CELT Development Corporation
WORK PACKAGE



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| **Work Package Title:** | **Caltech IRMOS Feasibility Study** |
| Performing Institution: | California Institute of Technology |
| Period of Performance (Total): | June 13, 2005 - April 15, 2006 |
| Period of Performance (This Period): | June 13, 2005 - April 15, 2006 |
| Work Package Manager: | Richard Dekany |
| TMT Project Work Package Manager: | David Crampton |
| TMT WBS Element Number: | TMT.INSTR-8.3.5.2 |
| TMT WBS Element Dictionary: | |

Summary of Work To Be Performed:

Caltech and its partners will undertake the feasibility study of the IRMOS instrument based upon tiled focal plane field segmentation. We will develop the science case and produce an Operational Concepts Definition Document (OCDD). We will consider the flowdown of the science case and OCDD into instrument requirements that will be captured in a Functional Requirements Definition Document (FRDD). We shall refer to an entire class of tiled focal plane multiobject adaptive optics (MOAO) concepts developed at Caltech as ***TiPi***.

IRMOS is intended to efficiently facilitate the compelling goal of multiobject spectroscopy at excellent, but not quite diffraction-limited resolution at infrared wavelengths, while extending over a much larger field of view (FoV) than the diffraction-limited NFIRAOS/IRIS adaptive optics system / IFU spectrograph combination. Dynamical studies of distant, spatially resolved, galaxies provide an illustrative case where the field density and characteristic angular scales of scientific targets favor multiplexed observations that span a wide FoR. TMT's light collecting power and the further enhancement of sensitivity afforded by adaptive optics provide a critical competitive advantage over multi-object spectrographs on 8-10m telescopes. Noting the significant scientific territory available, the TMT Science Advisory Committee (SAC) has placed great priority on an infrared multi-object spectrograph, IRMOS – an instrument with deployable integral field units (d-IFUs) patrolling an AO-compensated field. IRMOS distinguishes itself from the on-axis, single object, diffraction-limited, instrument (NFIRAOS / IRIS) by virtue of its multiplex gain and coarser sampling, making it particularly suitable for survey applications.

***A tiled steering mirror concept allows for a wide variety of science applications from sparsely-distributed galaxies through clustered sources and diffuse compact objects to blind searches requiring contiguous coverage. Such versatility is very powerful when considering the range of science that may exploit such a technique. We shall study the scientific benefit of various instrument configurations to arrive as a feasibility statement on the science return and technical readiness of IRMOS for TMT.***

The ***TiPi*** concept proposed for this study aims to provide a multiobject near-IR spectroscopic capability with minimum technical risk. We shall consider MOAO architectures that use only existing deformable mirror technology and shall show the compelling science even such conservative assumptions provide. Further, we shall explore modest extrapolations in technology (e.g. adaptive secondary mirrors) to discover the science capability that may be possible at first light for TMT and beyond.

In the basic ***TiPi*** architecture, an optical relay images the entire of scientific regard (FoR) onto a low order, high stroke adaptive mirror. This 'woofer mirror' provides low order atmospheric compensation for both natural and laser guidestars, and may be an adaptive secondary (AM2). After compensation, light from each laser beacon is split from the science field and directed into a wave-front sensor. The resulting wave-front measurements drive the woofer using a tomographic reconstruction algorithm. Because the lasers are sensed after compensation by the woofer, this mirror is driven in closed loop.

The science field is then imaged onto a focal plane tiled with mirrors. Selection of a spectroscopic target is performed by tip/tilt actuation of one of these mirrors, which directs light into a second optical relay. This relay may or may not contain additional deformable mirror (DM) elements. A goal of this study is to understand the science tradeoff with advancing mirror technology, and to establish the science benefit of using only today's DM technology.

Statement of Work:

Specifically, this work package will consist of the following major tasks:

1. Expand the IRMOS science case that examines the importance and technical impact of applications beyond the focused distant galaxy surveys given the highest priority in the SRD.
2. Develop IRMOS functional requirements based on scientific source and performance modeling, emphasizing architectures using current technologies and modest advances over the state-of-the-art
3. Perform cost and risk trade studies to determine the most conservative approach to obtaining IRMOS science capability.
4. Develop feasible optomechanical designs and analysis of the necessary tiled focal plane, adaptive optics, and spectrograph subsystems.
5. Define the Observatory interfaces to IRMOS

6. Develop feasible control architecture and data handling capabilities
7. Develop a plan and budget for a Conceptual Design Phase study for IRMOS

Deliverables:

- Monthly Progress reports
- Initial Operational Concept Definition Document (IOCDD)
- Initial Functional and Performance Requirements Document (IFPRD)
- Feasibility Study Report (FSR)
- Material Supporting a Feasibility Study Review

Contracts and Major Procurements:

$10,000 subcontract to Eric Prieto of Laboratoire d'Astrophysique de Marseille (LAM) to support optomechanical design for IRMOS (With additional budget $4,000 for travel to enable Eric Prieto to visit Caltech once during the period of performance.)

Collaborating Institutions:

Laboratory for Adaptive Optics (LAO), University of California, Santa Cruz
Laboratoire d'Astrophysique de Marseille (LAM)

Schedule and Key Milestones:

Interim milestones for this study shall conform to the requirements of the RfP, namely:

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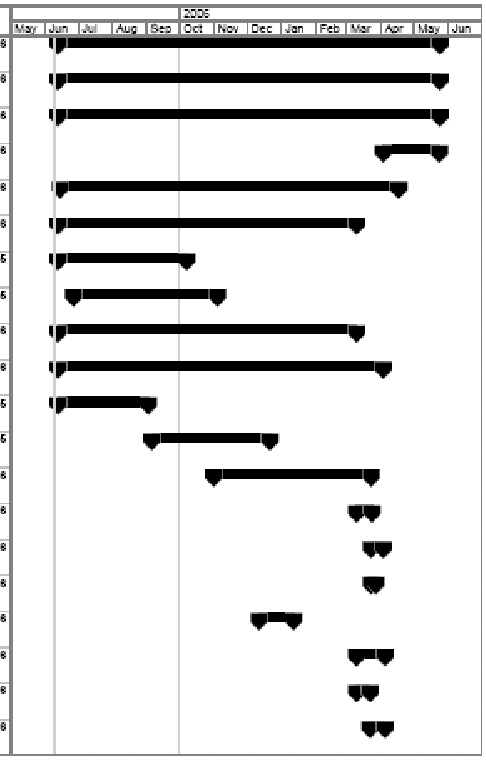
| • Draft IOCDD | 3rd month after start of work |
| • Draft IFPRD | 4th month after start of work |
| • Final IOCDD | 5th month after start of work |
| • Final IFPRD | 6th month after start of work |
| • Deliver FSR | 15-Apr-2006 |
| • Final amended FSR | 13-May-2006 |

A major Feasibility Study Review will be held in coordination with the TMT project office in Pasadena in April 2006. Periodic written progress reports shall be provided monthly, including technical progress, problems, costs, and updated schedule and cost forecasts for the subsequent two months.

A Gantt representation of the overall schedule is shown in the following figure.

IRMOS Feasibility Study Schedule
6/9/05

| ID | WBS | Task Name | Work | Start | Finish |
|---|---|---|---|---|---|
| 1 | 1 | IRMOS feasibility study | 66.83 w | 6/13/05 | 6/24/06 |
| 2 | 1.1 | Management and Reporting | 8.88 w | 6/13/05 | 6/24/06 |
| 3 | 1.1.1 | Project Controls | 2 w | 6/13/05 | 6/24/06 |
| 6 | 1.1.2 | Production of Final Report / Proposal | 4.88 w | 4/3/06 | 6/24/06 |
| 12 | 1.1.3 | Travel and meeting costs | 1.7 w | 6/15/05 | 4/17/06 |
| 19 | 1.2 | Science Requirements Flow-down | 24.8 w | 6/13/05 | 3/10/06 |
| 20 | 1.2.1 | Science Case | 6.4 w | 6/13/05 | 10/7/05 |
| 27 | 1.2.2 | Initial Functional Requirements | 6 w | 6/27/05 | 11/4/05 |
| 35 | 1.2.3 | Performance Modeling | 12.4 w | 6/13/05 | 3/10/06 |
| 46 | 1.3 | Instrument Concept | 21.3 w | 6/13/05 | 4/3/06 |
| 47 | 1.3.1 | MOAO Optical Relay | 2.2 w | 6/13/05 | 9/2/05 |
| 51 | 1.3.2 | Cryostat | 4.2 w | 9/6/05 | 12/21/05 |
| 55 | 1.3.3 | Cold Box (incl. tiled focal plane) | 13.4 w | 11/1/05 | 3/23/06 |
| 61 | 1.3.4 | Detector | 0.4 w | 3/10/06 | 3/24/06 |
| 64 | 1.3.5 | Control Electronics | 0.7 w | 3/23/06 | 4/3/06 |
| 67 | 1.3.6 | LGS Wavefront Sensor | 0.4 w | 3/23/06 | 3/27/06 |
| 69 | 1.4 | Observatory Interfaces | 1 w | 12/12/05 | 1/12/06 |
| 74 | 1.5 | Software Architecture | 1.06 w | 3/10/06 | 4/6/06 |
| 75 | 1.5.1 | Instrument control | 0.8 w | 3/10/06 | 3/22/06 |
| 79 | 1.5.2 | Data acquisition and reduction | 0.46 w | 3/22/06 | 4/6/06 |

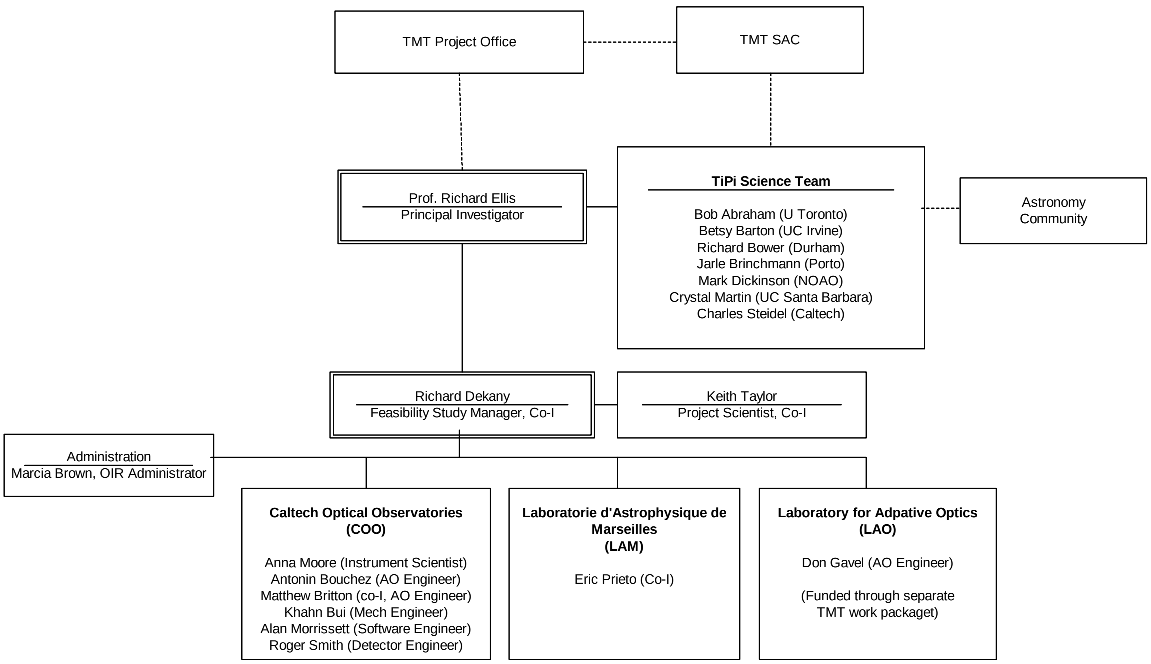



Key Staff:

Prof. Richard Ellis (Caltech) is the Principal Investigator (PI). Keith Taylor (Caltech) is co-Investigator (co-I) and Instrument Scientist. Matthew Britton (Caltech) is co-I. Eric Prieto (LAM) is co-I and technical lead for d-IFU spectrograph unit. Richard Dekany (Caltech) is co-I and Feasibility Study Manager (herein also referred to as Project Manager (PM)).

Other Staff:

The complete organization chart of this work package is shown in the following figure.




*Caltech IRMOS feasibility study organization chart.*

Budgeted Costs for Work Scheduled:

| WBS # | WBS Element | Cost |
|---|---|---|
| 1.1 | Project Controls | $6,764 |
| 1.2 | Reporting (incl. Final Report) | $17,084 |
| 1.3 | Reviews and Travel | $11,151 |
| 2.1 | Science Case | $3,122 |
| 2.2 | Initial Functional Requirements | $17,080 |
| 2.3 | Performance Modeling | $18,107 |
| 3 | Instrument Concept | $43,756 |
| 4 | Observatory Interfaces | $3,150 |
| 5 | Software Architecture | $3,131 |
| | **Total Work Package Cost** | **$123,345** |

Issues and Risks (Technical):

The major technical risk issues for IRMOS are the quality of tomographic wavefront sensing, and the technical readiness of small diameter, high actuator density deformable mirrors. The work being conducted by the NFIRAOS team and by Don

Gavel at LAO will help address the question of feasible tomographic wavefront sensing accuracy. The technical readiness of MEMS or similar DMs is a parameter to be studied in this work package.

Issues and Risks (Costs):

Reporting requirements for TMT are not fully understood at this time. We assume here a constructive relationship with TMT designed to provide maximum value to the Project. Should reporting requirements consume unexpectedly large amounts of engineer time, higher costs may result.

Issues and Risks (Schedule):

We envision a close collaboration with the TMT Project Office with particular emphasis on the development of the MOAO adaptive optics system. Implemented as an optical relay containing a common 'woofer' deformable mirror driven in closed-loop for IRMOS, we believe that MOAO will possess significant technical overlap with the facility NFIRAOS system. In particular, we believe the following subsystems, to be developed by the Project Office for NFIRAOS, can be directly used in the IRMOS MOAO relay:

- High-order laser guide wavefront sensors
- Low-order natural guide star wavefront sensors
- Real-time wavefront reconstruction algorithms and hardware
- Large dichroic mirrors
- Atmospheric dispersion compensation
- Multiple sodium laser beacon calibration sources
- Rapid tip/tilt control stages capable of supporting 300-500mm class deformable mirrors
- Observation planning software

Because of the extensive AO subsystem overlap with NFIRAOS, we do not intend to explore the many trade issues in this proposed work package. Rather, we shall concentrate on the areas of AO system design in which our IRMOS/***TiPi*** architecture differs from the NFIRAOS concept, namely in areas of:

- Open-loop deformable mirror control
- Natural guide star acquisition

Should the NFIRAOS conceptual design work not proceed according to plan, there may be a schedule and cost impact to this work package, to the extent the subsystems described above would require parallel design effort at Caltech.

**Approved by:**

Richard Dekany

Digitally signed by Richard Dekany
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| _________________________ | _________________________ |
| David Crampton<br>TMT Work Package Manager | Richard Dekany<br>Work Package Manager |
| _________________________ | _________________________ |
| R. David Goodman<br>TMT Business Manager | Gary H Sanders<br>TMT Project Manager |