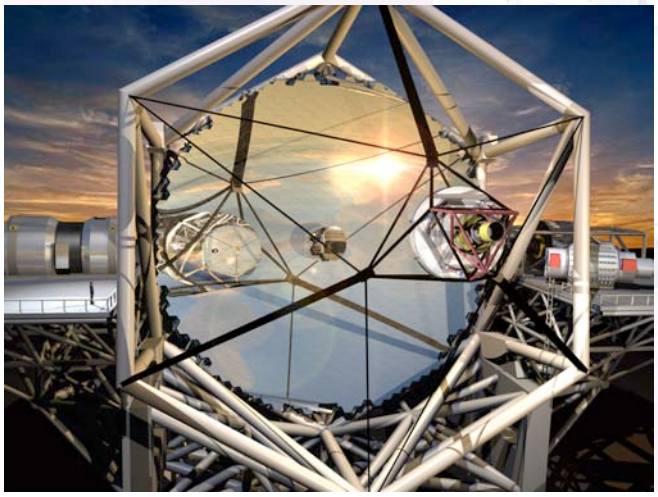
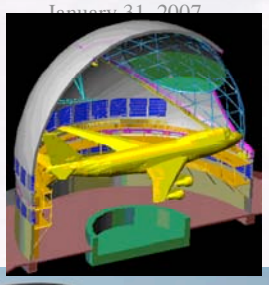
TMT Overview
Telescope / Instruments / Sites

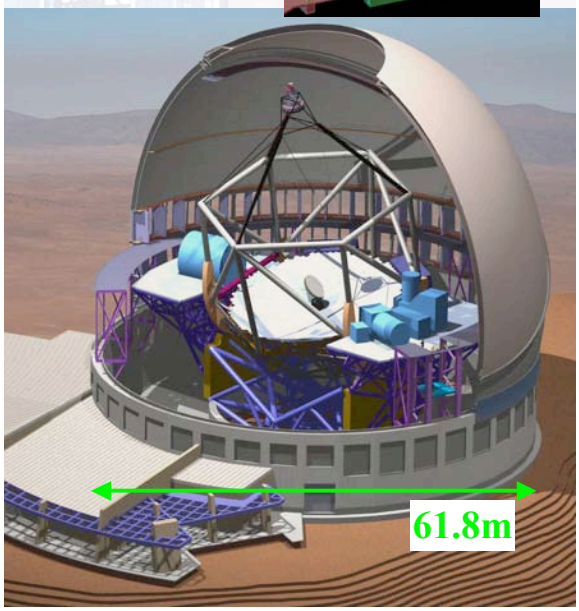


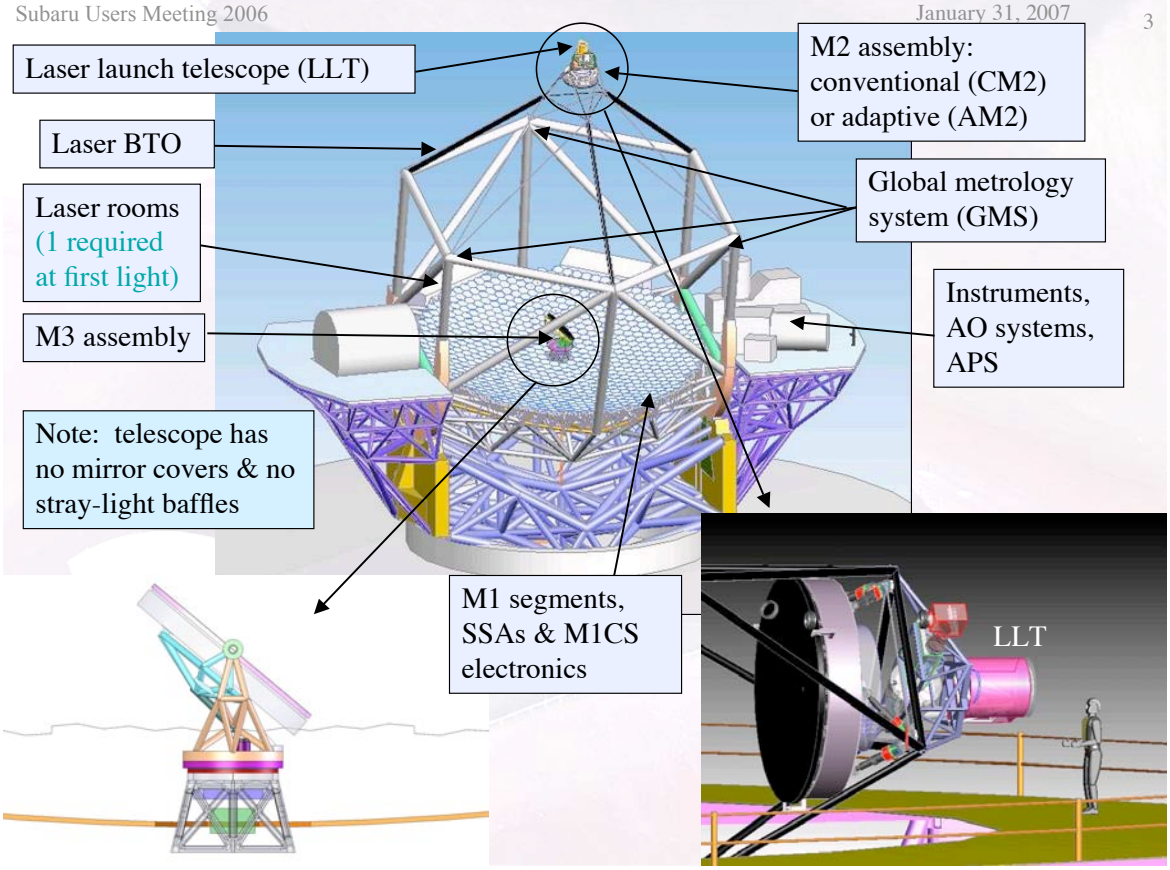
Tomonori USUDA
(SUBARU Telescope)

TMT Reference Design (as of Dec '06)

- Costs: **$743M (US$ / FY2006)**
- **30m** filled aperture, highly segmented
- Aplanatic Gregorian (AG) two mirror --> **Richey-Chretien** (RC) two mirror
- f/1 primary
- f/15 final focus
- 1.2m x 738 --> **1.4m x 492 segments**
- M2/M3 size: 3.6/4.1m ϕ --> **3.0/3.5m**
- Two Nasmyth foci (No Cassegrain)
- Field of view 20 --> **15 arcmin**
- Wavelength coverage 0.31 – 28 μm
- Operational El angle: 25° ~ 89°
- Conventional M2 w/ LGS (Adaptive M2 future capability)
- AO system requirements and architecture defined
- First generation instruments: **2~3**

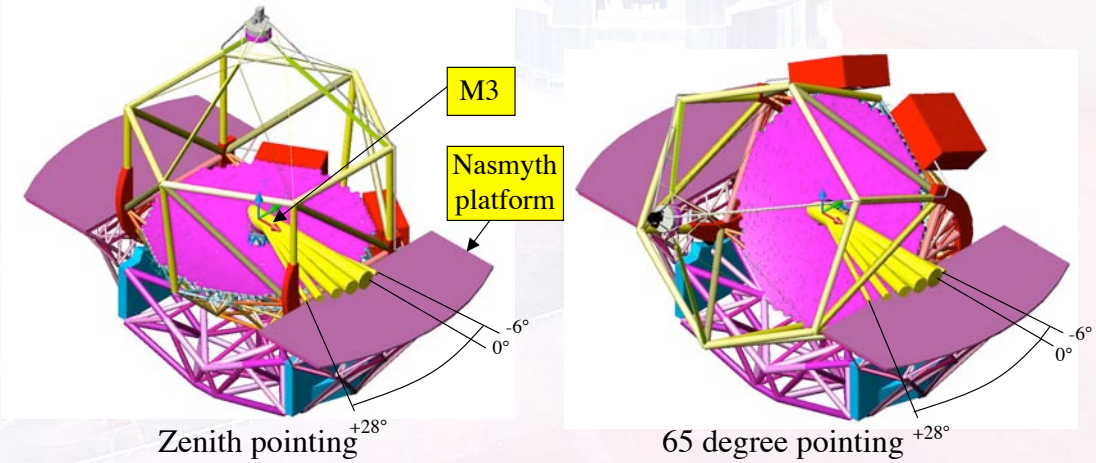






Beam Clearance

- Tertiary (M3) to Nasmyth (Ns) Instrument Beam
  - Range on Ns platform 34° (-6° to +28°) for zenith angle -1° to +65°
  - Strongly influences structural configuration
    - Drives allowable M2 support configurations (vertical column position)
    - Restricts configuration and spacing of elevation journals



Zenith pointing 65 degree pointing

TMT Science Instrument Summary

Instrument	Spec. Res.	Science Case
Near-IR DL Spectrometer & Imager (**IRIS**)	≤4,000	Assembly of galaxies at large redshift Black holes/AGN/Galactic Center Resolved stellar populations in crowded fields
Wide-field Optical Spectrometer (**WFOS**)	300 - 5,000	IGM structure and composition 2<z<6 High-quality spectra of z>1.5 galaxies suitable for measuring stellar pops, chemistry, energetics
Multi-slit near-IR Spectrometer (**IRMS**)	2,000 - 10,000	Near-IR spectroscopic diagnostics of the faintest objects JWST followup
Mid-IR Echelle Spectrometer & Imager (**MIRES**)	5,000 - 100,000	Physical structure and kinematics of protostellar envelopes Physical diagnostics of circumstellar/protoplanetary disks: where and when planets form during the accretion phase
Near-IR, DL Echelle (**NIRES-B** (JHK))	5,000 - 30,000	Radial velocities of M-stars and detection of low-mass planets IGM characterizations for z>5.5
Multi-IFU, near-DL, near-IR Spectrometer (**IRMOS**)	2,000 - 10,000	Near-IR spectroscopic diagnostics of the faintest objects JWST followup
ExAO I (**PFI**)	50 - 300	Direct detection and spectroscopic characterization of extra-solar planets
Optical Echelle (**HROS**)	30,000 - 50,000	Stellar abundance studies throughout the Local Group ISM abundances/kinematics, IGM characterization to z~6 Extra-solar planets
Near-IR, DL Echelle (**NIRES-R** (LM))	5,000 - 30,000	Radial velocities of M-stars and detection of low-mass planets ISM abundances/kinematics, IGM characterizations for z>5.5
MCAO imager (**WIRC**)	5 - 100	Galactic center astrometry Stellar populations to 10Mpc

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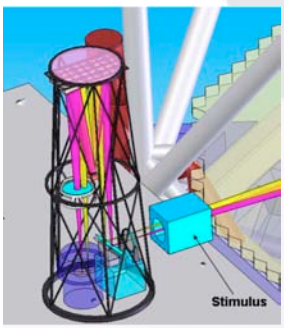
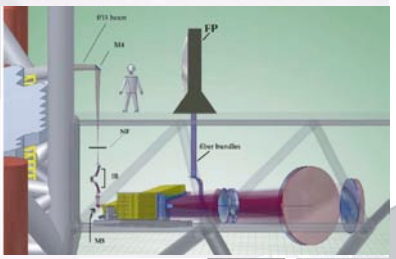
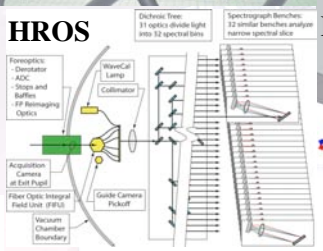
Instruments



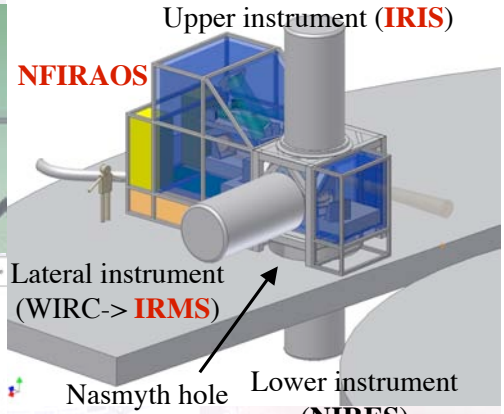


HROS



Upper instrument (**IRIS**)

NFIRAOS

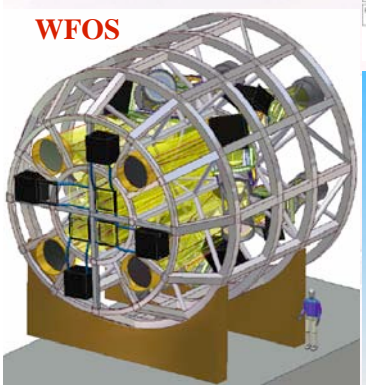


Lateral instrument (WIRC-> **IRMS**)

Nasmyth hole

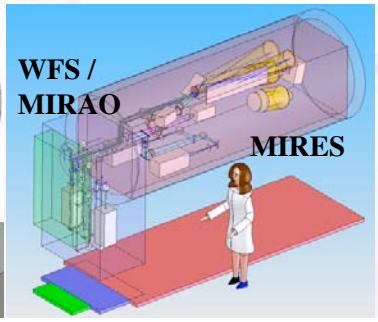
Lower instrument (**NIRES**)

WFOS

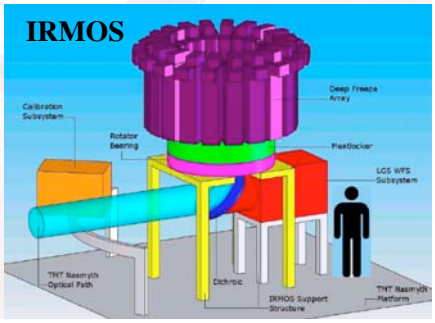


WFS / MIRAO

MIRES



IRMOS



IRIS: InfraRed Imaging Spectrograph

- Upgrade of OSIRIS on Keck
- Coupled to MCAO (NFIRAOS) System
- 0.8~2.5um /18" imaging field 4mas sampling
- Up to 4 lenslet modules of:
  - **128x128 IFU 5 ~ 25mas pix / R=4000 over JHK**
  - 4k x 4k Rockwell Detector with 10 μm pixels (4 Hawaii2-RG)
  - FOV: 1"x1" (5mas) ~ 6"x6" (25 mas)
- Two - Three mirror anastigmats (TMAs)
- Grating – 42 lines/mm for K-band
- Expandable with dithered lenslets
- Install (2015) / 1st light (2016) w/o LGS / (2016~2017) w/ LGS
  cf. Telescope partial 1st light (2015/04) / 1st light (2016/01)

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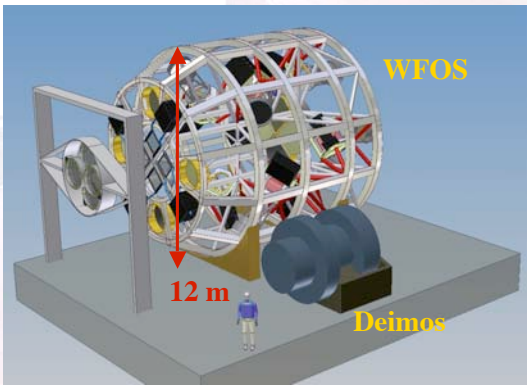
WFOS: Wide Field Optical Spectrograph

- Multi-object spectroscopy over as much of **20' field** as possible
- Two barrels w/ Red & Blue Cameras in each barrel (goal: four)
- Wavelength: 0.31-1.0μm (0.30-1.6μm goal). ADC required
- **Field of view: 50 arcmin^2 ;(goal: 300 arcmin^2)**
- Image quality: ≤ 0.2" FWHM over any 0.1μm
- Spatial sampling: ≤0.15"/pix, (goal ≤ 0.10")
- **Spectral Res: R=500~7500 for 0.75" slit; (goal: 150~6000)**
- GLAO enhanced image quality
- Upgrade path to IFU mode



Candidate Sites

	Elevation [m]	Cloudiness Clear [%]	Cloudiness Usable [%]	PWV 50% [mm]	PWV 10% [mm]
Tolar	2290	81	85	4.02	1.59
SP Martir	2830	73	80	2.63	1.06
Armazones	3064	80	86	2.87	1.15
Mauna Kea	4210	69	78	1.86	0.72
~~Quimal~~	~~4275~~	~~77~~	~~84~~	~~2.05~~	~~0.93~~
Tolonchar	4480	70	78	1.70	0.70

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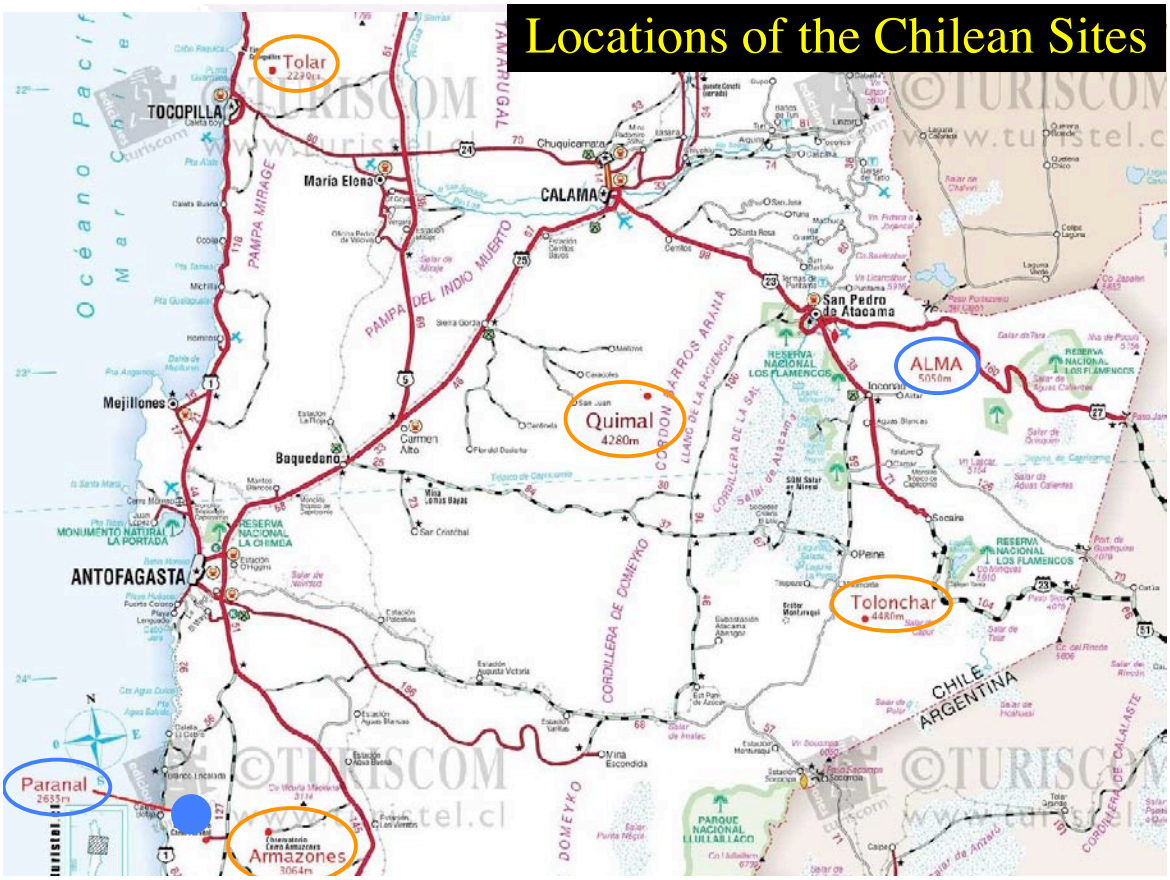
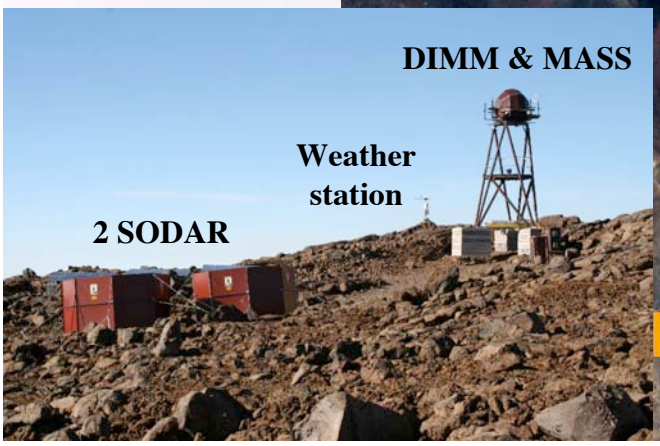
Locations of the Chilean Sites



Mauna Kea



Results (~ Nov '06)

		T1 Tolar	T2 Armazones	T3 Tolonchar	T4 SPM	T6 Mauna Kea
DIMM seeing	[as]	0.63	0.64	0.64	0.78	0.73
DIMM seeing 10%	[as]	0.42	0.41	0.44	0.50	0.45
MASS seeing	[as]	0.43	0.44	0.48	0.36	0.32
MASS seeing 10%	[as]	0.23	0.23	0.24	0.17	0.14
GL seeing	[as]	0.38	0.37	0.39	0.60	0.59
Isoplanatic angle	[as]	1.81	1.80	1.80	1.69	2.69
Temperature @ 2m	[C]	14.0	8.0	-0.8	5.2	2.8
Temp. 10-90% @ 2m	[C]	5.7	7.0	9.1	15.8	6.4
Wind @ 2m	[m/s]	3.4	5.4	3.0	(2.6)	4.5
Wind @ 7m	[m/s]	4.9	6.7	4.9	(2.7)	5.9
Humidity @ 2m	[%]	19.0	21.0	33.0	39.0	27.0

- All Layer Seeing (DIMM)
  (Good) Tolar ~ Armazones ~ Tolonchar < MK < SPM (Bad)
- Higher layer (>500m) Seeing (MASS)
  (Good) MK < SPM < Tolar ~ Armazones < Tolonchar (Bad)
- Ground Layer Seeing
  (Good) Tolar ~ Armazones ~ Tolonchar < MK < SPM (Bad)
- Isoplanatic angle
  (Big) MK > SPM > Tolar ~ Armazones > Tolonchar (Small)

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Site Merit Function

$$M = \sum_{i=1}^{3} w_i \prod_{j=1}^{10} C_j^{k_{ij}}$$

- Cj is value of jth parameter
- kij is typically 1 or 0 depending on whether that parameter matters or not for that kind of observing

Types of observing :

- Seeing limited 50%
- Near IR with AO 40%
- Mid IR with AO 10%

Types of site characterostics

- Clear time fraction
- Seeing
- Wind speed
- × Water vapor
- × Time variability of seeing
- × Atmospheric time constant
- Atmospheric isoplanatic angle
- Mean temperature
- Annual range of temperature
- Diurnal temperature range

×: No real data

- Optical: Tolar ~ Armazones > Tolonchar > MK > SPM
- NIR: Tolonchar > MK > Armazones > Tolar > SPM
- MIR: Tolonchar > MK > Armazones > SPM > Tolar
- **Total: Armazones > Tolonchar > Tolar > MK > SPM**

Schedule / Discussion

Schedule:

- 2007 4Q: Site reports will be submitted
- 2008 1Q: Site decision by TMT board

Discussions about Mauna Kea 13N (MK13N):

- MK13N should be the **only one or No.1**.
- Other factors (e.g., Infrastructures, Collaboration etc.): **MK best**
- **Is the seeing at 13N worse than Chilean site?**

  cf.) Cross-check the data with UH IfA and Subaru

  cf.) Seeing conditions @VLT site is worse than before.
- We have only one year to obtain some evidences which easily show that MK is the best site for TMT.