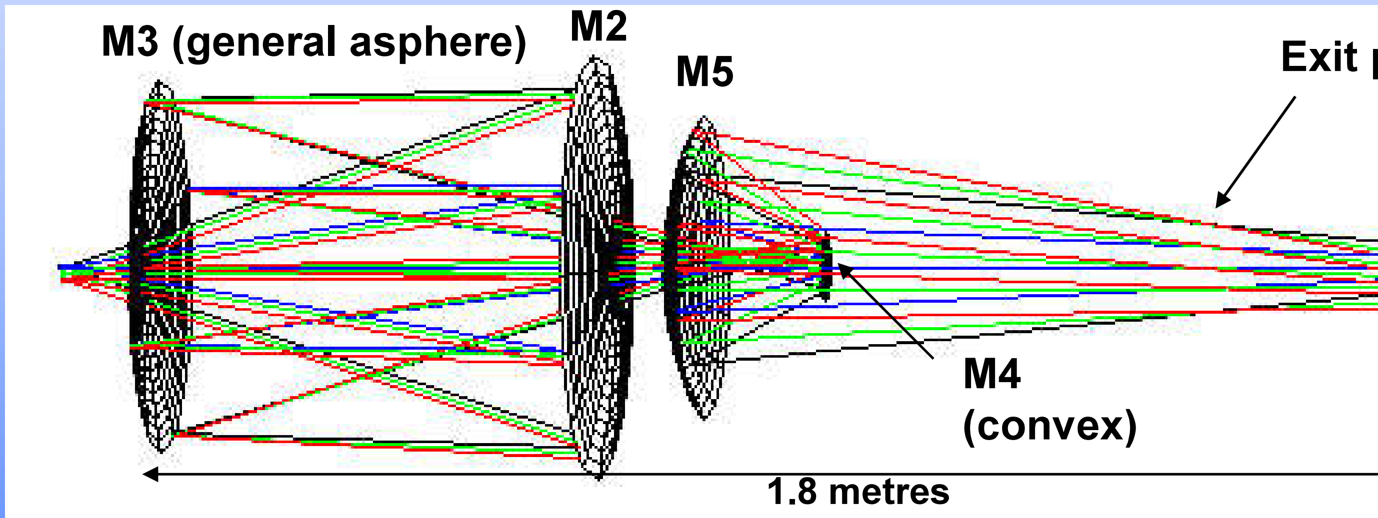


SALT Spherical Aberration Correct

- Contracted to SAGEM/REOSC (France)
- All mirrors coated with LLNL multilayer coating (Ag/Al)



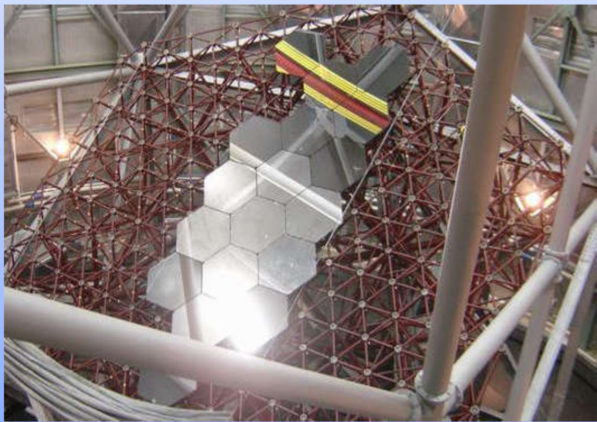




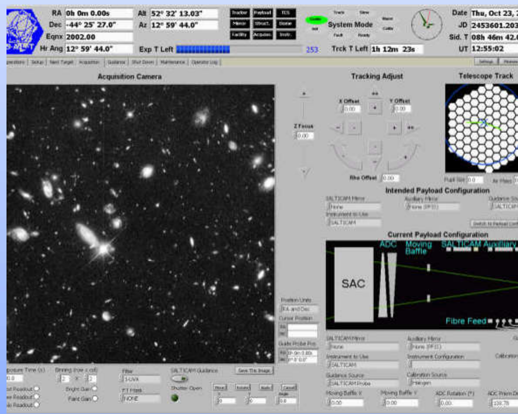
The Telescope Subsysten

Structure & Dome

Facility Building & Services



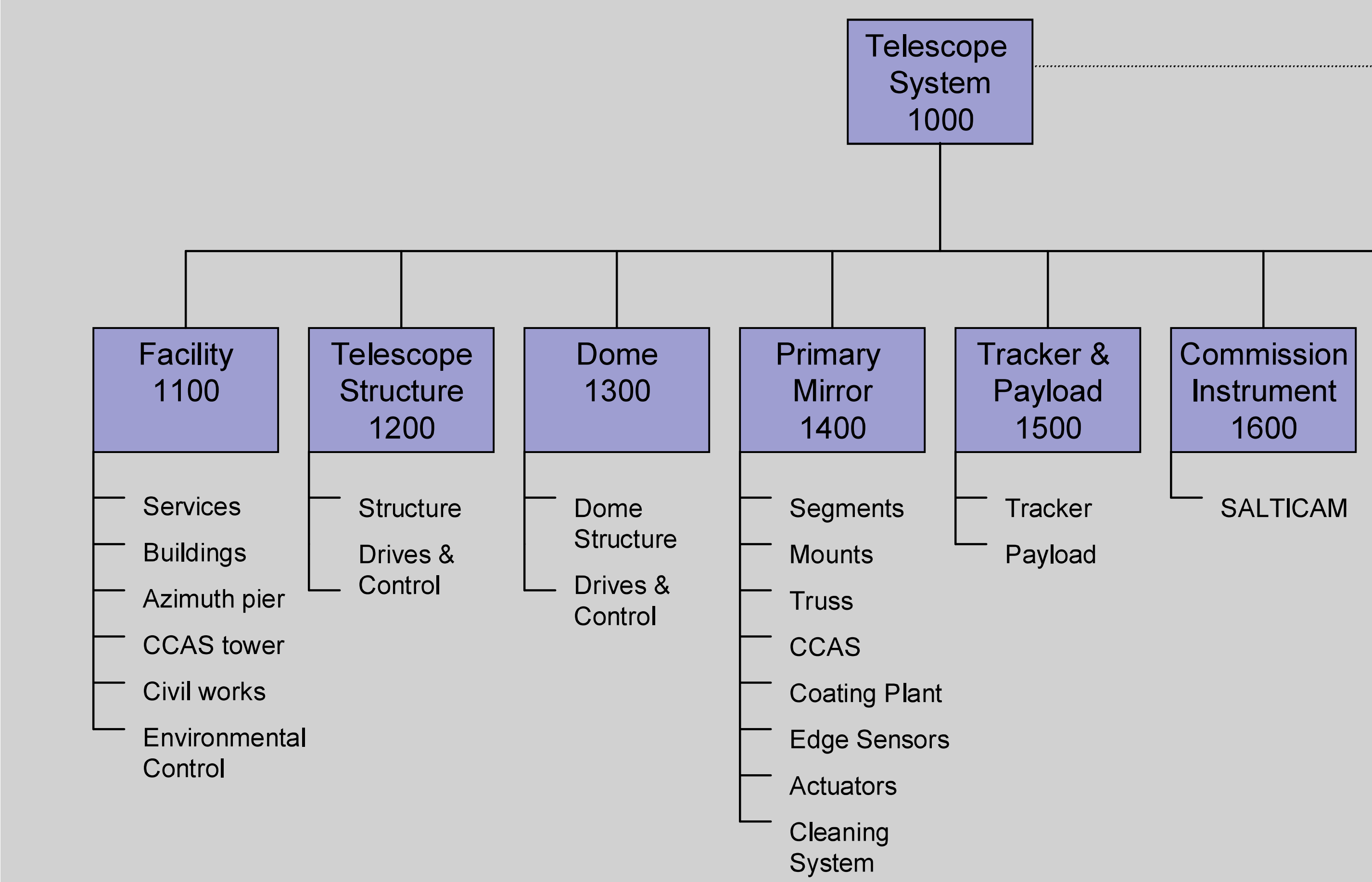
Primary Mirror System



Software

How was the SALT Construction

SALT Hardware Breakdown



Major subsystems had Project Managers responsible 'from cradle to grave', i. through to commissioning. These individual subsystems were contracted out

Exceptions: design of payload (Prime Focus Payload, including guiding/focus baffles, calibration system), TCS software.

SALT Science

SALT IDEALLY SUITED TO THE FOLLOWING TYPES OI

- ***Survey Spectroscopy:*** **Where astronomical targets ar distributed on the sky and have sky surface densities square degree OR are clustered on a scale of a few ar**
  - **Tracker window (12 x 12 deg) / field of view of SALT (8 x 8 arcn**
- ***Time variability studies:*** **on time scales of ~0.08 sec u or > a day (photometry, spectroscopy, polarimetry)**
- ***Multi-wavelength studies:*** **Ideal suite of UV-visible ins large telescope aperture and flexible scheduling**
- ***Unique capabilities:*** **Highly competitive spectroscopy from UV (320 nm to 900 nm initially, extending eventu NIR).**
  - **Wide range of parameter space & multiplex advantage (R = 370 objects; F-P spectroscopy of 1000's of objects.**

Queue scheduling will give the SALT a unique ability for fle allowing for time sampled programs

SALT Science has so far exploited mostly high-speed imagin spectroscopy.

SALT First-Generation Science Instr

- Instruments chosen to give SALT a wide range of ca
- Ensure competitiveness with niche operational mod
  - UV, Fabry-Perot, high-speed, polarimetry
- Take advantage of SALT design and *modus operand*
- Nominally budgeted for 3 "first generation" instrum
- First two completed & installed, third being built
- First two ('first light') instruments:
  - SALTICAM: a $0.6M sensitive "video camera" (up to ~
  - Robert Stobie Spectrograph (RSS): a ~$5M versatile in spectrograph
- Last one is the fibre-fed High Resolution Spectrogra
  - Design completed 2005
  - Contract awarded (U. Durham) in 2007
  - Commissioning due to begin early 2012

SALTICAM (built at SAAO)
PI: Darragh O’Donoghue

An efficient “video” camera over entire science FoV (8 arcmin).

Efficient in the UV/blue (capable down to atmospheric cutoff at 320nm)

Capable of broad and intermediate-band imaging and high time-resolution (to ~70 ms) photometry.

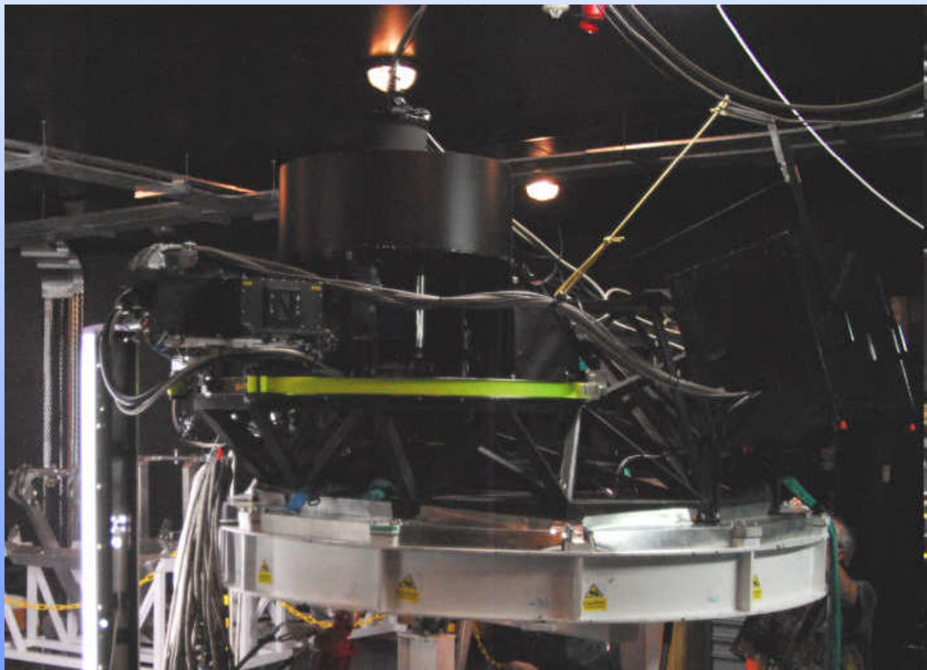
Fulfills role as both an acquisition camera and science image (ACSI) and commissioning/verification instrument (VI).

SALTICAM AC

The Robert Stobie Spectrograph (F
(built at Wisconsin, Rutgers & SA
PI: Ken Nordsieck

An efficient and versatile Imaging Spectrograph

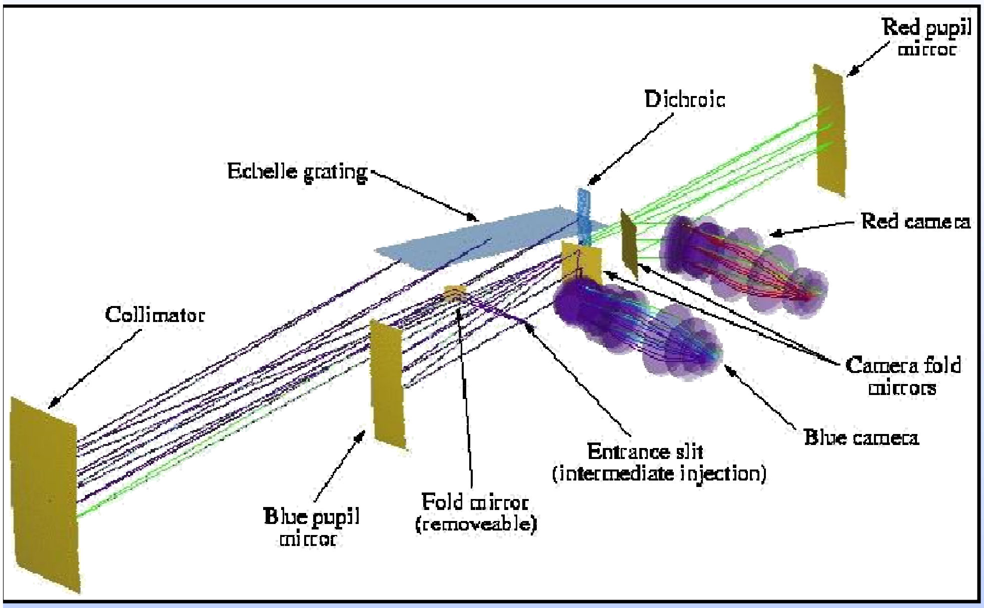
- capable of UV-vis spectroscopy (VPHGs)
- high time resolution ablility
- polarimetry capability
- Fabry Perot imaging (many narrow filters)
- multiple object spectroscopy
  - Can observe ~100 objects at once



RSS being tested in SALT spectrometer room (Mar 2011)

RSS installe

SALT High Resolution Spectrograph (H
3rd "First Gen" SALT Instrument



Fibre-fed with dua
subtraction and no

R ~ 16,000 – 70,000
λ ~ 380 – 890 nm

Designed for very *hi*
- **Housed in vacuun**
- **Temperature stab**
- **Minimize air index**
- **Minimize dimensi**
- **Precision radial v**
  - **extra-sola**

Under construction at Centre for Advanced Instrumentation, Durham University (UK)

- **Started in late 2007, assembly begun; commissioning early-2012**
- **Based on University of Canterbury CDR level design**