# Project Management Plan

## Project Scope

Development and implementation of a next generation ultra-wideband digital signal processing technology will occur in two phases. The scope of work planned and budgeted under this proposal is for phase 1 only. Phase 1 will 1) explore the technical feasibility of new, innovative technologies to enable the digitization of signals from the telescope to occur right at the receiver and 2) develop and assess RFI excision techniques enabled by this technology. This will be pioneering work into the use of technologies having only recently been released. Digitization at the receiver has the great potential to address interference issues caused by signal contamination introduced during the processing chain. New digitization techniques are also expected to improve stability and simplify signal processing thereby improving reliability.

Phase 1 includes the basic and applied research into newly available technologies including Field Programmable Gate Array boards (Xilinx FGPA boards) and new high-speed analog-to-digital converters (ADCs). The project team will design and build printed circuit boards to interface the ADC evaluation boards and the Xilinx VCU118 FGPA. RFI excision techniques will be developed and evaluated by splitting the radio frequencies into three sub-bands and conducting band-pass sampling at a lower sampling rate. Randy/Jason probably know more about under-sampling than me, but I would rephrase this to be something like… but then this almost seems like a detail for the proposal – I’m not sure “The band will be undersampled and split into 3 subbands, corresponding to the first three Nyquist zones – this will enable a larger Effective Number of Bits (ENOB), and thus higher precision than typical Nyquist sampling. This will also allow for additional levels of RFI excision evaluation.”

The planned RFI excision development is crucial to the successful use of the ultra-wideband receiver currently under development by GBO, and will also be directly relevant to other observatories. Evaluating potential RFI excision algorithms independently across different sub-bands will identify if interference might be more prevalent in one region than across the band. Wilson has measurements for the amount of RFI in different bands, so I think we should rather focus on the removal of the different types of RFI that are prevalent at different frequencies – but maybe that’s splitting hairs? Isolate efficacy tests for various types of RFI within the different bands (ie. Impulsive RFI at low frequencies vs digital RFI that’s more common above 2GHz). This will enable the project team to assess the efficacy of excision techniques in a very systematic way. It is anticipated that algorithms developed for RFI excision could be packaged into core modules that ultimately could be made available and merged into other digital signal processing system designs.

During phase 1, GBO will work collaboratively with University of California, Berkeley’s SETI do we need to spell out the SETI acronym? Research Center and CASPER (Collaboration for Astronomy Signal Processing and Electronics Research) teams, who will serve as advisors to the project to ensure that the efforts are synchronized, and knowledge is shared across multiple interested groups. In parallel, the CASPER team will be evaluating and integrating new technologies into the CASPER open-source platform. An undergraduate summer student from Berkeley will assist in the RFI excision research during both years of the project. A shared strategic goal for both GBO and Berkeley is to transition from current ROACH2 (Reconfigurable Open Architecture Computing Hardware) based architectures as that technology is becoming obsolete.

From a systems engineering perspective, phase 1 will encompass basic and applied research into new digitization technologies and RFI excision techniques, include a preliminary design for a new system, and conclude with a technical proof of concept. The preliminary design work in phase 1 will also enable GBO to develop a more detailed plan and cost for phase 2.

Phase 2 of the project (out of scope for this proposal) will build upon the preliminary design to enter into a detailed design phase. It is anticipated that phase 2 will build out two or more additional digitization frontends to integrate the technology across all the sub-bands for simultaneous operation. Phase 2 will include software and backend development, integration verification and validation, and commissioning. Significant outreach to the US and International astronomy community will be required to validate that the RFI excision techniques do not have any adverse impacts on the science data products. The goal of phase 2 is to deliver innovative digital signal processing hardware and software designs and RFI excision techniques that can be made available to the US science community as well as a GBO user instrument to the Observatory.

## Project Governance and Resources

### B.1 Project Team

Dr. Ryan Lynch will provide scientific leadership to the Ultra-wideband Digital Signal Processing project. The research and development for the project will take place at the GBO, where the staff have 60 years’ experience in building and maintaining facility instruments for the scientific community. GBO digital engineers will work collaboratively with Lynch and project management resources.

Research and development for the ultra-wideband digital signal processing system will require expertise in digital signal processing algorithms, RFI mitigation, and FPGA and GPU firmware development. Assessment and testing of the new technologies will also require extensive experience in operating wideband frequencies on the Green Bank Telescope (GBT), and detailed knowledge of the science requirements.

As a Federally-Funded Research and Development Center (FFRDC), GBO has been granted an exemption by NSF to submit this proposal since the technical innovations developed through this project will make unique contributions to the needs of researchers across the international scientific community. GBO staff have proven expertise in taking research projects from concept through design and construction with a goal of repeatable, reliable, maintainable, and scalable production use. Through its operation of the GBT and other site telescopes and its work within the radio quiet zone, GBO staff have unique experience in how to identify, assess, and mitigate RFI emissions. System design requirements will need to consider weather factors and performance specifications for real-world application. This GBO-led project, developed in collaboration with Berkeley, ensures that rigorous systems engineering approaches will be employed to enable the technical proof-of-concept developed under this proposal to move forward into a future, production-ready implementation stage.

### B.2 Project Organization

The Ultra-wideband Digitization project will be managed using documented GBO budget management, project management, and systems engineering processes developed in adherence with the NSF’s requirements as per its *Large Facilities Manual* (NSF 17-066, March 2017). Experienced GBO Program Managers will coordinate, track, and report on activities from a project and programmatic view. Scope, schedule, costs, and risks will be managed by GBO Program Managers.

GBO and Berkeley have collaborated successfully on many projects over a number of years, and the project will benefit from established coordination mechanisms. Full project team teleconferences will be held monthly, and face-to-face meetings and short working sessions will be scheduled as required.

[Note: I’m assuming that we can discuss specific roles and UC-Berkeley’s role in more detail in the “Facilities, Equipment, and Other Resources” document?]

## Risk Management

An Ultra-wideband Digitization Risk Management plan identifies uncertainties in the project and mitigations to reduce loss, while identifying and realizing opportunities. As a research and development effort using newly released technologies, there are a number of risks related to uncertainties that will be mitigated through systematic basic and applied research. These uncertainties are to be expected in the development of innovative techniques.

To address these risks associated with a research and development effort, the highest risk items will be tackled and tested first, in order to identify subsequent approaches. If testing validates the assumptions, performance, and hypothesis, then risks are reduced as the project progresses. If testing does not validate assumptions, then the risks are not reduced and reassessment will be required. Iterative project management techniques will be applied ensure the project moves forward as outcomes are progressively elaborated.

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| # | **Risk and Rating** | | **Mitigation Strategy** |
| 1 | The integration of the planned technologies has never been done before; therefore expected outcomes cannot be guaranteed | HIGH | A systematic approach to the basic and applied research, with multiple iterations to assess outcomes and refine assumptions. The planned phased approach takes incremental steps which reduces risk. |
| 2 | Specifications for the technologies to be used are still in development. For example, full specifications for the 12-bit AD9213 chip have not yet been released | HIGH | Current hypothesis are based on expected performance specifications for the chips. These assumptions will need to be validated through iterative testing of the technologies as they are integrated. |
| 3 | ROACH2 technology currently used by CASPER and GBO Digital Signal Processing systems is reaching end of life | HIGH | This is an opportunity risk that will be realized if the research into new technologies for digitization is not undertaken in a timely basis. |
| 4 | Potential impacts of RFI excision on data products | MED. | RFI excision algorithms will be systematically tested against individual sub-bands. Detailed comparisons to pre-excised data will be conducted. |
| 5 | Alignment of GBO digitization efforts with CASPER | MED. | The CASPER team at UC-Berkeley is a collaborator on the project. GBO and Berkeley have a good history of working collaboratively on projects. |
| 6 | Availability of new digitization technology to support GBO ultra-wideband receiver | LOW | GBO has decoupled this digitization project from its development of an ultra-wideband receiver. The ultra-wideband receiver will be released use existing GBO systems until new digitization technologies are available. |

Table X: Compressed view of ultra-wideband digitization risk register.

## Schedule Management

The project outcome for phase 1 is a technical feasibility assessment and proof-of-concept. Research and development projects undergo iterative design, experimentation, test, verification, and validation phases. GBO’s schedule management will provide measurement of the R&D progress towards outcomes. The planned period of performance for phase 1 is two years from date of award. GBO plans to conduct preliminary evaluation of the new Xilinx VCU118 FGPA boards in collaboration with Berkeley SETI Research in advance of project award. This pre-work will address risks early on(?) and enable the project to commence immediately upon award.

The following table lists summarizes target milestones by quarter based on the project schedule and an assumed start date in Q3 of Fiscal Year 2019.

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| No. | Milestone | Target Completion (by FY Quarter) |
| 1 | GBO Electronics Printed Circuit Board Design; hardware procurements; RFI characterization and preliminary RFI excision algorithm design in collaboration with GBO REU and Berkeley summer undergrad students | FY2019 - Q4 |
| 2 | Development of new FGPA firmware | FY2020 – Q2 |
| 3 | Iterative FGPA Firmware Testing (Simulations) | FY2020 – Q3 |
| 4 | FPGA Firmware/Hardware Integration; RFI excision algorithm testing in collaboration with GBO REU and Berkeley summer undergrad students; GBO Summer Student Camp; Document standards and best practices for assessing RFI excision techniques | FY2020 - Q4 |
| 5 | Iterative Independent Instrument Testing with RFI Excision Techniques; Develop plan, schedule, and budget for phase 2 | FY2021 – Q1 |
| 6 | Iterative Integration Testing with VCU118s | FY2021 – Q3 |
| 7 | Document Outcomes and Final Report | FY2021 – Q4 |

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## Performance Measures

Program Management performance measures throughout the phase 1 project lifecycle will include:

* Analysis and monitoring of the project baseline (cost, schedule, scope), and controlling the baseline. Changes to the baseline will follow GBO’s Change Management Process.
* Measuring project activities through the appropriate allocation of iterative verification and validation of results against hypothesis
* Communications and stakeholder management through notifications, project reports, presentations, feedback, correspondence, meeting minutes, and other actions indicating transparency in the management of the project.
* Meaningful undergraduate summer student engagement and an organized summer student camp in year 2. Undergraduate summer students will receive assessments based on University requirements and are required to submit a project report.
* Controlling risks through active management of the risk register and the prioritization of highest risks through iterative research, development, and testing.

The GBO Program Manager will prepare and submit quarterly status reports for review by the project team, GBO Management, and collaborators. Annual, Final, and Outcomes reports will be submitted in accordance with NSF requirements.