Penn Array Receiver

Penn Array Receiver CDR Document 2: Project Overview

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Keys:

Revision History

Ver.	Changes	Date	Author
1	Draft	24 Sep 2003	Mark Devlin
2	Substantial revisions, addtions	25 Sep 2003	Brian Mason
3	Minor changes + add sect. 5	7 Oct 2003	Devlin+Mason

Contents

Abstract

We review the Penn Array project, including project management issues, history, and our project plan.

1 Introduction

This document is intended to provide a description of the project management. After a brief history of the project, we will discuss:

- The scope of the work.
- The responsibilities of the major parties.
- Risks and risk mitigation.
- An outline of the project plan.

2 History & Approach

The PAR was first proposed by Mark Devlin to NRAO in 1999 as a way of taking advantage of an existing receiver at Penn and the soon to be completed GBT telescope. At the time, Penn had a liquid helium bolometer system with approximately eight conventional detectors which could be configured to operate at 90 GHz. After several discussions we realized that the exisiting receiver would be inappropriate for the GBT. We wanted to accomplish several goals at once:

- verify the functionality of the telescope at 90 GHz.
- test detector and receiver technology which might be appropriate for future large format arrays.
- build a facility instrument that will return significant scientific observations to the community

What was needed was a low-cost array receiver that used similar technology to the next generation of large (thousands of elements) bolometric receivers similar to the SCUBAII instrument.

A collaboration was forged to build the receiver. While some of the responsibilities have shifted around (described below), the basic structure has remained the same. Under this plan the University of Pennsylvania would be primarily responsible for the design, construction and commissioning of the instrument; NASA-GSFC would provide the detectors and readout electronics; NRAO-GB would support some aspects of construction and commissioning; and the Cardiff group would provide the filters. A proposal was submitted to NSF's ATI program in 2000 and rejected. In 2001 NRAO obtained funds to build such an instrument. UPenn applied for and received the award.

The total award from NRAO was for $530K for 3 years starting in March of 2002. $430K was to go to Penn and $100K was to go to GSFC. (This has since changed due to difficulties transfering money to GSFC, but the basic distribution of resources remains the same). This is a small amount of money for a major instrumental capability; it is made possible by leveraging the large investments that GSFC and NIST have made developing TES detectors and SQUID multiplexed readout. GSFC's Penn-Array specific design and development work is essentially free. Cardiff is providing the filters at no cost. NRAO is responsible for control, data acquisition, and data analysis software. This approach has enabled the funding of the project but incurs significant schedule risk.

Subsequent to the NRAO award UPenn has applied twice to NSF (ATI) for funds to cover the addition of a filterwheel to the receiver. A filterwheel would enable higher sensitivity under a wide range of atmospheric loading conditions. Both proposals have included additional salary support for commissioning, integration, and software. The first proposal was rejected; results on the second are still pending.

Brian Mason joined the project in June of 2002 as NRAO project scientist and project manager. Prior to this there were effectively zero resources dedicated to the project at Green Bank. Subsequently we have been able to more effectively coordinate development (eg, to specify and negotiate telescope interfaces); to begin to address software issues; and to identify and deploy further Green Bank resources in support of the project.

3 Scope of Work & Responsibilities of Major Parties

The memorandum of agreement between NRAO and UPenn states:

"On a best efforts basis, UPenn will deliver a 64-pixel, 3 mm band, bolometer camera as described in the attached design document. Deliverables also include engineering documentation in hardcopy form and all CAD files in electronic form. At the time of delivery, the receiver becomes the permanent property of NRAO/NSF."

The project has grown since the original MOA; in particular, NRAO has taken on a much larger role in project management and software. The responsibilities are:

- UPENN: Management of the receiver production.
- UPENN: Design of the cryostat and control system.
- UPENN: Design and production of the optical system.
- UPENN: Documentation of receiver and electronics.
- GSFC: Array design and fabrication.
- GSFC/UPENN: Production of warm and cold TES electronics.
- NRAO: Analysis software; control & readout software for use with the GBT.
- NRAO: Machining of major receiver components.
- UPENN/NRAO: Telescope Integration/Commissioning support.

Several items are explicitly beyond the scope of the Penn Array project:

- Telescope Performance: NRAO-GB will deliver, on a best-effort basis, usable 3mm capability with the GBT. This includes adequate aperture efficiency and pointing performance. Current capabilities would be sufficient for basic commissioning tasks (bright source observations) but not useful for astronomy.
- Dynamic Scheduling: Conditions suitable for millimeter observing are limited at the Green Bank; in combination with GBT and Penn Array operational constraints, the instrument is not likely to efficiently utilize 3mm conditions until significant effort is invested in automated dynamical scheduling procedures. GB intends to deliver this capability eventually, but not in time for commissioning (winter 04/05).

It should also be noted that the original agreement does not provide resources for the software needed to operate the receiver as a facility instrument, or for significant salary support for UPenn personnel through commissioning. This was recognized prior to the signing of the MOA and NRAO has since provided internal resources to address the software issue. The commissioning issue will be addressed below.

It should be made clear that by "project" we mean the project as a whole, and not simply the contract under execution by UPenn and GSFC. Delivery of 3mm capability on the GBT is the responsibility of NRAO's Precision Telescope Control System (**PTCS**) project

4 Risks and Mitigation

The major weak link in the project is the production of the array at GSFC. GSFC has enthusiastically supported the project from the beginning. However, were it not for the fact that the requirements of the PAR are similar to several other instruments, the resources that the project is providing to GSFC would be impossibly inadequate. As it is, we are relying on Dominic Benford paying specific attention to the design and production of the PAR-specific arrays without supplying direct support for his work. Penn has been able to mitigate most of this risk by sharing the common load of all the projects with the PAR. This has allowed Benford to spend the time required to design and start the production of our arrays.

It should be recognized that the project lacks the resources for any significant research and development of new technologies. With this in mind, we have attempted to utilize existing technologies whenever possible. However there remain several significant areas of risk. The major technical risks include:

- Operational procedures for the cryogenics, SQUIDs, or TES detectors are poorly understood by those responsible for commissioning and future operations (NRAO). There are several responses to this: a) As the contract (or further funding) allows, UPenn will assist with GBT commissioning; b) UPenn will, on a best-effort basis, deliver documentation of the necessary procedures; c) NRAO personnel will work closely with UPenn and GSFC throughout 2004, will assist in generation of the required documentation, and will spend significant time in residence at Penn and GSFC.
- The arrays may not yield robust detectors. GSFC is working on design and test production of the arrays. Significant progress has been made, including the successful fabrication of a mechanical prototype (Sept. 2003). In the case that the full 64 element array is not in place for integration, a "few" pixels could be placed on the focal plane to test the functionality of the electronics and optics. In an extreme case, the same test pixels could even function on the GBT for initial engineering and commissioning tests.
- Vibrations in the receiver cabin could interfere with the detectors. Reducing vibrations was a major design constraint for the cryostat, resulting in a working, low-vibration 300 mK system; this should address the zeroth-order concern. We have measured the vibration spectum of the cabin. This will be compared with lab performance. If a problem arises, steps will be taken to notch out the vibration bands from the receiver at the mount.
- The magnetic fields in the receive cabin could interfere with the SQUID multiplexers. This should not be a large risk since the sensitive electronics have been carefully shielded. We intend to make sensitive measurements of the magnetic fields in the GBT receiver room in the future, which will indicate if further mitigation is needed.

The major schedule risks include:

- The detector production could be delayed (discussed above).
- The lens and AR coating production may be delayed. Several groups are now considering AR coated Silicon lenses (PENN, Princeton, JPL, Cardiff). In response the Cardiff group has made significant progress with this technology. However, it is not clear that they will be able to implement the AR coating on our lenses in time for our testing. While the AR coating is essential for the proper operation of the final receiver, testing can proceed without them.
- The control and readout software could be delayed. We have attempted to address this by careful planning, but delays could still occur either if there were delays in finalizing the DAQ interface; or if inadequate support is available from GB software and electronics divisions; or if NRAO is unable to quickly enough obtain information describing the procedures required to operate the instrument. This could delay commissioning. Finalizing the DAQ interface is largely beyond NRAO/Penn control, and the project will have to stay in close touch with GSFC on this front.

Any of these delays could result in a risk to the project if Penn is unable to participate in commissioning and/or transfer its operational knowledge as a result, or worse, if the integration and delivery of the actual receiver is pushed past the end of the contract. Collectively these add up to a substantial risk; many of the factors are largely external to the project (detector production; DAQ electronics; lens coating) so a contingency plan needs to be formulated.

At the beginning of Q3 2004 we will hold a project meeting to assess the status of the project. Should it be necessary and feasible, NRAO and UPenn will negotiate an equitable sharing of the expected liability. If an extension is required, it is expected that the greater part of the liability will be for some fraction of Simon Dicker's time (which might be shared with another project). If the receiver has not been successfully integrated in the lab due to schedule delays beyond UPenn/NRAO control, further resources may be needed.

5 Project Plan

5.1 Milestones

The timetable for the project is detailed in the project timeline that has been provided separately. Here we will give a brief summary of the status and plan of each of the major components:

- Optics Design. The optics design has been completed and undergone a semiformal external written review.
- Optics Construction. The mechanical design of the optics is essentially complete. The mechanical components will be manufactured at GB, the lenses will be contracted out to a company, the AR coating will be made by Cardiff, and the filters will also be made by Cardiff. The expected completion date is 4/30/04. Interfaces include the optics structure to the cryostat (mechanically and thermally), the detector mount to the optics, and the cable feedthroughs. The only interface which is not completed is the cabling (thermal and mechanical). However, there is sufficient flexibility in the placement that this should be straighforward.
- Detectors. The detector design parameters have been established. GSFC has made mechanical models of the proposed detectors. The mount for the detectors has also been designed and is ready to build. The planned completion date is 5/17/04. These represent one of the most significant schedule risks.
- Warm Electronics. Most of the warm electronics (housekeeping and detectors) have been obtained. Most of what remains is to integrate them with the LINUX operating system. There may be an issue with drivers for RedHat vs. Debian LINUX. Otherwise, we expect to be able to read-out and tune detectors.
- Cryogenics. The cryogenics have been built and tested on and off the GBT. We hope to have a spare set of refrigerators on-hand by mid-2004.
- Cryostat. The detailed mechanical design of the cryostat is complete and is pending construction in the GB machine shop. We expect it to be completed by the December of 2003.
- Receiver Integration. This involves the integration of the cryostat, cryogenic components, housekeeping electronics, optics, and detectors. Fortunately, we expect all but the last component to arrive on schedule, so we can make significant progress. The completion of the entire receiver is scheduled for 9/6/04.
- Software. Most of the software interface documentation has been provided to GB. There should be enough software in place for the receiver integration at GB in late 2004 early 2005. The user software will not be available until late 2005.
- Receiver Tests at GB. We have alloted 3 months of off-telescope testing at GB and 1 month of first light testing. This is scheduled for completion near the end of March 2005. Some of this testing may be done at Upenn.

5.2 Acceptance Testing

Prior to commissioning on the GBT, the Penn Array must satisfactorily pass through acceptance testing. An NRAO panel will be assembled to determine if the receiver is ready for acceptance and commissioning; this panel could consist of the NRAO Project Manager, Project Scientist, Project Engineer, and a representative from the electronics group. Acceptance testing will consist of:

- A demonstration of the receiver working in the laboratory. This demonstration will be conducted with the standard laboratory configurations employed by UPenn throughout development. All hardware and software necessary for the demonstration are deliverables. Capabilities to be demonstrated include: configuration of the multiplexer; readout of bolometer data; characterization of the bolometer sensitivity and loading conditions; firing the calibration pulse; setting bolometer biases appropriately; several helium fridge cycling procedures. These demonstrations could be conducted at UPenn or at Green Bank.
- A review of engineering documentation deliverables. These should document: the final state of the instrument as delivered (an update to CDR drawings); the location and function of all items needed for the demonstrations; and how to perform expected maintenance. They should also include an enumeration of outstanding faults and action items, with explanations of why the instrument can still be delivered with these.
- A review of lab measurements of the instrument which demonstrate the instrument's readiness for astronomical commissioning. The specific set of tests to be performed will be enumerated by the NRAO project scientist at a later point in collaboration with the UPenn team, and could include: load curves for each bolometer at several background levels; charts of cooldown, warmup, and helium cycling procedures at several elevations; measurements of bolometer speed; measurements of the calibration diode signal; measurements of the system's optical efficiency; basic characterization of sensitivity to microphonics.

The more precise elaboration of these items is an agenda item for the early-Q3 2004 project meeting, provided the outlook is still favorable for Fall/Winter 2004 commissioning.

5.3 GBT Commissioning

GBT commissioning of the Penn Array is a responsibility shared between NRAO and UPenn. However there are a number of schedule risks (some beyond the project's control) which may make it difficult or impossible for UPenn to fulfill these commitments, and this poses a project risk from the point of view of producing a user facility. If further support is available– either through NSF, NRAO, or another agency– the outlook would be better. It is expected that commissioning will be the joint responsibility of the NRAO project scientist (Mason) and the postdoc in charge of the project at Penn (Dicker); significant support will be required from other NRAO project team members (software and electronics). Since it will be difficult to understand the Penn Array's performance separate from that of the GBT itself we hope that Penn Array commissioning will be a collaborative effort with the PTCS[1] team or selected members of this team. The Penn Array can be expected to be very useful for characterizing mm performance of the GBT, this should be mutually beneficial.

There are several important caveats to our commissioning plan:

- GBT commissioning is contingent upon readiness of the proper monitor and control software. NRAO will not commission the instrument on the telescope with a quick and dirty solution.
- Since it is impossible to accurately predict performance of the GBT at 3mm and the Penn Array itself, and since both of these are technically difficult undertakings, NRAO will not announce the Penn Array to observers until after it has been commissioned successfully. Any potentially scientifically useful observations which are necessary for commisioning would be made public as quickly as feasible but with no support. It should be noted that this also precludes project team members from executing science programs until the season after commissioning.

[1] As noted in §3, **PTCS** stands for the Precision Telescope Control System, the NRAO project responsible for making the GBT a useful 3mm antenna

This approach will give the project team an opportunity to realistically characterize the GBT and Penn Array performance, to make plans to improve it if necessary, to invest the necessary effort in user-level analysis and operational software, and to improve dynamic scheduling procedures. Since there seems to be substantial interest from the astronomical community in the instrument these steps are important in order that expectations not be radically underfulfilled. Furthermore,

- Penn Array commissioning will *not* be made contingent upon progress of the PTCS since current pointing performance is adequate for commissioning observations in an on-the-fly mapping with a fully-sampled array. The present aperture efficiency would not be useful for science; partial commissioning is probably achievable with modest aperture efficiency improvments. The PTCS schedule calls for 3mm readiness in early 2005, but this is a very aggressive schedule in itself.

This is another reason to delay announcement of the Penn Array until after commissioning.

Fleshing out the plan for commissioning is an agenda item for the early-Q3 project meeting, again provided the outlook is favorable for Fall/Winter 2004 commissioning.

ID	Task Name	Duration	Start	Finish
1	CoDR	0 days	Fri 11/9/01	Fri 11/9/01
2	Signed MOU	0 days	Fri 11/9/01	Fri 11/9/01
3	Order Detectors	0 days	Fri 5/10/02	Fri 5/10/02
4	CDR	0 days	Mon 10/20/03	Mon 10/20/03
5	deliver receiver to gbt	0 days	Tue 9/7/04	Tue 9/7/04
6				
7	**Optics design**	**429 days**	**Fri 11/9/01**	**Wed 7/2/03**
10				
11	**Optics Construction**	**140 days**	**Mon 10/20/03**	**Fri 4/30/04**
12	make lenses	16 wks	Mon 10/20/03	Fri 2/6/04
13	coat lenses	2 mons	Mon 2/9/04	Fri 4/2/04
14	make filters	6 mons	Mon 10/20/03	Fri 4/2/04
15	Make mounts	3 mons	Mon 10/20/03	Fri 1/9/04
16	Integrate optics	1 mon	Mon 4/5/04	Fri 4/30/04
17				
18	**Detectors**	**441 days**	**Mon 9/9/02**	**Mon 5/17/04**
19	Detector parameters	2 mons	Mon 9/9/02	Fri 11/1/02
20	**Design components**	**115 days**	**Fri 8/22/03**	**Thu 1/29/04**
27	**Fabrication of Detectors**	**151 days**	**Fri 9/5/03**	**Fri 4/2/04**
34	**Testing**	**149 days**	**Mon 10/6/03**	**Thu 4/29/04**
48	**Procurment of cabling**	**30 days**	**Fri 9/12/03**	**Fri 10/24/03**
53	**Assembly of Electronics**	**80 days**	**Fri 8/22/03**	**Thu 12/11/03**
57	**Integration**	**192 days**	**Fri 8/22/03**	**Mon 5/17/04**
62				
63				
64	**Warm electronics**	**276 days**	**Mon 9/9/02**	**Mon 9/29/03**
65	Detector readout (test)	6 mons	Mon 9/9/02	Fri 2/21/03
66	houskeeping & power	3 mons	Mon 9/9/02	Fri 11/29/02
67	packaging	1 mon	Tue 9/2/03	Mon 9/29/03
68				
69	**Cryogenics**	**355 days**	**Fri 11/9/01**	**Thu 3/20/03**
76				
77	**Cryostat**	**359 days**	**Fri 8/9/02**	**Wed 12/24/03**
78	Design	6 mons	Fri 8/9/02	Thu 1/23/03
79	Check drawings	21 days	Mon 7/7/03	Mon 8/4/03
80	build	3 mons	Tue 8/5/03	Wed 12/24/03
81				
82	**Receiver integration**	**183 days**	**Thu 12/25/03**	**Mon 9/6/04**
83	Integrate cryogenics	2 mons	Thu 12/25/03	Wed 2/18/04
84	test cryogenics	2 mons	Thu 2/19/04	Wed 4/14/04
85	integrate optics	1 wk	Mon 5/3/04	Fri 5/7/04
86	Integrate detectors	1 mon	Tue 5/18/04	Mon 6/14/04
87	Noise tests	3 mons	Tue 6/15/04	Mon 9/6/04
88				
89				
90	**Software**	**600 days**	**Sun 6/1/03**	**Fri 9/16/05**
91	command and control	15.75 mons	Sat 8/9/03	Fri 10/22/04
92	DAQ	10.75 mons	Sat 8/9/03	Fri 6/4/04
93	Data Analysis	15.75 mons	Sun 6/1/03	Fri 8/13/04
94	Final User Data Analysis	130 days	Mon 3/21/05	Fri 9/16/05
95				
96	**Receiver tests at GB**	**105 days**	**Mon 10/25/04**	**Fri 3/18/05**
97	Integration	2 mons	Mon 10/25/04	Fri 12/17/04
98	Noise Tests	1 mon	Mon 12/20/04	Fri 1/14/05
99	First Light	1 mon	Mon 2/21/05	Fri 3/18/05