# WKU Sisterhood Grant 110222: Big Red Radio Telescope

**12-Month Status Report**

*Steven Gibson, November 11, 2020*

## 1. Overview and Goals

The Big Red Radio Telescope project is converting an old 10-foot satellite TV dish and receiving system into a scientific instrument that WKU students and faculty will use to explore the "invisible" universe for education, research training, and public outreach. Goals of this effort include:

1. Foster significant collaboration between the WKU astronomy, physics, and engineering programs in the design and construction of the radio telescope.

2. Give students in these programs hands-on experience in many aspects of a complex technical project, providing invaluable professional training.

3. Augment student education and career training in several areas, including direct and remote astronomical observations, classroom demonstrations using live and recorded telescope data, computer interfacing and control systems, mechanical engineering design and build experience, and complex project management, coordination, and communication.

4. Working with WKU's Hardin Planetarium, enrich public education and outreach to school groups and the broader community by using the telescope and related concepts to demonstrate the "invisible universe" revealed by radio waves; WKU students involved in this effort will also gain science education experience.

5. Raise the public profile of the University, and support its mission as a student-focused university serving the region and providing exposure to science and critical thinking, while also strengthening ties with the local community.

This project has been going since 2016 but, with the help of the WKU Sisterhood, it should soon see the full assembly and installation of a working radio telescope. We give relevant details below, with particular focus on recent activities and others anticipated within the remainder of the grant period, which has been extended another 8 months to June 30, 2021.

## 2. Project Timeline (WKU Sisterhood Grant Period: 2019-2021)

| Acad. Yr. | Milestones |
|---|---|
| 2016-2017 | Acquire dish and receiver, analyze dull system, and assess upgrade needs. |
| 2017-2018 | Begin work with student teams to improve mechanical and electronic systems. |
| 2018-2019 | Survey telescope sites, develop control interfaces, and build azimuth system. |
| 2019-2020 | Design altitude system; improve motor and receiver interfaces. [cut short by COVID] |
| 2020-2021 | Final interfacing; build and integrate full system, deploy, test, and start observing! |
| 2021-2022 | Begin full use as teaching/outreach facility. |

## 3. General Outcomes

Many project goals have already been met at least partly, and fulfillment of the rest is anticipated in due course. Progress in the past year has been hampered by the COVID-19 pandemic, but we are poised for rapid action once people can work together again safely. Categorized in reference to the goals above, significant accomplishments include:

1. Astronomy and Physics faculty have been working closely with each other on this project since it began, and with School of Engineering and Applied Sciences (SEAS) faculty since 2017. This work includes considerable coordination and co-advising of students involved in the early retrieval and assessment of the initial telescope hardware, plus several offerings of the PHYS 318 computer-electronics interfacing course, an array of Engineering senior design and construction courses (ME 400, ME 412, ENGR 490, ENGR 491), and a handful of independent student projects outside the standard curriculum.

2. Many student projects in physics and engineering have been carried out in hands-on mechanical design and fabrication, control interfaces, signal handling, and system analysis. A number of these efforts have led to publications and presentation for the relevant courses, or to other interested groups; a partial list is given below (§8). A total of 40 WKU students have been involved to date; their names are provided in a separate section (§7).

3. Although the telescope is not yet functional for classroom teaching or field use to teach students about astronomy or the physics of waves, it has provided students involved in its development with real-world experience and technical training.

4. Design of educational materials using the telescope for college classes or public outreach has been deferred to focus on the physical instrument but will be tackled at the first opportunity.

5. The project has been presented in many public forums, as listed below (§8). We have also had contact with outside consultants, e.g., in the Kentucky Colonels Amateur Radio Club.

## 4. Highlights of the Past Year

Some major accomplishments of the project in the last 12 months are:

- In the Spring 2020 ENGR 490 Senior Design course, a team of mechanical engineering students designed the upper half of the radio telescope mount and motor drive system. This "altitude axis" subsystem pivots the telescope up or down to reach any desired angle above the horizon. It sits atop the "azimuth axis" subsystem that turns the telescope to a particular compass direction. The azimuth subsystem was designed by a previous ME 400+412 team in Spring + Fall 2018 and built by a different ENGR 491 team in Summer 2019. *(Plans to build the altitude system in Summer 2020 were delayed by COVID-19 to Fall 2020 and then Spring 2021.)* Motion about both axes enables the telescope to aim at any point in the sky. The original donated satellite dish lacked this ability, greatly limiting its functionality as a radio telescope.

- The ENGR 490 team also added several safety features to the telescope, including: (1) mechanisms to stop the telescope from turning too far in azimuth, to avoid damaging it; (2) cable pathways and suspension systems to protect data and power lines during mechanical motions;

(3) a mounting frame connecting the reflector dish to the altitude axis subsystem, which has been stress tested in numerical simulations of storm wind loading; and (4) an external cover to shield the mechanical and electrical systems from weather, insects, and other natural hazards.

- Physics students in the Spring and Fall 2020 PHYS 318 Data Acquisition courses have proceeded with several related efforts: (1) a special encoder system to tell the telescope its absolute position along each axis was researched, purchased for the azimuth axis, and integrated into the larger mechanical design; (2) newer and more versatile software-designed radio receivers have been acquired, and a new control interface is being designed to use them; (3) improvements to the motor control interface are in development and will be tested on a small working model of the mechanical system; and (4) lightning mitigation systems are being researched to protect the telescope in the field. *(As was true for engineering, this work by physics students was curtailed by the COVID epidemic in the second half of Spring 2020, and Fall 2020 work has proceeded in a more constrained manner given safe working requirements.)*

- In addition to these classroom efforts, two physics students worked independently over Summer 2020 on control interfaces for the telescope motor and receiver systems. One student got the basic interfacing software to work with the new software-defined radio (SDR) receiver systems ordered last spring, which will provide broader frequency coverage for the telescope observations. Unfortunately this work was constrained by COVID limitations. The other student however made more progress on the motor control code, which now includes correct speed and position calibrations as well as extra safety limits that stop the motors automatically if any control connection is lost. The motor control code has also been moved to a portable interface computer that can be used for field operations.

## 5. Plans for Next Year

Presuming the COVID pandemic recedes sufficiently for building activity to resume, we plan to complete the construction of the Big Red Radio Telescope by next summer. Major tasks remaining:

- Build the altitude axis assembly designed in Spring 2020, incorporating a similar encoder mechanism as used on the azimuth axis.

- Integrate both mechanical axis assemblies with receivers and related signal-path electronics.

- Complete control interfaces for the motors and radio receivers that allow for remote (internet) operability. Test these systems first in the lab with a small 3D-printed mechanical model.

- Perform a full system test of the entire telescope on WKU Campus.

- Select exact remote site for telescope installation and prepare this area for the telescope, including all necessary digging, trenching, and cabling for power and signal needs.

- Disassemble telescope on campus, transport, and install at remote site.

- Commission telescope by orienting pointing system, testing and calibrating all mechanical controls, verifying tracking and receiving systems, and performing other operational tests.

- Conduct trial observing experiments and work to develop instructional and outreach materials.

## 6. Financial Accounting

Our total budget is $11,900. Most grant expenditures will occur in the build and deploy phases (site preparation, foundation, laying cables, etc.). However, we have made some purchases already for reference books for students, new radio receivers, and the first of two special axis position encoders. These are listed below, with orders separated by horizontal lines (*books are in italics*).

| Product or Service | Vendor | Cost | Qty | Ship | Tax | Total | Date |
|---|---|---|---|---|---|---|---|
| *Understanding Basic Electronics* | ARRL | $29.95 | 1 | $12.50 | $5.39 | $107.74 | 2020 Feb 7 |
| *Understanding Basic Radio* | ARRL | $29.95 | 1 | – | – | – | – |
| *Understanding Basic Antennas* | ARRL | $29.95 | 1 | – | – | – | – |
| *Grounding and Bonding* | ARRL | $22.95 | 1 | $10.50 | $2.21 | $49.61 | 2020 Mar 14 |
| *Elimination of Electrical Noise* | ARRL | $13.95 | 1 | – | – | – | – |
| RSPdx software-defined radio | SDRPlay | $179.95 | 3 | $21.71 | $0.00 | $561.56 | 2020 Mar 18 |
| IncOder Inductive Angle Encoder | Zettlex | $540.20 | 1 | $6.48 | $47.74 | $594.42 | 2020 Mar 18 |
| **All purchases as of 2020 Oct 30** | | | | | | **$1313.33** | |

Some additional purchases are anticipated prior to full assembly, including a second encoder, interfacing hardware, and possibly other mechanical parts. The grant budget also includes funds for student wages. So far, students have only worked on the project for course credit or on a volunteer basis, but we may hire students for interfacing or testing work, and additional paid labor is anticipated for the telescope assembly and deployment.

## 7. Personnel

Here we list all people involved in the project to date, in chronological order within each category. People actively working in the past year are noted with an asterisk(*). Colors indicate affiliations with *Astronomy*, *Physics*, *Engineering*, *Manufacturing*, or *Other Groups*, although some people could be counted in more than one area.

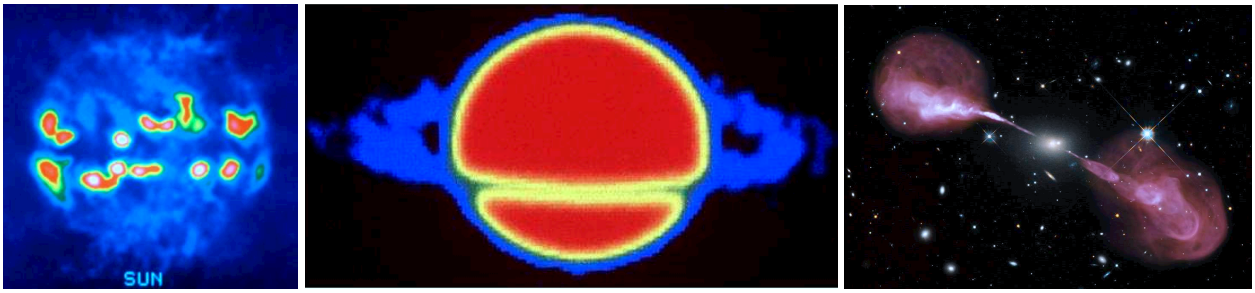
- **WKU Faculty & Staff (13):** Steven Gibson*, Mike Carini, Jason Boyles, Jason Wilson, Doug Harper*, Chris Byrne, Joel Lenoir*, David Laney, Greg Arbuckle, Brian Janes, Kyle Moss, Wade Decker*, Gordon Smith*
- **WKU Students (40):** Stacy Hicks, Trason Carter, Joshua Stewart, Rebecca Brown, Benjamin Thornberry, Phillip Wilkerson, Clarissa Roe, Patrick Stewart, Seth Harper, Noah Anderson, Luke Goodaker, Grant Taylor, Lane Wilson, Lateef Alnesafi, Dylan Lacefield, Ricky Stevens, Samuel Rapini, Mickey McClellan, Courtney Smith, Nihad Ferhatovic, David Hall, Devon Loomis, Andrew Riley, Marcus Todd, Lauren Cooper, Jacob Dobler, Lincoln Curry, Caleb Dillingham*, Christopher Adams, Connor Powell, Jarret Sippola, Maxwell Street, Micah Thornton*, Jared Parker*, Parker Stewart*, Tanner Whatley*, Brianna Rech*, Mahran Al-Mahri*, Landon Owens*, Carlos Gomez*
- **External Advisors (5):** John Gibson*, Mark Bunce, Jerry Hicks, Henry Cantrell*, Albert Lederer

For project role details, please see physics.wku.edu/~gibson/radio/dish/dish_credits.html.

## 8. Presentations, Press, and Other Project Visibility (web links in blue)

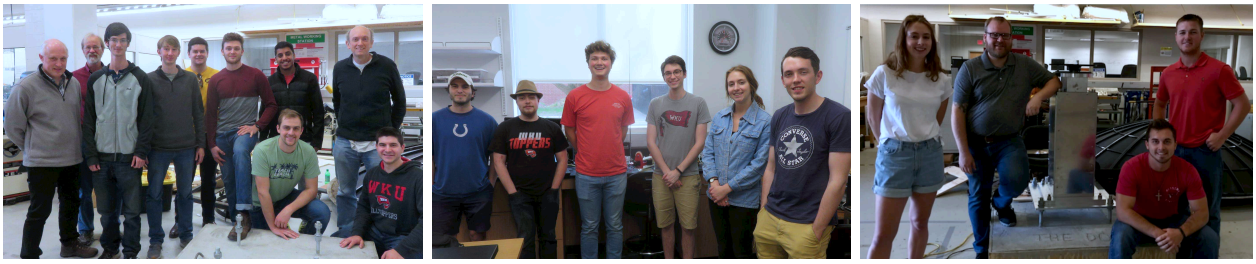
- *"Big Dish Telescope"*, Gibson, S. J. 2017, Project Overview, Physics Department website
- *"A Hands-On Radio Telescope for WKU"*, Wilkerson, P., Gibson, S. J., Cantrell, H., Boyles, J., Hicks, S., Harper, D., Carter, T., Brown, R., Stewart, J., Thornberry, B., & Pierce, J. 2017 March 25, Poster Presentation, WKU Student Research Conference, session 57, poster 36
- *"WKU Radio Telescope"*, Wilkerson, P., & Gibson, S. J., 2017 April 11, Invited Talk, Kentucky Colonels Amateur Radio Club
- *"Automated Radio Telescope, The Dob"*, Heath, T., & Fogle, L. 2018 November 19, Press Release, *WKU News* blog [retracted for revision]
- *"WKU Engineering Students Contribute to Radio Telescope Project"*, Mudd, A. 2018 December 8, Article, *Bowling Green Daily News*, p. 3A
- *"ME 412 Senior Project: Radio Telescope"*, Taylor, G., Wilson, R., Rapini, S., Goodaker, L., Stevens, R., Alnesafi, L., & Lacefield, D. 2018 December 12, Senior Project Talk, WKU SEAS Engineering Day seminar
- *"Star Light, Star Bright: How Two WKU Professors Help Tell the Story of Space"*, Shamberger, K. 2019 January 4, Feature Article, *WKU Research Foundation* blog
- Ogden College of Science and Engineering tweets on PHYS 318 Presentations, 2019 May 8
  - "*Students Using LabVIEW to Develop Control Software for Radio Telescope*"
  - "*Pan-Tilt Prototype Model for Radio Telescope Pointing Control*"
  - "*Students Demonstrate Software-Defined Radio Control Interface*"
- Gibson attended a talk titled *"The York County Astronomical Society Radio Telescope"* by Todd Ullery during the International Astronomy Teaching Summit in Baltimore, MD, 2019 July 17; this automated 15-foot instrument is being built in York, PA; made contact with the YCAS as a possible resource.
- *"Team Dish"*, Al-Mahri, M., Stewart, P., Whatley, T., & Rech, B. 2020 May 5, ENGR 490 Senior Project Talk
- *"Team Dish Proposal Documentation"*, Al-Mahri, M., Rech, B., Stewart, P., & Whatley, T. 2020 May 20, ENGR 490 Senior Project Report

## 9. Sample Figures

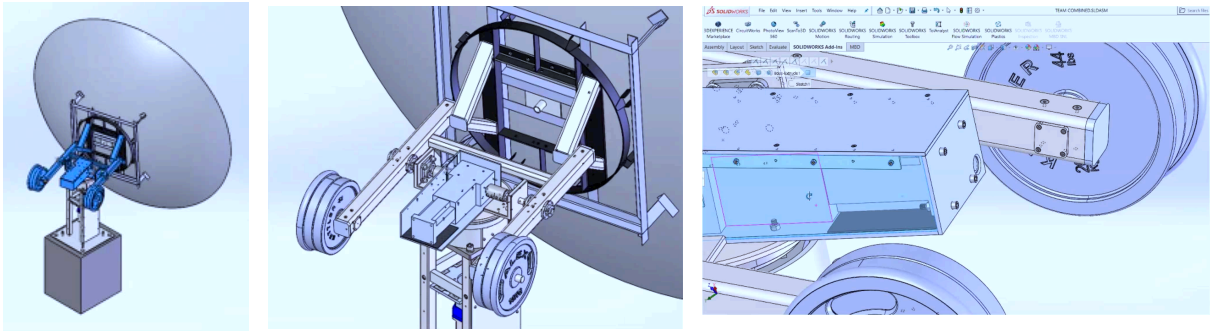



Radio images of some of the types of objects we hope to observe with the Big Red Radio Telescope. *Left to right:* Solar storm eruptions on the Sun, heat radiation from planet Saturn, and jets of energetic particles thrown out of a distant galaxy by a supermassive black hole.

Early work on the project. *Left to right:* WKU physics students retrieving the 10-foot satellite dish in Summer 2016, a student studying the original mount system in Spring 2017, and a Summer 2017 engineering model of the original mount, which was unable to point at all desired celestial targets and thus required upgrading.




Some WKU student teams who have worked to convert the satellite dish system into a proper radio telescope. *Left to right:* Engineering azimuth axis design team (with faculty advisors), Fall 2018; Physics motor control and receiver interface teams, Spring 2019; Engineering azimuth axis build team, Summer 2019



Recent mechanical engineering design work from Spring 2020. *Left to right:* Full model of redesigned mechanical system (now able to point anywhere in the sky); altitude axis assembly; motor enclosure and counterweights.