The Advanced Technology Solar Telescope

Status Summary

Steve Keil

http://atst.nso.edu

skeil@nso.edu
505 434-7039

The ATST Project is funded by the National Science Foundation through the National Solar Observatory which is operated by the Association of Universities for Research in Astronomy (AURA), Inc.

ATST US Collaboration

- **PI**
  - **National Solar Observatory**
    - ***Stephen Keil*, Thomas Rimmele, Christoph Keller, NSO Staff**
- **Co-PIs**
  - **HAO**
    - ***Michael Knölker*, Steve Tomczyk, Dave Elmore, Phil Judge, Tim Brown**
  - **University of Hawaii**
    - ***Jeff Kuhn*; Haosheng Lin, Roy Coulter**
  - **University of Chicago**
    - ***Bob Rosner*, Fausto Cattaneo**
  - **New Jersey Institute of Technology**
    - ***Phil Goode*; Carsten Denker, Haimin Wang**

Science Working Group

Ayres, T.	U of Colorado
Berger, T.	Lockheed Martin
Cattaneo, F.	U. of Chicago
Cauzzi, Gianna	Arcetri, Italy
Collados-Vera, M.	IAC, Spain
Deforest, Craig	SWRI
Gary, G. Allen	NASA/MSFC
Jennings, Donald E.	NASA/GSFC
Judge, Philip G.	HAO
Keller, Christoph U.	NSO
Kuhn, Jeffrey R.	IfA, U of Hawaii
Leka, K.D.	Colorado Research
Lin, Haosheng	IfA, U of Hawaii
Lites, Bruce W.	HAO
Palle, Pere	IAC, Spain
Rimmele, Thomas (Chair)	NSO
Sigwarth, Michael	KIS, Germany
Smaldone, L.	U. Naples, Italy
Socas-Navarro, Hector	HAO
Stein, Robert F.	U.of Michigan
Stenflo, Jan	ETH Switzerland
Tomczyk, Steve	HAO
Van Ballegooijen, Adriaan	CfA Harvard
Wang, Haimin	BBSO/NJIT

Site Survey Working Group

- Jacques Beckers – U. Chicago
- Tim Brown – High Altitude Observatory (Chair)
- Manolo Collados-Vera – Instituto de Astrofisica de Canarias
- Carsten Denker – New Jersey Institute of Technology
- Frank Hill – National Solar Observatory
- Jeff Kuhn – U. Hawaii - Institute of Astronomy
- Matt Penn – National Solar Observatory
- Hector Socas-Navarro – High Altitude Observatory
- Dirk Soltau – Kiepenheuer-Institut fuer Sonnenphysik
- Kim Streander – High Altitude Observatory

In House Eng/Management Team

- Project Scientist, AO – Thomas Rimmele
- Project Manager – Jim Oschmann
- Deputy Project Manager – Jeremy Wagner (acting PM)
- System Engineer – Rob Hubbard
- Mechanical Engineer – Mark Warner
- Optical-Mechanical Engineer – Ron Price
- Thermal Engineer – Nathan Dalrymple (USAF)
- Lead Software/Controls – Bret Goodrich
- Software Engineers – Steve Wampler / Janet Tvedt
- Facility Engineer – Jeff Barr
- Adaptive Optics Engineer – Kit Richards
- AO & Site Survey Manager – Steve Hegwer
- Optical Design – Ming Liang
- Admin Support – Jennifer Purcell
- Outreach – Dave Dooling

In-house Science and Instrumentation Team

• Project Scientist	–	Thomas Rimmele
• Narrowband Imaging	–	K. S. Balasubramaniam
• Near-IR spectrometer	–	Matt Penn
• Polarimetry	–	Christoph Keller
• Thermal IR	–	Han Uitenbroek
• Site Survey	–	Frank Hill
• Adaptive Optics	–	Maud Langlois, Gil Moretto
• Simulations	–	Uitenbroek, Balasubramaniam, Keller

The ATST

- How is it different
  - Open air, built in AO & aO, built in polarization modulation, larger aperture, coronagraphic capability
- Challenges
  - Limit telescope and instrumental seeing
    - Thermal control
    - Optics quality
    - M1 Figure – open air vs. wind loading
  - Cleaning – dust is the major enemy of coronal observations
- Design driven by instrumentation
  - Visible and IR polarimetry
  - Spectroscopy and narrow band imaging
- Why now?
  - Technology –
    - aO, AO
    - Thin mirror active support technology
    - Fast camera's
  - Modeling has outstripped observational capability

Goals of the ATST

- **Magnetic fields control the inconstant Sun**
- **The key to understanding solar variability and its direct impact on the Earth rests with understanding all aspects of these magnetic fields**
- **Magnetic fields are the “*dark energy*” problem of solar physics**
- **ATST designed specifically for magnetic remote sensing, careful flow down from science objectives to telescope parameters**

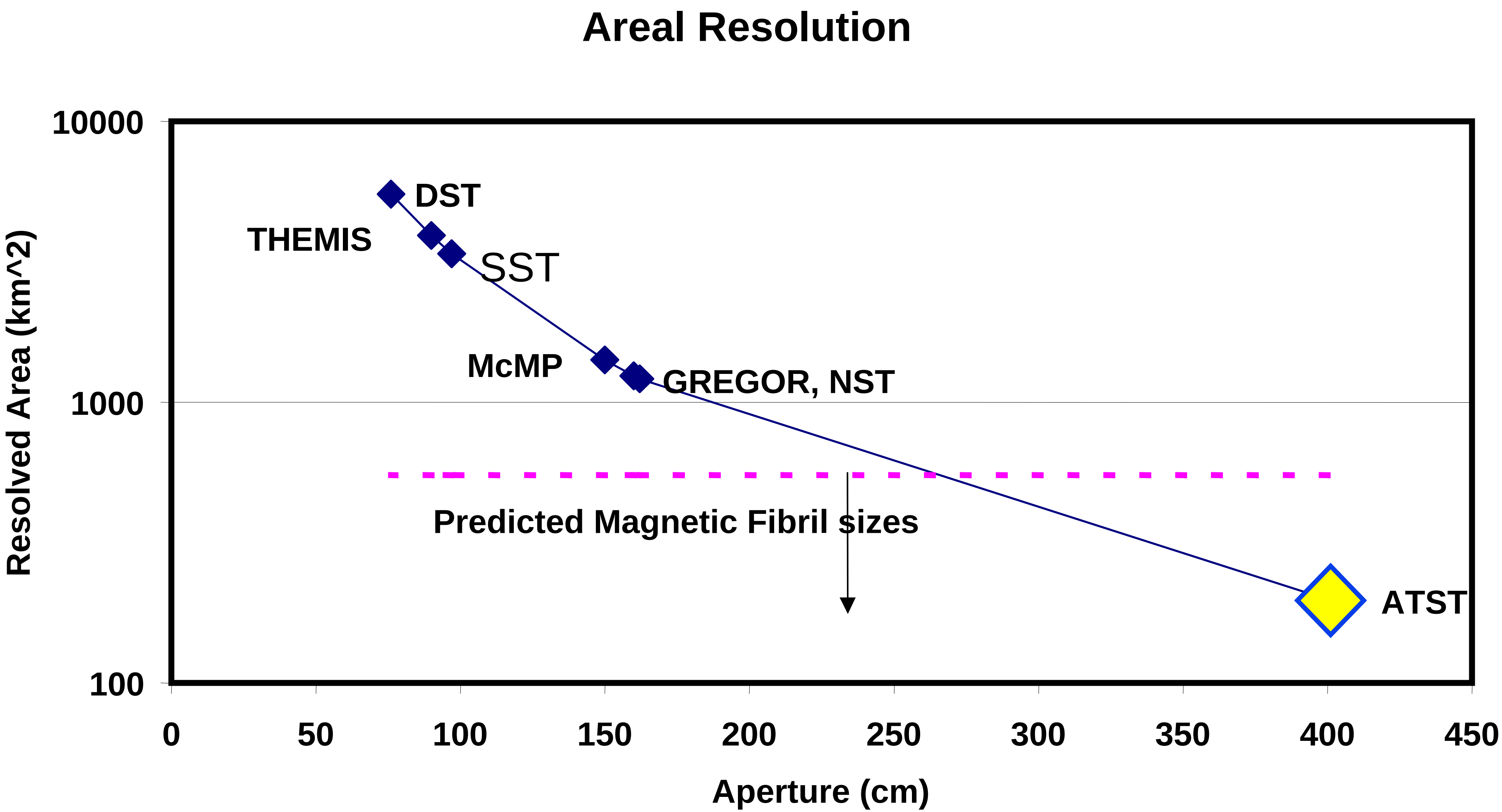
Test Models of:

- Magneto-convection
- Flux emergence, transport and annihilation
- Flux tube formation and evolution
- Sunspot magnetic fields and flows
- Atmospheric heating, Solar Wind acceleration, Irradiance variations
- Solar Activity

ATST is:

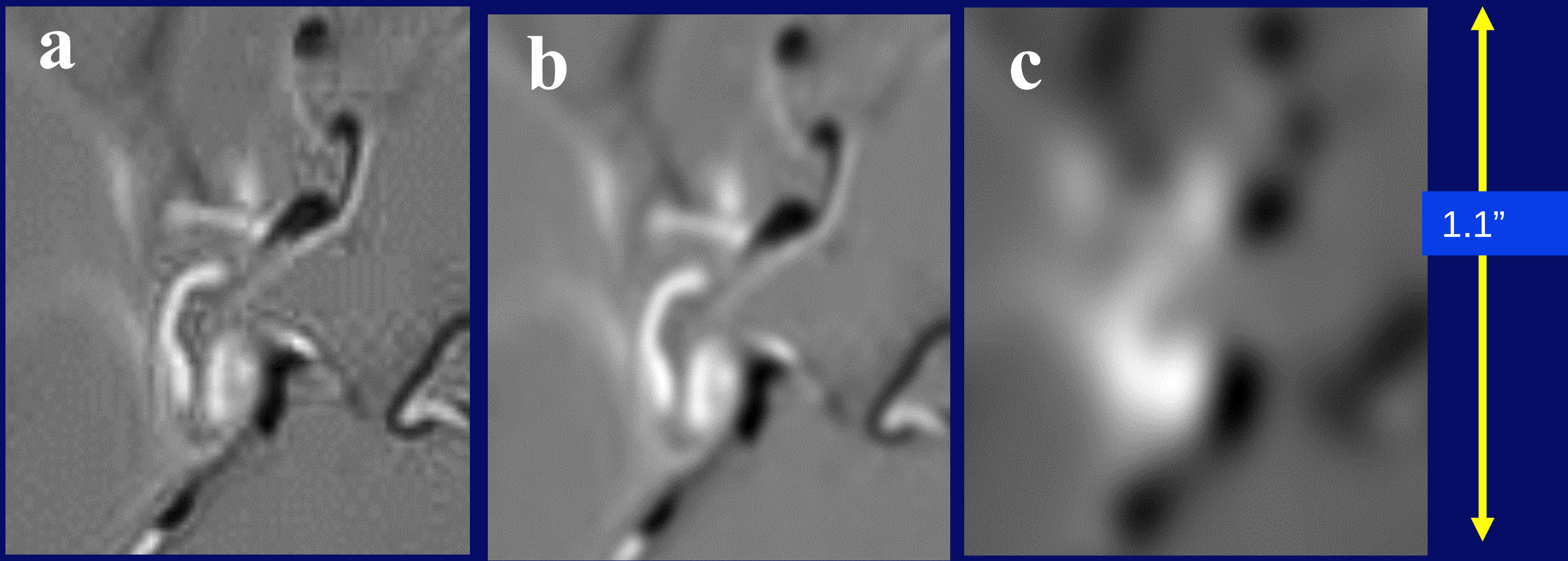
- **The ultimate tool to investigate the magnetic structure of the solar atmosphere at the smallest size scales ⇒ *the actual sources of solar variability***
- **Needed for spectro-polarimetry at increasingly small scales in the solar atmosphere *allowing for identification of physical mechanisms***
- **Providing for a combination of spatial and time resolution in spectro-polarimetric observations to observationally connect *solar vector magnetic fields throughout the dynamic solar atmosphere***

Comparison with other Telescopes



Why an ATST

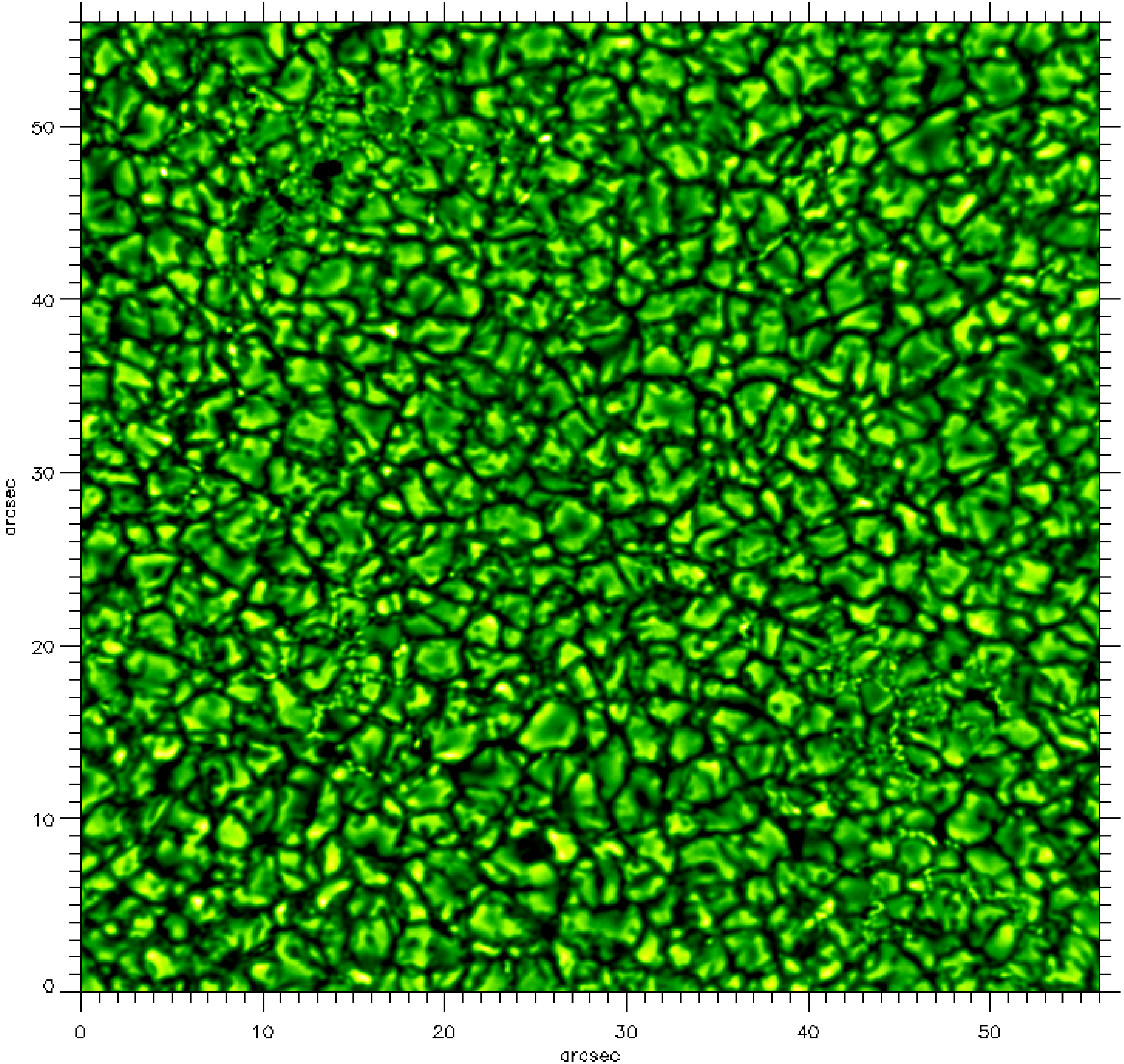
Theory and Modeling have gone beyond our ability to test observationally



a. Numerical simulation of magneto-convection (courtesy of Fausto Cattaneo

b. As viewed with a diffraction limited 4-m telescope

c. As viewed with a diffraction limited 1-m telescope

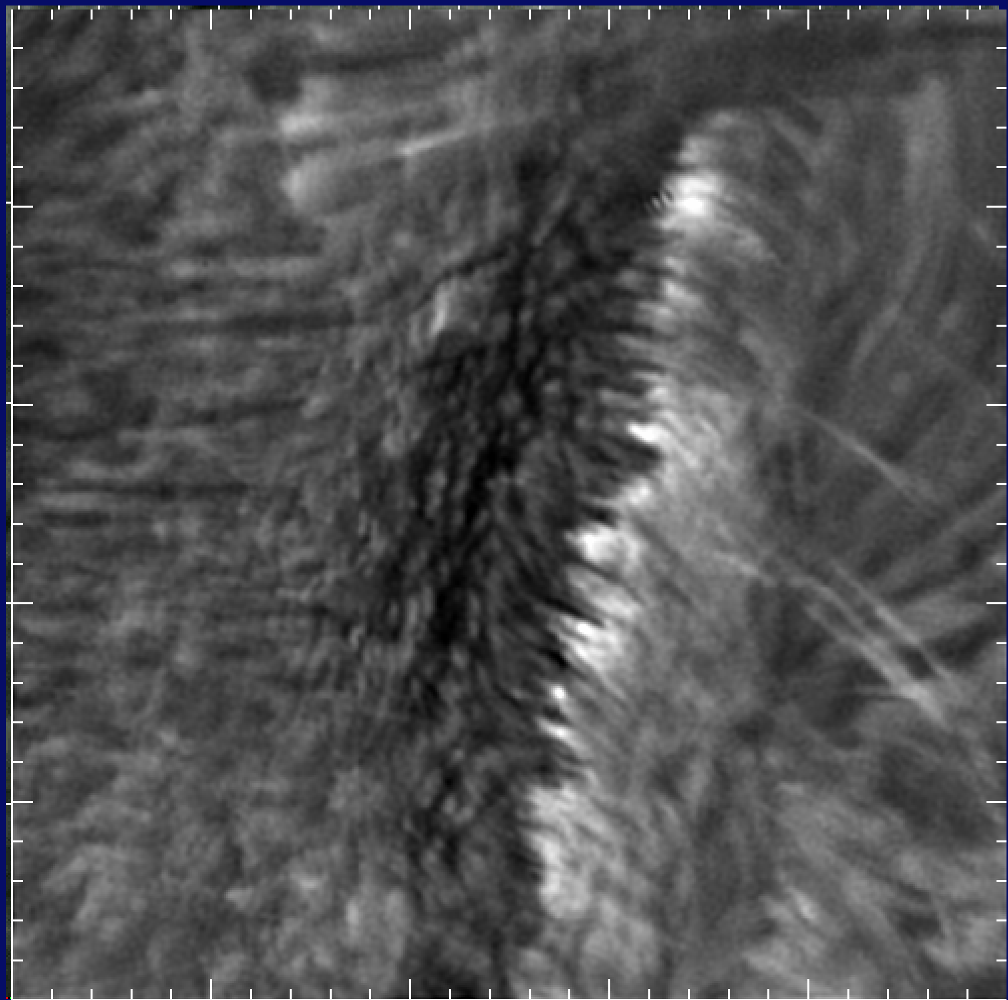


3 sec exposure

Tip/tilt on

AO loop on

Flare Structure

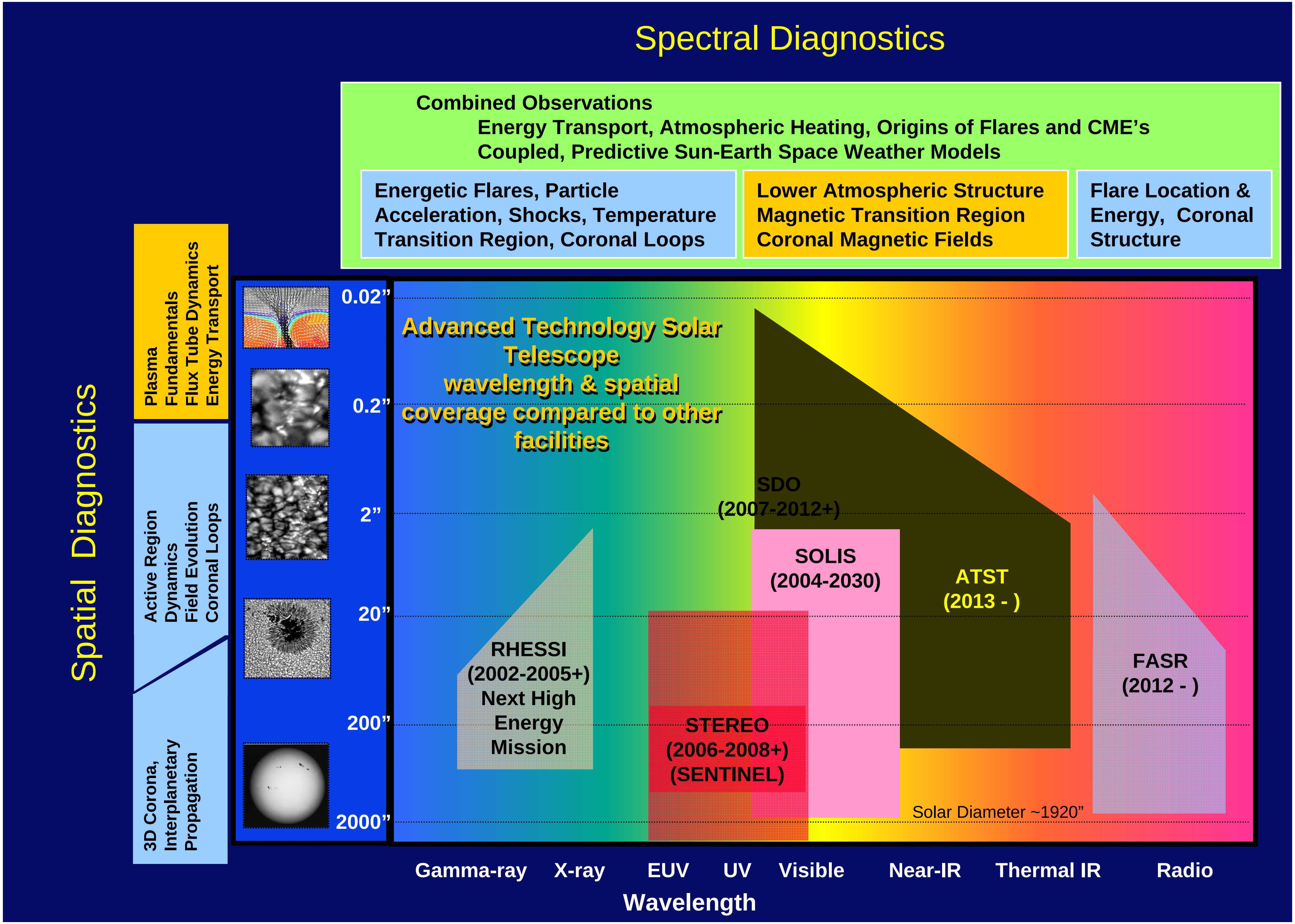


DST + AO

UBF
Hydrogen - alpha
1” tic marks

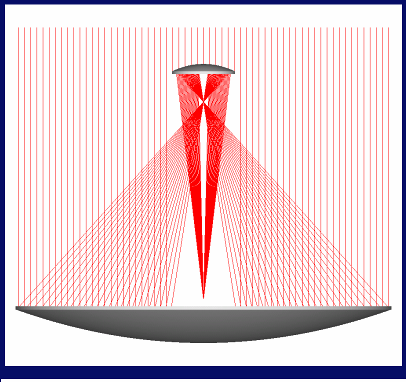
AR 0486 observed close to east limb
10/24/03 UT 18:14 – UT 19:31

First observation of flare structure at 0.”2 resolution

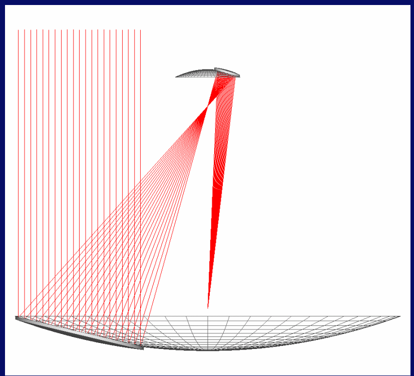


Spectral Diagnostics
Combined Observations
Energy Transport, Atmospheric Heating, Origins of Flares and CME's
Coupled, Predictive Sun-Earth Space Weather Models
Energetic Flares, Particle Acceleration, Shocks, Temperature Transition Region, Coronal Loops
Lower Atmospheric Structure Magnetic Transition Region Coronal Magnetic Fields
Flare Location & Energy, Coronal Structure
Spatial Diagnostics
Plasma Fundamentals Flux Tube Dynamics Energy Transport
Active Region Dynamics Field Evolution Coronal Loops
3D Corona, Interplanetary Propagation
0.02"
0.2"
2"
20"
200"
2000"
Advanced Technology Solar Telescope wavelength & spatial coverage compared to other facilities
SDO (2007-2012+)
SOLIS (2004-2030)
ATST (2013 -)
RHESSI (2002-2005+) Next High Energy Mission
STEREO (2006-2008+) (SENTINEL)
FASR (2012 -)
Solar Diameter ~1920"
Gamma-ray
X-ray
EUV
UV
Visible
Near-IR
Thermal IR
Radio
Wavelength

Optical Design Overview
The Off-axis Telescope

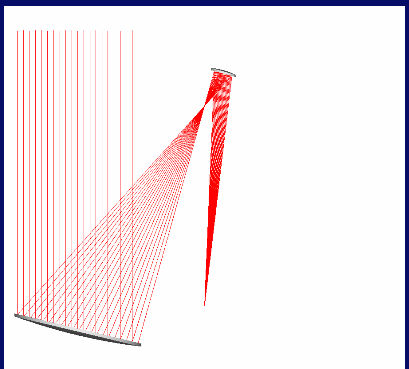


12-meter
$f/0.6$
Symmetric
Gregorian

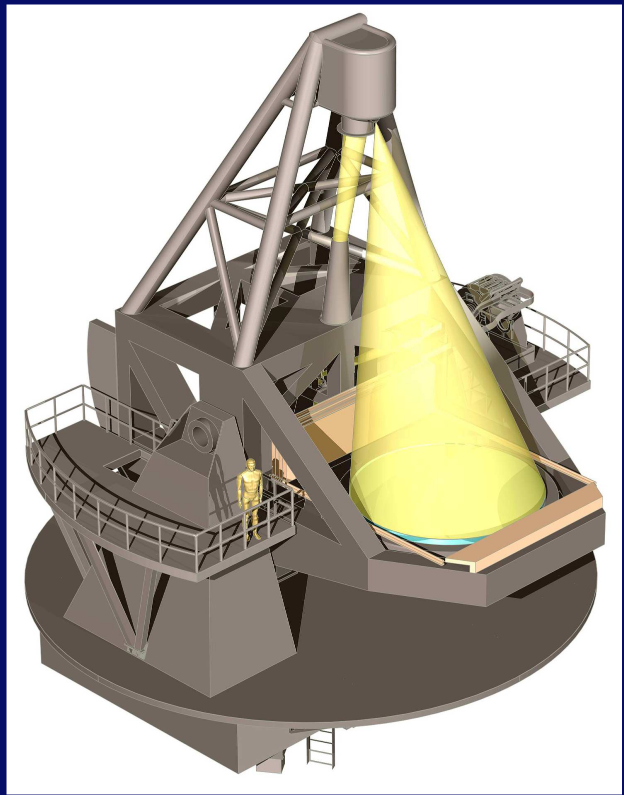


Illuminate one side only

... Then trim unused portions



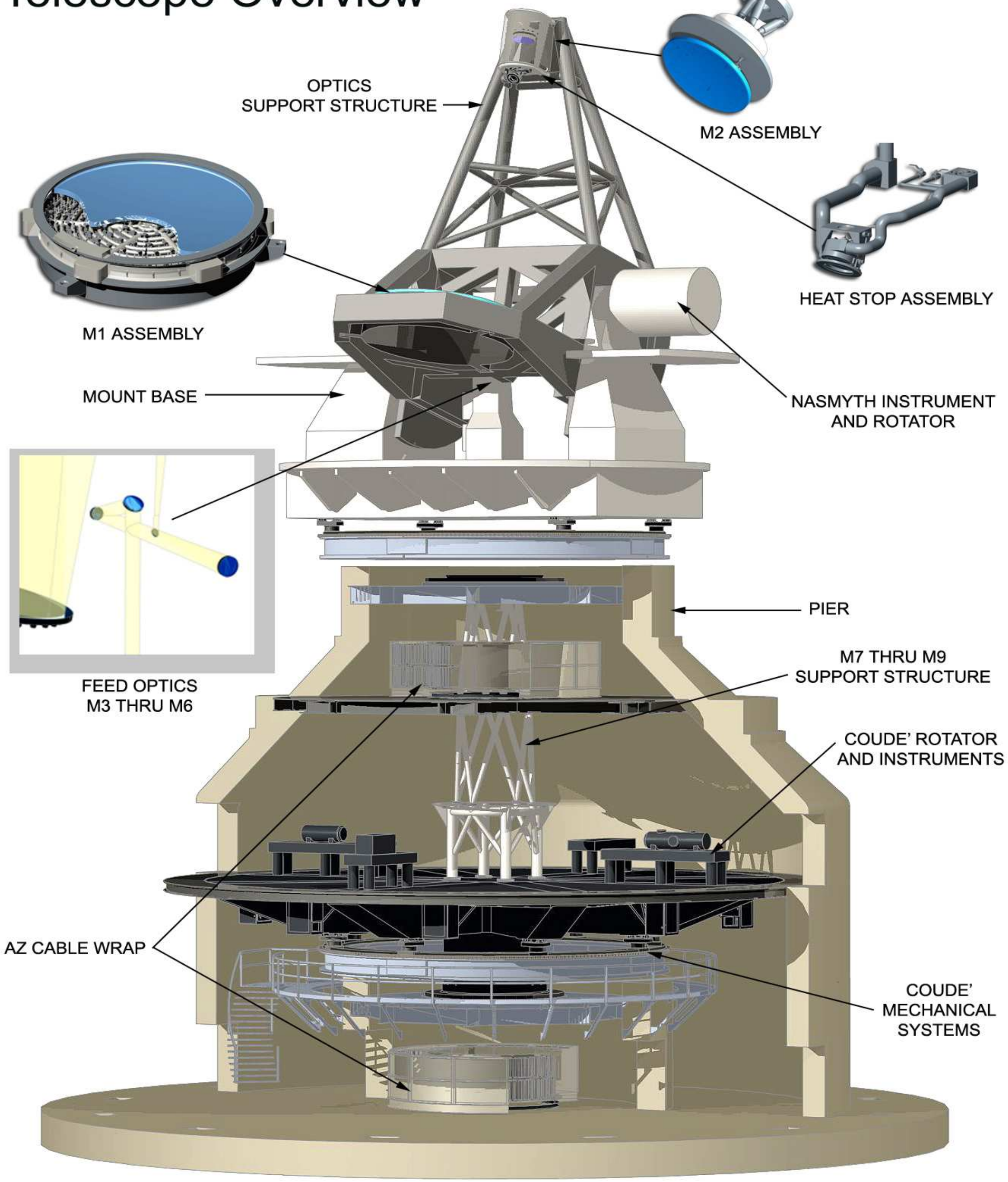
4-meter
$f/2$
Off-axis
Gregorian

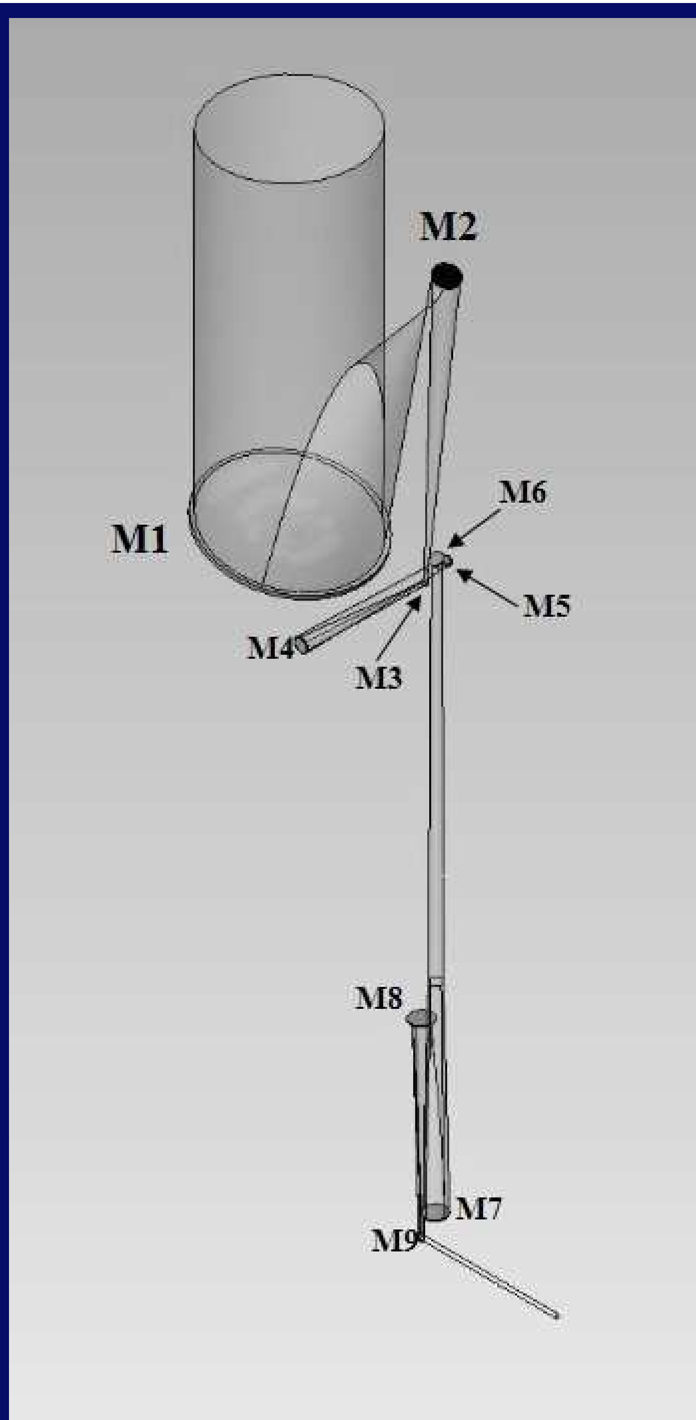


Off-axis advantages

- There is no obstruction of the beam by the secondary mirror
- There is no diffraction from the secondary support structure to degrade coronal images.
- Coolant and other services can be delivered to the secondary mirror without crossing the beam.

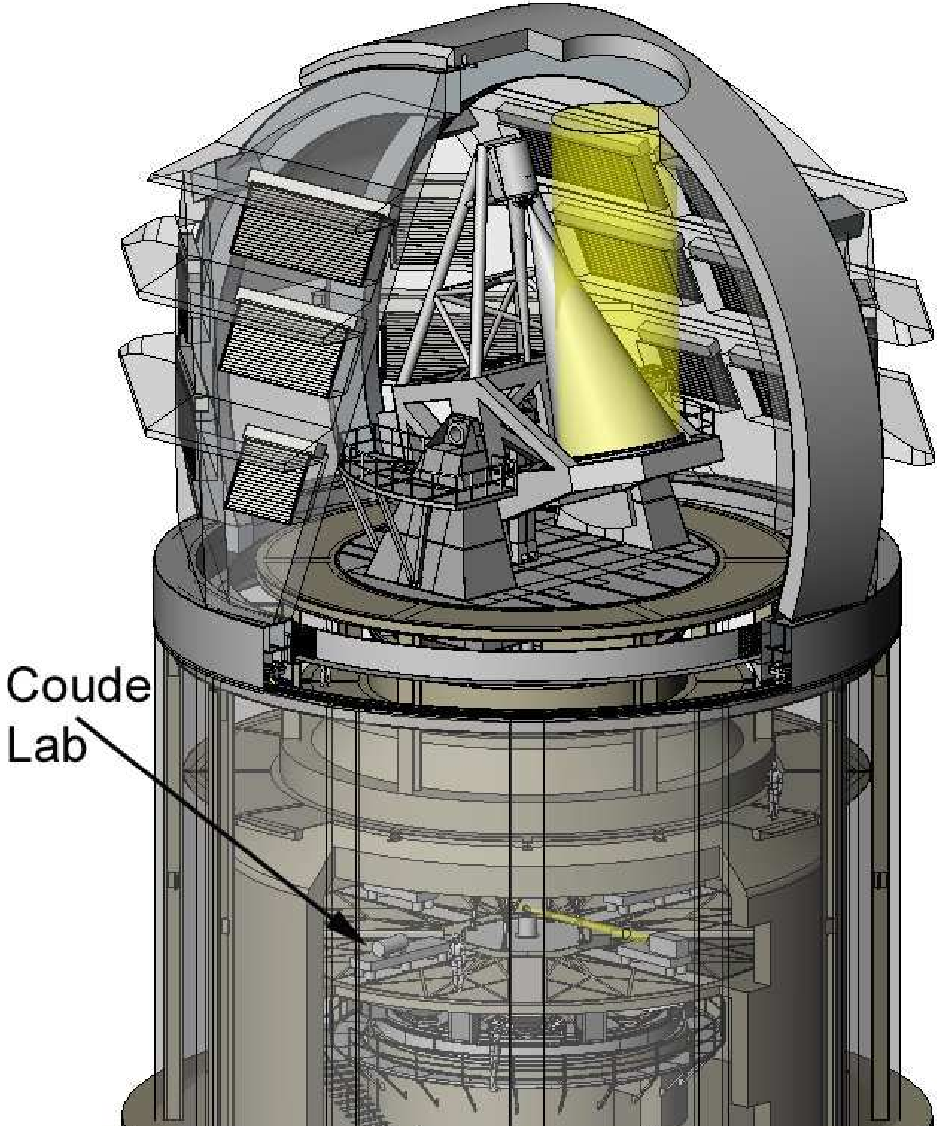
Telescope Overview

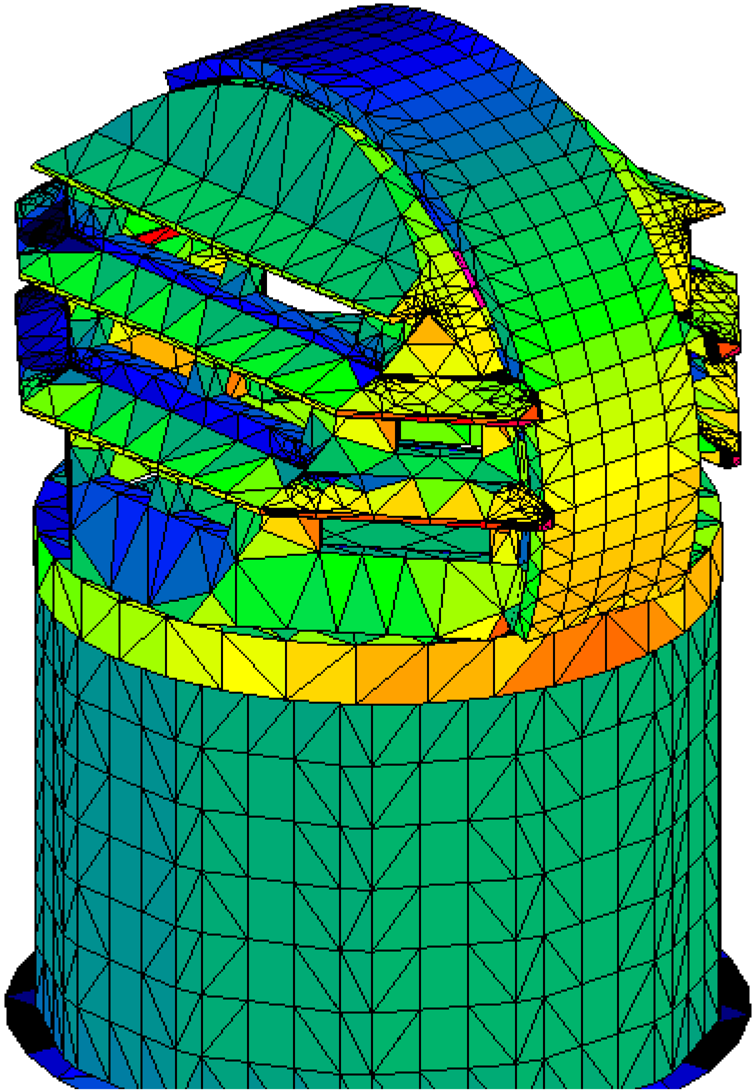




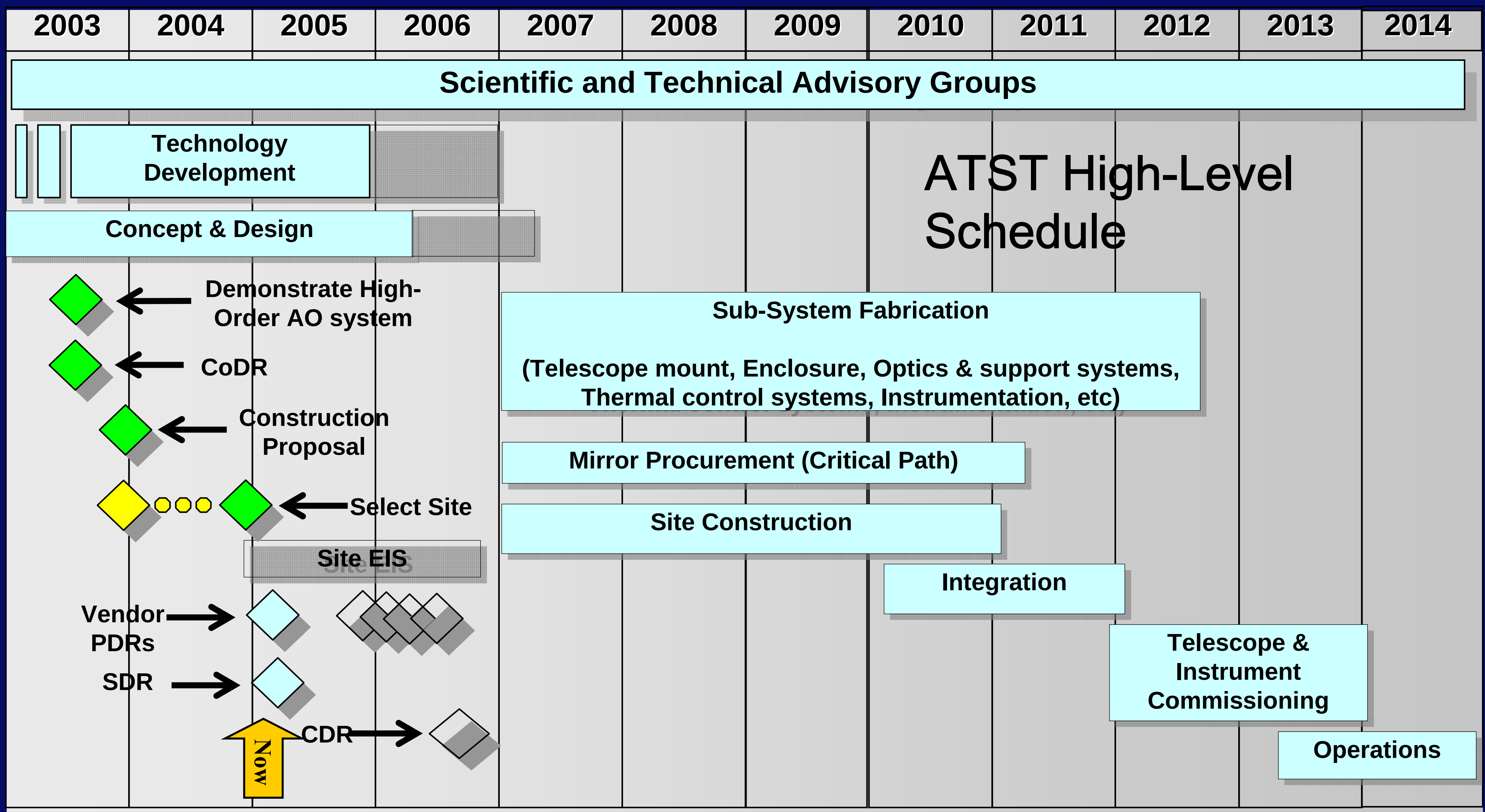
Thermal Control – Enclosure

Hybrid, actively cooled co-rotating enclosure





ATST Timeline
2007 construction start



Next Steps

- MREFC Process
  - National Science Board Ranking
  - Budget Process – OMB, Congress
- System Level Review
- Instrument PDRs
- Vendor Feasibility Studies of design concepts
  - Insure constructability
  - Retire remaining high risk technical areas
- Contracts for final design and construction of major components

Partnerships

- International support and interest
  - Italy
    - Letter of support received
    - Science, adaptive optics subsystems, post-focus instruments
  - Spain
    - Letter of support received
    - Science, polarization expertise
  - Germany
    - MOU signed
    - Proposal to German Government in June
    - Director of KIS – Potential of $10M independent of site
  - Switzerland
    - Near UV instrumentation

Partnerships

- Air Force
  - AFOSR
    - Purchase and Polish Mirror
    - Recoating facility on Haleakala
    - Potential support for instruments at university partners
    - Collocation of AF staff and participation in operations
  - Military Construction Fund (AFOSR, AFRL pursuing)
  - Tracking (ACOS)
  - Space Debris (DARPA, white paper this spring)

- NASA
  - Thermal-IR instrumentation
  - Visible tunable filter

Cost Estimate Broken Down by WBS Elements - $175M total

(includes inflation & contingency)

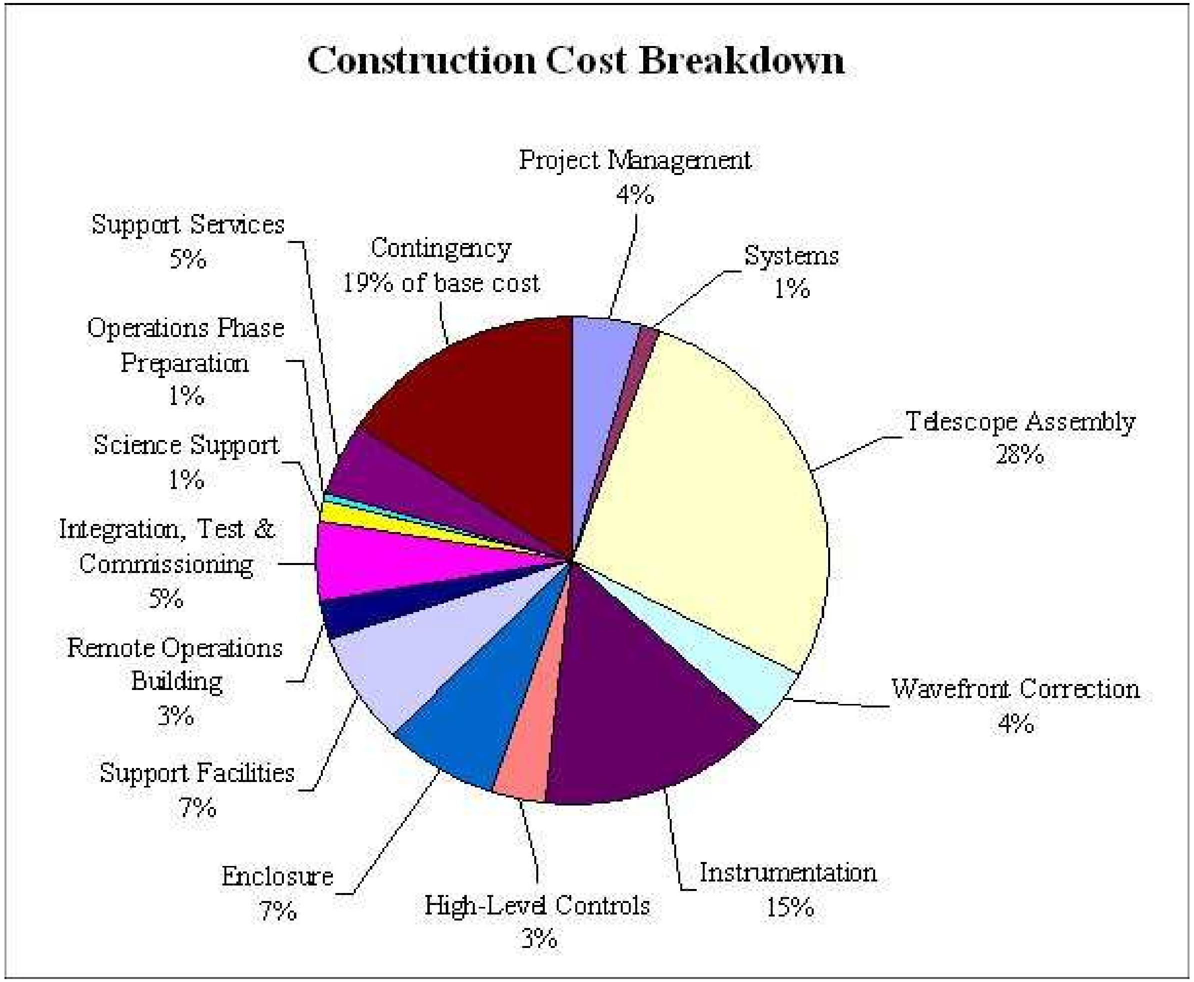


Figure 5.2. Construction Cost Breakdown

Potential Partner Sharing*

- We have draft MOU with Germany, letters from Spain, Italy, & Switzerland
- Potential for EU consortium, Japan

Construction Proposal Cost	175
AF	12
Germany	10
Italy	5
Spain	10
Sweden	4
France	TBD
EU	TBD
University of Hawaii	3
US Cost	131

ATST
advanced technology solar telescope

Summary

- The 4m ATST is essential to solve many outstanding problems in solar astronomy & astrophysics. Substantial vs. incremental progress!
- These problems are highly relevant to humankind!! – Sun-Climate, Sun-Space Weather, Sun-Laboratory Plasma, Sun -Cosmic Magnetic Fields
- ATST with its cutting edge instrumentation will provides us with a powerful tool solve the mysteries of solar magnetism.
- New diagnostics tools (e.g. IR) and new technology (e.g. AO) are at hand.
- Complementary role of ATST and Space Missions – coordination is essential.

Contact Information

Stephen L. Keil, NSO Director
skeil@nso.edu
1-505-434-7039

Thomas Rimmele, Project Scientist, 1-505-434-7022
Jeremy Wagner, Project Manager, 1-520-318-8249
Frank Hill, Site Survey Operations & Data, 1-520-318-8138

For More Information see:

http://atst.nso.edu