#### The Instrumentation Plan for the Giant Magellan Telescope (GMT)





- Project Overview
- Project Status

- Instrument candidates
- The selection: a challenging and dynamic process
- Early science plans

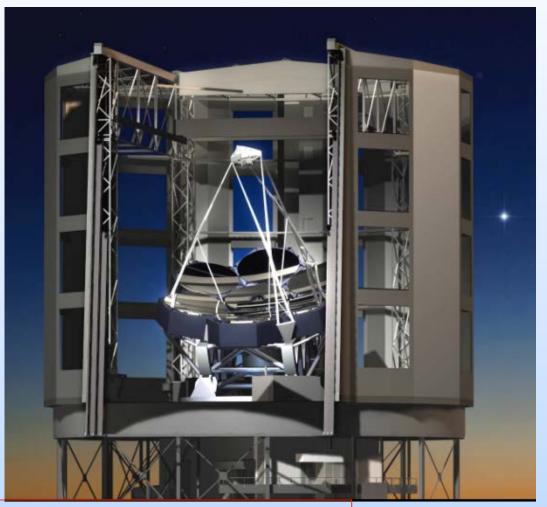
GIANT MAGELLAN TELESCOPE



#### The GMT Concept

#### Giant-Segmented Mirror Telescope

- 7 8.4-m primary segments (25.4-m diam; 21.9-m area)
  - 7 1.1-m secondary segments
  - 20 arcmin field of view
  - f/0.7 primary focal ratio
    - f/8.2 final focal ratio
  - Plate scale ~ 1.0"/mm



GMT is the smallest of ELTs (Area=E-ELT/e), But has fewest reflections, and widest-field

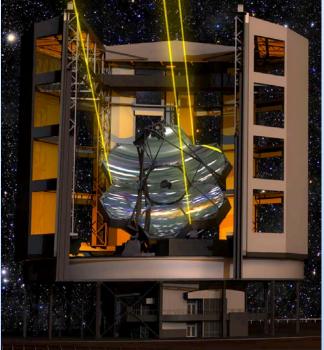
#### Integrated Adaptive Optics System

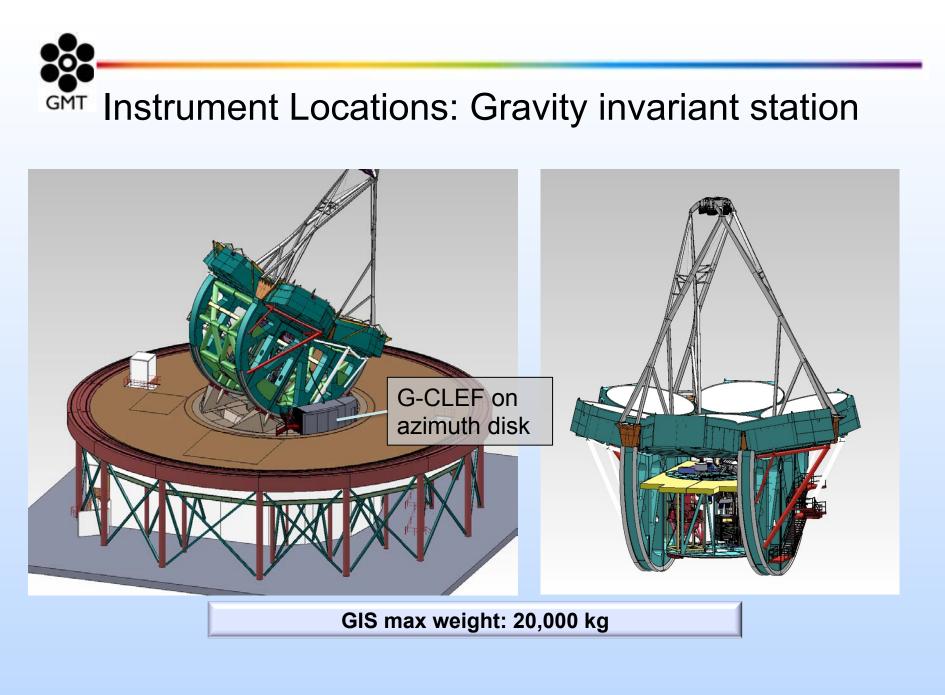
Adaptive Secondary Mirrors (ASM)
 7 x 1.1-m segments, 4704 actuators

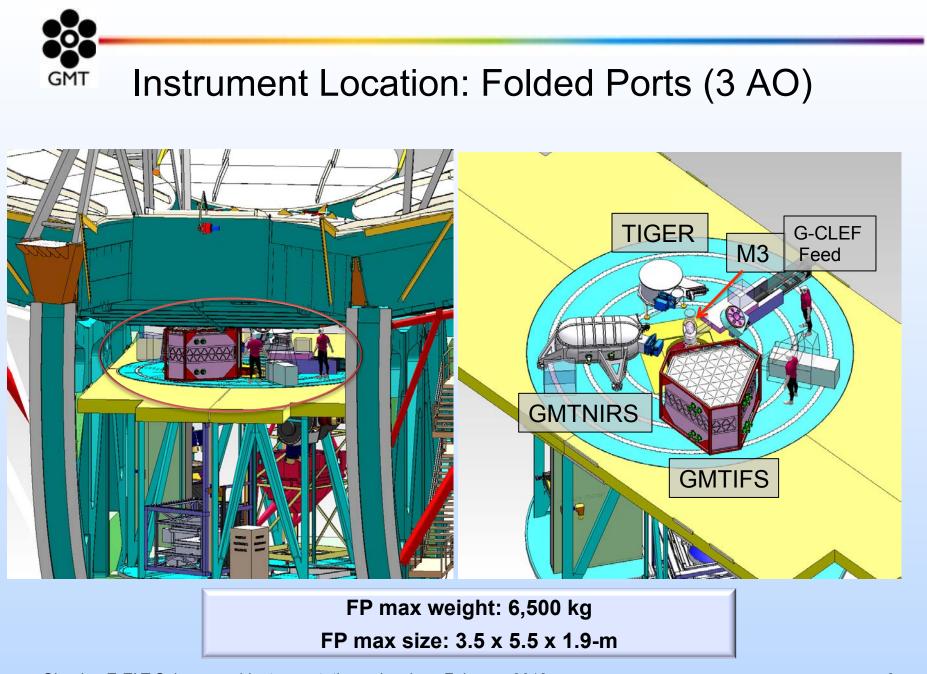
GMT

- ASM heritage: MMT, LBT, Magellan, (VLT)
- NGSAO/LTAO wavefront sensor package replicated for each AO instrument
- On-instrument IR sensor(s) for tip-tilt, truth
- GLAO using NGS (always available)
- 6 x 20 W sodium lasers for LTAO
- Available to all instruments (with WFS)

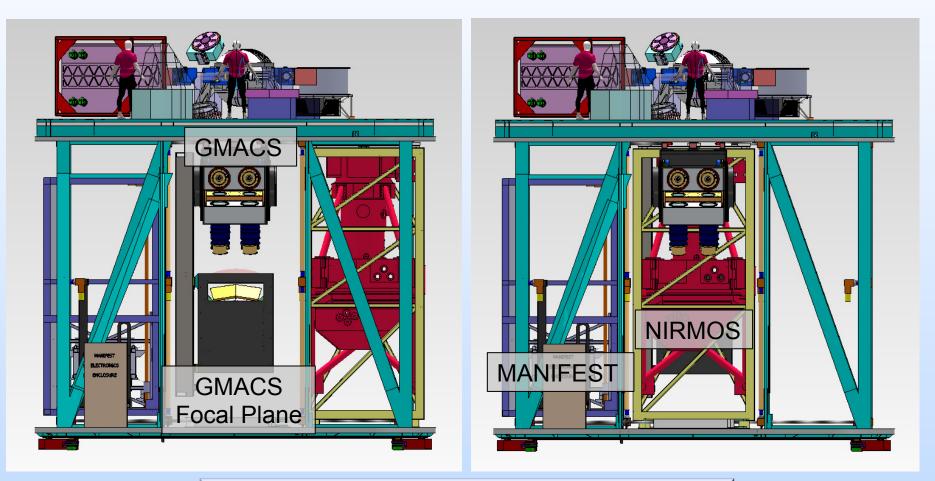




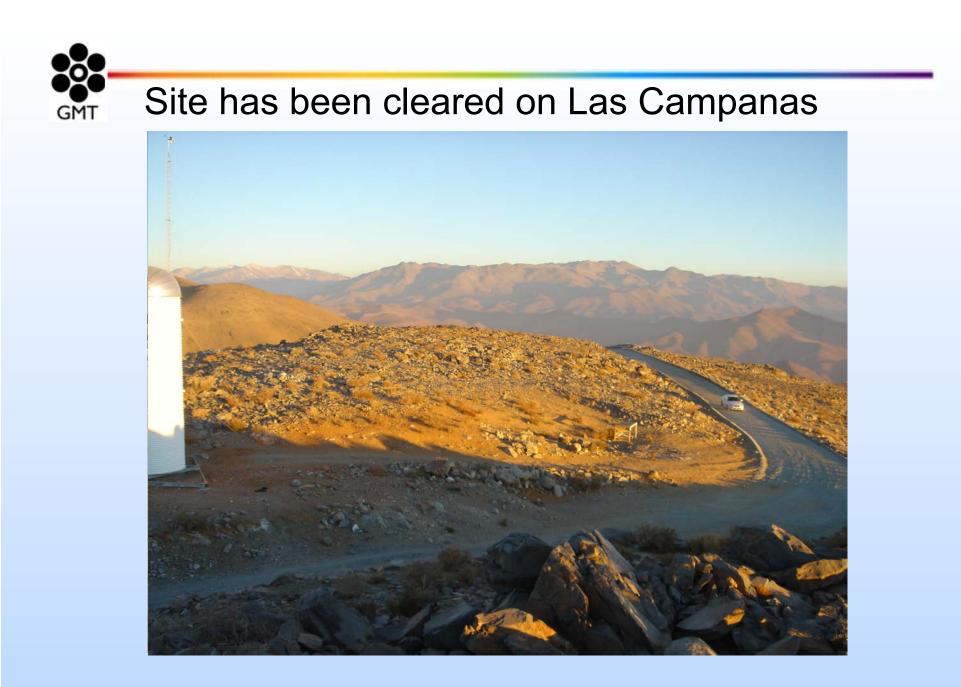




GMT Gregorian Instrument Rotator (4 natural seeing)



GIR max weight: 11,500 kg GIR max size: 2.8 x 2.8 x 5.5-m



#### Big enough for 2 telescopes



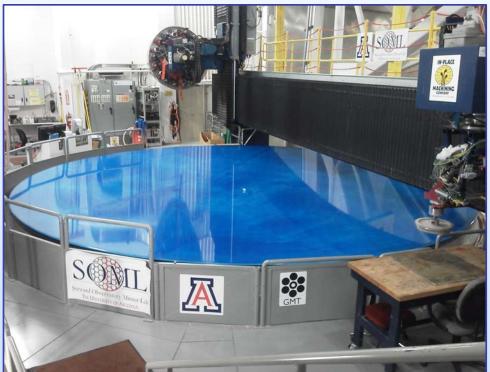
Primary Mirror Segments (8.36-m)

First segment accepted (off-axis)
 Accurate to 19 nm RMS

GMT

- Seg 2 was cast: Jan 2012

   Back-side surface generation
- Seg 3 to be cast: Aug 24, 2013
- Seg 4 glass on order (center)
- Commissioning to start ~2019 with 4 segments





#### GMT2 / GMT3 Segments



GMT2 being prepared for rear surface generation. LSST M1/M3 in background.

Preparing the furnace for firing of GMT3 in August 2013.



#### Major Milestones – One Year Horizon

• Design Reviews

<ul> <li>Enclosure and facilities:</li> </ul>	[Jan 2013]	Passed
<ul> <li>Adaptive Optics:</li> </ul>	[May 2013]	
<ul> <li>Telescope systems:</li> </ul>	[Aug 2013]	
<ul> <li>Software and controls:</li> </ul>	[Sep 2013]	
— System-wide PDR:	[Oct 2013]	

- Construction approval: [Jan 2014]
- Instrument Contracts to start next design phase (workshops)

<ul> <li>Near-IR IFU/Imager</li> </ul>	[Apr 2013]	(Mar 12-13, 2013)
<ul> <li>Optical MOS</li> </ul>	[Apr 2013]	(Jun 13-14, 2013)
— Echelle	[May 2013]	(Oct 22-23, 2013)

GMT

### Approx Schedule Plans – Later Years

<ul> <li>Primary segment 4 delivered:</li> </ul>	Q1 2019	
<ul> <li>Telescope commissioning start:</li> </ul>	Q2 2019	
First instrument delivered:	Q2 2019	G-CLEF
<ul> <li>Second instrument delivered:</li> </ul>	Q4 2019	GMACS
Early science begins:	Q2 2020	
<ul> <li>AO commissioning begins:</li> </ul>	Q1 2021	
Third instrument delivered:	Q1 2021	GMTIFS (AO)
<ul> <li>Primary segment 7 delivered:</li> </ul>	Q1 2022	
Construction phase complete:	Q1 2023	



## GMT Instruments: Candidates and Selection

(details in SPIE 2012 papers)



#### Instrumentation Background Thoughts

- Selection pre-determines the science focus 7 years later
   Example: Planet characterization vs galaxy assembly at z~7
- Science focus affects the perceived impact of the facility — With funding sources, among our peers, with the public
- Challenges
  - Science landscape will change after selection
  - Can't have it all; scientists want it all ... at first light
  - Budget: limited <u>and</u> changing; instruments expensive
- "Magellan philosophy": keep instruments simple; do a few things well



#### **Selection Activities**

• First notions in 2004, leading to GMT System CoDR in 2006

Instrument	<b>λ(μm)</b>	Resolution	FOV	Notes
GMTNIRS	1-5	50-120K	2''	Si Emersion R2 & R4 Echelle
MIISE	3-28	5-2000	2' x 2'	Two Channels; nulling
HRCAM	1-2.5	5-2000	1' x 1'	Coronographic mode
NIRMOS	0.9-2.5	1500-3500	5' x 5'	7' x 5' imaging field of view
GMACS	0.4-1.0	3500-5000	9' x 18'	Four double spectrographs

- Conceptual design studies (7 instr): Jun 2010 Oct 2011
- Instrument Advisory Panel: Feb 2012 → 3 instruments (or 5?)
  - Partner scientists recommend first generation instruments
- Implementation plan submitted to Board: Jun 2012
  - Accommodate IAP report within budget and schedule
- Board authorization to release contracts: Mar 2013 ???
  - Instrument teams on "hold" since CoDR (now ~16 months)



#### IAP Selection Factors: "Static"

- Science potential of each & the combined suite of instruments
- Technical merit, readiness to advance
- Cost envelope for instrumentation
- Operational balance (bright vs dark, site conditions)
- Synergies with other facilities



Instrument Advisory Panel Representing GMT partners With 2 community members Feb 2-3, 2012



#### Other Factors: "Dynamic"

- Global economy and government support
- Total budget and cash flow profile
- Project time line and schedule
- When is it time to decide? Later is better, but can't be too late!
  - Can respond to changing science landscape
  - Instrument teams (and others) continue to think up great ideas
  - Desire to keep many partners engaged intellectually
  - Technical advances (detectors, AO performance)
  - Design disasters (some widget or design fails to perform)



#### The GMT Plan Today

Instrument	Function	λ Range, µm	Resolution	Field of View
G-CLEF*	Optical High Resolution Spectrometer / PRV	0.35 – 0.95	20 – 100K	Single Object
GMACS*	Optical Multi-Object Spectrometer	0.36 – 1.0	1500 – 4000, 10,000	40-50 arcmin <sup>2</sup>
GMTIFS	NIR AO-fed IFU / Imager	0.9 – 2.5	4000 – 10,000	10 / 400 arcsec <sup>2</sup>
GMTNIRS <sup>†</sup>	JHKLM <b>AO</b> -fed High Resolution Spectrometer	1.2 – 5.0	50 – 100K	Single Object
NIRMOS*	Near-IR Multi-Object Spectrometer / imager	0.9 – 2.5	2700 – 5000	42 arcmin <sup>2</sup>
TIGER	Mid-IR <b>AO</b> -fed Imager and Spectrometer	1.5 – 14	300	0.25 arcmin <sup>2</sup>
MANIFEST*	Facility Robotic Fiber Feed	0.36 – 1.0		300 arcmin <sup>2</sup>
Optical 1-2.5 um Mid-IR Proceed to Next Design Phase				

Oplical

1-2.5 µm IVIIQ-

★ GMACS, NIRMOS, and G-CLEF can be fed by MANIFEST (20 arcmin FoV, multi-IFUs, image slicers)

**Develop Grating Technology** 

**Develop Prototype** 

Include in Second Generation Call

GMTNIRS now includes Y-Z coverage @ R ~8000 +



#### **Development Toward Science Goals**

Science Topic/Stage	Early (1)	Enhanced (2AB)	) Full (3)	1 <sup>st</sup> Decade	Techniques
Primary mirrors	4 segments	7 segments	7 segments	7 segments	separated beams, stacked, phased
Instruments	G-CLEF/MACS	GMTIFS	MANIFEST/NIRS	TIGER, NIR Spec	near-UV through mid-IR imaging and spectroscopy
Science Book Chapter/Modes	Seeing	8m AO	24m AO Wide field	ExAO, GLAO	NGSAO, LTAO, GLAO, EXAO
Formation of Stars and Pla	netary Syste	ems			
2.1 From Stars to Planets					AO imaging of disks
2.2 Young Stars					Spectroscopy, Chemical analysis
2.3 The IMF and Planets					Imaging, Astrometry
2.4 Disk Evolution					Spectroscopy, AO Imaging
2.5 System Architecture					Spectroastrometry
2.6 Solar System Studies					Imaging, low-dispersion spectroscopy
Properties of Exoplanetary	Systems				,
3.1 Formation Models					Doppler, transit, and imaging demographic studies
3.2 Atmospheres					Transit Spectroscopy
3.3 Imaging Exoplanets					Reflected light and thermal imaging
3.4 Habitable Worlds					Precision Radial Velocities
Stellar Populations and Che	mical Evolu	ition			
4.1 Population Studies					High-resolution spectroscopy, Survey follow-up
4.2 Stellar Archeology					High-resolution spectroscopy
4.3 Abundances in Dwarfs					High-resolution spectroscopy, photometery
4.4 Milky Way Halo					High-resolution spectroscopy
4.5 Globular Clusters					Integrated light spectra, AO Imaging & Photometry
Assembly of Galaxies					Integrated light speetra, Ao Integrity a Protonical
5.2 Local Dwarf Galaxies					High-resolution spectroscopy, photometry
5.3.1 Mass Assembly	_				visible/near-IR spectroscopy, photometry, AO
5.3.2 Dynamical Masses					spectroscopy, IFU
5.3.3 Gas Kinematics					IFU spectroscopy
5.3.4 Mass-Metalicity Relation					Rest-frame visible spectroscopy
5.3.5 Feed-Back and the IGM					Rest-frame UV spectroscopy
5.4 Massive Black Holes					IFU Spectrocopy
Dark Matter, Dark Energy,	P. Eundamo	tal Physics			ПО Бреспосору
6.1 Cosmological Parameters		ital Physics			Survey follow-up, spectroscopy, High A-Omega
6.2 LSST Follow-up	5				Multi-object spectroscopy, Near-IR imaging
6.3 Clusters & Dark Matter					Spectroscopy
6.4 Dark Matter in Dwarfs					Radial velocity surveys
First Light and Reioinzation					Radial velocity surveys
	1			_	New ID sectores
7.2 First Stars & Galaxies		_			Near-IR spectroscopy
7.3 Early Galaxies				-	AO imaging, visible and near-IR spectroscopy
7.4 Population III Stars					Near-IR spectroscopy
7.5 Probing Reionization					Red and near-IR spectroscopy
7.6 HI Topology					Lyman alpha imaging
7.7 IGM Spectroscopy	1				Intermediate and high-resolution spectroscopy
Transient Phenomena				-	
8.2 Long-Duration GRBs					High-resolution spectroscopy, photometry
8.3 Supernovae	1				low-resolution spectroscopy, spectropolarimetry
8.4 Other Transients					rapid response spectroscopy

Little or no Match

Some Match

Strong Match

Excellent Match

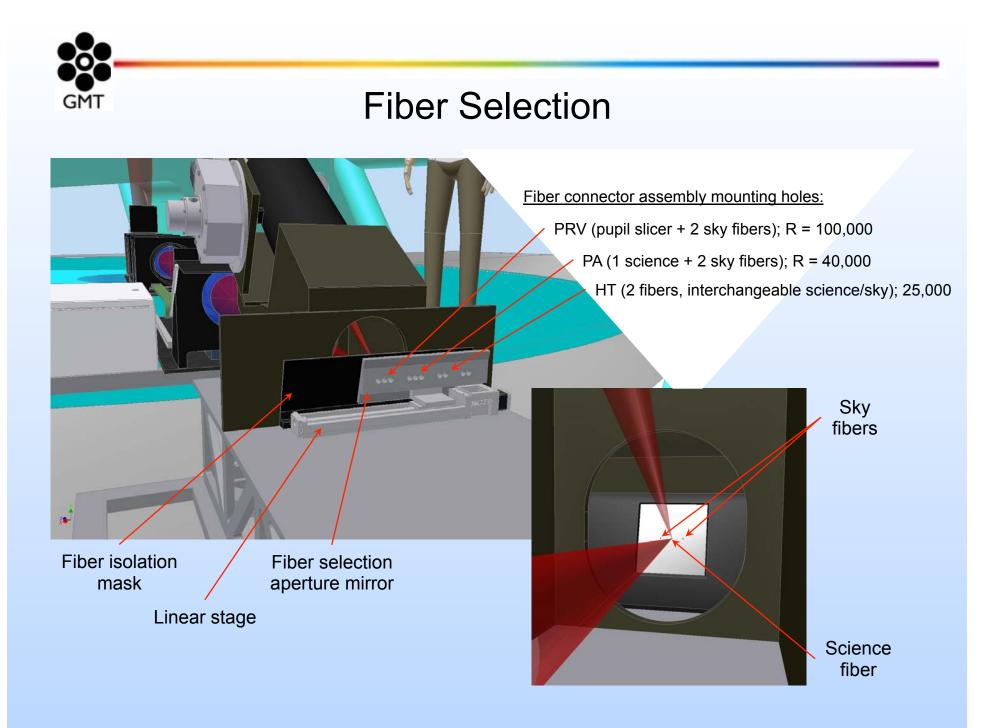
Science Book Chapter/Modes         Seeing         Bm AO         24m AO Wide Field         ExAO, GLAO, EXAO         NGSAO, LTAO, GLAO, EXAO           2.1 Form Stars to Planets         AO imaging of disks         Spectroscopy, Chemical analysis           2.2 Young Stars         Spectroscopy, Chemical analysis         Spectroscopy, Chemical analysis           2.3 The IMF and Planets         Spectroscopy, Chemical analysis         Spectroscopy, Chemical analysis           2.3 System Architecture         Spectroscopy, Chemical analysis         Spectroscopy, Chemical analysis           2.4 Disk Evolution         Spectroscopy, Chemical analysis         Spectroscopy, Chemical analysis           3.1 Formation Models         Spectroscopy, Chemical analysis         Spectroscopy, Chemical analysis           3.2 Atmospheres         Spectroscopy, Chemical analysis         Spectroscopy, Chemical analysis           3.4 Habitable Worlds         Precision Radial Velocities         Stellar Population studies         Precision Radial Velocities           Stellar Population Studies         Spectroscopy, Chemical Back         Precision Radial Velocities         Stellar Archeology           4.1 Population Studies         High-resolution spectroscopy, Survey follow         High-resolution spectroscopy, photometry           4.3 Abundances in Dwarfs         High Presolution spectroscopy, photometry, A         Spectroscopy, Choumetry, A           5.3.1	Science Topic/Stage	Early (1)	Enhanced (2AB	) Full (3)	1 <sup>st</sup> Decade	Techniques
Selence Book Chapter/Modes         Seeing         BM AD         24m AD Wide field         EXAD, GLAD, EXAD           2.1         Formation of Stars and Planetary Systems         AO imaging of disks         Spectroscopy, Chemical analysis           2.2         Young Stars         Imaging, Astrometry         Spectroscopy, Chemical analysis           2.3         The JMF and Planets         Spectroscopy, Chemical analysis         Spectroscopy, Chemical analysis           2.3         The JMF and Planets         Spectroscopy, Chemical analysis         Spectroscopy, Chemical analysis           2.4         Total Spectroscopy, Chemical analysis         Spectroscopy, Chemical analysis         Spectroscopy, Chemical analysis           2.5         System Studies         Spectroscopy, Chemical analysis         Spectroscopy, Chemical analysis           3.1         Formation Models         Spectroscopy, Chemical analysis         Spectroscopy, Chemical analysis           3.1         Imaging Exoplanets         Doppler, transit, and imaging demographic         Transit Spectroscopy, Chemical analysis           3.1         Imaging Exoplanets         Media Velocities         Precision Radial Velocities           Stellar Archeology         High-resolution spectroscopy, Survey follow         High-resolution spectroscopy, Survey follow           4.3         Abundances in Dwarfs         High-resolution spectroscopy, photome	Primary mirrors	4 segments	7 segments	7 segments	7 segments	separated beams, stacked, phased
Formation of Stars to Planets       AO imaging of disks         2.1 From Stars to Planets       AO imaging of disks         2.3 The IMF and Planets       Imaging, Astrometry         2.4 Disk Evolution       Spectroscopy, Chemical analysis         2.5 System Architecture       Spectroscopy, AO Imaging         2.6 Solar System Studies       Imaging, Iow-dispersion spectroscopy         Properties of Exoplanetary Systems       Doppler, transit, and imaging demographic         3.1 Formation Models       Dappler, transit, and imaging demographic         3.2 Atmospheres       Transit Spectroscopy         3.3 Imaging Exoplanets       Reflected light and thermal imaging         3.4 Habitable Worlds       Precision Radial Velocities <b>Stellar Populations and Chemical Evolution</b> High-resolution spectroscopy, photometry         4.1 Population Studies       High-resolution spectroscopy, photometry         4.2 Stellar Archeology       High-resolution spectroscopy, photometry         4.3 Abundances in Dwarfs       High-resolution spectroscopy, photometry, A         5.4 Local Dwarf Galaxies       Integrated light spectra, AO Imaging & Pho         5.2 Local Dwarf Galaxies       Spectroscopy, IFU         5.3.2 Dynamical Masses       Spectroscopy, IFU         5.3.3 Chamical Masses       Spectroscopy, IFU         5.3.4 Mass-Metalicity	Instruments	G-CLEF/MACS	GMTIFS	MANIFEST/NIRS	TIGER, NIR Spec	near-UV through mid-IR imaging and spectroscopy
2.1 From Stars to Planets       A0 imaging of disks         2.2 Young Stars       Spectroscopy, Chemical analysis         2.3 The IMF and Planets       Imaging, Astrometry         2.4 Disk Evolution       Spectroscopy, AO Imaging         2.5 System Architecture       Spectroscopy, AO Imaging         2.6 Solar System Studies       Imaging, low-dispersion spectroscopy         Properties of Exoplanetary Systems       Doppler, transit, and imaging demographic         3.1 Formation Models       Transit Spectroscopy         3.2 Atmospheres       Transit Spectroscopy, Survey follow         3.3 Imaging Exoplanets       Precision Radial Velocities         Stellar Populations and Chemical Evolution       High-resolution spectroscopy, Survey follow         4.1 Population Studies       High-resolution spectroscopy, Survey follow         4.2 Stellar Archeology       High-resolution spectroscopy, Survey follow         4.3 Abundances in Dwarfs       Integrated light spectra, AO Imaging & Pho         Assembly of Galaxies       Integrated light spectra, AO Imaging & Pho         5.3 Local Dwarf Galaxies       Integrated light spectroscopy, Intometry, A         5.3 Local Dwarf Galaxies       Integrated light spectroscopy, Intometry, A         5.3 Local Dwarf Galaxies       Survey follow-up, spectroscopy         5.3.4 Mass-Metalicity Relation       Rest-frame visible spectr	Science Book Chapter/Modes	Seeing	8m AO	24m AO Wide field	ExAO, GLAO	NGSAO, LTAO, GLAO, EXAO
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3.3 Imaging Exoplanets       Reflected light and thermal imaging         3.4 Habitable Worlds       Precision Radial Velocities         Stellar Populations and Chemical Evolution       High-resolution spectroscopy, Survey follow         4.1 Population Studies       High-resolution spectroscopy, Survey follow         4.2 Stellar Archeology       High-resolution spectroscopy, photometery         4.3 Abundances in Dwarfs       High-resolution spectroscopy, photometery         4.4 Milky Way Halo       High-resolution spectroscopy, photometery         4.5 Globular Clusters       High-resolution spectroscopy, photometry         5.2 Local Dwarf Galaxies       High-resolution spectroscopy, photometry         5.3.1 Mass Assembly       High-resolution spectroscopy, photometry         5.3.2 Dynamical Masses       High-resolution spectroscopy, photometry         5.3.3 Gas Kinematics       High-resolution spectroscopy         5.4 Massive Black Holes       High-resolution spectroscopy         5.4 Massive Black Holes       High-resolution         6.1 Cosmological Parameters       Survey follow-up, spectroscopy, High A-Om         6.2 LOST Follow-up       Survey follow-up, spectroscopy, Near-IR imaging         6.3 Clusters & Dark Matter       Survey follow-up, spectroscopy, Near-IR imaging         6.4 Dark Matter in Dwarfs       Survey follow-up, sible and near-IR spectroscopy						
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4.1       Population Studies       High-resolution spectroscopy, Survey follow         4.2       Stellar Archeology       High-resolution spectroscopy, photometery         4.3       Abundances in Dwarfs       High-resolution spectroscopy, photometery         4.4       Miky Way Halo       High-resolution spectroscopy, photometery         4.4       Miky Way Halo       Integrated light spectra, AO Imaging & Pho         Assembly       Glabaxies       Integrated light spectra, AO Imaging & Pho         5.3       Local Dwarf Galaxies       High-resolution spectroscopy, photometry         5.3       Mass Assembly       Visible/near-IR spectroscopy, photometry, A         5.3       Dynamical Masses       Spectroscopy         5.3       Dynamical Masses       Spectroscopy         5.3       Fed-Back and the IGM       Rest-frame Visible spectroscopy         5.4       Massive Black Holes       IFU Spectroscopy         5.4       Massive Black Holes       IFU Spectroscopy         6.1       Cosmological Parameters       Survey follow-up, spectroscopy, Near-IR imaging         6.3       Clusters & Dark Matter       Spectroscopy         6.4       Dark Matter in Dwarfs       Near-IR spectroscopy         7.2       First Stars & Galaxies       AO imaging, visible and near-IR spectroscopy		mical Evolu	ution			
4.2       Stellar Archeology       High-resolution spectroscopy         4.3       Abundances in Dwarfs       High-resolution spectroscopy, photometery         4.4       Milky Way Halo       High-resolution spectroscopy         4.5       Globular Clusters       Integrated light spectra, AO Imaging & Pho         Assembly of Galaxies       High-resolution spectroscopy, photometry         5.2       Local Dwarf Galaxies       High-resolution spectroscopy, photometry, A         5.3.1       Mass Assembly       Mass       Spectroscopy, IFU         5.3.2       Dynamical Masses       Spectroscopy       Spectroscopy         5.3.4       Mass-Metalicity Relation       Rest-frame visible spectroscopy         5.3.5       Feed-Back and the IGM       Rest-frame UV spectroscopy         5.4       Massive Black Holes       IFU Spectroscopy         5.4       Massive Black Holes       Survey follow-up, spectroscopy, Near-IR imaging         6.1       Cosmological Parameters       Survey follow-up, spectroscopy, Near-IR imaging         6.3       Clusters & Dark Matter       Survey follow-up, spectroscopy, Near-IR imaging         6.4       Dark Matter in Dwarfs       Radial velocity surveys         First Light and Reioinzation       All       Near-IR spectroscopy         7.5       Forbing Reioniza		incur Evora				High-resolution spectroscopy, Survey follow-up
4.3       Abundances in Dwarfs       High-resolution spectroscopy, photometery         4.4       Milky Way Halo       High-resolution spectroscopy         4.5       Globular Clusters       Integrated light spectra, AO Imaging & Pho         Assembly of Galaxies       High-resolution spectroscopy, photometry         5.1       Mass Assembly       High-resolution spectroscopy, photometry, A         5.3.1       Mass Assembly       Sible/near-IR spectroscopy, photometry, A         5.3.2       Dynamical Masses       Sible/near-IR spectroscopy, photometry, A         5.3.4       Mass-Metalicity Relation       Rest-frame visible spectroscopy         5.3.5       Feed-Back and the IGM       Rest-frame UV spectroscopy         5.4       Massive Black Holes       Rest-frame UV spectroscopy         6.1       Cosmological Parameters       Survey follow-up, spectroscopy, High A-Om         6.2       LSST Follow-up       Survey follow-up, spectroscopy, Near-IR imaging         6.3       Clusters & Dark Matter       Spectroscopy         6.4       Dark Matter in Dwarfs       Near-IR spectroscopy         7.2       First Light and Reioinzation       Near-IR spectroscopy         7.3       Early Galaxies       AD imaging, visible and near-IR spectroscopy         7.4       Population III Stars       Near-IR s						
4.4       Milky Way Halo       High-resolution spectroscopy         4.5       Globular Clusters       Integrated light spectra, AO Imaging & Pho         Assembly of Galaxies       High-resolution spectroscopy, photometry         5.2       Local Dwarf Galaxies       High-resolution spectroscopy, photometry         5.3.1       Mass Assembly       Visible/near-IR spectroscopy, photometry, A         5.3.2       Dynamical Masses       Spectroscopy, IFU         5.3.3       Gas Kinematics       IFU spectroscopy         5.3.4       Mass-Metalicity Relation       Rest-frame visible spectroscopy         5.4       Massive Black Holes       IFU Spectroscopy         6.1       Cosmological Parameters       Survey follow-up, spectroscopy, Near-IR imaging         6.2       LSST Follow-up       Survey follow-up, spectroscopy, Near-IR imaging         6.3       Clusters & Dark Matter       Spectroscopy         6.4       Dark Matter in Dwarfs       Radial velocity surveys         First Light and Reioinzation       Near-IR spectroscopy       Near-IR spectroscopy         7.3       Early Galaxies       AO imaging, visible and near-IR spectroscopy         7.4       Population III Stars       AO imaging         7.5       Probing Reionization       Red and near-IR spectroscopy						
4.5       Globular Clusters       Integrated light spectra, AO Imaging & Pho         Assembly of Galaxies       High-resolution spectroscopy, photometry         5.2       Local Dwarf Galaxies       High-resolution spectroscopy, photometry         5.3       Mass Assembly       Spectroscopy, IFU         5.3.3       Gas Kinematics       Spectroscopy, IFU         5.3.4       Mass-Metalicity Relation       Rest-frame visible spectroscopy         5.4       Massive Black Holes       Rest-frame UV spectroscopy         5.4       Massive Black Holes       IFU Spectroscopy         5.4       Massive Black Holes       IFU Spectroscopy         6.1       Cosmological Parameters       ISU Survey follow-up, spectroscopy, Near-IR imaging         6.2       LSST Follow-up       Survey follow-up, spectroscopy, Near-IR imaging         6.3       Clusters & Dark Matter       Survey follow-up, spectroscopy, Near-IR imaging         6.4       Dark Matter in Dwarfs       Reat-Frame UV spectroscopy         7.4       Population III Stars       Near-IR spectroscopy         7.5       Frobing Reionization       Near-IR spectroscopy         7.4       Population III Stars       Near-IR spectroscopy         7.5       Frobing Reionization       Lyman alpha imaging         7.6       H			-			
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5.2       Local Dwarf Galaxies       High-resolution spectroscopy, photometry         5.3.1       Mass Assembly       visible/near-IR spectroscopy, photometry, A         5.3.2       Dynamical Masses       spectroscopy, IFU         5.3.3       Gas Kinematics       IFU spectroscopy         5.3.4       Mass-Metalicity Relation       Rest-frame visible spectroscopy         5.3.4       Mass-Metalicity Relation       Rest-frame UV spectroscopy         5.3.4       Mass-Metalicity Relation       Rest-frame UV spectroscopy         5.4       Massive Black Holes       IFU Spectrocopy         Dark Matter, Dark Energy, & Fundamental Physics       IFU Spectroscopy, Near-IR imaging         6.1       Cosmological Parameters       Survey follow-up, spectroscopy, Near-IR imaging         6.3       Clusters & Dark Matter       Spectroscopy         6.4       Dark Matter       Spectroscopy         7.4       Population III Stars       Near-IR spectroscopy         7.5       Frobing Reionization       Red and near-IR spectroscopy         7.5       Probing Reionization       Red and near-IR spectroscopy         7.5       Probing Reionization       Red and near-IR spectroscopy         7.6       HI Topology       Intermediate and high-resolution spectroscopy         7.6 <t< td=""><td></td><td></td><td></td><td></td><td></td><td>Integrated light spectra, AO inlaging &amp; Photometry</td></t<>						Integrated light spectra, AO inlaging & Photometry
5.3.1       Mass Assembly       visible/near-IR spectroscopy, photometry, A         5.3.2       Dynamical Masses       spectroscopy, IFU         5.3.3       Gas Kinematics       IFU spectroscopy         5.3.4       Mass-Metalicity Relation       Rest-frame visible spectroscopy         5.3.5       Feed-Back and the IGM       Rest-frame UV spectroscopy         5.4       Massive Black Holes       IFU Spectroscopy         5.4       Massive Black Holes       IFU Spectroscopy         5.4       Massive Black Holes       IFU Spectroscopy         6.1       Cosmological Parameters       Survey follow-up, spectroscopy, Near-IR imaging         6.2       LSST Follow-up       Survey follow-up, spectroscopy, Near-IR imaging         6.3       Clusters & Dark Matter       Spectroscopy         6.4       Dark Matter in Dwarfs       Near-IR spectroscopy         First Light and Reioinzation       Near-IR spectroscopy         7.2       First Stars & Galaxies       AO imaging, visible and near-IR spectroscop         7.4       Population III Stars       Near-IR spectroscopy         7.5       Probing Reionization       Red and near-IR spectroscopy         7.6       HI Topology       Lyman alpha imaging         7.7       IM Spectroscopy       Intermediate and high						High recolution constructions, photometry
5.3.2       Dynamical Masses       spectroscopy, IFU         5.3.3       Gas Kinematics       IFU spectroscopy         5.3.4       Mass-Metalicity Relation       Rest-frame visible spectroscopy         5.3.5       Feed-Back and the IGM       Rest-frame UV spectroscopy         5.4       Massive Black Holes       IFU Spectrocopy         Dark Matter, Dark Energy, & Fundamental Physics       IFU Spectroscopy, Near-IR imaging         6.1       Cosmological Parameters       Survey follow-up, spectroscopy, Near-IR imaging         6.3       Clusters & Dark Matter       Spectroscopy         6.4       Dark Matter in Dwarfs       Readial velocity surveys         First Light and Reioinzation       Readial velocity surveys         7.2       First Stars & Galaxies       AO imaging, visible and near-IR spectroscopy         7.4       Population III Stars       AO imaging, visible and near-IR spectroscopy         7.4       Population       Red and near-IR spectroscopy         7.5       Probing Reionization       Red and near-IR spectroscopy         7.6			-			
5.3.3 Gas Kinematics       Image: Constraint of the constraint	· · · · · · · · · · · · · · · · · · ·				_	
5.3.4       Mass-Metalicity Relation       Image: Constraint of the con					_	
5.3.5       Feed-Back and the IGM       Rest-frame UV spectroscopy         5.4       Massive Black Holes       IFU Spectrocopy         Dark       Matter, Dark Energy, & Fundamental Physics       Survey follow-up, spectroscopy, High A-Om         6.1       Cosmological Parameters       Survey follow-up, spectroscopy, Near-IR imaging         6.3       Clusters & Dark Matter       Survey follow-up, spectroscopy, Near-IR imaging         6.3       Clusters & Dark Matter       Survey follow-up, spectroscopy, Near-IR imaging         6.3       Clusters & Dark Matter       Survey follow-up, spectroscopy         6.4       Dark Matter in Dwarfs       Survey follow-up, spectroscopy         First Light and Reioinzation       Radial velocity surveys         7.2       First Stars & Galaxies       Near-IR spectroscopy         7.3       Early Galaxies       Near-IR spectroscopy         7.4       Population III Stars       Near-IR spectroscopy         7.5       Probing Reionization       Red and near-IR spectroscopy         7.6       H Topology       Lyman alpha imaging         7.7       IGM Spectroscopy       Intermediate and high-resolution spectroscop         7.7       IGM Spectroscopy       High-resolution spectroscopy, photometry         8.2       Long-Duration GRBs       Motometry <td></td> <td></td> <td></td> <td></td> <td></td> <td></td>						
5.4       Massive Black Holes       IFU Spectrocopy         Dark Matter, Dark Energy, & Fundamental Physics       Survey follow-up, spectroscopy, High A-Om         6.1       Cosmological Parameters       Survey follow-up, spectroscopy, High A-Om         6.2       LSST Follow-up       Multi-object spectroscopy, Near-IR imaging         6.3       Clusters & Dark Matter       Spectroscopy         6.4       Dark Matter in Dwarfs       Radial velocity surveys         First Light and Reioinzation       Near-IR spectroscopy         7.2       First Stars & Galaxies       Near-IR spectroscopy         7.4       Population III Stars       AO imaging, visible and near-IR spectroscopy         7.5       Probing Reionization       Red and near-IR spectroscopy         7.6       HI Topology       Lyman alpha imaging         7.7       IGM Spectroscopy       Intermediate and high-resolution spectroscopy         7.7       IGM Spectroscopy       Intermediate and high-resolution spectroscopy         8.2       Long-Duration GRBs       Image: Start S						
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7.3       Early Galaxies       AO imaging, visible and near-IR spectroscop         7.4       Population III Stars       Near-IR spectroscopy         7.5       Probing Reionization       Red and near-IR spectroscopy         7.6       HI Topology       HI Topology         7.7       IGM Spectroscopy       Intermediate and high-resolution spectroscopy         High-resolution GRBs						
7.4       Population III Stars       Image: Constraint of the synthesis of the synthe synthesis of the synthesis of the synthes						
7.5       Probing Reionization       Image: Constraint of the constrain						AO imaging, visible and near-IR spectroscopy
7.6       HI Topology       Image: Comparison of the	7.4 Population III Stars					Near-IR spectroscopy
7.7       IGM Spectroscopy       Intermediate and high-resolution spectroscopy         Transient Phenomena       Intermediate and high-resolution spectroscopy         8.2       Long-Duration GRBs       Intermediate and high-resolution spectroscopy, photometry	7.5 Probing Reionization					Red and near-IR spectroscopy
Transient Phenomena         8.2 Long-Duration GRBs       Image: Construction of the sector	7.6 HI Topology					
Transient Phenomena         8.2 Long-Duration GRBs       Image: Construction of the sector	7.7 IGM Spectroscopy					Intermediate and high-resolution spectroscopy
	Transient Phenomena					
						High-resolution spectroscopy, photometry
						low-resolution spectroscopy, spectropolarimetry
8.4 Other Transients rapid response spectroscopy						

G-CLEF: GMT-CfA, Carnegie, Catolica, Chicago Large Earth Finder Andrew Szentgyorgyi (CfA)

- Natural seeing dual-beam optical R4 Echelle (0.35 1.0 μm)
- Full spectrum coverage

- R ~ 20,000 100,000 (depends on fiber mode)
  - Accurate abundances
  - Precision velocities (goal ~10 cm/s)
- Good spectrograph throughput
  - ~40% from 400 800 nm
  - ~12% all inclusive (tel, feed)
  - ~20% with AO
- Accepts MANIFEST facility fiber feed
  - 20' FoV
  - MOS -- 40 objects (limited λ-coverage)
- Workshop Oct 22-23 (tentative)





# GMACS: GMT Areal Camera and Spectrograph Darren DePoy (Texas A&M)

- Classic optical dual-beam MOS
- ~5 x 9 arcmin field
- Excellent sensitivity over 370 950 nm
- ~12 Multi-slit masks ~80 slits per mask
- R ~1000-2000 (blue); 2500-5000 (red)
- Accepts fiber feed from MANIFEST
  - full 20 arcmin coverage
  - R ~ 10,000 with image slicer
  - Deployable IFUs
- Currently in re-design for on-axis operation
- Workshop June 13-14 (tentative)

#### Early Science

- Survey spectroscopy
  - Lyα galaxy distributions & luminosity functions to z ~ 6 (source of re-ionization)
  - Local Group dark matter distributions (kinematics in galaxy halos and dwarfs)
  - Stellar populations and streams (kinematics and abundances)
  - Galaxy assembly (gas inflow and outflow over time)
- Follow-up LSST / DECam targets

# GMTIFS: GMT Integral Field Spectrograph Peter McGregor (ANU)

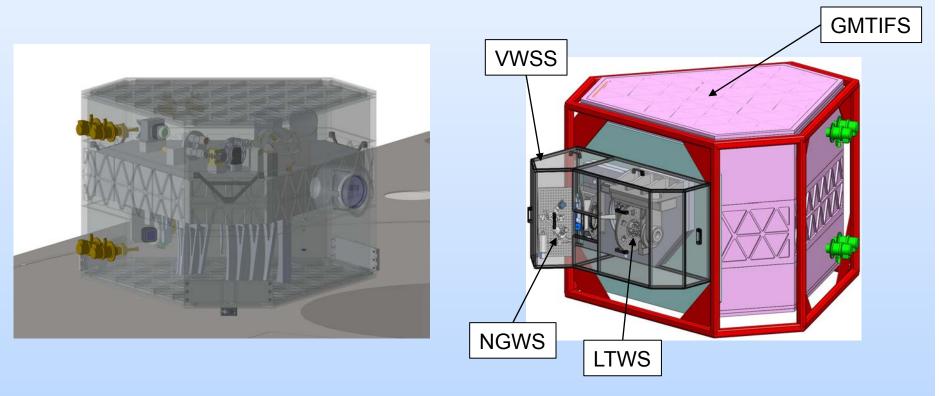
- ZJHK Integral Field Spectrograph image slicer system
- Medium resolution: R ~ 5,000 and 10,000
- Multiple scales and fields of view
- Data cube (rectangular prism): 45 (slits) x 88 (slitwise) x 4096 (spectral)

Spaxel size (mas)	6	12	25	50	
Field of view (arcsec)	0.54×0.27	1.08×0.54	2.25×1.13	4.5×2.25	
<ul> <li>Near-IR AO imager ( — 5 mas/pixel, 20.4 — Dual filter wheel</li> <li>Workshop March 12</li> </ul>	** 20.4" FoV (~16 filters)	<ul> <li>Hα emis</li> <li>Black ha (galaxy kinemat)</li> <li>Star form</li> </ul>	Early Scier assembly vs ti sion kinemati ble and galaxy nuclei from sto ics) nation and ch by systems (re	ime with Lyα a cs / formation ellar and gas emical histori	
SPIE Amsterdam July 4, 2012					



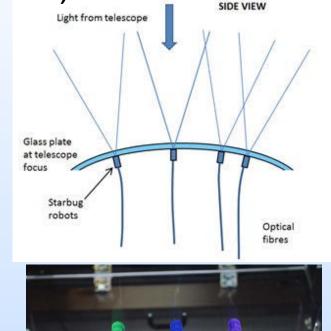
#### **Instrument Design**

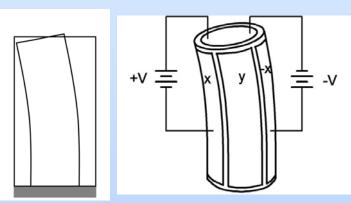
- Three levels
  - Upper: Imager
  - Lower: Integral Field Spectrograph
  - Center: Optical feed and science selector, guide star optics



MANIFEST: MANy Instrument FibEr SysTem Jon Lawrence (AAO)

- ~2000 moving Starbugs
- Covers the GMT's full 20' diameter field
- Single-fiber, image-slicer, and IFU feeds for GMACS and G-CLEF (simultaneously)
- Configuration time < 3 min
- Object spacing ~ 10 arcsec
- Excellent for "AΩ science" (e.g. LSST/DECam follow-on)

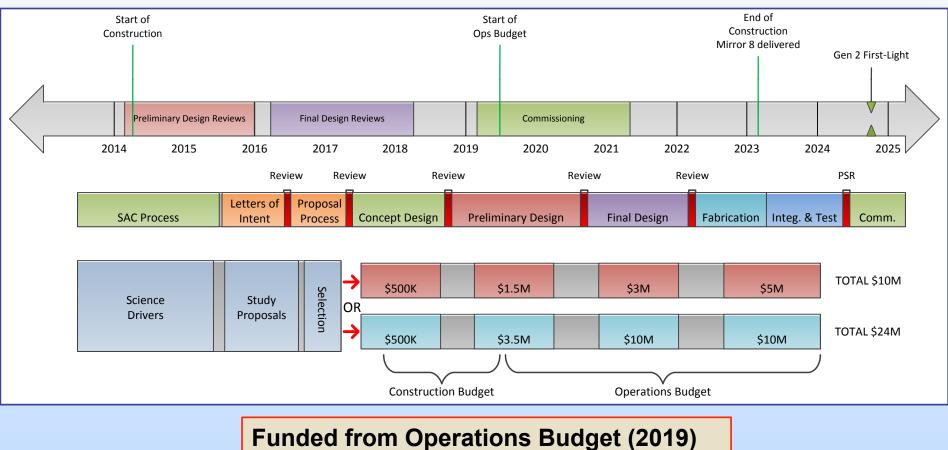




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### Second-Generation Instrument Roadmap

(notional! still under discussion)



#### Process can be repeated every few years



#### Summary

- GMT project is advancing
  - In production mode for 4 primary segments
  - Subsystem reviews being completed or scheduled
  - Instrument design toward PDRs about to start
- First generation instruments have broad application
  - Largely meet demands of GMT partnership & science case
    - Strengths in extragalactic, chemical abundances, planet characterization
    - Meets operational demands for bright/dark, AO/non-AO modes
- E-ELT instrument selections all good choices!
  - An optical MOS is always a good idea (Gemini)
  - High resolution spectrograph on large telescope has high impact (Keck)
  - A mid-IR instrument on a southern ELT will be unique for years



#### END