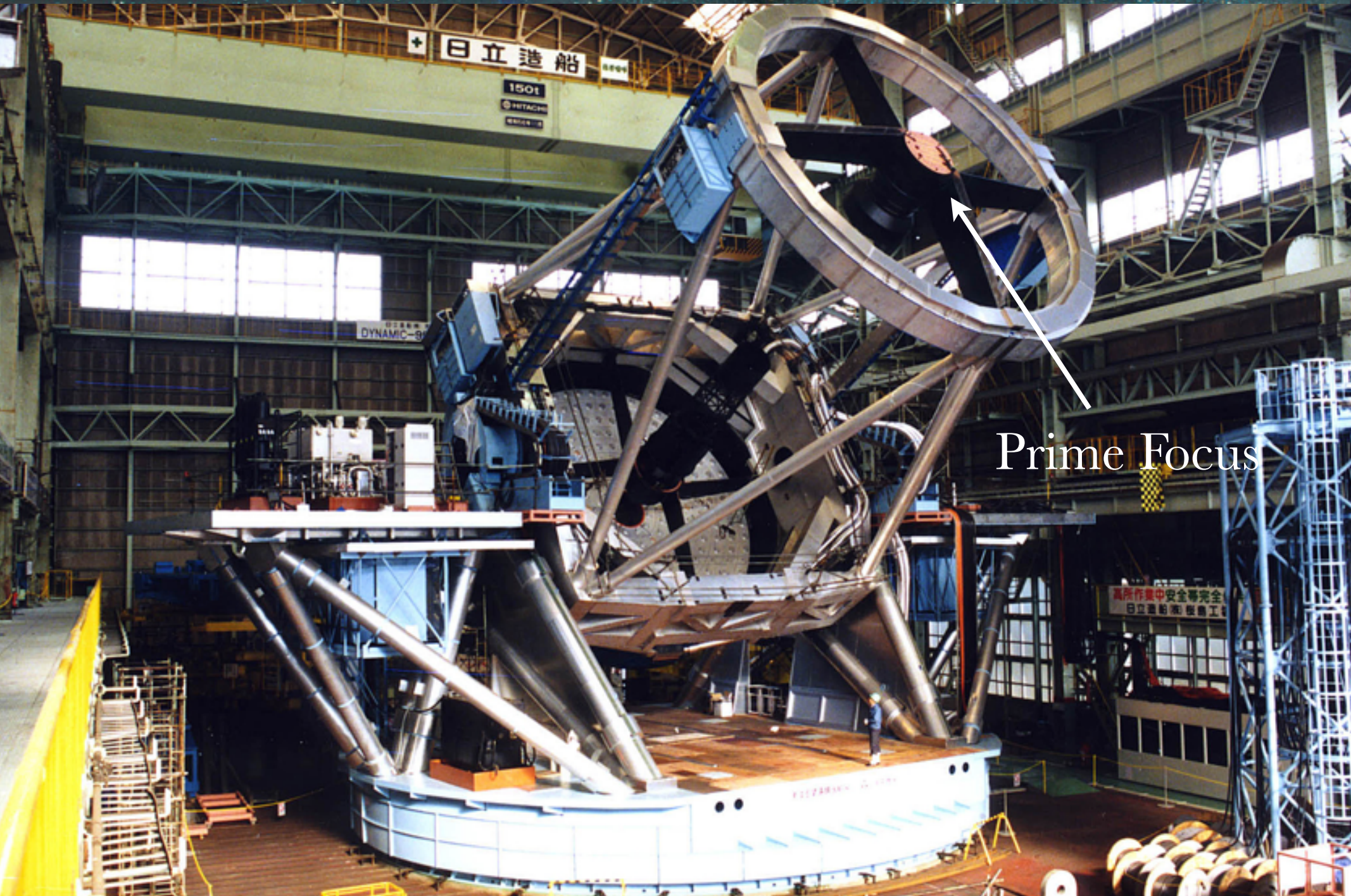
Hyper Suprime-Cam

Satoshi Miyazaki
National Astronomical Observatory
of Japan

2007/10/24
ROE-JSPS Workshop 2007

Subaru Telescope

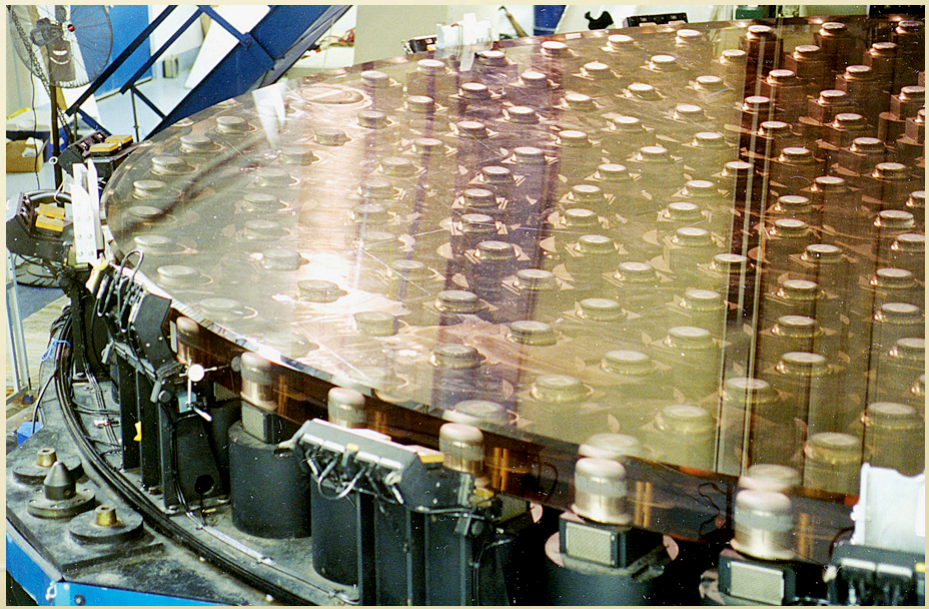
National Astronomical Observatory of Japan



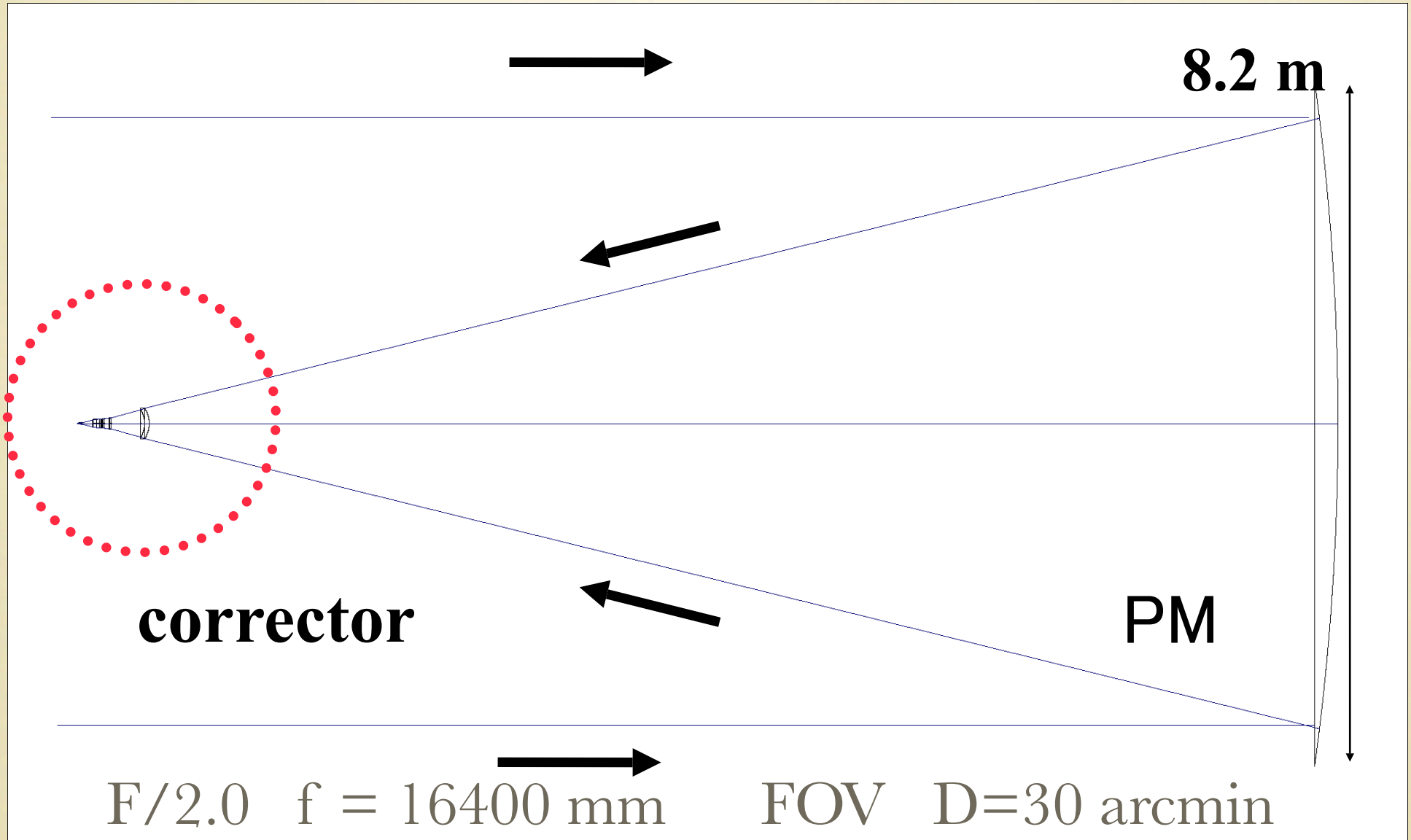
Subaru telescope

- One of thirteen 8-10 m class telescopes in the world (2007)
- Superb image quality (mostly natural seeing limit)
  - PM Actuators are controlled based on a static table.
  - Tracking is stable (0”.1 rms in 10 min blind tracking)
  - High Image quality wide field camera is realized.

No image stabilizer is necessary



Suprime-Cam

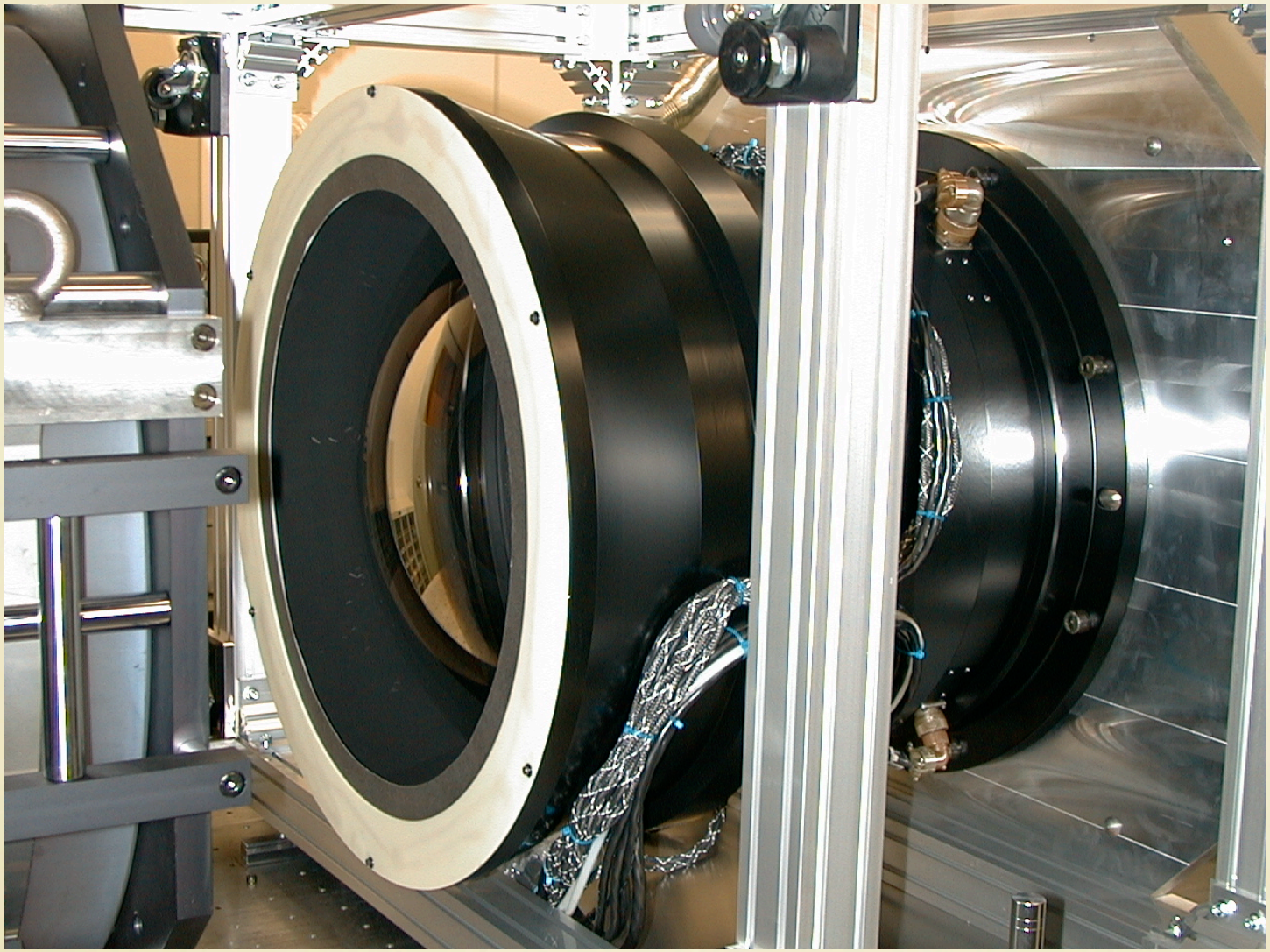


3D LAYOUT

SUPRIM CAM
FRI JUL 1 2005

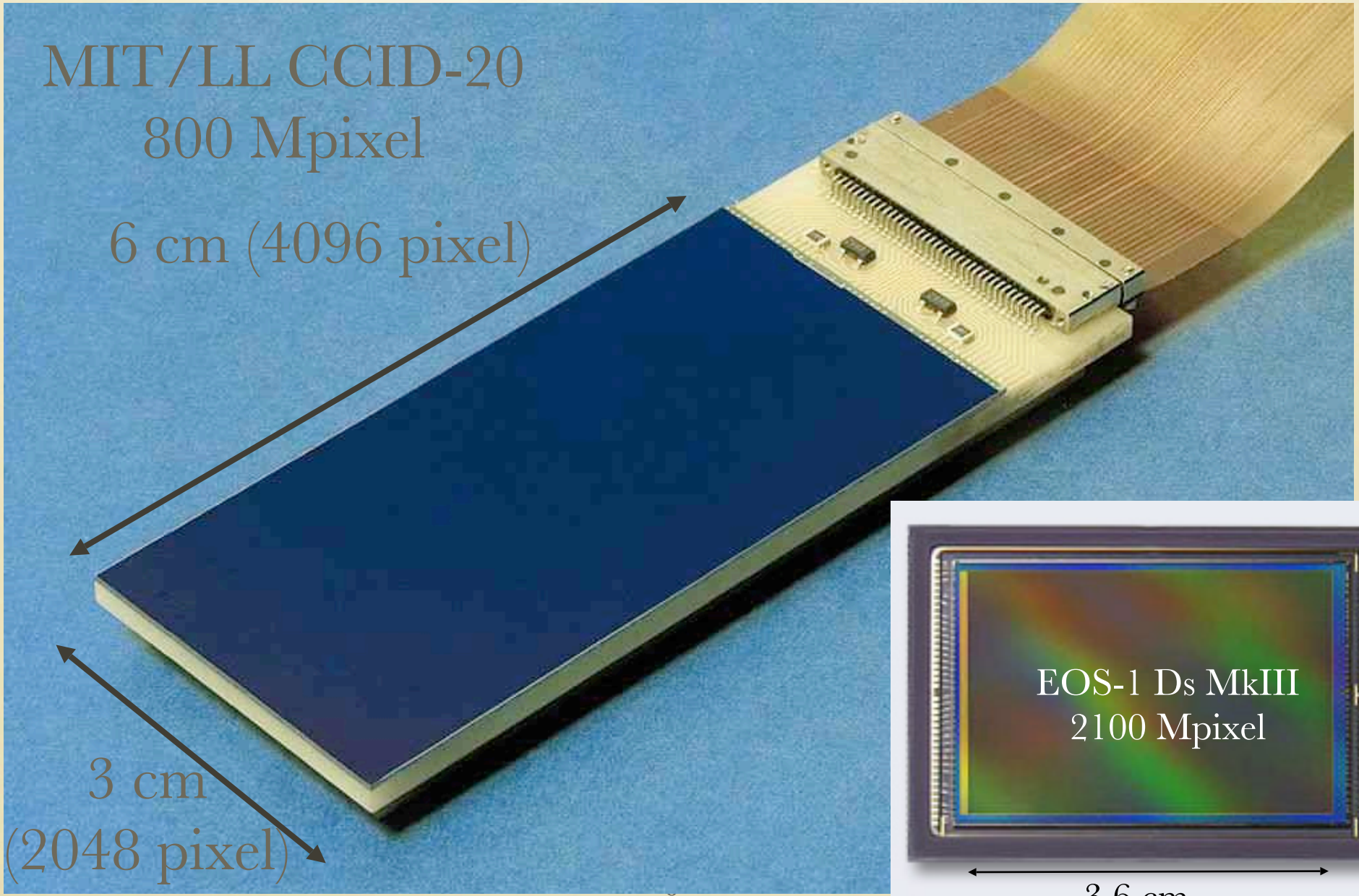
SUBARU TELESCOPE
650 N AOHOKU PLACE
HILO HI96720

TEST.ZMX
CONFIGURATION 1 OF 1



Canon G1 Phi 50 cm

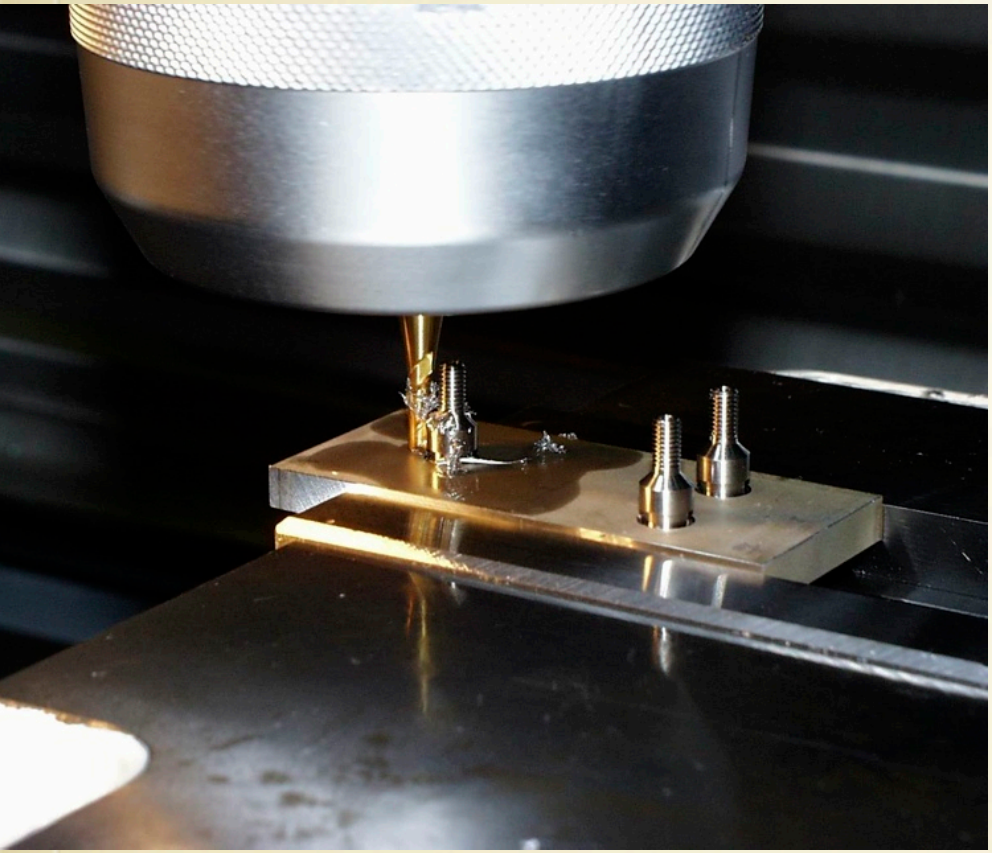
Suprime-Cam CCD



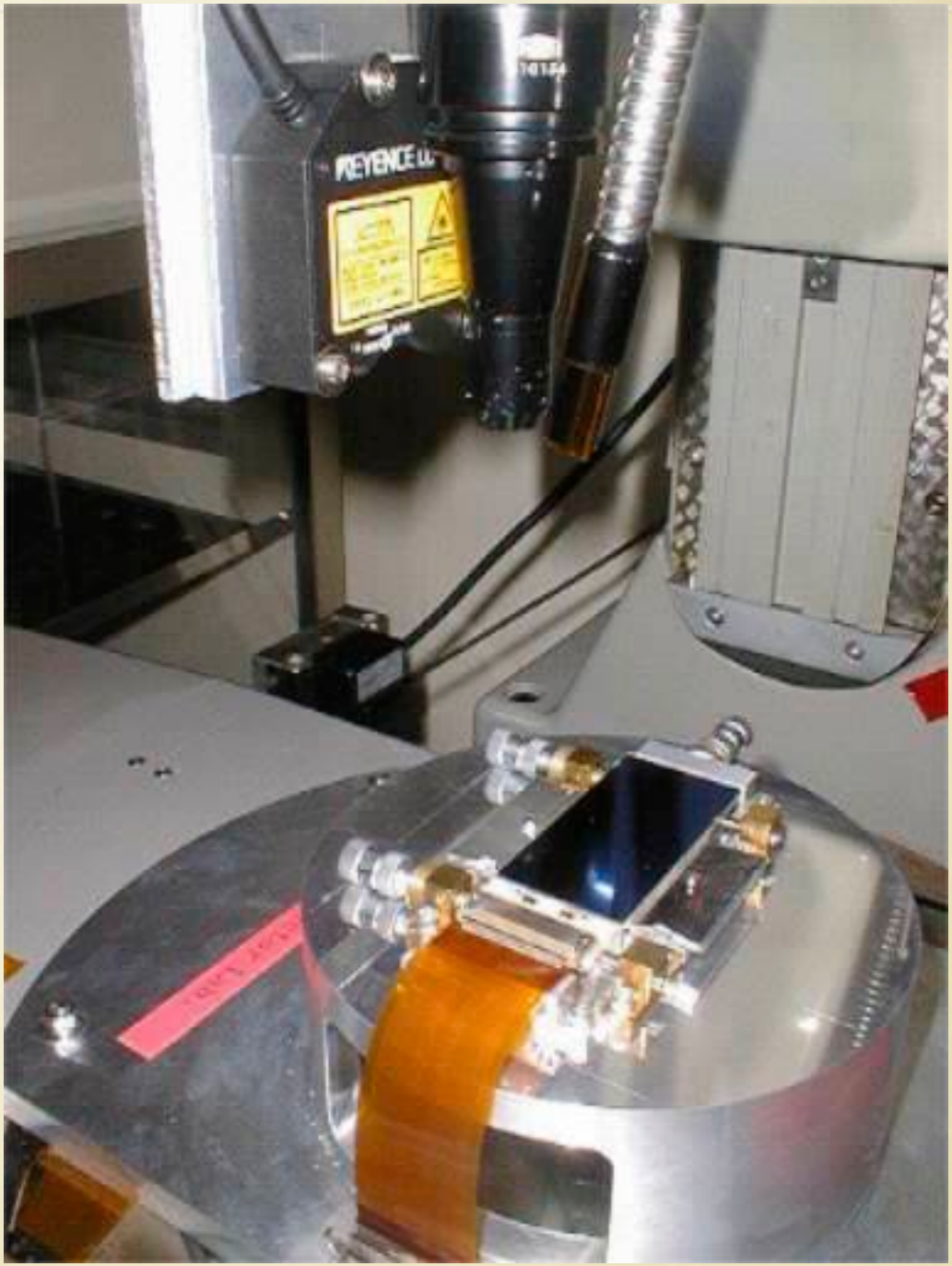
MIT Lincoln lab CCD

- One of X-ray CCD suppliers
  - ASCA, Chandra, Suzaku
- Low Noise, High CTE, Thick depletion layer (~ 40 micron)
- Optical CCD was supplied for astronomy communities through University of Hawaii

Alignment Pins

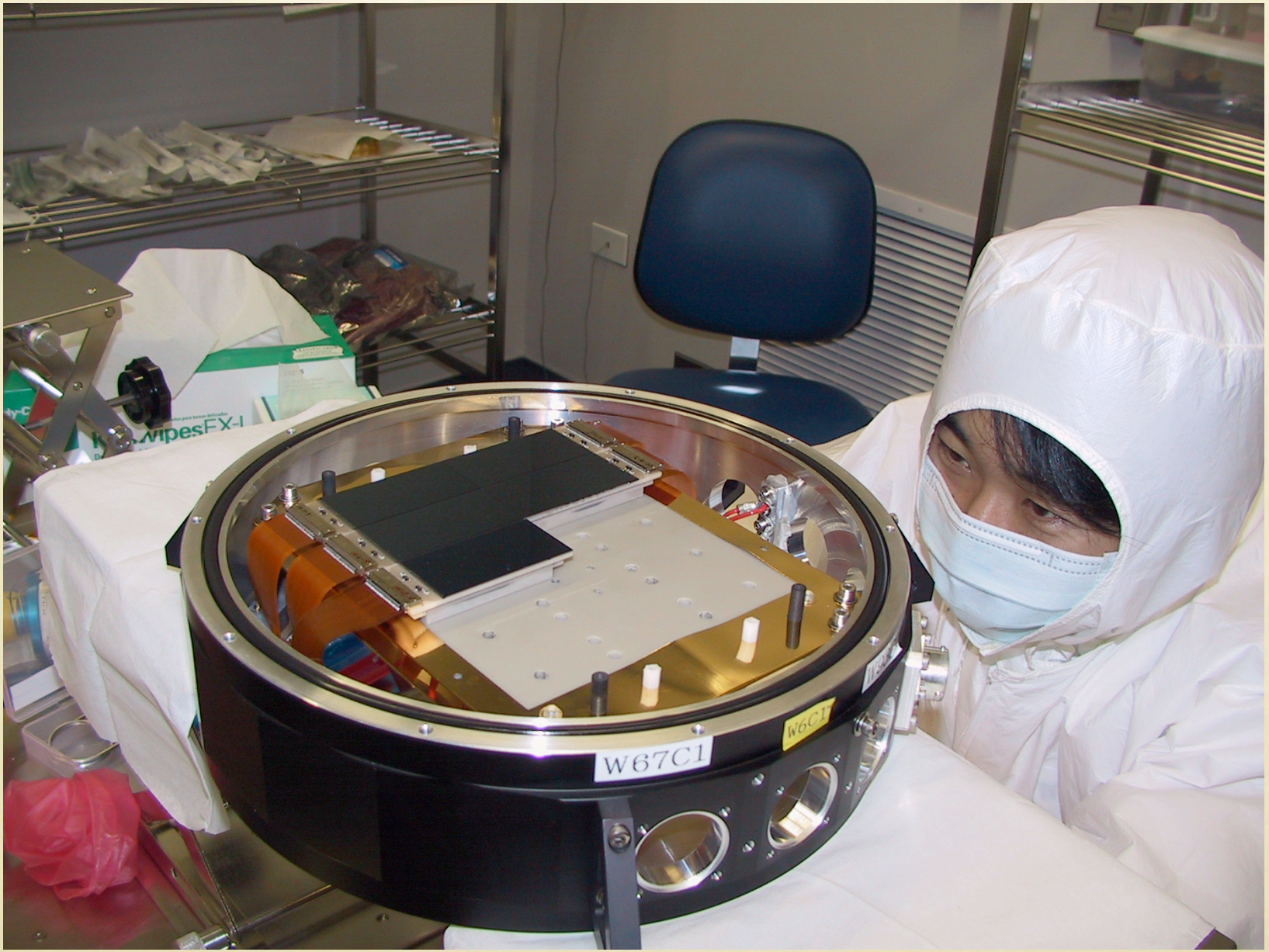


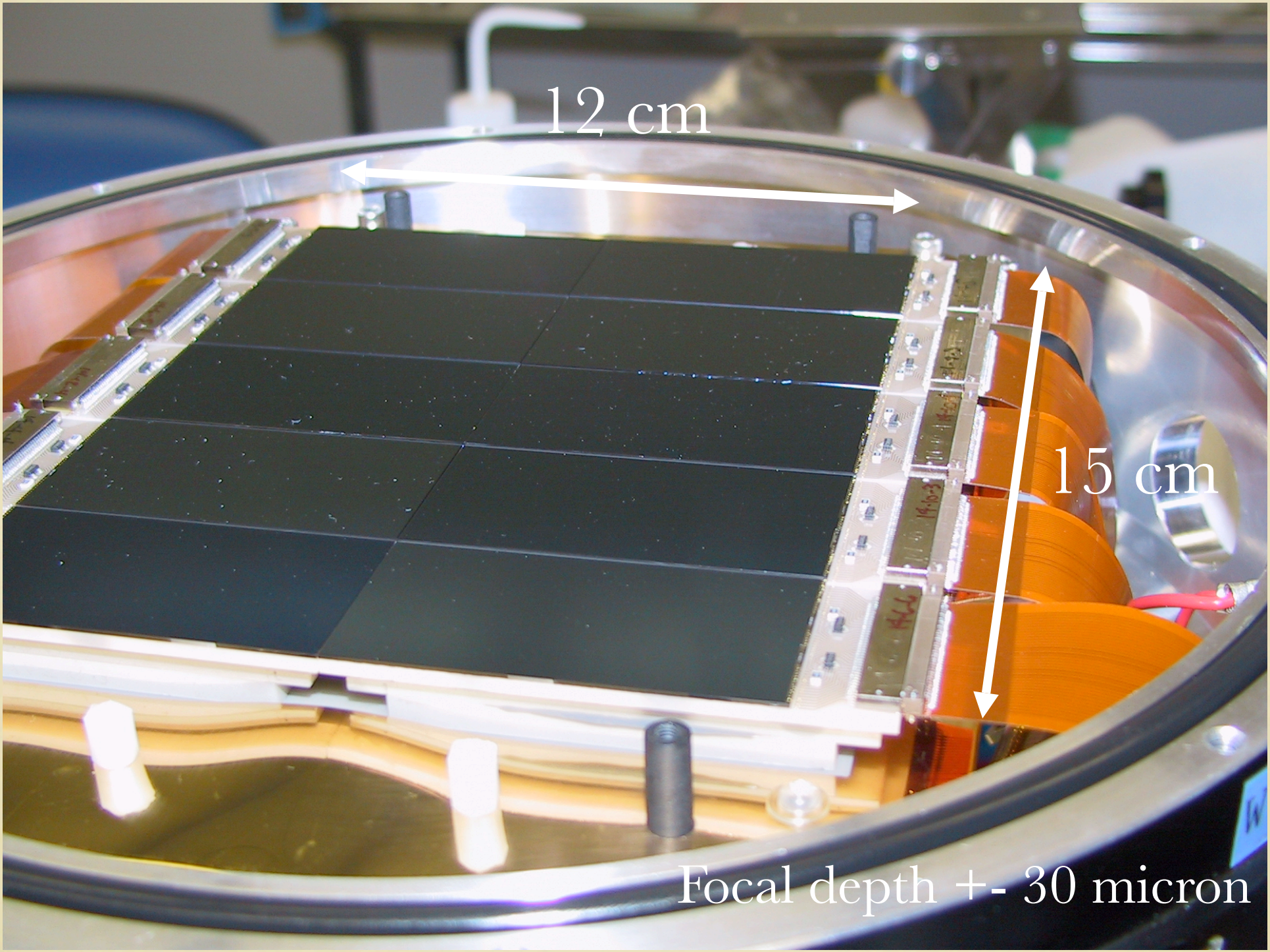
buffer blocks



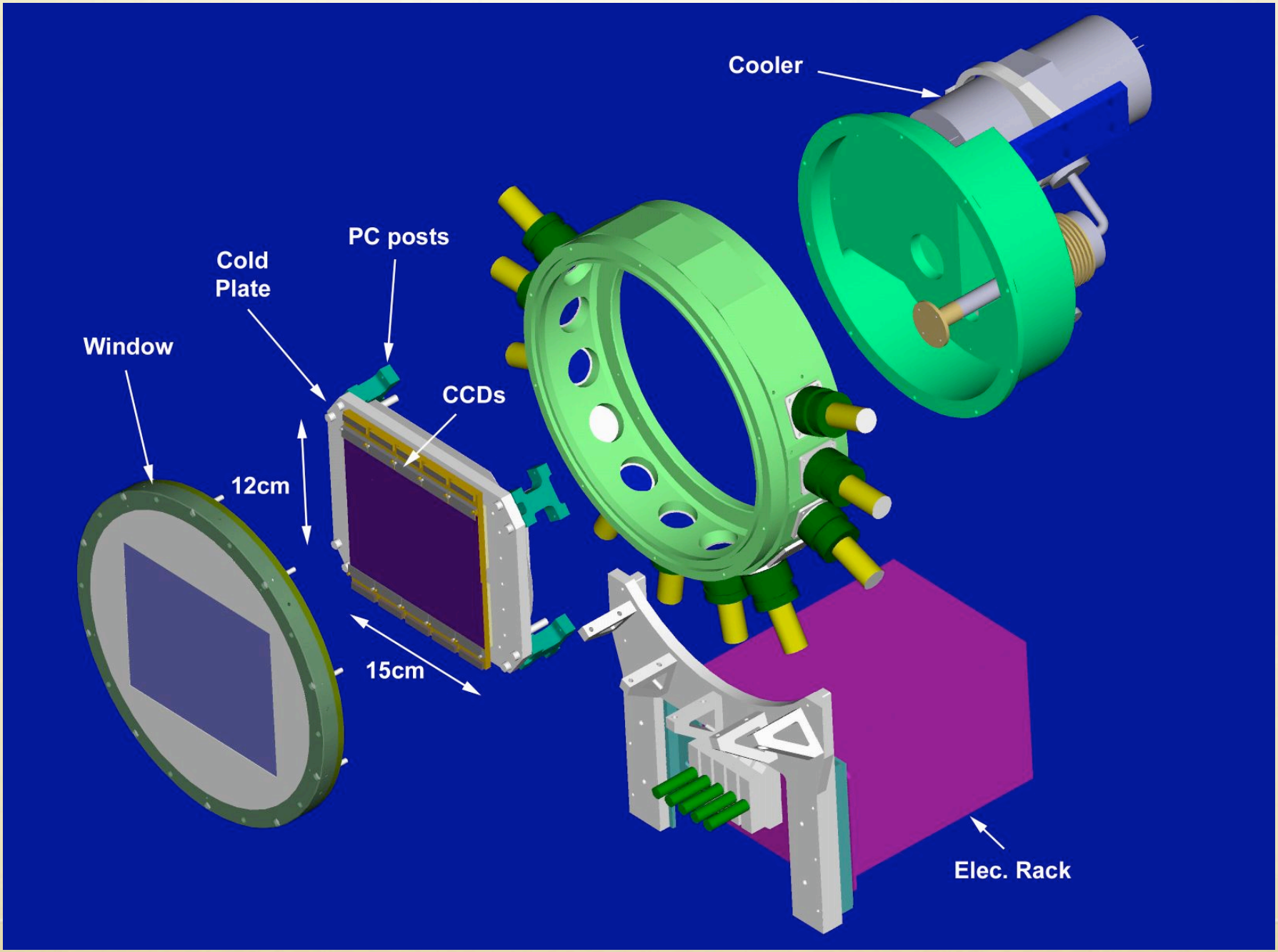
Epoxy buffer block

Placement into the dewar




12 cm
15 cm
Focal depth +- 30 micron

Suprime-Cam冷却デュワー

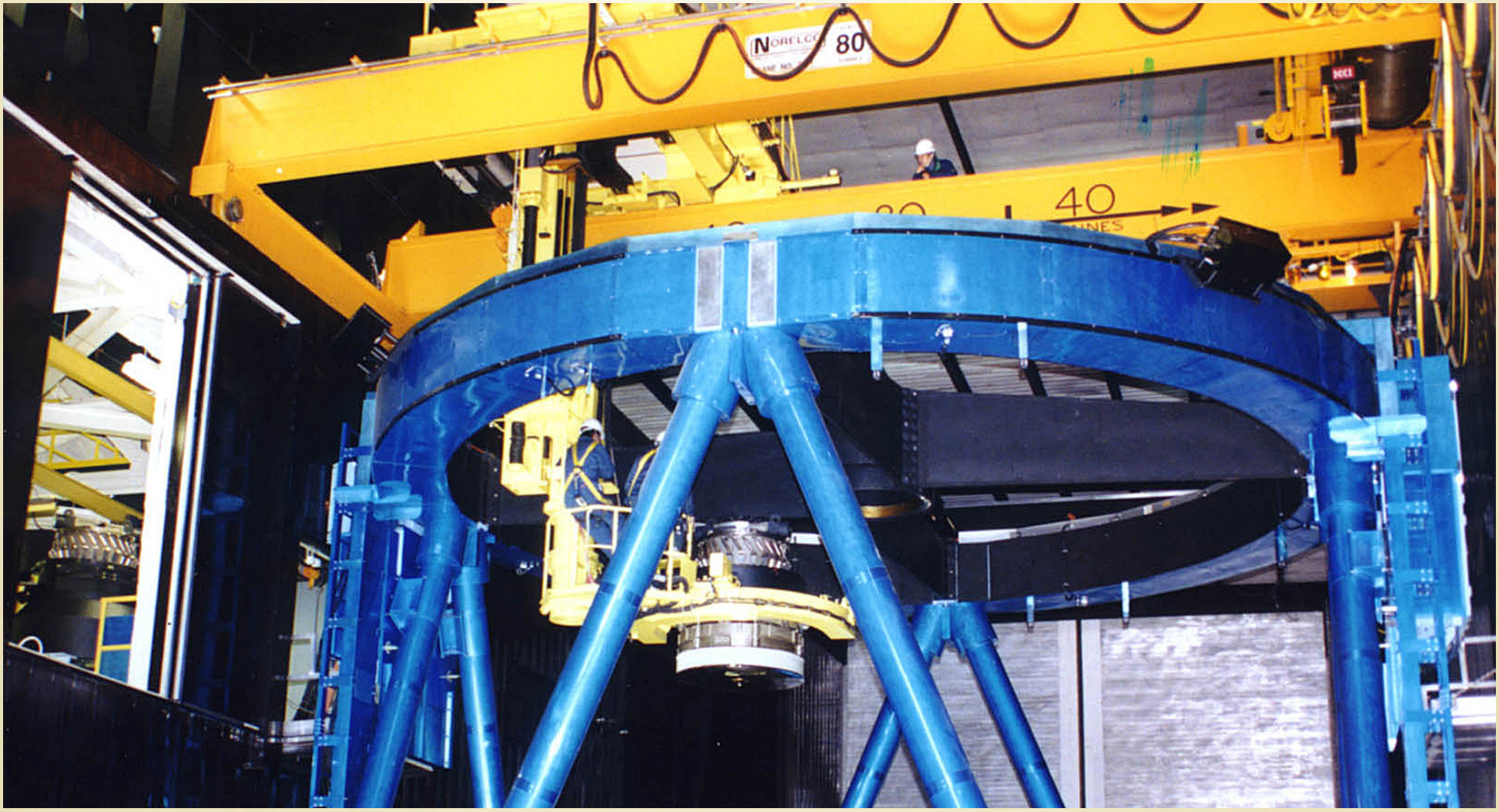


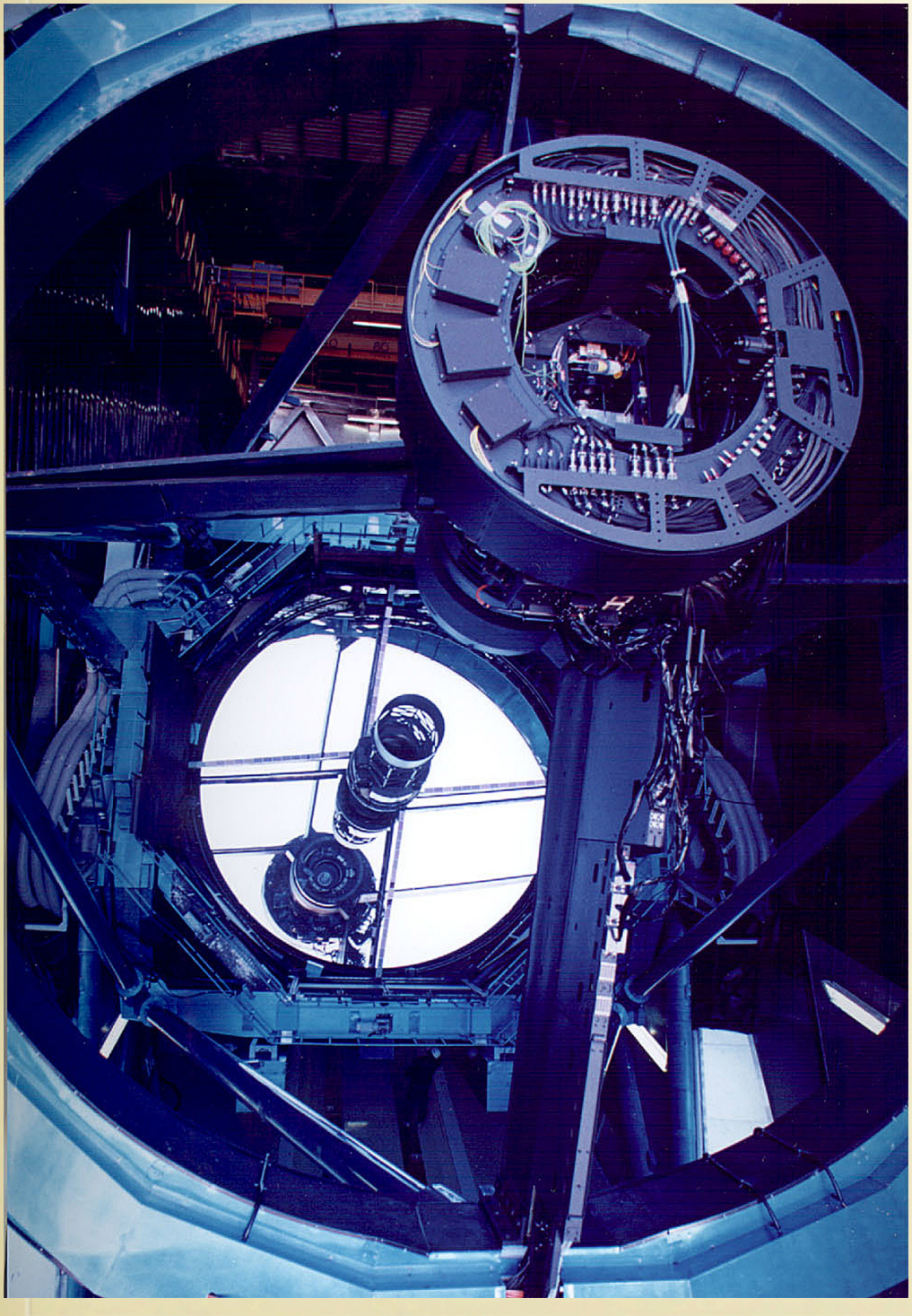

Suprime-Cam
filter juke box
filter elevator
Dewar

Prime Focus Unit
(Lens, Attitude Control,
Cable wrapper)


Mounting on the telescope

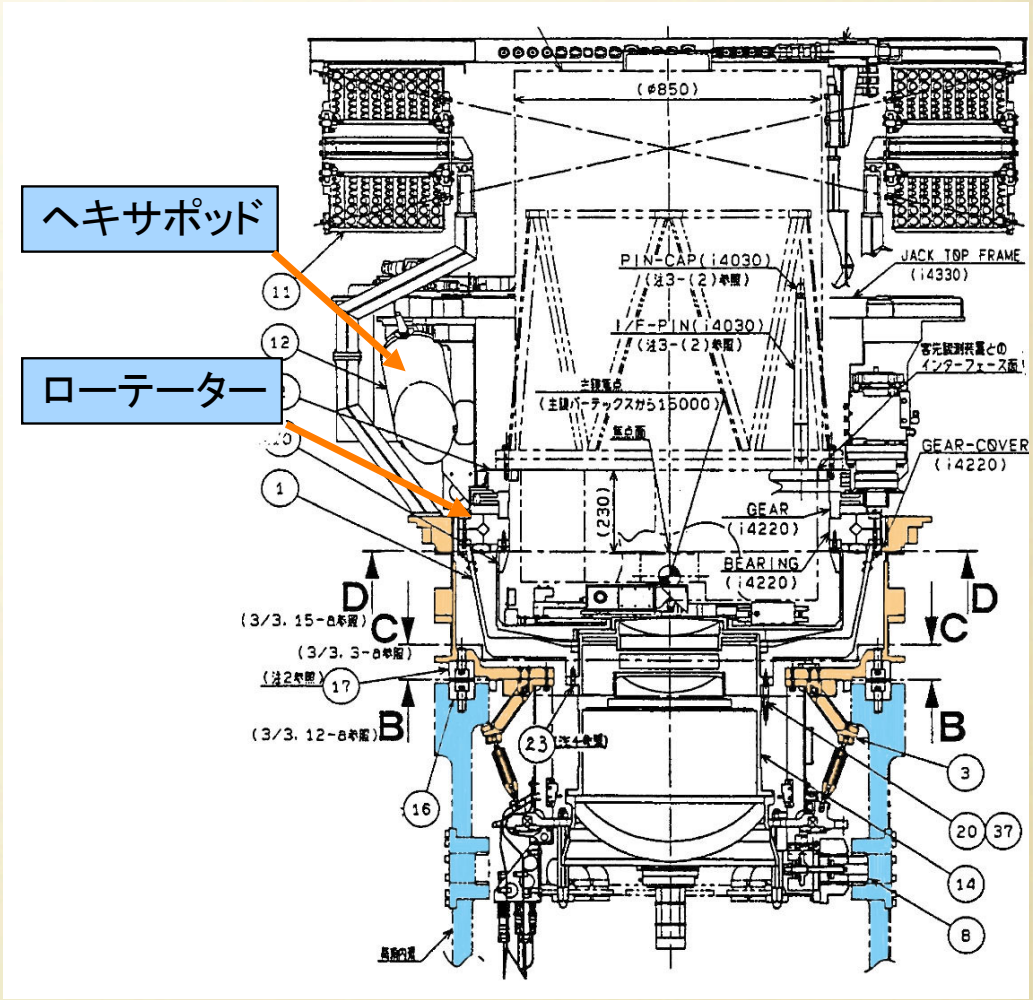
Top Unit Exchanger (TUE)



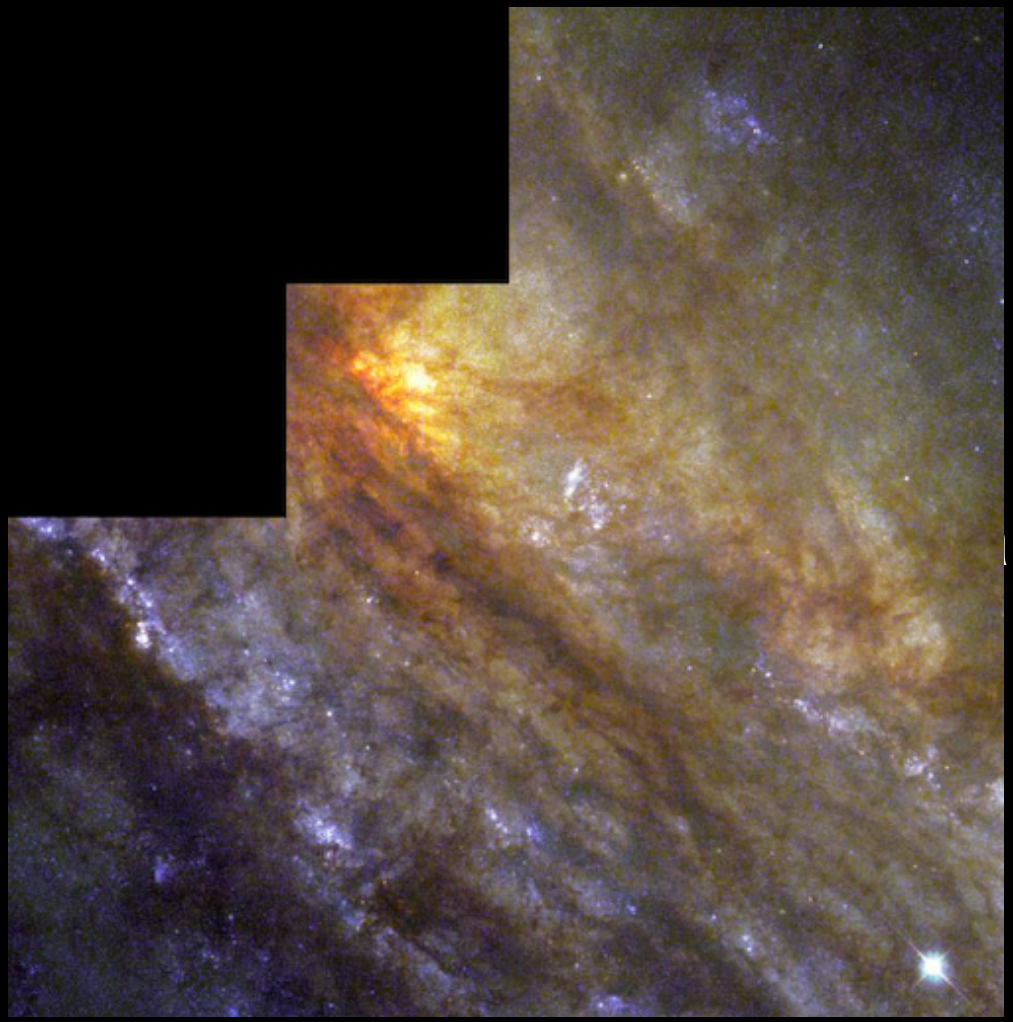


ヘキサポッド

ローテーター

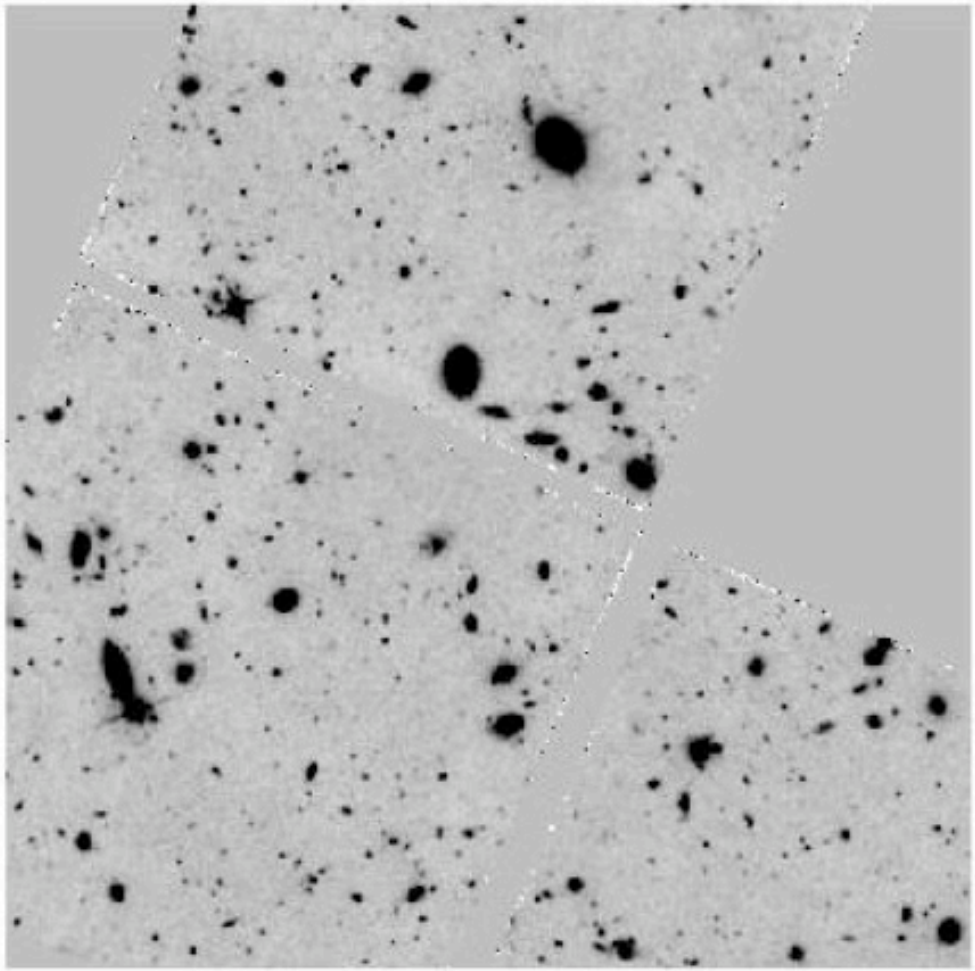



NGC 253 (B, V, Ic)

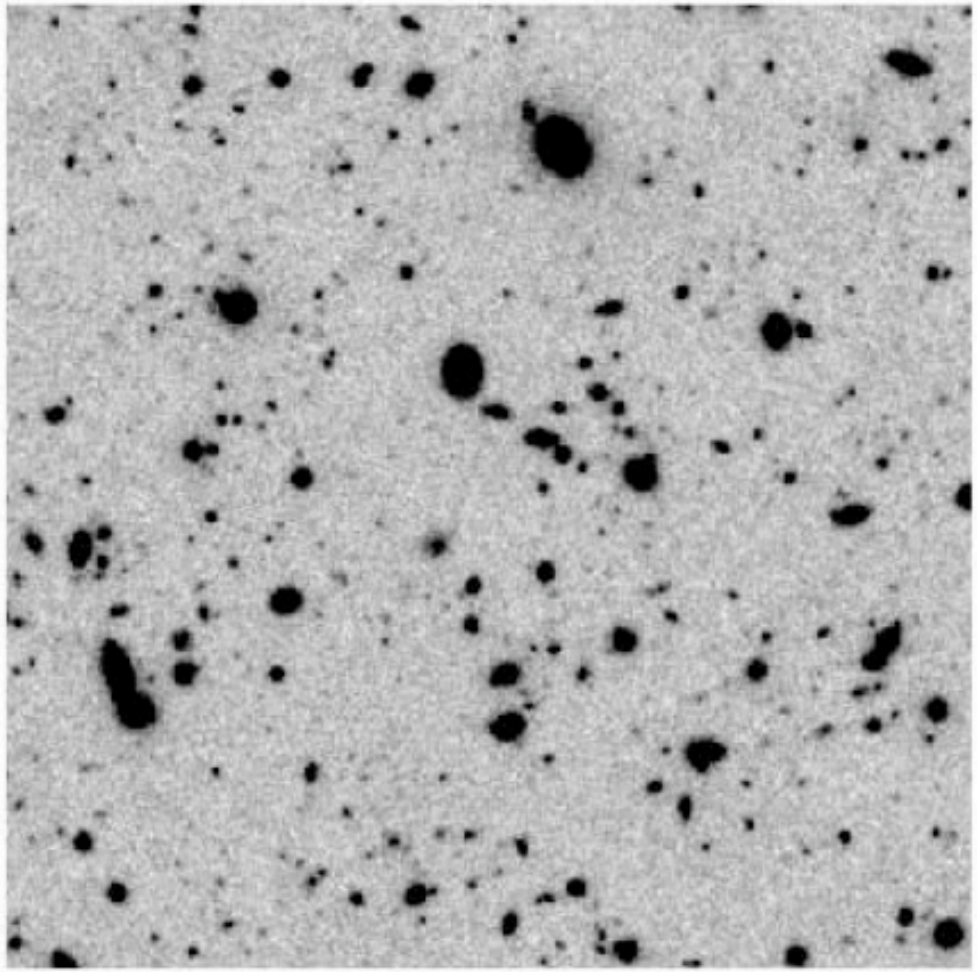


HST WFPC2
(All FOV)

Suprime-Cam
(FOV/100)



HST 'wide-I' continuum



NB816 narrowband

HST WFPC2
(All FOV)

Suprime-Cam
(FOV/100)

Suprime-Cam

- Large Aperture
- Superb Img Qlty
- Wide Field
- High QE in red

High Redshift Galaxies

Table 1: The most distant galaxies with measured redshift (as of Sep.14, 2006).

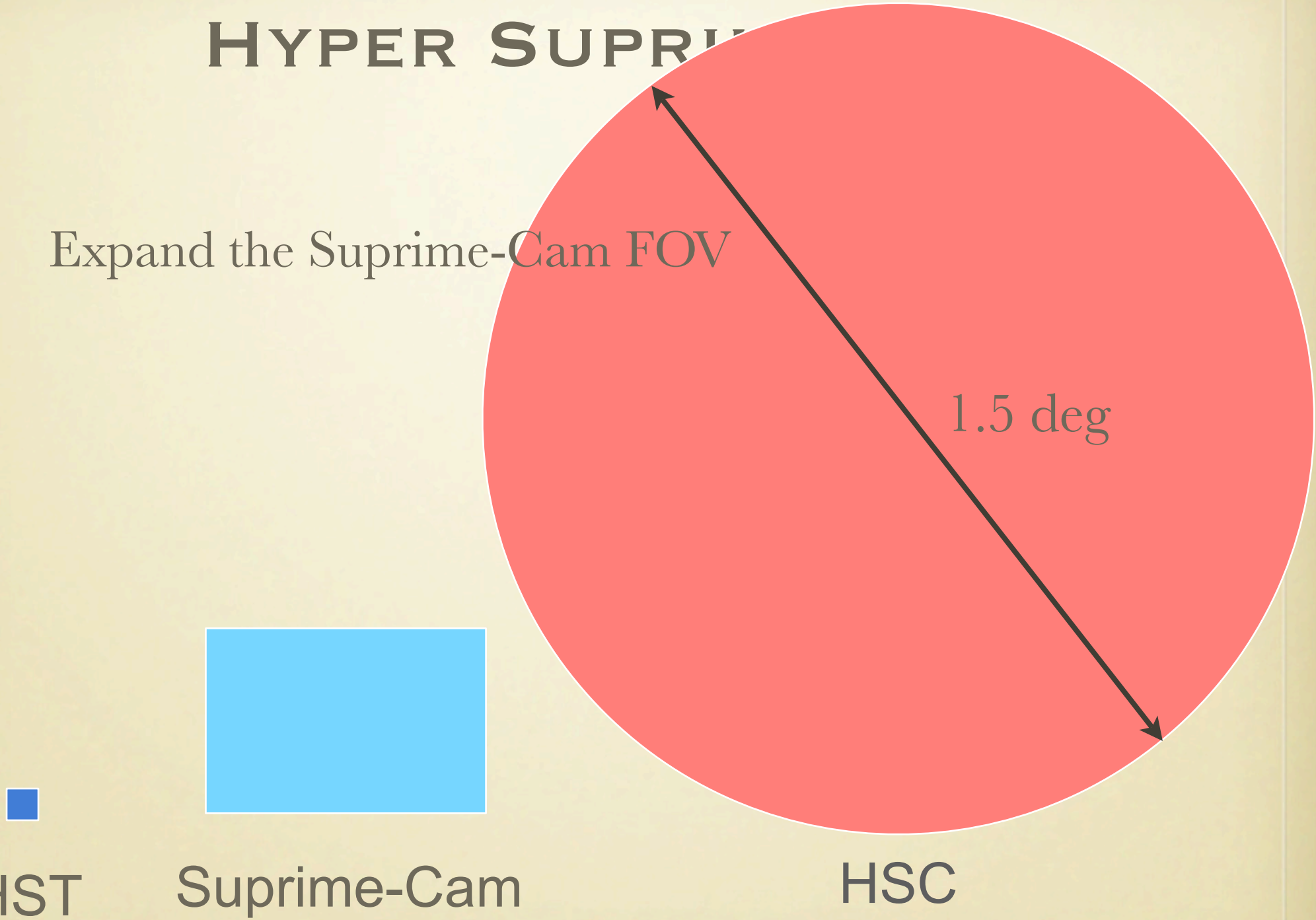
Rank	Identification	Coordinates	Redshift	Distance#	Paper	Publishing date
1	IOK-1	J132359.8+272456	6.964	12.8826	Iye et al.	Sep. 14, 2006
2	SDF ID1004	J132522.3+273520	6.597	12.8250	Taniguchi et al.	Feb, 25, 2005
3	SDF ID1018	J132520.4+273459	6.596	12.8248	Kashikawa et al.	Apr. 25, 2006
4	SDF ID1030	J132357.1+272448	6.589	12.8238	Kashikawa et al.	Apr. 25, 2006
5	SDF ID1007	J132432.5+271647	6.580	12.8222	Taniguchi et al.	Feb. 25, 2005
6	SDF ID1008	J132518.8+273043	6.578	12.8219	Taniguchi et al.	Feb. 25, 2005
6	SDF ID1001	J132418.3+271455	6.578	12.8219	Kodaira et al.	Apr. 25, 2003
8*	HCM-6A	J023954.7-013332	6.560	12.8189	Hu et al.	Apr. 1, 2002
9	SDF ID1059	J132432.9+273124	6.557	12.8184	Kashikawa et al.	Apr. 25, 2006
10	SDF ID1003	J132408.3+271543	6.554	12.8178	Taniguchi et al.	Feb.25, 2005

Distance in billion light years calculated for a model of the Universe that has an age 13.66 billion years.
* This object was discovered by Keck telescope. All the rest were discovered by Subaru Telescope in the Subaru Deep Field.

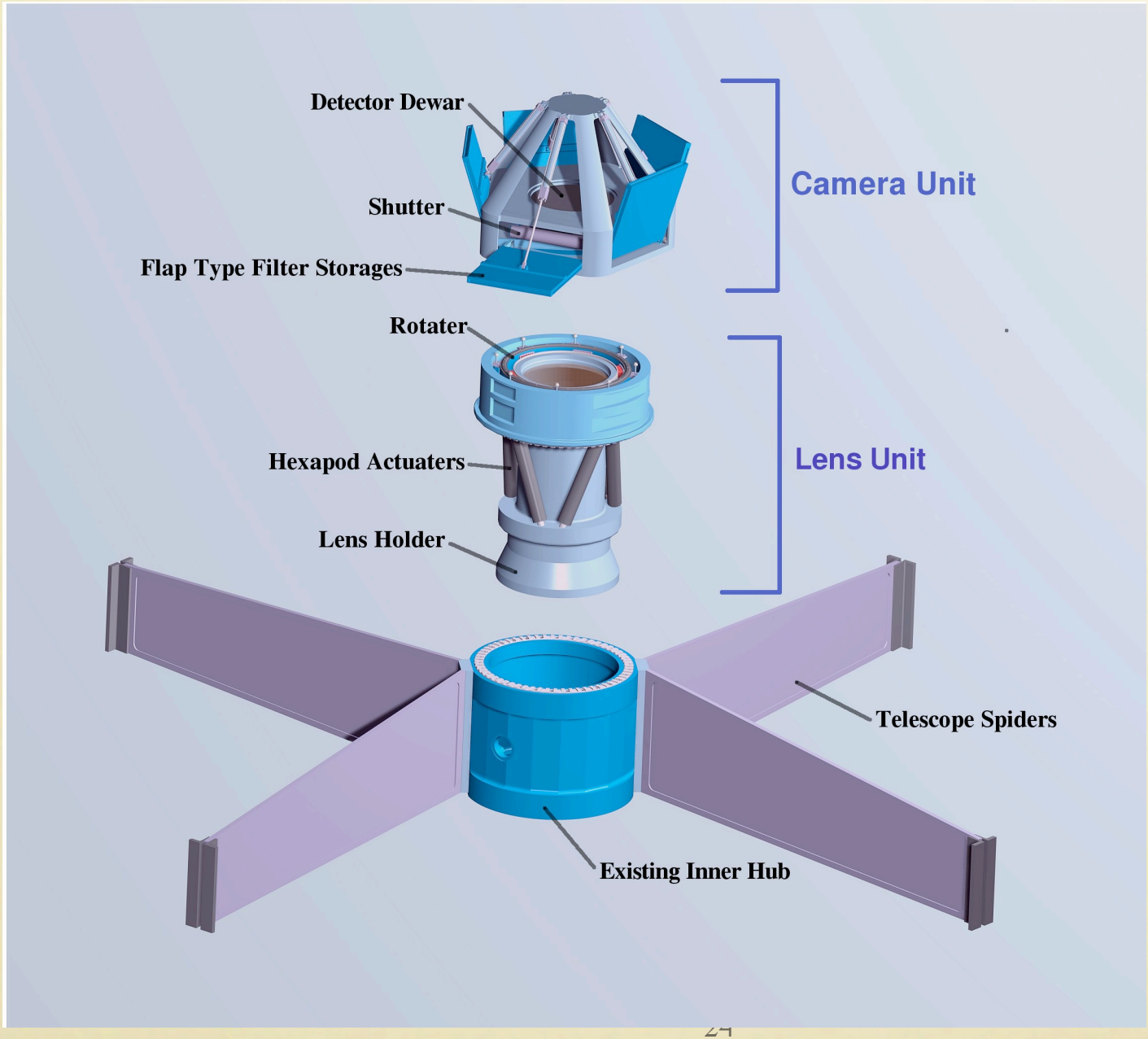
Good example to show Suprime-Cam strength

Hyper Suprime-Cam

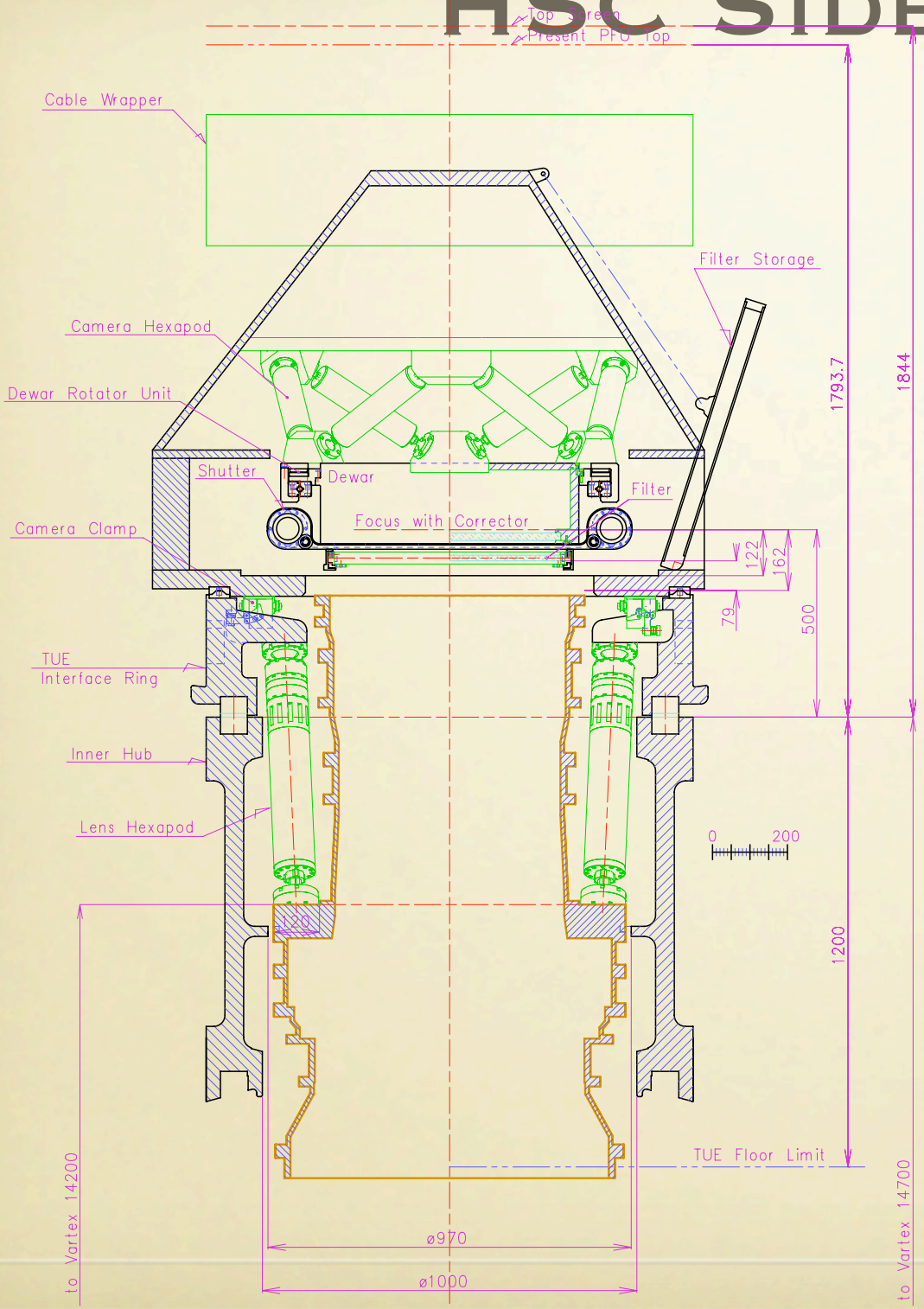
Expand the Suprime-Cam FOV

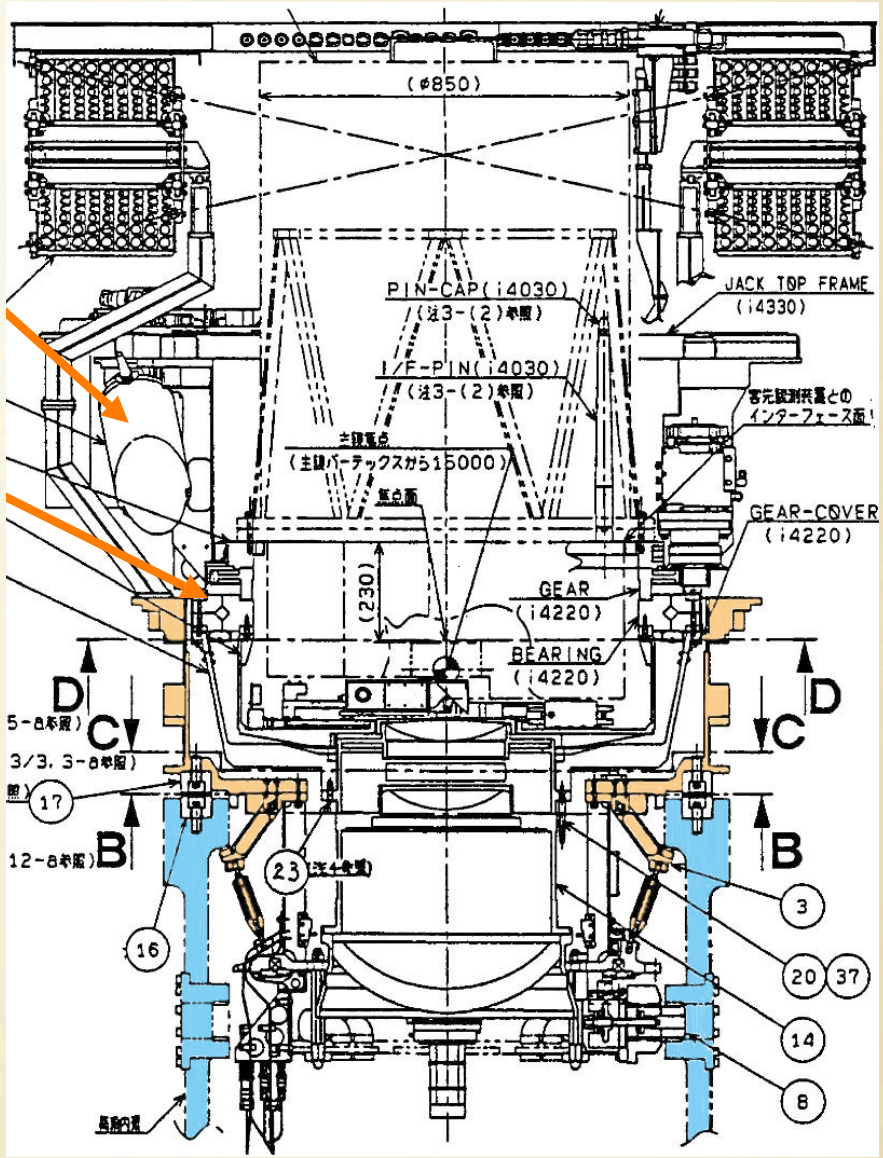


Hyper Suprime-Cam Config

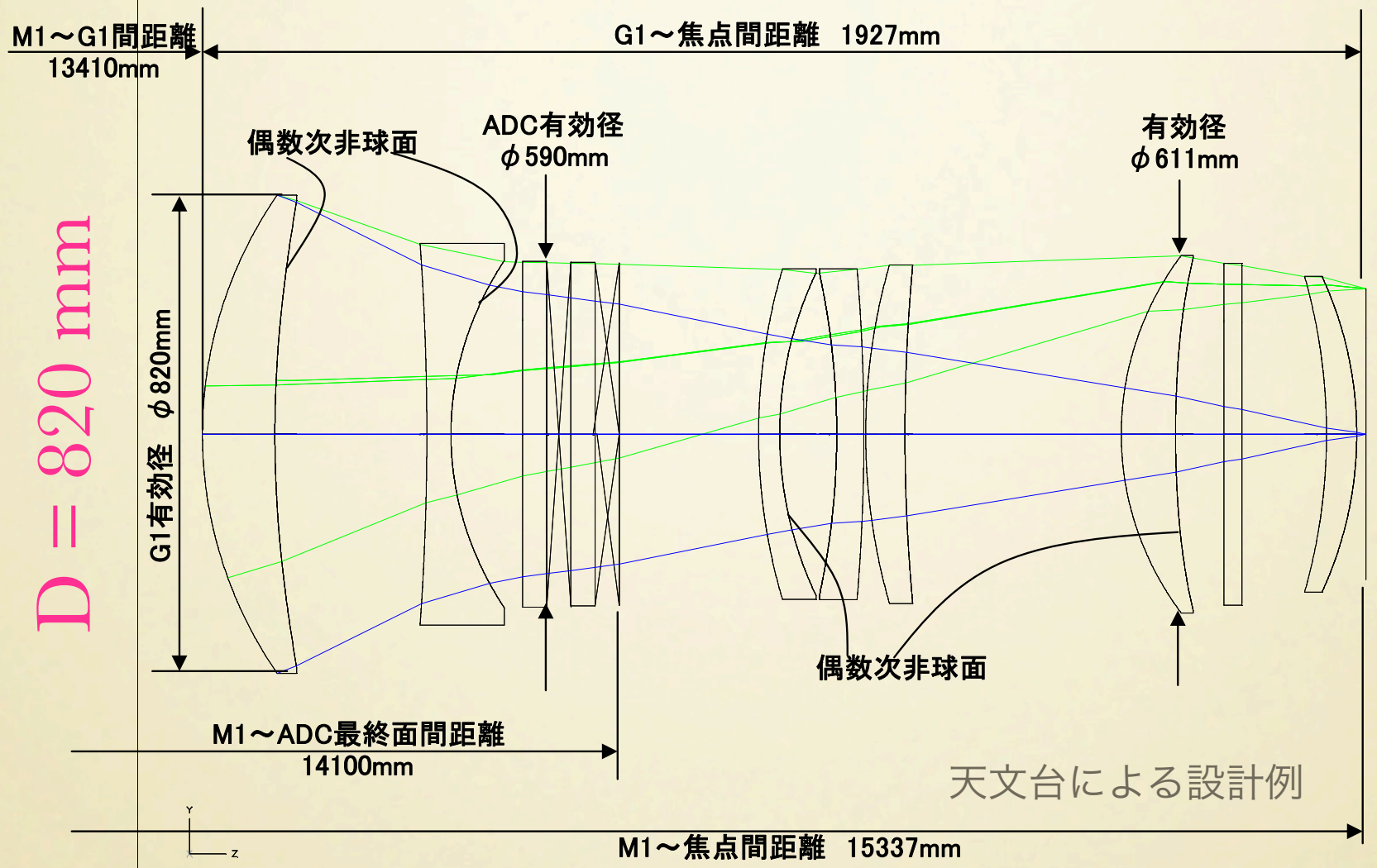


HSC Side View





HSC WFC NAOJ Design



Silica for large Lens

Large aspheric surface

設計性能

	EL = 90				
	WFMOS	g	r	i	z
r80(um)	12	11.2	7.6	7.8	9.6
D80(sec)	0.264	0.246	0.167	0.171	0.211

Img Qlty equivalent with SC

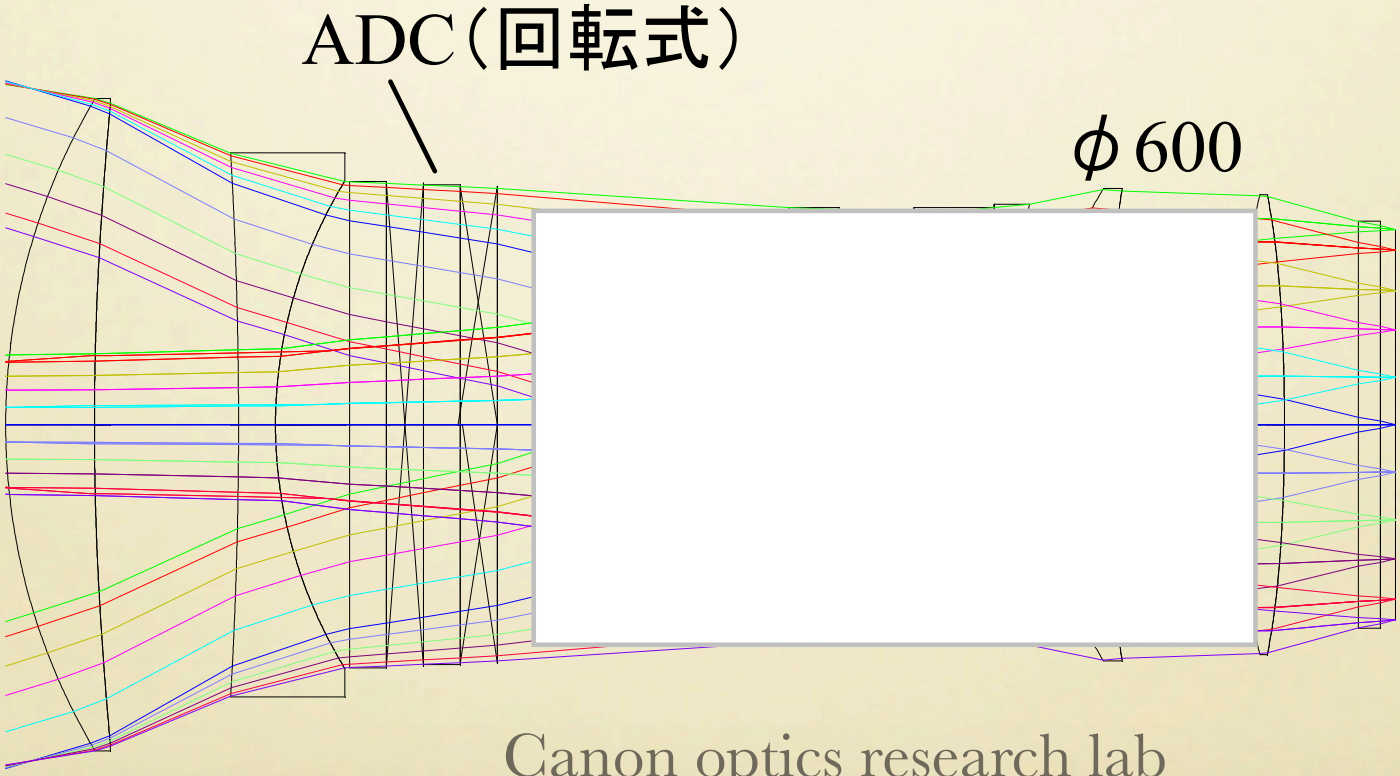
HSC Optics

Canon

Final design considering manufacturablity

Detail tolerance analsysi

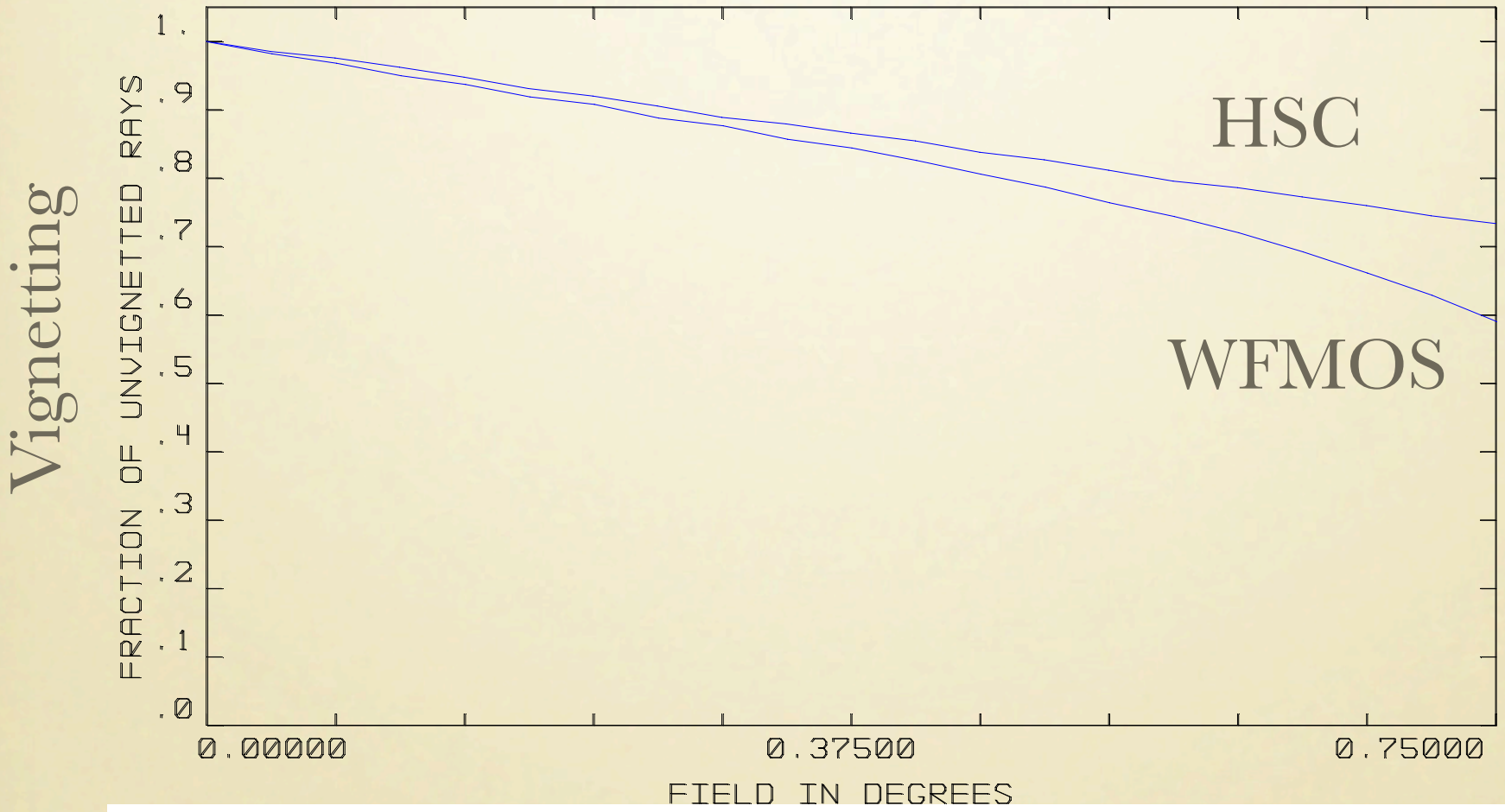
Design of Lens Barrel



Canon optics research lab

HSC WFC Issues

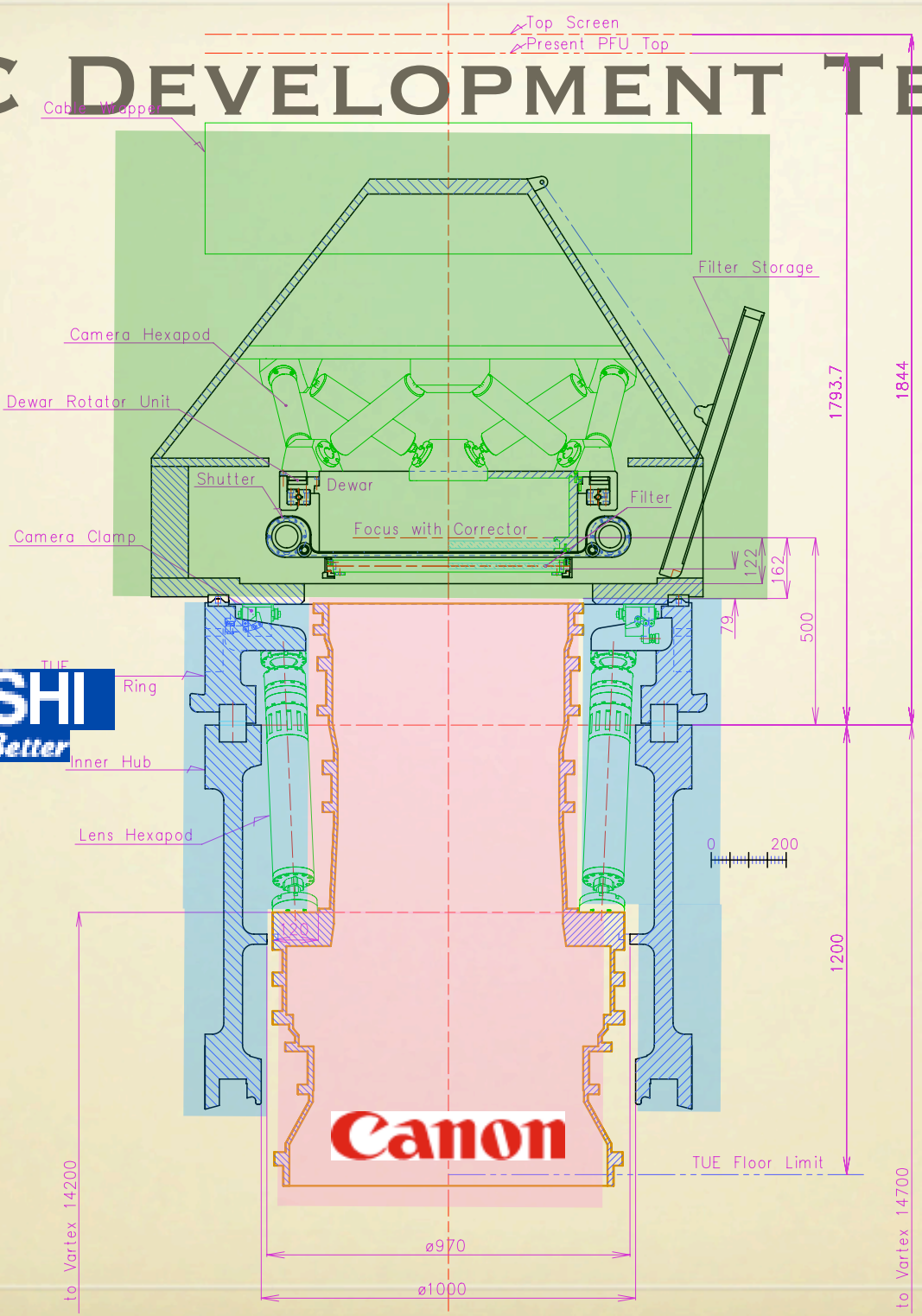
- Tele-centricity must be improved to satisfy WFMOS specfication



HSC Development Team

Camera Body

NAOJ
U. Tokyo
KEK

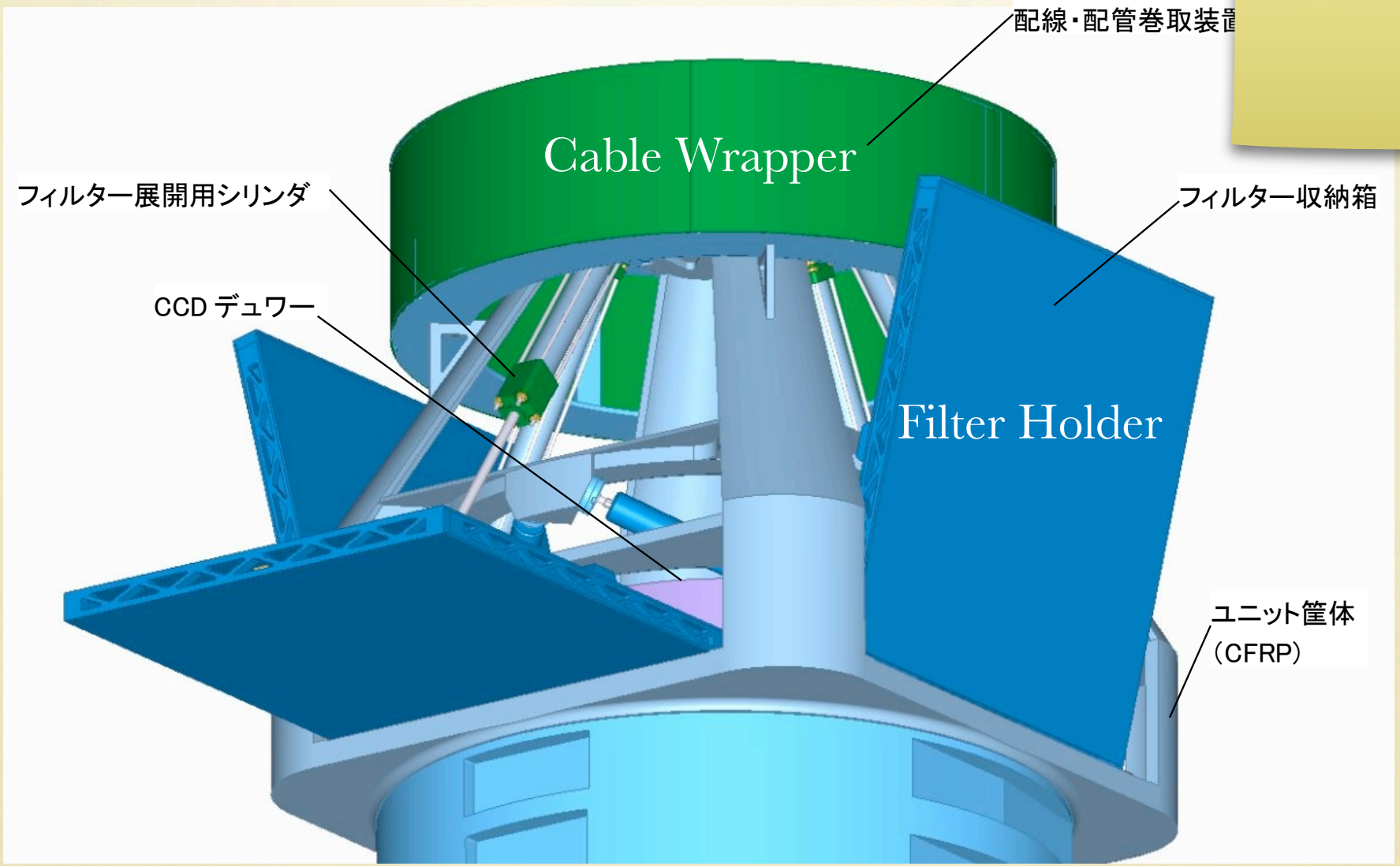


MITSUBISHI
Changes for the Better

Canon

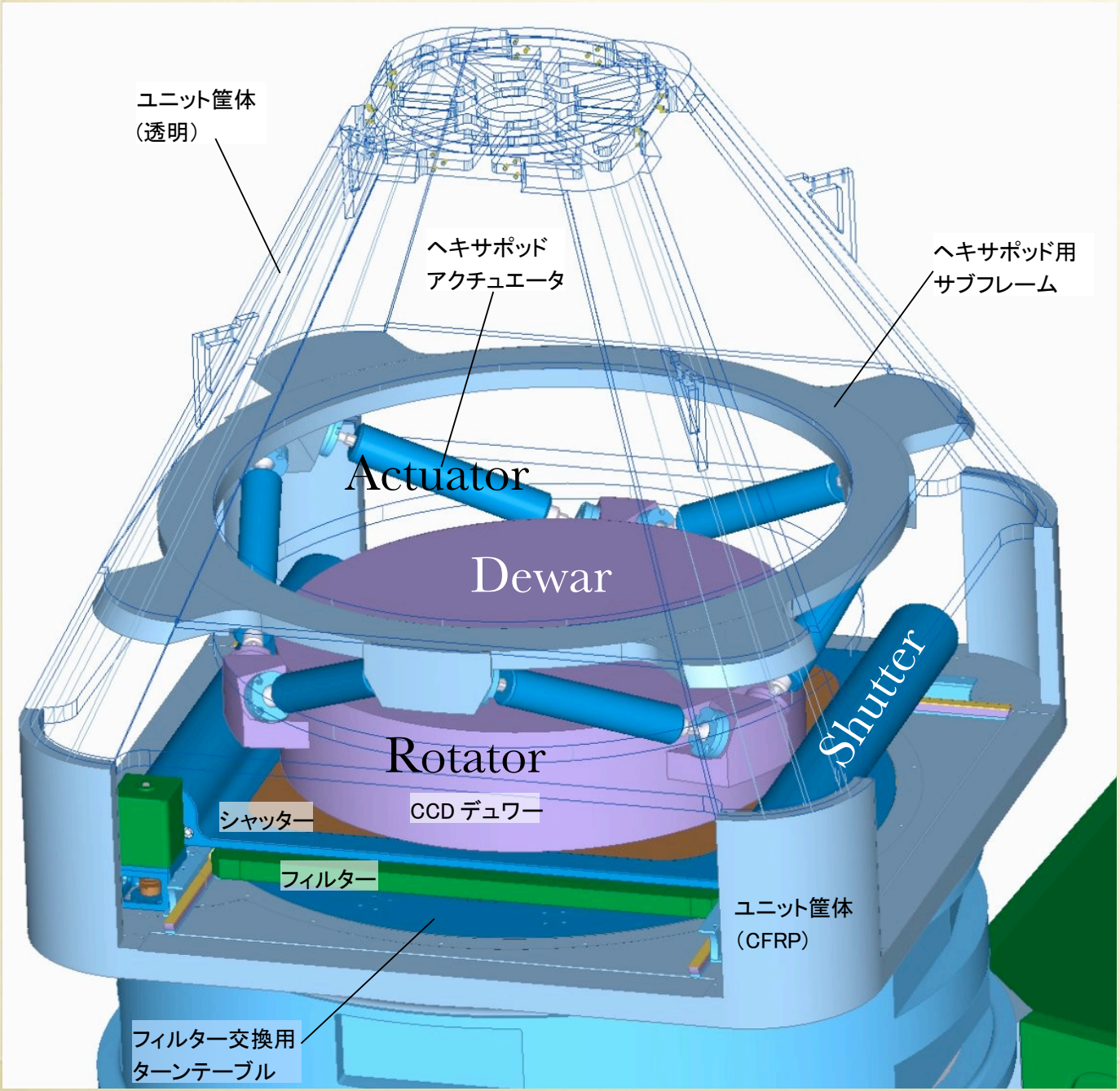
Camera Unit

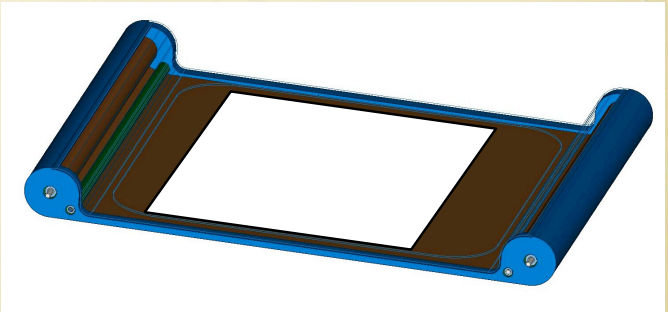
rotator付きの最新のにupdateする



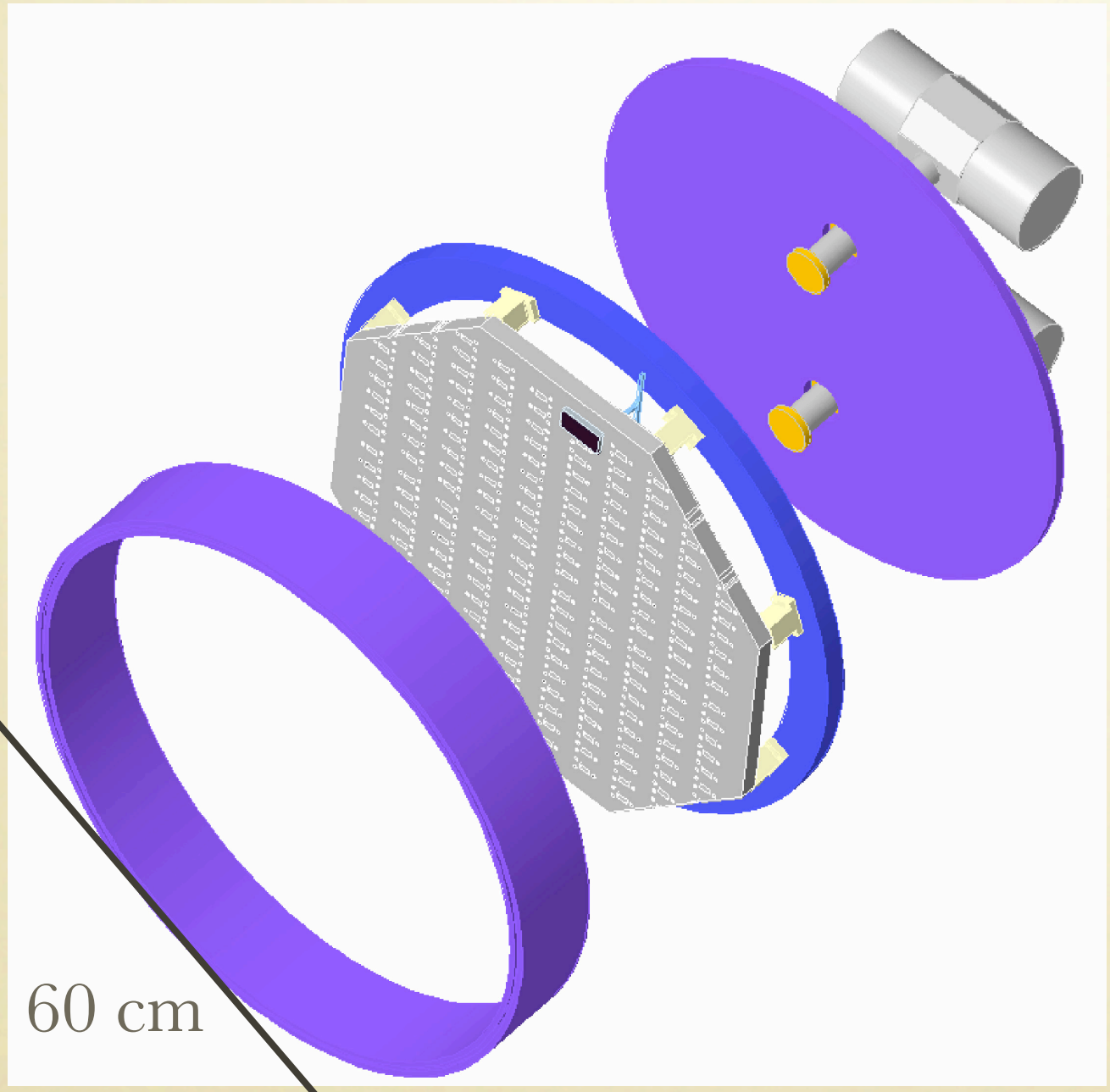
Camera Unit

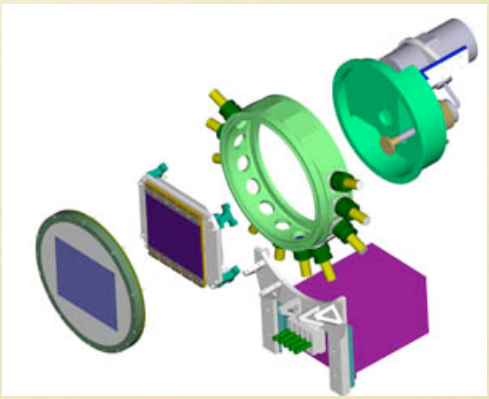
rotator付きの最新のものにupdateする





CCD Dewar



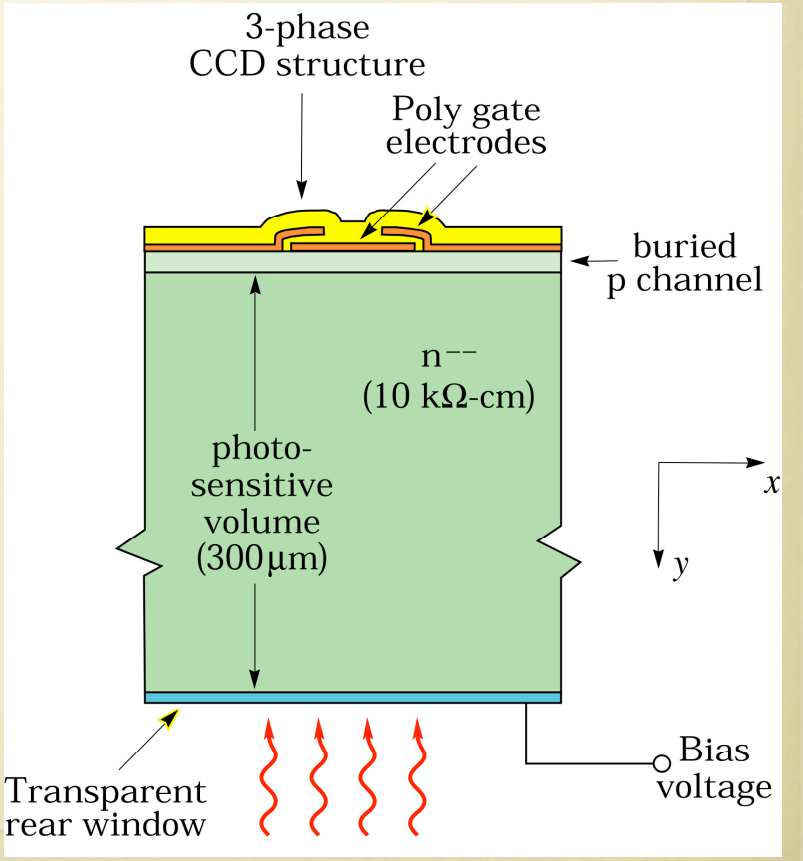


Fully Depleted CCD

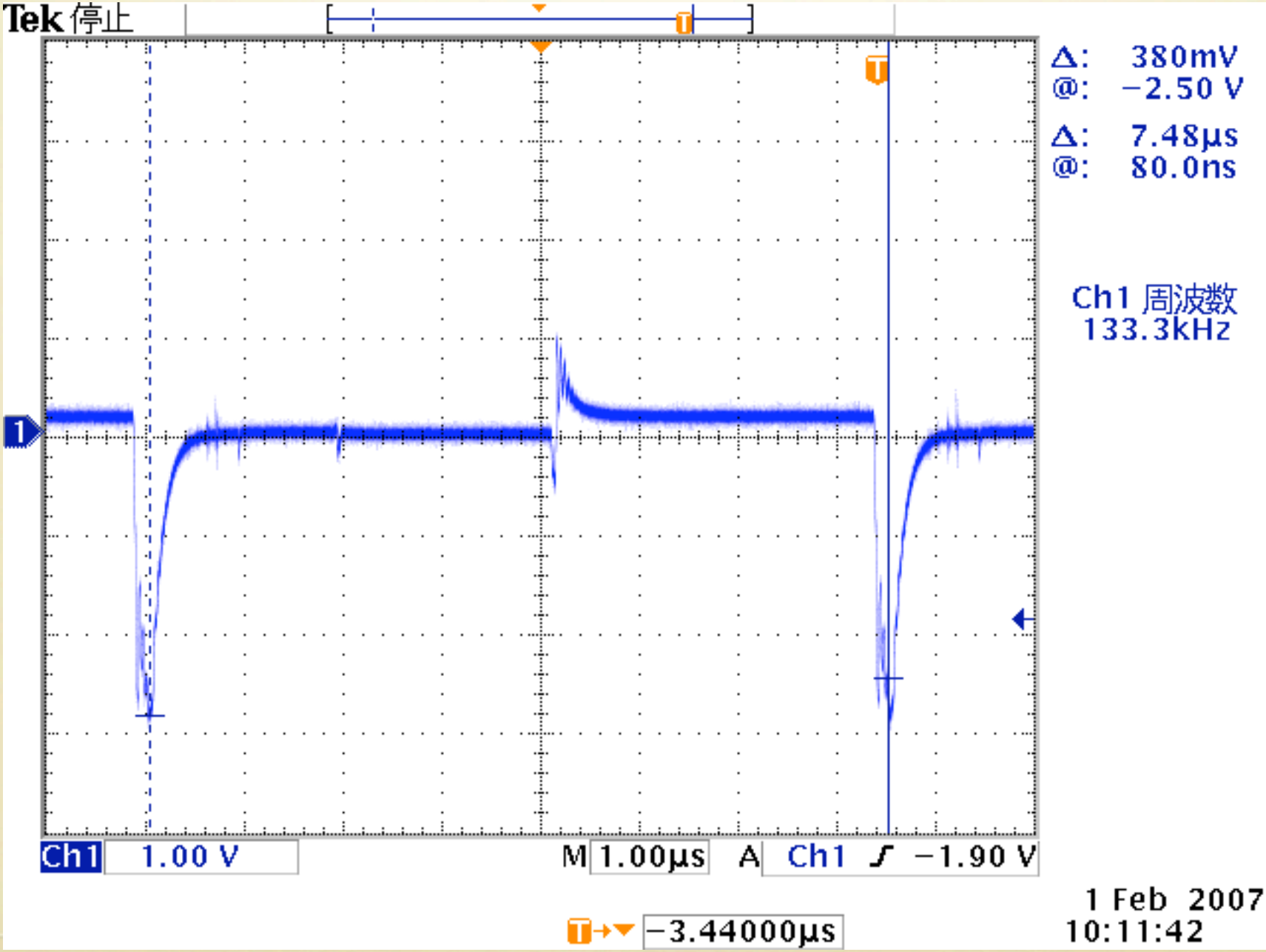
- Red QE drops because the CCD is transparent: need thicker depletion layer (DL) to improve it
- $d_{DL} \propto \rho \ \ [\Omega\text{cm}]$
- High ρ n-type Si is obtained through neutron dose

Merit

High QE in red
Less fringing
Easier to obtain BI CCD



Signal is carried by Holes

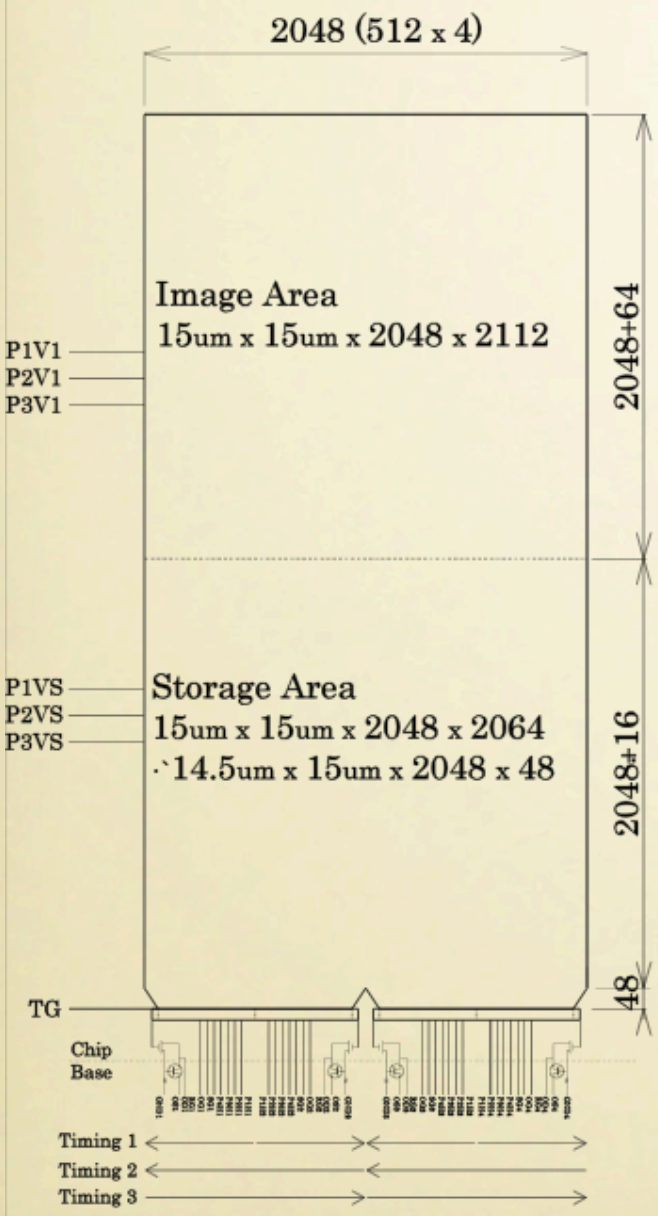


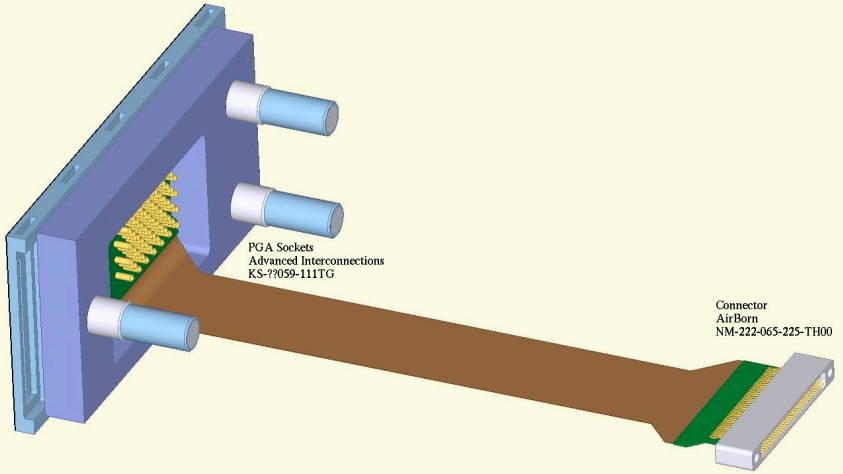
Collaboration with HPK

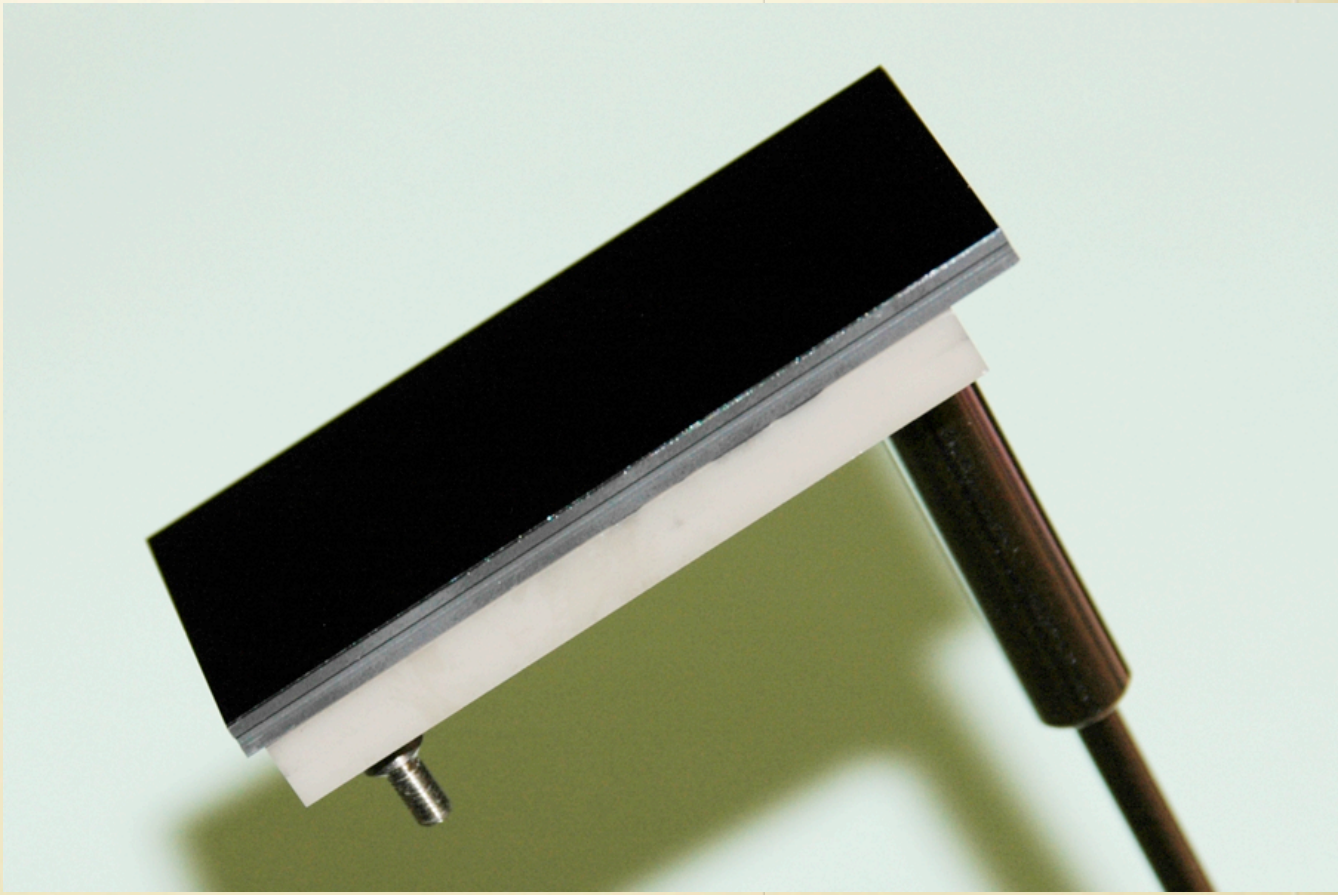
HAMAMATSU Japan

- 2000 NAOJ - HPK Collaboration started
- 2001 Japanese X-ray groups joined
- 2006 2k4k BI CCD delivered

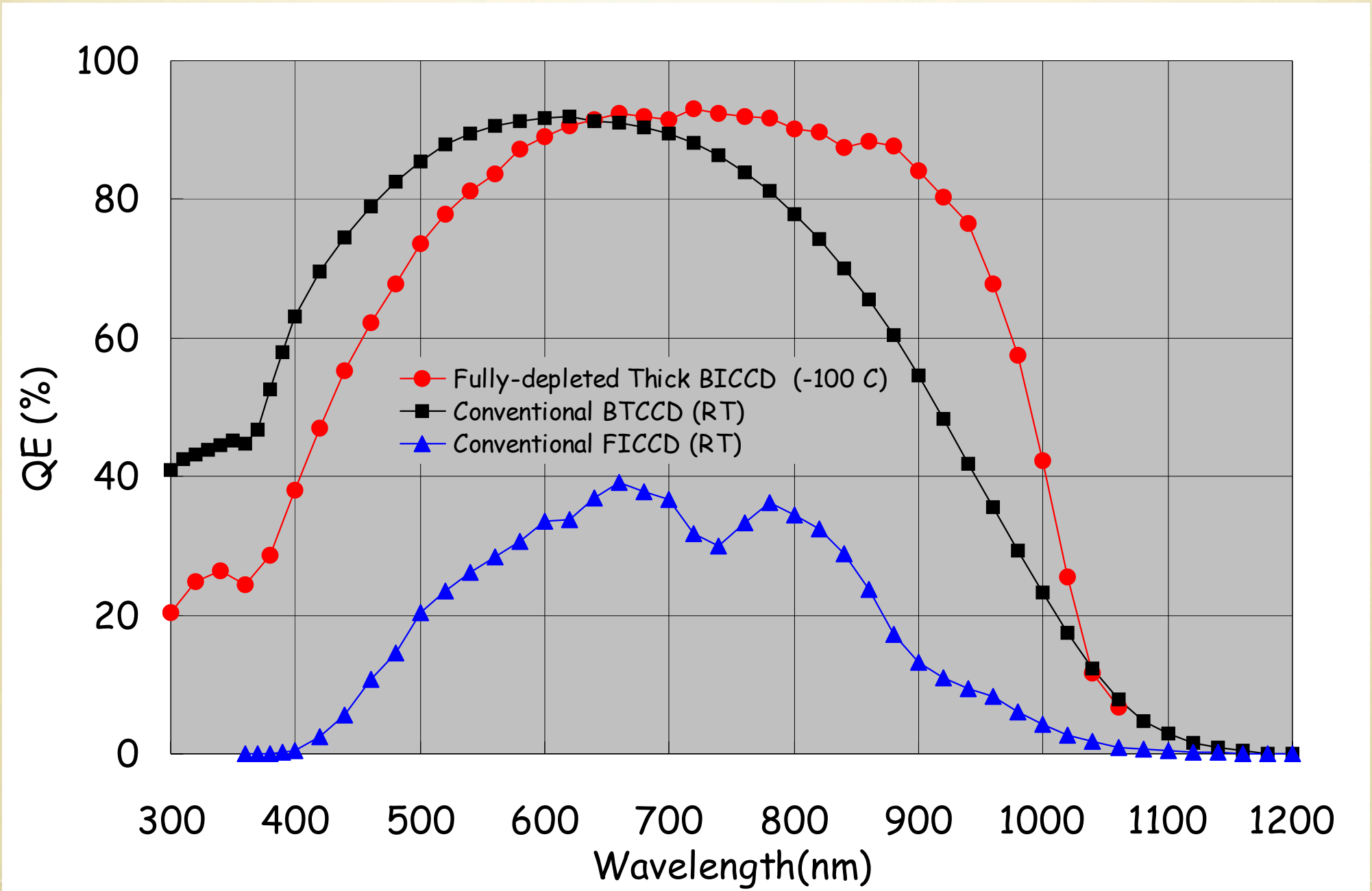
HPK FDCCD


2048 (512 x 4)
Image Area
15um x 15um x 2048 x 2112
P1V1
P2V1
P3V1
2048+64
P1VS
P2VS
P3VS
Storage Area
15um x 15um x 2048 x 2064
14.5um x 15um x 2048 x 48
2048+16
TG
48
Chip
Base
Timing 1
Timing 2
Timing 3

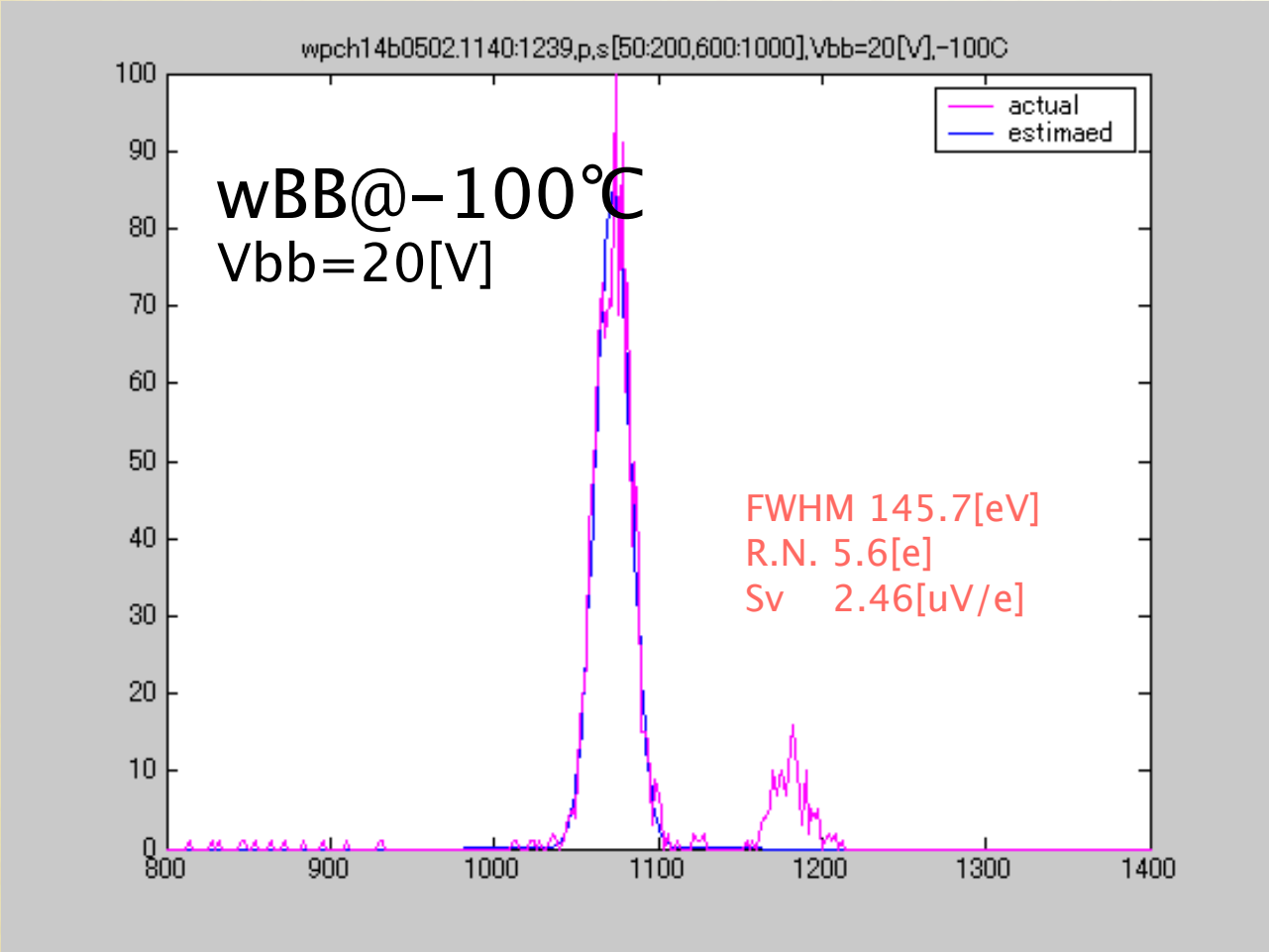

PGA Sockets
Advanced Interconnections
KS-??059-111TG
Connector
AirBorn
NM-222-065-225-TH00

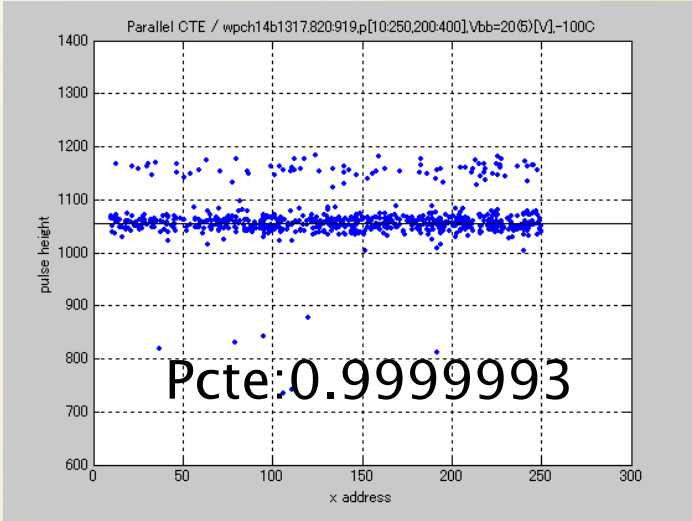


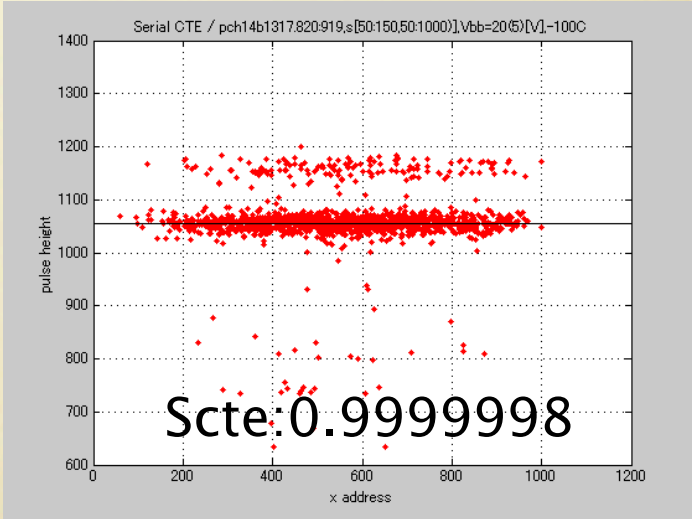
FDCCD QE


100
80
60
40
20
0
QE (%)
Fully-depleted Thick BICCD (-100 C)
Conventional BTCCD (RT)
Conventional FICCD (RT)
300
400
500
600
700
800
900
1000
1100
1200
Wavelength(nm)

X-ray Energy Resolution







FDCCD Characterization

Parallel CTE	0.999995
Serial CTE	0.999995
Quantumn Efficeincy	40 % (400 nm)
	90 % (650 nm)
	40 % (10000 nm)
Thickness	≥ 150 [μm]
Dark Current	1.4 [e/hour/pixel]
Full Well	180,000 [e]
Amplifier Responsivity	5.8 [μV/e]
Read Noise	4.4 e at 150 kHz reaout

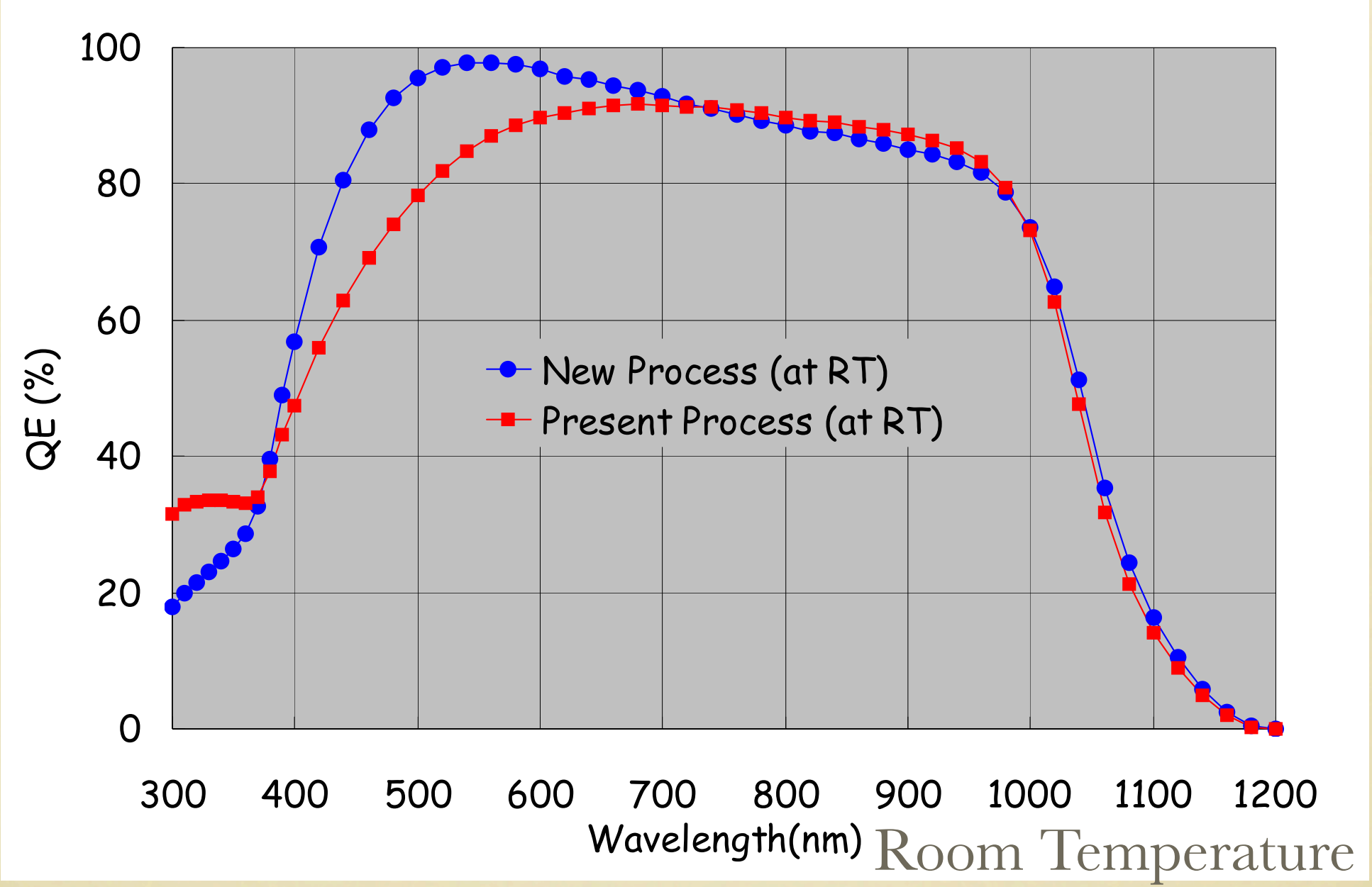
$$\mathrm{T_{CCD}} = -100^{\circ}\mathrm{C}$$

Sc CCD Replacement

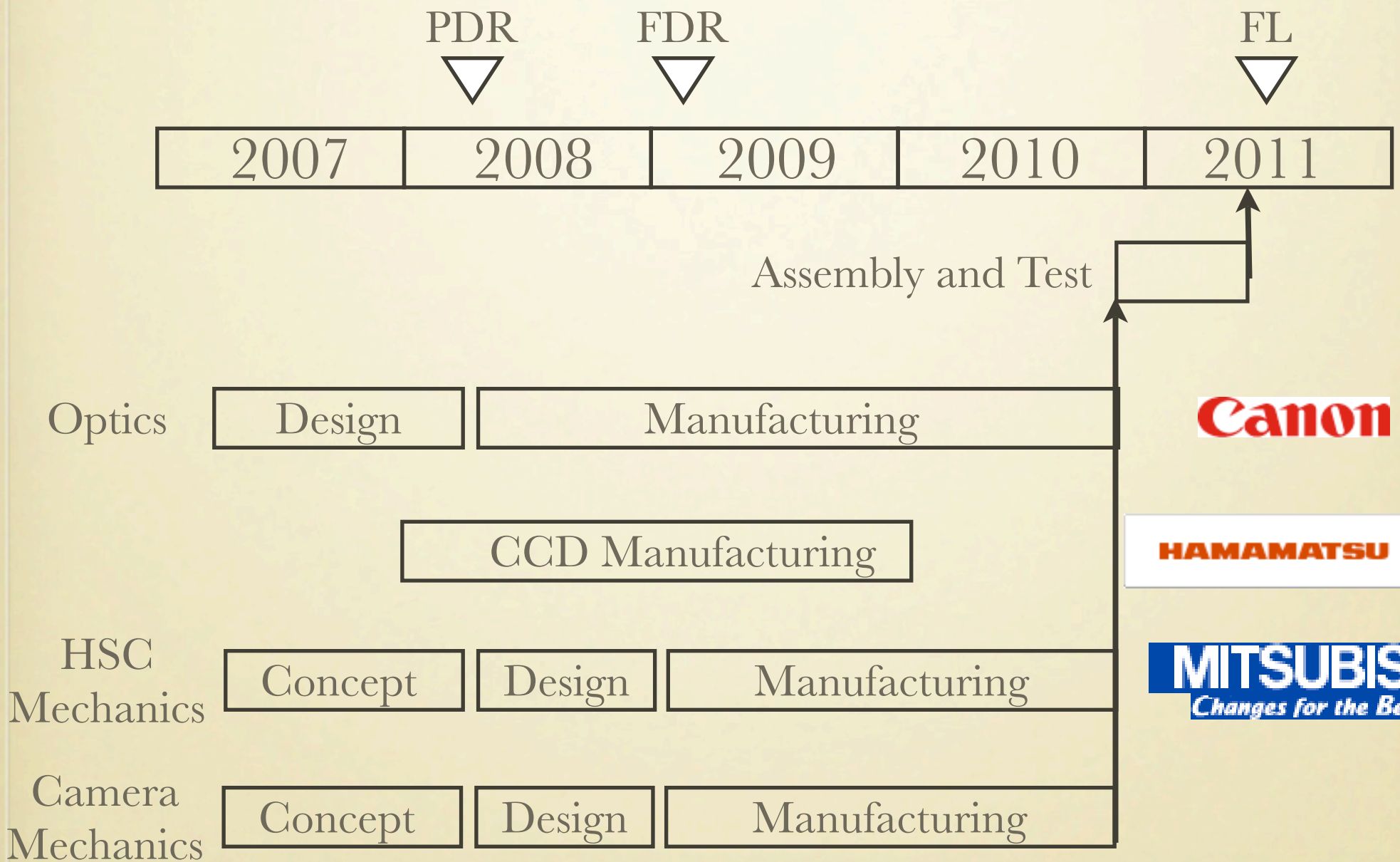
- 2007 MIT/LL CCIDs of Suprime-Cam will be replaced

New Dewar for
HPK FDCCD

FDCCD for HSC



HSC Schedule



Comparison

Project	AΩ	F.L.	Obs. Time	Survey (deg^2)
DES	37	2009	△	5000
Pan-STARRS	13.4×4	2007 PS1	○	1200, 31000
HSC	91	2011	×	2000
LSST	329	2013∼2014	○	20000
DUNE	0.57	-	○	20000
SNAP	1.1	-	○	1000, 10000

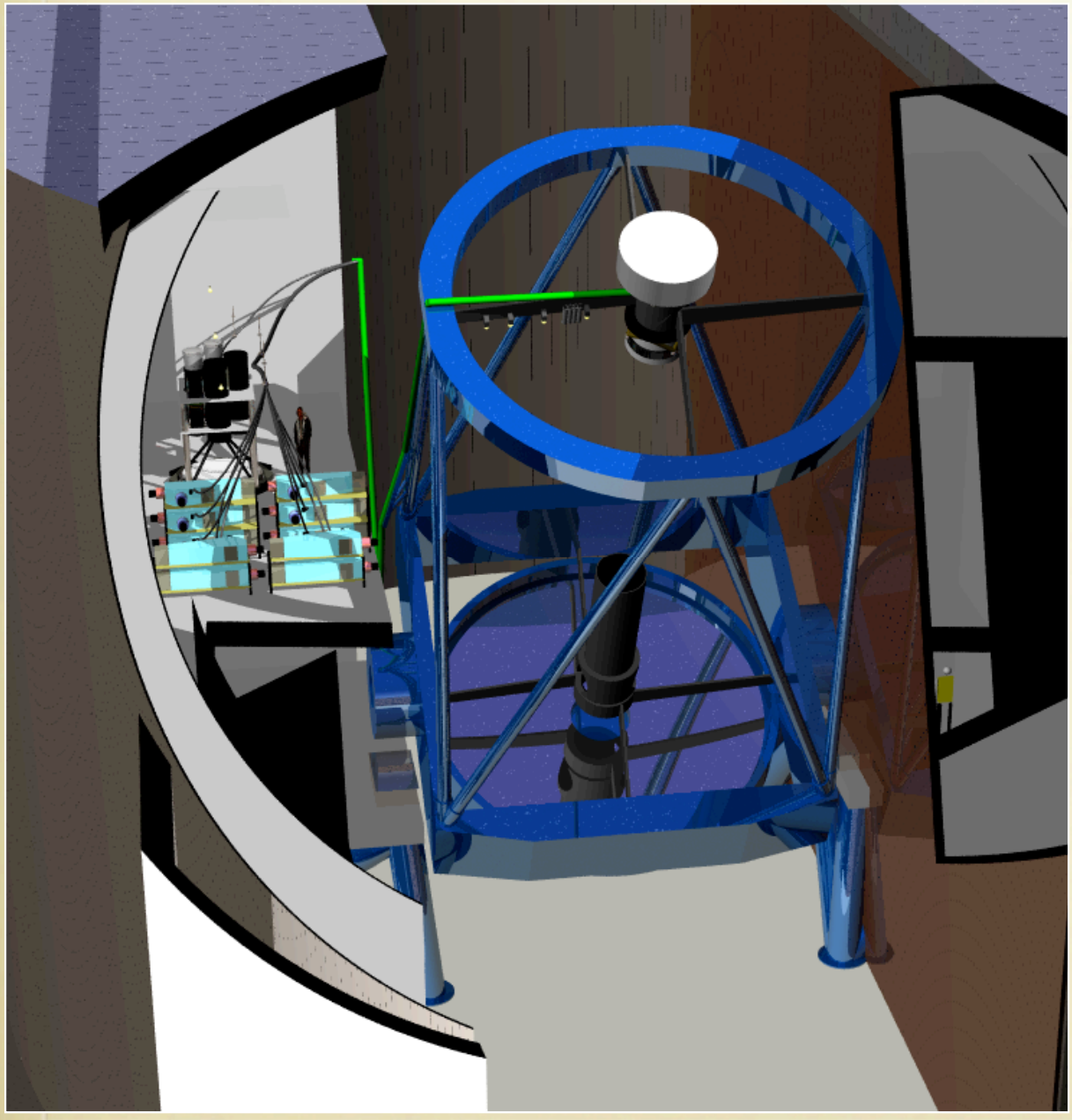
HSC Pros

- Demonstrated High Img Qlty
- High Performance CCD

HSC Cons

- Difficulty in obtaining telescope time

Message to WFMOS Design Team



Happy to work with you

Space constraint is tighter than originally expected.

Some compromises of specs. will be inevitable. (eg vignetting)

More flexible and frequent communication is crucial at this stage.

Summary

- HSC ~ 10*SC with red QE enhancement
    - Competitive with others but not outstanding
- Telescope time is hard to obtain:
    - Pursuing single science case (eg DE) is not the only option.
- Good Astronomical Survey have to be designed
    - Princeton collaboration
- WFMOS extension is unique and interesting.

Thank You