CHINA-US Bilateral Workshop, Beijing 20-25 April

Project FAST

Five hundred meter Aperture Spherical radio Telescope

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content

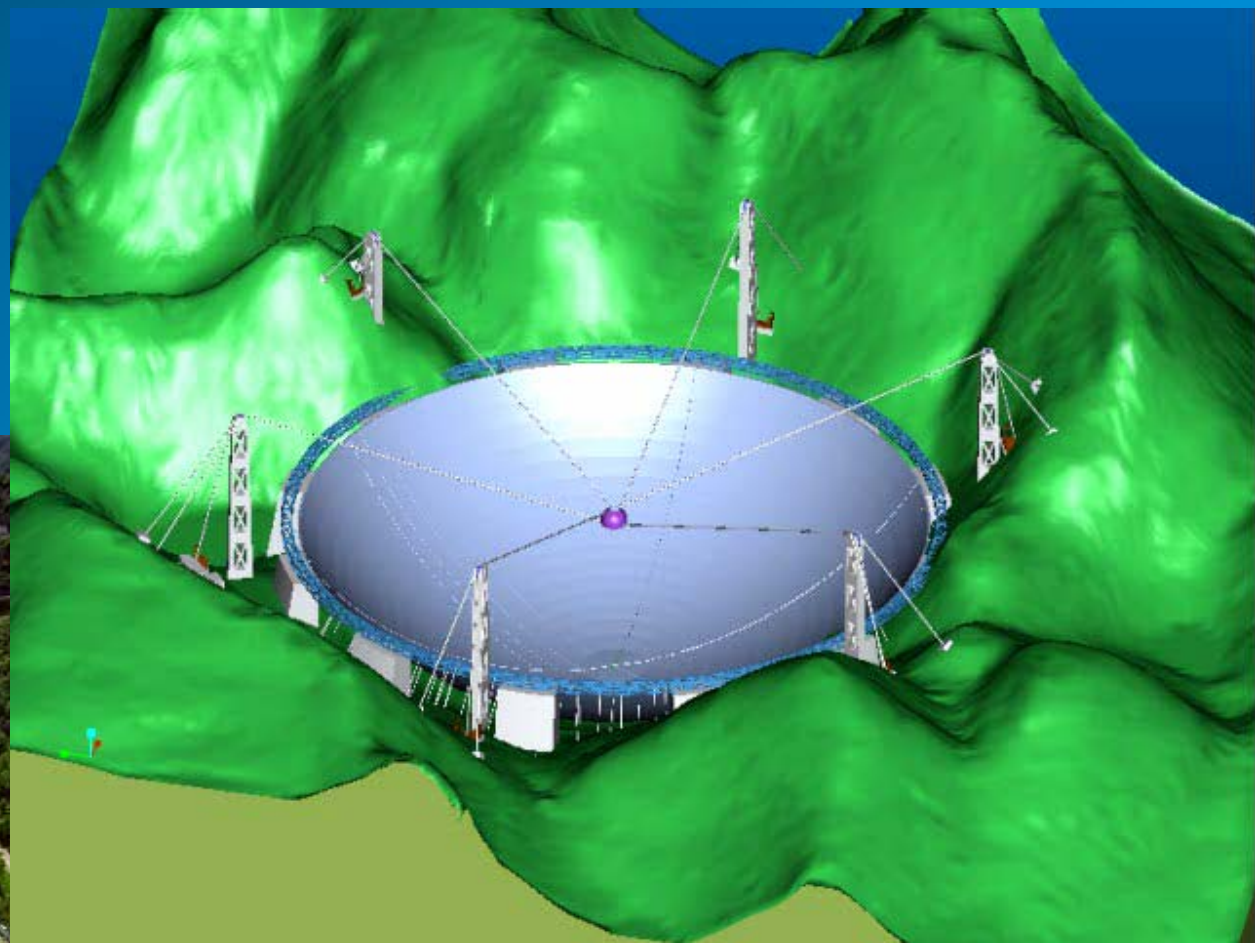
- FAST sciences
- General technical specifications
- Technical plan – critical technologies
- Feasibility study of critical technologies
- Current state of FAST project

- Project has been approved by the NDRC

- Report on feasibility studies has been reviewed

Five hundred meter Aperture Spherical Telescope

- Unique Karst depression as the site
- Active main reflector
- Cable - parallel robot feed support



1. FAST sciences

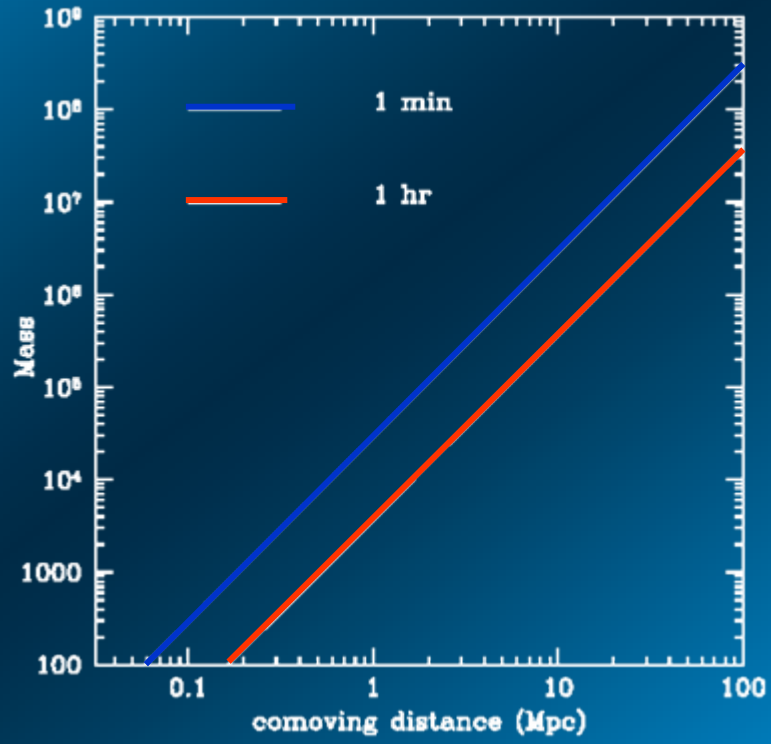
- Neutral Hydrogen line (HI) surveying
- Pulsar research
- Joining VLBI network
- Molecular lines
- Search for Extraterrestrial Intelligence (SETI)
- Possible early sciences with FAST

Neutral hydrogen (HI) survey

Cosmic history is written in the characters of weak HI line emission. To read this encyclopaedia, a super sensitive telescope is required

Blind detection of HI clouds with an interference-free observing period of 1h, z~0.7

Warm HI shell around AGN, the detection range limit in a moderate integration time, z~3



Kravtsov - Simulation on dark matter distribution in a normal galaxy

Xuelei Chen – Estimated FAST detection sensitivity of 1 min & 1 h
Line width 30km/s,S/N -10

Duffy et al

Number of galaxies to be detected per day (18h) using FAST 19 beams with different san range

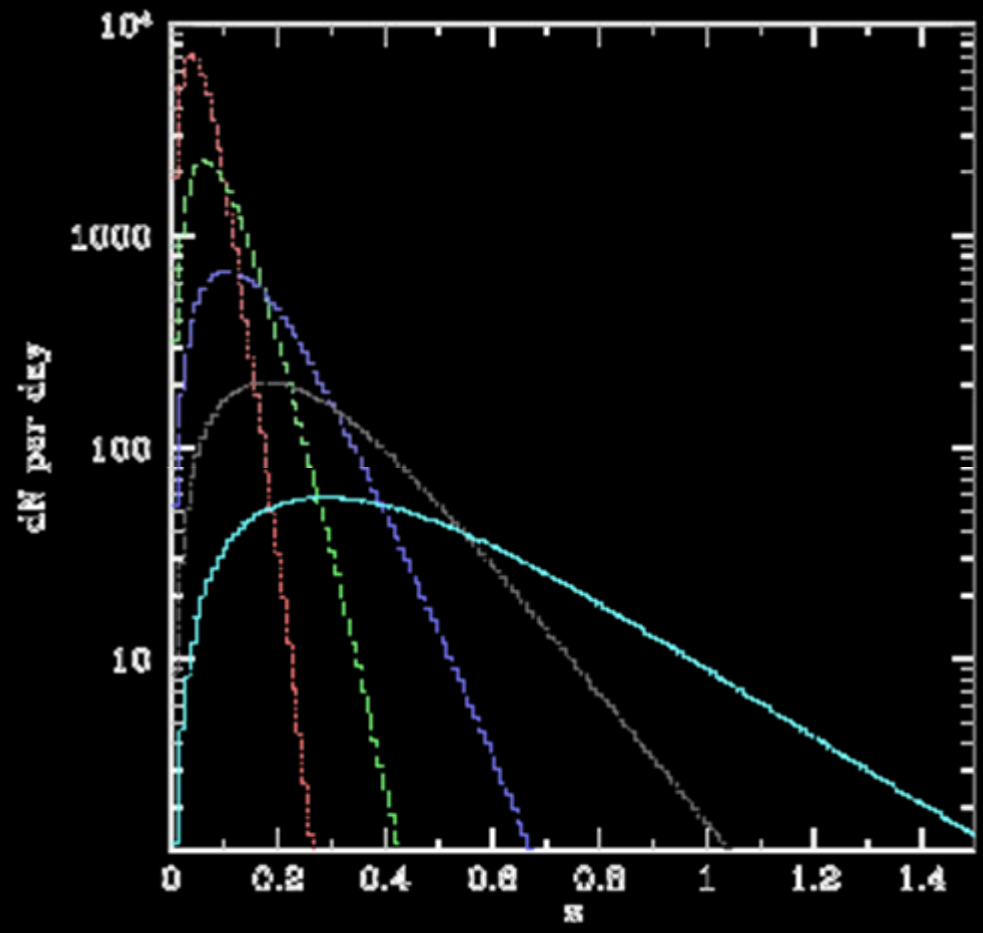
---- 6 sec

---- 60 sec

---- 600 sec

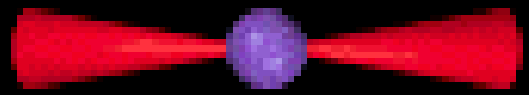
---- 6000 sec

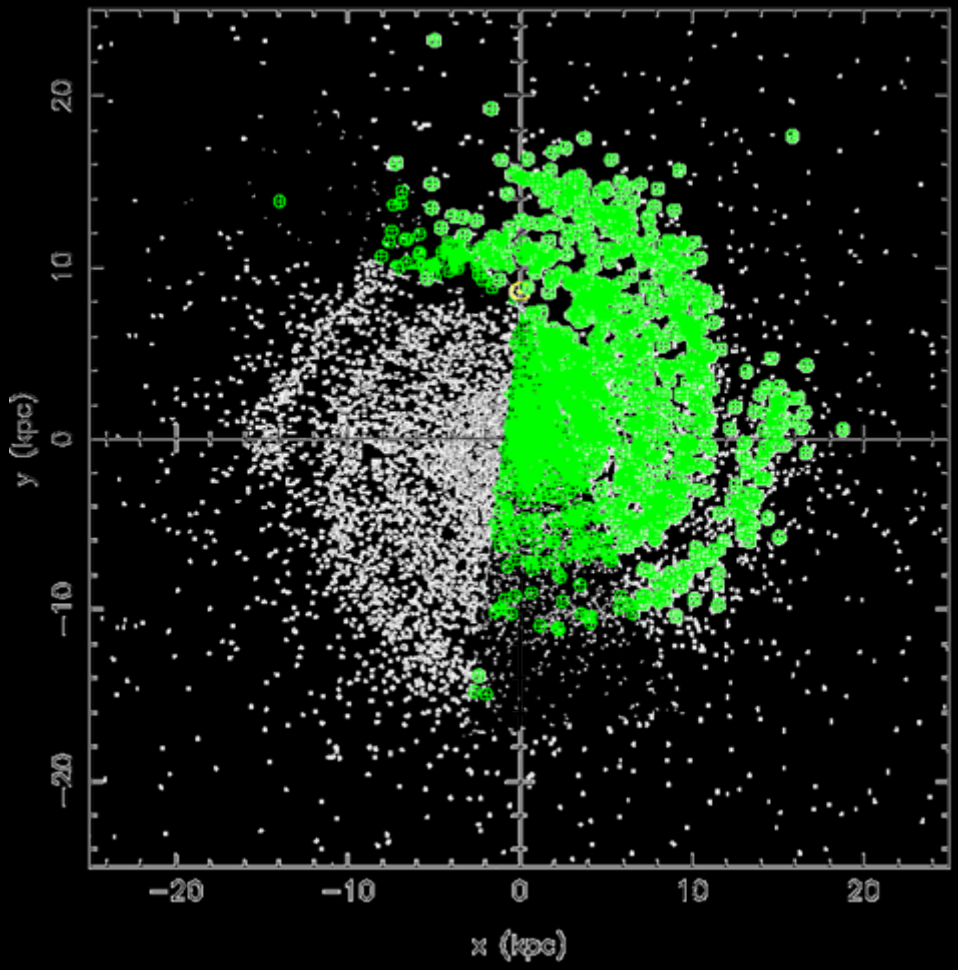
---- 60000 sec



FAST Pulsar Survey

There are ~ 6 x 10^4 detectable pulsars in the Galaxy, half is in FAST sky

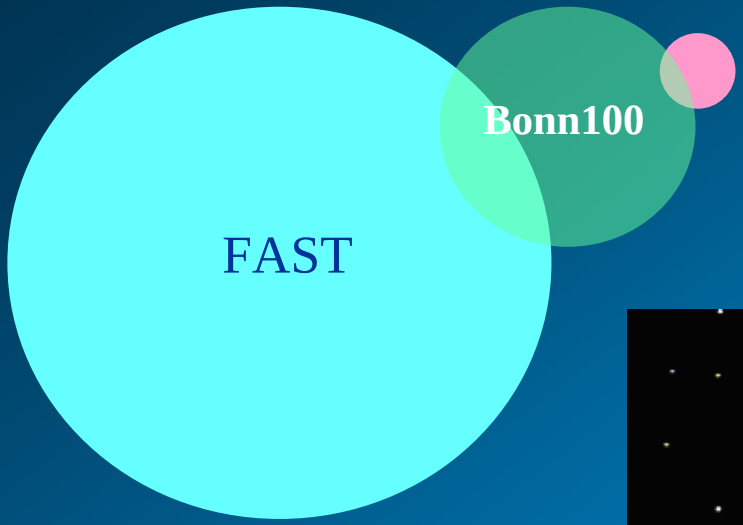




~ 10^4 pulsars

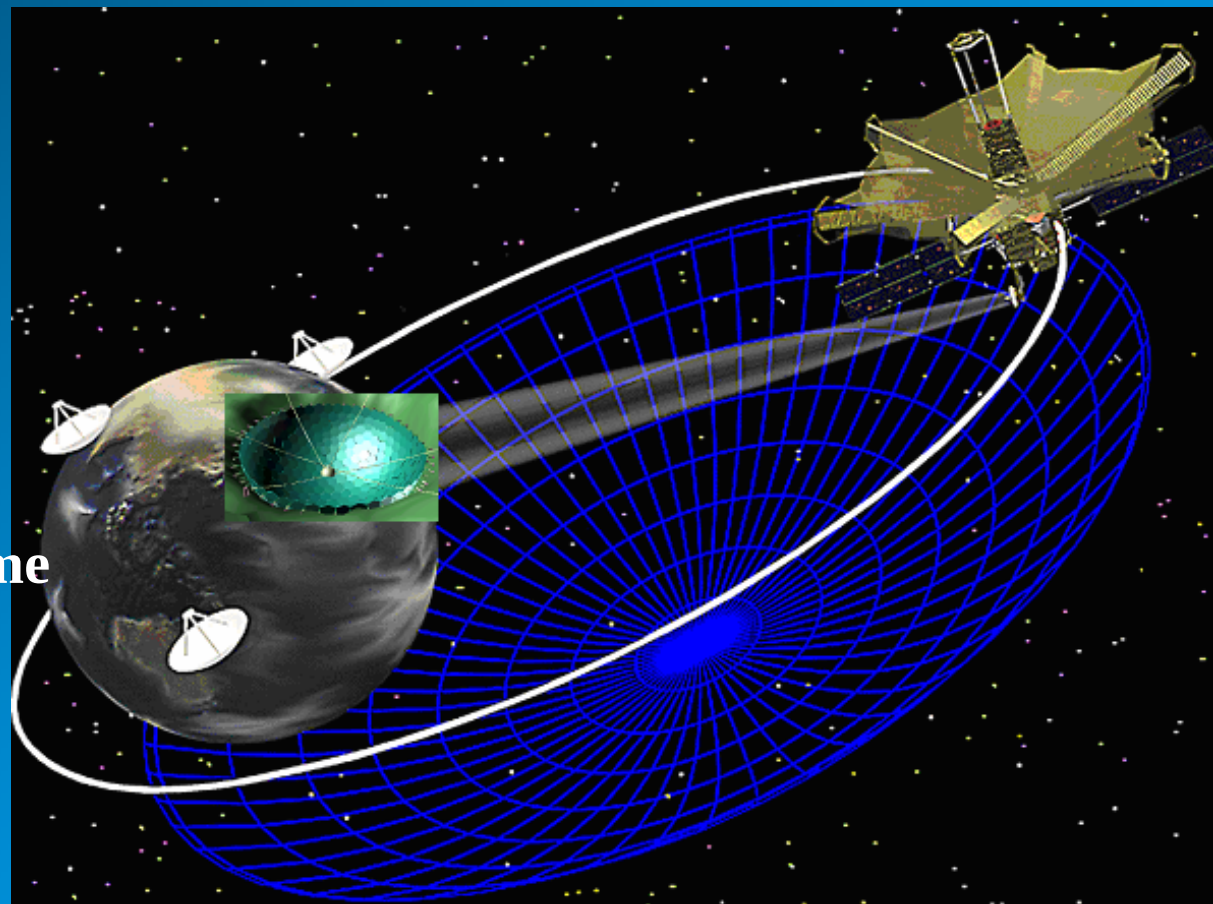
- **Rare objects**
  Exotic stars – quark matter
  Pulsar-BH binary
  ….
- **Stellar evolution before SN**
- **ISM map of unprecedented details**

A ‘master’ of VLBI network



VLBA	**80**	**μ Jy**
HSA	**5.5**	**μ Jy**
HSA+FAST	**3.1**	**μ Jy**

Much longer source on time

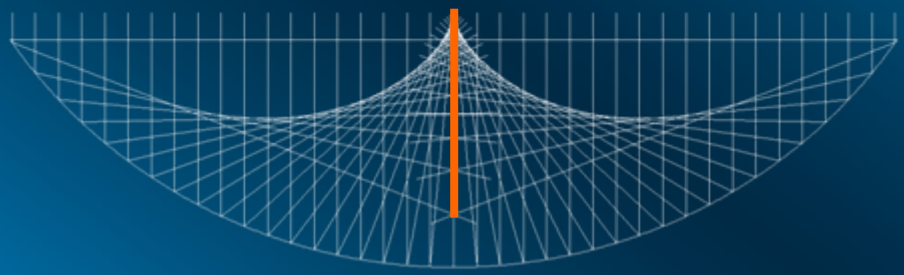


Early sciences with FAST– bilateral meeting in JBO

- HI – small scale deep survey of H-z
- Pulsar – BH binary
- M31 – extragalactic pulsars
- Survey more pulsars in clusters, more about this by Scott
- OH masers at z ~ 1
- Lines in Orion e.g. $C_{20}H_{10}$? By Di

Follow-ups of LOFAR/ASKAP ….

Make use of the whole 500m aperture by adopting a long linear feed to achieve ?



2. General Technical Specification

Spherical reflector：Radius～300m, Aperture～500m, Opening angle 110~120°

Illuminated aperture：D_{ill}=300m

Focal ratio：f/D =0.467

Sky coverage：zenith angle 40°（up to 60° with efficiency loss) tracking hours 0~6h

Frequency：70M ~ 3 GHz（up to 8GHz in future upgrading）

Sensitivity (L-Band)：A/T~2000, T~20 K

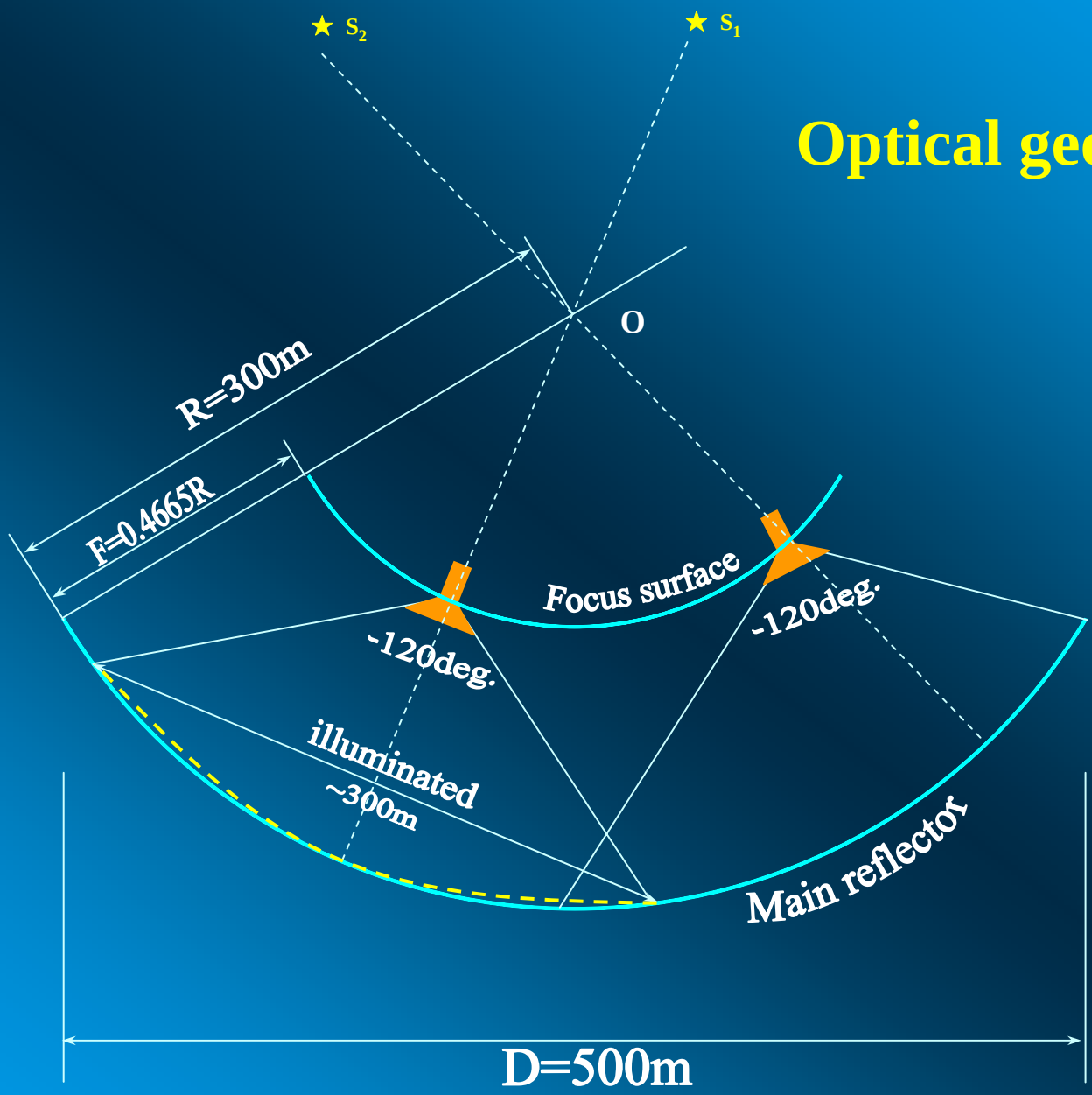
Resolution (L-Band)：2.9′

Multi-beam (L-Band)：19, beam number of future FPA >100

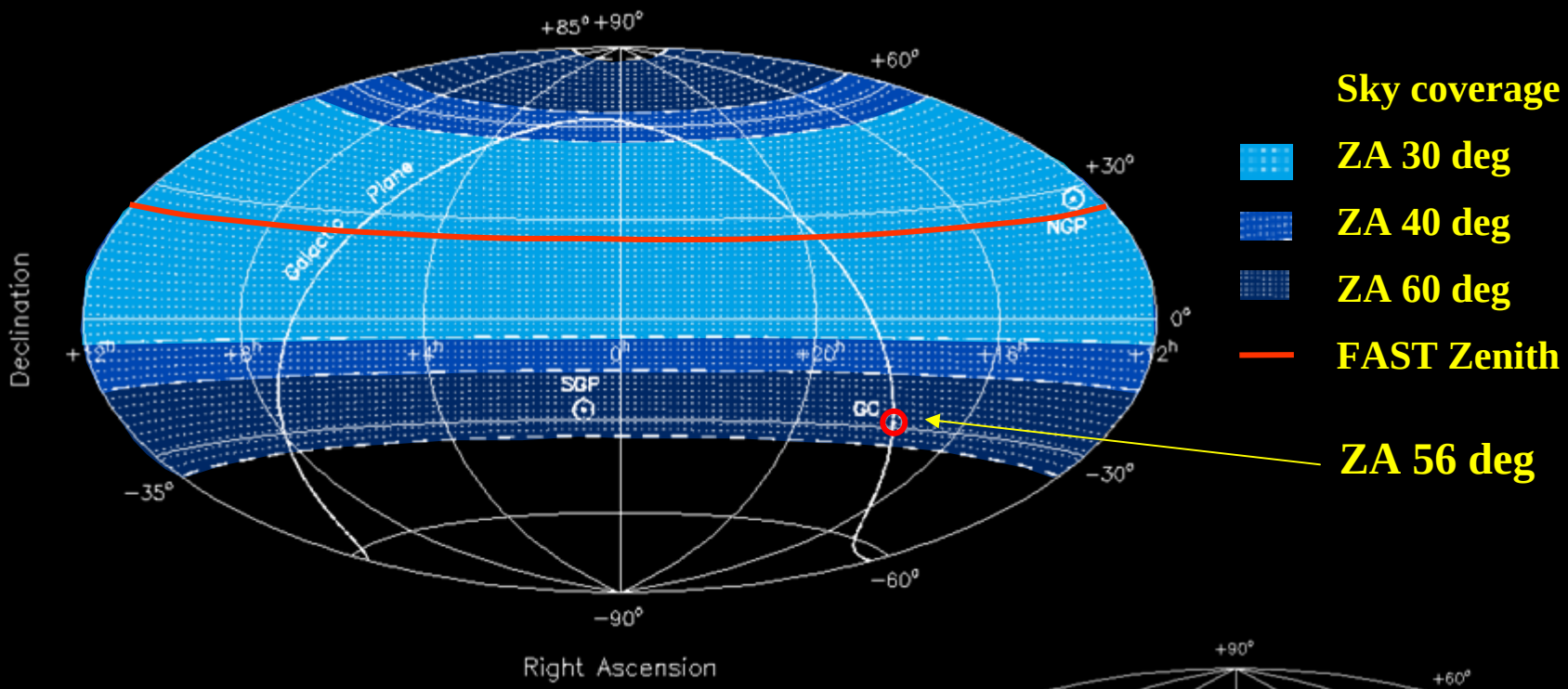
Slewing：<10min

Pointing accuracy：8″

Optical geometry

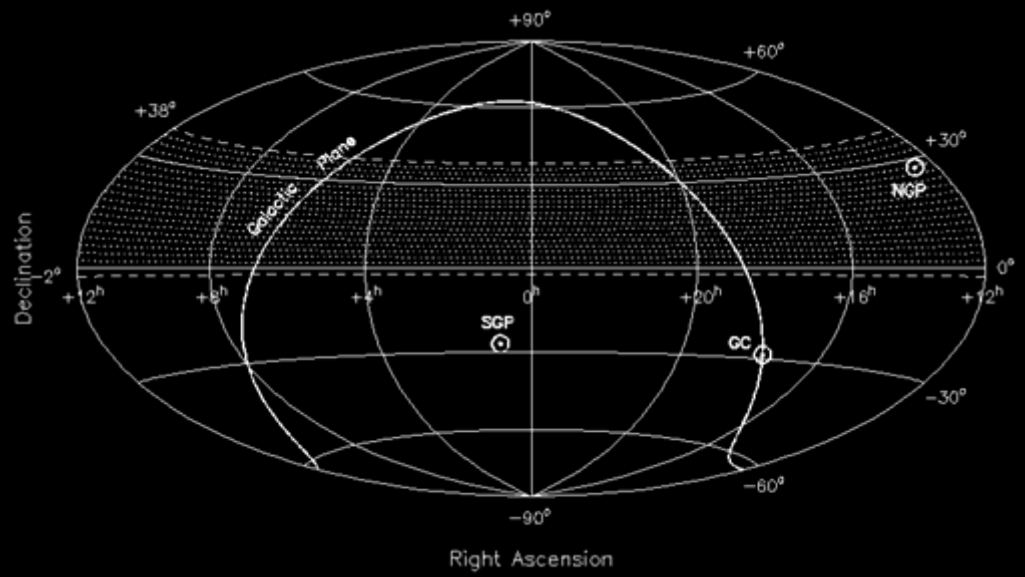


Opening angle - sky coverage

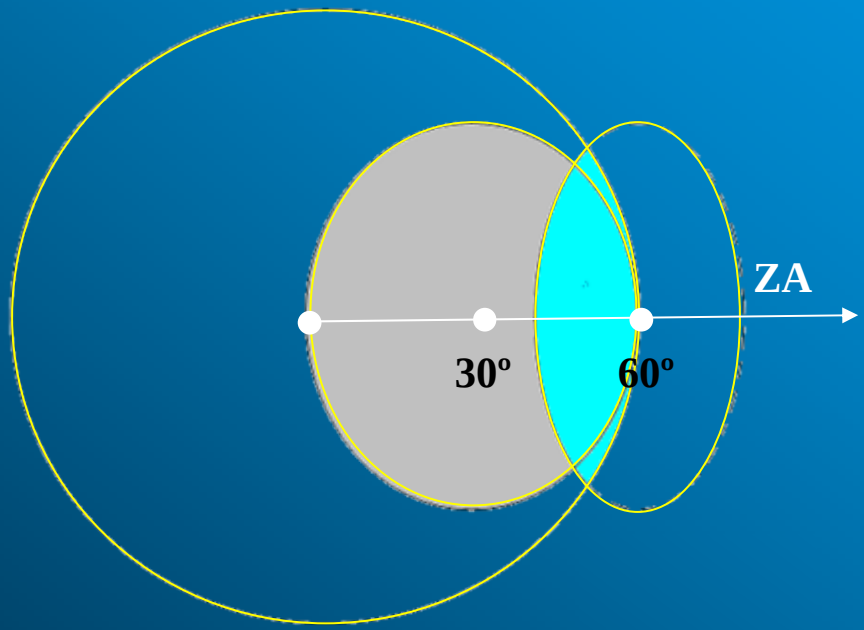


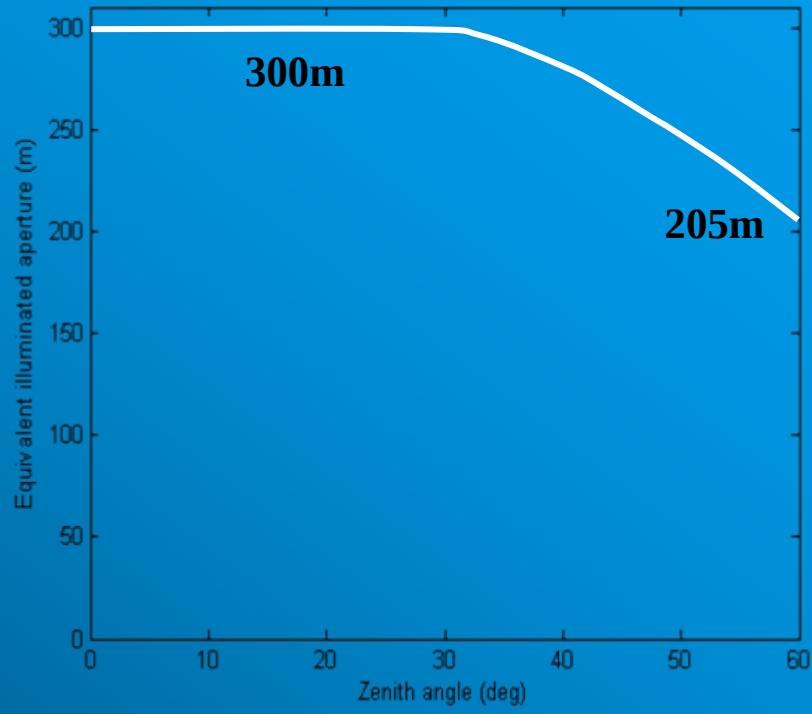
Sky coverage

FAST vs. Arecibo



Opening angle - sky coverage (cont.)



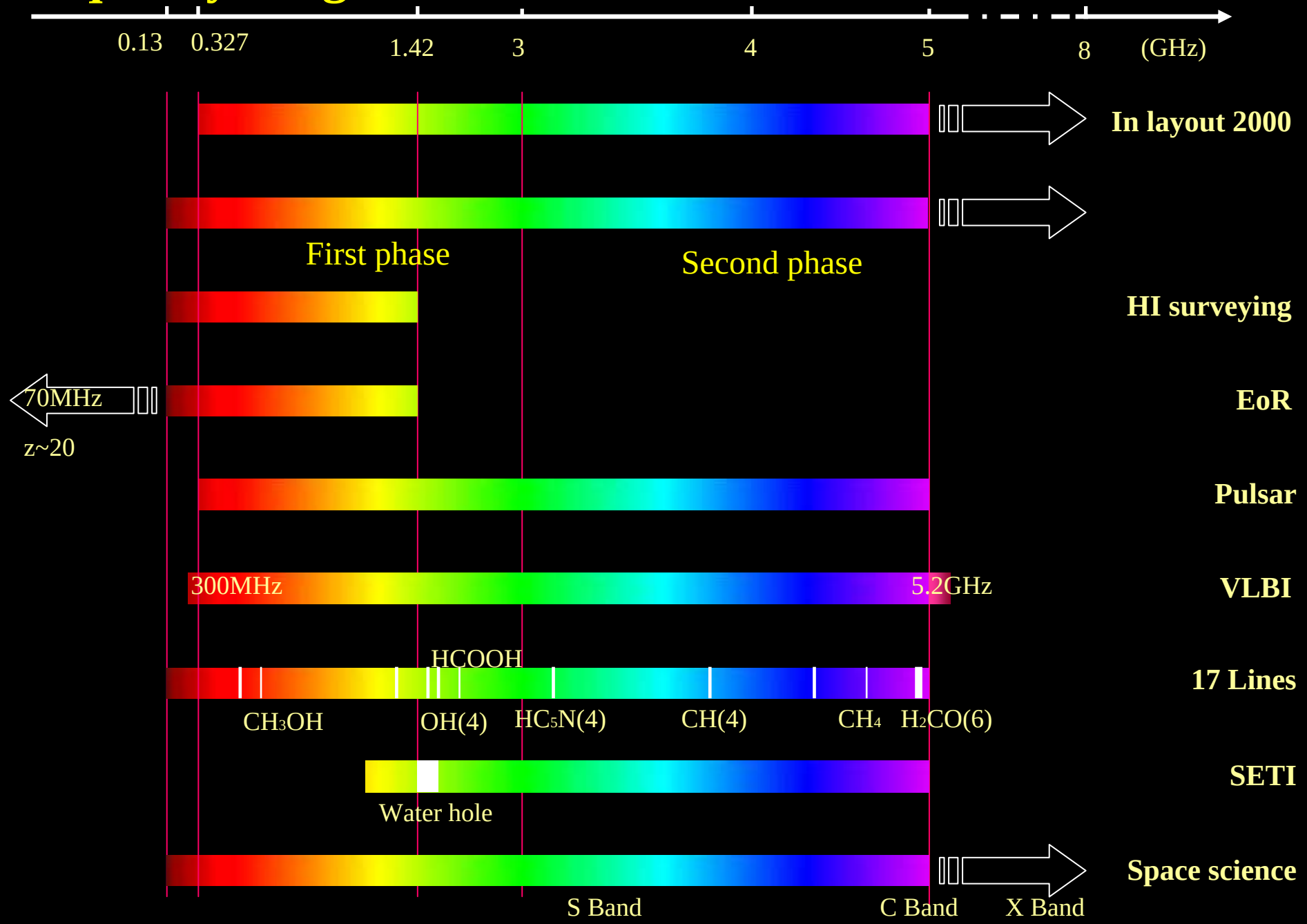


If FPA technology could form an irregular beam to fully match the desired portion

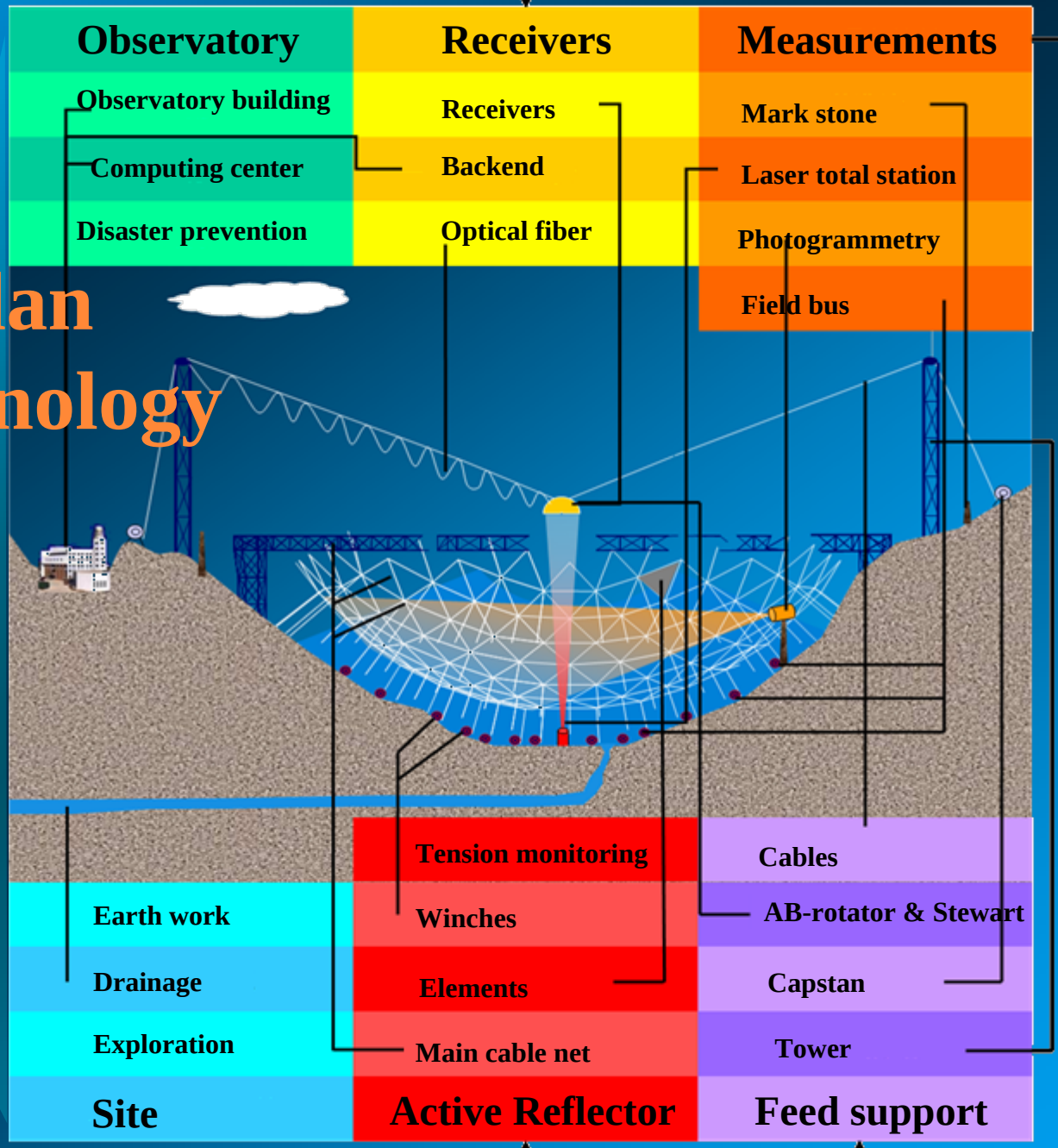
We can have a large single dish ~ 200m at zenith 60˚

We are interested to have the Roger's talk on FPA

Frequency range



3.Technical plan – critical technology



- Site
- Active Reflector
- Feed support
- Measurements
- Receivers
- Observatory

3.Technical plan– critical technology

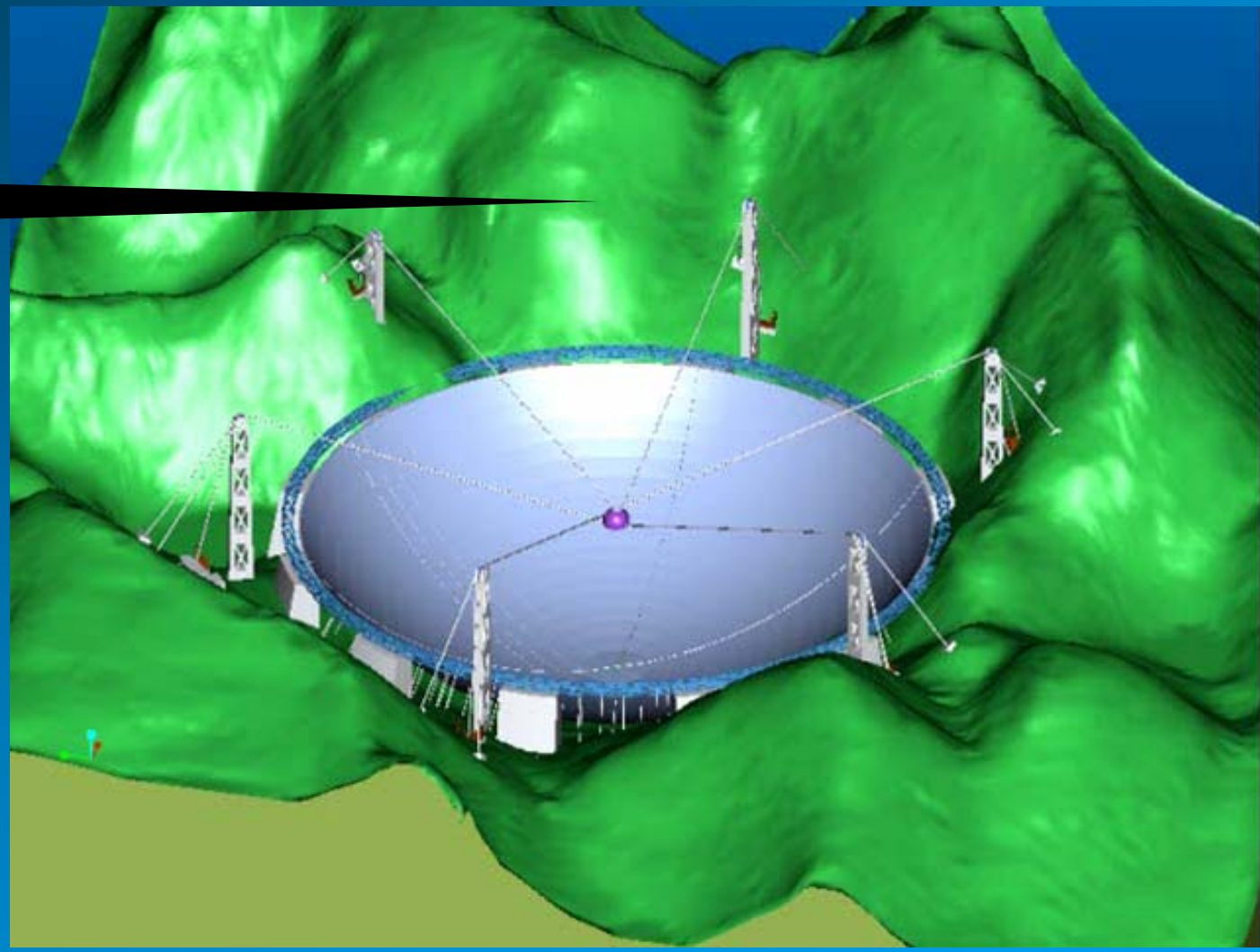
Site

Active reflector

Feed support

Measurements

Receiver



Site Surveying in Guizhou

Location: N25.647222º E106.85583˚

Site: the Karst region in south Guizhou Province


Quick Bird Fly Oct. 6, 2005

3.Technical plan– critical technology

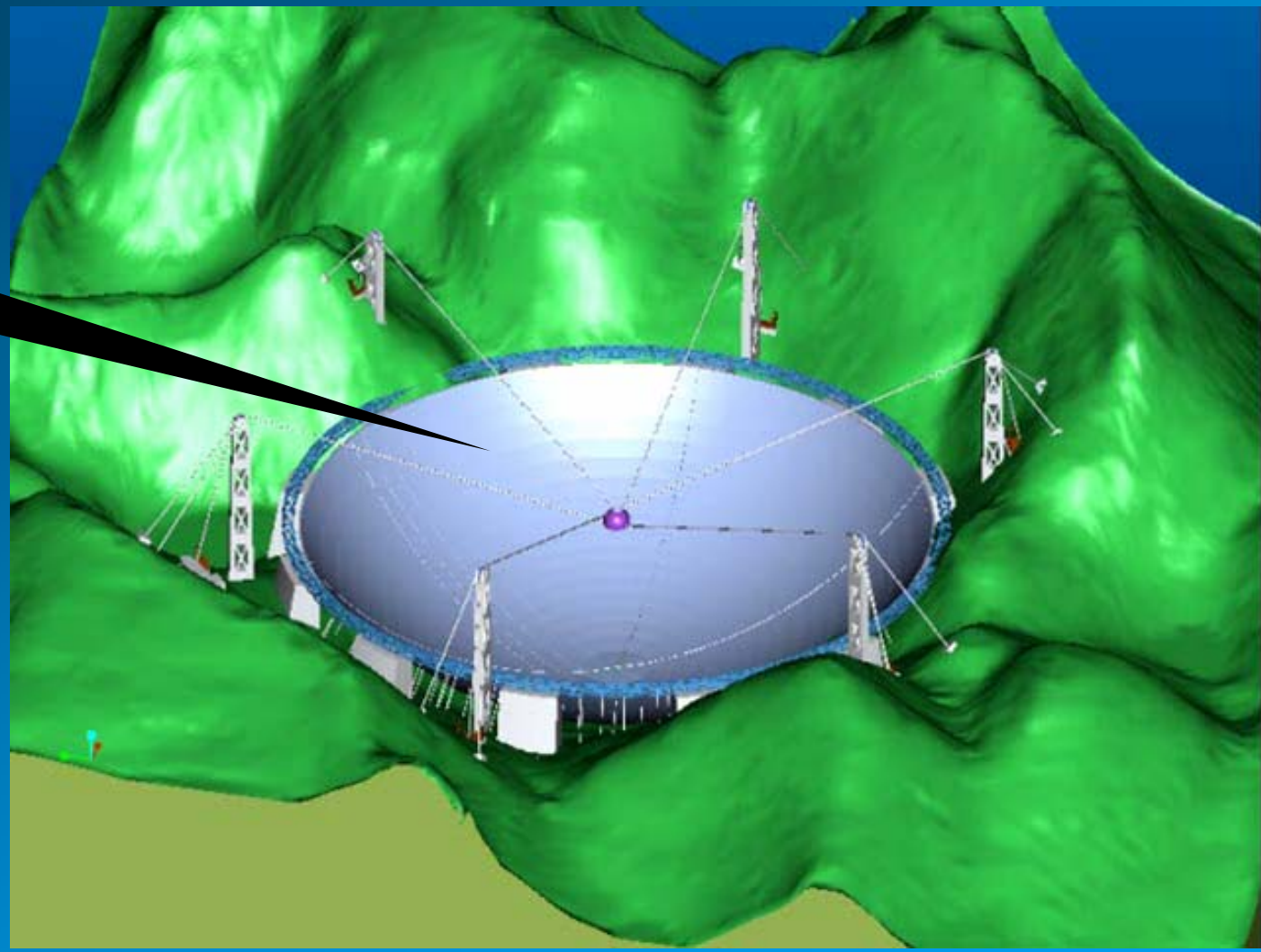
Site

Active reflector

Feed support

Measurements

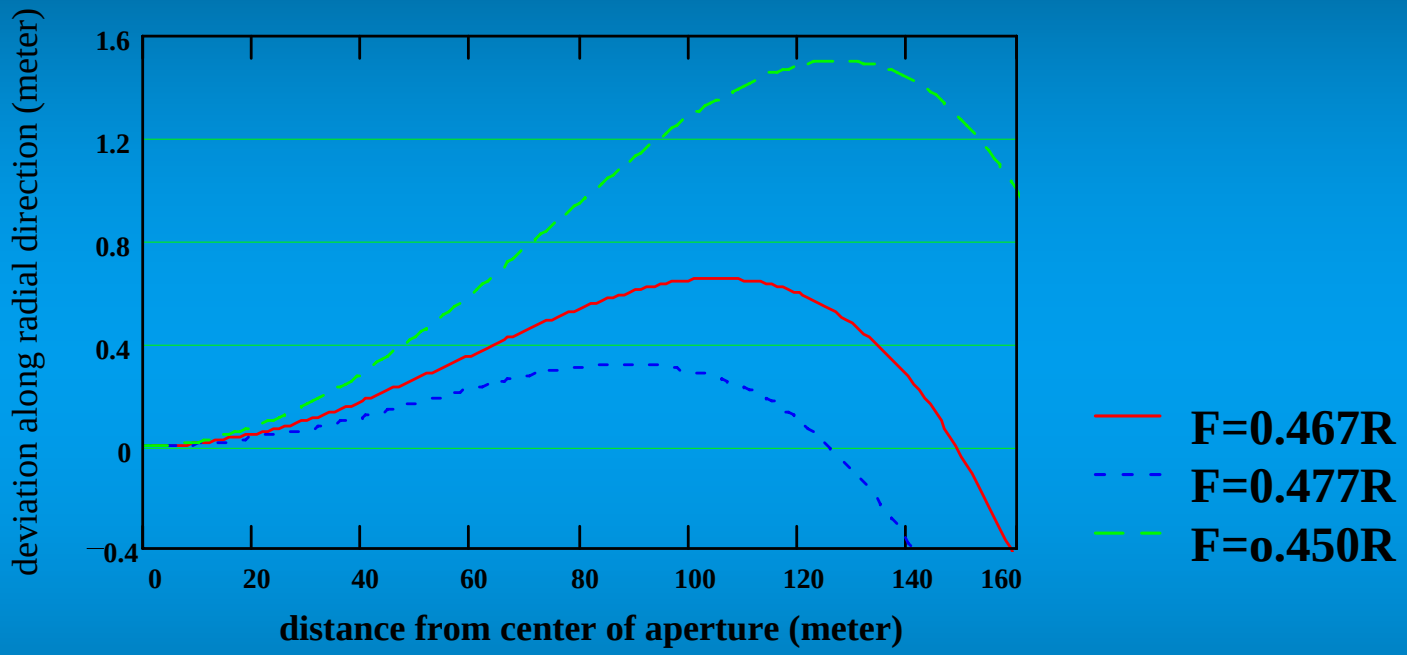
Receiver



Central part of sphere is close to paraboloid as f/D is proper

Minimized deviation is 0.67m as f/D ~ 0.467 R

Maximum slope of deviation curve gives maximum rate 0.7mm/s



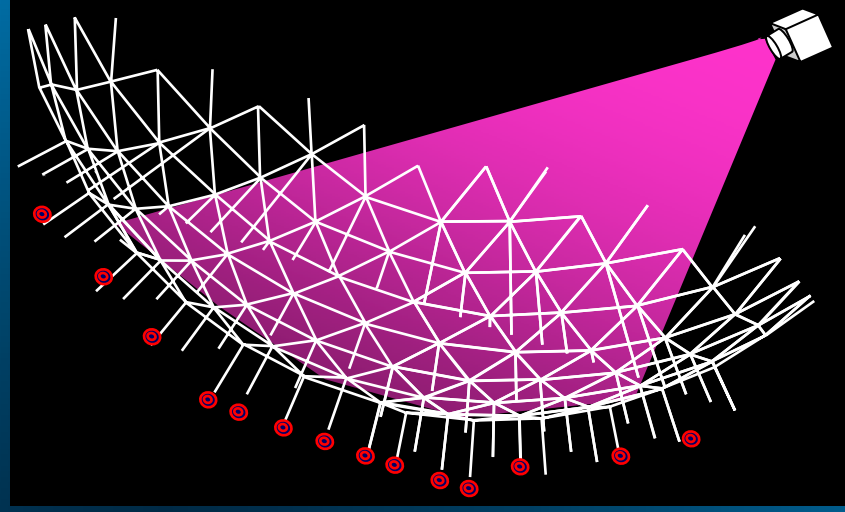
Main reflector is composed of small element units

~ 2000 hexagons of 15m – rms 4mm

~ 4600 triangles of 11m – rms 2.2mm

~2400 winches

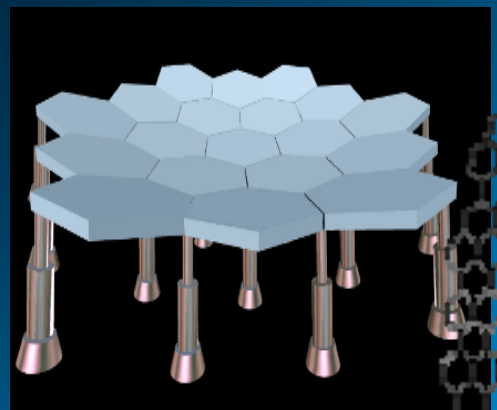
~4600 panels



Adaptive cable-mesh

Two realizations of main reflector

Solid panel-actuator



~2000 panels and actuators

3.Technical plan– critical technology

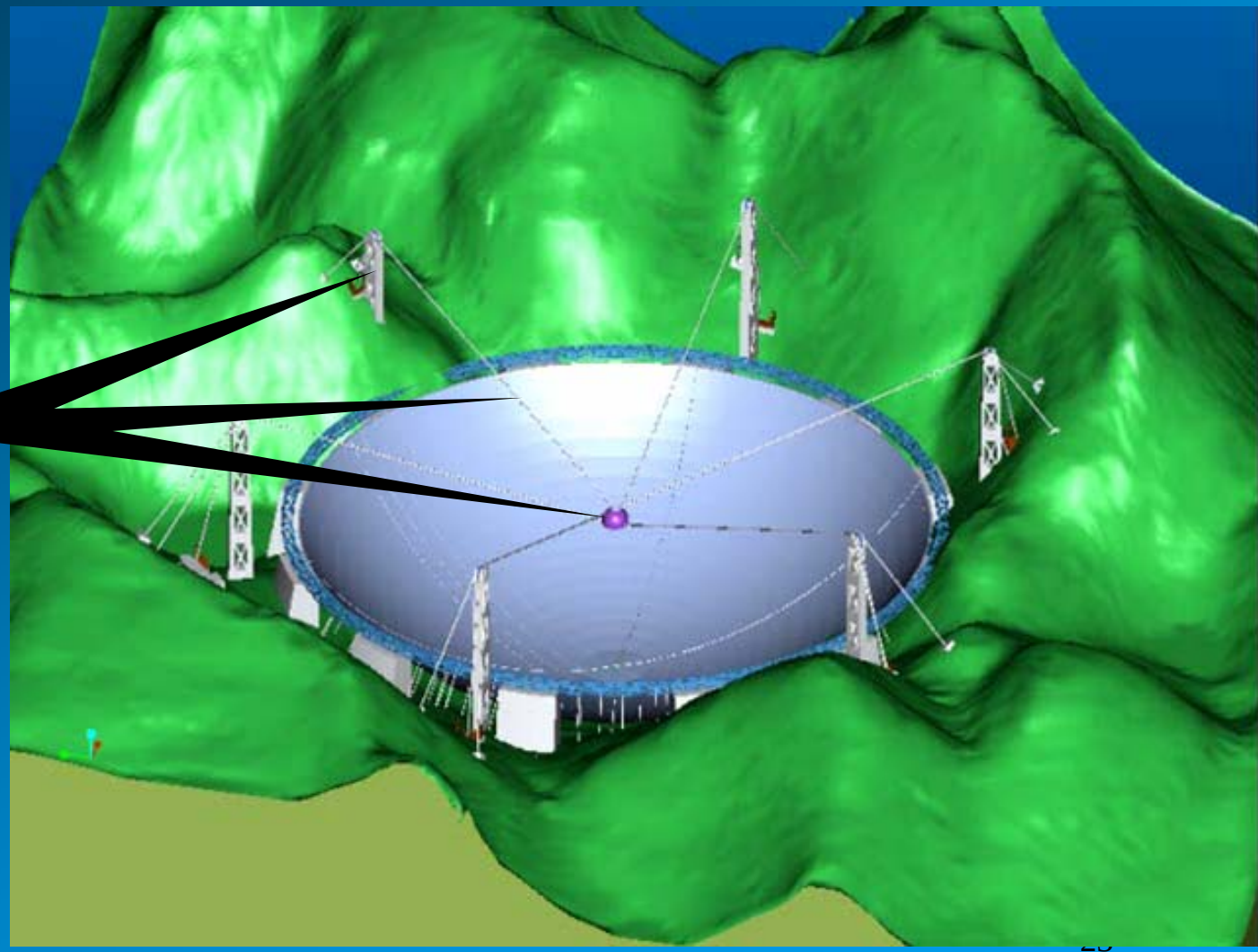
Site

Active reflector

Feed support

Measurements

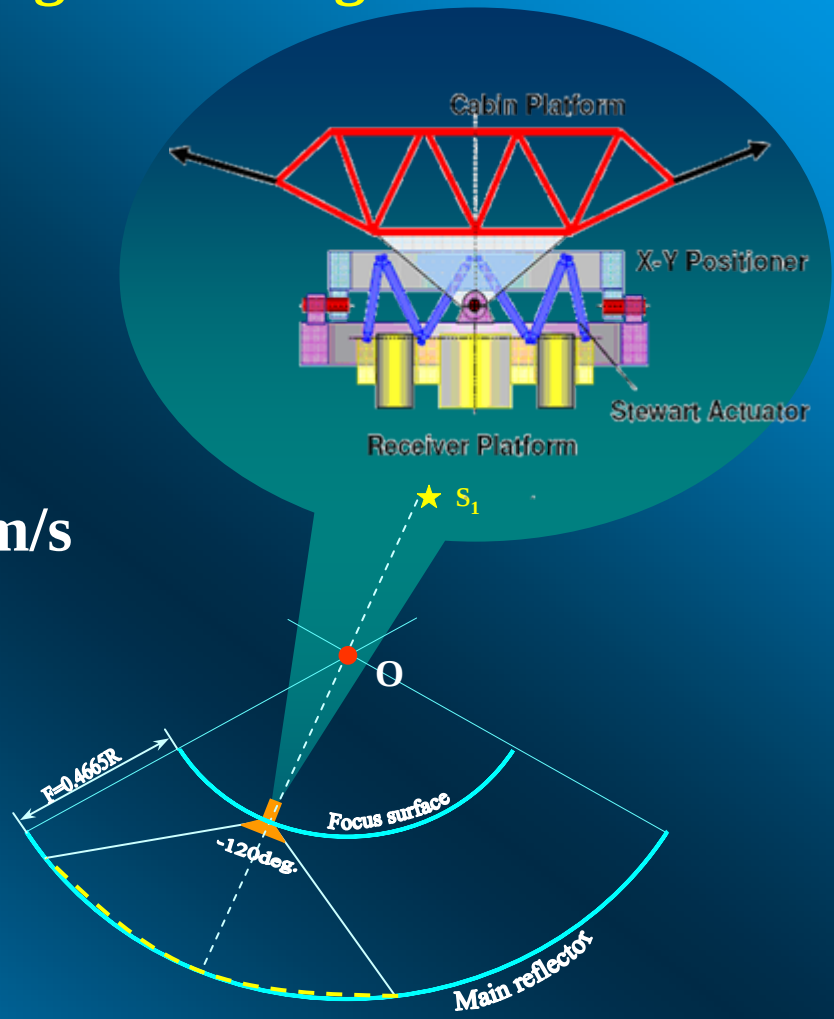
Receiver



Feed support

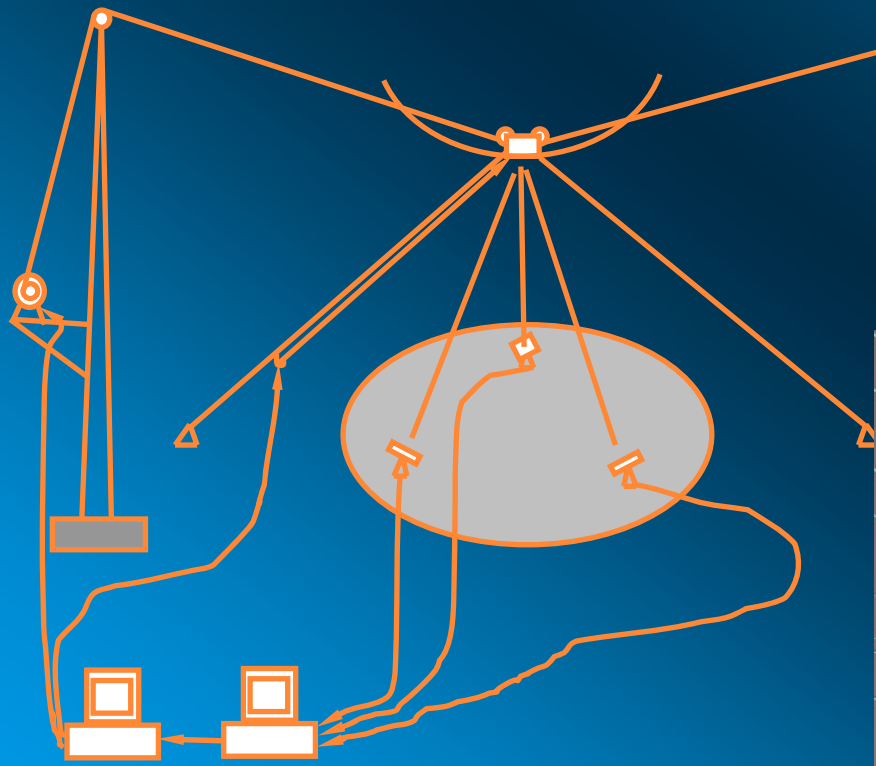
mechanical-electronic-optical integrated design

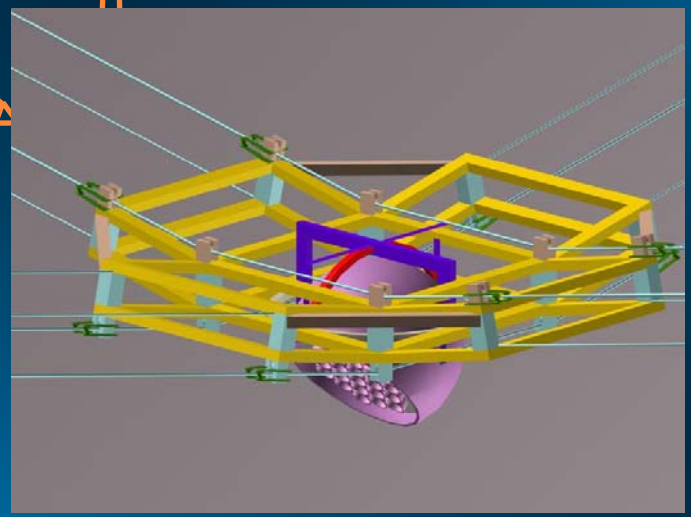
- Focal cap diameter 206m
- Cabin in total ~30t
- Load on lower plate ~3t
- Maximum tracking 11.6mm/s
- Slewing 400mm/s
- Position error <10mm
- Pointing accuracy 8”



Three main parts of cabin suspension

- Cable network - first adjustable system
- Stewart - secondary adjustable system
- Close loop control





3.Technical plan– critical technology

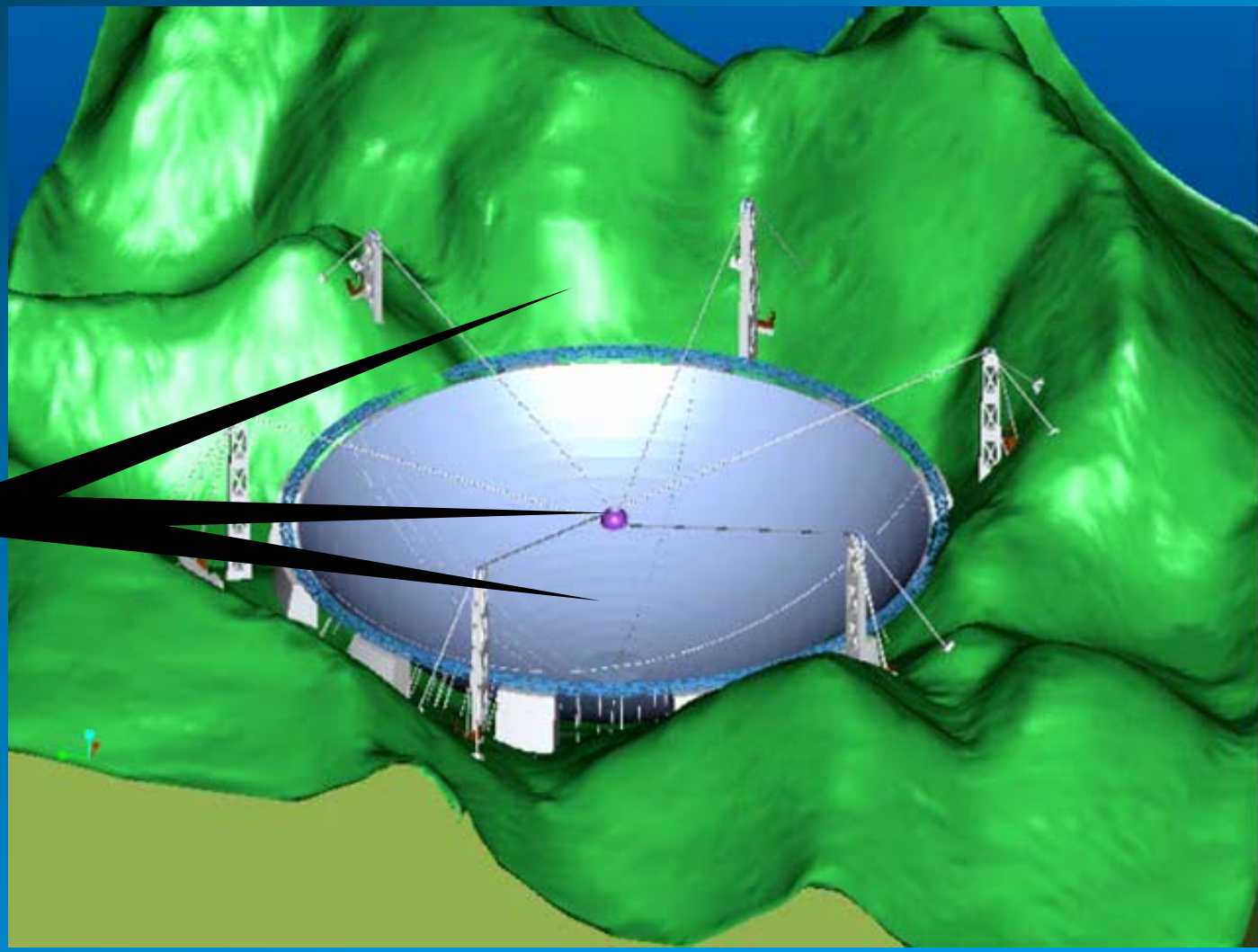
Site

Active reflector

Feed support

Measurements

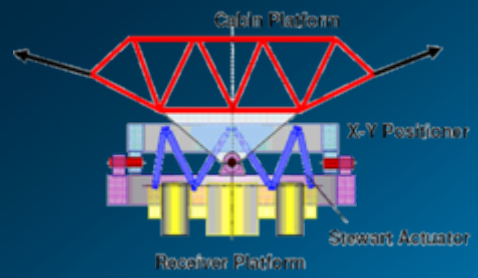
Receiver



Measurement – precise, quick and in long distance

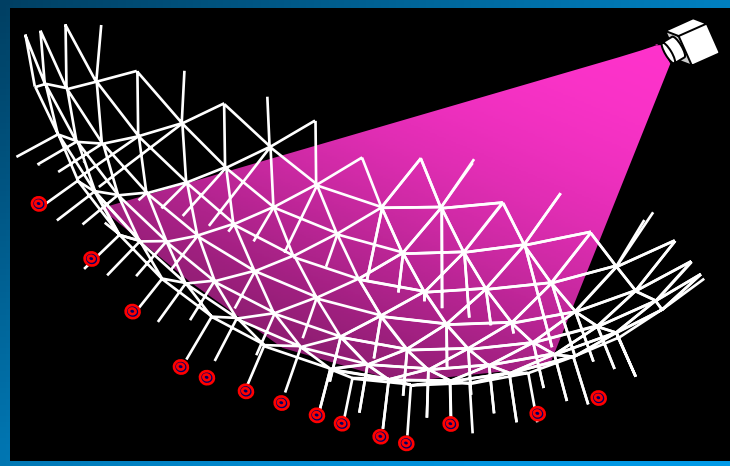
Task 1: 3-D spatial positions of focus cabin

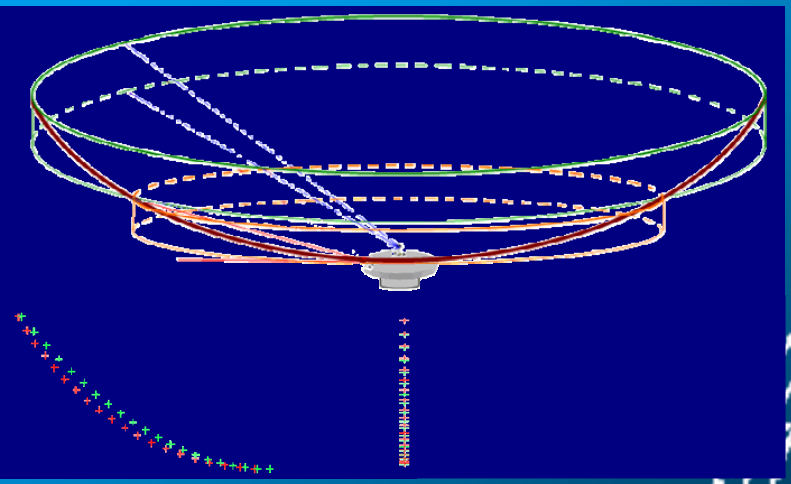
- Large working range up to 300 m
- Errors ~1 mm
- Sampling rate > 10 Hz



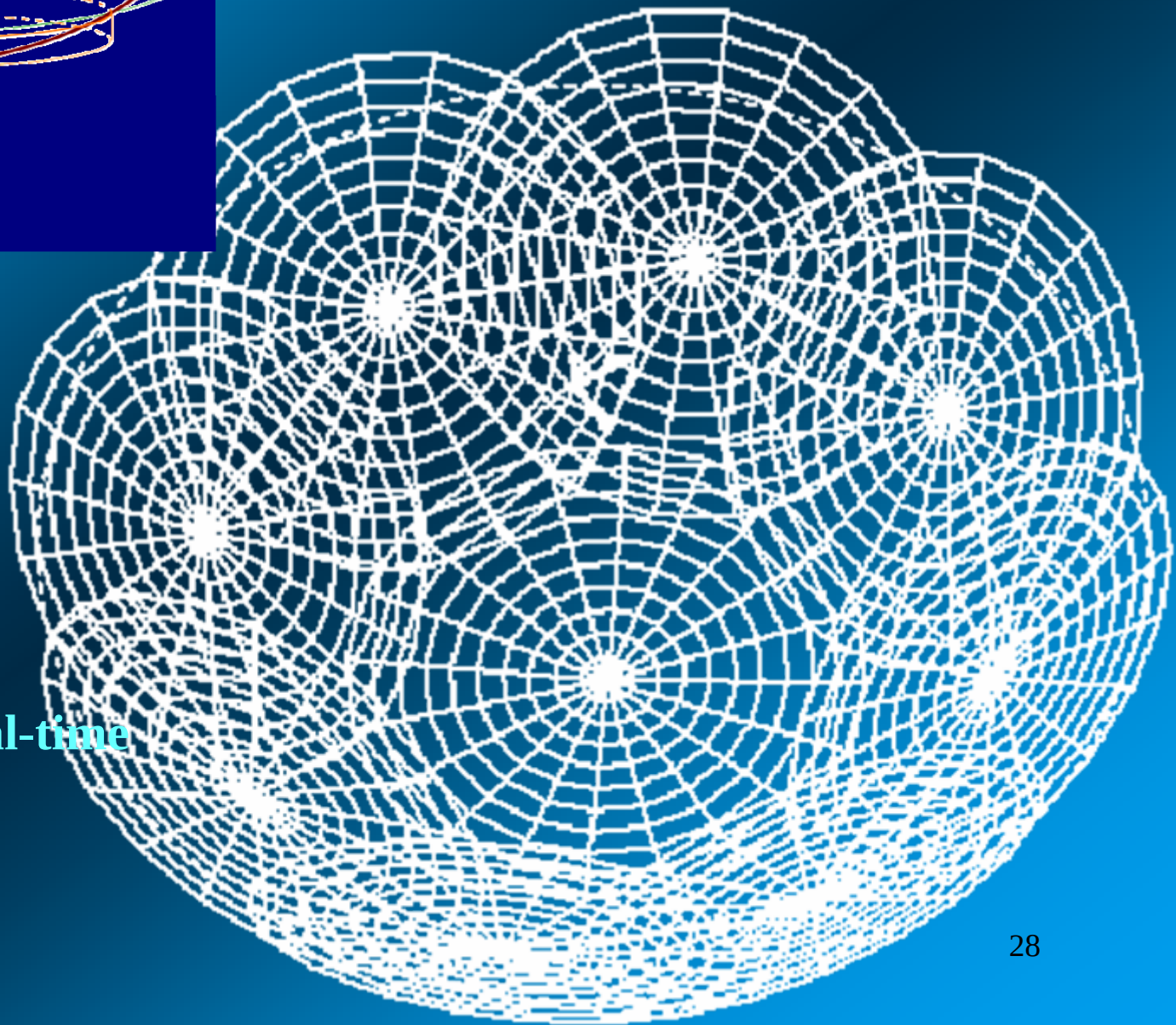
Task 2: profiles of main reflector

- Number of targets ~2400
- ~1000 in illuminated area
- Accuracy 1~2mm
- Sampling interval 10 sec ~ few min





Photogrammetry
Surveying reflector profile



1000 nodes within
illuminated area
to be scanned in real-time
period ~ 1 min

3.Technical plan– critical technology

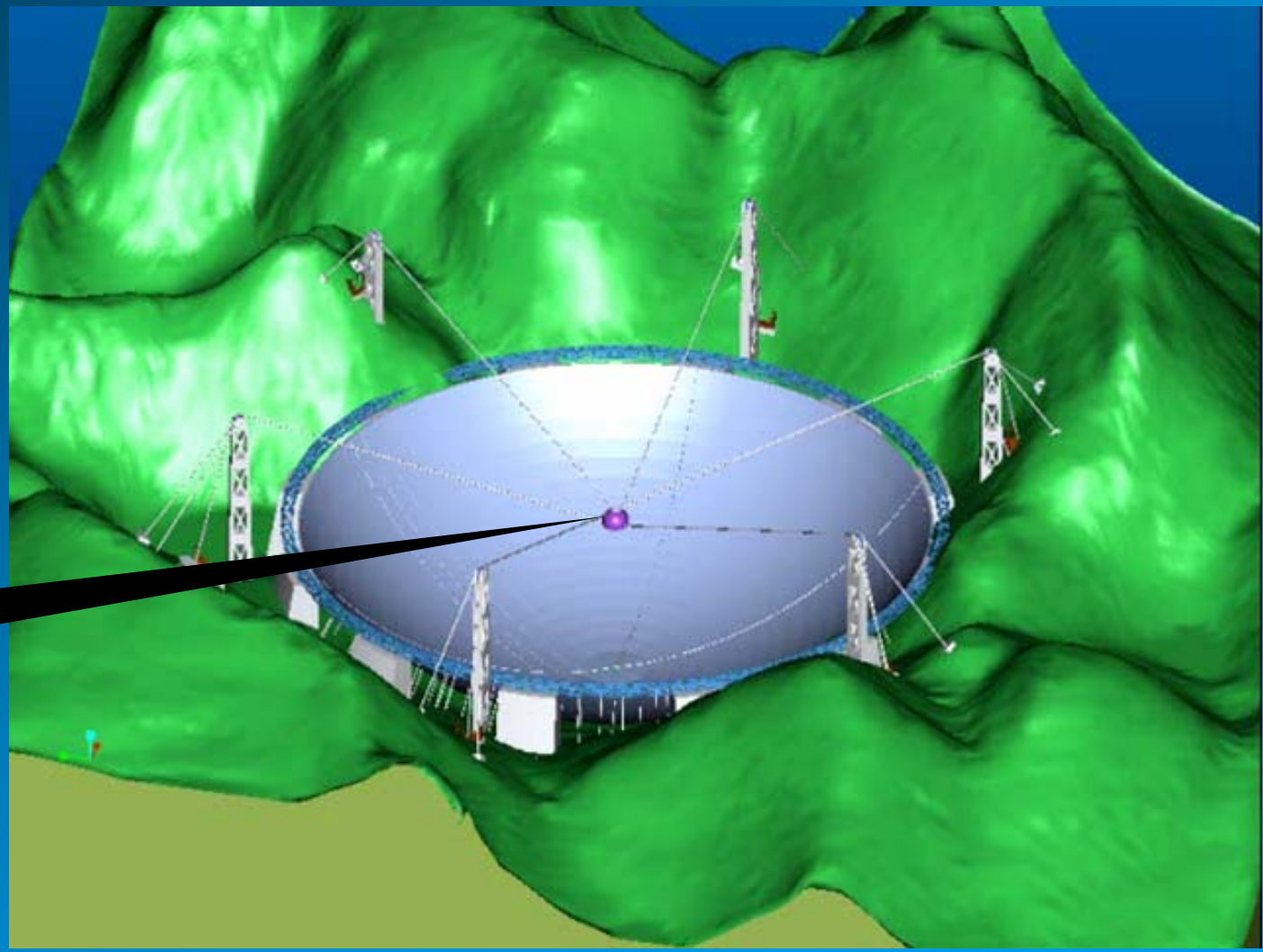
Site

Active reflector

Feed support

Measurements

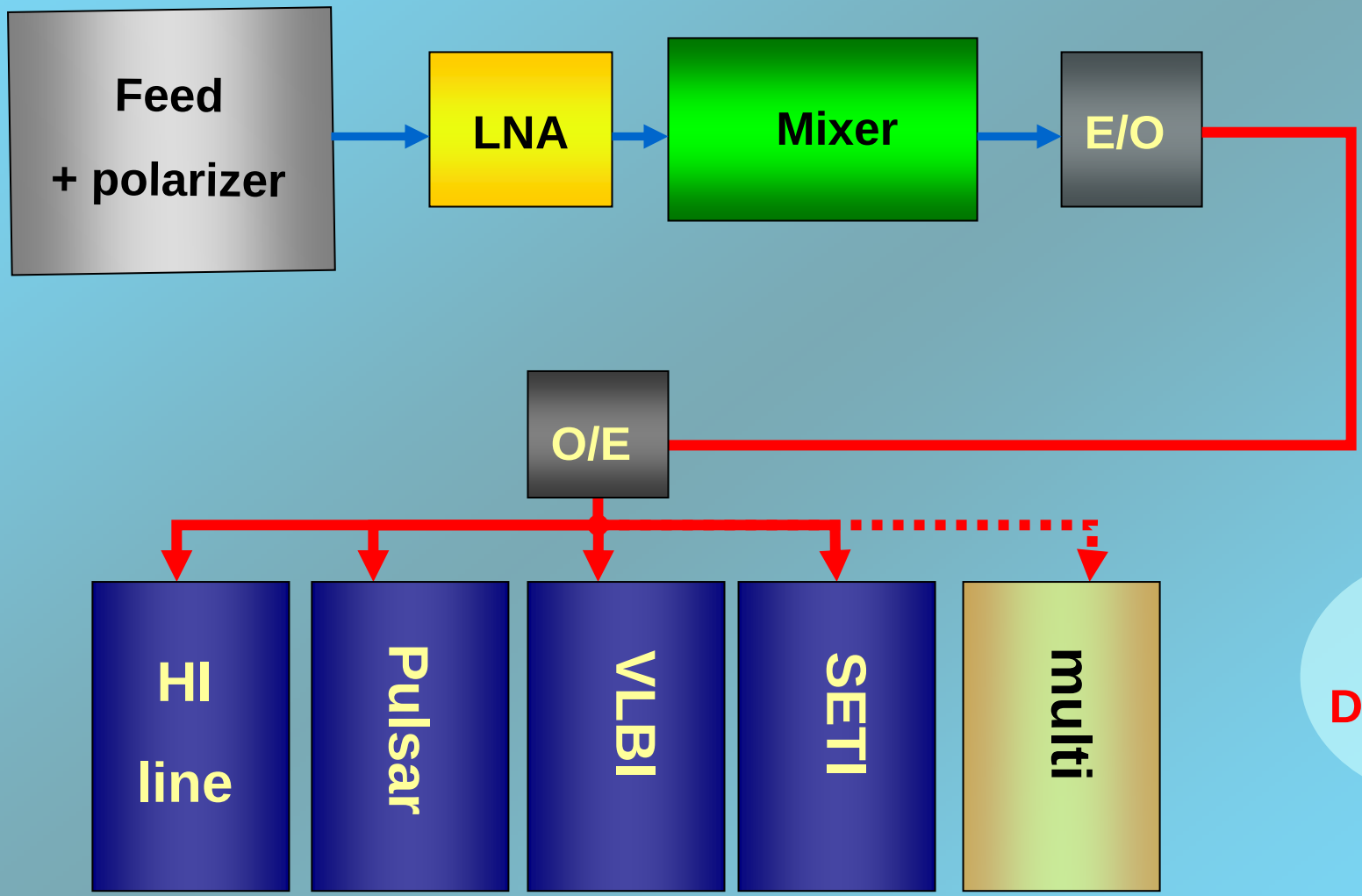
Receiver



9 sets of FAST receivers NAOC - JBO

No	Band (GHz)	Beams	Pol.	Cryo Tsys(K)	Science
1	0.07 – 0.14	1	RCP LCP	no 1000	High-z HI(EoR),PSR, VLBI, Lines
2	0.14 – 0.28	1	RCP LCP	no 400	High-z HI(EoR),PSR, VLBI, Lines
3	0.28 – 0.56	1 or multi	RCP LCP	no 150	High-z HI(EoR),PSR, VLBI, Lines Space weather, Low frequency DSN
4	0.56 – 1.02	1 or multi	RCP LCP	yes 60	High-z HI(EoR),PSR, VLBI, Lines Exo-planet science
5	0.320 – 0.334	1	RCP LCP	no 200	HI,PSR,VLBI Early sciences
6	0.55 – 0.64	1	RCP LCP	yes 60	HI,PSR,VLBI Early Sciences
7	1.15 – 1.72	1 L wide	RCP LCP	yes 25	HI,PSR,VLBI,SETI,Lines
8	1.23 – 1.53	19 Lnarrow multibeam	RCP LCP	yes 25	HI and PSR survey, Transients
9	2.00 – 3.00	1	RCP/ LCP	yes 25	PTA, DSN, VLBI, SETI

Receiver -- Schematic Diagram



4. Feasibility study of critical technologies

Feasibility study of critical technologies started since 1994.
More than a hundred scientists and engineers from 20 institutions
The project is ready to move on to actual programming.

- **Fast sciences**
- **Site surveying**
- **Active main reflector -**
  - **Solid panel-actuator design**
  - **Adaptive cable-mesh design**
- **Feed support**
  - **Cables + stabilizer**
  - **Cables + rotation mechanism + stabilizer**
- **Measurement**
- **Receiver**

Exploration in depression site and the rock-soil samples from ground

breaking load experiment

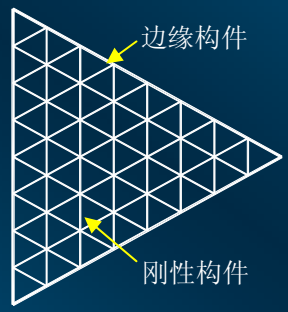
cables

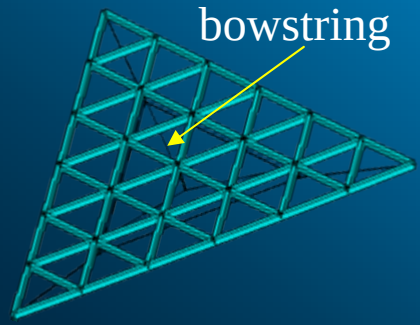
nodes

Prototyping the back-structure of reflector element

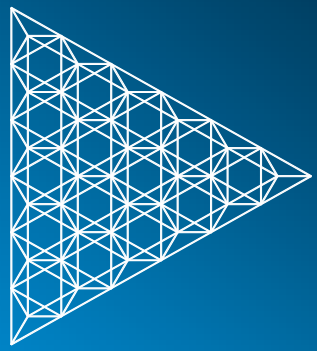
Simple, enable mass production, strong weather resistance.

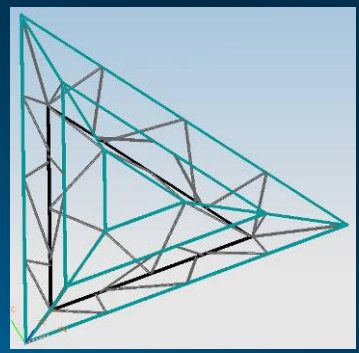
10kg/m^2 is a up-limit





Rear rib: hollow rectangular tube, Z-shaped …

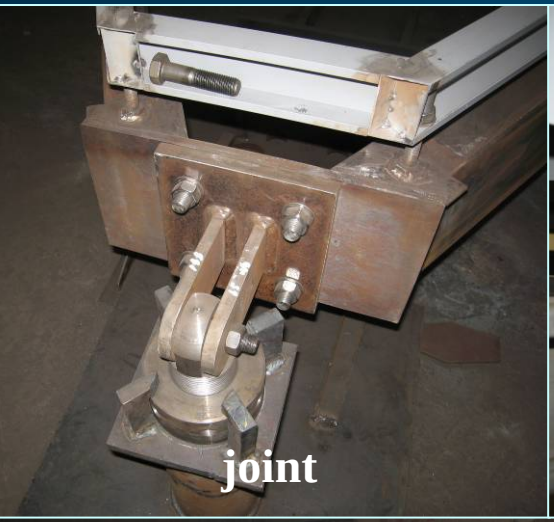




Spatial truss backup (costly)

Prototyping rear rib

Less than 1mm curved, gravity – no gravity



joint

Adjust screw

Bow-string

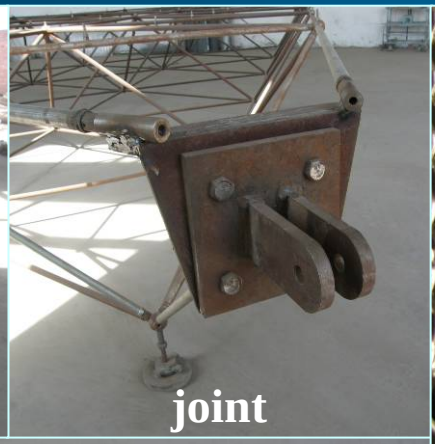
Single rear ib

Single rear rib with bow-string

Spatial truss backup (costly)

Deformation 2.5mm by gravity

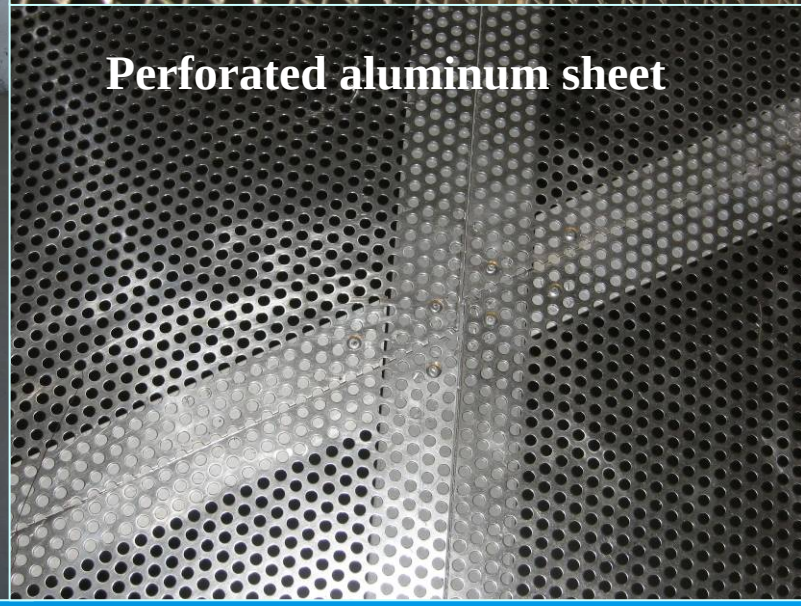
Adjust screw



joint

Spacial truss back structure

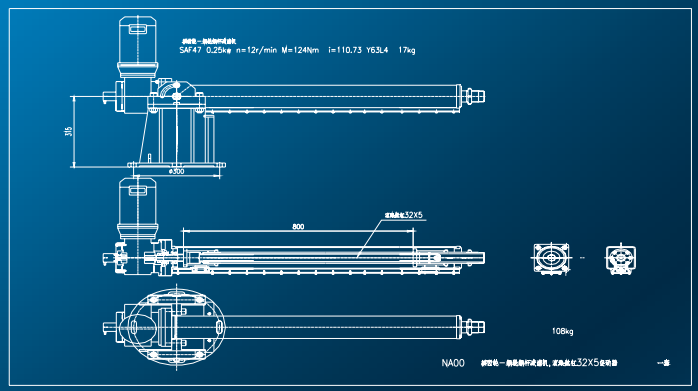
Expanded
aluminum mesh

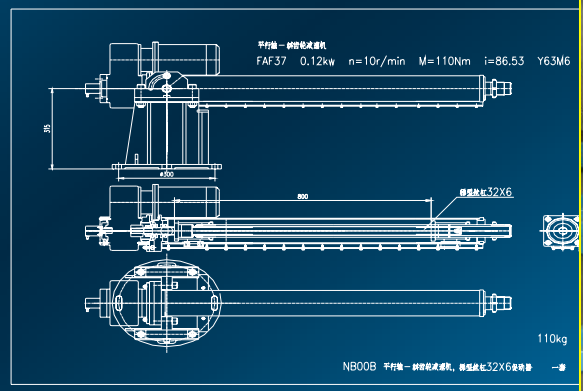


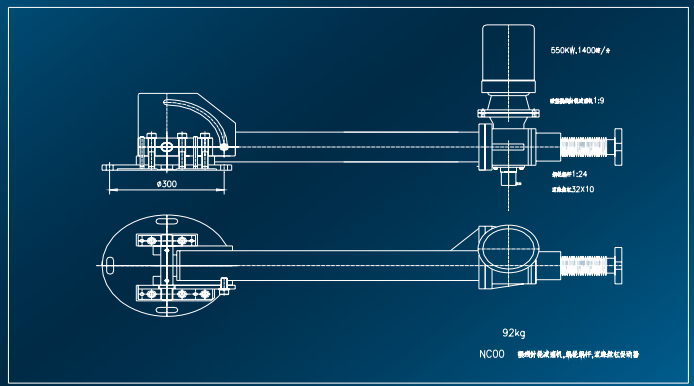
Perforated aluminum sheet

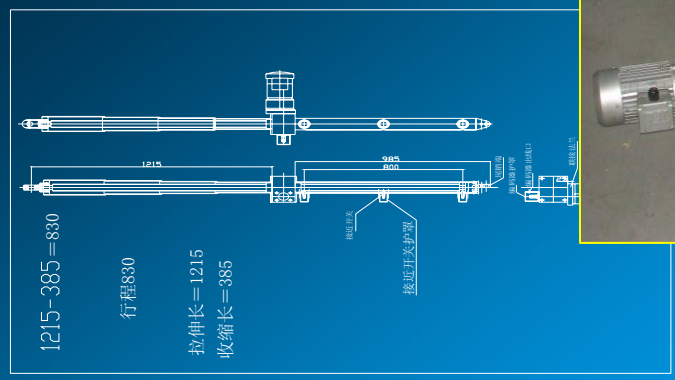
Prototyping the winches

- worm-wheel/ball screw
- cycloidal-pin wheel /sliding screw
- serial worm wheel/ball screw
- cycloidal-pin wheel /worm wheel /sliding screw





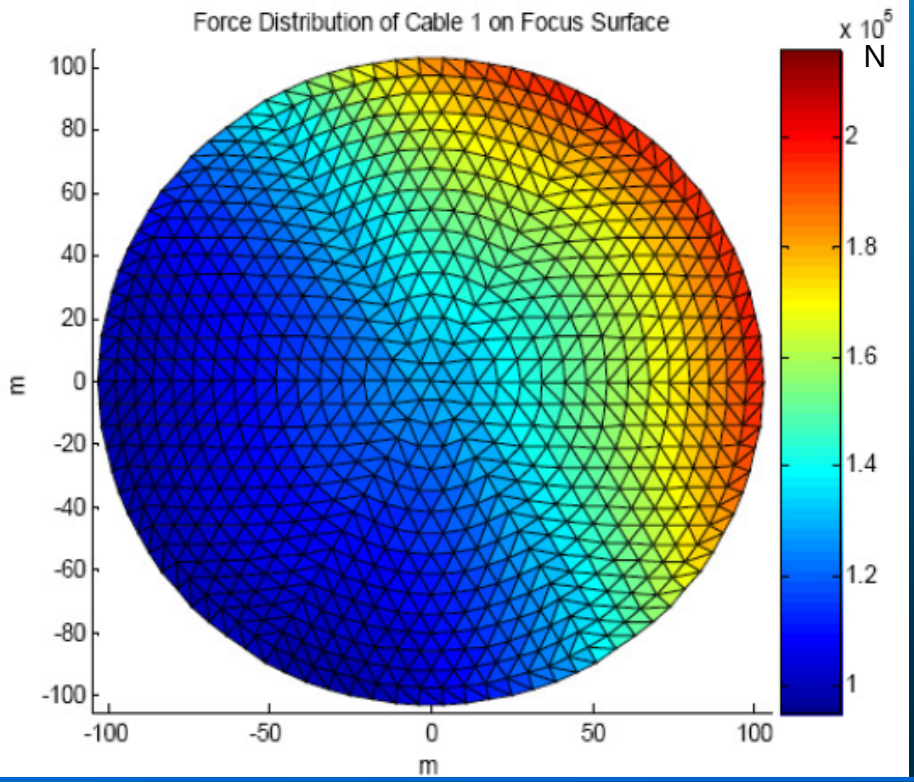


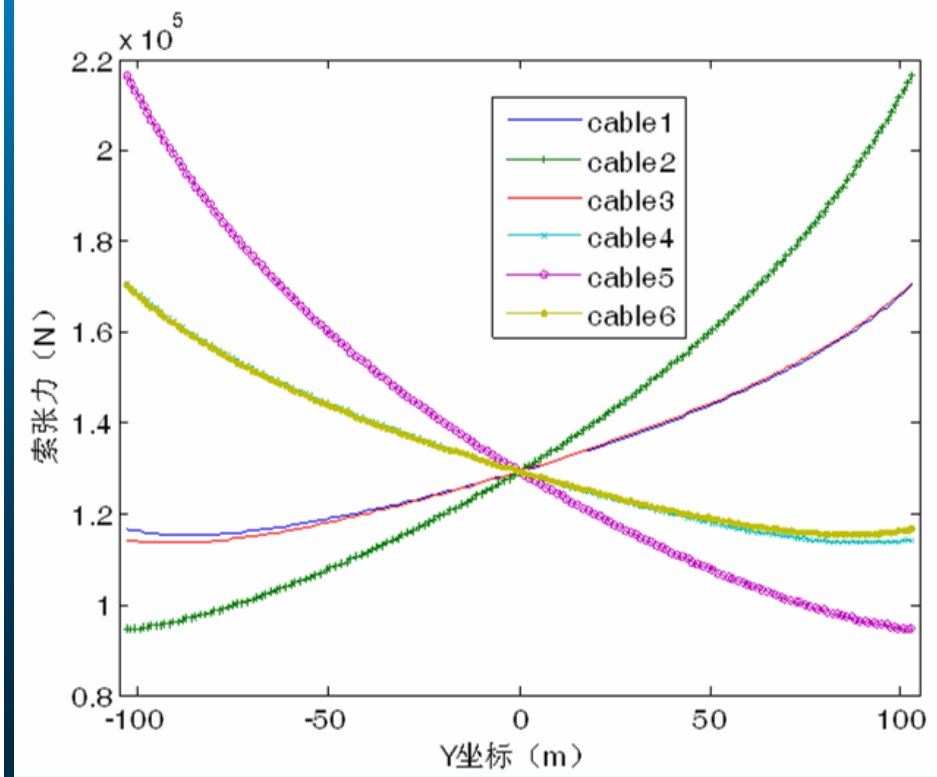


Prime focus position control

Experiment on the cable supporting system, Dec. 2001

Dynamic experiment on Stewart stabilizer, Sept. 2002





Collaboration with MT and TUD

Optimization of cable tension force :

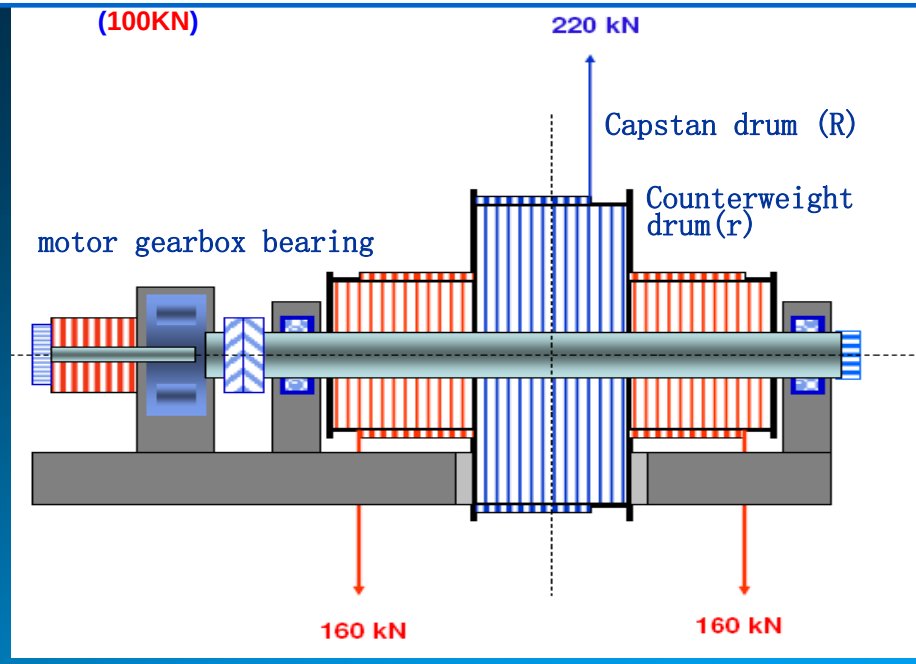
Max.: 220KN; Min.: 100KN

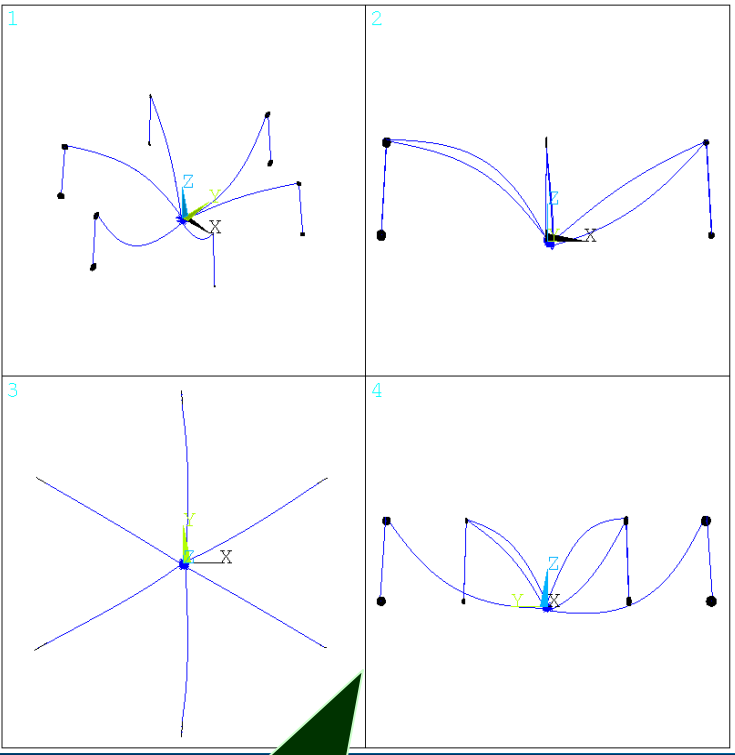
Design of counter-weights :

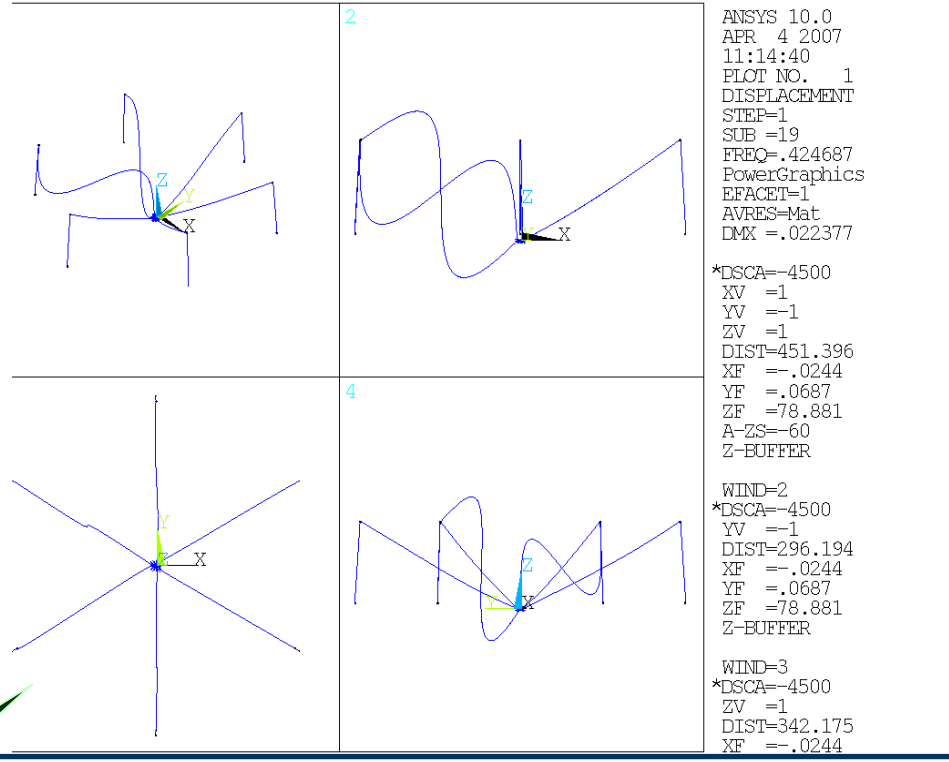
travel range reduction: R = 2r

counter-weight =

[(220 + 100)/2]*2 = 320KN



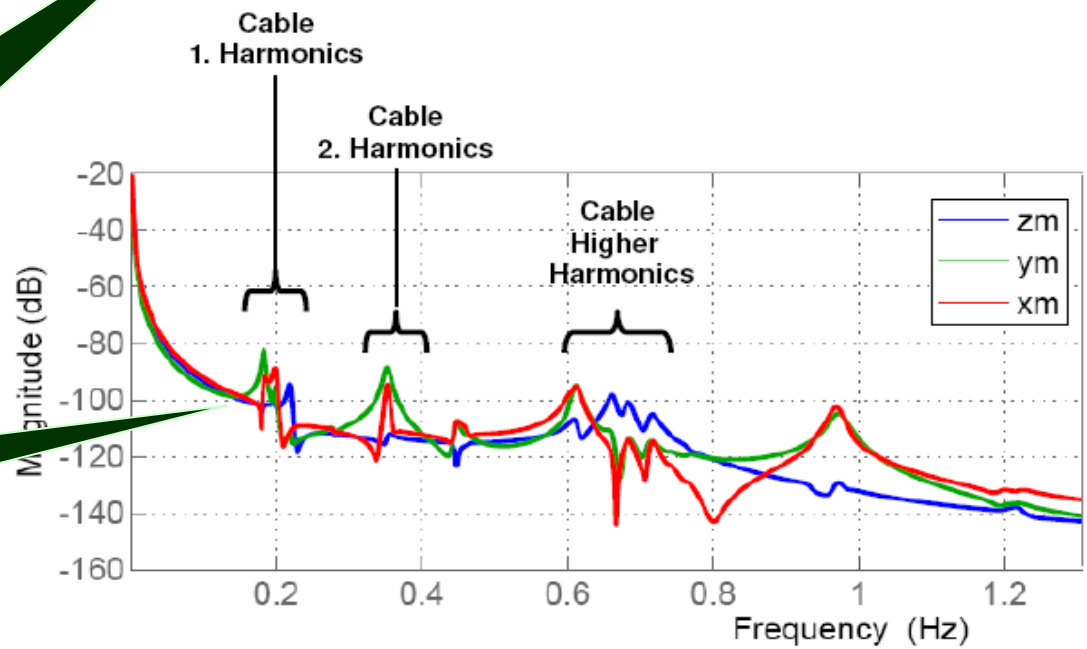




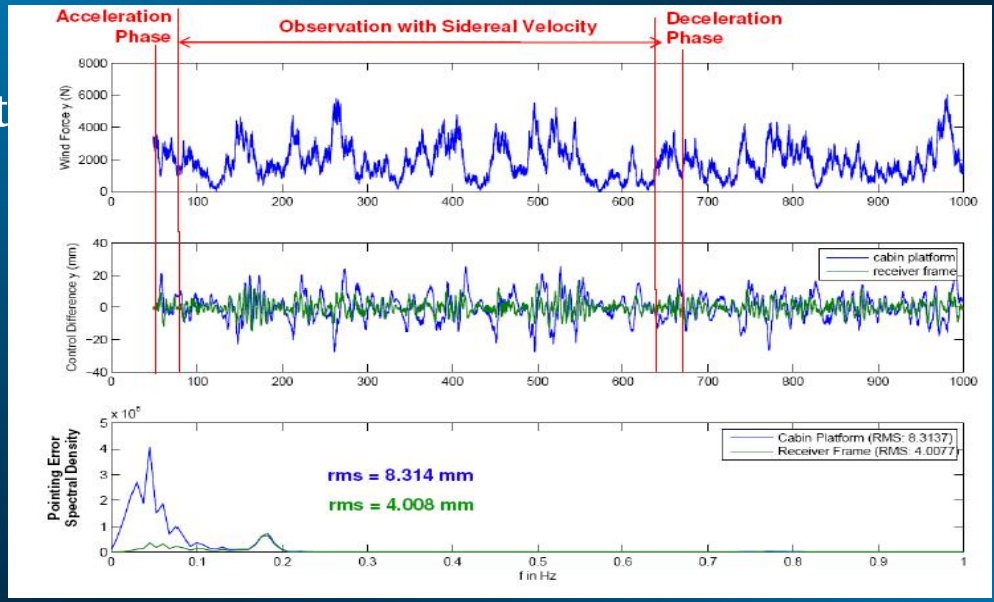
1st harmonic (0.182455Hz)

2nd harmonic (0.4247Hz)

Vibration modes and Bode diagram of suspension cables

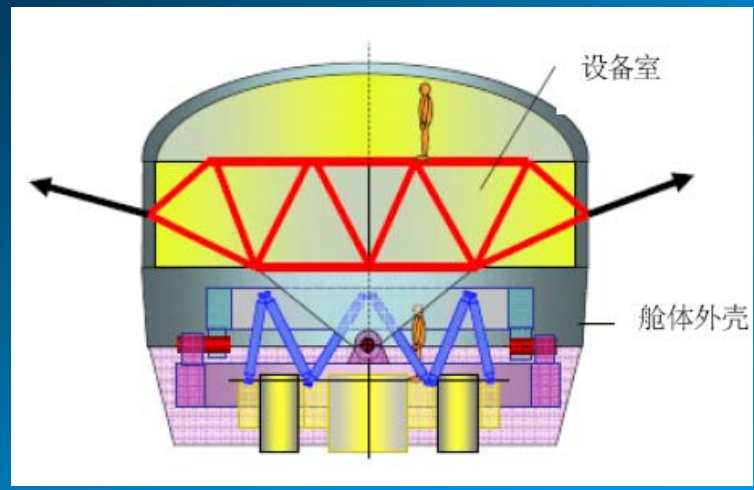


- under the wind 8m/s, 1st adjustment reaches control accuracy 8mm
- as the stabilizer is switched on accuracy 4mm
- spectra - 0.18Hz



Total weight of cabin ~ 30t

receivers	4
Stabilized platform	2
actuators	1,5
X-Y Frames	4
Y- positioner base	4
cladding	8
Top frame – star truss	4
total	27,5

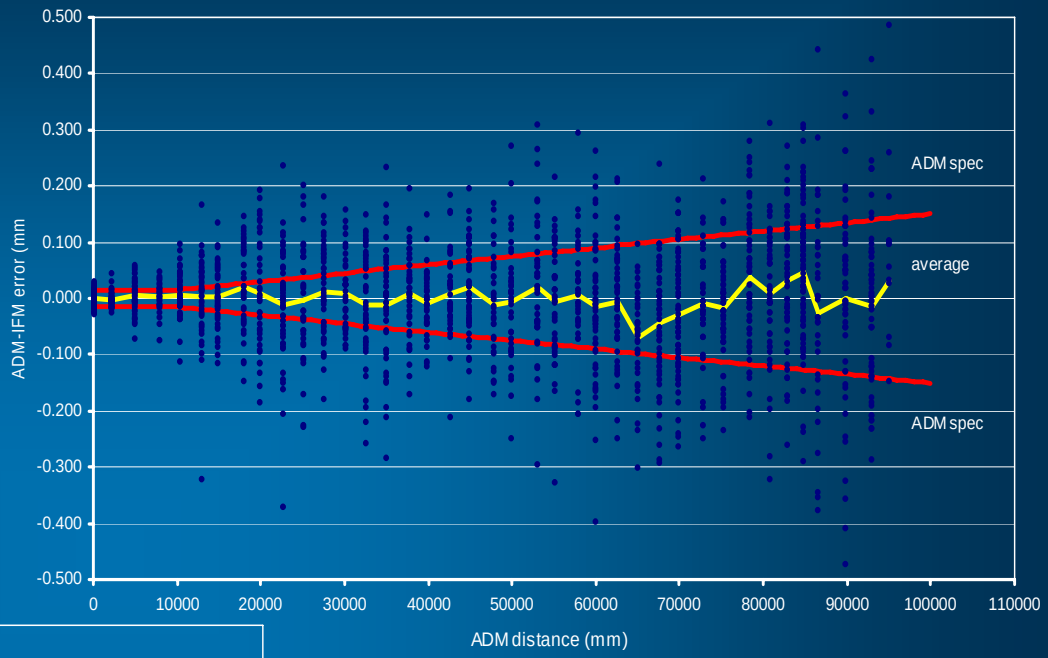


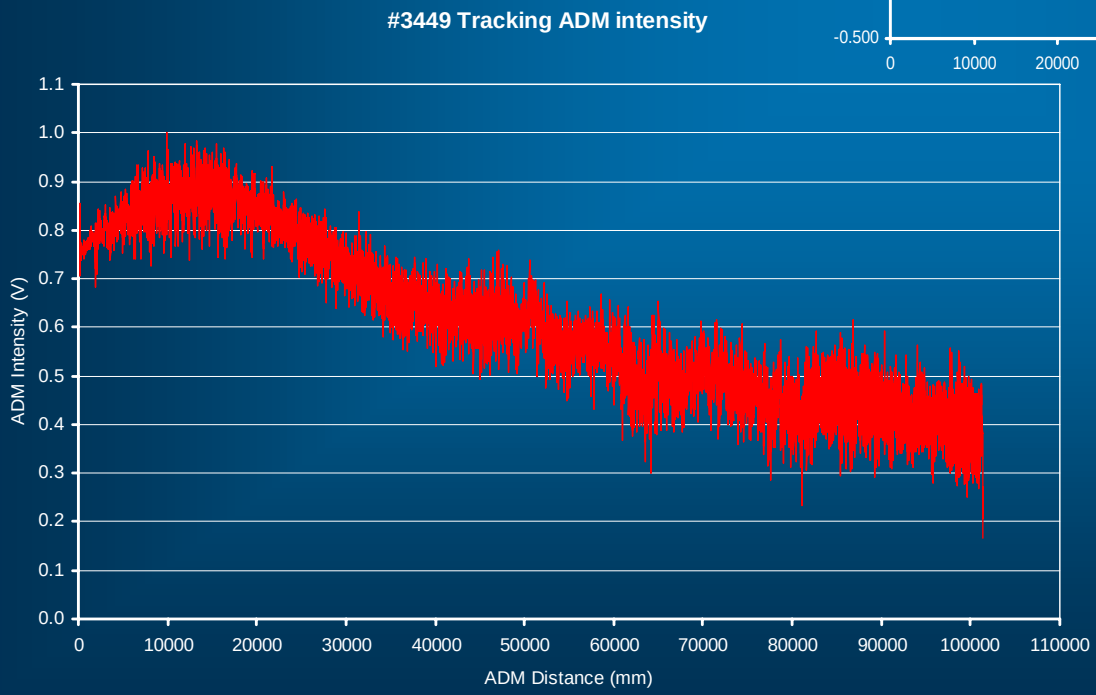
Most precise laser ranger API

Maximum ranging distance – 120m

TCRA2003: 1+1ppm

API: 0+5ppm





To expand the ranging

Reshape the beam

New detector – 150V

Avalanche breakdown voltage


CCD： 20Hz； 0.5cm


DGPS： 10Hz； 1cm
2002/10/10 11:04am

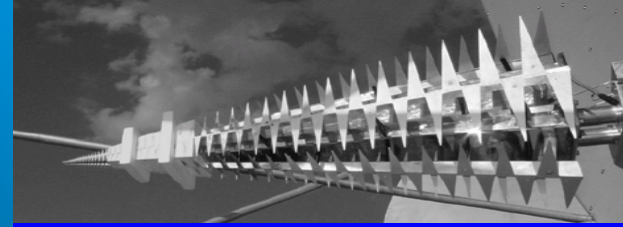

IMU：0.1°


Laser Tracker：1KHz；0.05mm
Measuring
21 10:45 AM


Total station

Receiver layout

- Main focus, -13dB, G/T – 2000 m^2/K
- 70MHz - 1GHz, 4sets 1-octave band
- L – one wide band receiver
  19 multi-beam receivers
- 2 - 3GHz scaled JBO C - band



ATA 0.5 – 11GHz

LOFAR 120 – 240MHz

WSRT 115 – 180MHz

1.23-1.53 GHz multi-beam

f - range : 1.23-1.53 GHz

feed : 19 coaxial horns

f/D: 0.46, less curved than Parkes

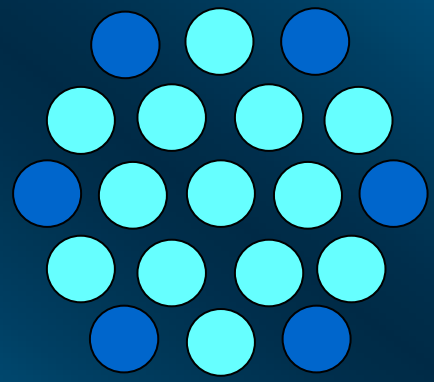
LNA: HEMT cooled

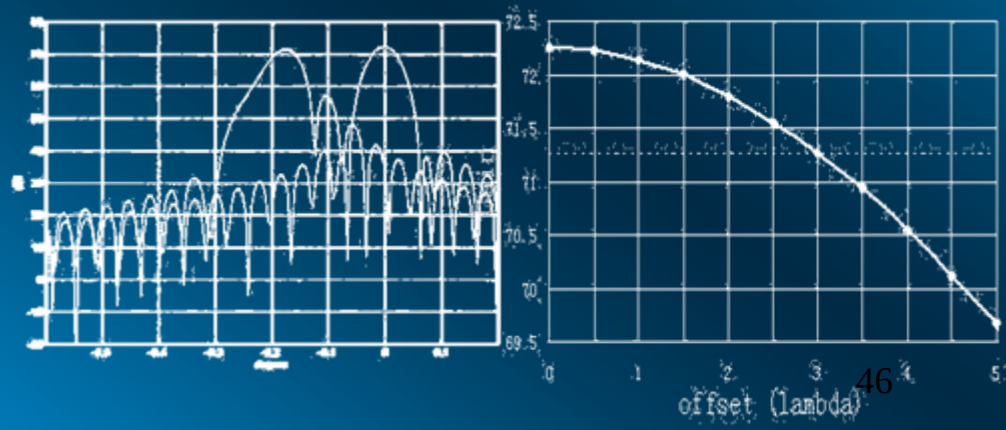
IF : optical fiber cabin - ground

Backend : HI

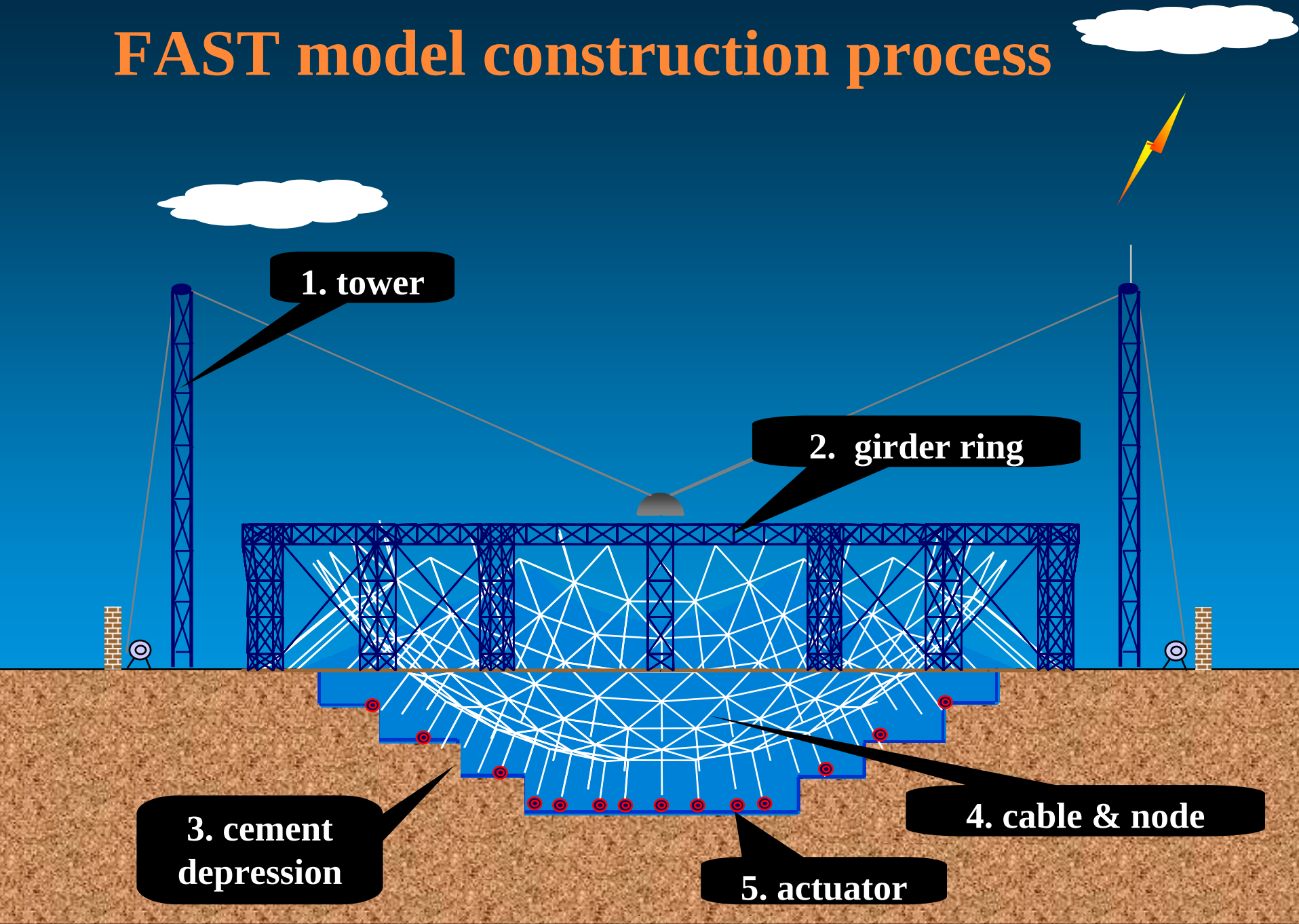
Pulsar

Transients

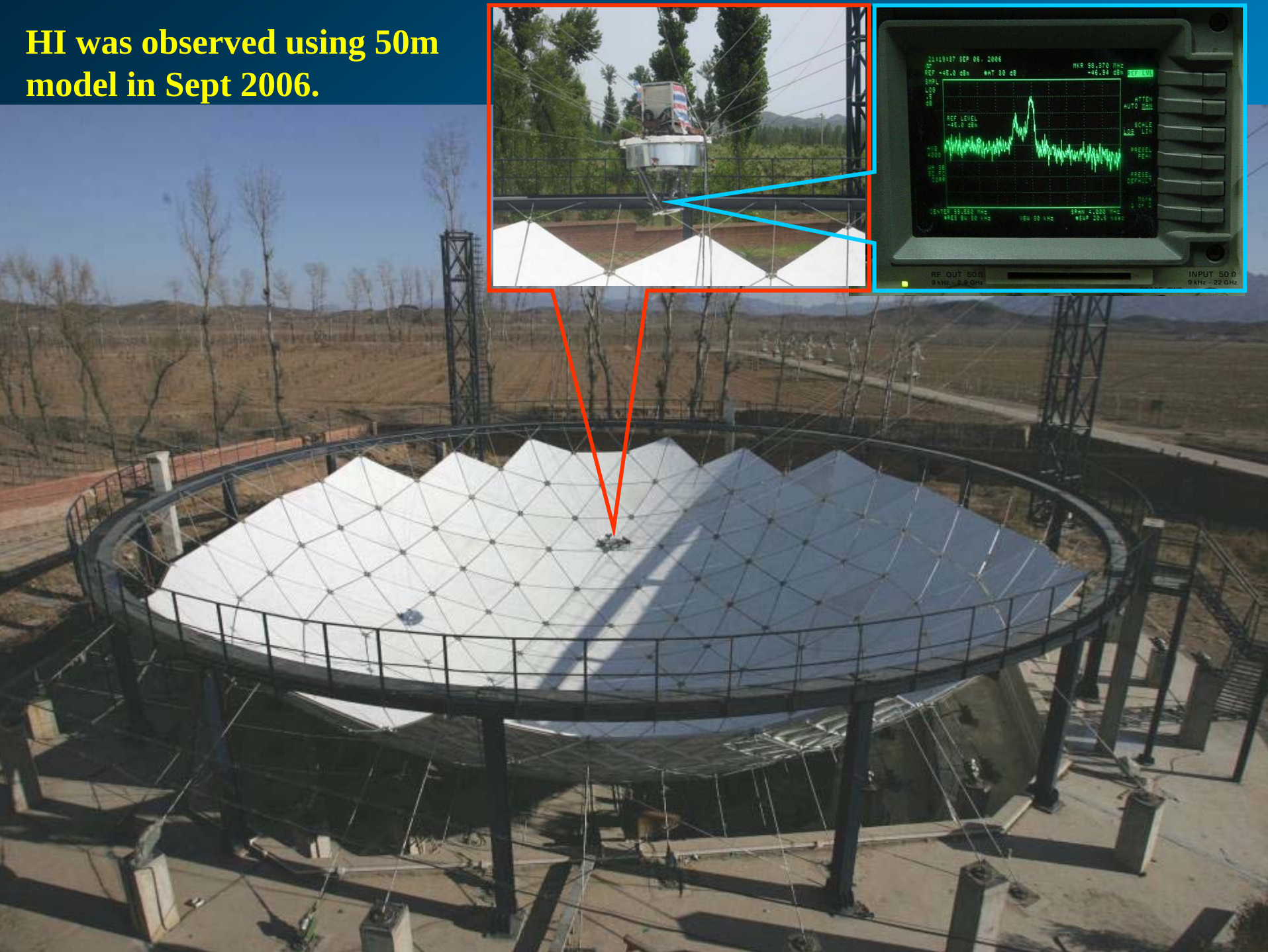




FAST model construction process



HI was observed using 50m model in Sept 2006.



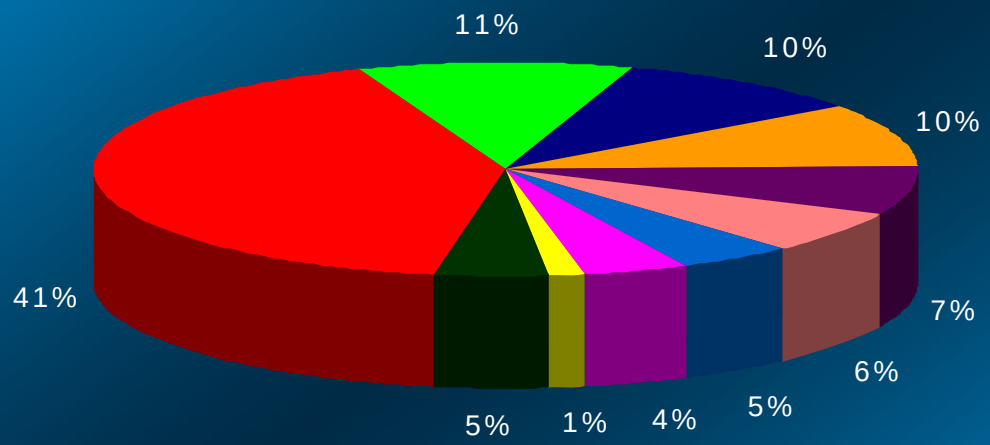
5. Current state of FAST project

Total budget ~ 688 millions ¥ (600 millions admitted)

Budget in feasibility report is ~ 700 millions ¥

Project time 5.5yrs from foundation

Budget pie



- **Main reflector**
- **Earthwork**
- **Feed support**
- **Receivers**
- **Measurement and control**
- **Infrastructures**
- **Design**
- **Observatory and facilities**
- **Site investigation**
- **Unexpected**

SKA
SQUARE KILOMETRE ARRAY

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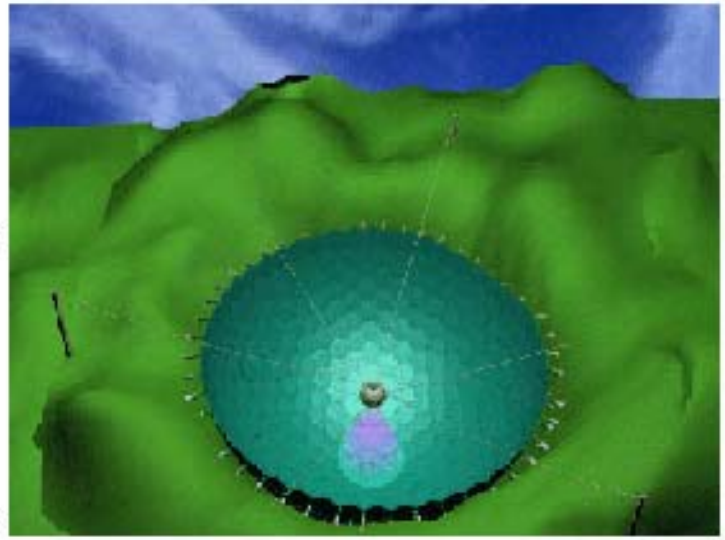
- Contacts
- Site map

EUR 60M funding approved for China's 500m FAST telescope

27.07.07



The National Astronomical Observatories, Chinese Academy of Sciences (NAOC), headquartered in Beijing, China, has been informed that funding for the FAST project has been approved by the National Development and Reform Commission (NDRC). The approved budget is now CNY 627M (EUR 62.7M), of which NAOC will receive CNY 600M (EUR 60M) from NDRC.

The FAST (Five hundred meter Aperture Spherical Telescope) will be constructed in the karst landscape of Guizhou Province in southwest China and will act as a pathfinder telescope for the SKA, demonstrating innovative technologies that could be incorporated into the full SKA instrument. The FAST will be the largest telescope in the world, with the radius of its spherical surface being 300 m, and having an overall diameter of 500 m. The FAST's main spherical reflector, by conforming to a paraboloid of revolution in real time through actuated active control, will enable the realisation of both wide bandwidth and full polarisation capability while using standard feed design. In addition, its feed support system will integrate optical, mechanical and electronic technologies which will effectively reduce the cost of the support structure and control system. More information on the FAST project can be viewed at http://www.bao.ac.cn/english/home.asp.

Approval appears on SKA webpage

http://www.skatelescope.org/pages/page_newfront11.htm

Thanks