MRO FTT/NAS & FLC

FTT/NAS & FLC Development Plan

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The Cambridge FTT Team

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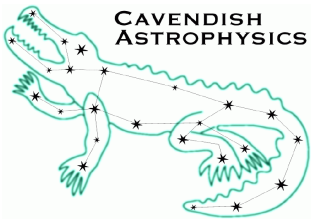
3 September 2010



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Change Record

Revision	Date	Author(s)	Changes
0.1	2010-08-26	MF	Initial draft
0.2	2010-08-30	MF	Main body incorporated
0.3	2001-09-10	CAH	Adjust content to refer to SOW
0.4	2010-09-02	MF	Insert revised figures. Minor corrections
0.5	2010-09-03	CAH	Minor typographical corrections
0.6	2010-09-03	MF	Inserted new systems figures and text
0.7	2010-09-03	MF/CAH	Minor corrections
1.0	2010-09-03	JSY	Final cosmetic edits

Objective

To outline the development plan for the Preliminary Design Phase of the FTT/NAS & FLC work-package.

Scope

The development plan for the whole of the Preliminary Design Phase of the MROI FTT/NA system is presented. This activity is split into two distinct phases of work, of which only the first phase (Phase 1a) has been funded. NMT have an option to fund the second phase (Phase 1b) of the activity should they wish. This option must be exercised by Spring 2011.

Reference Documents

RD1 Statement of Work: Fast Tip Tilt/NA System Development – Phase 1a and Option for Phase 1b (INT-403-CON-0128) – Version of June 16th 2010

Applicable Documents

None

Acronyms and Abbreviations

FTT Fast Tip-Tilt

FLC First Light Camera

ICD Interface Control Document

ISS Interferometer Supervisory System

MROI Magdalena Ridge Observatory Interferometer

NAS Narrow-field Acquisition System

NMT New Mexico Tech

TBC To be confirmed

TBD To be determined

UT Unit Telescope

Table of Contents

1 Introduction

The goals of Phase 1 of the FTT/NAS development work package are the completion of the conceptual and preliminary design of the fast tip-tilt (FTT) and narrow-field acquisition system (NAS) for the unit telescopes of the Magdalena Ridge Observatory Interferometer (MROI) and the delivery of a First Light Camera (FLC) suitable for use with the first AMOS delivered Unit Telescope (UT).

The scope of Phase 1 that forms the subject of this Development Plan involves two sub-phases:

1. Phase 1a: Conceptual design of the FTT/NAS and FLC systems, substantial completion of the preliminary design of the FTT/NA and FLC systems and the submission of an Interim Preliminary Design Report.
2. Phase 1b: Laboratory testing, shipment, installation and acceptance testing of the FLC system in New Mexico, submission of the Preliminary Design Report for the FTT/NA system – including results of risk-reduction experiments and integrated testing of a prototype – and participation in a PDR.

The eventual delivery of a working FTT/NA system will be the subject of Phase 2 of the FTT/NAS development work package and is not part of the scope of this review process. It is expected that the statement of work and contract between NMT and the University of Cambridge to cover this final part of the delivery will be developed in early 2011.

In the text below we first review the system components for the FTT/NA and FLC (section 1.1) and then present product trees for the FTT/NA and FLC systems individually. Our development strategy is described in brief in section 2 which gives an overview of the work breakdown structure for the Preliminary Design Phase and also identifies the most important near-term tasks. Finally we present a milestone schedule in section 3 and discuss the risks associated with the FTT/NAS development work package in section 4.

A much more complete presentation of the specific tasks, resourcing and elapsed times required for each of the elements of the work breakdown structure outlined here can be found in the contractual "Statement of Work" associated with Phases 1a and 1b of FTT/NAS development work package (RD1). We have assumed the reader has full access to that document and so in this document we have primarily focused on areas which may have changed since that document was prepared (June 16th 2010) or topics that are not covered there.

1.1 FTT/NAS and FLC system overview

1.1.1 FTT/NA system overview

The components of the hardware system we are required to deliver are shown in schematic form in Figure 1 for the FTT/NA system. The major component parts of the system to be delivered are shown in the yellow blocks except for the common base-plate which is shown in outline only, for clarity. The illustration does not show the EIE cooling system which will connect to the camera cooling control nor the enclosure air supply to the air dryer equipment. Connections to other components of the FTT/NA system not supplied by this work-package are shown for completeness. However, apart from these items, it serves to remind the reader of the components and interfaces that are referred to in the product trees that are presented in the following subsections.

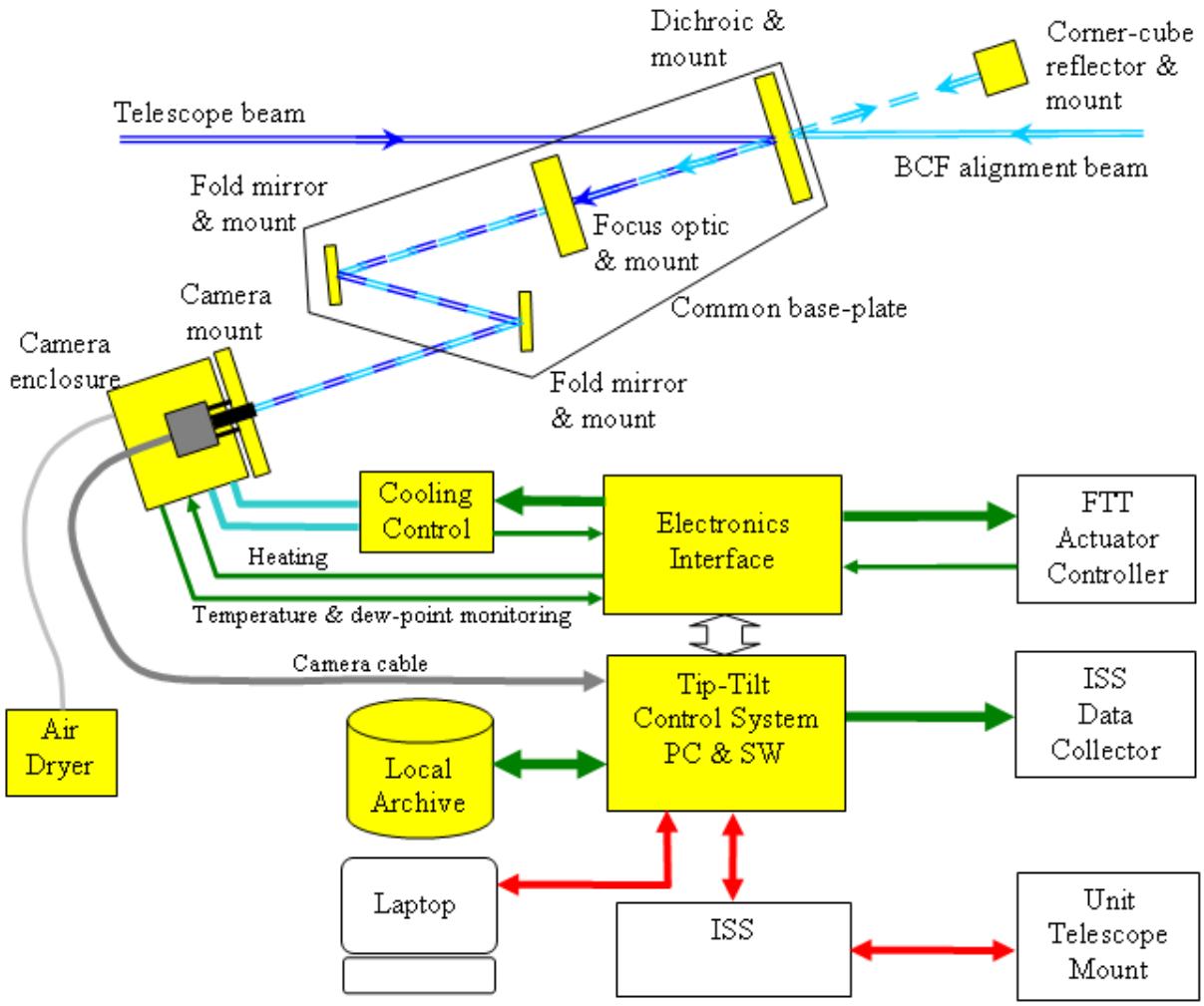

Figure 1: Illustration of the component parts of the FTT/NA System. The deliverable parts are blocked in yellow apart from the common base-plate which is shown in outline only for clarity. The corner cube is to be supplied by the customer, though one will be required for our system-level testing. Telescope enclosure services to the cooling control block and air drying block are not shown.

1.1.2 FLC System overview

The components of the hardware system we are required to deliver for the FLC system are shown in schematic form in Figure 2. The major component parts of the system to be delivered are shown in the yellow blocks. The camera mount and enclosure, cooling control and air dryer, and the electronics interface are identical to the components to be supplied for the FLT-NA system. The focus optic and mount, the fold mirror and mount and an exchangeable filter which is to be incorporated into the camera enclosure assembly are all specific to the FLC design. The illustration does not show the EIE cooling system which will connect to the camera cooling control nor the enclosure air supply to the air dryer equipment. Connections to other components of the FTT/NA system not supplied by this work-package are shown for completeness. However, apart from these items, it serves to remind the reader of the components and interfaces that are referred to in the product trees that are presented in the following subsections.

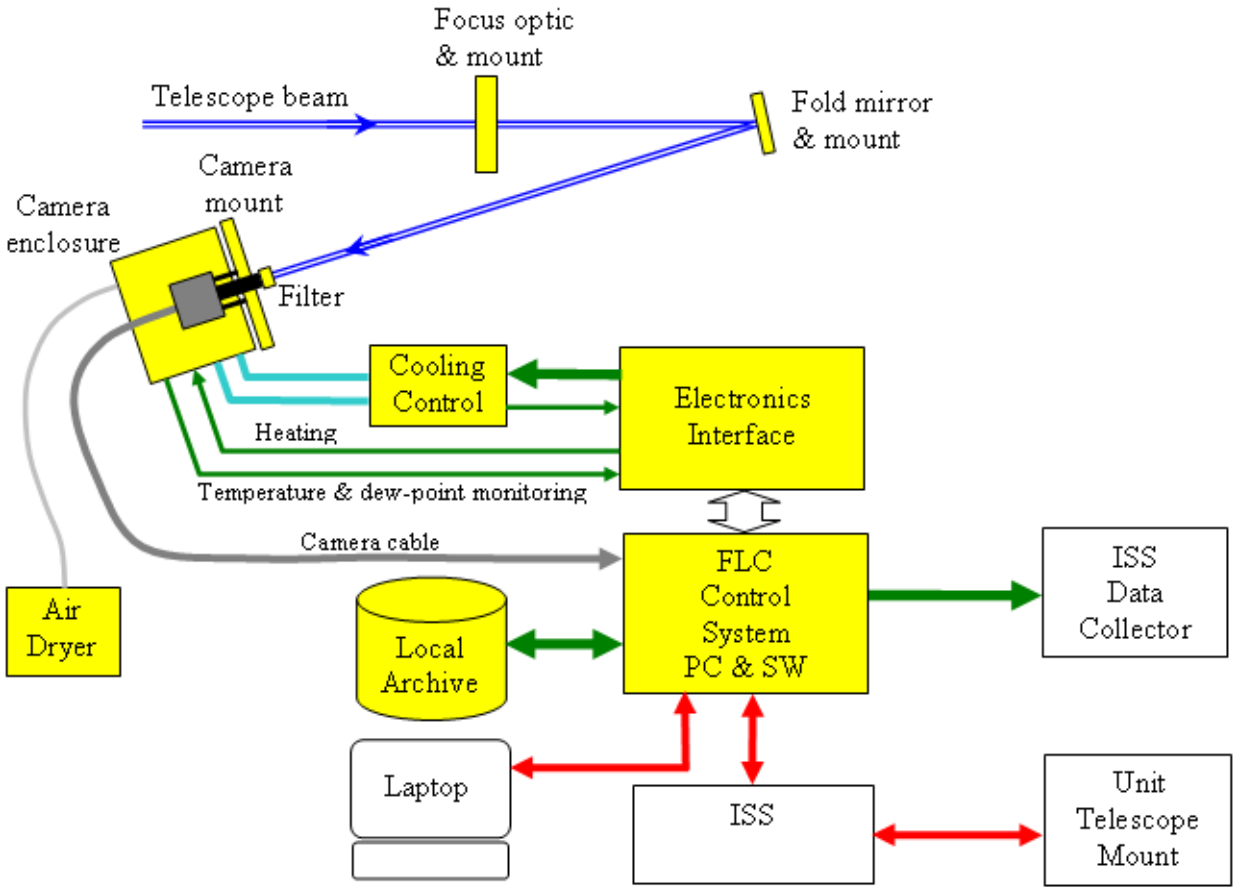

Figure 2: Illustration of the component parts of the FLC System. The deliverable parts are blocked in yellow. The camera mount and enclosure, cooling control and air dryer, and the electronics interface are identical to the components to be supplied for the FLT-NA system. The focus optic and its mount and the fold mirror are specific to the FLC design and an exchangeable filter is to be incorporated into the camera enclosure assembly. Telescope enclosure services to the cooling control block and air drying block are not shown.

1.2 Product Trees

The full list of Cambridge deliverables originally associated with Phases 1a and 1b of the FTT/NAS development work package is presented in section 5.1 of RD1. Since that document was prepared, we have agreed with NMT that one addition be made to the list of hardware components delivered:

1. The equipment needed to dry the air supplied to the FLC (and FTT/NAS in Phase2).

In order to help better understand the detail of the components comprising the deliverables enumerated in RD1 we provide below two product trees, one for the FTT/NA system and one for the FLC system. There are a number of common items between the two systems, notably the camera system, the camera enclosure, the computer system and interfaces, the custom electronics interface and the provision of cooling and dry air facilities. There are, however, expected to be no common optics nor common mounts other than the camera mount.

The software that will be delivered with the FLC camera will be limited to what is required for the FLC purposes except where the camera driver is common to the FTT/NAS application. However, it will be possible to run the FLC software system on the final hardware delivered in Phase 2 for the FTT/NA system. In that way, a fully compliant FTT/NA system will be able to emulate an FLC should the need arise.

1.2.1 FTT/NAS Product tree

The product tree for the FTT/NA system is shown in Figure 3. This lists the expected components of the FTT/NA system determined by our conceptual design. There is no associated deliverable list as the statement of work for Phase 2 of the work-package has not been developed yet.

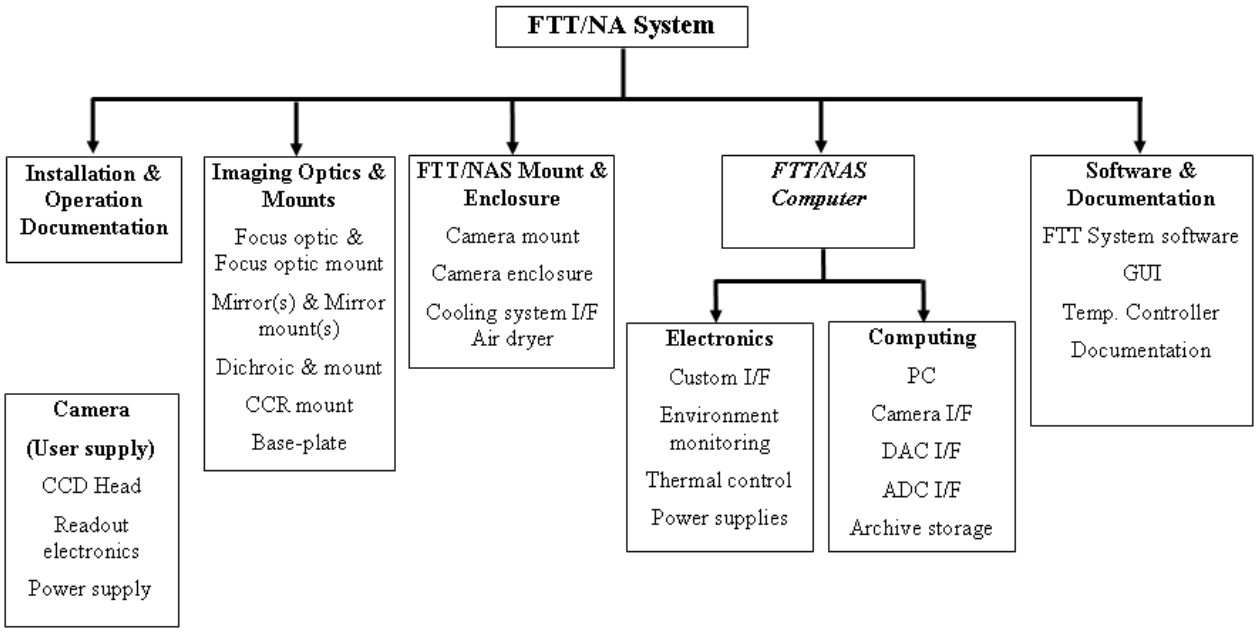

Figure 3: The expected product tree for the FTT/NA system. A new set of imaging optics and mounts replaces the FLC optical components but the camera, its mount and enclosure, the computer system and electronics interfaces remain the same. The FLC system software is replaced with the FTT system software.

1.2.2 FLC Product tree

The FLC product tree is shown in Figure 4. This lists the expected components of the FLC system and incorporates a reference to the top-level deliverables enumerated in section 5 of RD1.

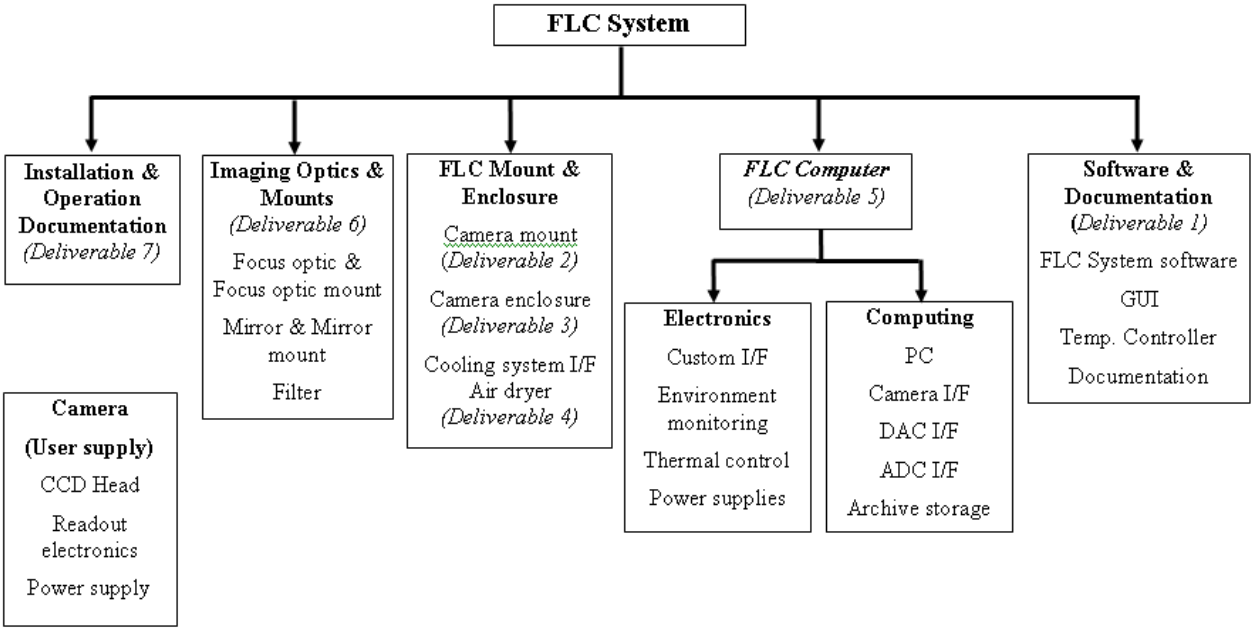

Figure 4: The current product tree for the FLC System. The reader should note that although many of the components of the FLC and FTT/NAS will be shared (the camera system, the camera enclosure, the computer system and interfaces, the custom electronics interface and the provision of cooling and dry air facilities) the optics and optics and mirror mounts will be different for the two systems.

2 Development Strategy

Our development strategy is based on the work breakdown structure presented in RD1 and so the reader is referred to that document for further details of the outline presented below. There are three primary components of the development plan:

WBS-01 – **Initial Preliminary Design**. Elapsed time 12.0 months including the submission of an Interim Preliminary Design Report;

WBS-02 – **Integrated Testing**. Elapsed time 5.5 months including the submission of the complete FTT/NAS Preliminary Design Report;

WBS-03 – **First Light Camera Delivery**. Elapsed time 3.0 months including testing and delivery/install of the FLC at the Magdalena Ridge.

The completion of WBS-01 will signal the end of Phase 1a of the Development work package, while WBS-02 and WBS-03 comprise Phase 1b of the work package. Each of the three major elements of work is described in the subsections below.

2.1 WBS-01 – Initial Preliminary Design Phase

The primary goals of WBS-01 are to address the major key technical risks identified in the conceptual design, to down-select and individually test suitable hardware for all the key components of the FLC and FTT/NA systems to ensure compliance with the top-level requirements, to prepare draft lists of the systems' ICDs and acceptance test procedures, and to prepare an Interim Preliminary Design Report. The elapsed time for this phase is 12.0 months and the manpower resources are estimated at 27.3 man months. Two academic staff, two software engineers, one mechanical engineer, one controls engineer, one graduate student and two technicians will be contributing to the tasks.

There will be four principal deliverables:

1. An “Interim Preliminary Design” report covering both the FLC and FTT/NA systems to include test results on individual components of these systems so as to demonstrate that the major risks have been mitigated and the proposed designs are feasible;
2. A draft list of interface control documents;
3. A draft list of acceptance tests and procedures for the production FLC (to be finalised by PDR) and a draft list of acceptance tests for the FTT/NAS;
4. A response to NMT’s evaluation of the “Interim Preliminary Design” report.

The eight major activities we envision for the work package are summarised in Table 1.

Activity	Major tasks
Optical design	Overall optical design and tolerancing. Selection and procurement of optics, alignment corner cube and prototype dichroic for mount tests.
Mechanical design and production	Overall mechanical design. Design and manufacturing, (or selection and procurement, as appropriate) of opto-mechanical mounts. Analysis of thermal behaviour and development of tests to validate this.
Electronic design and production	Overall electronic design for camera head, cooling, controls etc. Identification and procurement (or design/manufacturing, as appropriate) of all electronic hardware and related controls.
Test design and development	Design of laboratory tests to validate suitability and compliance of opto-mechanical hardware, electronic equipment, camera head, and software algorithms. Design and development of initial list of acceptance test procedures to confirm compliance. Preparation of “Draft list of Acceptance Test Plans and Procedures”.
Software design and development	Design of baseline software architecture for FLC and FTT/NA systems. Selection and procurement of computer components. Development of camera drivers for FTT readout. Confirmation of performance including latency and frame rate times.
Preliminary testing	Laboratory testing of detector readout and validation that optical performance (e.g. readout, frame time, latency) is consistent with top-level requirements. Thermal testing of camera head and enclosure to ensure operability in the environmental conditions expected for the UTE. Component testing of all opto-mechanical and electronic components to validate compliance with derived requirements, in particular short and long term opto-mechanical stability.
Systems engineering	Review of system requirements and interfaces. Development of “Draft list of Interface Control Documents”.
Interim design report	Preparation of “Interim Preliminary Design Report”.[1]

Table 1: Summary of the eight major activities associated with WBS-01.

Since the preparation of our initial Statement of Work for NMT (RD1) we do believe there have been any substantial changes in our estimation of the effort required for these tasks.

1 This will be an interim report: the final version of the Preliminary Design report will be delivered roughly three months later.

2.2 WBS-02 – Integrated Testing Phase

The primary goals of WBS-02 are to complete the integrated testing of an FTT/NA prototype and to prepare and submit all the documentation required for a Preliminary Design Review and participate in that review. The elapsed time for this phase is 5.5 months and the manpower resources are estimated at 5.7 man months. Two academic staff, two software engineers, one mechanical engineer, one controls engineer and a graduate student will be contributing to the tasks.

There will be four principal deliverables:

1. A complete set of ICDs for the FTT/NA system;
2. A completed "Acceptance Test Plan" for the FTT/NA system;
3. The finalised "Preliminary Design" report for the FTT/NA system including the results of integrated tests of a prototype system so as to demonstrate that the major risks have been mitigated and the proposed design is feasible;
4. A response to NMT's evaluation of the Preliminary Design Review.

The two major activities we envision for the work package are summarised in Table 2.

Activity	Major tasks
Integrated testing	Integrated testing of the prototype FTT/NA system in lab, so as to validate that all major risks have been mitigated and the proposed design is compliant with the top-level requirements.
PDR review	Preparation of detailed ICDs, "Acceptance test plans and procedures" document, and "Preliminary Design Review" document for the FTT/NA system. Attendance at PDR, demonstration of risk-reduction experiments to visiting MROI team (if desired) and post-review follow-up.

Table 2: Summary of the two major activities associated with WBS-02.

At present, we have no new information that would allow us to alter our initial estimates of the resources needed to execute the these tasks. As the activities of WBS-01 are rolled out, we will be in a better position to inform NMT about any necessary adjustment of resources and schedule.

2.3 WBS-03 First Light Camera Delivery Phase

The primary goals of WBS-03 are to test, ship, integrate, re-test and handover a First Light Camera system, compliant with the the top-level requirements, to the Project Office. The elapsed time for this phase is 3 months and the manpower resources are estimated as 1.0 man months. One software engineer, one mechanical engineer and a graduate student will be contributing to the tasks.

There will be four principal deliverables:

1. A Laboratory Test Report for the FLC;
2. The activities associated with the shipping, integration and testing of the FLC;
3. The "Site Acceptance Test" report for the FLC;
4. The FLC system itself (but **excluding** the actual camera head and associated readout electronics[2]).

2 It has been agreed that NMT will purchase these two items locally so that the first camera head and set of readout electronics can be retained in Cambridge for use during the development, prototyping and testing of the first of the FTT/NAS.

The two major activities we envision for the work package are summarised in Table 3.

Activity	Major tasks
FLC testing	Set-up and execution of laboratory tests to validate system performance. Collation and drafting of test results; preparation and transmission of the Laboratory Test Report to NMT.
FLC shipping and installation	Packing and shipment of the FLC system components (excluding the camera head and associated readout electronics) to NMT. Delivery of the software to allow NMT to test camera functionality. Unpacking, assembly and integration of the FLC at the MROI site. Execution of campus or on-site acceptance tests as desired. Reporting of acceptance tests to Project Office.

Table 3: Summary of the two major activities associated with WBS-03.

2.4 FTT/NAS Immediate tasks for WBS-01

Our Conceptual Design investigations have allowed us to converge on a set of immediate tasks that we feel are of highest important to undertake. These will performed as soon as we proceed with the Preliminary Design phase WBS-01. These high priority tasks are summarised in Table 4. Please note that, unless otherwise stated, the ordering within the table does not signify any particular priority between the tasks.

Priority Task	Key activities
#1 Down-select camera	Order custom software and evaluate. Purchase camera as soon as suitability has been established.
# 2 Refine optical layout	Investigate zoom layout further. Optimize favoured optical design.
# 3 Refine mechanical design	Design and analysis of dichroic mount. Design test apparatus.
# 4 Thermal design	Complete full thermal model. Specify coolant supply required. Specify air drying equipment.
# 5 Preparation for tests	Order optical table (similar to UT item). Design specific tests and order any long lead items.
# 6 Software development	Investigate risk of PCI bus conflicts. Close on inter-task communication scheme.
# 7 FLC tasks	Confirm FLC layout. Procure focusing optic. Design focus optic mount. Initiate thermal enclosure design.

Table 4: Enumeration of the near-term high priority tasks associated with WBS-01.

3 Schedule

The schedules for Phase 1a and Phase 1b of the FTT/NAS & FLC development work package are shown schematically in Figure 5.

Phase 1a delivers an interim report which covers both the FLC and FTT/NA systems, and will include test results on individual components of these systems so as to demonstrate that the major risks have been mitigated and the proposed designs are feasible.

Phase 1b will complete the integrated testing of an FTT/NA prototype and produce all the documentation required for a Preliminary Design Review. In addition, this phase will include participation in the review, lead to a response to the review and will deliver the First Light Camera system following the review. The precise delivery date of the FLC following the review will depend upon the timing needs of NMT although we intend to work to a delivery date of 30th July 2011.

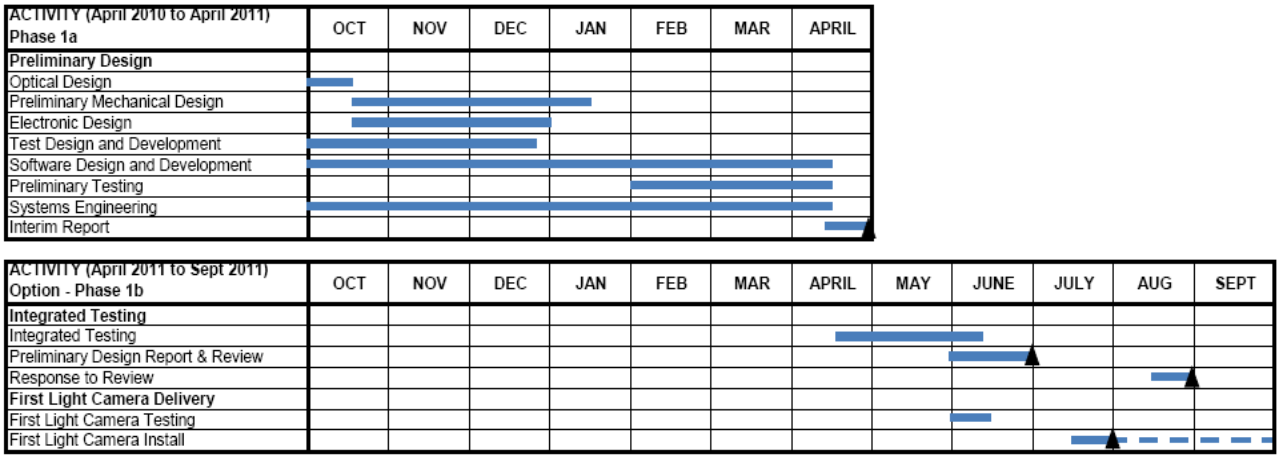

Figure 5: The Top-level Gantt chart for the whole of the PDR Phase. This is an updated version of the schedule presented in RD1 that has accommodated some modest slippages associated with some additional non-FTT/FLC related work that the Project Office have asked us to undertake.

In comparison to the schedule presented in our original Statement of Work (RD1) this revised schedule has slipped the dates of the major work package milestones by roughly one month, in particular the dates for the submission of the Interim PDR report and the PDR completion and the handover of the FLC. This has not been the result of any unanticipated difficulties in our tasks, but rather reflects a request that the Project Office has made that we prioritise some additional new work for the MROI that is unrelated to the FTT/NAS. We have confirmed with the Project Office that these adjustments are consistent with the overall Project schedule and so they have agreed to this no-cost change order.

4 Identification and evaluation of risks

The major risks we have identified during the conceptual design of the FTT/NA and FLC systems have been grouped into a number of major categories and are listed in the sub-sections below. Each major risk has been provisionally assessed and our current thoughts on possible mitigation strategies are noted.

4.1 Camera selection

Each of the cameras we have evaluated has a different level and type of risk. The Andor camera is expected to meet all our derived requirements but relies on the vendor implementing a custom fast read-out mode for a small arbitrarily located 23×23 pixel array. The risks associated with the alternative cameras will only arise

if the Andor camera has to be rejected as an appropriate choice.

Subsystem vendor	Description of risk	Probability of occurrence	Proposed mitigation
Andor	Fastest readout cannot be programmed.	Low	Consider alternative camera if specifications cannot be met.
Princeton Instruments	Cannot remove enough heat from camera. Software not available.	Medium	Increase size of enclosure. Consider low speed fan. Outsource custom s/w.
Hamamatsu	Survival in low temperature not guaranteed.	High	Consider battery backup heater.

4.2 Mechanical

We believe that the the major mechanical risk will be associated with the stability of the Nasmyth optical table. This is not within the purview of the FTT/NAS & FLC supplier – the technical requirements document specifies that the table may be presumed perfectly stable from the point of view of validating the FTT/NAS & FLC designs – but this is a system risk which we believe should be reported to the Project Office at this time.

Subsystem	Description of risk	Probability of occurrence	Proposed mitigation
Optics mounts	Stability of mounts cannot be met with simple designs.	Low	Use composite materials. Use Invar material.
Camera enclosure	Design cannot remove sufficient heat.	Low	Increase enclosure size or areas of cold plates.
Optical table	Thermal gradient bends table and shifts tip-tilt zero point during night.	High	Shield table from sky. Ensure airflow. Use thermal straps.

4.3 Software

Our initial survey suggests that the software component of the FTT/NAS Development is relatively low risk. There may be a need to outsource some custom s/w associated with the camera readout if the preferred camera head cannot be selected. We have included this risk in the “Camera selection” subsection above.

Subsystem	Description of risk	Probability of occurrence	Proposed mitigation
PC	PCI bus conflicts.	Low	Buy equipment and resolve conflicts early.

4.4 Schedule

Delays to the schedule could occur if the camera software promised by vendors is delayed in delivery. Also, the very demanding specifications on opto-mechanical stability may require more development work than envisaged or, more likely, will require longer to test and validate. We have included the risks associated with re-working of designs and re-testing in both the schedule and cost risk tables.

Subsystem	Description of risk	Probability of occurrence	Proposed mitigation
Camera head	Preferred camera head is not allowed. Additional thermal and software design tasks necessary.	Low	Close on camera capabilities as soon as possible. Develop thermal models and solutions as soon as possible.
Camera Software	Camera driver takes longer to procure or develop.	Low	Pull forward software effort or reschedule tasks.
Mechanical	Development and testing of mounts takes longer than expected.	Medium	Develop most critical mount quickly and test early. Plan tests and set up test facility and check performance early.
	Preliminary versions of the mounts prove non-compliant and re-work and re-testing is necessary.	Low	Develop and test most critical mount first to minimise impact on schedule.
System	Difficulties are encountered in testing opto-mechanical stability to the level of precision required.	Medium	Develop test strategies early.

4.5 Cost

We believe that our cost estimates for the majority of the hardware associated with the FTT/NAS are relatively secure and any uncertainty is of low risk to the project. However, the major cost risk is that our prototype designs for the opto-mechanics may be non-compliant necessitating re-design and re-work. This could incur significant cost rises due to the labour costs involved.

Subsystem	Description of risk	Probability of occurrence	Proposed mitigation
Camera head	Preferred camera head is not allowed. Additional thermal and software design tasks necessary.	Low	Close on camera capabilities as soon as possible. Develop thermal models and solutions as soon as possible.
Opto-mechanical	Preliminary designs are tested and found to be non-compliant. Re-design and re-testing of more complex components is needed.	Low	Analyse and optimize designs early. Develop most representative mount early. Set up test facility early.

4.6 Safety

The safety risks associated with the FTT/NAS are primarily associated with the integrity of the hardware being compromised by external influences, e.g. thermal and unexpected mechanical loads. There are few risks associated with personnel safety.

Subsystem	Description of risk	Probability of occurrence	Proposed mitigation
Camera	Failure of cooling system causes environmental specifications for camera head to be exceeded. Hamamatsu camera may get too cold if power system shuts off.	Low Low	Incorporate monitoring to control environment/shut camera down. Consider battery back-up for camera enclosure heating purposes.
Optics	Damage to system occurring during relocation.	Medium	Analyse shock loads and recommend removal of optics during relocation if necessary. Provide for handling and storage of components or base-plate.
Optics	Damage from falling debris within UTE.	High	Recommend that systems on Nasmyth table are covered.
Personnel	Personal safety for staff when accessing components on the Nasmyth table for alignment or removal.	Medium	Take into account during design process. Develop appropriate handling procedures.

We intend to set up and maintain a formal risk register early in the PDR phase. This will log and evaluate risks and hazards identified during the design phase, using industry standard techniques, and will allow us to track and report on these to the Project Office from time to time.

At present, we believe that the most critical area to address expeditiously is that of camera selection. If the custom software needed for the preferred Andor camera head cannot be delivered, then the use of one of the alternative options for the head will likely have a cost and schedule impact.

5 Summary

We have presented the outline of our development plan for the Preliminary Design Phase of the FTT/NAS & FLC work package (primarily concentrating on the FTT/NAS). This is not substantively different from our plan presented in the SOW (RD1) but we expect to refine our plan based on input from the review team and as our PDR work progresses.

There are a number of high-risk areas that have been identified as part of our Conceptual Design work. We have prioritised these and intend to close on some of the most important of these as soon as we begin our Preliminary Design phase WBS-01.