Quiet Skies: Exploring Radio Astronomy and the Noisy World we live in.

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Team Members

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Program Category: Curriculum Development
Intended Audience: K-12
Evaluation Type: Process; Outcome
Budget: $47940.00
# of Years to be funded: 2 Years

Institution's Authorizing Official:

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Primary's institute underrepresented?: No
Co-Investigator's institute underrepresented?: No

IDEAS Grant Proposal: Quiet Skies

Abstract:

NRAO proposes to develop instrumentation and curriculum that will allow students in grades 7-12 to join us in the quest for "quiet skies". Just as optical astronomers combat light pollution in order to conduct their research, radio astronomers have similar problems. For them, visible light is not an issue; rather, it is radio frequency interference (RFI).

NRAO staff will design and build the initial prototype Quiet Skies detectors in 2004. NRAO will then collaborate with teacher-interns to test, calibrate and modify the instrument, and to develop a curriculum. In 2005, we will ask a larger group of teachers to field-test "Quiet Skies" with their students. "Quiet Skies" will be launched statewide in 2006, and nationally in 2007.

Through the use of our "Quiet Skies Detector", students will investigate and measure the RFI environment at their schools and in their towns. Students will measure RFI levels at frequencies of critical importance to radio astronomy, learning radio astronomy content along the way. They will provide this data to an NRAO database in an effort to map the RFI levels across West Virginia during the 2-year span of the IDEAS grant.

In related activities, students will also investigate how the radio spectrum is allocated. They will learn that the world is indeed a noisy place, and that commercial use of the spectrum provides many benefits, while at the same time jeopardizing radio astronomy research. Science and technology are interrelated, and the relationship is often complicated! Students will explore these issues.

Introduction

Optical and radio astronomy are incredibly important areas of astronomical research, in part because observations can be carried out from the ground. Visible light and radio waves pass through Earth's atmosphere making it possible to build large, technologically advanced instruments with which to investigate celestial phenomena. The Green Bank Telescope and the Very Large Array, at the National Radio Astronomy Observatory (NRAO), are premier examples of such large advanced instruments in the area of radio astronomy.

In fact, the mission of NRAO is to provide state-of-the-art radio telescope facilities for use by the scientific community. We conceive, design, build, operate and maintain radio telescopes used by scientists from around the world. Scientists use our facilities to study virtually all types of astronomical objects known, from planets and comets in our own Solar System to quasars and galaxies billions of light-years away.

Technology is a sword that cuts both ways in radio astronomy: new developments in telescope design, manifested by the Green Bank Telescope, make it possible to "see" farther, and detect fainter objects. But the proliferation of ground and space-based communication technologies—cell phone towers, satellite communications systems and the like-- create interference which can effectively blind radio telescopes at certain frequencies.

Staff at the NRAO, therefore propose to launch *Quiet Skies*, a project in which students in grades 7-12 will explore radio astronomy science, investigate radio frequency interference (RFI) in their home districts, and tackle the Science-Technology-Society issues surrounding radio observatories' quest for quiet skies.

Goals and Objectives

The aim of *Quiet Skies* is to promote student awareness of radio astronomy and radio frequency interference through an inquiry-based research project. We will design and prototype a portable interference detection system for loan to schools. In collaboration with classroom teachers, we will develop curricula and an interactive web site to accompany the instrument.

Over the two-year lifespan of the IDEAS grant, our goal is to develop and test the instrument and curriculum with teachers and schools in West Virginia. Our long-term goal is to disseminate *Quiet Skies* to schools and museums across the country. Students using Quiet Skies will become support scientists to the NRAO, collecting, reducing and finally, submitting RFI data to a national database maintained by the NRAO.

Through *Quiet Skies*, students will:

- Measure interference levels at their schools and in their communities;
- Reduce and transmit their data to an NRAO data base;
- Use online spectrum allocation data, and local information to determine possible causes of interference in their area;
- Analyze the complex trade-offs between radio astronomy's need for quiet skies, and other commercial, and non-commercial uses of the spectrum and share their insights with others;
- Debate how the spectrum should be allocated.

Project *Quiet Skies* addresses numerous National Science Education Standards in the categories of <u>Science as Inquiry</u>, and <u>Science/Technology</u> interdependence. (Specific NSES standards addressed by our project are described in Appendix A.) While students are conducting experiments and making field measurements of RFI in their home districts, they will also be investigating the myriad uses to which the radio spectrum is put. Students will be asked to reflect upon the many pressures on the radio spectrum and offer suggestions to resolve competing interests.

Project Description

Phase One: NRAO scientist Ron Maddalena, educator Sue Ann Heatherly, and engineer Steve Hicks will form the initial IDEAS team. Over the course of winter/spring, 2004 we will design and build 2 prototype RFI detector systems, and construct a simple *Quiet Skies* web site.

In many ways, NASA's Radio Jove has been the inspiration for the *Quiet Skies* RFI detector. The Radio Jove system is inexpensive and designed for ease of use by students. It is designed for a single purpose and so has no superfluous "bells and whistles". Our *Quiet Skies* Detector will share these properties with Radio Jove:

<u>Characteristics of Detector design.</u> The detector will:

1. be portable and easy to use in the field. The entire system, including antenna, receivers, and detector can be designed to fit on a notebook-sized printed circuit board.
2. use a directional antenna - as opposed to an omni-directional antenna. The antenna, essentially a directional log-periodic, will be etched right onto the circuit board. By mounting the system on a tripod, students will record data as a function of cardinal direction, providing clues to the source of the interference.
3. result in data that would be meaningful to NRAO. Compromising between wide frequency coverage and simplicity in design, the IDEAS team has determined that the system should operate at 3 bands: 800 MHz, 1.4 GHz, and 1.6 GHz. These frequencies are extremely valuable to radio astronomers. Neutral hydrogen atoms emit radio waves at a frequency of 1.4 GHz; the hydroxyl radical at 1.66 GHz. Lower frequencies such as 800 MHz are important to pulsar astronomers. Students will select the frequency to be measured and record RFI levels as a function of frequency. They will also record RFI as a function of cardinal direction and time of day for their location.
4. be inexpensive enough to "mass-produce". One could use commercially available equipment for a project such as this, but components, such as a wide-band radio, antenna, and total power detector or spectrum analyzer, but the system would be cumbersome and expensive. By developing an instrument streamlined for the purpose of detecting RFI over one octave in frequency, costs will be contained.

These characteristics will guide the design of the RFI detector in its first stages. Classroom teachers will join the IDEAS team in the next phase.

Phase Two: During summer 2004, NRAO will recruit 2 teacher-interns to work with the IDEAS team for six weeks. They will test, calibrate and offer design modifications to the Quiet Skies Detector. In addition, they will be the primary authors of the accompanying curriculum.

<u>Orientation Activities</u>. The NRAO in Green Bank is essentially an academic village. Engineers, technicians, scientists and programmers collaborate closely in the development of instrumentation for the Green Bank Telescope, and in supporting visiting astronomers. *Quiet Skies* teacher-interns will be immersed in this rich environment:

1. In order to introduce radio astronomy and radio frequency interference to our teacher-interns, they will participate in on-site activities at the NRAO. Teacher-interns will:

- Gain experience in radio astronomy techniques by conducting an observing project using a forty foot diameter radio telescope;
- Participate in ongoing NRAO RFI monitoring;
- Join in Green Bank Telescope observing sessions where researchers are using the frequency bands *Quiet Skies* will monitor.

2. The NRAO hosts several professional development opportunities for teachers each summer, including a 2-week institute and a Research Experience for Teachers (RET) program funded by the National Science Foundation. Teacher-interns funded through the NASA IDEAS program will participate in many of the activities organized through these programs.

Quiet Skies Activities. *Quiet Skies* teacher-interns will employ NRAO's state-of-the-art anechoic chamber to calibrate the prototype RFI detectors. By measuring the detector's response to an artificial noise source, they will characterize the directionality of the antenna and the system's overall response to RFI levels. These experiments will result in ideas for modification to the detector as well as provide ideas for student experiments. The teacher-interns will define accurate and easy data collection strategies for students in the field.

Our teacher-interns, in collaboration with the IDEAS Team and other NRAO staff members will also develop curriculum themes and activities. There are many good sources for basic content on subjects such as the EM spectrum and multi-wavelength astronomy among NASA and other web sites. These resources will be utilized and new content materials will be developed that are specific to the *Quiet Skies* project. Ideas for novel content include:

1. Astronomy at 800, 1420 and 1665 MHz. Astronomers use these frequencies to study pulsars, atomic hydrogen and the OH radical respectively. Content and activities will include exploration of spectral line data as well as astronomical images.
2. The Quiet Zone. The National Radio Quiet Zone (NRQZ) was established by the Federal Communications Commission (FCC) in 1958 to minimize harmful interference to the National Radio Astronomy Observatory (NRAO) in Green Bank. Thirteen thousand square miles in area, it provides NRAO with the ability to regulate fixed commercial transmitters. Consequently, Green Bank is more radio quiet than equally isolated areas around the country. Students will compare RFI data in their regions to that in the Quiet Zone. Students will learn how NRAO models the effects of transmitter placement on the RFI environment at the Observatory using techniques such as terrain mapping.
3. Spectrum Allocation and Societal Impacts. The World Radio Communications Conference sets the stage for global allocation of the radio spectrum. Activities will be developed where students role-play a specific interest in the spectrum and argue their case for allocation of frequency. Students will research arguments and opinions by studying the briefs of organizations such as the International Union sub committee (IUCAF), which advocates for the cause of radio astronomy and other passive science applications of the spectrum.

Phase Three. Our teacher-interns will field test the *Quiet Skies Detector* and curriculum with students in their schools. Through e-mail and quarterly face-to-face feedback meetings with students and teacher-interns, ideas for modifications to both detector and curriculum will be implemented, resulting in a beta version of the *Quiet Skies* dectector. During summer 2005, NRAO will hold a three-day workshop for 20 teachers from the school districts surrounding us. Teacher-participants will complete an observing project using the Forty Foot telescope, receive instruction in radio astronomy, and use the *Quiet Skies* materials. These teachers will further field-test *Quiet Skies* in their classrooms. Select teachers from this group will be invited to present *Quiet Skies* at the West Virginia Science Teachers Conference, as part of our initial roll-out of the project state-wide.

<u>Quiet Skies Forum for teachers and students</u>. To culminate this grant, NRAO will host the first annual "Quiet Skies Forum" for students and teachers in the spring of 2006. The first annual forum will be held at NRAO, in future years, the forum will locate to other areas in the state where *Quiet Skies* is underway. Participation is voluntary. During the Forum students will present their research results to NRAO staff and each other, discuss spectrum issues with experts in the field, and participate in hands-on activities.

Web Development. The NRAO IDEAS team will undertake the initial development of the Quiet Skies web site. NRAO will host the site and the RFI database. Sue Ann Heatherly and Ron Maddalena will construct the basic site in year one and make content modifications to the site in year two. Before state-wide launch of Quiet Skies, in-house and, if necessary, outside graphic artists will be called upon to create the overall look and feel of the site.

Dissemination Plan

- Over the course of the grant, NRAO will establish a *Quiet Skies* web page, complete with cgi scripted data entry forms, and a listserve for teachers. Lesson plan, student narratives, and *Quiet Skies* results will be posted on the web site. An online sign out schedule for the *Quiet Skies Detector* will be available as well.

- NRAO staff and our cadre of pilot-test teachers for *Quiet Skies* will train other teachers throughout West Virginia at science and math teacher conferences.

- We will develop a *Quiet Skies* brochure to be mailed to teachers at all West Virginia schools in late Autumn, 2005.

- In West Virginia, and surrounding region, NRAO will offer Quiet Skies for **loan** to schools, and distribute it via UPS or US mail. NRAO will cover the costs of distribution.

- National dissemination to observatories, informal science centers and schools will begin in 2007, through the Association of Science and Technology Centers web site and newsletter, NSTA publications, and through organizations such as the NASA OSS EPO Broker network. Laurie Ruberg, program manager for the mid-atlantic Broker/Facilitator Program, has read the proposal and is interested in disseminating within our OSS region. *Quiet Skies* has potential to become a national student "service" project in science. Like Radio Jove, we expect dissemination to grow slowly and steadily.

The long-range goal of this project is to disseminate the *Quiet Skies* project to students nation-wide. We do not yet know whether we can distribute the detector in kit form (like Radio Jove), or if NRAO will need to build and calibrate the detector. The prototyping phase of the project will determine if individual detectors share nearly identical sensitivity and directionality, and if adequate field calibration techniques can be developed. Either way, NRAO will provide Quiet Skies detectors and materials **at cost** to informal learning centers and schools.

The end product from NRAO's standpoint is a national database of RFI data built by student measurements. Students should feel like they are part of a national team, acquiring data that is useful to NRAO. We want students from across the country to dialogue about their measurements and seek advice from one another. So, it is important that students are able to compare data collected by different detectors at different locations.

Timeline

Date	Tasks
December 2003 – May, 2004	• Engineering design of Quiet Skies Detector • Build, test, modify prototype • Initial web site development.
March 2004	• Advertise for two summer positions for teacher-interns.
Summer 2004	• Teacher-interns test, calibrate, modify prototype, build 4 detector systems, develop curriculum • NRAO develops web-based reporting form for students
October 2004	• Hold Quiet Skies workshop at the West Virginia Science Teachers Conference. • Recruit participants and field sites for 2005.
Academic year 2004/2005	• Students field test Quiet Skies • Quarterly feedback meetings with teacher-interns and students • Web site is refined with student, teacher feedback • Modify Quiet Skies Detector
October 2004	• Hold Quiet Skies workshop at the West Virginia Science Teachers Conference. Recruit participants and field sites for 2005.
Summer 2005	• 3-day Quiet Skies workshop at NRAO for 20 WV teachers. • Quiet Skies web site is launched
Academic Year 2005/2006	• Field –test Quiet Skies at 20 sites, modify curriculum. • Quiet Skies Student Forum at NRAO
September-Nov. 2006	• Statewide rollout of Quiet Skies via mailings, state and county math and science workshops, and Web-based dissemination.
Fall 2007	• Begin national dissemination of Quiet Skies to observatories, science centers and schools.

Evaluation Plan

Our evaluation plan includes both Process and Outcome evaluation strategies, to answer the following questions.

1. Implementation of Quiet Skies Equipment and Materials. Is the *Quiet Skies Detector* easy to use and appropriate for the target audience? Is the curriculum clear and appropriate to the target audience? *Strategies.* We will rely on teacher/student feedback and classroom observations to critique *Quiet Skies* equipment and materials. IDEAS team members will visit classrooms during implementation of *Quiet Skies*, and work with student groups using the detector. Through face-to-face focus group discussions and e-mail, *Quiet Skies* teachers and students will provide frank and detailed feedback on the instrument and the curriculum.

2. Content Gain and Attitudes toward Science. Do students know more about radio astronomy as a result of completing *Quiet Skies* activities? Do they gain understanding of the nature of science? Do students feel accomplished as a result of participating in *Quiet Skies*? Do they feel like scientists and/or engineers?

Strategies: Students participating in Quiet Skies will complete a pre-post Likert style attitudinal survey. The survey was developed by NRAO for use in its professional development program, and has been tested for reliability(see Appendix D). Students will also complete pre-post concept maps to measure growth in content knowledge. Teachers will score the maps and provide NRAO with this data.

3. Professional Development.

Teacher-interns: Did the internship provide them with tools, people and other resources needed to accomplish the development goals of *Quiet Skies*? Do teacher-interns feel more prepared to deliver inquiry-based science in general and *Quiet Skies* in particular? Is communication between teachers and NRAO staff adequate during the school year?

Phase 3 Teachers. Did the workshop prepare teachers to implement Quiet Skies in the classroom?
Strategies: Again, NRAO will use pre-post surveys to assess individual components of the internship and workshops. We will also evaluate teachers' readiness to embrace inquiry-based instruction (instruments in Appendix D).

Budget

Organization Associated Universities, Inc./National Radio Astronomy Observatory			
Principal Investigator/Co-PI	Ronald J. Maddalena/Sue Ann Heatherly		
Budget Category		**Funds Requested**	
		year one	year two
A. Team Staff			
Name	**Title**		
Ronald J. Maddalena	Staff Astronomer	$0.00	$0.00
Sue Ann Heatherly	Education Officer	$0.00	$0.00
Steve Hicks	Staff Engineer	$0.00	$0.00
B. Staff Travel			
Maddalena, Hicks, Heatherly to regional education conferences		$1,000.00	$2,000.00
C. Teacher Support Costs			
	Stipends	$12,000.00	$3,960.00
	Travel	$0.00	$2,500.00
	Subsistence	$0.00	$4,290.00
	Educational Materials		$2,200.00
D. Instrument Development and production costs		$4,000.00	$6,000.00
E. Curriculum Development/Dissemination			$2,000.00
F. Overhead (20%)			$7,990.00
	sub total	$17,000.00	$30,940.00
	Two-Year Total		**$47,940.00**

Budget Justification (years 1 and 2)

A. Senior Personnel: The PI for this project is Dr. Ron Maddalena, Staff Astronomer and Chief GBT Commissioner. He will coordinate the development of the kit, assist in web site development and work with the teachers to learn about Green Bank Telescope operations.
The IDEAS Program at NRAO-GB will be coordinated by Co-PI, Sue Ann Heatherly. She is the Education Officer at the West Virginia Site. She will be responsible for coordinating all activities for the teachers, developing the web site and compiling evaluation results. Steve Hicks will design the *Quiet Skies* detector and will be responsible for building them. He will also assist in training teachers. Other personnel include the scientists and engineers who will work closely with participants on this project. No support is requested for senior personnel.

B. Travel: $3,000 to support travel by Sue Ann Heatherly, Ron Maddalena and/or Steve Hicks to NSTA meetings, state and regional science education meetings and to schools field-testing *Quiet Skies*. Workshops will be held to introduce the kits to interested teachers.

C. Participant Support:

Stipends: During the first year, NRAO will hire two teacher-interns to build and test the RFI kits and to design curriculum. $1,000/week x 6 weeks x 2 teachers = $12,000/year. The national average salary for teachers is $40,000/ year or $4,000/month in a 10-month year. NRAO requests stipends equivalent to the national average.

During the second summer of the program, NRAO will host a 3-day workshop for 20 teachers from West Virginia and surrounding states. Our two intern teachers from year-one will return to assist with the workshop. Participants will receive instruction on radio astronomy, use a 40 Foot diameter radio telescope, and learn how to use the RFI detector in their classrooms. This cadre of teachers will field test the instruments and curriculum during the 2005-2006 school year. We request stipends for 22 teachers (total) at a rate of $60/day.

Travel: Travel support is requested for select teacher-interns to present *Quiet Skies* at state science/math teachers meetings during the second year of the program. School districts will be asked to support their teachers in terms of substitutes (1-2 days/teacher).

Subsistence: During the first year, our teacher-interns will be paid a summer "salary". Therefore, they will not receive subsistence compensation. Reasonable rental housing is available at NRAO and in the local community. We request funds to cover room and board at NRAO during the teacher workshops, second year. 22 teachers x $65/day x 3 days = $4,290.

Educational Materials: Radio astronomy materials/posters, RFI detector curriculum, etc. for teachers' classrooms. $100 x 22 = $2,200

Other Direct Costs:

D. **Materials and supplies:** Research and Development for 4 prototype detectors and construction of 6-10 additional RFI instruments in year 2 at $10,000.00 total. The goal is to be able to produce an RFI detector for $500.00 or less so that they can be readily made and distributed to a larger audience. This figure assumes higher initial costs during prototyping. Any funds remaining will be used to construct additional detectors.
Up to $1000.00 of this amount may be used to outsource graphic design for the final version of the Quiet Skies Web site.

E. **Dissemination**: advertisement in science teacher journals, production and regional mailing of kit brochure.

F. **Overhead.** As per the IDEAS grant application materials, NRAO charges 20% in indirect costs = $7,990.00

Cost share: Quantifiable sources of cost-share include:

- Workshops given by teachers will result in need for substitute teachers: first year: 2 teachers x 2 days/teacher x $100/day = $400.00/year; second year: up to 10 teachers @1 day/teacher = $1,000.00
- PI, Co-PI. Engineer Salary: time not charged to the grant: $17,500/year.
- NRAO staff: equivalent of at least 20% of 2-3 scientist/engineer's time during the 6 week appointment. Assuming $60,000 as average salary, this amounts to time without renumeration of $4,160.00/year.
- Fringe benefit of salaries at 32.5% = $7,039.00/year.

APPENDIX A

TARGET AUDIENCE

K-12 Formal Education: *Quiet Skies* addresses K-14 science, mathematics and/or technology education, and includes professional development of teachers at the NRAO in Green Bank, WV. *Quiet Skies* addresses the following goals (italics) as paraphrased from the National Science Education Standards. Bold-faced text describes how the *Quiet Skies* program applies to the goals:

1) Science and Technology

a) Science often advances with the introduction of new technologies. Solving technological problems often results in new scientific knowledge. New technologies often extend the current levels of scientific understanding and introduce new areas of research.

Radio Astronomy is dependent upon research and development in radio frequency and digital engineering. New technology was developed specifically for the Green Bank Telescope (GBT), in part, to reduce the telescope's suseptablity to RFI. Students will investigate the unique engineering in the GBT.

b) Science and technology are pursued for different purposes. Scientific inquiry is driven by the desire to understand the natural world, and technological design is driven by the need to meet human needs and solve human problems. Technology, by its nature, has a more direct effect on society than science because its purpose is to solve human problems. Technological solutions may create new problems.

Communications techniques developed over the last decade are increasingly ubiquitous in our society. Developments in technology that make it possible to talk to "anyone, anywhere" have negative consequences for radio astronomy.

c) Understanding basic concepts and principles of science and technology should precede active debate about the economics, policies, politics, and ethics of various science- and technology-related challenges.

Once students have made field measurements of RFI in their home schools and hometowns, and understand the challenges to radio astronomy, they can weigh this new information against other uses for the EM spectrum. Students will be able to derive informed opinions about the allocation of the radio spectrum.

d) Individuals and society must decide on proposals involving new research and the introduction of new technologies into society. Decisions involve assessment of alternatives, risks, costs, and benefits and consideration of who benefits and who suffers, who pays and gains, and what the risks are and who bears them.

***Quiet Skies* provokes students into analyzing the costs and benefits of spectrum allocation for commercial and non-commercial use.**

Inquiry

a) Design and conduct scientific investigations.

Students using Quiet Skies will investigate Radio Waves and RFI unique to their hometowns and districts. They will determine where and how to collect data to sample their location, collect and analyze RFI data, use online databases to derive possible sources of RFI in their neighborhoods.

b) Use appropriate tools and techniques to gather, analyze, and interpret data. The use of tools and techniques, including mathematics, will be guided by the question asked and the investigations students design. Students should be able to access, gather, store, retrieve, and organize data, using hardware and software designed for these purposes.

Quiet Skies designs, builds and provides a scientific instrument to students, and framework within which to participate in a shared experiment across the state.

c) Develop descriptions, explanations, predictions, and models using evidence.

d) Communicate scientific procedures and explanations. With practice, students should become competent at communicating experimental methods, following instructions, describing observations, summarizing the results of other groups, and telling other students about investigations and explanations

Students will communicate and discuss their results with their peers in the classroom and present their results to other students at the Quiet Skies Forum.

PROGRAM CATEGORY

Quiet Skies combines student research, through use of a Radio Frequency Interference Instrument, and curriculum development in the areas of radio astronomy, and technology issues facing allocation of the radio spectrum. The program will focus on:

- Curriculum Development, including
  - Lesson Plans
  - Teacher Guides
  - Web site for students
- Research Opportunities for students including:
  - Labs
  - RFI measurements

APPENDIX B

EQUIPMENT CERTIFICATION

The following certification document must be executed by an authorizing official of the grantee organization and submitted with the grantee's proposal. The grantee organization certifies that any major pieces of equipment (e.g., telescopes, Starlabs, etc.) or items costing over $1,000 with a useful life of more than two years purchased through a grant resulting from this proposal will be used solely for the purpose of directly supporting the program during the life of the grant. This certification covers, but is not limited to:

1. HARDWARE/SOFTWARE

Any hardware/software purchased through a grant resulting from this proposal will be used solely for the purpose of directly supporting the approved program during the life of the grant. Additionally, the ongoing use of any hardware/software purchased will be for educational activities only.

2. OTHER

The ongoing use of any major pieces of equipment (e.g., telescopes, Starlabs, etc.) or items costing over $1,000 with a useful life of more than two years purchased will be for educational activities only.

This certification is a material representation of fact upon which reliance was placed when this transaction was made or entered into. Any person or institution that does not comply with the certification will forfeit the use of equipment as well as any remainder of grant funding.

____
Signature of Certifying Authorizing Official

National Radio Astronomy Observatory
____
Institution Name

10/22/2003
____
Date

06-02

CERTIFICATIONS

The following certification document must be executed by an authorizing official of the grantee organization and returned along with the grant proposal document:

1. CIVIL RIGHTS:
The grantee certifies that it has filed with the Nat9ional Aeronautics and Space Administration, NASA Form #1206 (rev. Mar. '84), which is an Assurance of Compliance with Title VI of the Civil Rights Act of 1964 (42 U.S.C 2000d). If that form has not been filed with NASA, it must be included with the signed grant award notification document when it is returned to the Institute.

2. DEBARMENT AND SUSPENSION AND DRUG-FREE WORKPLACE:
The grantee certifies that it is in compliance with the provisions of 14 CFR 1265, Government-wide Debarment and Suspension, and Government Requirements for a Drug-Free Workplace, unless excepted by paragraphs 1265.770 or 1265.610. The grantee further represents that it maintains such regulations and shall provide a separate filing, if requested.

3. CERTIFICATION REGARDING LOBBYING:
For grants exceeding $100,000, the undersigned certifies, to the best of his or her knowledge and belief, that:

A. No Federal appropriated funds have been paid or will be paid, by or on behalf of the undersigned, to any person for influencing or attempting to influence an officer or employee of any agency, a Member of Congress, an officer or employee of Congress, or an employee of a Member of Congress in connection with the awarding of any Federal contract, the making of any Federal grant, the making of any Federal loan, the entering into of any cooperative agreement, and the extension, continuation, renewal, amendment, or modification of any Federal contract, grant, loan, or cooperative agreement.

B. If any funds other than Federal appropriated funds have been paid or will be paid to any person for influencing or attempting to influence an officer or employee of any agency, a Member of Congress, an officer or employee of Congress, or an employee of a Member of Congress in connection with this grant, the undersigned shall complete and submit Standard Form-LLL, "Disclosures Form to Report Lobbying," in accordance with its instructions.

C. The undersigned shall required that the language of this certification be included in the award documents for all subawards at all tiers (including subcontractors, subgrants, and contracts under grants, loans, and cooperative agreements) and that all subrecipients shall certify and disclose accordingly.

This certification is a material representation of fact upon which reliance was placed when this transaction was made or entered into. Submission of this certification is a prerequisite for making or entering into this transaction imposed by section 1352, title 31, U.S. Code. Any person who fails to file the required certification shall be subject to a civil penalty of not less than $10,000 and not more than $100,000 for each such failure.

Signature of Certifying Authorizing Official

National Radio Astronomy Observatory

Institution Name

10/22/2003

Date

GF-99-8

Appendix C: List of Major Grant Awards Received by NRAO-Green Bank over the past 5 years

2000, 2001, 2002-2005: **Astronomy Research Experience for Science Teachers (AREST)** REU Supplement Proposal to the NSF to support the NRAO RET program, funded 2001, 2002, 2003.

1997: **Radio Astronomy Research Enhancing Coodinated and Thematic Science (RARE CATS)** Proposal to the NSF Teacher Enhancement Program, funded 1998-2003.

1997: **Catching the Wave, Enhancing the NRAO Public Education Program** Proposal to the NSF ISE Program, funded 1998-2001.

1997: **New Connections Partners in Education**
Proposal to Apple Computers, Inc., funded May 1997-May 1999.

NSF supported programs in which we participate:

1988-present: **Chautauqua Short Course: A Radio View of the Universe** The annual Chautauqua Short Course is an NSF sponsored program that provides an opportunity for NRAO astronomers to communicate new knowledge, concepts, and techniques directly to college teachers in ways which are immediately beneficial to their teaching. http://www.engr.pitt.edu/chautauqua/index.html

2000-present: **Contemporary Laboratory Exercises in Astronomy** (CLEA), summer workshop. Project CLEA staff and teachers develop laboratory exercises that illustrate modern astronomical techniques using digital data and color images. Their summer workshop series includes an overnight experience at the NRAO. http://www.gettysburg.edu/academics/physics/clea/CLEAhome.html

1996-present: **Hands-On Universe (HOU).** HOU is an educational program that enables students to investigate the Universe while applying tools and concepts from science, math, and technology. The NRAO participates as an informal site for HOU as well as offering an annual teacher-training workshop. http://handsonuniverse.org/

1991-present. **Hands-On Science Outreach (HOSO).** HOSO is an after-school science and math enrichment program primarily for K-6 students. NRAO has been leading HOSO programs in the local school since 1991. http://www.hands-on-science.org/

Others

2003-present: **NASA/NRAO Astronomy Institute.** Under the *Living with a Star* program and co-sponsored by NASA-Goddard, NRAO and NASA jointly hosted the first annual NASA/NRAO Astronomy Institute for science teachers in summer 2003.

Appendix D: Evaluation Instruments

Last Four digits of Social Security #				

The Nature of Science and Science Teaching

Please indicate how important each of the following is to you as a science teacher.

		not important			very important
1.	Working in a research setting or laboratory.	____	____	____	____
2.	Analyzing data.	____	____	____	____
3.	Conducting background research.	____	____	____	____
4.	Making science important to my students.	____	____	____	____
5.	That science is a body of absolute truth.	____	____	____	____
6.	That students show curiosity.	____	____	____	____
7.	That students have a questioning attitude.	____	____	____	____
8.	Allowing students to explore for themselves.	____	____	____	____
9.	Having a highly structured science program.	____	____	____	____
10.	Covering the content in the textbook	____	____	____	____
11.	Integrating inquiry into classroom instruction.	____	____	____	____
12.	That students show skepticism.	____	____	____	____
13.	Using a laboratory manual.	____	____	____	____
14.	Teaching science facts through lecture.	____	____	____	____
15.	Teaching science facts through experiments.	____	____	____	____
16.	Science is an activity performed primarily by individuals.	____	____	____	____
17.	Science is an interactive group activity.	____	____	____	____
18.	Science is a way to generate ideas.	____	____	____	____
19.	Science is a way to test theories.	____	____	____	____
20.	Science is a way to solve problems.	____	____	____	____
21.	Trial and error is unscientific.	____	____	____	____
22.	Science is a set of principles/ theories to be learned	____	____	____	____
23.	The facts of science should be questioned	____	____	____	____
24.	Contributing to the body of scientific knowledge	____	____	____	____

02-A

Last Four digits of Social Security #				

Internship evaluation

Please rate the quality of the following aspects of your experience as an MPS Intern. Please answer on the lines provided.

P = poor F = fair G= good E = excellent

	P	**F**	**G**	**E**
1. Living accommodations and dining	_____	_____	_____	_____
2. Access to scientists	_____	_____	_____	_____
3. Access to NRAO personnel	_____	_____	_____	_____
4. Access to equipment	_____	_____	_____	_____
5. Access to scientific facilities	_____	_____	_____	_____
6. Astronomy Background Activitie	_____	_____	_____	_____
7. Education Sessions	_____	_____	_____	_____
8. Coordination of the Program	_____	_____	_____	_____
9. Astronomy Enrichment Lectures	_____	_____	_____	_____

How valuable were each of these components of the experience to you:

	Low value			**High value**
10. Learning to use telescopes and equipment.	_____	_____	_____	_____
11. Learning radio astronomy content	_____	_____	_____	_____
12. Working with NRAO staff	_____	_____	_____	_____
13. Developing classroom activities	_____	_____	_____	_____
14. Working in a team	_____	_____	_____	_____
15. Reading relevant research	_____	_____	_____	_____
16. Group sharing of energy and ideas	_____	_____	_____	_____
17. Collecting Quiet Skies data	_____	_____	_____	_____
18. Interpreting Quiet Skies results	_____	_____	_____	_____

please continue.

Indicate to what extent you agree or disagree with the following statements by using this scale.

SA = Strongly Agree A = Agree D = Disagree SD = Strongly Disagree

As a result of my participation in this program, I am better prepared to:

	SA	**A**	**D**	**SD**
19. Involve my students in research.	______	______	______	______
20. Listen to students.	______	______	______	______
21. Have students generate their own questions	______	______	______	______
22. Teach students how to collect data	______	______	______	______
23. Teach students how to record data	______	______	______	______
24. Teach students how to make inferences	______	______	______	______
25. Develop alternative assessments	______	______	______	______
26. Engage in totally unfamiliar subjects	______	______	______	______
27. Conduct experiments	______	______	______	______
28. Teach astronomy content	______	______	______	______
29. Expect the unusual	______	______	______	______
30. Tolerate other opinions	______	______	______	______
31. Accept criticism of my ideas	______	______	______	______
32. Take risks	______	______	______	______
33. Express opinions in presence of experts	______	______	______	______
34. Test new ideas	______	______	______	______
35. Record data accurately	______	______	______	______
36. Look for alternative solutions	______	______	______	______
37. Teach engineering concepts.	______	______	______	______

Please be sure that you have answered all items on the lines provided.

Teacher Code				

Student Code				

Student Attitude Toward Science

Please respond to each statement on the lines provided.

	None of the time			All of the time
1. Science class is fun.	____	____	____	____
2. Science class is boring.	____	____	____	____
3. Science class makes me feel uncomfortable.	____	____	____	____
4. Science class makes me feel successful.	____	____	____	____
5. In science class I state my own opinion.	____	____	____	____
6. Information learned in science is used in daily life.	____	____	____	____
7. Being a scientist would be fun.	____	____	____	____
8. In science it is important to plan experiments	____	____	____	____
9. In science class I follow the textbook.	____	____	____	____
10. In science class I answer the questions at the end of the chapter.	____	____	____	____
11. In science class I solve problems.	____	____	____	____
12. I ask questions in science class.	____	____	____	____
13. I work in groups.	____	____	____	____
14. I use computers in my science class.	____	____	____	____
15. I use equipment in my science class.	____	____	____	____
16. Being an engineer would be fun.	____	____	____	____
17. My science teacher encourages me to find my own solutions.	____	____	____	____
18. In science class I record my observations.	____	____	____	____
19. I worry when results do not match those of my classmates.	____	____	____	____

Please continue.

	None of the time			All of the time
20. I make graphs or charts using my results.	____	____	____	____
21. In science I share my data and results.	____	____	____	____
22. My science teacher admits not knowing all the answers.	____	____	____	____
23. While solving problems I make predictions.	____	____	____	____
24. I listen to the ideas of others.	____	____	____	____
25. I use materials other than the textbook to get information.	____	____	____	____
26. Science is a list of facts.	____	____	____	____
27. Science is thinking through problems.	____	____	____	____
28. Science is testing ideas.	____	____	____	____
29. Science never changes.	____	____	____	____
30. Engineers use math and do experiments	____	____	____	____

Demographics

1. Your age: ___________
2. Grade level: _________
3. Male ______ Female_______
4. Last report card grade in science (Please circle) A B C D F
5. Race/Ethnicity:
   Caucasian ______
   African American ______
   Hispanic ______
   Native American ______
   African ______
   Asian ______
   Other ______

Appendix D. Curriculum Vitae

Ronald J. Maddalena
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Green Bank, WV 24944
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Professional Preparation

1985	Ph.D.	Astronomy; Department of Astronomy, Columbia University, New York, NY
1983	M. Phil.	Astronomy; Department of Astronomy, Columbia University
1981	M.A.	Astronomy; Department of Astronomy, Columbia University
1980	B.A.	Astrophysics; Department of Astronomy, Columbia University

Appointments

1998 -	Scientist	1988	Assistant Scientist
1992	Associate Scientist	1985	System Scientist

Synergistic Activities

- Project scientist for commissioning the Robert C. Byrd Green Bank Telescope. Entails defining the commissioning program, designing commissioning tasks, assigning responsibilities to commissioning team members and scheduling their activities (2000-).

  Designed and manage the CLEO software project that provides an interface for staff members who need to use any piece of GBT hardware or software (1997 -).

- Astronomical research: Galactic and extragalactic interstellar medium. The structure, kinematics, evolution, distribution, and properties of molecular clouds; the relationship of atomic and ionized gases to molecular material.

- Member of the advisory committee for the design of the informal science exhibits for the NRAO science education center (1998-).

- Teacher enhancement programs: Involved in over two dozen NSF-sponsored institutes for teacher enhancement; developed research problems and guided participants through their assigned research (1987-). Supervised participants in the NSF-funded *Research Experience for Teachers* program (2000-). Provide lectures and hands-on classes to teachers at meetings of the West Virginia Teachers Association (1994-) and the National Science Teachers Association (2000).

- Curriculum development: Involved in the planning for the NRAO-Green Bank Elementary-Middle School collaborative education project (1997-2000). Create educational material for use in the classroom and for the NSF-sponsored *Hands-on Universe* program (1997-). Member of the Organizing Committee for the *NAIC-NRAO School on Single-Dish Radio Astronomy* (2000-).

- Coordinate the Green Bank NSF-REU summer student program (1987-). Supervised or acted as mentor to about 24 students at the high school, undergraduate, and graduate levels (1986-). Consulted and lectured in the Glenville State College "Upward Bound Math and Science Program" for high school students (1992-93).

Selected Publications

"A Large, Cold, and Unusual Molecular Cloud in Monoceros," Maddalena, R. J., and Thaddeus, P. 1985, *Ap. J.*, 94, 231.

"The Large System of Molecular Clouds in Orion and Monoceros," Maddalena, R. J., Morris, M., Moscowitz, J., and Thaddeus, P. 1986, *Ap. J.*, 303, 375.

"Learning to Investigate the Universe: Immersing Science Teachers in Research," Maddalena, R. J. and Heathery, S. A. 1993, *Bull. Am. Astr. Soc*., 25, 1429.

"Outburst of Jupiter's Synchrotron Radiation Following the Impact of Comet P/Shoemaker-Levy 9," de Pater, I., Heiles, C., Wong, M., Maddalena, R. J., Bird, M., Funke, O., Neidhofer, J., Price, R. M., Kesteven, M., Calabretta, M., Klein, M. J., Gulkis, S., Bolton, S. J., Foster, R. S., Sukumar, S., Strom, R. G., Lepoole, R. S., Spoelstra, T., Robison, M., Hunstead, R. W., Campbell-Wilson, D., Ye, T., Dulk, G., Leblanc, Y., Galopeau, P., Gerard, E.,and Lecacheux, A. 1995, *Science*, 268, 1879.

"A Large Photo-dissociation Region around the Cold, Unusual Cloud, G216-2.5," Williams, J. P., and Maddalena, R. J. 1996, *Ap. J.*, 464, 247.

"Obtaining High Precision HI Fluxes for Galaxies," van Zee, L., Maddalena, R. J., Haynes, M. P., Hogg, D., and Roberts, M. S. 1997, *A.J.*, 113, 1638.

"Tools to Assess the Impact of Teacher Enhancement Programs," Heatherly, S.A., and Maddalena, R.J. 1997, *Bull. Am. Astr. Soc.*, 29, 787.

"Recent Activities and Lessons Learned from the NRAO-Green Bank Science Education Programs," Maddalena, R.J. and Heatherly, S.A., 1999, *Bull. Am. Astr. Soc.*, 31, 1240.

"Radio Spectra: Tolls for Measuring the Structure of the Universe," WVSTA 2000, National Science Teachers Association Convention. (http://www.nrao.edu/~rmaddale/Education/Wvsta'98)

"Research Experience for Teachers at NRAO-Green Bank: Predicting Good Observing Periods for High Frequency Radio Astronomy," Maciolek, A.A. and Maddalena, R.J., 2000, *Bull. Am. Astr. Soc.*, 32, 1555.

"The Orion Nebula in 3.6 cm Continuum Emission: The First Combination of VLA and GBT Data," Shepherd, D.S., Maddalena, R.J., and McMullin J.P., 2001, *Bull. Am. Astr. Soc.*, 33, 1502.

"Reduction and Analysis Techniques," Maddalena, R.J., 2002, in *Single-Dish Radio Astronomy: Techniques and Applications*, ed. Stanimirovic, Altschuler, Goldsmith, and Salter (San Francisco: ASP)

"The user interfaces for the NRAO-Green Bank Telescope," Maddalena, R.J. 2002, in *Advanced Telescope and Instrumentation Control Software II.*, ed. Hilton, Proceedings of the SPIE, Volume 4848, pp. 316-327.

"Research Experience for Teachers at NRAO-Green Bank: Calibration of Data from the Green Bank Telescope and Classroom Activities in Radio Astronomy," Johnson, C.H. and Maddalena, R.J., 2003, *Bull. Am. Astr. Soc*., 34, 1196.

Vita: Sue Ann Heatherly

September, 2003

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e-mail: sheather@nrao.edu

Professional Preparation:

Doctoral student, Science Education, WEST VIRGINIA UNIVERSITY
M.A., Secondary Science Education, 1985, WEST VIRGINIA UNIVERSITY
B.A., Biology, 1981, WEST VIRGINIA UNIVERSITY

Appointments:

National Radio Astronomy Observatory, Green Bank, WV, Education Officer (1989-present)
Pickens School, Pickens, WV, Secondary Science Teacher 7-12 (1986-1989)

Publications:

"Contact! Radio Astronomers for a Day!", Hemler, D., Heatherly, S., Govett, A., Lomano, M. 1999, Science Scope, (accepted for publication in April, 1999).

"Tools to Assess the Impact of Teacher Enhancement Progams", Heatherly, S., Maddalena, R., Govett, A., Hemler, D., 1997, Bull. American Astronomical Society, 29, 787-788.

"History and Development of Teacher Institutes at the National Radio Astronomy Observatory", Obenauf, P., Evans, J., Gansneder, B., Govett, A., Heatherly, S., Hemler, D., Pyle, E., Abstracts, Annual Meeting, National Association for Research in Science Teaching, 70, 165.

"Inservice and Preservice Teacher Research Experiences: Impact on Views of Science and Science Teaching", Heatherly, S., Evans, J., Gansneder, B., Govett, A., Heatherly, S., Hemler, D., Obenauf, P., Pyle, E., Abstracts, Annual Meeting, National Association for Research in Science Teaching, 70, 125.

"The Development and Testing of a Suite of Instruments for Assessing the Impact of Research Oriented Science Teaching.", Gansneder, B., Evans, J., Govett, A., Heatherly, S., Hemler, D., Obenauf, P., Pyle, E., Abstracts, Annual Meeting, National Association for Research in Science Teaching, 70, 115.

Synergistic Activities:

Our Place in the Universe Project (director)
1997-current. A 4-week multidisciplinary astronomy curriculum unit for all local 7th grade students, where collaborative groups investigate the radio and optical universe. Student groups receive mentoring from NRAO scientists. All of the local middle school staff (Language Arts, Social Studies, Science and Mathematics) collaborate to provide thematic content during the project. At the end of the unit, each group presents the results of their work to their peers, school staff, and NRAO scientists. **Our Place in the Universe** received recognition at the Smithsonian Education Symposium, From School to Work: Shaping the Journey in 1998 (http://www.cwheroes.org/his_4a_detail.asp?id=3373). This project was supported by a grant from Apple Computers, Inc.

Catching the Wave Informal Education Project

Radio Astronomy Investigations for Young Scholars
1993-1999. 2001-current. Originally part of the NSF Young Scholars Program based in Fairmont, WV, which targets minority and low income children. Over two hundred and fifty young scholars have experienced science and engineering first-hand as they participate in lectures and activities and conduct radio astronomy observations while at NRAO-Green Bank. Continuing as an Upward Bound Program.

Select Presentations:

2002	**Math in Cosmology: Measuring the Universe** Sonia Kovalevsky Day, Miami University, Oxford Ohio
2001	**Radio Jove Extension Activities** Build Your Own Technology Workshop, Yerkes Observatory, WI
2000	**From Hubble to Hubble: Measuring the Age of the Universe** National Science Teachers Association, Orlando, FL West Virginia Governor's Honors Academy, Morgantown, WV
1999	**NRAO Education Programs, Poster Session** West Virginia Higher Education Symposium, Charleston, WV. **Science, Technology and the Noisy World we Live in: The Story of Radio Astronomy and the GBT** West Virginia Governor's Honors Academy, Morgantown, WV **Interference Detective: A Hands-on Radio Astronomy Activity for Middle School Students** WVSTA Conference, Charleston, WV
1998	**Multimedia in the Science Classroom**, Hands-on Computer short course, WVSTA Conference, Snowshoe, WV. **Green Bank School: Our Place in the Universe. A Multidisciplinary Astronomy Project** Smithsonian Education Symposium, From School to Work: Shaping the Journey Washington, D.C.
1997	**Conveying the Nature of Science Through Student Research** NSTA Conference, New Orleans, LA. **Science Research Experiences in Teacher Education: Radio Astronomy as a Baseline Context for Constructing Understandings of the Processes of Science, paper set** NARST Conference, Chicago, IL.

Steven D. Hicks

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Education

B.S. Electrical Engineering The University of Memphis; Memphis, TN. 2000.

Current Employment

National Radio Astronomy Observatory, Green Bank, West Virginia. (June 2003 – Present)
Education Center Exhibit Engineer. Designing and repairing interactive science museum exhibits; assisting with calibration and testing of receivers and electronics for Forty Foot Educational Radio Telescope; giving tours and presentations of radio telescope theory, components, and facilities.

Previous Employment

West Virginia Division of Natural Resources, Elkins, West Virginia (May 2002 – June 2003)
Survey Crew Leader & Geographical Information Systems (GIS) Technician. Main responsibilities included leading a river surveying crew in remote mountain areas, analyzing survey and GPS data, writing software program to plot maps from survey data. Other activities included: mapping and analyzing statewide RF radio-path coverage of agency communication system; repairing various electronic equipment for biologists and Law Enforcement officials; installing and repairing communication radios and antennas in agency vehicles; designing and building remote outdoor motion-activated digital cameras for studying wildlife activity

Princeton University, Princeton, New Jersey (worked remotely from WV) (September 2002 – June 2003)
Part time hydrologic technician. Designed, built, and installed instrumentation for hydrological and hydrometeorological monitoring; designed devices for remote water level and windspeed measurements.

Randolph County Office of Emergency Services, Elkins, West Virginia. (October 2002 – March 2003)
GIS Consultant & Point of Contact for FEMA Hazard Mitigation Plan Development.
Compiled GIS data and wrote preliminary report for FEMA which mapped and analyzed all natural hazards in the county; organized and headed public meetings with the community on development of the report.

Blacklight Power, Inc., Cranbury, New Jersey. (June 2000 – May 2002)
Electrical Engineer (June 2000 – Dec. 2001); Research Engineer (Jan. 2002 – May 2002).
Designed and built circuitry for high voltage plasma drivers and gas flow-meter controllers; developed plasma Langmuir probe electronics; designed and built Gaussmeter and assisted with electromagnet development; conducted microwave discharge and high voltage glow discharge plasma experiments; responsible for troubleshooting, repairs, and maintenance on scientific equipment and instruments.

McCarley & Associates, Inc., Memphis, Tennessee. (November 1997 – May 2000)
Part-time co-op job as computer technician, software instructor, and technical consultant.
Instructed clients on use of computers and software; developed accounting database software; performed computer upgrades.

National Radio Astronomy Observatory, Green Bank, West Virginia. (May - August 1999)
Research Student for Electronics Division. Assisted in designing and building intercom system for GBT; assisted with testing of space satellite electronics; designed circuits using Xilinx CPLDs; PC board layout design; various other electronics projects.

National Radio Astronomy Observatory, Green Bank, West Virginia. (May – Nov. 1997; May - Aug. 1998).
Co-op job as Electrical Engineering Associate. Designed and built various circuits and devices; created technical AutoCAD drawings; designed web pages; assisted in design of internet network for local school; assisted other engineers on various projects.

Publications

R. Mills, N. Greenig, S. Hicks, "Optically Measured Power Balances of Anomalous Discharges of Mixtures of Argon, Hydrogen, and Potassium, Rubidium, Cesium, or Strontium Vapor", *International Journal of Hydrogen Energy*, Vol. 27, No. 6, (2002), pp. 651-670.