Call for Interest in the `IMAKA Phase A

`IMAKA Phase A Planning Document

Inquiries about this call and responses to be sent to
director@cfht.hawaii.edu

Deadline for responses is September 3, 2010

Table of Contents

1 INTRODUCTION

The `IMAKA team has recently finished a feasibility study for the `IMAKA wide-field high-resolution optical imager for CFHT and is now preparing a proposal for its Phase A design study. The proposal will lay out the work to be done in the instrument's design through Preliminary Design Review and identify the resources and costs for the study. With this we will seek funding approval from the CFHT Board at their December meeting with the intent to start the study as soon after Board approval as possible.

This document describes `IMAKA and its Phase A design study work packages. It is intended to help the `IMAKA team develop the proposal for the Phase A study and in particular provide a source of information about the instrument and its Phase A work for groups within the CFHT communities who are interested in participating in the design. It is meant as a working document to guide the process and *we fully expect that the definitions, scope, and requirements laid out in this document will evolve as a result of the discussions with interested groups/labs*. Interested groups/individuals are encouraged to provide input into this process. In addition, there are a number of supporting documentations (see list in appendix).

This preparation of the proposal will take place during summer 2010 and the effort will lead up to the CFHT User's Meeting in November 2010 and then ultimately to the presentation of the `IMAKA Phase A proposal to the SAC (November 2010) and the Board (December 2010).

It is critical that the proposal define what work will be done and contain an estimate of the Phase A study cost and schedule. To ensure an appropriate level of confidence we must have all the major tasks and WPs identified. The key steps in developing the proposal for the Phase A study are:

1. defining the scope of the work and work packages,
2. identifying the interested parties and available resources to work on the design,
3. developing a rough cost and schedule for the work, and
4. writing the Phase A study proposal for the CFHT Board

The schedule is roughly as follows:

- End of July 2010: Call for Phase A interest and release of this document
- End of August 2010: Optical design down-select
- **September 03, 2010: Requested deadline for response from interested groups.**
- ~Sep 22-24 (tentative): In-person meeting of `IMAKA team and interested parties in Toronto, Canada to develop work package distribution.
- End September: Iterate costs and resources with groups and `IMAKA team.
- October 2010: `IMAKA team writes proposal
- through ~March 2011: Develop and refine the detailed scope and contracts.
- November 3, 2010: Deadline for documentation to SAC
- November 18, 2010: Phase A Plan (summary of scope, budget, and schedule) presented to SAC/Board
- December 2010: Board presented with detailed Phase A proposal
- Jan 2011: With Board approval commence Phase A study (duration ~ 1.5 years) culminating in Preliminary Design Review.

Responses to the call for interest will initiate a dialog with the team on the areas of interest (e.g. work packages), areas of expertise, and discussions to clarify the `IMAKA project and its Phase A work scope and requirements.

An in-person meeting with all of the `IMAKA groups will take place in September. The intent here is to bring together the potential team, find potential collaborations, ensure that all areas of the design study are covered, and develop a first pass at the overall cost and resources for the study. To this end it will be important for the parties at the in-person meeting to have:

- rough costing with costing basis (rates, overheads, labor categories, etc.),
- schedule of available resources and whether schedule drives cost/availability,
- and, finally, what procedures and other levels of authority are needed to make commitments to the work (contract with CFHT Corporation for the work - see draft contract in supporting information).

The actual Phase A study proposal will be completed in October following the in-person meeting. A SAC version of this proposal needs to be submitted to SAC at the beginning of November. We expect that the SAC will comment on the science case and maturity of the Phase A plan while the Board will make a decision on whether to fund the Phase A study. If the Board approves the study, we would immediately proceed with the work. Our goal for the Phase A design development (up to the Preliminary Design Review) is 18 months from Jan 2011 to mid 2012.

1.1 `IMAKA Overview

`IMAKA is an instrument concept for a new wide-field high-resolution optical imager for CFHT. It uses a combination of a ground layer adaptive optics (GLAO) system plus a camera that uses orthogonal-transfer CCDs (OTCCDs) to deliver images with a FWHM ~ 0.3” at an imaging wavelength of 0.7 microns over a one-degree diameter field of view. The delivered image quality varies with wavelength being better at longer wavelengths and the science case requires `IMAKA to work in multiple broad bandpasses filters from 0.4 microns to 1.1 microns (nominally the standard astronomical photometric filters of g, r, i, z, and Y).

The efficacy of `IMAKA lies in the fact that a large fraction of the wavefront aberrations at CFHT arises within a few tens of meters of the telescope in the atmosphere's ground layer, in the telescope enclosure (dome seeing), and within the optics of the camera and telescope. It is the proximity of the wavefront distortions that gives rise to the wide corrected field of view while it is the excellent free-atmosphere seeing on Mauna Kea that permits the corrected images to reach these angular resolutions.

The GLAO system corrects for wavefront aberrations that are correlated over the full field (e.g. those that arise locally) (see for example Tokovinin, 2004, PASP, 116, 941). To do so, the adaptive optics system must measure the wavefront from a number of stars distributed about the field. Simulations show that the number of guide stars needed to produce a uniform correction over a one-degree field of view is at least four and preferably six. With the wavefront sensor measurements the GLAO control electronics derive the wavefront which is appropriate over the full field. A simple approach is to simply average the multiple wavefront sensor signals but a more sophisticated tomographic reconstruction of the three-dimensional distribution of wavefront aberrations may lead to a better correction (`IMAKA Feasibility Report). A single deformable mirror, here conjugate to a location very close to the telescope pupil, corrects the wavefront for the entire science field of view. GLAO has been implemented on a number of telescopes: William Herschel (WHT), the MMT, and SOAR telescopes but these implementations differ from `IMAKA in the science wavelength of interest (all near-infrared to date) and the science field of view (~ 2-3 arcminutes). These limitations are set by (1) the overall strength of the residual (uncorrected) wavefront after GLAO and (2) the distribution of turbulence in altitude above the site. In both of these respects Mauna Kea stands out. First, the residual wavefront after GLAO correction is expected to be small due to the good seeing at the site. Second, the distribution of optical turbulence above Mauna Kea implies a one-degree corrected field of view.

As a second level of correction, `IMAKA will deploy a science camera with focal plane sensors that can shuffle charge between pixels in real-time to compensate for image motion. These devices, called orthogonal-transfer CCDs (OTCCDs), very effectively correct for small telescope tracking/guiding errors, some wind shake, and some of the atmosphere induced image motion (See for example Tonry et al 1997PASP..109.1154 and Tonry et al. 2004, Astronomy and Space Sciences Library: Scientific Detectors for Astronomy, 300, 385). To accomplish the image motion correction, the CCD array controller requires a control signal (a guiding signal) typically determined by monitoring the image motion of a bright star by reading out the pixels immediately adjacent and containing the bright star at high rates (e.g. up to 100Hz has been accomplished). Groups of pixel cells (~600x600 pixels) can be shuffled independently. Note that due to decorrelation of the wavefront tilt over large angles, the correction determined from a single star is generally appropriate over a field of view of only a few arcminutes. As such, multiple stars within the `IMAKA field of view are necessary to achieve full correction over the one-degree diameter field.

The top-level requirements for `IMAKA are given below:

Top-Level Performance Requirements

TLPR01: Science field of view: 1 degree diameter or equivalent solid angle
TLPR02: Science wavelength range: 0.4 to 1.1 micron
TLPR03: Delivered image quality of 0.3" or better at r-band under median seeing conditions and an RMS variation of the FWHM less than 10% over entire field. The delivered image quality is defined as that measured on the science image. Seeing conditions include atmospheric and telescope (dome, mirror, wind shake) figure error contributions.
TLPR04: Photometric measurements with an accuracy of 1% absolute and 0.1% relative across the entire wavelength range and field of view.
TLPR05: Astrometric measurements with an accuracy of 40mas absolute and 0.8 mas relative across the entire wavelength range and field of view.
TLPR06: Sky coverage >90% in Galactic plane and > 50% at North Galactic Pole for full GLAO+OTCCD correction.
TLPR07: Sensitivity requirement?

Top-Level Functional Requirements

TLFR01: A GLAO system with wavefront sensors that sense the wavefront aberrations that arise from effects near the ground using stars within the instrument field of view and a deformable mirror that corrects this wavefront across the field.
TLFR02: A focal-plane camera capable of making tip/tilt wavefront corrections with independent corrections over fields a few arcminutes in size.
TLFR03: `IMAKA can not preclude the use of other CFHT facility instruments
TLFR04: Access to the CCD camera and DM systems should be provided with `IMAKA on the telescope.
TLFR05: An exchange to `IMAKA should be completed in less than one working day
TLFR06: Capability for a functional checkout while the instrument is in storage, prior to installation onto the telescope.

For the `IMAKA feasibility study we concentrated on the technical issues that posed the largest barriers to the realization of the instrument, with the intent of leaving other, better understood issues, to the Phase A engineering work. We therefore did not develop many specific details such as the ADC, DM and control, optical design of the wavefront sensors, and the data pipeline. The key development relating to the actual implementation was to develop an optical design that met the basic performance and functional requirements. The feasibility study found two viable approaches to implement `IMAKA. The two optical designs, shown below, are as follows:

> ***`IMAKA-Prime*** - a prime focus design developed by Com Dev (Ottawa, Canada) consisting of two independent channels with largely independent GLAO systems and focal-plane cameras. The fields of each are 0.4 x 1.0 degrees in size and the two fields are separated by 2 degrees.
>
> ***`IMAKA-Cassegrain*** - a Cassegrain design developed by John Pazder (HIA, Canada) that employs a Wynne-Dyson double-pass lens design. This contains a single contiguous one-degree diameter field of view but the current design requires a figure change of the secondary mirror.

At this point, both designs are being carried forward. However, in order to make progress in the Phase A study, we recognize that a down-select of the optical designs will need to occur before or very soon after the start of the Phase A study. Further optical design work is progressing during July/August 2010 and we expect to down-select to one optical design mid-September.

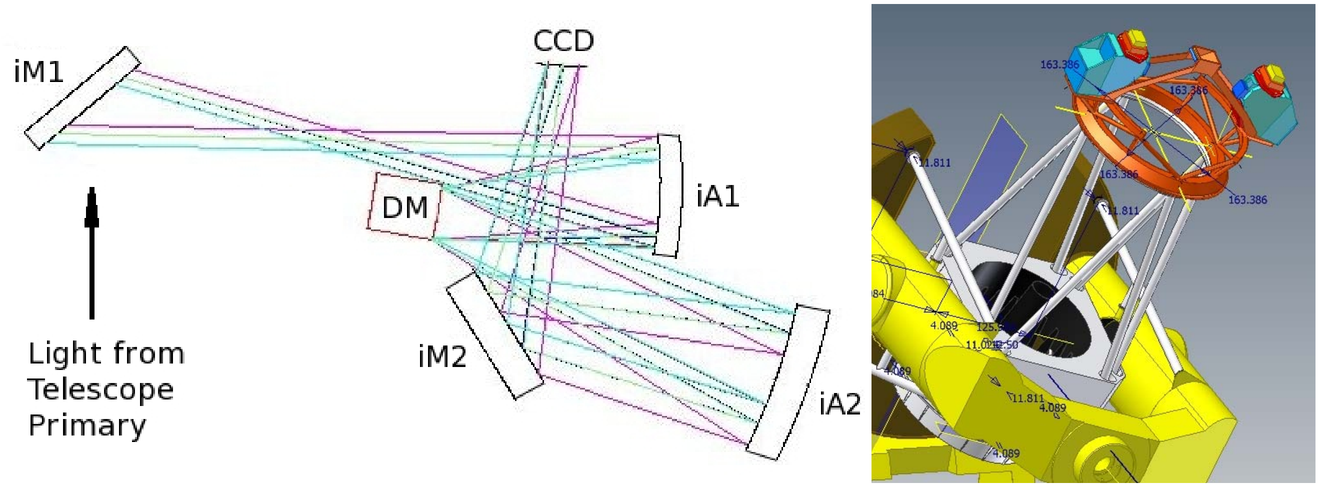


Figure 1: `IMAKA-Prime design by COM DEV. Left: The optical path through one of the two channels. The first mirror (iM1) folds the beam out towards the outer ring of the telescope. This mirror and the corresponding mirror in the second channel replace the current telescope secondary mirror. Two aspheres (iA1 and iA2) correct the telescope's field aberrations and provide a pupil position for the DM. Right: A CAD rendering of a mechanical layout for the concept. The two channels are shown with the new telescope top-end (orange). At the focal plane, the camera (yellow), wavefront sensor package (orange), and filter (red) are schematically shown.

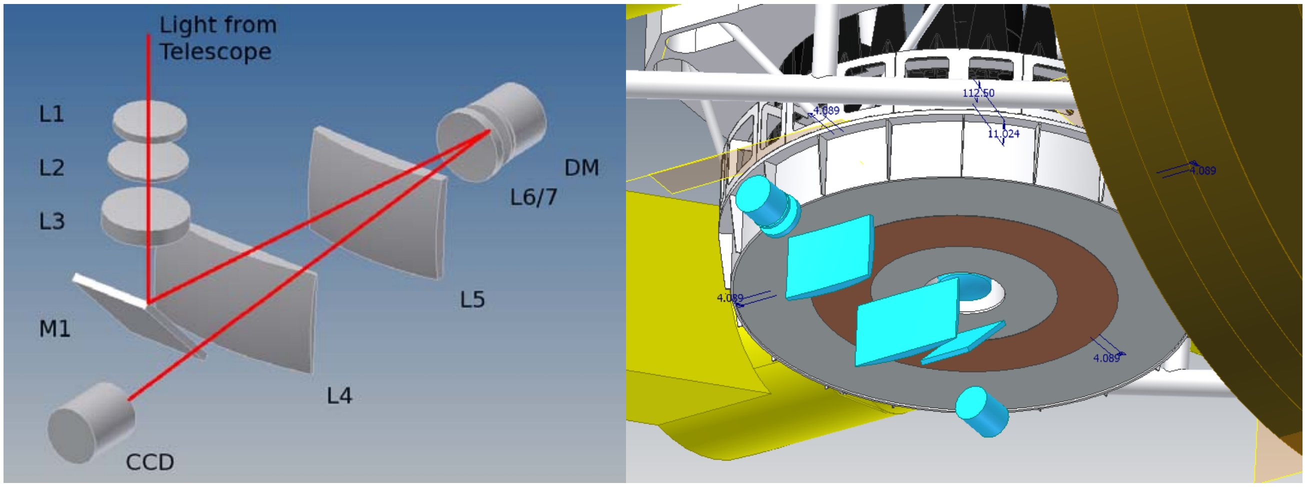


Figure 2: `IMAKA-Cassegrain design by John Pazder (HIA). Left: The ray path from the telescope through the two lens systems (L1-L3 and L4-L7) and the DM and CCD camera. Right: The layout of the concept at the back of the telescope. The structure at the back of the telescope is the mirror cell. Note that (1) the usual instrument interface at the rear of the telescope ("Cass-Bonnette") must be removed for clearance and (2) as currently designed, requires refiguring of the telescope secondary mirror.

Given the requirements for a large field size and high image quality, both designs are large in scale and will need either a dedicated upper end or full access to the volume behind the primary mirror cell. In addition to the imaging optics, we require that the CFHT telescope be kept in roughly its current operational configuration. In particular, it must be compatible with existing or currently planned instrumentation. A new telescope top end is consistent with this requirement though changes to the Cassegrain focus optical prescription are not. To support the GLAO correction, we also require that the instrument have (1) a well defined and accessible intermediate telescope pupil where a deformable mirror (DM) can be placed and (2) a set of approximately 6-8 wavefront sensors that can be deployed about the field. To support the additional tip/tilt correction in the free-atmosphere, we require a CCD camera system based on orthogonal transfer (OT) technology with a broad wavelength coverage. Given the desire to use wide bandpasses for the science and the sharp image quality, `IMAKA will also require an atmospheric dispersion corrector. Finally, as with previous instrumentation at CFHT, `IMAKA will need a instrument calibration and data reduction pipeline to provide astronomy-ready images with instrumental signatures removed.

1.2 Ongoing technical work (prior to start of Phase A)

Prior to the start of Phase A we are advancing the optical designs and continuing the simulation work. This importantly culminates in a down-select to a single optical design concept.

1.2.1 Optical Design Work:

The `IMAKA-Prime design will be developed further to include some or all of the following:

- Relocation of the DM closer to the pupil image / minimization of pupil distortions
- Increased beam clearance as the beam passes certain `IMAKA elements
- Baffling
- Optical design of an atmospheric dispersion compensator
- Refolding optics to free up space for filters, ADC, and WFSs.
- Inclusion of a tip/tilt plate
- Field flattener / filter combination
- Concepts for a 5 filter exchange mechanism

The `IMAKA-Cassegrain design will be developed further to include some or all of the following:

- Modify the existing Wynne-Dyson design to use the current f/8 CFHT secondary and within the current secondary focus range,
- Further optimize the design for further simplification and cost reductions
- Perform a ghost analysis and modify the design as needed
- Cost estimate
- ADC design

For both designs we will develop concept/costing: optical design + plus mechanical design concept to estimate rough volume/mass and costing (vendors), risk assessment.

Milestone: Optical design down-select

1.2.2 Simulations work:

- Explore impact of the field separation on GLAO performance and sky coverage
- Implement in instant-GLAO simulations the `IMAKA-Prime design and tomographic wavefront reconstructor

- Science simulations: revisit sensitivity numbers and develop algorithm for astrometry and photometry with varying PSF.

1.2.3 Science case:

- Further refine of the science case to highlight the cases unique to `IMAKA.
- Develop science data processing algorithms for photometry and astrometry.

Milestone: Submit revised science case to CFHT SAC

2 Major Subsystems and associated work packages

2.1 Phase A Requirements

The Phase A study encompasses the Conceptual and Preliminary design phases up to the Preliminary Design Review (PDR). For all work packages, the Phase A deliverables will include study reports, analyses, and designs at the Preliminary Design level. Of note, at the completion of the Phase A study the project development is expected to be at the following level:

- Optical design is complete and frozen with a final design including the optical relay, correcting elements (ADC, field flattener), and wavefront sensors.
- An opto-mechanical design will be developed around this design to a level where the costing, mass, and volume budget can be estimated at the ~20% level.
- All subsystem interfaces and requirements are complete and documented.
- All subsystems have a baseline design with preliminary mechanical, electrical, and software designs of each subsystem including interfaces and preliminary analyses.
- All mechanisms are identified, specified, and their interfaces/requirements are finalized.
- All subsystems and components are costed.
- Essential and Long-lead components are identified with vendors and lead times.
- Preliminary mechanical, electrical, software designs
- Systems: Preliminary assembly, commissioning, and operations plans. System end-to-end budgets (image quality, optics, mechanics, power, etc.). The basic design documents are finalized (Science Requirements/Reference Document, Operational Concepts Document, Instrument Requirements Document, and the Interface Controls Documents)
- Management: Cost, schedule, and staff resources for Critical Design and estimate for fabrication. Change control and document control are implemented.
- At the conclusion of the Phase A we will need a detailed plan ready for the critical design and fabrication phases. As such, all Phase A studies should be at a level where costs, schedule, resources, risk, and contingency can be estimated for the work in the following Critical design phase.

2.2 `IMAKA subsystems and work packages

The major instrument subsystems of `IMAKA are outlined in this section. A summary of the subsystems and associated work packages is given in the following table. These preliminary subsystem definitions are divided primarily by function. For each the main scope, function, and interfaces with other subsystems are listed. In addition, the work packages associated with each subsystem are identified at the end of each description.

Table 1: Summary of Subsystem and Work Packages

Subsystem	Work Packages
Main Support Structure	WP-MSS1 - Design of MSS
Optical Relay and Support Structure	WP-ORSS1 - Optical Design WP-ORSS2 - Bench/Relay opto-mechanical design WP-ORSS3 - Filter mechanism WP-ORSS4 - Filter design WP-ORSS5 - ADC mechanism WP-ORSS6 - Camera focus mechanism
GLAO System	WP-GLAO1 - WFSs, WFS mechanisms, and controller WP-GLAO2 - GLAO RTC WP-GLAO3 - AO Supervisory Controller WP-GLAO4 - DM WP-GLAO5 - Global tip/tilt corrector WP-GLAO6 - Lab integration and test system WP-GLAO7 - GLAO Calibration System WP-GLAO8 - On-sky demonstrator studies
Camera and Controller	WP-CAM1 - Camera, array controller, and dewar/cryostat WP-CAM2 - Shutter mechanism
Calibration Unit	WP-CAL1 - Photometric calibrator for camera
Science Data Pipeline	WP-DP1 - data pipeline s/w
Instrument Host Controller	WP-IHC1 - Instrument control system
Other studies	WP-SYS1 - Performance simulations WP-SYS2 - Science data simulations and data processing algorithms

2.3 Main support structure:

Scope: This is the structure that holds the instrument on the telescope. It includes the instrument handling equipment.

Function: This is the structure that supports each of the mechanical subsystems and interfaces them to the telescope. For the `IMAKA-Prime design this encompasses the new telescope top-end (orange structure in the `IMAKA-Prime figure above), while for the `IMAKA-Cassegrain design this encompasses the overall structure that holds the instrument beneath the primary mirror structure. This provides the instrument's interface to the telescope structure. It positions the instrument(s) and its subsystems appropriately, provides the interfaces to the observatory systems (power, cooling, communications), and interfaces with the instrument handling equipment. Its requirements will include positioning of the instrument with respect to the telescope opto-mechanics and flexure, mass/volume/center of gravity restrictions, and mechanical and electrical interfaces.

Interfaces:

- Optical: optical beam from the primary mirror (`IMAKA-Prime) or f/8 secondary (`IMAKA-Cassegrain)
- Mechanical: with instrument housing/body, with telescope top end or Cassegrain environment/Primary mirror cell, with telescope top-end handling system (for placement and removal)
- Electrical: provides interface for power, cooling, and network connections to the observatory electrical systems.
- Software: none

Work Packages:

WP-MSS1: Develop the design for the main support structure (e.g. new telescope upper end if necessary), storage, and handling. Explore designs, perform structure analyses and tolerancing.

Deliverables:

- Study Report including design, trades, analyses, and interface definitions
- Mechanical design: drawings, CAD files, 3D model

2.4 Optical Relay and support structure:

Scope: Includes the main optical relay including the optics, ADC, and filters, optical mounts, and housing. The housing could incorporate the main support structure if appropriate.

Function: These are the components that comprise the opto-mechanical relay. It includes the structure that houses the relay optics, positions/aligns the optics and related components within the system, and positions the system with respect to the telescope-instrument mechanical structure.

Filter mechanism: Controls and positions the five science filters. The mechanism must position the filters repeatably, and hold them in place in a changing gravity vector environment. Each filter will be encoded with a unique identification number. The in-beam filter must be identified after an exchange.

ADC mechanism: This mechanism controls the positioning of optics that compensate for the atmospheric differential refraction across the filter bandpasses. This will depend on the telescope elevation and the filter/science wavelengths and must be adjusted as the telescope tracks across the sky.

All mechanism designs will include the dedicated mechanism controller with a TBD interface with the instrument host and external cabling interfaces, encoders/sensors, limit switches, and internal cabling (terminated with connectors).

Interfaces:

- Mechanical and optical: telescope-instrument mechanical structure, instrument housing, DM, WFS package, filter exchange mechanism, camera, and calibration units.
- Optical: Filters and ADC are both inserted into the optical beam and must be consistent with the optical design
- Electrical: power, communications, CCD camera.
- S/W: interface with the telescope pointing/position. Interface between the mechanism controller and the instrument control computer?

Work Packages:

WP-ORSS1: Optical Design
Develop the optical design of `IMAKA to PDR (final optical design level). The detailed optical design will include tolerancing, alignment plan/error budget, and component specifications.

Deliverables:

- Study Report
- Detail design of relay, wavefront sensors, WFS pick-off mirrors, ADC, filters, field-flattener, and tip/tilt plate.
- Tolerance analysis
- Thermal tolerance analysis
- Alignment plan
- Component specifications.
- Focus changes and required range for focus mechanism (if necessary)

WP-ORSS2: Bench/Relay opto-mechanical design
Design the mounts, optical bench, and housing for the optical relay including the ADC and filters. A conceptual and preliminary design of the instrument mechanical structure, layout and packaging, and instrument optics/optical mounts. Initial engineering and analyses (e.g. flexure, thermo-mechanical stability) performed that verify that the design will meet the requirements of the IPRD

WP-ORSS3: Filter Mechanism and controller design
Design of the filter exchange mechanism. Desire five filters always available.

WP-ORSS4: Filter design
Design of the bandpass filters (coatings, specifications, etc.)

WP-ORSS5: ADC Mechanism and controller design
Design of the atmospheric dispersion compensator mechanism.

WP-ORSS6: Camera focus mechanism
If the instrument is at Prime focus, then we need a mechanism to compensate for changes in the telescope focus and filter focus offsets.

2.5 GLAO system:

Scope: WFS, real-time controller, DM (and possibly tip/tilt plate)

Function: This subsystem includes the main AO components: the deformable mirror (DM), the multiple wavefront sensors (WFSs), and the real-time AO control computer (RTC). The WFSs and RTC determine the appropriate wavefront to place on the deformable mirror. The DM control electronics send the DM commands to the DM. There will be restrictions on the size/volume of the components as well as requirements on the spatial and temporal sampling of the wavefront aberrations.

Interfaces:

- Optical: WFS and DM with Optical Relay
- Electrical: cabling between DM, WFS, and RTC; with telescope to off-load pointing errors, tip/tilt or pointing offsets to WFS probe arms/mechanisms
- Mechanical: DM and WFS: with optical relay, RTC: with ?
- Software: Must have access to read and change all loop/tomographic parameters (not real time). Must monitor all loop/real-time functions/status. Must be able to save WFS telemetry data (images, centroids, intensities, wavefront reconstruction(s),...XXX) at full system update rate and feed this to the engineering archive. Interfaces with the instrument controller (state, offloading, and diagnostics).

Work Packages:

WP-GLAO1: Wavefront sensors and mechanisms/controller
Scope: Design the WFS optics, opto-mechanics, and the mechanism/controller. Each WFS must be positioned to the guide stars: minimizing vignetting, account for any distortions in the field, accounting for focus offsets across field. There will be constraints on the total length of time need to acquire and achieve a stable closed-loop. Includes cabling to the RTC.

WP-GLAO2: GLAO RTC – AO s/w, h/w, and control algorithms
Scope: Design the GLAO components, requirements. Develop the hardware and software design for the RTC. Software design: a design including details of algorithms and program flow for all software to be provided by the Developer.

WP-GLAO3: AO Supervisory Controller
Scope: Non-real time optimizer, loop off-loader, and telemetry. Software design: a design including details of algorithms and program flow for all software to be provided by the Developer.

WP-GLAO4: Deformable mirror
Scope: design/provide DM mirror, drive electronics, and DM mount. This includes cabling to the RTC.

WP-GLAO5: Global tip/tilt corrector
Scope: Explore options for and develop design for the global tip/tilt corrector. This may be a tip/tilt stage for the DM or a tip/tilt plate (similar to MegaCam). Include control electronics, internal servos, and interfaces to control signals.

WP-GLAO6: Lab integration and testing of GLAO system
Scope: layout optical test bench and plan for testing/integrating the GLAO system prior to integration with `IMAKA.

WP-GLAO7: Calibration/Simulator for GLAO. Study the requirements for the calibrations for the GLAO system. Are interaction matrices needed routinely? If so, how often will they be needed, and what dependences are there (GS position, wavelength, WFS alignment, etc.)? Any GLAO calibration unit must reproduce the optical beam of the telescope (including any off-axis aberrations inherent in the design (e.g. `IMAKA-Prime's compensation of the telescope off-axis aberrations) and simulate sources (science and guide star) for alignment checks, AO interaction matrices, and acquisition checks. Software design: a preliminary design including details of algorithms and program flow for all software to be provided by the Developer.

Calibration unit must be available for instrument checkout when the instrument is off the telescope.

WP-GLAO8: On-sky demonstrator studies
Conduct on-sky experiments demonstrating `IMAKA and the gains possible.

2.6 Camera and controller:

Scope: Design ~1Gpixel OTCCD camera . Includes the housing/dewar, CCDs, controller, cryogenics, data handling

Function: This encompasses everything between the entrance to the camera dewar, to the OTCCDs, the array controller, through to the real-time data handling/storage systems. Control of the camera should be consistent with the overall software architecture. The camera system will configure the camera, read-out, and pass data to storage.

Interfaces:

- Optical: with opto-mechanical bench
- Electrical: shutter
- Mechanical: Interfaces to the opt-mechanical bench.
- Software: CFHT detector interface (detcom) , data handling system, shutter control

Work Packages:

WP-CAM1: Camera & Array controller, and basic data handling s/w & h/w. Software design: a design including details of algorithms and program flow for all software to be provided by the Developer.

WP-CAM2: Shutter mechanism: We note that in `IMAKA-Prime the optical relay magnifies the optical beam so the entrance focal plane is smaller than the final focal plane. As such, it may be advantageous to place the shutter at the entrance focal plane.

2.7 Calibration Unit:

Scope: Camera photometric calibration system:

Function: The instrument calibration unit will provide sources for flat-fielding the detector sensors, calibrate flexure, and calibrate distortions in the optical systems. Must be available as part of system checkout even when instrument is off the telescope. This unit plus the GLAO calibration unit are the source for instrument checkout.

Interfaces:

- Software: calibration unit will provide a simple low-level interface to control the calibration source (e.g. port & ascii commands).
- Optical: opto-mechanical bench
- Mechanical: opto-mechanical bench
- Electrical: camera

Work Packages:

WP-CAL1: Photometric Calibration system for camera providing means to photometrically calibrate the images.

2.8 Science Data Pipeline:

Scope: The software system that removes instrumental signatures and produces science-ready images.

Function: Takes the raw data from the camera data handling system and produces 'science-ready' images. This removes all the instrumental signatures including bad pixels, flat-fields, AO signatures???. The pipeline should interface with the CFHT engineering data archive to extract seeing measurements, turbulence profiles, RTC telemetry, and ??

Interfaces:

- Software: interfaces with the observatory data handling system and camera data handling.

- Electrical: interfaces with the camera raw data storage system.

Work Packages:

WP-DP1: Data pipeline: s/w and h/w for instrument calibration and data reduction. Software design: a design including details of algorithms and program flow for all software to be provided by the Developer.

2.9 Instrument Host Controller:

Scope: non-real-time software system that interfaces users with the instrument and supervisory control of all subsystems

Function: Provides the software/hardware interface between the instrument and all its subsystems with the observatory control/observing software (e.g. queue software). This must conform with the observatory control system.

Interfaces:
- Interfaces with RTC, camera controller, mechanism controllers.
- Interfaces with the observatory queue observing system.

Work Packages:

WP-IHC1: Instrument control system
Develop the architecture of the overall control system. This includes what protocols the subsystems use to interface with each other and the hardware/timing requirements of each of these interfaces. Software design: a design including details of algorithms and program flow for all software to be provided by the Developer.

Deliverables
- a s/w and h/w architecture design for subsystem communications
- s/w design of control system including documenting all functionality and requirements

2.10 Instrument Host Controller:

Work Packages:

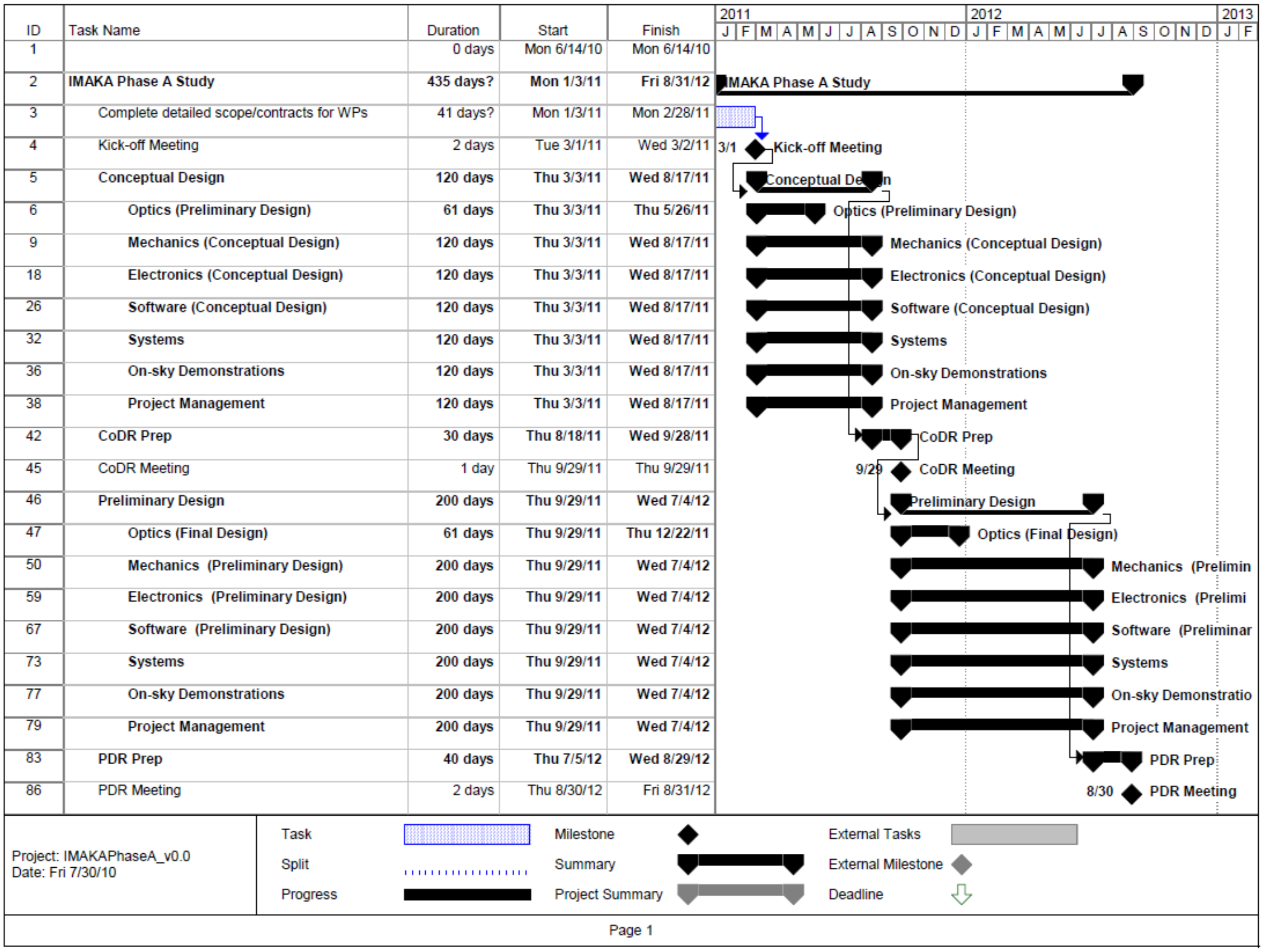
WP-SYS1: Performance Simulations studies – End-to-end performance studies
Simulations:
• Basic AO configuration: Finalize number of subapertures, sky coverage, and number of wavefront sensors; Error Budget development: preliminary error budgets for image quality (including mechanics and optics); True end-to-end simulations including temporal/bandwidth

issues, noise, distribution of guide stars, ...; and simulations feeding science case simulations and data reduction pipeline development.

- Error Budget development: preliminary error budgets for image quality (including mechanics and optics)
- Advanced simulations: True end-to-end simulations including temporal/bandwidth issues, noise, distribution of guide stars, ...
- Science team support: simulations feeding science case simulations and data reduction pipeline development.

WP-SYS2: Science data simulations and data processing/algorithms studies
Develop `IMAKA science data simulations and algorithms/processing techniques to deal with `IMAKA's PSF variations across the field of view and with wavelength.

3 Rough Schedule of Phase A



ID	Task Name	Duration	Start	Finish
1		0 days	Mon 6/14/10	Mon 6/14/10
2	**IMAKA Phase A Study**	**435 days?**	**Mon 1/3/11**	**Fri 8/31/12**
3	Complete detailed scope/contracts for WPs	41 days?	Mon 1/3/11	Mon 2/28/11
4	Kick-off Meeting	2 days	Tue 3/1/11	Wed 3/2/11
5	**Conceptual Design**	**120 days**	**Thu 3/3/11**	**Wed 8/17/11**
6	**Optics (Preliminary Design)**	**61 days**	**Thu 3/3/11**	**Thu 5/26/11**
9	**Mechanics (Conceptual Design)**	**120 days**	**Thu 3/3/11**	**Wed 8/17/11**
18	**Electronics (Conceptual Design)**	**120 days**	**Thu 3/3/11**	**Wed 8/17/11**
26	**Software (Conceptual Design)**	**120 days**	**Thu 3/3/11**	**Wed 8/17/11**
32	**Systems**	**120 days**	**Thu 3/3/11**	**Wed 8/17/11**
36	**On-sky Demonstrations**	**120 days**	**Thu 3/3/11**	**Wed 8/17/11**
38	**Project Management**	**120 days**	**Thu 3/3/11**	**Wed 8/17/11**
42	**CoDR Prep**	**30 days**	**Thu 8/18/11**	**Wed 9/28/11**
45	CoDR Meeting	1 day	Thu 9/29/11	Thu 9/29/11
46	**Preliminary Design**	**200 days**	**Thu 9/29/11**	**Wed 7/4/12**
47	**Optics (Final Design)**	**61 days**	**Thu 9/29/11**	**Thu 12/22/11**
50	**Mechanics (Preliminary Design)**	**200 days**	**Thu 9/29/11**	**Wed 7/4/12**
59	**Electronics (Preliminary Design)**	**200 days**	**Thu 9/29/11**	**Wed 7/4/12**
67	**Software (Preliminary Design)**	**200 days**	**Thu 9/29/11**	**Wed 7/4/12**
73	**Systems**	**200 days**	**Thu 9/29/11**	**Wed 7/4/12**
77	**On-sky Demonstrations**	**200 days**	**Thu 9/29/11**	**Wed 7/4/12**
79	**Project Management**	**200 days**	**Thu 9/29/11**	**Wed 7/4/12**
83	**PDR Prep**	**40 days**	**Thu 7/5/12**	**Wed 8/29/12**
86	PDR Meeting	2 days	Thu 8/30/12	Fri 8/31/12

Project: IMAKAPhaseA_v0.0
Date: Fri 7/30/10

Task	▨	Milestone	◆	External Tasks	▭
Split	┈	Summary	▬	External Milestone	◆
Progress	▬	Project Summary	▬	Deadline	⇩

Page 1

4 Team and Management Plan

The Phase A team organization will follow the usual CFHT practice of a Project Scientist and Project Engineer. A possible organization is shown below. On the science side we identify an overall Project Scientist and, due to the demand to cover the usually disparate fields of adaptive optics and wide-field astronomy, an adaptive optics project scientist (AOPS) and a wide-field project scientist (WFPS). They will over see the team(s) developing the science cases, performance analysis, and the science simulations. On the technical side, the Project Engineer will oversee all of the technical development. The Phase A work packages will be managed by a Project Manager (PM) which is usually, but not necessarily, also the Project Engineer (PE). A Systems Engineer (SysE) will develop the system requirements documentation, error budgets, and interface documentation. The PM, PE, and SysE are not necessarily three different people as these roles largely overlap.

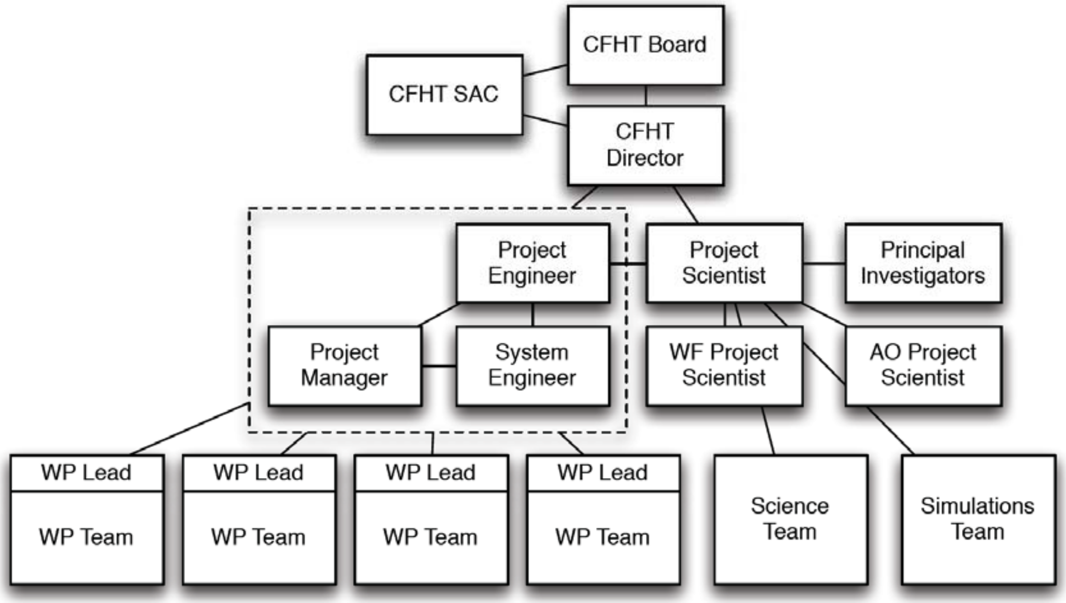


Figure 3: Team Structure for Phase A - Note that we expect to identify names for each of these roles in the proposal to the Board. The Project Scientists, Project Engineer/Manager, and System Engineer are ideally all co-located at CFHT.

The science work will be lead by the Project Scientist(s) and the science team. The Project Scientist is responsible for ensuring that the science requirements match the science goals and that the instrument as designed can meet these requirements. The AO Project Scientist is the lead on the GLAO+OTCCD performance simulations and works closely with the System Engineer in developing the overall error budget. Ideally the AO PS is an expert in adaptive optics. The WF Project Scientist leads the science case and data processing/algorithm development. Ideally this person is an expert in wide-field imaging and data processing.

The Project Engineer is the lead of all of the technical work. The Project Manager is responsible for developing the contracts, maintaining and documenting the project schedule, the project budget, documentation control, and the coordinating meetings and reports. The System Engineer is in charge of developing the system documentation (Instrument Performance Requirements Document (IPRD), Interface Control Documentation (ICD), Operating and Observing Plan Document (OOPD), and Science Requirements/Reference Documentation (SRD)), the system full error budgets. The SysE will flow the overall system requirements down to the subsystem requirements. As noted previously, the PE, PM, and SysE may be a single individual or a group of people. It is however necessary for a close interaction between the people filling these roles and nominally they are functionally resident at CFHT.

Project meetings
- Regular meetings every two weeks of WP leaders, PSs, PE/PM/SysE, and PIs.
- Design reviews: All teams will be participate in design reviews (in person?). Where, When

Reports
- Each WP team will provide quarterly written reports to the PM on the status of work and budget, identify any problems or potential problems, and major milestones achieved. These will be in the form of an electronic document (e.g. PDF)

Documentation Control
- How do we plan to do this? Wiki with key documents? something more sophisticated? Do we require WP teams to backup things here?

5 Outstanding Issues and Questions for Planning

There are a number of open questions regarding the Phase A. The following list is by no means exhaustive but are items that need to be answered soon.

- When is it necessary to down-select to one of the two optical designs. Clearly needed before Phase A starts but do we need this done to develop Phase A proposal?
    - *Goal is to down-select around the end of August/early September. Both optical designs are progressing forward with additional optical work to aid in the selection process.*

- When does the optical design need to be final/frozen? After CoDR, at PDR?
    - *Goal is to freeze the relay design as soon into CoDR as possible.*

- When do we need decisions made on the team organization? "Project Office" and WPs?

- There are many Systems Engineering tasks to complete. N.B. - This is an identified area where experience within the core Feasibility team is less than required and we are looking to supplement this in the Phase A work.

- Schedule:
    - Is the schedule of work appropriate for the scope defined?
    - Is it necessary to have a single CoDR or have less formal ones as subsystems reach that level?

...

6 Appendix: Supporting Information

6.1 IMPORTANT DOCUMENTATION

Reference documentation:

Available on the `IMAKA web pages on the CFHT web site
http://www.cfht.hawaii.edu/en/projects/IMAKA/

- `IMAKA's Feasibility Study Report
- 2010 SPIE meeting papers: Chun et al. 2010 (general summary), Lai et al. 2010 (performance simulations), and Evans et al 2010 (`IMAKA-Prime design).
- CFHT Instrument Design Specifications (IDS)

Available on request to director@cfht.hawaii.edu

- Optical Design Study reports: `IMAKA-Prime (COM DEV) and `IMAKA-Cassegrain (John Pazder)
- draft contracts – w/o technical specifications, requirements, and scope
- CFHT telescope mechanical drawings

6.2 ACRONYMS

- ADC: atmospheric dispersion compensator
- AO: adaptive optics
- AOPS: adaptive optics Project Scientist
- CCD: charge-coupled device
- DM : deformable mirror
- GLAO: ground-layer adaptive optics system
- OTCCD : orthogonal-transfer CCD
- PE: Project Engineer
- PM: Project Manager
- PS: Project Scientist
- RTC: real-time controller (GLAO system)
- SysE: Systems Engineer
- UI: User Interface
- WFS: wavefront sensor
- WFPS: Wide-field Project Scientist