IMAKA Design Phases and Deliverables

History:
- 2010-09-13: MC initial pass mostly PDR requirements
- 2010-09-14: MC adding in CoDR and CDR requirements
- 2010-09-15: MC editing, adding basic ICDs
- 2010-09-17: Incorporated DS/KH changes. Document currently only goes through CDR.

This document defines the design phases for IMAKA and the expected deliverables at the end of each phase. We call out five distinct phases in the project: NOTE: This nomenclature is a departure from the Phase A Call document which outlines Phase A to PDR.

- *Phase A* is to the Conceptual Design Review (CoDR)
- *Phase B* is to the Preliminary Design Review (PRD)
- *Phase C* is to the Critical Design Review (CDR)
- *Phase D* is Fabrication, Assembly, Integration, and Acceptance testing at development sites
- *Phase E* is the Shipment to CFHT, Integration on the telescope, Commissioning Phase and Early Science use

For this design study we are interested in working to PRD.

The IMAKA Team

- ***Team*** is the full IMAKA team working on the Phase A Study encompassing the CFHT project team, the Principal Investigators (PIs), the lead-institution teams, and the Science teams.
- ***System Team*** is the core CFHT-based project team consisting of the Project Manager, the Systems Engineering team, the Project Scientist, the Adaptive Optics Project Scientist, and the Wide-Field Imaging Project Scientist.
- ***Project Manager (PM)*** is the technical project manager and the technical director. This person is charged with defining the system design and constraints, leading the systems engineering, leading the study phases, and, in collaboration with the Project Scientist, ensuring that the instrument design meets the IMAKA technical requirements. They have ultimate project authority and responsibility.
- ***Project Scientist (PS)*** is responsible for setting out the overall scientific requirements of IMAKA in the Science Requirements Document and, working with the Project Manager, ensures that the IMAKA design meets its scientific requirements.
- ***Work Packages (WP)*** are the defined scopes of work for the design study. A single institution may handle more than one WP.
- ***Work Package Manager (WPM)*** is the person at each of the IMAKA lead institutions that oversees the WP work. The WPM makes technical and

management decisions with respect to their respective work packages. The WPM, working with the PM, ensures that the design is consistent with the requirements of IMAKA. All technical decisions that impacts the overall cost, schedule, or performance of the work will be made in consultation with the Project Manager.

- ***Institution Instrument Scientist*** is the scientist at each of the IMAKA lead institutions that ensures that the Institution's work is consistent with the scientific requirements of IMAKA. This person provides scientific direction but does not make technical/management decisions.

Overall Management Plan

- The WPMs are responsible for how and when the work at their institutions is completed. This work will be documented via usual large instrumentation development practices including: Work Breakdown structure to the level of individual design tasks, schedule (start/end dates, tasks, milestones, critical path analysis), resource loading, capital costs, and a list of key and supporting personnel and the fraction of time committed to the work based on a normal work week.
  - WPMs will provide the design (and later fabrication) costs of each design element, and the System Team will track the overall instrument cost as the design progresses.
- Meetings
  - Kick-off Meetings - Full IMAKA Team at start of design Phases.
  - Internal team meetings at the discretion of the WPMs
  - IMAKA Monthly Meeting - video-conference between PM/PSs and WPMs/ISs individually with each lead institutions
  - Quarterly Meetings - video-conference between PM/PSs and all WPMs/ISs.
- Progress Reports
  - Quarterly reports from WPMs to PM: technical status/accomplishments, problems, changes in Key personnel, cost/expenditures, schedule, plan for following month.
- Reviews
  - CFHT will call and conduct the Design Reviews at the completion of Phase A,B,C, and D. CFHT will select a review committee and a chair in consultation with the System Team and shall select the review committee members with the concurrence of the review committee chair.
  - Review presentation material will be delivered to CFHT 3 weeks before the review start date.
  - The respective WP design engineers will present the WP review material.
  - Attendance by IMAKA team as needed to fulfill the Review requirements.

General Interface Control Documents (ICDs)

Some of these do not exist but need to be defined over the course of the Phase A.

- Telescope opto-mechanical Interface: optics, mechanics
- Telescope electrical interfaces (power, network, and cooling)
- Observatory /Telescope and Instrument controls interface (s/w and h/w)
- Observatory Interlock System Interface
- Observatory observing data archives (science and engineering data, s/w and h/w interfaces)
- Observatory Engineering Document Control
- Instrument Handling Protocols/Procedures
- Observatory Software Programming standards
- Observatory Environmental requirements

Completion of Phase A (at CoDR)

Starting with the instrument concept developed during the feasibility study, the Team will develop a full Conceptual Design of IMAKA that is consistent with the IMAKA requirements and the CFHT standards and specifications used for instruments and facility systems. The IMAKA System Team will develop these standards/specifications in consultation with the IMAKA team during the course of Phase A.

General/Objectives

- The Team will develop a conceptual design for IMAKA and shall perform all analysis reasonably required to demonstrate that these concepts will meet all of the science requirements.
  - WP team(s) shall perform their respective design trade studies of technical approaches to the instrument/subsystems to assess cost/benefit options
  - WP team(s) shall develop and document the conceptual optical, mechanical, electronic, and software designs of IMAKA.
  - WP team(s) shall perform an on-sky experiment that demonstrates the level of performance possible with a GLAO+OTCCD correction over a one-degree field of view.
  - WP team(s) shall develop and document a management plan for the remainder of the effort necessary to design, fabricate, integrate, test, and commission IMAKA.
  - WP teams(s) shall document the design development and engineering for IMAKA including engineering concepts, thermal management scheme, and draft operations and maintenance concepts.
  - Estimate of overall cost and schedule to completion
- The documentation of the conceptual design will include, but is not limited to, a report detailing the science requirements for the instrument, the technical issues addressed during the study, the results of individual trade studies or other ways of addressing these technical issues, and the conceptual design for the instrument consistent with the key functional performance requirements in the preliminary OCD.
- Documentation Standards (start of Phase A)
  - Drawings/CAD files in a mutually agreeable format.
  - Drawings contain an identification number organized by subsystem and standardized by the CFHT Systems Team.
  - Design documentation delivered in PDF format and compatible with Windows, Macintosh, and Linux operating systems.

System Engineering

- The PSs will write the Science Requirements Document (SRD) developing the science case for IMAKA and defining the basic science requirements. This will include an estimate of the performance so that the technical viability of different science programs can be evaluated.

- Systems Team will develop the following system requirement documents
    - preliminary Operational Concepts Document (OCD) as per below
    - preliminary Function Performance and Requirements Document (FPRD) as per below
- Systems Team will develop the following system documents to a CoDR level
    - preliminary Interface Controls Documents (ICD)
    - CFHT hardware and software standards Document (Instrument Specifications Document ISD?): Including Volume, Mass, Moment constraints, S/W, H/W, Electrical standards used, Telescope interface definitions.

Operational Concept Document.

- System Team will develop the operational concept model for IMAKA and shall prepare a preliminary Operational Concept Document (OCD) which presents the science cases for which the instrument performance and requirements will be referenced to and discuss the key functional and performance requirements that IMAKA must meet.
- The preliminary OCD will also identify and discuss the key operational scenarios of IMAKA. These scenarios should be described in sufficient detail for a technically and scientifically skilled, but non-expert, audience to understand.
- The preliminary OCD will have a complete table of contents, a draft of all sections, and some sections in nearly final form to indicate the organization and level of detail of the document, but will not necessarily be complete.

Functional and Performance Requirements Document.

- System Team will develop the functional and performance requirements that the components of IMAKA will have to meet in order for the instrument to meet the requirements of the preliminary OCD and the science requirements, and will prepare a preliminary Functional and Performance Requirements Document (FPRD) that describes these requirements.
- FPRD will describe the origin of each functional and performance requirement and why each requirement was included.
- The initial FPRD must clearly state any assumptions regarding the characteristics or performance capabilities of the other parts of the observatory.
- A draft FPRD will have a complete table of contents, a first draft of all sections, and some sections in nearly final form to indicate the organization and level of detail of the document, but will not necessarily be a complete detailing of the requirements.

Optical Design

- An optical design with performance and tolerance analyses at the level of a PDR (one level ahead of other disciplines) including all elements for all subsystems (science optical train and wavefront sensors).
- Identified risks: glasses, sizes, tolerances.
- Preliminary set of opto-mechanical requirements and tolerances for mechanical design.

Mechanical Design

- A full 3-D computer model of the instrument including all subsystems, optics, mounts, important interfaces, mechanisms (filter exchange, ADC, WFS) and support and handling structures.

Electronics Design

- Electronic system block diagrams for all subsystems
- Electronic system requirements, specifications, and interfaces defined
- Instrument control
- AO system: deformable mirrors/control, WFS detectors/cameras,
- Camera system: vendors for detectors, optics, dewar/cryostat electronics, array controller, detector wiring
    - Description of the method used for selection of the type of science detector for the instrument, and of the work needed to optimize the array performance under different conditions
- Calibration controls
- Mechanism and mechanism controller

Software Design

- Review of the requirements – items to be controlled, interfaces to CFHT software systems, and major pieces of software to be developed.
- Overall approach to meeting the software requirements.
- Software design overview, giving each major item of software (e.g., task or process) and a description of how the various parts work together using data flow diagrams, hierarchical charts, and other graphical representations.
- Overall Control System: s/w architecture, associated computer h/w, and standards
- Mechanism control software: identified, functions defined.
- Data reduction pipeline: removing instrumental effects, extracting science data – requirements defined, algorithms identified

Project Management

- A Management Plan for the post-PDR work for IMAKA. The Management Plan shall cover all of the work necessary to design, fabricate, integrate, test, and commission IMAKA. This Management Plan shall include the following elements:

    - A Work Breakdown Structure (WBS) detailing all of the tasks necessary to design, fabricate, integrate, test, and commission IMAKA, with sub-tasks described down to the third level.
    - A schedule based upon the WBS, showing when each task will be completed.
    - A list describing the manpower, equipment, space, and other resources that will be needed to complete the work.
    - A procurement list describing all of the components and materials that will need to be purchased, and the approximate phasing of the procurements.
    - A budget, and total price, for the remainder of the work necessary to complete IMAKA.
    - The CVs of the proposed members of the IMAKA team.
    - A description of the roles and responsibilities of each team member, an organization chart, and what mechanisms will be used to track schedule and budget as the work progresses.
- The WPM and PM will agree upon the electronic format of documentation and design files.
- Describe the management tools and systems for tracking and controlling changes to drawings
- The Team shall prepare an outline of the Conceptual Design Study Documentation and deliver it to CFHT for review by the date given in the Schedule. This outline shall contain enough information to allow CFHT to evaluate the general design approach, the proposed individual documents and drawings to be included in the Conceptual Design Study Documentation, and the general format of the documents and drawings.
- The completion of the conceptual design is marked by the successful completion of the Conceptual Design Review (CoDR). The CoDR committee will be assembled by the CFHT Director and consist of outside experts.

Completion of the Phase B (at PDR)

Starting with the Conceptual Design, the Team will develop in detail a preliminary design for all components of IMAKA. At the conclusion of this stage, the requirements are met by a design that can be realized. All subsystems have a baseline design with preliminary mechanical, electrical, and software designs of each subsystem including interfaces and preliminary analyses. Existing commercial components are identified with costs and custom components have a design and an estimate of the cost to fabricate. A full 3D mechanical model of the instrument exists with a basic structural analysis completed. The optical design is notionally frozen at the end of the PDR. Goal is a costing to the level of ~20%.

General/Objectives

General Design Deliverables:

- Responses/rework in response to the CoDR.
- Subsystem designs in sufficient detail to illustrate the physical configurations and principles of operation.
- Description of the method and results of analyses that show compliance with each of the requirements in the FPRD
- Cost
  - All subsystems and components are costed with potential vendors.
  - Essential and Long-lead components are identified with vendors and lead times.

System Engineering

- All subsystem interfaces and requirements are complete and documented.
- Team will develop the following system documents to a PDR level
  - Operational Concepts Document (OCD)
  - Function and Performance Document (FPRD)
  - Review of the top-level instrument requirements derived from the science requirements during the conceptual design study.
  - Interface Controls Documents (ICDs)
- Review of the science requirements.
- Documentation of the methods used for, and results of, any additional analyses and trade studies performed since the CoDR.
- Review the flow of the science requirements down to the engineering requirements and show how the science requirements are reflected in the design.
- The basic design documents are finalized (Science Requirements/Reference Document, Operational Concepts Definitions Document, Instrument Requirements Document, and the Interface Controls Documents)
- Methods used for, and results of, all analyses and trade studies performed for the preliminary design are documented.
- Flowdown of science requirements to the engineering requirements showing how the science requirements are reflected in the design.

- All error and tolerance budgets (e.g. image quality, thermal optics, opto-mechanics, power, etc.) are updated.
- Opto-mechanical tolerances for all mechanisms in all modes.
- Updated OCD and FPRD updated. The updated FPRD shall show the degree of compliance of the design with each requirement in the FPRD using a matrix or list, or by discussing compliance in the section for each requirement.
- Preliminary assembly, commissioning, and operations plans.
- Management: Cost, schedule, and staff resources for Critical Design and estimate for fabrication. Change control and document control are implemented.

Optical Design

- Complete detailed optical design including the optical relay, correcting elements (ADC, field flattener, global tip/tilt compensator), wavefront sensors, and wavefront sensor acquisition units.
- Ray trace of all optical configurations of the instrument showing spot diagrams and encircled energy plots (or N^2 plots), for the center and the eight edges (top, bottom, right, left, and four corners) plus four positions at 70% radial distance from the field center for any science field.
- Optical throughput for all modes, both before and after the detector quantum efficiency is taken into account but excluding the telescope and atmospheric transmission.
- Scattered light and ghosting analysis for all configurations across the field of view for sources at least the positions defined above.
- Complete assessment of fabrication, thermal, and alignment tolerances for all optical elements
- Complete stray light analysis in all modes, indicating for a given ensemble of rays entering the instrument where the light ends up and the major problems.
- Complete baffling design to reduce stray light.
- Complete ghosting analysis
- Preliminary alignment plan
- Assessment of manufacturing risks and potential vendors
- Identification of long-lead optical materials or finished components to be ordered in advance of CDR.
- Final optical component specifications.
- Focus changes and required range for focus mechanism

Mechanical Design

This is a complete preliminary design with analysis that shows the mechanical design meets the system requirements. A full 3D computer model is expected at this stage.

- An opto-mechanical design will be developed around the optical design to a level where the costing, mass, and volume budget can be estimated.

- All mechanisms are identified, specified, and their interfaces/requirements are finalized.
- Finite element analysis model of telescope, instrument structure and camera
- Assessment of the opto-mechanical tolerances given by the Systems Team and any derived requirements that they imply.
- Assembly drawings of all mechanisms, and preliminary analysis to show they meet the opto-mechanical tolerances.
- Preliminary flexure analysis of the structure, camera, and mechanisms and including differential flexure between the WFS channels and the relay.
- Preliminary steady-state and transient thermal analysis showing temperature distribution at the end of the cooldown cycle.
- Preliminary instrument weight estimate, going down to each mechanism and structure, including the optics, electronics cabinets, cabling, and cooling systems on the telescope. Indicate weight and location of ballast needed to meet the weight, moment, and CG requirements.
- Show the complete instrument, with electronics and ballast mounted in a manner that meets the mechanical and space envelope requirements.
- Preliminary instrument handling approach, a design for implementing that approach, and an instrument handling scenario from instrument lab/storage area at the summit to the telescope and back.
- Documentation of a drawing tree and an estimate of the total number of assembly and fabrication drawings that shall eventually be needed.

Electronics Design

- System/subsystem overview of the instrument from the electronics perspective.
- Enumeration of all mechanisms and electronic subsystems with procurement method to each (e.g., commercial OTS, custom, hybrid, etc.).
- Complete designs of electronic systems in each major subsystem (e.g. Camera, WFS, AO controls, instrument controls, calibration system). For modification of electronics used on a similar instrument, list each modification to be made.
- Electronic system block diagrams and any other preliminary design materials for all custom hardware.
- Layouts of the electronics cabinets showing where each piece of electronics shall go. Include all components/equipment.
- Preliminary power consumption calculation for each cabinet.
- Detailed weight estimate for each cabinet, listing at least every rack-panel piece of equipment, more detail if available.
- Preliminary cable layout showing for each cable its major function, power and signals in the cable, types of connectors on each end, type of cable wire used (number of conductors, wire gauge, insulating material, and shielding), and length
- Preliminary design of heat exchanger system and interface on telescope
- Detector controller preliminary electronics and packaging design

Software Design

- For each major piece of software, the function it performs, number of subroutines or functions estimated to implement it, an estimate of the degree of difficulty of the code, and the total effort required to develop the software
- For each required functionality, an identified algorithm that is shown to meet the system requirements.
- Detector controller software/firmware preliminary design.
- Tools needed to do the development and testing, and indicate which are already in use and what still needs to be procured.

Project Management

- Review of the design engineering and drafting schedule, and the overall fabrication, assembly, and test schedule including the dates for project milestones, and dates for obtaining major purchased items (e.g., cryo-coolers, detector array, etc.)
- A complete bottom-up schedule that includes all the tasks discussed in the earlier presentations/reviews. For example, each major piece of software should be listed, each electronics custom board, each major mechanical assembly, optics fabrication and checking, etc.
- A detailed bottom-up cost estimate based on the above detailed schedule.
- Detailed plan for the critical design and fabrication phases.
- Describe the management tools and systems for tracking and controlling changes to drawings

Completion of the Phase C (at CDR)

Starting with the PDR design, the design is developed to a level ready to 'cut-metal' or 'start-coding'. The design is specified to the level of fabrication shop drawings, fasteners, subroutines, vendors, etc.

General/Objectives

- Design at the level of shop/fabrication drawings
- Fully identified/costed/specified components
- Documentation developed to CDR level:
    - Operational Concepts Document (OCD)
    - Function and Performance Requirements Document (FPRD)
    - Interface Controls Documents (ICDs)
    - Draft Acceptance & Integration Plan
    - Draft Maintenance Plan
    - Documentation of the design of the complete instrument: A report detailing the technical issues addressed during the design effort and describing the results of individual trade studies, prototype studies, or other methods of resolving these technical issues.
    - List of spares: A list of recommended spares for parts that are likely to need to be replaced during the lifetime of the instrument. This list should include the expected failure rate, sources for parts and current prices.

Systems Engineering

- Summary of changes since the PDR.
- Review of the science requirements, top-level engineering requirements, and major design drivers.
- A compliance matrix listing all of the Requirements, including all requirements from the Final FPRD, and stating whether or not each Requirement is met by the detailed design.
- Documentation of the methods used for, and results of, any additional analyses and trade studies performed since the PDR.
- Review the flow of the science requirements down to the engineering requirements and show how the science requirements are reflected in the design.
- Review the allocation of opto-mechanical errors across the instrument, review all error budgets and compare them with the initial estimates at the start of the project, describing major areas of change and what caused the changes. Indicate to what extent the instrument meets all requirements.
- All ICDs are final
- Final OCD and FPRD
- Updated error and tolerance budgets that include but are not limited to, throughput and image quality. These error budgets should explicitly call out

the contributions attributable to IMAKA, to the telescope, and to the atmosphere.
- A draft acceptance test plan (ATP) which describes how the Team will verify that the completed IMAKA meets all of the Requirements including those given in the Final FPRD, before IMAKA is packaged and shipped and after full integration, and describes how the Team will verify that IMAKA continues to meet all of the Requirements after being delivered. The ATP shall contain a summary matrix listing all of the Requirements with a brief description of how each Requirement will be verified. The ATP shall also contain full descriptions of the procedures for each test, analysis, and inspection to be performed in sufficient detail to allow CFHT to evaluate the appropriateness of each procedure. The ATP shall describe what facilities and resources will be needed at the delivery location to support the assembly and testing of the instrument after it is delivered.
- A verification and commissioning plan that describes a set of procedures adequate to systematically characterize the performance of the instrument in all of its modes. The verification and commissioning plan shall provide for measuring all aspects of instrument performance that would be necessary or helpful for planning science observations using the instrument. The verification and commissioning plan shall contain estimates of the time and resources required to perform each procedure, and an analysis of the total time and resources necessary to fully perform the plan.
- The updated FPRD shall show the degree of compliance of the design with each requirement in the FPRD using a matrix or list, or by discussing compliance in the section for each requirement.

Optical Design

Optical design is complete and final including tolerancing, component and materials specifications and vendors.

- Complete and FINAL optical design including the optical relay, correcting elements (ADC, field flattener), and wavefront sensors.
- Summary of changes since the PDR.
- Ray trace of all optical configurations of IMAKA showing spot diagrams and encircled energy plots (or N^2 plots), for the center and the eight edges (top, bottom, right, left, and four corners) plus four positions at 70% radial distance from the field center for any science field.
- Throughput for all modes, both before and after the detector DQE is taken into account.
- Alignment tolerances for all optical elements and reconciliation of mechanical and thermal flexures in optical design
- Final alignment plan.
- Fabrication drawings of all optical elements, properly toleranced, with any special treatments or procedures detailed in the drawings or accompanying fabrication specifications. This package should be ready to send to vendors immediately after the CDR.

- Final drawings and specifications for all optical components and coatings. These drawings and specifications shall be of sufficient detail and completeness to allow fabrication/procurement to begin immediately without any further design or drafting work.
- The updated FPRD should include a compliance list with all optical requirements.
- Documentation of all optical/mechanical interfaces.

Mechanical Design

This is a detailed mechanical design of the complete instrument with analysis of flexures, thermal, and vibrations. At CDR fabrication drawings are complete.

- Assembly drawings of all mechanisms, and analysis to show they meet the opto-mechanical tolerances.
- Flexure and mode analysis of the assembled instrument (including electronics cabinets and ballast), using lump masses for the mechanisms.
- Flexure and mode analysis of critical mechanisms.
- Thermal cold strap design for distributing cooling capacity to mechanisms and optics; each strap length, number of strands, and size of strands should be specified.
- Steady-state FEA thermal analysis showing temperature distribution at the end of the cooldown cycle; include all shields, all strapping in the final design, and lump masses for mechanisms.
- Cooldown analysis incorporating the cooler capacity as a function of temperature, strap capacity, shields, and other items. The model should be adequately detailed to give the prediction a maximum error of 20%.
- Engineering 3-D model developed in mutually agreed upon file standard.
- Detailed instrument weight estimate, going down to each mechanism and structure, including the electronics cabinets, cabling. Indicate weight and location of ballast needed to meet the moment and CG requirements.
- Show the complete instrument, with electronics and ballast mounted in a manner that meets the mechanical and space envelope requirements.
- The updated FPRD should include all error budgets and a compliance list with all opto-mechanical and mechanical requirements.
- Documentation of all optical/mechanical interfaces.
- A complete 3D model of the final instrument mechanical design which shows all of the instrument's components with enough detail to allow the immediate production of 2D fabrication drawings for all of the instrument's components without any further design effort.

Electronics Design

- System overview of the instrument from the electronics perspective.
- Enumeration of all mechanisms and electronic subsystems with approach to each (e.g., commercial OTS, custom, hybrid, etc.).
- Details of each major subsystem. For modification of electronics used on a similar instrument, list each modification to be made.

- Final design documentation for all electronic components of the assembled instrument that is complete enough to allow fabrication/procurement of all electronic components, cabling, and connectors to begin immediately. The design should include, but not be limited to, defining the locations of all power supplies, driver cards, processor cards, etc. within electronics cabinets, a cable/wiring count, cabling routes between the electronics enclosures and the camera vacuum jacket, and cabling routes within subsystems. This includes detailed cabling/wiring schematics.
- Include block diagrams and detailed circuit schematics for all hardware.
- Detailed designs of the electronics cabinets showing where every piece of electronics shall go. Show every board in each major subsystem.
- Detailed power consumption calculation for each cabinet, including power for each board, if possible.
- Complete thermal management system design.
- Detailed weight estimate for each cabinet, listing at least every rack-panel piece of equipment, more detail if you have it.
- Detailed cable layout showing for each cable its major function, power and signals in the cable, types of connectors and strain relief on each end, type of cable wire used (number of conductors, wire gauge, insulating material, and shielding), and length, and labeling at both ends.
- Review of science detector selection, device characteristics, and of any further work needed to optimize the array performance under different conditions
- Detector controller final design
- The updated FPRD should include a compliance list with all electrical and electronics requirements.

Software Design

"Ready to code".

- Review the requirements – items to be controlled, interfaces to CFHT software systems, and major pieces of software to be developed.
- Overall approach to meeting the software requirements.
- Software design overview, giving each major item of software (e.g., task or process) and a description of how the various parts work together using data flow diagrams, hierarchical charts, and other graphical representations. H/W and S/W control flow is diagrammed.
- For each major piece of software, the function it performs, number of subroutines or functions needed to implement it, total lines of code to develop, degree of difficulty of the code, and an estimate of the total effort involved in developing the software with a comparison of this estimate with the one made at PDR and an explanation of any discrepancies.
- Definition of all interfaces syntaxes and standards.
- All interfaces designed.
- Tools needed to do the development and testing, and indicate which are already in use and what still needs to be procured.

- Design documentation for detector, and AO controller software of sufficient detail and completeness to allow coding of all software modules to begin immediately.

Project Management

- Review the overall fabrication, assemble, integration, and test schedule including the dates for remaining project milestones.
- In an appendix, provide a complete bottom-up schedule that includes all the remaining tasks discussed in the earlier presentations. For example, each major piece of software should be listed, each electronics custom board, each major mechanical assembly, optics fabrication and checking, etc.
- A report showing the current schedule and spending status of the Work, and showing the revised schedule and budget through completion.
- Provide a detailed bottom-up cost estimate based on the above detailed schedule. This can be in a closed session with only the review committee or a subset of it if the team prefers.
- An updated Management Plan for the remainder of the project. The Management Plan shall cover all of the remaining work necessary to fabricate, assemble, test, and commission IMAKA. This Management Plan shall include the following elements:
    - A Work Breakdown Structure (WBS) detailing all of the tasks necessary to design, fabricate, integrate, test, and commission IMAKA, with sub-tasks described down to the third level. Each WBS element should have a duration, cost, manpower required, and resources required. Each WBS element should also have a brief description of how duration, cost, manpower, and resources were calculated or estimated, together with an assessment of the margin of error in the amounts given. This information can be in a separate document keyed to the task numbers.
    - A schedule based upon the WBS, showing when each task will be completed.
    - A list describing the manpower, equipment, space, and other resources that will be needed to complete the work. This list must be based upon the WBS, and must include the estimated cost with a margin of error, the source of cost information, dates required, and any additional information about the resources availability.
    - A procurement list describing all of the components and materials that will need to be purchased. This list must have the description of the component/material, the estimated quantity with a margin of error, the estimated price with a margin of error, a description of the source of pricing information, and the date the procurement will need to be initiated.
    - A budget for the remainder of the work necessary to complete IMAKA. This must be based on the data in the WBS, the procurement list, and the resources list, and must include an overall margin of error.
    - The CVs of the proposed members of the IMAKA Team.

- Describe the management tools and systems for tracking and controlling changes to drawings, the fabrication of parts, parts testing to ensure they are consistent with the tolerances in the drawings, parts storage while awaiting assembly, and subsytem assembly and testing.
- A description of the management techniques that will be used to ensure that IMAKA is completed on schedule and on budget. This should include descriptions of the roles and responsibilities of each team member, an organization chart, and what mechanisms will be used to track schedule and budget as the work progresses.
- Provide a complete list of recommended spares and costs
- A proposed table of contents for the Manuals.