REPORT TO THE CELT STEERING GROUP FROM THE INSTRUMENT WORKING GROUP

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Keith Taylor *(Vice Chair)*

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Ian McLean apologizes that he cannot be at this meeting in person since he is presently at the Keck installing a new detector into NIRSPEC. The position of the IWG will be reported by Keith Taylor.

The IWG has meet 4 times this year (January, February, April and May). The first two meetings were at UCLA and the next two at Caltech. The Minutes of the April and May meetings are given in the Appendix for reference.

Progress was made in discussing "strawman" instrument concepts in relation to what was known about possible telescope and AO configurations, and of course, the science goals. More questions than answers were raised! A concern among the committee members was the need for clearer science goals, and a better understanding of telescope and AO options.

Since May, McLean and Taylor have had some discussions on how to make progress. The IWG feels strongly that instrument and detector "enabling technologies" need to be investigated and supported during the telescope conceptual design phase. Earlier, we had suggested a budget of $241,000 (annual) which involved hiring at two instrument physicist/engineering types to support the work of the IWG at some point. There is also the question of funding advanced detector development programs at Rockwell and/or Raytheon.

Below is a summary of Tasks for Instrumentation, drafted by Keith Taylor and Ian McLean, for consideration as part of the overall planning for CELT. Please note also that the IWG feels that a significant development should be made in AO development studies for CELT, since AO is critical to many of the most probable instruments.

Instrument Working Group Task List:

Terminology:

SR = Science Requirements
S = Science goals impact
T = Telescope design impact
AO = AO capability impact

1. General:

1.1 Identify the range of instruments that optimally satisfy the SRs for the first decade. This has, in part, been done in a preliminary fashion by the IWG, but that initial first-pass needs fleshing out in considerable detail. **[S]**

1.2 For all listed instrument types, what are the requirements and constraints on input focal-plane (f-ratio; FoV; pre-AO image quality; AO mode) as a function of wavelength ?

In addition, how do these constraints modify the *ideal* science goals ?
[T ; S ; AO]

1.3 Given the full range of SRs, what range of instruments is envisaged through the first decade and what space/weight/cooling/power requirements does this imply ?
[T ; S ; AO]

1.4 What instrument scheduling and deployment modes are to be supported and what impact do such decisions have on telescope and instrument design ? **[T ; S]**

1.5 What instrument user-support modes are envisaged and what impact do such decisions have on design and cost of instruments ? **[S]**

1.6 For each instrument type and observation mode, what flux limit goals are set by the SRs and what is the likelihood of achieving these goals in practice ?
NB: Full system modeling (of source, atmosphere, telescope, AO-mode, instrument, detector) will be required. **[T ; S ; AO]**

1.7 Given the SRs, what 2D detector systems (wavelength span, pixel-size, format, speed, noise properties) are foreseen ?
NB: This should include primary science detectors & high-speed AO wavefront detectors. **[S ; AO]**

1.8 What implications do detector characteristics have on electronics controller specifications ? For example, is a whole new generation of detector controllers required ? **[S ; AO]**

1.9 What new technologies are required to be pioneered in CELT instrument development ? For example, larger format CCDs, buttable IR arrays, VPH gratings, slicers/IFUs and MEMS devices; 3D detectors. **[S]**

1.10 What are the SRs for full Stokes parameters and how will polarization measurements be handled ? **[S ; T ; AO]**

2. Telescope specific:

2.1 Given the range of instruments and scheduling requirements, is the available space at Nasmyth a constraint on telescope structure design ? Is an elevation axis below the primary mirror an advantage ? **[T]**

2.2 Does the range of instrument types and AO modes argue for interchangeable secondaries ? **[T]**
How often could such a secondary mirror change occur and what are the science implications ? **[S ; T]**

2.3 Do we need other focii (Prime or Cassegrain) ? **[T]**

2.4 How do we handle atmospheric dispersion correction, generically on the telescope or within each instrument ? **[T]**

2.5 What is the relative importance of low emissivity for the IR? What implications does this have on non-IR instruments and telescope/AO design ? **[S ; T ; AO]**

2.6 Will the next generation IR instruments require only LN2 cooling or will the telescope have to be plumbed for closed-cycle refrigerators ? **[T]**

3. Instrument specific:

3.1 For all instruments -

- Instrument or field rotation **[T]**
- Flexure/stability constraints at various focii **[T]**
- Space/weight constraints **[T]**
- Detector systems
- Cryogenic/cooling requirements
- Auto-calibration and pipe-line data reduction systems

3.2 Wide-field O and IR imagers (Seeing Limited (SL)) -

- FoV (contiguous or not) **[T]**
- Delivered image quality **[T]**
- Optimal sampling
- NB or tunable filter imaging
- Detector formats - detector technology development ?
- Optics constraints (size ; f-ratio ; materials) **[T]**

3.3 Wide-field O and IR MOS (Seeing Limited):

- Optimal slit-width * R products
- FoV (contiguous or not) **[T]**
- Slits, fibers or slicers
- Pick-off probes (IFU feeds)
- Optical constraints (size ; f-ratio ; materials) **[T]**

3.4 VIS HIRES (SL or Single Conjugate AO ?)

- Fiber/slicer feeds
- Length of fiber feeds **[T]**

3.5 MIR Imager and Spectrograph (SCAO)

- Cryo-slicer design
- Detector formats - detector technology development ?
- Forward cassegrain for lowest emissivity (~f/8) ? **[T]**

3.6 Near-IR imager and IFU spectrograph (Multi-Conjugate AO) -

- Detector format and performance - detector technology development ?
- PSF time and field variability **[AO ; T]**

- IFU technology (fibers or slicers) ?

3.7 Extreme AO instrumentation -

- Coronographic OIR imager **[AO]**

3.8 Non-specific instrumentation -

- Polarimeters **[S ; T]**

Finally, it is important to gauge the costs, both of development and construction, of CELT instruments as accurately as possible.

APPENDIX

CELT Instrument Working Group Meeting #3

Held: Caltech

Date: Wednesday, April 19, 2000

Attending : Rich Dekany, Richard Ellis, Shri Kulkarni, Raja Guhathakurta, James Graham, James Larkin, Ian McLean (Chair), Keith Taylor.

Apologies from Steve Vogt.

Introduction

Richard summarized events at the meeting of the chairs of all the working groups held at UC Santa Cruz. He mentioned that Jerry Nelson gave a figure of $305M for the telescope. Wal Sargent talked about sites - for operations and logistics reasons, Mauna Kea is still preferred. David Tytler discussed the challenge of the enclosure. Richard conveyed the IWG's sentiment in favor of more joint meetings and also asked for a workshop in July. No Action List emerged and there have been no minutes as yet from Wal or Joe. Rich Dekany pointed out that each working group needs a near-term goal, and we all agreed that this goal is basically to obtain the initial funds of $30M or so needed for detailed design studies ? Clearly, within the IWG, we have some top-level descriptions of the kinds of instruments needed, but we need to get a bit deeper. We agreed that what we need now is a 2-page report on each instrument as soon as possible.

1. Discussion of Jerry's questions to us

We agreed that we must provide Jerry with a formal response to the questions he posed at Meeting #2. The following points were raised while reviewing Jerry's questions.

1. Do we need a prime focus ?
   Mike Bolte says "no" from Science Working group.
   The IWG would concur, but see also the discussion below.

2. Do we really need a Cassegrain focus ?
Yes. We think Nasmyth is bad for polarimetry. We could use the "focal station" of Cassegrain, but instead of locating instruments there, we can mount a polarization modulator with fiber feeds. There may be an issue of back focal distance and therefore dome size. We could move the elevation bearing below the primary mirror - like a radio telescope.

3. Plate scale issue ?
Rich is concerned about a 4.2-m f/15 adaptive secondary; based on status of LBT. He has tried a 2-m adaptive secondary design - with 1000 actuators and a 4-mirror design. The dome would be larger because position of f/9 secondary would be farther out. Of course, all these mirrors have to be supported. The LBT secondaries are a baseline. This results in a FORWARD Cass focus about mid-way between primary and secondary - could be a good place to put a mid-IR instrument ! A polarimeter could go there too.

Question*:* What would the 10 micron instrument look like (size and mass) ? The 2-mirror relay (active) gives a diffraction limited field of 8' - final focal ratio is f/13. This could be Cass or a Nasmyth, IF the elevation bearing is under the telescope. Down side of this design - 2 big, aspheric, monolithic mirrors, both active, awkward location right behind primary, central obscuration and light loss is about 12m out of 30m.
Question: Is a 35% obscuration too much ? This design flattens the field a bit too. Would need to increase the size of the 4th mirror to give a large field of 20' for non-AO work.

Shri pointed out that perhaps we can have a VLA-type mode in which we make a huge engineering change e.g. between a 4.2 m secondary and a 2-m secondary and then stay in that mode for a long time, ~year.

4. How should IR be handled ?
James Graham presented a graph. Like the Gemini North 8-m, we would need a very low emissivity of 5% This implies the minimum number of mirrors and perhaps silver coatings.

General comments:

Keith cautions about worrying about slow f/numbers and curved focal planes. Instead, worry about the instrument considerations and complete the loop by looking at the boundaries that force the telescope designs. For example, having too big an entrance aperture for the 10 micron instrument.

Staging (of AO developments): Could have a 2-m adaptive secondary at First Light and a 4-m static secondary for seeing-limited work. Resolution is better than NGST but the background is a million times more. Of course, there may be no mid-IR on NGST.

NOTE: Remember that CELT will resolve spatially the nearby stars (a dozen or so). Does that mean we should have very high spectral resolution too, for stellar seismology ?

Discussion of Rich's questions ?

What is the range of f/numbers, how big are the instruments, do we want the forward Cass, do we accept the light loss, will there be a reduction of the 20' FoV for seeing-limited mode ?

Each IWG member should try to include these issues as part of the 2-page review for each instrument.

Instruments Review:

We need a 2 page summary on each instrument. Assignments are given below.

Reports should cover:

- **Rationale** - brief statement of capabilities and modes - rather than a science case
- **Parameters** - resolving power, angular resolution, wavelength range, field of view.
- **Detector parameters** - number of pixels, pixel size, read noise, dark current, QE.
- **Sensitivity estimates**
- **AO requirements -** Required Strehl ratio, PSF stability, need for internal wavefront sensor ?
- **Some characteristic sizes and scales of the instrument** - largest optical components
- **The effect that this instrument has on telescope design parameters**
- **What the telescope has to deliver for this instrument/science -** e.g. emissivity, FoV, curvature

Instruments - arranged by date and by AO mode:
[SL=seeing limited, SCAO=single conjugate AO, MCAO=multi-conjugate AO, EAO=extreme AO]

SL(Day 1)
- VISMOS (out to at least J band) — Richard Ellis
- VIS HIRES (echelle) with fiber feed/slicer(?) — Steve Vogt, Raja
  (FOV 20' - wide field)

SCAO(Day 1) - employs an adaptive secondary
- MIR imager — James Graham
- MIR Spectrometer (R>2000)
  + monolithic/non-deployable (slicer?) IFU — James Graham

MCAO (hopefully Day 1)
- NIR imager - 2' fov - Diff. Limited — Ian McLean
- NIR IFU spectrograph (cryogenic) — James Larkin

EAO (later)
- VIS Extreme HIRES R>>80,000 — Steve, Raja ??

- Polarimetry options — Shri Kulkarni
- Coronagraph + EAO — Shri, James Larkin

Reports due:

First drafts emailed to me, or directly to all the members, NO LATER than Wednesday, May 10. Give each other some feedback. Present and discuss final versions at the Ma y 17, IWG meeting.

Date of Next IWG: Wednesday, May 17 at Caltech.

CELT Instrument Working Group Meeting #4

Held: Caltech

Date: Wednesday, May 17, 2000

Attending : Rich Dekany, Raja Guhathakurta, James Graham, James Larkin, Ian McLean, Jerry Nelson.

Apologies from Steve Vogt, Richard Ellis and Shri Kulkarni. Judy Cohen joined us for lunch and the afternoon session.

Introduction

Primary agenda today is to review and discuss the strawman instrument designs, specially in the context of their impact on telescope and/or AO design.

Instruments Review:

Mid Infrared Camera - James Graham:

CELT with 5% emissivity is a few times worse than SIRTF, but has better angular resolution. SIRTF will probably be confusion limited, so CELT's angular resolution will be powerful. CELT would be important for the detailed study of disks at 10 and 20 microns. Such objects are bright and don't drive the emissivity requirements of the telescope. The scale is about 34.4 mas/pixel. Impact on telescope is mainly in terms of emissivity.

Comments: basically encouraging and do-able. Thermal IR should really have its own AO system !

ACTIONS:

What if we fed the camera at f/60 with an adaptive secondary ?

What if fed with f/15 but using a custom AO system at Nasmyth, which could be cryogenic ?

1. Deployable Integral Field Spectrograph - James Larkin:

Spatially resolved kinematics and chemistry, multiplexed over the field. Science case is intricate and needs to be developed more. Three traditional slicing techniques: lenslets, fibers, image slicers.
Combination of scales is awkward - Nyquist sampled image occupies about 20 microns yet total FoV is over 260 mm. Perhaps use a scale changer to make f/15 slower to f/60 to help the size of slicers, but then the focal plane is about 1 m in size. To get OH suppression, we need R > 4000 and perhaps get J, H and K at one shot with cross-dispersion, because the backgrounds are similar now? This would allow no moving parts.

Could have 16 modules (spectrographs) with 2k x 2k detectors (hard to get R>4000), or 4 modules with 4k x 4k detectors (then can go to R = 8000). Number of fibers would be about 2000 with 20 bundles of 10 x 10 fibers in each bundle. Relatively little impact on telescope design. Big impact on detector requirements. Assumes fed by AO system (with field rotator). But, do we really need a 120" AO-corrected fov? On statistical grounds, "more" field will be needed for galaxy studies.

ACTIONS:

How do you get multiplexing without compromising single object sensitivity ?

What is the trade off between number of deployable IFUs versus FoV of individual IFUs ?

2. AO NIR Camera - Ian McLean:

Relatively straightforward camera, especially for 1-2.5 microns. Enormous detector needed to cover the whole AO field. Could consider a 4-shooter with separate cameras.

ACTIONS:

Is a camera for a 30 m telescope with only 2' fov superior to a wider field camera on a smaller telescope ?

Is this camera needed if the IFU instrument can synthesize images ?

4. Case for Wide-field 30-m telescope - Richard Ellis (Judy Cohen talked about this)

Look at objects with a rapidly rising luminosity function. Case for wide field is somewhat incremental. Therefore, need multiplex spectroscopy - seeing limited images - using multiple deployable IFUs. Large and complex instrument. 4 doublebeam spectrographs servicing 100 deployable IFUs feeds. Covers 20' field FoV. Curvature of focal plane not a problem. Cooled optics for H band. Cameras will be ~ f/1. Sampling is 0.1" (~ 1 mm slices) with a total field of view of 1" x 1.5".

Assuming 0.25" seeing (r0 of 40 cm) should be degraded by telescope optics no more than 10%. This is twice more stringent than Keck.

ACTIONS:

Are VPH gratings fully demonstrated ?

Why combine IR spectroscopy with the CCD spectroscopy - rationale for added complexity?

3. High resolution echelle spectrometer - Steve Vogt:

This is a day-1, seeing-limited instrument. No AO is assumed, hence this instrument is a scaled-up HIRES or a super-ESI. Single-object, short slit. Wavelengths of 0.5 microns where AO is very difficult. Challenging camera (f/1, 60-inch diameter). Slit width x resolution = 45,000". Echelle and cross-dispersers will be mosaics 1 m x 3 m in size. Fits on an 11 x 18 m Nasmyth and weighs 23 tons.

ACTIONS:

Why is there a break point at f/8 for the telescope focal ratio ?

Are there other approaches to this kind of spectroscopy ?

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Additional Discussion:

Should we put details on the Web page? Jerry said we can send them to Paula Towle.

Why don't we have an "optical" imager at the seeing limit ?

What is status of budget support ? Money for travel is OK, but eventually need to carry out more detailed design studies.

Date of Next IWG? Wait for "general" meeting!