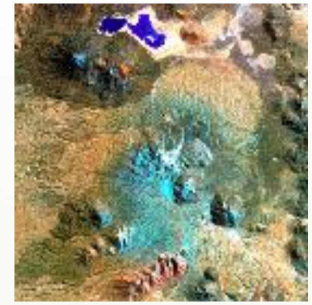
CCAT: Overview & Status

Large Aperture Millimeter/Submillimeter
Telescopes in the ALMA Era
Osaka Prefecture University
12-13 Sept, 2011

Jeff Zivick
CCAT Project Manager
Cornell University

Guiding Principles



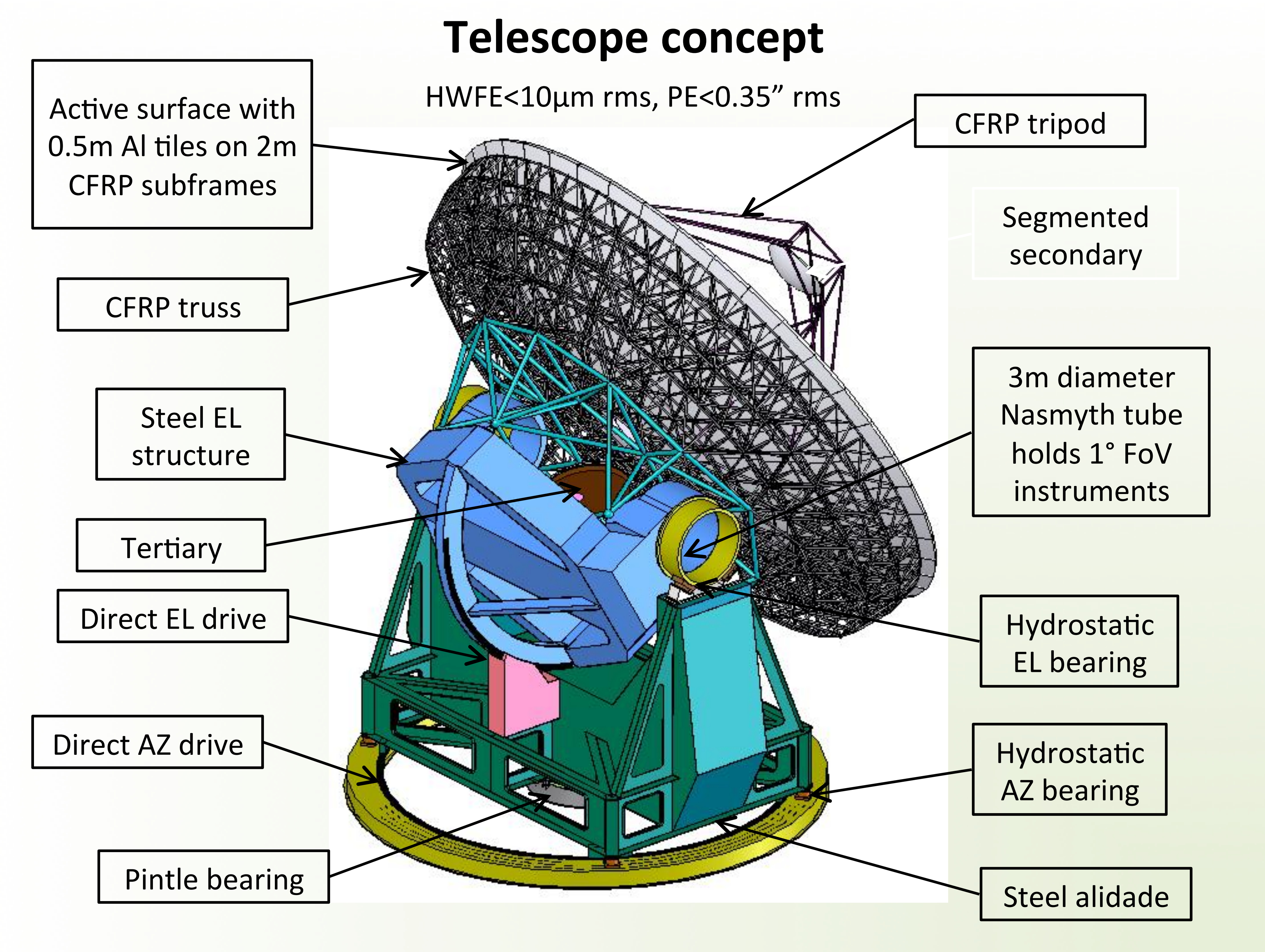
- Scientific excellence
- Designed to take advantage of fast-moving detector technology

  ➔ Fast surveyor

- At the best possible, easily serviceable Earth location with full coverage of Equatorial skies
- High synergy with (and enabler to) ALMA
- Synergy among partner institutions

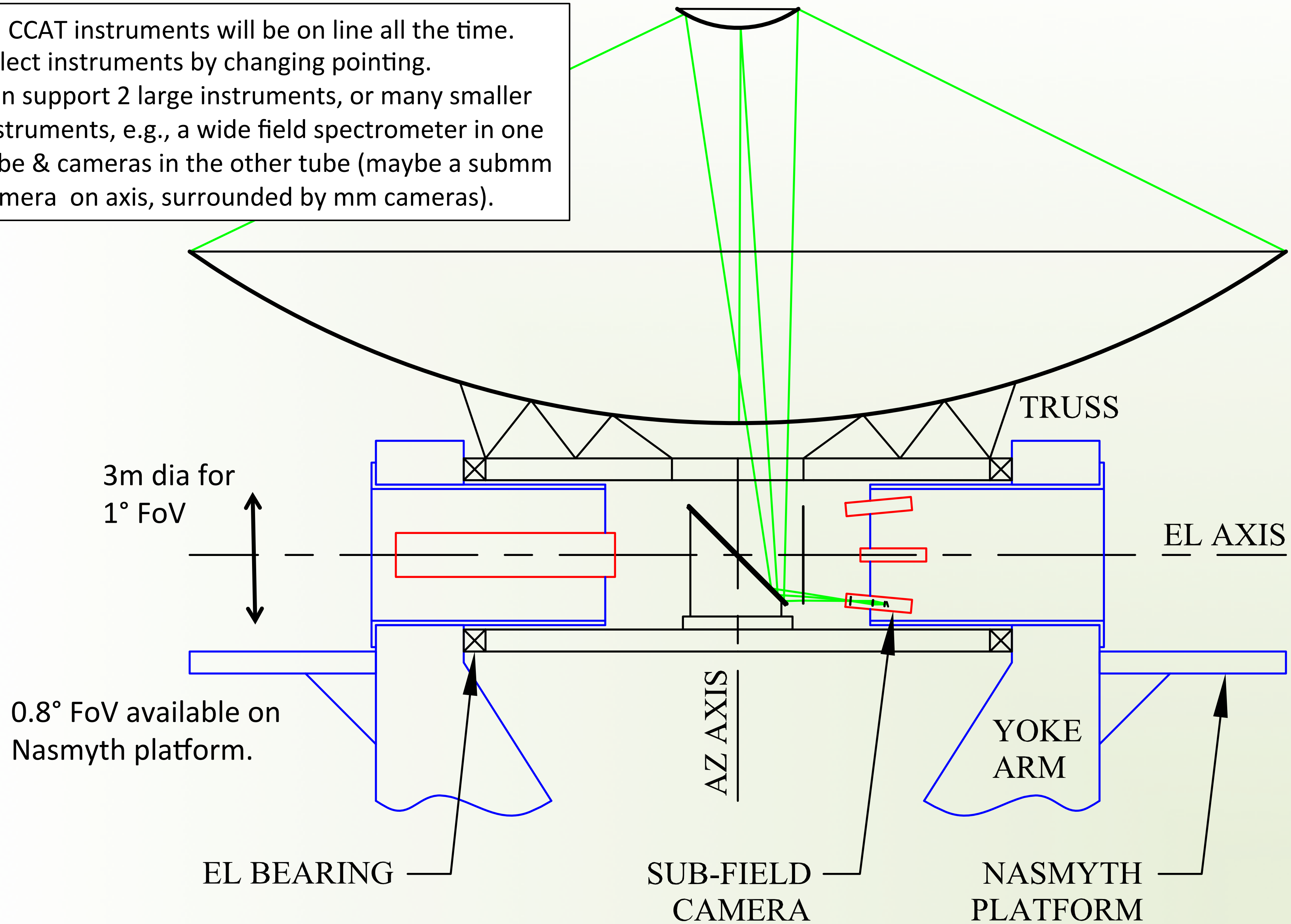
  ➔ Nimble, University-led facility, with top instrument-building groups

A joint project of Cornell University,
the California Institute of Technology
the University of Colorado,
the Universities of Bonn & Cologne,
a consortium of 9 Canadian Universities
and Associated Universities, Inc.


Telescope concept
HWFE<10µm rms, PE<0.35” rms
Active surface with 0.5m Al tiles on 2m CFRP subframes
CFRP tripod
Segmented secondary
CFRP truss
3m diameter Nasmyth tube holds 1° FoV instruments
Steel EL structure
Tertiary
Direct EL drive
Hydrostatic EL bearing
Direct AZ drive
Hydrostatic AZ bearing
Pintle bearing
Steel alidade

Instrument interface

All CCAT instruments will be on line all the time.
Select instruments by changing pointing.
Can support 2 large instruments, or many smaller instruments, e.g., a wide field spectrometer in one tube & cameras in the other tube (maybe a submm camera on axis, surrounded by mm cameras).



CCAT Performance Requirements

Contribution	HWFE (μm rms)	PE (arcsec rms)	Notes
Aberrations	3.65	0.00	Ritchey-Chretien design
Primary open-loop	7.21	0.03	CFRP truss
Primary closed-loop	7.48	0.52	Steel truss
Secondary	6.28	0.20	
Tertiary	4.45	0.10	
Instrument	0.05	0.04	
Mount	0.00	0.09	No HWFE from mount
Alignment	2.19	0.10	Regular pointing with science camera, occasional wavefront measurements with WFS
Telescope RSS open loop	11.37	0.26	
Telescope RSS closed-loop	11.55	0.58	
Telescope requirement	10.00	0.35	<50% increase in integration time, PE<1/10th beam, from CCAT-TM-48
Atmosphere	5.74	0.23	1st quartile

Observatory parameters

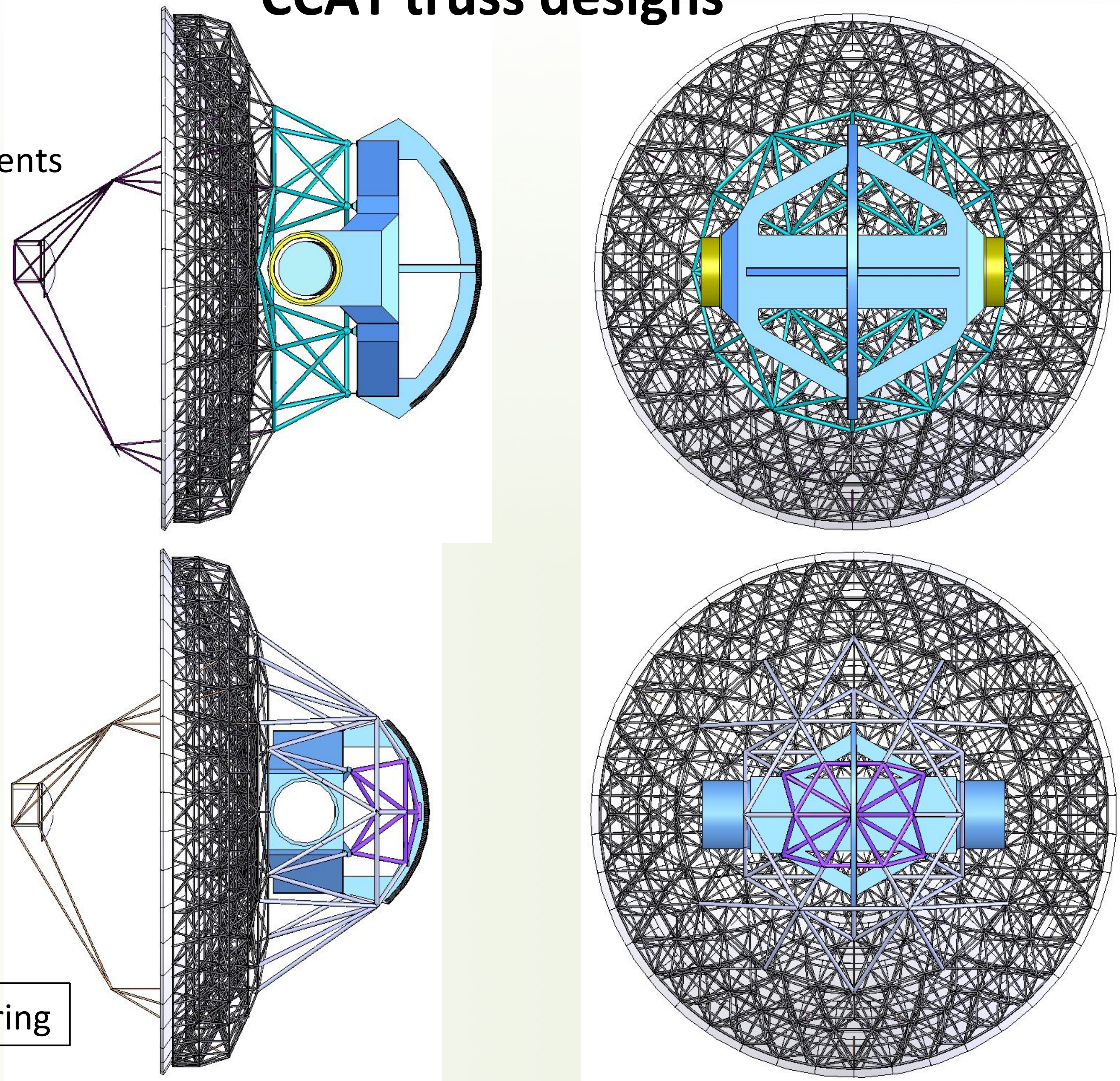
Parameter	Value	Units	Notes
Wavelength	350	μm	
Mean outside wind speed	6	m/s	3rd quartile
Wind speed for pressure	8.484	m/s	$2^{1/2}v_{outside}$, see CCAT-TM-56
Density of air	0.7	kg m^{-3}	At 5600 m altitude
Scan acceleration	0.4	deg s^{-2}	0.4 deg s^{-2} if λ<620μm, else 2 deg s^{-2}, from CCAT-TM-48
rms temp gradient in dome	1	K	From TMT CFD
Soak temp change	20	K	Diurnal & longer
Flux density of pointing source	0.1	Jy	For >1 source/deg^2, S<0.3Jy at λ=350μm and S<40mJy at λ=850μm, see Fig. 4.9 in feasibility study
Pointing integration time	120	s	< a few min for reasonable observing efficiency
Field angle	0.08	deg	

CCAT truss designs

Ring & pillar
30,000 kg truss
12,000 kg segments
(25 kg m^{-2})
7-8 Hz

3d

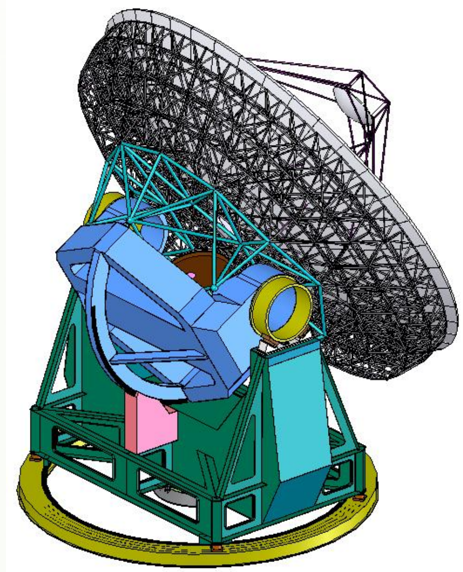
Stutzki Engineering

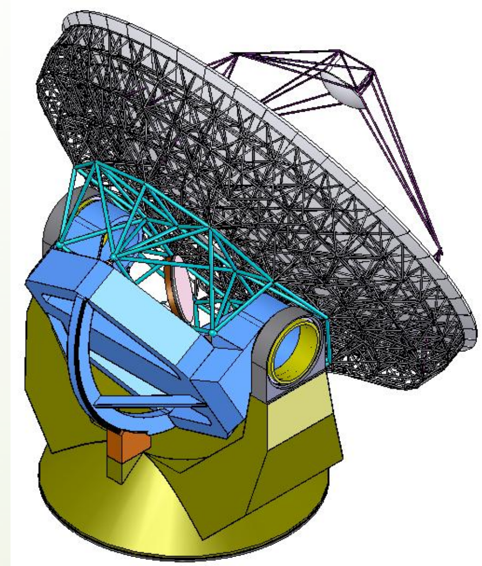


CCAT bearing & truss options

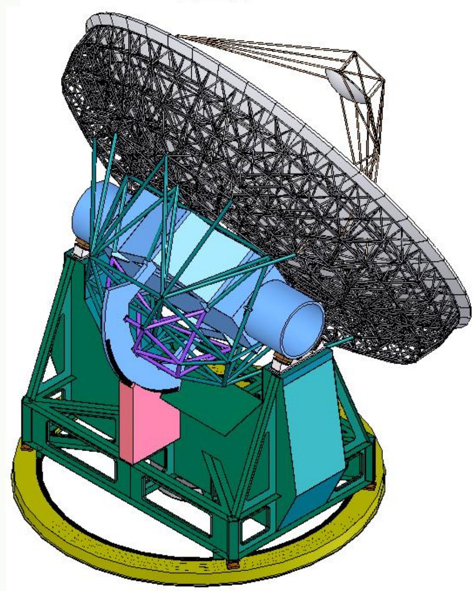
General Dynamics

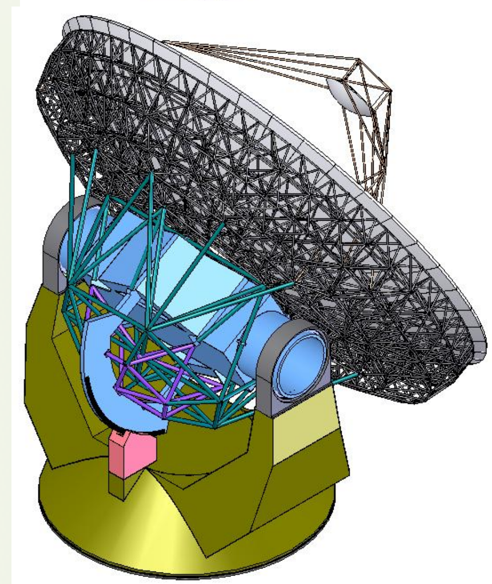
Ring & pillar





3d

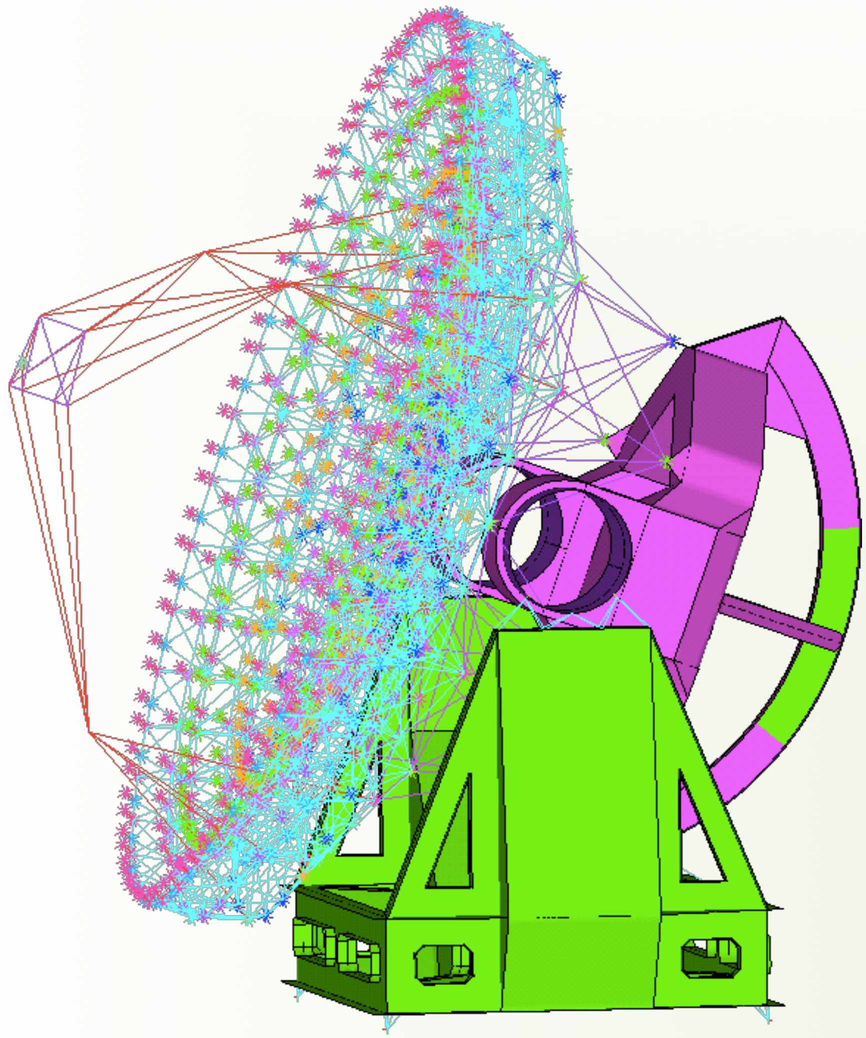




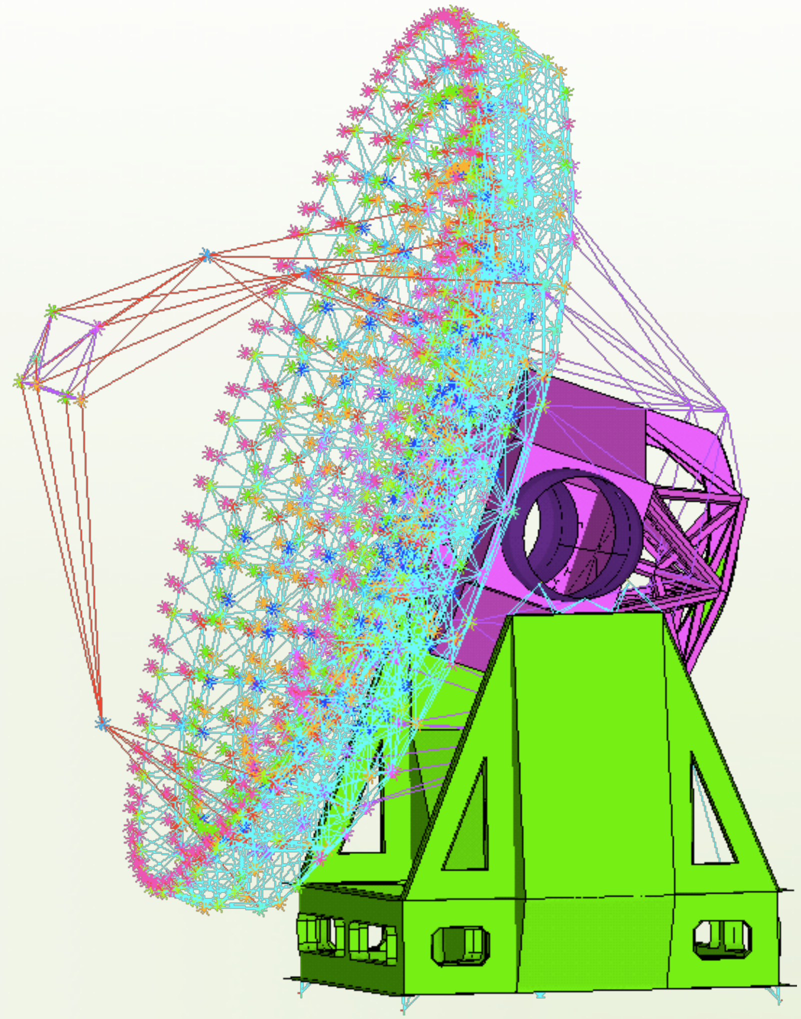
Hydrostatic bearings

Rolling element bearings

Finite element models

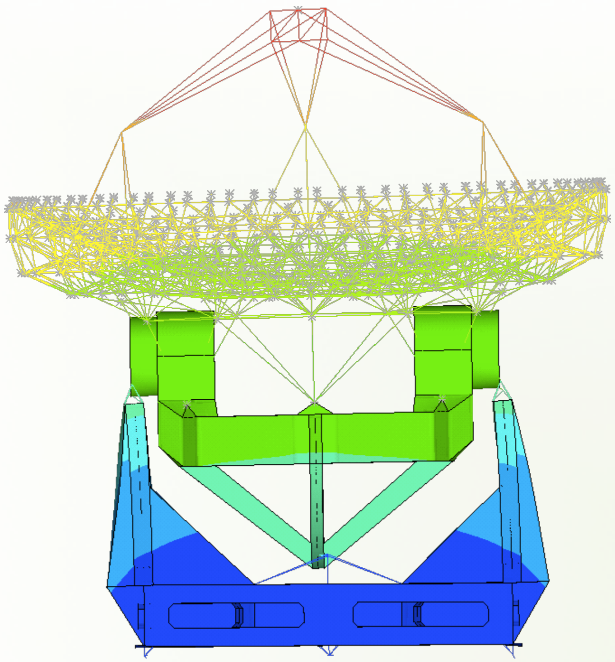


Ring & pillar

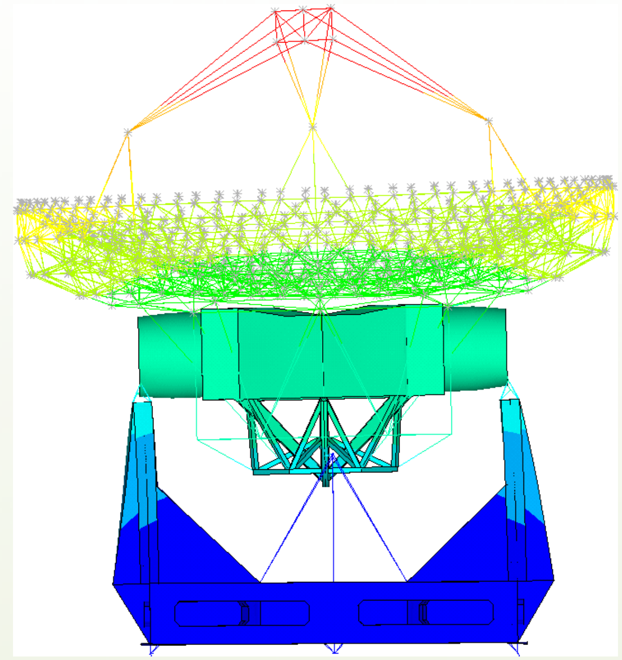


3d

FEA results



Ring & pillar 3.5 Hz



3d 3.3 Hz

Load case	zenith	EL=20°	Analytical model µm rms
	µm rms	µm rms	
Gravity	287	276	
0.4°s^{-2} acceleration	1.7	1.3	0.7
20K soak	3.8	5.0	3.1
1K vertical	0.2	0.7	
1K horizonal	0.9	0.9	3.3

Load case	zenith	EL=20°
	µm rms	µm rms
gravity	360	187
0.4°s^{-2} acceleration	2.3	1.5
20K soak	69.2(!)	69.2
1K vertical	0.7	1.7
1K horizonal	1.8	1.8

Bearing Performance

Azimuth

Parameter	Units	Wheel	Hydrostatic	Rolling	Notes
Diameter	m	18	18	14	
Friction torque	kNm	99.9	9.0	123.9	3kNm for wrap + 4kNm for pintle
Axis stiffness (3d)	kNm/arcsec	360	360	612	From finite element model
Axis stiffness (ring)	kNm/arcsec	599	599	659	
PE due to friction (3d)	arcsec	0.28	0.03	0.20	
PE due to friction (ring)	arcsec	0.17	0.02	0.19	
Repeatable PE	arcsec rms	3.0	3.0	1.25	0.25mm track error, rolling bearing PE seems small (cf 2" in SPT)
Non-repeatable PE	arcsec rms	1.3	0.2	0.12	10µm rms oil film variation, 10% of repeatable for rolling

Baseline hydrostatic bearings

Elevation

Parameter	Units	Hydrostatic	Rolling	Notes
Friction torque	kNm	2.0	55.5	3kNm for wrap + 4kNm for pintle
Axis stiffness (3d)	kNm/arcsec	43.7	63.0	From finite element model
Axis stiffness (ring)	kNm/arcsec	167	261	
PE due to friction (3d)	arcsec	0.05	0.88	
PE due to friction (ring)	arcsec	0.01	0.21	
Repeatable PE	arcsec rms	4.4	7.4	4.4" shaft runout, 3" bearing runout
Non-repeatable PE	arcsec rms	0.3	0.3	10µm rms oil film variation, runout across 14m for rolling bearings

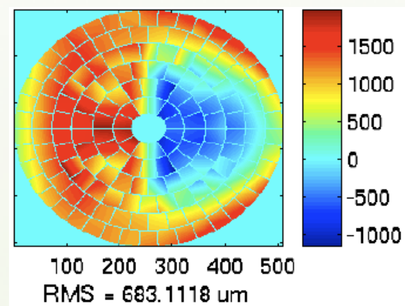
Primary surface control

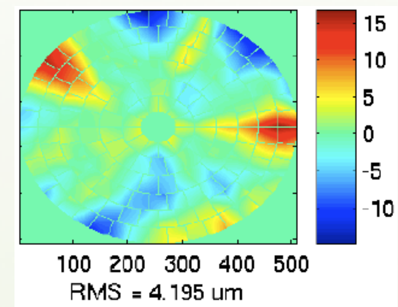
J. Lou, JPL

EL=45°, 1µm rms edge sensor noise, no secondary position sensor noise

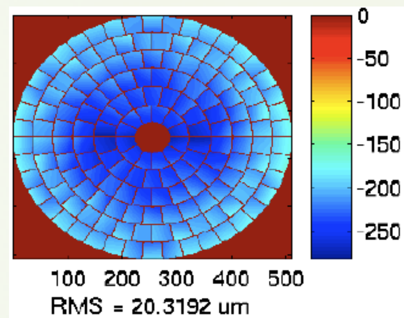
Perturbed wavefront | Controlled wavefront

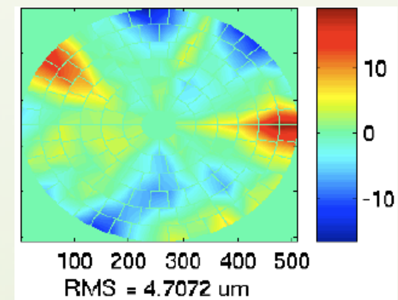
1g



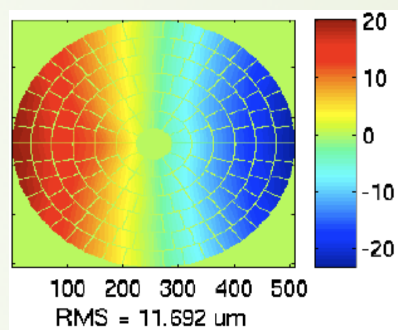


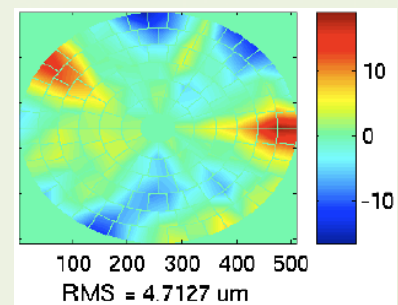
20K soak





1K vertical gradient

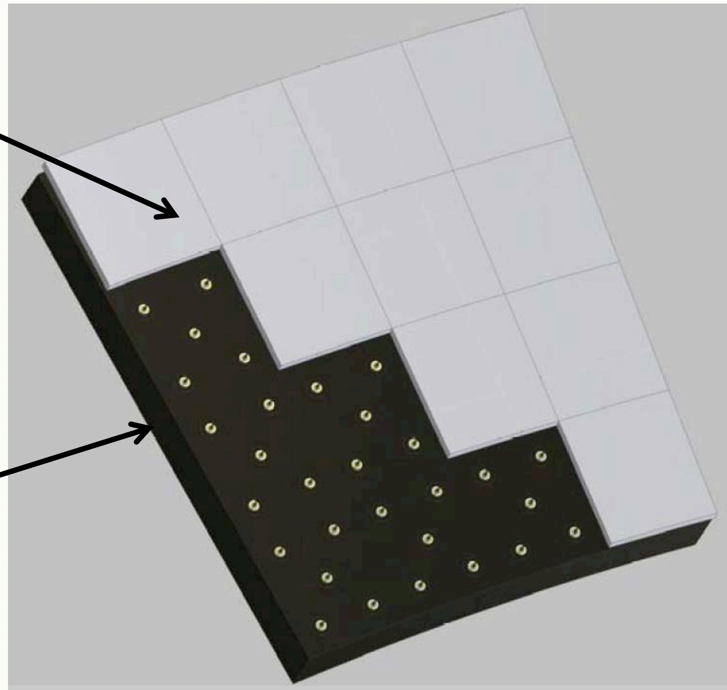


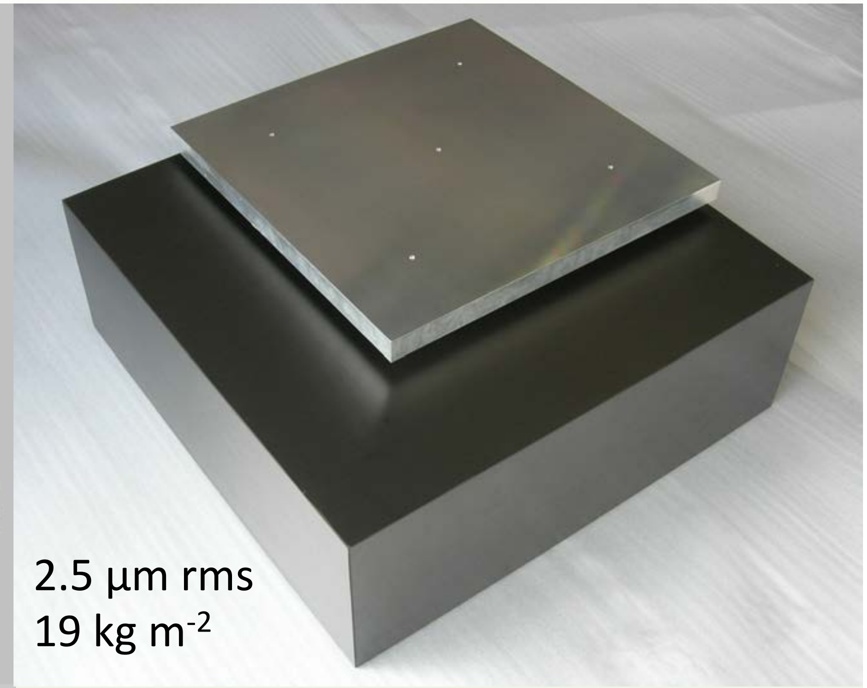


Compound segments

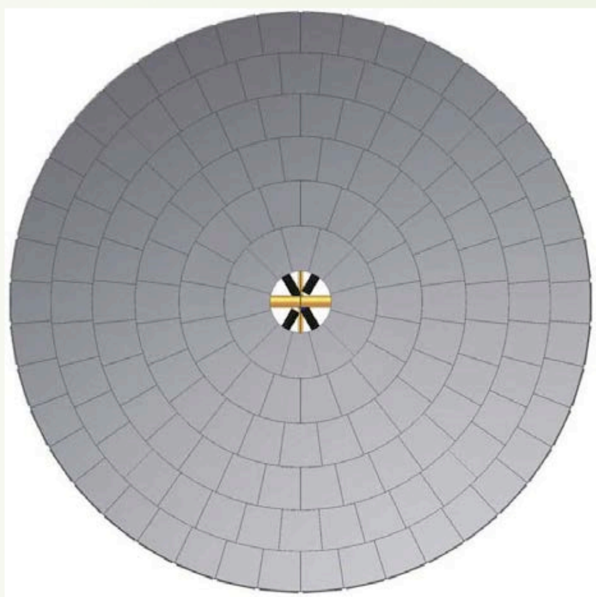
Aluminum tiles

Insulated carbon-fiber frame or box





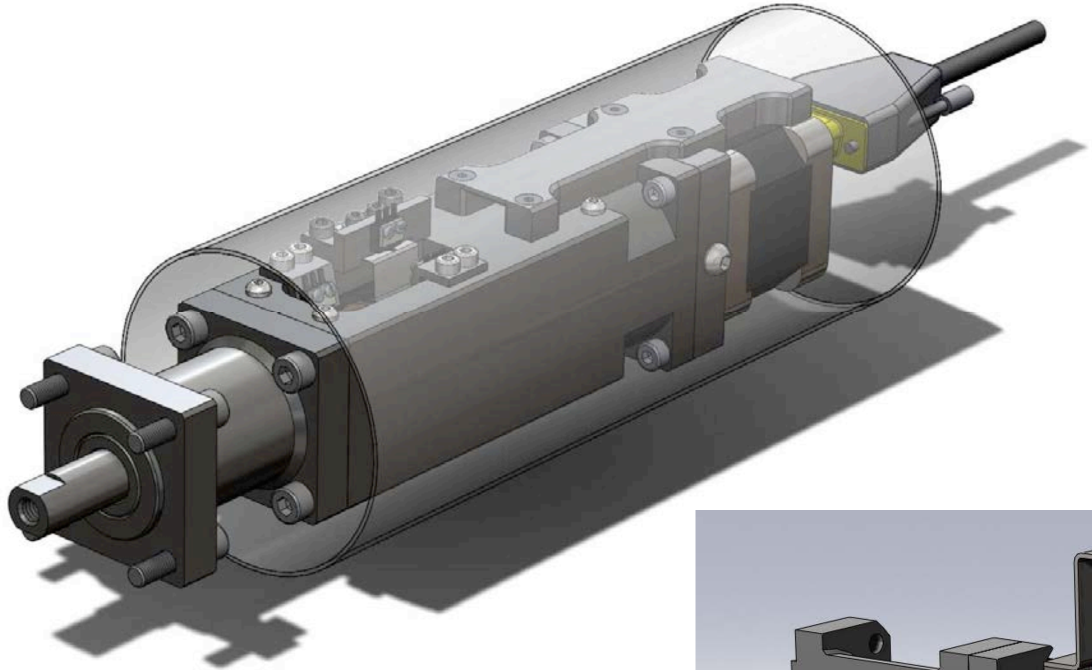
Prototype subframe

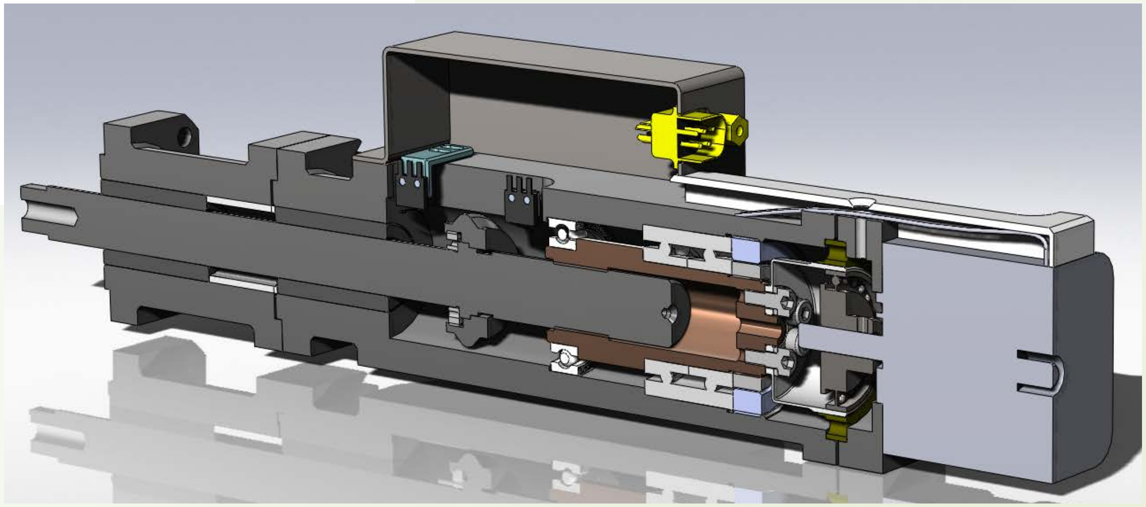


Keystone-shaped segments were originally chosen to give the option of replicating tiles.

For a simple 3-point support, segment size is limited to ~2m, so 6 rings, for a total of 162 segments.

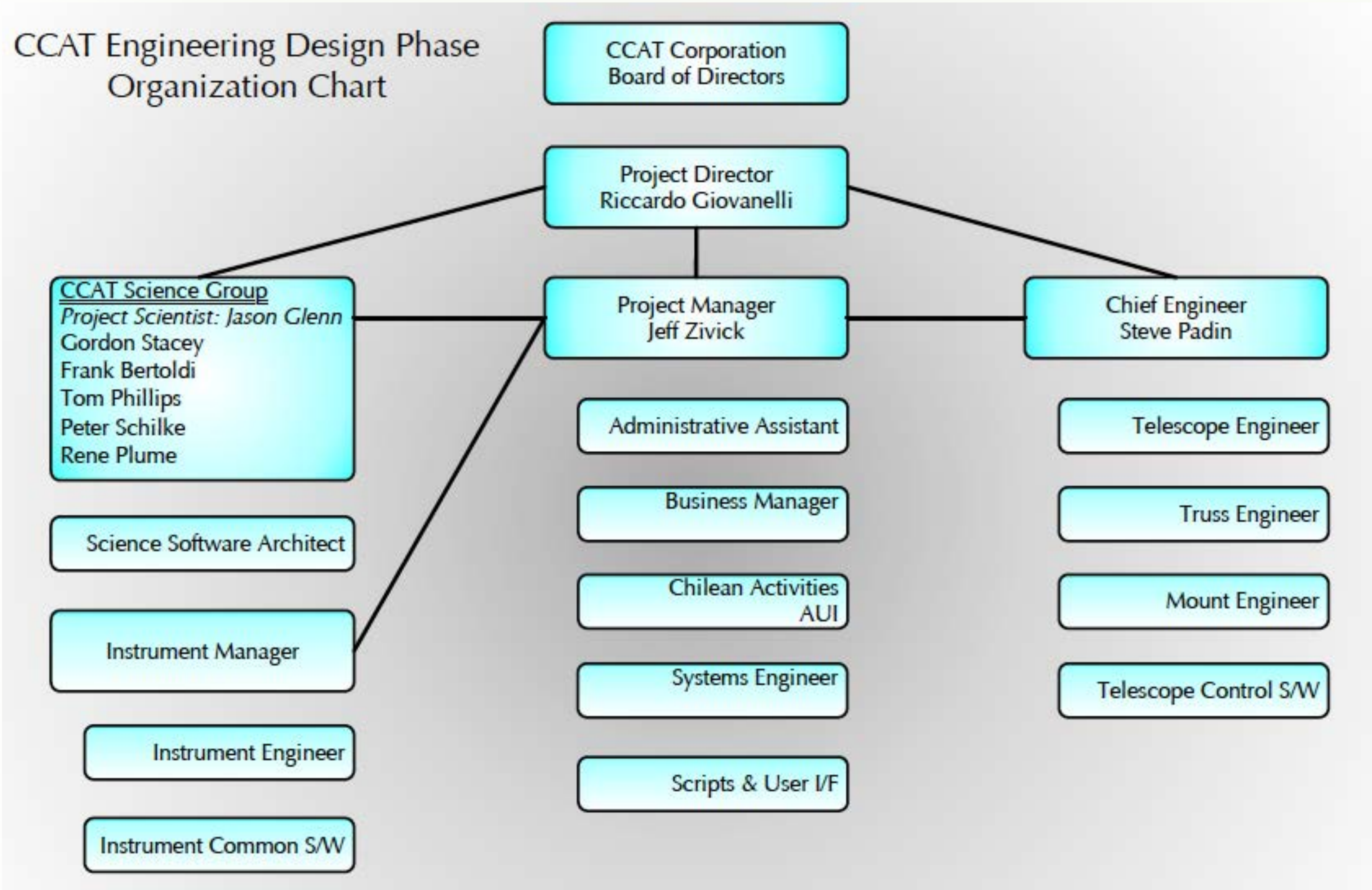
Actuator concept





Stepper + 80:1 gearbox + nut
Linear encoder on screw between output bearings
Linear bearings to support the output shaft

Current CCAT Organization



CCAT Historical Perspective

2003: Cornell proposes concept to Caltech;
Collaboration workshop in Pasadena

2004: MOU signed by Caltech and Cornell;
Project Office established at Cornell;
Feasibility study initiated.

2005: Feasibility study executed

2006: Feasibility study review

2006-2010: Expand partnership (U Colo, U Cologne, U Bonn, Canada);
Finalize site selection;
Review high risk issues;
Initiate preliminary engineering trade-off analyses;
Astro2010;
Step up fundraising.

CCAT Feasibility Review

Review Panel:

Robert Wilson (Harvard-Smithsonian, Chair)
Mark Devlin (Penn)
Fred Lo (NRAO)
Matt Mountain (STScI)
Peter Napier (NRAO)
Jerry Nelson (UCSC)
Adrian Russell (ALMA, NA)

"CCAT is an important and timely project that will make fundamental contributions to our understanding of the processes of galaxy, star and planetary formation, both on its own and through its connection with ALMA. It should not wait."

New Worlds, New Horizons in Astronomy and Astrophysics

Committee for a Decadal Survey of Astronomy and Astrophysics

National Research Council

"Only one medium project is called out, because it is ranked most highly. Other projects in this category should be submitted to the Mid-Scale Innovations Program for competitive review." pg 7-37

The one project is CCAT.

"CCAT is called out to progress promptly [. . .] because of its strong science case, its importance to ALMA and its readiness." pg 1-12 & 7-38

Recommends that US National Science Foundation participate in CCAT with funding 1/3 of construction costs .

CCAT Looking Ahead

2011-2013: NSF proposal review;

Engineering design phase (telescope, instruments, enclosure, site);

Assemble project staff;

Prototype development of key components;

Demonstration testing of essential functionality (control algorithms, wavefront sensing technique, instrument detectors);

Construction of improved access road and site infrastructure;

Establish CCAT Corporation.

2013: Critical Design Review.

2013-2017: Construction ➔ First light

CCAT Budget

CCAT was asked to provide Astro2010 detailed information to be used for the CATE process carried out by the Aerospace Corp.

Their estimates of the cost and time to completion of construction were higher than the project team's:

➔ \$140M vs. \$110M

➔ 2020 vs. 2017

Engineering Design Phase goal: reduce error in estimate

(Construction costs include \$20M towards first-light instrumentation)

Over last 5.5 yr the CCAT project \$ burn rate has been \$1-2M/yr,
adding up to > \$8.0M to date,
fully funded by partners.

CCAT Support at U.S. national level

Nov 2010: Proposal submitted to US NSF asking $4.85M (~45% of total estimated cost) to complete EDP by early 2013

May 2011: NSF communicates that an award of $4M will be made

June 2011: NSF communicates that the award will be $4.5M

1 Aug 2011: award for first year ($2.5M) transferred to Cornell

…while at the private level…

On Nov 12, 2010 …

Cornell University

CHRONICLEONLINE

Nov. 12, 2010

$11M gift for Atacama telescope will help astronomers answer fundamental questions about galaxy, star formation

By Lauren Gold

Retired businessman Fred Young '64, M.Eng. '66, MBA '66, has committed $11 million to CCAT, the Cerro Chajnantor Atacama Telescope, a proposed 25-meter aperture telescope that will be the largest, most precise and highest astronomical facility in the world.

The Department of Astronomy announced the gift Nov. 12 at a workshop for CCAT scientists. Vice Provost for Research Robert Buhrman called it "a beautiful day in Ithaca, a great day for astronomy and a great day for Cornell."

Jason Koski/University Photography

Provost Kent Fuchs, left, introduces benefactor Fred Young '64, who committed $11 million to support the CCAT telescope, at a workshop for CCAT scientists.