Instrumentation: Enabling Science in the Ground-Based O/IR System

For: The 2nd Community Workshop on the Ground-Based O/IR System

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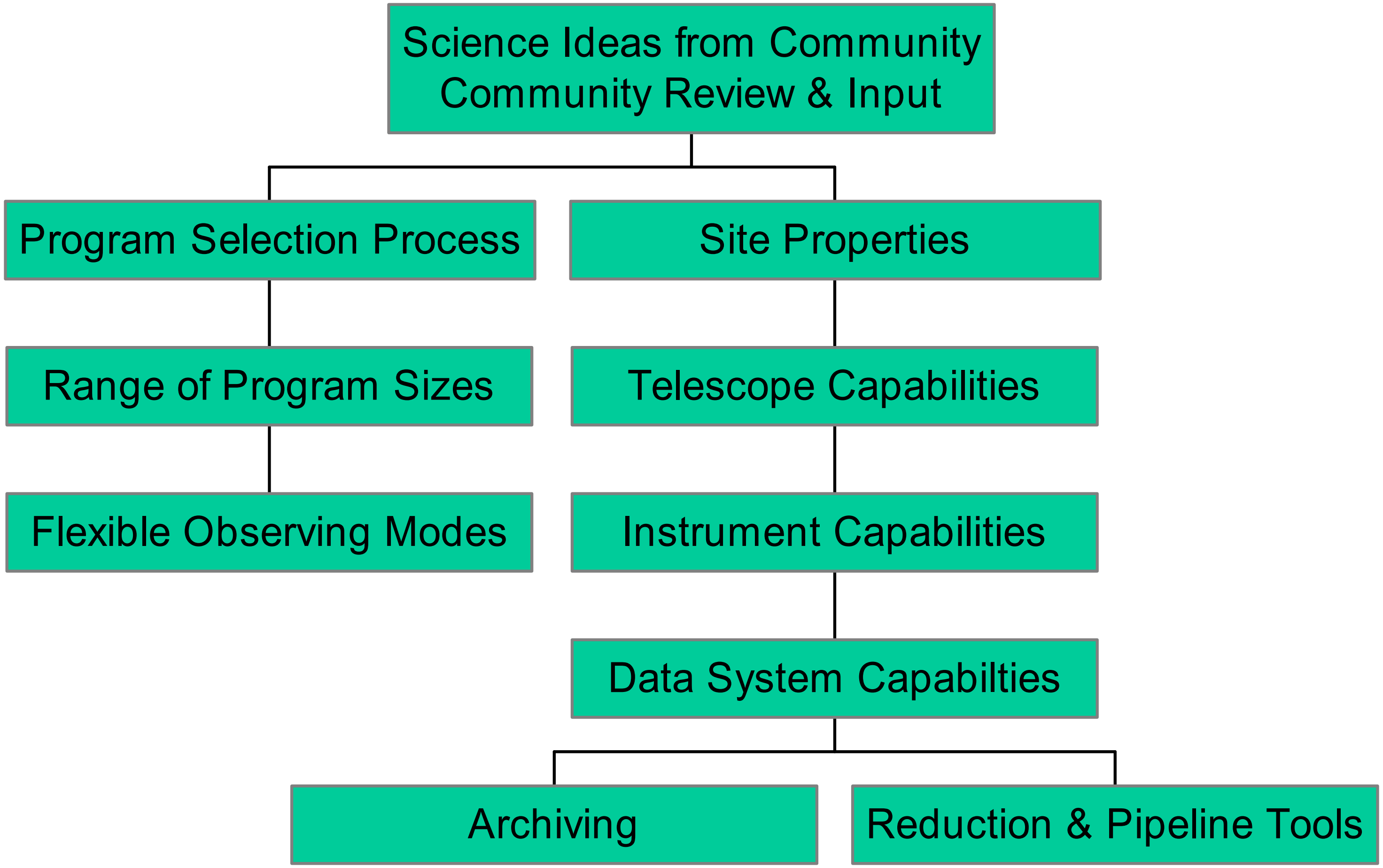
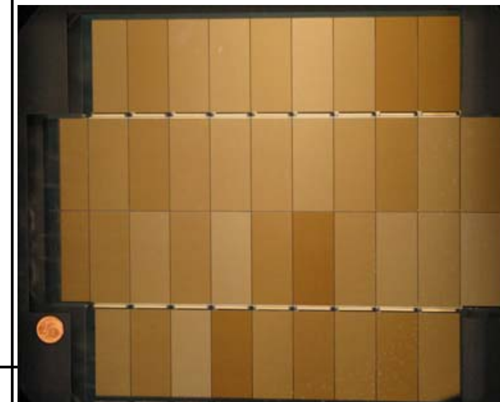
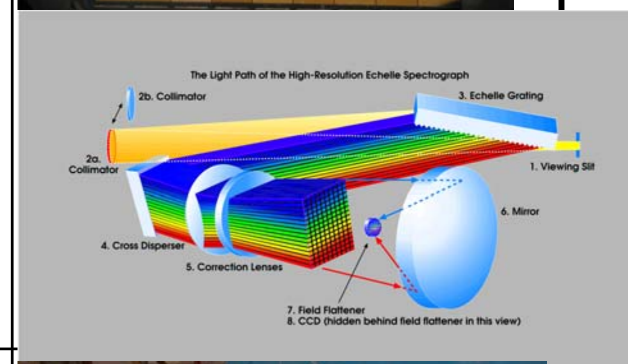
Elements of the Observing System



Instrumentation as Enabler of Science

- Instrumentation development can respond to scientific opportunities relatively rapidly
  - Lower cost than telescopes
  - Shorter duration projects than facilities
  - Can respond to technological developments relatively quickly
  - More institutions / groups capable of developing instruments than building telescopes
- Technological developments drive effectiveness gains in instrumentation
  - CCDs & IR arrays
  - Adaptive optics
  - Real-time computing power
  - Grating technology; diamond-turned optics fabrication

Instrumentation with Impact

CCD Mosaic Imagers at 4m's (KPNO, CTIO, CFHT)	CCD Imaging over very wide field (1degree scale)	
HIRES at Keck	First high-resolution spectrograph @ 8-10m telescope	
DEIMOS & IMACS	Wide-field multi-object spectroscopy @ 8-10m telescope	

Which instrumentation should one build to benefit science?

- Consider
  - Scientific opportunities
  - Technological developments
  - What is already available in Observing System
  - Costs
  - Timescales
- Involve
  - Community of potential users
  - Technical experts and potential builders

Gemini Instrument Planning 2003

- U.S. Workshop: May 2003; Tempe, Arizona
- Goal: Key Gemini Science Programs for 2008-2010 Realm
  - Limited number of high-impact science questions / projects
  - What observations are needed to answer the science question?
- 40 participants; diverse in science interests & institutional affiliation
- E-mail & telecon preparatory discussions
- Four Science Breakout Groups
  - Stars, the Solar System, and Extra-Solar Planets (leader: J. Valenti)
  - Star Formation Processes and the ISM (leader: M. Meyer)
  - Structure and Evolution of the Milky Way and Nearby Galaxies (leader: R. Wyse)
  - Formation and Evolution of Distant Galaxies and the High-Redshift Universe (leader: K. Glazebrook)
- Written report on Tempe conclusions (on NGSC Web site)

Gemini Instrument Planning 2003

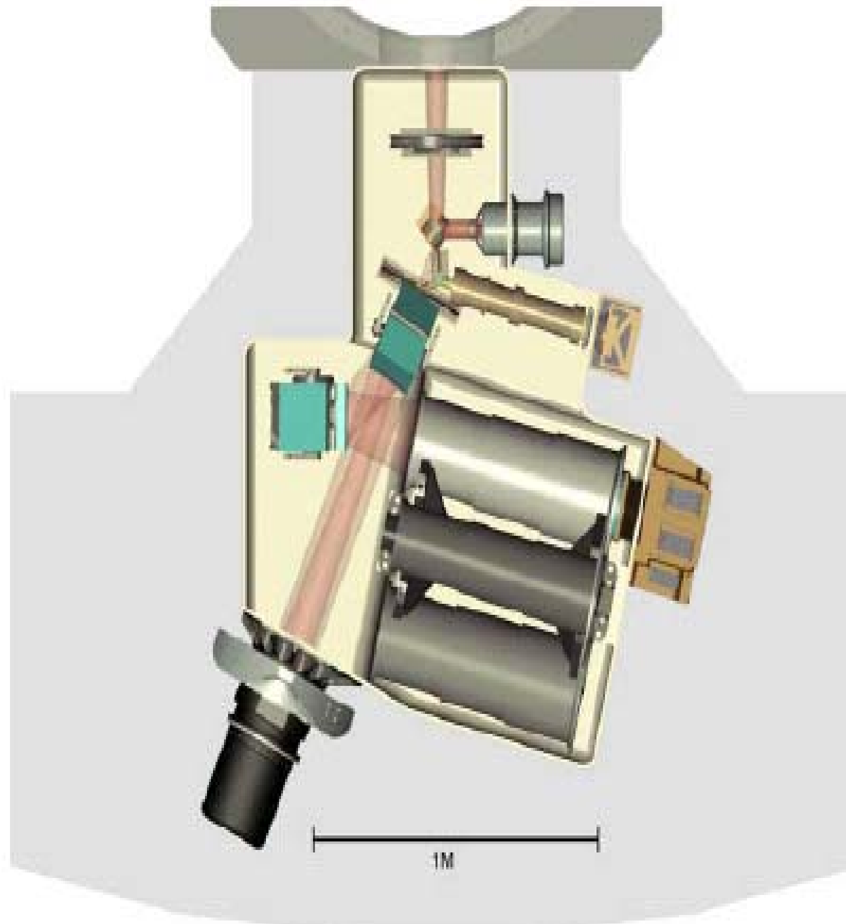
- Gemini International instrument planning workshop
- Include representatives from national workshops
- June 2003, Aspen, Colorado
- 93 participants
- Science-area-based breakout groups
- Synthesis of science goals into instrument requirements

Gemini Instrument Planning 2003

Science Group	Capability Summary	λ	Spatial Resolution	Spectral Resolution	Field of View	Multiplex Gain	Primary Mode
Stars, Solar System, etc.							
Census of Planets	Extreme AO with IFU and Polarisation	0.9-2.5	SR>0.9	30-300	3"	1	IFU+Polarisation+AO
Planets and stars	HiRES NIR Spectrometer	0.9-2.5	See	70K (HIGH STAB)		1	molecular absorber (X-disp)
Planets and stars	Optical HiRES spec	0.3-1.0	See	50-100K		1	
Star Formation/ISM							
How does structure/comp of ISM evolve?	1	8-17um	DL	$>10^5$	PS	1	X-dispersed
	2	1-5um	DL	$>3x10^4$	>2'	100	MOS
How are stars/planetary systems assembled?	3	1-5um		$>10^5$	PS	1	X-dispersed
What determines the masses of stars?	4	1-5um	.05"	5	2"	1	$contrast>10^7$
Structure/Evolution of MW and Nearby Galaxies							
Galaxy genesis	Optical MOS med-high res	3400A-9000A	Natural seeing	3K-20K (?) or 40K (?)	LARGE 40'	~1000	MOS
Dark matter Explorer	IR AO-fed spect.	2-2.4um	0.05	2k	20"X20"	1	IFU
Stellar pops.	Optical IFU spect	3400A-9000A	Natural seeing	5k	3'X3'	1	IFU
Local group proper motions	GLAO IR imager	0.6-2.5um	need 0.4 mas/dec		>10'		imager
Distant galaxies, high-Z universe							
Dark energy and Gal. Form	Opt-NUV MOS	3400A-1u	(Good) Natural seeing	>500	>~30'	>1000	MOS
1st Light and Gal. Form	GLAO-fed NIR mapper	NIR	0.2"	>3000	10'	panoramic	Imager--> dIFU--> (TF?)

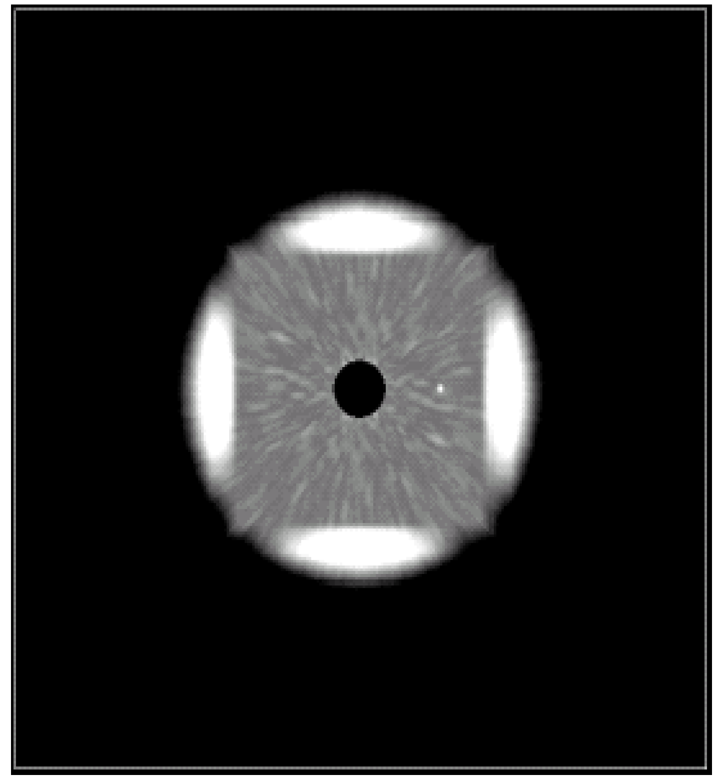
Future Gemini Instrument #1: High-Res Near-IR Spectrograph

- **Wavelength Range:** 1.1-2.5 μm OR 3-5 μm simultaneously
- **Modes:**
  - Single slit cross-dispersed seeing limited spectrometer
  - Multi-object MCAO-fed cross-dispersed spectrometer (15-30 objects)
- **Spectral Resolution:** 70,000 (single slit) & 30,000 (MOS)
- **Field of View:** 2 arcmin (MOS mode)
- **Cost:** ~$24M



Future Gemini Instrument #2: Extreme-AO Coronagraph

- **Wavelength Range:** 0.9 - 2.5 μm
- **Modes:** Adaptive Optics Coronagraphic
  - multi-band IR imaging
  - Integral field unit (IFU)
- **Field of View:** ~3 arcsec
- contrast ratio of $\sim 10^7$ within a 0.1-1.5" radius of central target
- **Cost:** ~$14M



Simulation of Extreme-AO observations of $8M_{Jupiter}$ planet orbiting a star 36 light years away.

Future Gemini Instrument #3: Wide-Field Multi-Object Spectrograph

- **Wavelength Range:** 0.39 -1.0 μm
- **Simultaneous stellar targets:** 4000-5000
- **Field of View:** ~1.5 deg
- **Spectral Resolutions:** R ~ 1000 - 30,000
- Fiber fed prime focus instrument
- **Cost:** ~$32M

Challenges

- High cost of scientifically enabling instrumentation ↔ funding issues
  - Challenge securing funding
  - Impact of potential overruns on institution budget
- Difficulty of managing such large projects
- New enabling technology carries risk
- Few groups have infrastructure to build large instruments
  - Clean rooms
  - Telescope / flexure simulation capability
  - Project management (expertise, culture)
  - System engineering (performance of integrated system)
- Difficulty keeping team together between projects

Overcoming Challenges

- Some combination of partnerships and outsourcing can help overcome challenges
- Development partners (i.e., collaborators)
  - Bring significant expertise & infrastructure
  - Share risk
  - Benefit from funding & science gain
- Outsourcing to Suppliers (i.e., vendors)
  - Brings expertise
  - Can bring to bear fabrication capability much larger than at typical university or observatory
  - Fixed-price commercial contract lowers risk
- Scientific partners
  - Gain scientific influence & an instrument to use

Examples of Contributions by Partners or Suppliers

- Advanced grating technology (VPH; Si)
- Adaptive optics experience
- Optical & infrared array detector expertise
- Array controllers
- Multi-object spectroscopy techniques
- Coronography expertise
- System engineering
- Optical design
- Flexure test facility
- Software interface simulation
- Data pipeline expertise

Implementing Partners & Suppliers

- Cannot exceed number of partners that can be managed effectively
- Emphasis on project management & communication
  - Management of geographically & institutionally dispersed project
    - Strong Project Manager
    - Team meetings
    - Extended visits at partner institutions
    - Reporting transparency (schedule, financial)
  - Clarity of requirements & status
    - Formal requirements & interface specifications for instrument
    - Formal requirements & interface specifications for each subsystem
    - Document version control & distribution
  - Formal non-advocate reviews of project
    - CoDR, CDR, PDR, Pre & Post Ship Tests, Quarterly Reviews

Implementing Partners & Suppliers

- Need partners & suppliers with proper resources, experience, & commitment
- Clearinghouse for potential partners & suppliers needed?
  - Which suppliers & partners have been used by "system" projects? How did they perform?
  - Possible models:
    - Chamber of Commerce?
    - Web Yellow Pages?
    - E-bay seller ratings?

Summary

- Instrumentation plays a crucial role in enabling groundbreaking science.
- Scientific planning for future instrumentation that involves the community is essential.
- Instrumentation is technically challenging & expensive, and getting more so.
- Scale & technical complexity drive us toward collaborative projects.
- Managing such projects well is crucial and requires particular skill & planning.