

CALTECH OPTICAL OBSERVATORIES / NASA JET PROPULSION LABORATORY
PALM-3000 PROJECT

PALM-3000
Project Management Plan (PMP)

CIN #627

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Revision Sheet

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0.1	11/7/07	Initial draft of all sections by A. Bouchez and R. Dekany
1.0	11/9/07	Added WBS dictionary, budgets, review guidelines. A. Bouchez.

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1 GENERAL INFORMATION

1.1 Purpose

This document is the Project Management Plan for the PALM-3000 adaptive optics system. It describes the management, communications, and risk mitigation functions for the PALM-3000 project.

1.2 Scope

The PMP addresses the following areas:

- Project Scope
- Work Breakdown Structure
- Resource Plan
- Project Schedule
- Risk Management Plan
- Document Control Plan
- Communications Plan

1.3 Acronyms and Abbreviations

AO	Adaptive Optics
BTO	Beam transfer optics (for laser beam transport from Coude to Prime focus)
DPM	Deputy Project Manager
DM	Deformable mirror
ERD	Enclosure Requirements Document
FPRD	Functional and Performance Requirements Document, superseded in P3K by the IRD and subsystem Requirements Documents (e.g. ERD, RRD).
HOWFS	High-order wavefront sensor
IAD	Instrument Architecture Document
IICD	Instrument Interface Control Document
IPT	Integrated Product Team
IRD	Instrument Requirements Document
IRTT	Infrared Tip/tilt Wavefront Sensor
LGS	Laser guide star
LOWFS	Low-order wavefront sensor (for PALM-3000 indicating tip/tilt/focus sensing)
Na	Sodium
NGS	Natural guide star
OSD	Observing Scenarios Document
P3K	PALM-3000
PALAO	The original NGS AO system at Palomar commissioned in December 1999
PALM-3000	The visible light AO upgrade to PALMAO
PALMAO	Upgrades to PALAO, particularly after the April 2003 upgrade
PALM LGS	The laser guide star upgrade to PALMAO
PBS	Product Breakdown Structure
PCP	P3K Commissioning Plan
PM	Project Manager

PS	Project Scientist
PSR	Pre-ship Review
POM	P3K Observer's Manual
RRD	RTC Requirements Document
SDM	System Design Manual
SwRD	Software Requirements Document
SRD	Science Requirements Document
TICD	Telescope Interface Control Document
TT	Tip/tilt
TWFS	Truth wavefront sensor
WBS	Work Breakdown Structure

1.4 Inputs

- P3K Science Requirements Document (SRD, CIN #612), R. Dekany
- P3K Instrument Interface Control Document (IICD, CIN #603), A. Moore
- P3K Observing Scenarios Document (OSD, CIN #623), A. Bouchez

1.5 Related Products

- P3K System Design Manual (SDM); J. Roberts
 - Note: many of the subsystem interfaces will be captured in the SDM, as opposed to a multitudinous collection of subsystem ICD's.
- P3K Observer's Manual (POM); A. Bouchez
- P3K TWiki Pages at:
http://www.oir.caltech.edu/twiki_oir/bin/view.cgi/Palomar/Palm3000/WebHome
- P3K Commissioning Plan (PCP); A. Bouchez

1.6 References

- Palomar LGSAO Standard Operating Procedures; R. P. Thicksten, J. Cromer

1.7 Points of Contact

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2 SCOPE MANAGEMENT

2.1 Scope Planning

The PALM-3000 project scope is defined by the science goals described in the Science Requirements Document (SRD), with the significant constraint that this project is an upgrade to the existing facility PALM LGS system. Our approach to scope planning, therefore, is to understand the minimal upgrade work scope that will meet the SRD, while minimizing disruption to the on-going science usage of PALM LGS. Input to this process includes the Observing Scenarios Document (OSD), which details the observational use cases for execution of typical SRD science programs. This work scope will then be organized into a work breakdown structure, based upon an existing product breakdown structure (e.g. the existing instrument), as modified by new PBS elements on the optical bench (such as new wavefront sensors) and new WBS elements specific to PALM-3000 (such as needed observatory infrastructure modifications.) The WBS will be verified by the subsystem Integrated Product Team (IPT) leaders, who have primary responsibility for confirming that all necessary work is captured in the WBS.

2.2 Scope Statement

The PALM-3000 project shall consist of a minimal (10-year lifecycle) cost upgrade of the PALM LGS system to integrate the a new 3,368 actuator DM, along with its supporting high-order wavefront sensor, real-time-computer, and instrument interface modifications to support multiple science instruments. This upgrade shall exploit the potential science benefits on bright NGS and support all PALM functionality in LGS mode. As a goal, PALM-3000 will increase LGS performance for large sky fraction according to the specifications in the IRD. Should higher LGS returns become available, PALM-3000 must have the capability of realizing the potential performance benefits, rivaling NGS performance given sufficient LGS photo-return.

2.2.1 Work Breakdown Structure

Based on the process described above, the top-level work breakdown structure for PALM-3000 has been defined as:

WBS 1	Management
WBS 2	Systems Engineering
WBS 3	Optical Bench
WBS 4	Adaptive Mirrors
WBS 5	Wavefront Sensors
WBS 6	Electronics
WBS 7	Embedded Systems
WBS 8	Operations Systems
WBS 9	Observatory Infrastructure
WBS 10	Laser Guide Star Facility
WBS 11	Commissioning

A WBS dictionary down to WBS level 2 is provided in Appendix A. A fully detailed WBS is provided in Appendix B.

2.2.2 Scope Verification

The formal acceptance of the PALM-300 project scope, its science priorities, instrument requirements, and set of deliverables will be verified at a Project Review to be held on November 12, 2007. All

stakeholders, including builders, users, collaborators, and senior management will be invited to this review to be held at the Caltech campus (8:30am-5:30pm, Salvatori Room, 365 S. Mudd building).

2.2.3 Scope Control

Once verified, the project scope, as defined by the WBS, will be placed under control of the project manager and a formal change control process established. This process will be based upon the formal approval of all scope changes by a Change Control Board consisting of the PM, DPM, PS, and the individual IPT Leads. In addition, scope changes resulting in *any* increase in project cost or schedule will require the advice of the Director of Caltech Optical Observatories, as representative of the Caltech Observatory Council.

Formally, the Change Control Process shall follow a standard series of actions:

1. Developing scope changes are discussed by staff and the IPT Leads of the affected work breakdown elements. These conversations should be based upon documented identification of a project variance or actualized technical risk, and be made in the context of several alternate mitigation strategies.
2. IPT Leads, the PM, the DPM, or the PS may initiate a Change Request by written submission to the PM, who is obliged to forward the issue the Change Control Board (CCB) for review.
3. The CCB discusses the Change Request and may undertake a technical study of the proposed change, to be completed within 10 working days.
4. The CCB advises the PM to accept or reject the Change Request.
5. If the Change Request results in project cost or schedule change, the PM shall seek concurrence of the PI and the COO Director.
6. The PM accepts or rejects the Change Request and issues to the full P3k Team a Change Control Notice (CCN) documenting the change.
7. If necessary, the PM revises the schedule or cost estimate to reflect the change in project scope.

3 TIME MANAGEMENT

3.1 Activity Definition and Sequencing

Based upon the initial WBS, the individual IPT Leads will add subsequently revised and expanded levels to the WBS down to the individual activity level. In some cases, where the specific activities cannot be initially predicted (as when the WBS element subsystem requirements are not yet known), the technique of rolling planning will be employed to develop the WBS in more detail as each work package start approaches.

3.2 Resource Estimation

IPT Leads will have primary responsibility for estimating resource requirements for the execution of the work within each of their work breakdown elements. In most cases, the IPT Leads have significant experience with the deployment of the original PALAO system, the PALM LGS upgrade, or both. IPT Leads will consult with staff assigned to the execution of the work to derive resource estimates based upon the experience of the team and our overall understanding of the technical challenge (risk assessment).

3.3 Duration Estimation and Scheduling

The IPT Leads will identify interdependencies of all activities within their work breakdown element. The project manager will then work with the corresponding COO and JPL line managers to negotiate the availability of resources for the execution of the work plan. Based upon the concurrent commitments of

staff to other projects, the PM will seek guarantees of availability of staff to P3K for the needed duration of their work packages.

Due to the small scale of the project, overall project sequencing will be performed by the project manager, and reviewed by the DPM, PS, and IPT Leads. The PM will take into account scheduled holidays and expected vacation and sick leave time when leveling the commitment level of all staff. The PM will utilize the critical path method to identify bottlenecks in the execution of the project and to recommend plan changes to maintain overall project schedule.

3.4 Schedule Control

Each IPT Lead will provide the PM with performance reports, which may be informal, detailing schedule performance, including which work packages have been started as scheduled, which have been completed as scheduled, or to raise issues requiring management attention in the future.

The schedule change control system will consist of the PM issuing periodic (if not regular) updates to the project schedule, relative to the initial schedule baseline, detailing newly scheduled activities arising from rolling project planning or other schedule modifications. The PM is empowered to issue these changes affecting all work elements contained in the development organizations (COO and JPL), but will seek concurrence from the respective facility or instrument lead for schedule changes effecting infrastructure, instrument I&T, or commissioning activities.

The PM may issue Recommended Corrective Actions to ensure timely completion of scheduled activities and bring future schedule performance in line with the approved schedule baseline. This may include redistribution of work among staff, requests for extended work periods, or scope reductions through the established Change Control Board process.

3.5 Schedule Baseline

The baseline high-level schedule, including key project milestone dates, is shown in Figure 1. Of particular interest are the expected dates of the system-level and subsystem-level reviews, which are listed in Table 4 and Table 3. A fully detailed baseline project schedule is provided Appendix B.

4 COST MANAGEMENT

4.1 Cost Estimation

The PALM-3000 project cost estimate is based primarily on a detailed understanding of the component hardware necessary for the PALM-3000 upgrade and the labor resource estimates developed during the activity resource estimation process described in Section 3.2. The following labor cost bases have been used to generate the cost estimate. They are based on a blended labor rate of all expected project participants, weighted by their fractional commitment.

- COO Labor \$74.50 / work-hour (1808 hours per work-year)
- JPL Labor \$80.93 / work-hour (1820 hours per work-year)

Hardware costs are usually based upon firm vendor quotes, but occasionally they rely on engineering judgment. The experience of the P3K team in having developed PALAO and PALM LGS provides significant background for analogous estimation of component costs.

All P3K cost estimates will be provided in FY07 dollars (corresponding to project initiation).

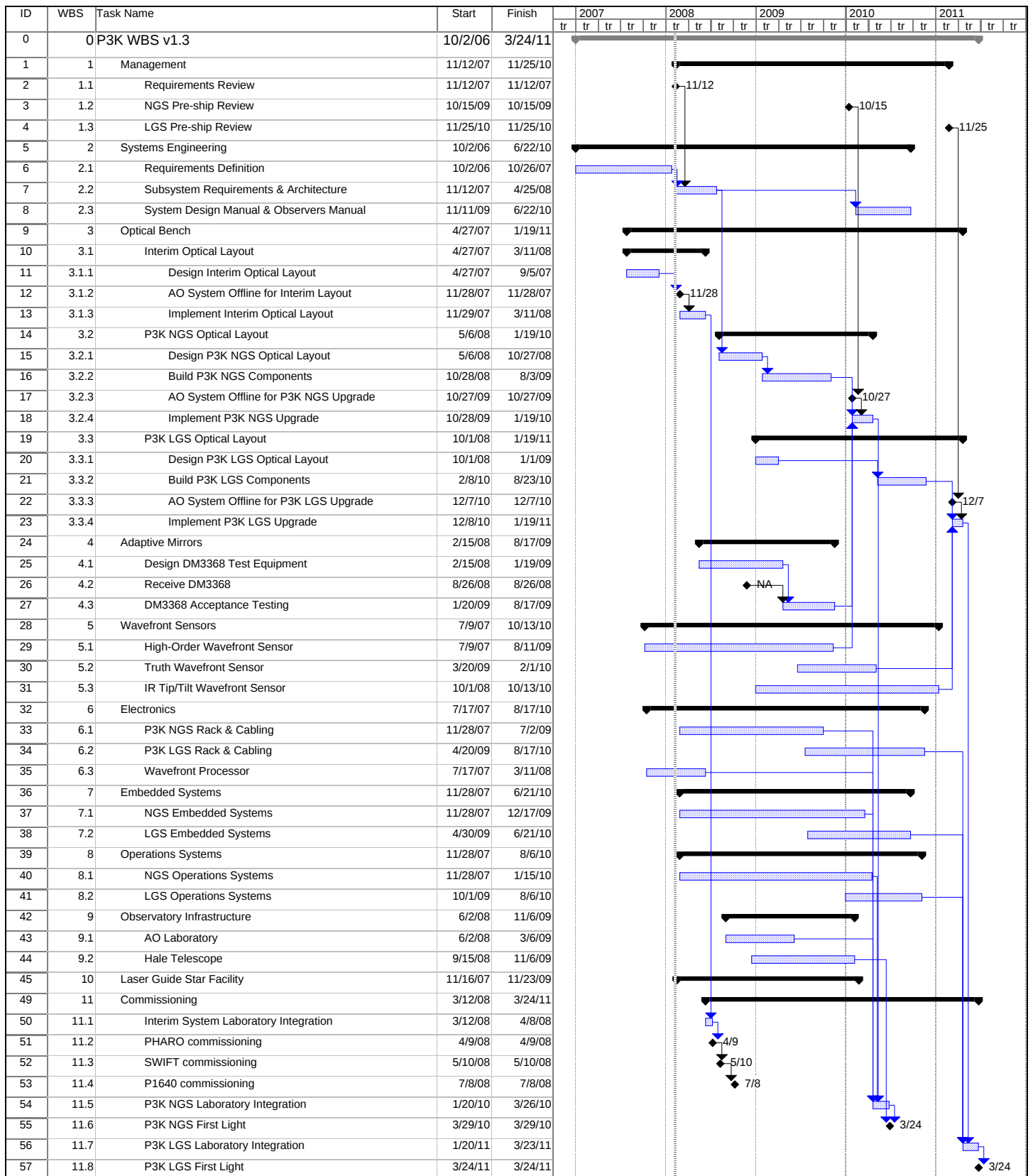


Figure 1: PALM-3000 Baseline Schedule (P3K WBS v1.3), showing only top-level work packages and major milestones.

4.2 Cost Budgeting

The breakdown of projects costs by WBS elements and fiscal year, along with the identified sources of funding, is presented in Table 1. The WBS elements have been combined into four broad categories, against which expenditures will be tracked. Funding sources marked in blue are contingent upon the continuation of the JPL MOU, and funding priorities at COO. A significant shortfall exists in FY09, due to the present lack of identified funds for development of the infrared tip/tilt sensor (IRTT). Our current strategy is to continue to actively seek additional funding for this subsystem, while carrying out the NGS PALM-3000 upgrade with the available funds.

Project costs by WBS	FY07	FY08	FY09	FY10	FY11
1-2: Mgmt. & Sys. Eng.	\$264,679	\$346,793	\$338,300	\$260,469	\$40,222
3-5: Bench, DMs & WFS	\$108,383	\$1,123,656	\$967,549	\$296,821	\$47,741
6-8: Software & Electronics	\$58,025	\$604,342	\$598,950	\$115,823	\$0
9-11: Facility & Commis.	\$0	\$311,315	\$119,230	\$159,100	\$119,416
Total	\$431,087	\$2,386,106	\$2,024,029	\$832,213	\$207,379

Identified Funding Sources					
NSF MRI	\$207,057	\$492,943	\$234,000	\$180,000	
JPL MOU	\$110,000	\$564,784	\$580,000	\$350,000	\$100,000
COO		\$200,000	\$400,000	\$300,000	\$110,000
Helin Funds	\$73,000	\$127,000			
DURIP	\$43,575	\$197,186			
NASA SBIR		\$800,000			
Total	\$433,632	\$2,381,913	\$1,214,000	\$830,000	\$210,000
Shortfall	\$2,545	-\$4,193	-\$810,029	-\$2,213	\$2,621

Table 1: Project costs and identified funding sources (\$FY07).

4.3 Cost Control

The PALM-3000 PM will generate, with COO Business Office support, regular financial reports describing performance metrics based upon Earned Value Analysis (TBC). This includes:

- Planned Value (PV) – the budgeted cost for the work scheduled
- Earned Value (EV) – the budgeted amount for work actually performed
- Actual Cost (AC) – the total cost incurred in accomplishing work
- Cost Variance (CV) – Equal to EV – AC
- Schedule Variance (SV) – Equal to EV – PV
- Cost Performance Index (CPI) – Equal to EV/AC
- Schedule Performance Index (SPI) – Equal to EV/PV

These metrics will be tracked from inception to date, though they may also be analyzed on a period basis (particularly AC, EV, CV, and CPI).

Analysis of project performance may result in a Change Request to change some aspect of the project through the standard Change Control Board process when project scope is affected, or in lesser Recommended Corrective Actions for scope neutral changes such as redistribution of activity budgets.

4.4 Major Procurements

PALM-3000 is a capital intensive project, requiring significant project resources expenditures on major hardware components. The major procurements, organized by delivery date, are described in Table 2.

Component	Vendor	Cost (\$FY07)	Delivery Date	Risk / Mitigation
DM3368	Xinetics, Inc.	\$800,000 including electronics	Expected Aug 2008	This is a single point failure risk for the project. No practical alternative is known matching our optical requirements (pupil size), nor does the project carry any contingency capable to developing alternative mirrors. Risk is mitigated by written specification of mirror requirements and frequent contact with the vendor (the development contract monitor is on the P3K team.)
IR Tip/Tilt Sensor (IRTT)	Custom development with COO based on Teledyne H2RG Detector	Est. \$760,000 including \$300,000 for the Teledyne array	Teledyne array in hand	Use of the H2RG array in a rapid region-of-interest (ROI) readout is a new application of this device for adaptive optics. Failure to meet IRTT performance goals will reduce performance for certain, high sky fraction science cases.
HOWFS CCD Camera	SciMeasure Analytical Systems, Inc. based upon E2V, Inc. 128x128 pixel CCD50 detector	\$80,000 including custom timing control board for LGS synchronization	Delivered Aug 2007	This camera appears functional, but characterization of its fundamental properties (quantum efficiency, dark current, etc.) will not be initiated until 2009 due to limited personnel resources.
Truth WFS (TWFS) CCD Camera	Custom development using SciMeasure CCD39-based detector	\$40,000	In hand	This camera will be a previously characterized CCD from the Palomar Tomograph project (R. Dekany, PI). Low risk.
Star Selection Mirrors (SSM's)	TBD	Est. \$40,000 hardware cost	TBD	P3K IRD requires the replacement of the current PALM LGS SSM's to meet precision dither motion and flexure control specifications. No commercial solutions are immediately available so may require custom engineering.
Real-time wavefront processor computer	Either Analog Devices TigerSharc or NVIDIA GForce	Up to \$210,000	February 2008	RTC funding is provided by an award from the AFOSR through the DURIP program. However, all components must be costed by

(RTC)	Graphic Chip Architectures (TBD)			February 2008. There is some risk that the preferred, lower cost NVIDIA option will not meet performance specifications. However, sufficient DURIP funds are in hand for a fallback TigerSharc architecture expected to meet requirements.
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Table 2: Major PALM-3000 procurements.

5 QUALITY ASSURANCE PLAN

5.1 Mini-PDRs

As a project upgrading an existing facility instrument, PALM-3000 will use a series of mini-PDR's (preliminary design reviews) for each major WBS element in lieu of a global PDR for the project (see Table 3.) The overall system-level description of the instrument is described in the IAD (Instrument Architecture Document) and the SoAD (Software Architecture Document). The use of mini-PDR's will allow in-depth concentration on the technical issues relevant to modifying each subsystem. Due to the compressed schedule for the project, there will be no subsequent mini- or global DDR (detailed design review). Instead, there will be for each upgrade phase of the project a PSR (Pre-Ship Reviews), which serve as milestones to assess project readiness for taking the AO system offline for that upgrade phase.

WBS	Subsystem	Date
1.3.4.1	Interim Optical Layout	4/20/07
1.3.4.2	Stimulus	12/14/07
1.3.4.3	Operations Systems	4/17/08
1.3.4.4	Real-time Computer	4/17/08
1.3.4.5	Electronics	6/19/08
1.3.4.6	High Order WFS	6/25/08
1.3.4.7	Embedded Control	8/5/08
1.3.4.8	NGS Optical Layout	11/5/08
1.3.4.9	Observatory Infrastructure	2/4/09
1.3.5.1	LGS Optical Layout	1/13/09
1.3.5.2	IR Tip/Tilt WFS	6/30/09
1.3.5.3	Truth WFS	7/20/09

Table 3: Expected dates for PALM-3000 subsystem mini-PDRs.

The organization, execution, and completion of action items arising from each mini-PDR shall be the responsibility of the WBS element Lead. Guidelines for mini-PDR's applicable to PALM-3000 as well as all Caltech Optical Observatory instrumentation projects are presented below:

- Attendance (minimum)
 - WBS element Leads for all interfacing subsystems
 - Two or more 'project external' experts

- Can be a remotely located reviewer (supported with prior approval of the PM) or a local technical expert not directly associated with the project
 - Project Management
 - Instrument Engineer, Deputy Project Manager, Project Manager, and PI
- Basic review outline
 - Review of the WBS Dictionary element for each work package
 - Subsystem requirements summary and traceability to governing documents
 - Interfaces
 - Design constraints
 - Proposed technical solution
 - Technical risks
 - Estimate of scope and schedule to completion, noting critical path
- Inputs
 - Documentation in support of the mini-PDR should be completely posted to the appropriate OIR TWiki review page (password protecting file-by-file if necessary) three working days prior to the review.
 - Review participants are expected to have reviewed posted material prior to the mini-PDR.
 - Minor revisions to presentation material leading up to the mini-PDR are acceptable.
- Output
 - Review minutes
 - A designated recorder for the meeting should produce a summary of the mini-PDR discussion, including:
 - Action items including a specific assignment, due date, and a customer to verify action completion (default will be the PM if left unspecified)
 - Observer comments
 - Mini-PDR observers are encouraged to forward notes, comments, or suggestions to the WBS element Lead upon completion of the review, with carbon copy to the PM. The WBS element Lead retains authority, with PM concurrence, to accept or ignore this advisory material.
 - Interface Control Documents
 - All design changes subsequent to mini-PDR that affect subsystem interfaces shall be documented in technical memoranda jointly agreed upon by affected WBS element Leads
 - System Design Manual
 - Design changes wholly internal to the WBS element shall be documented in the SDM, which supercedes the mini-PDR documentation as the final, as-built description of the instrument

5.2 Pre-Ship Reviews

Three pre-ship reviews (PSRs) are planned, to assess our readiness to perform the upgrades at Palomar Observatory at each stage of the project (see Table 4). The organization of the pre-ship reviews shall be the responsibility of the PM, with the relevant WBS leads taking part in the preparation of documentation, presentation of material, and the completion of action items. The guidelines for mini-PDRs apply, supplemented by the additional requirements below:

- Review Committee
 - A review committee consisting of two or more ‘project external’ experts, the Instrument Engineer, Deputy Project Manager, Project Manager, and PI shall be convened.
- Committee Charge
 - The committee shall develop a consensus recommendation regarding the project’s readiness for the proposed work.

WBS	Review	Date
1.3.3.1	Interim Relay Layout Pre-ship Review	11/21/07
1.3.3.2	PALM-3000 NGS Pre-ship Review	10/15/09
1.3.3.3	PALM-3000 LGS Pre-ship Review	11/25/10

Table 4: Expected dates of PALM-3000 system-level reviews.

6 HUMAN RESOURCE MANAGEMENT

6.1 Project Organization Chart

The key project roles are identified and described in the following Figure 2.

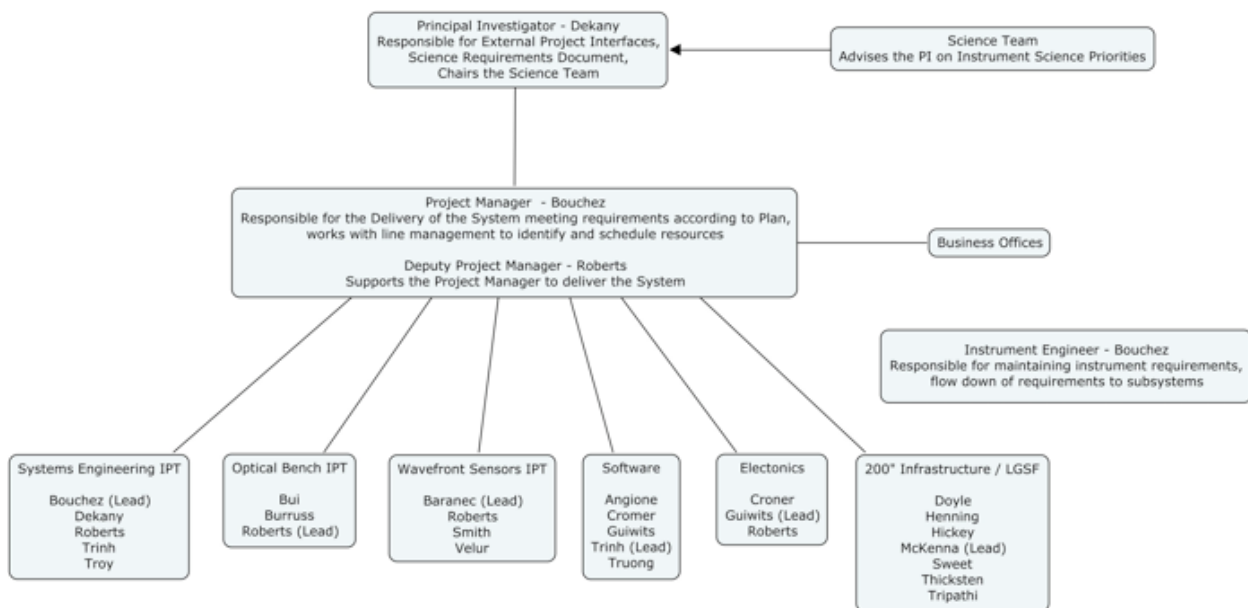


Figure 2: PALM-3000 organizational chart.

The majority of OIR staff report to the Associate Director for Development, Richard Dekany, Palomar staff report to Site Superintendent Dan McKenna, and the majority of JPL staff report to the Group Supervisor for the Adaptive Optics and Astronomical Instrument Group, Mitchell Troy.

6.2 Team Management

PALM-3000 shall be managed as a single project consisting of staff from several organizations, but all reporting to the P3K Project Manager for their responsibilities within the P3K project. The PM will maintain a Team Management Issue Log to capture emergent issues, develop potential solutions with staff involvement, and track through to the successful issue closure.

The Project Manager will track team member performance, provide feedback to staff and line management, resolve issues, and coordinate assignments to enhance project performance.\

7 COMMUNICATIONS MANAGEMENT

7.1 Responsibilities

The Project Scientist shall be responsible for the external distribution of information relevant to ensuring the science productivity of P3K and the overall strategic coordination among stakeholders pursuant to identification of project funding. This will include regular communication with the P3K Science Team, the Caltech Observing Council, external science partners at Oxford University and AMNH, and elsewhere.

The Project Manager shall be responsible for the internal distribution of information to the entire project team, including Approved Change Requests, performance metrics, changes to the schedule from the baseline, and task coordination between IPTs.

The Deputy Project Manager shall be responsible for regular external reporting the JPL STMC.

7.2 Team Meetings

The PM shall call periodic team ‘all-hands’ meetings to distribute timely information, highlight technical progress, and discuss project-wide management issues. We expect these meetings to be held with an approximately 3-month cadence, punctuated by an annual 2-3 day ‘many-hands’ retreat to assess annual project performance, identify new opportunities for organizational or execution efficiencies, and recognize personal achievement.

APPENDIX A. WBS DICTIONARY

WBS Number	Element Name	Element Description
1	Management	The business and administrative planning, organizing, directing, coordinating, controlling, and approval processes used to accomplish overall Project objectives that are not associated with specific hardware (HW) or software (SW) elements.
1.1	Science Management (SRD)	The technical and management efforts of directing and controlling the Science investigation aspects of the project. Includes the efforts associated with defining the science requirements and ensuring the integration of the science requirements with the instrument. The Principal Investigator (PI) manages relationships between other elements of the project and the science investigators. Includes maintenance of science documents, implementing support agreements and MOUs with external partners, serving as the scientific spokesperson for the project, coordinating student participation in the project, reporting to the funding institutions. Document products include Science Requirements Document; Observing Scenarios Document. Includes travel, workshops, and publications.
1.2	Planning Management (PMP)	Plan the overall project for delivery of the instrument. Includes project manager, deputy. Products include the Project Management Plan; budget and monthly financial reporting; Project Task Plan and Schedule; inputs to support agreements and MOUs with external partners.
1.3	Execution Management	Lead the overall project for delivery of the instrument. Includes project manager, deputy, IPT Leads. Includes project schedule management; IPT schedule and task management; setting up and participating in reviews (system and subsystem).
1.4	Communications Management	Inform team and sponsors of project progress. Includes team and sponsor meetings; vendor meetings; project website. Provides for setting up and attendance at project meetings. Provides the project internal website, which is the focal point for the project information management.
2	Systems Engineering	The technical and management efforts of directing and controlling an integrated engineering effort for the project. Includes conducting trade studies; the integrated planning and control of the technical program efforts of design engineering and integrated test planning; the effort to transform Project objectives into a description of system requirements and a preferred system configuration; the technical oversight and control effort for planning, monitoring, measuring, evaluating, directing, and replanning the management of the technical program. Documentation Products include Instrument Requirements Document (IRD), Instrument Architecture Document (IAD), Error Budget Summary (EBS), Software Requirements Document (SoRD), Software Architecture Document (SoAD), External Interface Control Documents, PALM-3000 Observer's Manual (POM), System Design Manual (SDM).
2.1	Instrument Requirements Document (IRD)	Top level requirements for the instrument derived directly from the science requirements.
2.2	Instrument Architecture Document (IAD)	Overall system architecture that fulfills the instrument requirements; provide the structure for the subsystems.

2.3	Error Budget Summary (EBS)	Provides estimates of the science performance based on the instrument architecture and environmental parameters
2.4	Software Requirements Document (SwRD)	Top level requirements for the system software derived from the instrument and science requirements.
2.5	Software Architecture Document (SwAD)	Overall system software architecture that fulfills the software requirements.
2.6	External Interface Control Documents	Optical, mechanical and software interface specifications for science instruments and other equipment which can be installed with the system.
2.7	PALM-3000 Observer's Manual (POM)	Instructions for use of the system on the telescope.
2.8	System Design Manual (SDM)	Complete documentation of the final system configuration. Includes optical and mechanical design documents; hardware specifications; software documentation.
3	Optical Bench	Perform overall instrument optical designs so that they meet science and instrument requirements at each stage of the project; Includes requirements definition, optical and mechanical design, procurement, assembly, alignment, and documentation for the final subsystem. Also includes procurement of stages and motors required for the design.
3.1	Interim Optical Layout (new instruments)	Design and implement a modified optical layout to accommodate new science instruments in FY08. Includes requirements definition; opto-mechanical design of layout; procurement; electronic interfaces to system; assembly; alignment; testing; design and performance documentation.
3.2	P3K NGS Optical Layout (DM, HOWFS, LOWFS)	Design and implement an optical layout for P3k NGS to include DM3368, DM349, the P3k HOWFS and the LOWFS. Includes requirements definition; opto-mechanical design of layout; procurement; electronic interfaces to system; assembly; alignment; testing; design and performance documentation.
3.3	P3K LGS Optical Layout (TWFS, IRTT)	Design and implement an optical layout for P3k LGS to include the TWFS, the IRTT and the selection mechanisms for these sensors in addition to the elements of the NGS layout. Includes requirements definition; opto-mechanical design of layout; procurement; electronic interfaces to system; assembly; alignment; testing; design and performance documentation .
4	Adaptive Mirrors	Procure, integrate and test adaptive mirrors. Includes contract management, testing along with the necessary equipment & test facilities, hardware integration and documentation.
4.1	DM3368 procurement	Procure DM3368. Includes requirements definition and contract management.
4.2	DM3368 auxiliary hardware	Design and build DM3368 auxiliary hardware. Includes protective cover, pupil mask and mounting base.
4.3	DM3368 acceptance testing	Test DM3368. Includes test plan, test equipment, testbed setup, actuator spatial and temporal performance measurements, wavefront measurements, documentation.
4.4	DM349 procurement	Procure new driver electronics for DM349. Includes requirements definition.
4.5	DM349 auxiliary hardware	Design and build new DM349 auxiliary hardware as needed. Includes protective cover, pupil mask and mounting base.

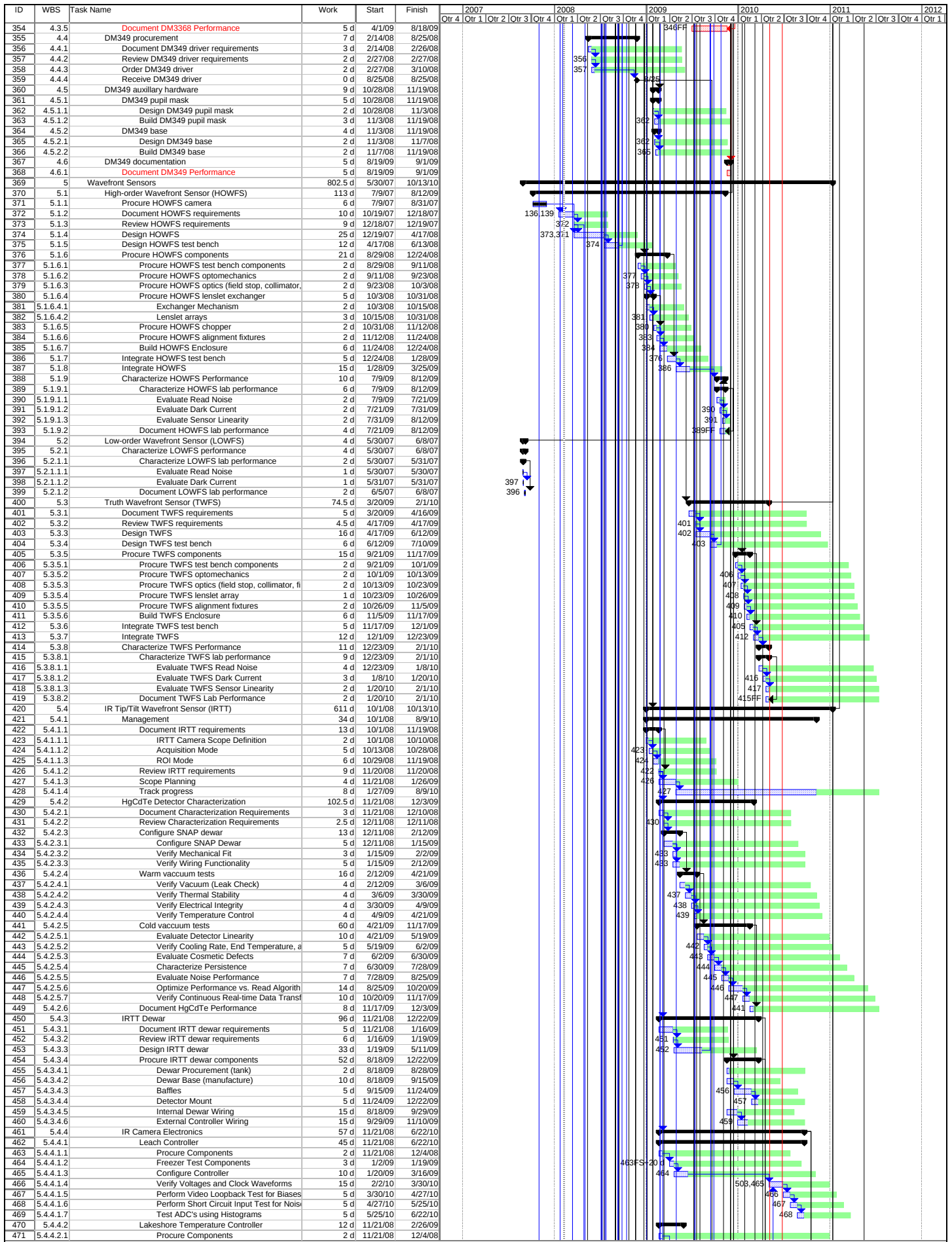
4.6	DM349 documentation	Verify and document DM349 performance with new electronics.
5	Wavefront Sensors	Design, build, and test wavefront sensor subsystems. Includes requirements definition, optical and mechanical design, procurement, assembly, alignment, testing and documentation of the final subsystem. Also includes equipment & test facilities needed to align and test each sensor.
5.1	High-order Wavefront Sensor (HOWFS)	Design and implement a visible sensor to measure high spatial frequencies in the wavefront from either an NGS or LGS. Includes requirements definition; WFS design; opto-mechanical design; procurement; electronic and mechanical interfaces to system; testbed setup; assembly; alignment; testing; design and performance documentation.
5.2	Low-order Wavefront Sensor (LOWFS)	Design and implement a visible sensor to measure low spatial frequencies in the wavefront from an NGS. Includes requirements definition; WFS design; opto-mechanical design; procurement; electronic and mechanical interfaces to system; testbed setup; assembly; alignment; testing; design and performance documentation.
5.3	Truth Wavefront Sensor (TWFS)	Design and implement a visible sensor to measure tip/tilt and focus in the wavefront from an NGS. Includes requirements definition; WFS design; opto-mechanical design; procurement; electronic and mechanical interfaces to system; testbed setup; assembly; alignment; testing; design and performance documentation.
5.4	IR Tip/Tilt Wavefront Sensor (IRTT)	Design and implement an IR sensor to measure tip/tilt in the wavefront from an NGS. Includes requirements definition; WFS design; opto-mechanical design; procurement; electronic and mechanical interfaces to system; testbed setup; assembly; alignment; testing; design and performance documentation.
6	Electronics	Design, build, and test instrument electronics for each stage of the project. Includes requirements definition, hardware procurement and assembly (power supply; real-time and supervisory control processors; memory; data storage; data collection; Analog-to-Digital (A to D) conversion; telemetry collection; cabling), testing and documentation of the final subsystem.
6.1	P3K NGS rack electronics	Design and implement electronics to support the P3k NGS system. Includes power, computers, motor controllers, mirror controllers, camera controllers.
6.2	P3K NGS Cabling	Design and implement cabling to support the P3k NGS system. Includes cabling internal to the racks, internal to the bench and between the bench and racks.
6.3	P3K LGS rack electronics	Design and implement electronics to support the P3k LGS system. Includes power, computers, motor controllers, mirror controllers, camera controllers.
6.4	P3K LGS Cabling	Design and implement cabling to support the P3k LGS system. Includes cabling internal to the racks, internal to the bench and between the bench and racks.
6.5	Wavefront Processor	Design and implement electronics to support the wavefront processors in the P3k system.

7	Embedded Systems	Design, code, integrate and test the embedded systems software. Includes requirements definition; software to control system hardware, pass information between software subsystems, process WFS data and perform real-time loop calculations; testing; documentation.
7.1	Supervisory Control Software	Design and implement software to control P3k system hardware; control the interaction between the user interface, wavefront processors and telemetry system; provide telemetry on system configuration. Includes requirements definition, coding, hardware test setup, testing and documentation.
7.2	RTC Software	Design and implement real-time software to process data from the wavefront sensors, reconstruct the wavefront, provide open- and closed-loop control to the adaptive mirrors and provide telemetry on the wavefront sensor data, adaptive mirrors and real-time system parameters. Includes requirements definition, coding, hardware test setup, testing and documentation.
8	Operations Systems	Design, code, integrate and test the operations systems and software. Includes requirements definition; software for the user interface and upper level automations; user workstation design and setup; testing of software and hardware; documentation.
8.1	Dataroom workstation	Design and implement a workstation to host the system software, user interface and telemetry system. Includes requirements definition, coding, procurement, hardware test setup, testing and documentation.
8.2	Operations Software	Design and implement software for the user interface, non-real-time system automations and telemetry system. Includes requirements definition, coding, hardware/software test setup, testing and documentation.
9	Infrastructure	External systems that provide support for the instrument. Includes instrument electronic and mechanical requirements on the telescope as well as in the lab and software interfaces to facility data systems.
9.1	Hale Telescope	Installation of the instrument on the telescope. Includes input power (current), output power (thermal) and weight requirements.
9.2	AO Laboratory	Installation of the instrument in the Palomar lab. Includes input power (current), support structure and cleanliness requirements.
9.3	P18 MASS / DIMM	Interface with the MASS/DIMM to transfer atmospheric information to the AO system.
10	Laser Guide Star Facility	Upgrades to existing Laser Guide Star facility to meet science requirements. Includes facility modifications and laser installation.
10.1	Laser Laboratory	Location of Na guidestar laser. Includes modifications to laser facility to improve ease of use, cleanliness and provide space for additional lasers.
10.2	Beam Transfer Optics	Control of laser beam from Laser Lab to Laser Launch Telescope. Includes modifications to the BTO as needed with Laser Lab changes.
10.3	Laser Launch Telescope	Projects Na guidestar laser out to the Na layer.
10.4	CSFL Subsystem	Current Na guidestar laser. Will be used with P3k system as it is with the PALAO system.
10.5	Future Lasers	Additional Na guidestar lasers to be borrowed or purchased. Includes installation and integration of the laser at Palomar.

11	Commissioning	Integrate and functionally test the instrument assembly. Test and verify hardware and software interfaces. Characterize Instrument performance. Includes lab and on-sky testing with each science instrument.
11.1	PALM-241 / PHARO integration and testing	Integrate and test the Interim Optical Bench Layout with PHARO. Includes alignment and calibration to PHARO, in-lab closed-loop performance testing, on-sky performance testing (NGS and LGS).
11.2	PALM-241 / SWIFT integration and testing	Integrate and test the Interim Optical Bench Layout with SWIFT. Includes alignment and calibration to SWIFT, in-lab closed-loop performance testing, on-sky performance testing (NGS and LGS).
11.3	PALM-241 / P1640 integration and testing	Integrate and test the Interim Optical Bench Layout with P1640. Includes alignment and calibration to P1640, in-lab closed-loop performance testing, on-sky performance testing (NGS and LGS).
11.4	PALM-3000 NGS integration and testing	Integrate and test the P3k NGS system with PHARO. Includes complete software check-out, alignment and calibration to PHARO, in-lab closed-loop performance testing for all operating modes, on-sky performance testing (NGS and LGS).
11.5	PALM-3000 LGS integration and testing	Integrate and test the P3k LGS system with PHARO. Includes complete software check-out, alignment and calibration to PHARO, in-lab closed-loop performance testing for all operating modes, on-sky performance testing (NGS and LGS).

APPENDIX B. DETAILED WBS AND BASELINE SCHEDULE

	WBS	Task Name	Work	Start	Finish	2007 Qtr 4	2008 Qtr 1	2008 Qtr 2	2008 Qtr 3	2009 Qtr 4	2010 Qtr 1	2010 Qtr 2	2010 Qtr 3	2011 Qtr 4	2012 Qtr 1
0		P3K WBS v1.3	5,570.5 d	10/2/06	11/30/11										
1	1	Management	1,473 d	10/2/06	12/8/10										
2	1.1	Science Management (SRD)	59 d	10/2/06	10/1/10										
3	1.1.1	Write SRD	7 d	10/2/06	2/16/07										
4	1.1.2	Write observing scenarios document	2 d	2/19/07	4/13/07										
5	1.1.3	Science Team Reporting	10 d	10/2/06	10/1/10										
6	1.1.4	Observatory Council Reporting	20 d	10/2/06	10/1/10										
7	1.1.5	STMC Reporting	20 d	10/2/06	10/1/10										
8	1.1.6	Summer student support	0 d	10/2/06	10/1/10										
9	1.2	Planning Management (PMP)	40 d	8/8/07	10/1/10										
10	1.2.1	Draft PMP Outline	1 d	8/8/07	8/21/07										
11	1.2.2	Write PMP	25 d	8/22/07	10/17/07										
12	1.2.3	Maintain PMP	5 d	10/18/07	10/1/10										
13	1.2.4	Monthly Earned Value Reports	9 d	10/1/07	10/1/10										
14	1.2.5	P3K LGS funding secured	0 d	10/1/08	10/1/08										
15	1.3	Execution Management	1,017 d	10/2/06	12/8/10										
16	1.3.1	Project Management	200 d	10/2/06	10/1/10										
17	1.3.2	IPT Leadership	400 d	10/2/06	10/1/10										
18	1.3.3	System Level Reviews	115 d	10/9/07	12/8/10										
19	1.3.3.1	Conceptual Design Review (CoDR)	11 d	10/9/07	11/26/07										
20	1.3.3.1.1	Invite CoDR participants	1 d	10/9/07	10/12/07										
21	1.3.3.1.2	Distribute CoDR documentation	1 d	10/19/07	10/22/07										
22	1.3.3.1.3	Conduct P3K CoDR	7 d	11/12/07	11/12/07										
23	1.3.3.1.4	Document CoDR outcome	2 d	11/13/07	11/26/07										
24	1.3.3.2	P3K NGS Pre-Ship Review (NGS PSR)	55.5 d	8/20/09	10/27/09										
25	1.3.3.2.1	Invite NGS PSR participants	1 d	8/20/09	8/25/09										
26	1.3.3.2.2	Schedule date and venue	0.5 d	8/20/09	8/21/09										
27	1.3.3.2.3	Produce NGS PSR documentation	28 d	9/2/09	9/23/09										
28	1.3.3.2.4	Distribute NGS PSR documentation	1 d	9/24/09	9/24/09										
29	1.3.3.2.5	Prepare NGS PSR responses	14 d	10/9/09	10/14/09										
30	1.3.3.2.6	Conduct P3K NGS PSR	7 d	10/15/09	10/15/09										
31	1.3.3.2.7	Document NGS PSR outcome	4 d	10/16/09	10/27/09										
32	1.3.3.3	P3K LGS Pre-Ship Review (LGS PSR)	48.5 d	9/30/10	12/8/10										
33	1.3.3.3.1	Invite LGS PSR participants	1 d	9/30/10	10/6/10										
34	1.3.3.3.2	Schedule date and venue	0.5 d	9/30/10	10/4/10										
35	1.3.3.3.3	Produce LGS PSR documentation	24 d	10/13/10	11/4/10										
36	1.3.3.3.4	Distribute LGS PSR documentation	1 d	11/4/10	11/5/10										
37	1.3.3.3.5	Prepare LGS PSR responses	12 d	11/19/10	11/25/10										
38	1.3.3.3.6	Conduct P3K LGS PSR	6 d	11/25/10	11/26/10										
39	1.3.3.3.7	Document LGS PSR outcome	4 d	11/26/10	12/8/10										
40	1.3.4	P3K NGS Subsystem Preliminary Design Reviews	223 d	4/11/07	4/6/09										
41	1.3.4.1	Interim Optical Layout Preliminary Design Re	22 d	4/11/07	9/1/07										
42	1.3.4.1.1	Invite participants	1 d	4/11/07	9/1/07										
43	1.3.4.1.2	Schedule date and venue	1 d	4/11/07	4/11/07										
44	1.3.4.1.3	Produce documentation	3 d	4/12/07	4/19/07										
45	1.3.4.1.4	Conduct Interim Optical Layout PDR	6 d	4/20/07	4/20/07										
46	1.3.4.1.5	Document review outcome	1 d	4/23/07	4/23/07										
47	1.3.4.1.6	Respond to review action items	10 d	4/24/07	9/11/07										
48	1.3.4.2	Stimulus Preliminary Design Review (STIM P	16 d	11/28/07	1/18/08										
49	1.3.4.2.1	Invite participants	0.5 d	11/28/07	11/29/07										
50	1.3.4.2.2	Schedule date and venue	0.5 d	11/28/07	11/29/07										
51	1.3.4.2.3	Produce documentation	2 d	12/18/07	12/26/07										
52	1.3.4.2.4	Conduct Stimulus PDR	7 d	12/26/07	1/2/08										
53															



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ID	WBS	Task Name	Work	Start	Finish	2007				2008				2009				2010				2011				2012
						Qtr 4	Qtr 1	Qtr 2	Qtr 3	Qtr 4	Qtr 1	Qtr 2	Qtr 3	Qtr 4	Qtr 1	Qtr 2	Qtr 3	Qtr 4	Qtr 1	Qtr 2	Qtr 3	Qtr 4	Qtr 1	Qtr 2	Qtr 3	Qtr 4
590	6.1.5.2.2	DM 349 Driver	23 d	2/9/09	4/14/09																					
591	1.5.2.2.1	Interface Board	8 d	2/9/09	3/3/09																					
592	1.5.2.2.2	Driver Boards	12 d	3/3/09	4/6/09																					
593	1.5.2.2.3	DM 349 Cable Interface Panel	3 d	4/6/09	4/14/09																					
594	6.1.5.2.3	Fiber Interface Panel	4 d	4/14/09	4/24/09																					
595	1.5.2.3.1	Shutter Connector	2 d	4/14/09	4/20/09																					
596	1.5.2.3.2	White Light Fiber Connector	1 d	4/20/09	4/22/09																					
597	1.5.2.3.3	Laser Fiber Connector	1 d	4/22/09	4/24/09																					
598	6.1.5.2.4	High Voltage Power Supply	4 d	4/24/09	5/6/09																					
599	6.1.5.2.5	Video Monitor	2 d	5/6/09	5/12/09																					
600	6.1.5.2.6	Cooling Fan	2 d	5/12/09	5/22/09																					
601	6.1.5.2.7	Rack Power Supply	10 d	7/24/08	8/21/08																					
602	1.5.2.7.1	Power supply	5 d	7/24/08	8/7/08																					
603	1.5.2.7.2	Remote Power Switch	5 d	8/7/08	8/21/08																					
604	6.1.5.3	Modify lights and drivers rack for P200 install	8 d	7/24/08	8/15/08																					
605	6.1.5.3.1	Cooling Enclosure	3 d	7/24/08	8/1/08																					
606	6.1.5.3.2	Heat Exchanger	3 d	8/1/08	8/11/08																					
607	6.1.5.3.3	Mounting hardware	2 d	8/11/08	8/15/08																					
608	6.1.5.4	Integrate Lights and Drivers Rack Electronics	10 d	5/22/09	6/19/09																					
609	6.1.5.5	Verify Lights and Drivers Electronics Function	15 d	6/19/09	7/3/09																					
610	6.1.6	DM3368 Rack	42 d	1/15/08	1/14/09																					
611	6.1.6.1	Layout DM3368 rack electronics	4 d	1/15/08	2/7/08																					
612	6.1.6.2	Modify DM3368 rack for P200 installation	8 d	7/24/08	8/15/08																					
613	6.1.6.2.1	Cooling Enclosure	3 d	7/24/08	8/1/08																					
614	6.1.6.2.2	Heat Exchanger	3 d	8/1/08	8/11/08																					
615	6.1.6.2.3	Mounting hardware	2 d	8/11/08	8/15/08																					
616	6.1.6.3	Install DM3368 Electronics	15 d	10/15/08	12/22/08																					
617	6.1.6.3.1	DM3368 Drivers	10 d	10/15/08	12/12/08																					
618	6.1.6.3.2	Power Supply	5 d	12/12/08	12/22/08																					
619	1.6.3.2.1	Power supply	3 d	12/12/08	12/22/08																					
620	1.6.3.2.2	Remote power switch	2 d	12/12/08	12/18/08																					
621	6.1.6.4	Verify DM 3368 electronics functionality	15 d	12/24/08	1/14/09																					
622	6.2	P3K NGS Cabling	84 d	4/1/08	6/17/09																					
623	6.2.1	Document P3K NGS cabling requirements	10 d	4/1/08	5/12/08																					
624	6.2.2	Review P3K NGS cabling requirements	3 d	5/13/08	5/13/08																					
625	6.2.3	Design P3K NGS cabling	10 d	5/13/08	6/11/08																					
626	6.2.4	Build P3K NGS Cables	37 d	7/24/08	12/24/08																					
627	6.2.4.1	Rack - Rack Cables	10 d	7/24/08	9/4/08																					
628	6.2.4.2	Bench - Rack Cables	26 d	9/4/08	12/19/08																					
629	6.2.4.2.1	Monster Motor Cable	2 d	9/4/08	9/11/08																					
630	6.2.4.2.2	DM 349 Cables	5 d	9/11/08	10/2/08																					
631	6.2.4.2.3	DM 3326 Cables	10 d	10/2/08	11/11/08																					
632	6.2.4.2.4	Laser Light Source Fiber	1 d	11/11/08	11/14/08																					
633	6.2.4.2.5	NGS Source Fiber	1 d	11/14/08	11/19/08																					
634	6.2.4.2.6	Yellow Light Fiber	1 d	11/19/08	11/24/08																					
635	6.2.4.2.7	HOWFS Power Cable	1 d	11/24/08	12/1/08																					
636	6.2.4.2.8	HOWFS Data Cable	2 d	12/1/08	12/8/08																					
637	6.2.4.2.9	LOWFS Power Cable	1 d	12/8/08	12/11/08																					
638	6.2.4.2.10	LOWFS Data Cable	2 d	12/11/08	12/19/08																					
639	6.2.4.3	Rack - Instrument Cables	1 d	12/19/08	12/24/08																					
640	6.2.4.3.1	Instrument Shutter Signal Cable	1 d	12/19/08	12/24/08																					
641	6.2.5	Document P3K NGS Cabling	24 d	12/24/08	6/17/09																					
642	6.2.5.1	Document P3K NGS Installation and Deinstal	4 d	12/24/08	1/28/09																					
643	6.2.5.2	Document P3K LGS Full System Schematics	20 d	1/28/09	6/17/09																					
644	6.3	P3K LGS rack electronics	34.5 d	4/20/09	8/17/10																					
645	6.3.1	Document P3K LGS rack electronics requirements	7.5 d	4/20/09	5/22/09																					
646	6.3.2	Review rack electronics requirements	3 d	5/25/09	5/25/09																					
647	6.3.3	P3K LGS Controller Rack	24 d	5/25/09	8/17/10																					
648	6.3.3.1	Layout P3K LGS Controller Rack Electronics	4 d	5/25/09	6/16/09																					
649	6.3.3.2	Build P3K LGS Controller Rack Electronics	10 d	6/16/09	7/14/09																					
650	6.3.3.2.1	TWFS Camera Controller Chassis	5 d	6/16/09	7/14/09																					
651	3.3.2.1.1	TWFS Camera Controller	5 d	6/16/09	7/14/09																					
652	6.3.3.2.2	IRTT Camera Controller Chassis	5 d	6/16/09	7/14/09																					
653	3.3.2.2.1	IRTT Camera Controller	5 d	6/16/09	7/14/09																					
654	6.3.3.3	Integrate P3K LGS Controller Rack Electronic	10 d	6/22/10	8/17/10																					
655	6.4	P3K LGS Cabling	34 d	4/20/09	8/20/09																					
656	6.4.1	Document P3K LGS cabling requirements	10 d	4/20/09	5/29/09																					
657	6.4.2	Review P3K LGS cabling requirements	3 d	6/1/09	6/1/09																					
658	6.4.3	Design P3K LGS cabling	5 d	6/1/09	6/15/09																					
659	6.4.4	Build P3K LGS Cables	10 d	6/15/09	7/9/09																					
660	6.4.4.1	Rack - Rack Cables	3 d	6/15/09	6/23/09																					
661	6.4.4.2	Bench - Rack Cables	7 d	6/23/09	7/9/09																					
662	6.4.4.2.1	TWFS Power Cable	1 d	6/23/09	6/25/09																					
663	6.4.4.2.2	TWFS Data Cable	2 d	6/25/09	7/1/09																					
664	6.4.4.2.3	IRTT Power Cable	1 d	7/1/09	7/3/09																					
665	6.4.4.2.4	IRTT Data Cable	2 d	7/3/09	7/9/09																					
666	6.4.4.2.5	Temperature controller cables	1 d	6/23/09	6/25/09																					
667	6.4.5	Document P3K LGS Cabling	6 d	7/9/09	8/20/09																					
668	6.4.5.1	Document P3K LGS Installation and Deinstal	2 d	7/9/09	7/23/09																					
669	6.4.5.2	Document P3K LGS Full System Schematics	4 d	7/23/09	8/20/09																					
670	6.5	Wavefront Processor	75 d	7/17/07	3/11/08																					
671	6.5.1	Wavefront Processor Development System	43 d	7/17/07	11/2/07																					
672	6.5.1.1	Document WFP requirements	2 d	7/17/07	7/27/07																					
673	6.5.1.2	Review WFP requirements	4 d	7/27/07	7/30/07																					
674	6.5.1.3	Design WFP development system	20 d	7/30/07	8/27/07																					
675	6.5.1.4	Procure WFP development system	2 d	8/27/07	8/31/07																					
676	6.5.1.5	Integrate WFP development system	5 d	10/12/07	10/19/07																					

