MONSOON PDR Report
22 May 2002

Presented to Jeremy Mould (Director), Larry Daggert (head of Engineering) and Barry Starr (MONSOON System Engineer)

by the PDR External Committee
30 May 2002

Executive Summary

Our committee commends the excellent work done by the MONSOON project team. With very limited resources, they have designed an advanced architecture and have developed close relationships with external development groups. Our recommendations and comments are as follows:

<u>*Project Review*</u>

- NOAO should clarify its project review process. We do not consider our meeting to have been a PDR for the MONSOON project. Instead, we addressed issues in two areas: IR prototype and long term MONSOON development project.

<u>*IR Prototype for testing ORION detectors*</u>

- The limited MONSOON resources are stretched across two prototype development projects – a 12 channel CCD prototype system and a 36-channel IR prototype system.
- With limited resources, we recommend that the MONSOON team concentrate on the highest priority – the IR prototype. Not only is the IR prototype required first, but it is 100% compatible with the long term MONSOON design. Delay the CCD prototype (which does not have 100% compatibility) until after the IR prototype system is handed over to the ORION detector team.
- We strongly recommend that the IR prototype system be used to advance the detector head electronics (DHE) design and testing. In order to do this, the printed circuit board designs must be reviewed by the external PDR committee before fabrication. There was not time to do this as part of the May 22 meeting.
- We recommend that the DHE design be modified to: (a) eliminate the Rabbit controller and the Ethernet port, (b) put the bias voltages on the same board as the (CCD) video channels, and (c) make it possible to slow the system clock so that extender boards can be used for testing at the operational clock speed.
- The MONSOON software can not be delivered with the IR prototype. The schedule constraints demand a temporary, "lash up" software system be implemented for operating the ORION detectors.

<u>*Long term MONSOON development*</u>

- We strongly endorse the MONSOON vision. There is real opportunity for a breakthrough here.
- MONSOON is critical for future NOAO projects (NEWFIRM, GSAIO, QUOTA, ODI, LSST) and NOAO needs to make the long term commitment of resources that is necessary for MONSOON to be a success.
- We find the hardware architecture and preliminary design to be technically sound.
- We strongly endorse the pursuit of collaboration with other observatories. A collaboration will bring additional FTEs to the development, but more importantly, a collaboration will bring a wealth of experience and will produce a better product. The external collaborators can probably contribute most in the area of software.
- Project management assistance is needed soon, but NOAO should ensure that Barry Starr maintains a technical leadership position.

1. Introduction

The MONSOON PDR was held on Wednesday, May 22, 2002 (9 am – 5 pm) at the NOAO headquarters on Cherry Avenue in Tucson, Arizona. Over 40 persons attended the presentation in person, 8 participated via videoconference from CTIO in Chile and 3 persons participated by telecon from the Keck Observatory in Hawaii. The PDR committee members were: James Beletic (Keck) – chair, Steve Heathcote (SOAR), George Jacoby (WIYN), Mike Lesser (U. Arizona), Roger Smith (Caltech), Richard Stover (UCO Lick), and Jason Weiss (UCLA).

The presentations made by the MONSOON team covered the following subjects (with the presenter's name in parantheses):

- Project overview (Barry Starr)
- Science drivers – IR and OUV (Mike Merrill, Chuck Claver)
- System design and detector head electronics design (Starr)
- Detector head electronics backplane (Gustavo Rahmer)
- Software design (Nick Buchholz)
- Project status and project management (Starr)

The PDR committee was provided with a notebook that contained the Powerpoint slides from the presentation and charts of MONSOON Work Breakdown Structure and Document Hierarchy. The following morning, the PDR committee met and discussed the MONSOON project. A half-hour presentation was made to the MONSOON team and NOAO and CTIO management .

2. MONSOON – Overview and Initial Comments

MONSOON is an ambitious project to develop and implement an entirely new generation of detector system electronics. In this context, electronics encompasses both hardware and software. MONSOON addresses the needs of both optical and infrared detector focal planes and has the expandability to operate extremely large focal planes, such as that proposed for the LSST. The MONSOON system encompasses three functional components: (1) a supervisory layer; (2) a pixel acquisition node (PAN); and, (3) the detector head electronics (DHE). The supervisory layer provides the software interface between MONSOON and the client (the human user or another computer). The PAN contains the software that controls the electronics and manages the data flow. The DHE contains the analog and digital electronics that interfaces with the focal plane detectors.

For small- and medium-sized systems, there will be a single DHE and the supervisory layer resides in the same computer as the PAN. The hardware for the PAN is envisioned to be 100% commercially available parts (PC running Linux), while the DHE are custom-designed (6U in size) printed circuit boards that are connected by a commercially available compact PCI backplane. For very large mosaics, the system will expand to multiple DHEs with several PANs that are coordinated by a supervisory layer that resides in its own PC.

The PDR committee commends Barry Starr and the MONSOON project team for the large amount of technical progress that has been made on the system design. The architecture for the MONSOON system appears to fulfill all of the ambitious system level requirements. In addition, the MONSOON team has invested a large amount of time to develop a system that satisfies the needs of the broader astronomical community. Specifically, the MONSOON team has developed an excellent relationship with a similar development effort being undertaken by the California astronomy community (Keck, Lick, Palomar) and there is good potential for a much broader development effort. In addition, the MONSOON project team has developed excellent relationships with the staff of CTIO and one of the persons who is critical to the MONSOON effort is based in Chile (Gustavo Rahmer).

MONSOON will leapfrog the technology used in all other detector systems and will establish a new paradigm for the operation of focal plane detectors. MONSOON will be smaller, faster and less expensive than other systems and it has the expandability to operate very large mosaics. MONSOON has the potential to become the standard for next generation systems used in ground-based astronomy. The MONSOON development approach will also enable the user community to keep control of the technology – something that is a problem with many existing detector systems.

3. PDR or not? The project review process at NOAO

The first question addressed by the PDR committee was whether this review should be a Preliminary Design Review or something else. We perceived ambiguity on this issue within NOAO itself. We recommend that NOAO assess their review process and define the CoDR, PDR and CDR process for all scales of projects.

Given our concerns about whether this was a PDR, we asked and received further guidance from Larry Daggert, head of engineering. He directed us to address two issues:

1. Is the plan for producing a MONSOON prototype for testing ORION devices feasible, in terms of resources and schedule?
2. Assess the long term MONSOON development plan? What about the system design? The software and hardware designs? The management plan? Comment on the potential for collaboration with other observatories.

The following two sections address these two issues.

[The consensus of the committee is that the overall MONSOON project is not yet at the stage of PDR – the software design is only partially defined and the long term development plan is unclear. On the other hand, if we are only assessing the use of a MONSOON prototype for the ORION detectors, an external review committee is probably not required. However, the committee is very pleased to be able to contribute our comments at this stage of a potentially very important project.]

4. MONSOON prototype to test ORION Infrared 2k x 2k detectors

The committee believes the hardware architecture and preliminary design are technically sound. Relative to existing systems, the hardware has the potential to provide a significant improvement in cost, performance, packaging, system integration, scalability, and power consumption. Many of the hardware concepts of MONSOON can be tested by the IR prototype and NOAO should use this opportunity to advance the DHE hardware as much as possible. Thus, we recommend that NOAO have the printed circuit board designs be reviewed by the external PDR committee prior to being sent out for fabrication.

The software concept and design are less defined than the hardware and will require more design work before proceeding to the coding phase. Since there is great pressure to deliver the prototype IR system to test the ORION detectors, there will not be time for the MONSOON team to design and develop the MONSOON software for the IR prototype. While we recognize these programmatic constraints, we note that in order to make schedule, the IR prototype software will necessarily be an adaptation of a previously developed package and thus will not significantly advance the long term MONSOON software development.

The draft OCDD and draft FPRD are incomplete and contain inadequate science requirement details. However, Barry Starr and the MONSOON team have enough knowledge of the detector requirements to carry out the prototype project.

The prototype development schedule is overly optimistic since the small project team is planning to concurrently pursue three significant efforts: (1) CCD prototype, (2) IR detector prototype and (3) community collaboration on long term design. In addition, the prototype schedule does not allow any time for mistakes being made in the design, fabrication or integration of the printed circuit boards. Obtaining very low noise for detector electronics is difficult to achieve and the plan should allow time for iteration on board design. Thus, the committee does not expect the IR prototype system to demonstrate low noise performance with actual detector operation by the project plan date of October 2002.

We understand that the highest priority near term goal is a system that can test the ORION detectors. In order to successfully achieve this goal, the committee recommends that the project team narrow its focus to the IR prototype and delay CCD prototype development until after the IR prototype is completed. An Acceptance Review (or project status review) should be scheduled for early 2003, after the IR prototype system is demonstrated. The criteria that define success should be defined within the next few months so that there are clear goals for the prototype phase. A detailed test plan also needs to be developed for the prototype system.

The committee feels that the number of FTEs (~6) is an appropriate level for the IR prototype effort but we do not have enough information to be confident that the mix or cadence of FTEs is appropriate. We are concerned that this project is being set up from the start to suffer the "multiplexing syndrome" that is endemic in the present day U.S. research environment. Many of the FTEs are from short term or part-time (less than 50%) staff. The use of student interns on critical design elements may produce considerable delays and this approach will leave NOAO with an experience/knowledge gap when these students leave. Since NOAO is starting a new development area with MONSOON, we recommend that NOAO utilize this opportunity to break the multiplexing syndrome and dedicate the long term staff that would provide continuity and be a more efficient use of FTEs.

Despite all of these FTE issues, we expect that technical challenges will dominate the IR prototype project timing.

Given these recommendations, the proposed CDR date of December 2002 is no longer appropriate. We recommend that the MONSOON CDR be delayed till the mid-2003 and the

CDR should address MONSOON within the context of NOAO participation in a community development effort.

5. Longer term development project & collaboration with outside groups

The committee strongly endorses the long range vision for MONSOON. Even without detailed cost analysis, it is clear that NOAO should develop a next generation detector system for the large focal planes required in the new optical and infrared instrumentation (NEWFIRM, GSAIO, QUOTA, ODI, and LSST).

The broader astronomical community has similar needs for high channel count systems but would like the same technology to scale down economically as well. We believe the architecture of the Monsoon system will allow this, serving applications such as guiding and wavefront sensing with minimal customization.

No institution in the USA currently has the resources to succeed alone in this project. Collaboration is both necessary and highly desirable as it will harness the expertise available in the community and guarantee a superior result through wider review. As a larger group adopts the same technology, economies of scale will be achieved in production and test, and software costs will drop as interfaces are standardized across observatories. This is likely to reduce costs in associated activities such as testing detectors, developing data handling systems, and user interfaces.

Coordinating a collaborative effort between various divisions of NOAO and within the community will require additional management effort but total workload should be less than producing a series of in-house solutions. It will be tempting to allow near term goals to drive the schedule and resources. One has only to look to the past for examples of such false economies. NOAO by itself has developed at least a dozen different detector systems and is now faced with maintaining at least 8 different versions. Other observatories have similar woes.

The committee believes that the time is ripe for initiating a community collaboration for next generation detector electronics. However, it takes time to build and maintain multi-institutional relationships and management at all concerned organizations should recognize the overhead that is required for these relationships.

The MONSOON team has insufficient resources to promote collaborative design while rapidly developing the IR prototype. Besides the technical resources (engineers, technicians), we recommend the addition of a project manager, whose responsibility is handling the budget, schedule, and internal coordination of the NOAO resources. The project manager is necessary to free up the system engineer (Starr) to concentrate on system design and development, and coordination with the development groups at other observatories.

Even during the IR prototype phase, the committee recommends that NOAO continue to put effort into establishing a community-wide development effort. This collaborative effort should establish clear agreements on areas of responsibility, deliverables and schedule. In order to make a collaboration work, there will need to be strong commitment to standards, and clear interface definitions. The collaborative agreement will need to clearly state what is provided to the partners, and which organization is responsible for fabrication (economy of scale argues for a single organization taking the lead). The collaboration should give proper attention to the 1, 2 or 4-channel systems that will be the majority of the applications, and avoid concentrating too much attention on the very large focal plane applications. The collaborative agreement should be formalized in a Memorandum of Understanding (MoU) between participating institutions. We propose that NOAO and external institutions should formalize these relationships by early 2003, at the time of the Acceptance Review for the IR prototype system.

Developing a system such as MONSOON will require strategic vision and high level institutional commitment. We forewarn NOAO that decisions based on the cost for a single system will always argue against a long term multi-system development effort. NOAO should avoid any more "one off" detector systems for new instrument developments.

NOAO also needs to define the accounting for the development costs of MONSOON. Will those costs be accumulated in a development account and not charged to the instruments that use MONSOON? Will the instruments only be charged "marginal cost" without amortizing the development? If only marginal costs are charged for MONSOON, what costs are included in the marginal cost?

6. Other issues & additional thoughts

This section is somewhat of a catch-all, to ensure that we include all of the wide ranging comments that the committee provided. Some of these thoughts may be repetitive of earlier text, but we would rather risk repetition to ensure that all of the comments from the committee are expressed.

Requirements definition

Project scientists should provide written requirements for achieving science goals, without regard to feasibility or cost. These written requirements should describe the most stringent observing requirements. They should be written without consultation with the MONSOON team. These requirements will especially help in detailed MONSOON software design.

Detector head electronics (DHE) design issues

- *Design review by external experts*
    - The MONSOON team should get outside review of their printed circuit boards. Specifically, they are just beginning on some of the critical Xilinx design. That design needs to be reviewed. Xilinx design is similar to programming. The MONSOON team is using the VHDL design language. The design should be done in a way similar to traditional software design and should be held to design documentation standards at least as high as traditional software. The design documents should include a logic module breakdown with design specifications and performance requirements for the various modules. These documents should be readable by anyone, even if they don't know VHDL.
    - Other aspects of the hardware should also be reviewed. There was no opportunity at the May 22 meeting to review any of the boards. Schematics stuck to the walls of the meeting room does not constitute a review opportunity. We emphasize that we like the

architecture but we don't have enough information to say much about implementation. Review of the implementation needs to happen soon.

- *Use of external expertise early in the design process*
  - Considerable expertise already exists within the other groups who may become part of the larger, community-wide development effort. For instance, Mingzhi Wei at UCO/Lick has already designed and built a complete CCD controller based on the Xilinx FPGA (field programmable gate array). Bringing this expertise into the MONSOON development at an early stage is important.

- *Strict pixel synchronization*
  - The most effective way to suppress noise patterns in high speed low noise imaging systems is to isolate and shield the DHE, and ensure that all signals within that protected environment are synchronous with the pixel period. Using the same master clock is not sufficient: one must also ensure that there are no state machines or program loops which are asynchronous with pixel read. Data transfers must be slaved to the pixel rate: no FIFO's should be used in the data path on the DHE side of the fiber link. For these reasons it is strongly recommend that the Ethernet port and the Rabbit controller be removed.

- *Bias voltage generation*
  - We recommend that bias voltages be generated on the video card. This has the following benefits:
    - using a common ground will reduce crosstalk
    - the number of bias voltages required is proportional to the number video channels.
    - bias voltage specifications are related to the type of video chain needed.

- *Backplane*
  - The packaging scheme and backplane are well conceived, making good use of existing standards, and addressing the need for easy board exchange, protection against static discharge and accidental hot swap, and providing access to all backplane signals for measurement.

- *Extender cards, clock frequency and ability to test printed circuit boards*
  - For testing the printed circuit boards, it is essential that an extender card be provided. The clock frequency will have to be reduced in order to accommodate the combined length of the backplane and card extender. This reduced clock frequency should be the norm, since slowing the clock only when the extender is in use implies a significant change in behavior when a diagnostic is being performed. In the committee's experience, reducing the fundamental clock to 30 or 40 MHz should be sufficient for most applications.

- *Reliability*
  - Self-diagnostics
    - Self test capabilities should be designed into hardware and software wherever practicable. This has been identified as a requirement but it is advisable to produce a document focussed on describing the full spectrum of self test capabilities rather than making (only) scattering references throughout the documentation. This will give a

coherent picture of how these capabilities work together, what supporting software is required, and will allow easier review for completeness.

  - It is important that diagnostics be provided for software as well as hardware. The idea that software is static and will always work after initial test has proven to be incorrect! Simulation of data and commands can be used to validate correct performance, speed and reliability.

- *Board commissioning*
  - The committee strongly endorses the plan to develop formal written test procedures and software to allow full verification of board level performance. We recommend that the first draft of these procedures be incorporated into the specification documents since this will force an analysis of what standards the boards will be measured against.

- *Manufacturability*
  - The MONSOON hardware design needs to address issues of manufacturability from the beginning of the project, else the system may fall into a problem that other systems (e.g. FIERA) have faced. Oftentimes, a very good design depends on parts that are not normally stocked by the PCB manufacturers.

- *Ease of maintenance*
  - Needs to be addressed from the beginning of the design process.

<u>Software design</u>

At this stage of its design, the software package appears to be well thought out and well designed. The modular system architecture provides a framework that can handle scales from small systems, such as a single channel guider, to very large systems, such as the 1400-channel system needed for LSST. The software design provides an upgrade path, so that the upgrade or replacement of one module should not affect other modules. An effort has been made to define interfaces that are intended to be unchanging over the lifetime of the project.

- *Technical applications*
  - For wide application, the system must support "technical" applications (acquisition, guiding, adaptive optics, etc). These applications were partially addressed in the MONSOON documentation but not all aspects were addressed (e.g. frame store). We emphasize that all potential modes of operation need to be designed into the software architecture from the beginning of the project.

- *Timing specifications*
  - Appropriate emphasis was given to observing efficiency in the PDR and supporting documents. In addition to maximizing readout speed, attention should be given to other overheads on each exposure. Inter-exposure overheads and command execution speeds are often neglected. As a result serious delays are incurred during system commissioning and test due to slow system initialization and macro execution, leading to inefficient debugging and loss of observing time when there are problems Therefore it is very important that the execution speed of all software components be specified, and that each module be tested for compliance.

- *Documentation & design status*
  - Thus far, the effort to document the software design has been directed primarily at defining requirements and writing Interface Control Documents (ICDs). A complementary effort is now needed to subdivide the PAN in to smaller modules with particular emphasis on defining the functionality of these modules. The ICDs should be then reviewed again. We strongly recommend that the software design rely heavily on collaboration with outside institutions since there is a large experience base and significant pool of resources available. It is unlikely that the software will be truly successful without harnessing this broader base of expertise and critical review.

- *Role of the database*
  - Need description about its role and implementation. Where does it run? (within the PAN or the supervisory node?) What software accesses it? How is it used exactly? What are the requirements?

- *CMOS Cameras/Other Operating Systems*
  - Do not constrain the overall architecture any more than necessary. Allow for the MONSOON software to work with a wide variety of controllers, including CMOS cameras in which the computer interface may be a proprietary board or new type of port. In the same manner, do not require the computer OS to be Linux. A Windows application which supports the ICD should be acceptable. It is the interfaces and client applications which should be universal, not the details of the hardware interface.

Specific issues (in bullet form)

Management

- Project needs to undertake long term planning to estimate resources needed.
- Project management issues need to be addressed soon.
- More resources needed to do this project in a timely fashion.
- There needs to be clear definition of metrics of success of various phases. What are the products? What defines success? (e.g. prototype phase, ORION phase)

Technical

- Open source concept is excellent. All designs will be openly shared with the entire astronomical community.
- Detector-limited performance mantra should never be forgotten.
- Fiber link conceptual issues still to be resolved. The committee recommends keeping the design as simple as possible and thus endorse a single bi-directional high speed fiber link between the DHE and the PAN.
- Remove the Rabbit processor and the Ethernet port in the DHE.
- Would be best to have extender cards work at operational clock speed. System should work for most applications with a 30 or 40 MHz clock – go with that?
- Beware of too much flexibility in board / module design – need to limit the variation of systems that are produced.
- Lowest noise will probably not be achieved on the first iteration. Need to manage expectations in this area.
- Need to avoid attachment to any specific component (e.g. Systran, analog processor modules) – project lead has a tendency to do that.

- Best to overlap user and engineering interfaces.
- Definition of images unclear. What is produced? FITS? Real-world coordinates? Binning, mosaics, etc. This is an area in which other observatories have expended a large amount of effort. The MONSOON project should take advantage of the previous efforts.

Collaboration

- Strongly support it and recommend that NOAO do it, and give proper resources.
- Need clearly defined MoU, standards, ICDs.
- Collaboration will produce better ICDs that normally produced.