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Preliminary Proposal for a LIGO Scientist/Student/Teacher (LIGO-SST) Program

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Abstract

A program for teacher enhancement, through the multiple-year engagement of scientist/student/teacher teams in LIGO research and research transfer from LIGO Hanford Observatory to the participating high schools is described. This effort adapts an existing program at PNNL to LIGO with the intent to develop and test this program as a model for a national effort to involve secondary school teachers and students in active research and to bring the process of "live" science into the secondary school classroom. This addresses several needs from the training of our next generation of scientists to improving science instruction in our schools and increasing the general understanding of "science as a process" within the lay public.

1 INTRODUCTION

The LIGO Scientist/Student/Teacher (SST) program seeks to build on a program, developed at Pacific Northwest National Laboratory (PNNL) and funded by the NSF Teacher Enhancement program (NSF grant ESI 97-312334), to engage teams of scientists, students and teachers in the transfer of research from national science facilities to high schools and their school districts. The LIGO Laboratory, a joint venture of the California Institute of Technology (Caltech) and the Massachusetts Institute of Technology (MIT) under sponsorship of the NSF, is constructing and operating gravitational-wave observatories[1] in Washington and Louisiana as national facilities and as part of an international network of gravitational-wave detectors. The quest to make first detection of gravitational waves involves pushing the art of experimental physics to the edge of modern technology. Monumental laser interferometers, that measure 4-km on a side but are limited in their precision only by the fundamental laws of thermodynamics and quantum mechanics, will seek to uncover a universe hidden from our electromagnetic senses. We want to make this exciting science accessible to America's high schools as part of a broader LIGO outreach program[2].

We believe that LIGO has unique resources for developing SST into a national program. LIGO science is a first-class, interdisciplinary effort that cuts across physics, mathematics, engineering and astronomy, offering a rich mixture of pure and applied science research opportunities. LIGO is an NSF Research Experiences for Undergraduates (REU) site and thereby offers synergy

1. Gravitational waves, first hypothesized in 1916 by Einstein as part of the theory of General Relativity, are propagating distortions in the fabric of space and time produced when star-sized chunks of matter undergo violent acceleration. Phenomena that we can imagine generating these waves are collisions of black holes or neutron stars, the rapid spin-down of neutron stars or the rotation of neutron stars with small deformations, supernovae and the big bang itself. Gravitational waves have so far escaped direct detection, although Hulse, Taylor and collaborators have firmly established the energy loss in a binary neutron star system due to gravitational radiation, confirming Einstein's theory. Hulse and Taylor were awarded the 1993 Nobel Prize for this pioneering work.
2. A draft document discussing a broader vision for LIGO outreach can be found on the web at http://www.ligo-wa.caltech.edu/~fjr/vision.pdf

between the teacher/student teams and undergraduate researchers during the summer programs. Teachers can discover how young undergraduates are taught to do research, better enabling them to prepare their students; high-school students benefit from exposure to college-aged and more advanced researchers; REU students are given opportunities to learn valuable leadership and mentoring skills. LIGO has a national presence with observatories under common management in both Washington and Louisiana, and LIGO has developed an international set of collaborating institutions, known as the LIGO Science Collaboration, comprised of more than 200 scientists across the U.S., Europe, Asia and Australia. This network provides a natural platform for expanding this program to the national level and beyond. The LIGO-SST effort will gain from its close proximity to the PNNL facility (15-minutes by car) and will share expertise and services (teacher development workshops, project evaluation and administration, etc.) with PNNL and Associated Western Universities (AWU). LIGO-SST will effectively complement the PNNL program, adding several new dimensions, by introducing projects in physics and related fields of physical science, extending opportunities to teachers without prior research experience and regionalizing the program beyond Washington state, with an eye toward national access to research opportunities.

2 NEED ADDRESSED BY LIGO-SST PROGRAM

Science is a process, not just a collection of facts, principles and algorithms. The typical classroom science experience focuses on the latter with few mechanisms to expose students to the process of science. We eventually reap the bitter harvest of this neglect through public misunderstanding of the nature of science and public disdain when scientific debates reach the general press. This project addresses the need to bring to our secondary schools insights into the true nature of scientific and technical processes. Many accomplished science teachers at the high school level have excellent scholastic underpinnings in the science they teach but have not had research experience. Without this experience, teachers can communicate the “what” of science but they are challenged in trying to communicate the “how” of science. The need exists (1) for science teachers to have an intimate knowledge of scientific process, that can only be obtained first-hand, (2) for students to gain experience with the tools, teamwork and methods practiced by science and technology professionals to augment scholastic activities in the classroom, and (3) for school districts to have a base of teachers with the capability to manage and mentor research efforts within the school district.

3 SST PROGRAM OBJECTIVE AND GOALS

The objective of LIGO-SST is to involve teams of high-school teachers and students in actual research projects with observatory scientists and engineers. The research project starts within the environment of the observatory and then moves to the school and the classroom. Over the course of this project, the team develops first-hand insights into the process of scientific research, the teacher develops research mentoring and management skills as well as acquiring valuable experience to enrich classroom time, the students build valuable teaming skills and the school develops a real-world window into the professional world of science, engineering and mathematics. These research experiences provide:

- relevant educational opportunities as envisaged in the School-To-Work Opportunities Act, by allowing students to explore professional career opportunities
- support for state educational reform efforts which call for certification of mastery in essential areas and career pathways for 11th and 12th grade students

- support for standards-based science and technology education by providing students with the knowledge and skill necessary to understand and use scientific concepts and principles, to conduct scientific investigations individually and cooperatively, to hone their communication and presentation skills, and to understand the connection between science and the real world.

Students also acquire new purpose and motivation by seeing both how their scholastic learning is incorporated in actual practice and what career paths are available in these areas. The net effect is to make education more relevant for future careers in science and for lifelong learning. The teacher, who will invest several years of effort in this endeavor is rewarded with first-hand research and management skills that can greatly strengthen his teaching role in the school and the district. The schools, which are requested to make a substantial "buy-in" investment to support the research, establish a base for maintaining research-based course offerings for their curricula and gain highly trained teachers, who become effective at leading and managing a research effort. This can be a strong mechanism for flowing down experience with the "how" of science to other grade levels in the district. Finally, the observatory obtains real research results and develops resources that will provide future research, personnel recruitment and outreach possibilities.

4 SST PROGRAM DESCRIPTION

The Scientist/Student/Teacher program was originally designed by the University and Secondary Education Programs group (USEP) at Pacific Northwest National Laboratory (PNNL) to involve high school teachers and students into research in a long-lasting and effective manner. SST provides a multi-year experience for a cadre comprised of a teacher and students who will establish a research center at their high school that produces real research results for the collaborating laboratory. This is a serious endeavor that requires a multi-year commitment of time on the part of the teacher and sponsoring scientist and a significant buy-in by the administration of the high school.

We propose extending the SST model to LIGO Hanford Observatory. LIGO has committed funds (approximately $30K drawn from reserved operating funds) for a pilot program beginning in Summer 1999, but needs additional funding to continue the program in future years. We envisage three years of funding to firmly establish and expand the program. LIGO pilot funds will allow two SST teams to be formed in 1999 that will work with the observatory's Physics Environment Monitoring system to produce research results for LIGO. Coordinating with the PNNL program, research will be conducted at the observatory over an eight-week period during the summer, followed by research conducted at the participating high schools throughout the academic years. One day per week of the eight-week period will be devoted to training and planning workshops to prepare the teams to effectively transfer the research to the classroom.

A local high school teacher, Norman Graham, who teaches physics and AP physics courses at Kamiakin High School in Kennewick, WA but has no previous research experience, has been recruited for the first team. This team will use seismic monitoring equipment to isolate and analyze seismic events and seismic spectra (in a frequency band from 0.5 to 50 Hz) created by human activity in the land and communities surrounding LIGO Hanford Observatory. They will look for signals related to traffic patterns, railroad activity, dam operations and river flows, military exercises, nuclear waste remediation activities, etc. During Summer 1999, Mr. Graham will become acclimated to the research environment and will work with LIGO staff to develop tools (hardware and software) for carrying out research in future years. During the 1999-2000 academic year Mr. Graham will recruit a three-member team of 11th-year students to return in Summer 2000 to continue the pursue the project at the observatory, provided this project becomes funded by NSF.

Starting in Autumn 2000, the project will move to Kamiakin High School. Mr. Graham and Kamiakin High School have agreed to make a three-year commitment to this program.

A second teacher, Dale Ingram from Gladstone High School, near Portland, Oregon, has been recruited with an eye toward expanding SST regionally throughout the Pacific Northwest and eventually throughout the U.S. This teacher has a background teaching both chemistry and physics courses. Taking advantage of Mr. Ingram's prior research experience, his team will start at the 2nd-year level in the program, with Mr. Ingram recruiting a team of three 11th-year high-school students to participate in Summer 1999. This team will analyze motion of the LIGO observatory buildings at frequencies below 0.5 Hz. This low frequency band will be dominated by geophysical effects and physical details of the LHO site. We expect the data from seismometers and tiltmeters to show significant effects due to earth tides, microseismic waves generated by ocean-wave activity, thermal expansion effects of the ground and responses to rainfall and solar irradiation. Working with LHO staff, the team will become familiar with the research equipment and will develop on-site software and web-based tools to support their research activities back at the high school. Portland is approximately a 3.5 hour drive from LHO, close enough to arrange visits without undue difficulty but far enough to approximate limitations that could be encountered operating a similar program at greater distance. Based on extensive experience within LIGO with working groups whose members collaborate effectively from thousands of miles away, we believe that appropriate use of the internet and web-based tools can transform our experience with this team into a model that has national applicability. Mr. Ingram and Gladstone High School have agreed to make a two-year commitment to this program, recruiting new 11th-year students for Summer 2000 and the following academic year, provided NSF funds the program.

Table 1. Plan for SST Team Selection and Activities

Grant Year	*Period Funded*	*Slot 1 Activity*	*Slot 2 Activity*
Pilot	Summer 1999	Kamiakin Teacher	Gladstone Team 1
	Academic 99-00	Recruit Kamiakin Team 1	Research @ Gladstone
1	Summer 2000	Kamiakin Team 1	Gladstone Team 2
	Academic 00-01	Research @ Kamiakin	Research @ Gladstone
2	Summer 2001	Kamiakin Team 2	New School A Teacher
	Academic 01-02	Research @ Kamiakin	Recruit School A Team
3	Summer 2002	New School B Teacher	School A Team 1
	Academic 02-03	Recruit School B Team	Research @ School A

We propose to expand the program to third team in Summer 2001 as funding ceases for the Gladstone team and to add a fourth team in Summer 2002 as funding ceases for the Kamiakin team. We propose to award these slots based on a competitive application process covering the Pacific Northwest. By this time we anticipate being joined in nationalizing this effort by a proposed program of similar nature hosted by LIGO Livingston Observatory, covering the Gulf region and the Southern U.S.

These projects have been selected for synergy among the different working teams, transferability of the research experience to the high schools and maximum gain to observatory staff who work with these teams. Having two teams with different levels of experience in the program at any time provides additional support for the less experienced teacher while the more senior teacher gains experience in mentoring less-experienced professional colleagues. Topics have been chosen so that the teams will be working with close but separate goals and using similar but complementary techniques. In addition a SURF/REU student, who has just finished his freshman year at Caltech, has been recruited to build an earth-tide model for the LIGO Hanford site that will be used eventually by the Gladstone team to analyze data. This allows the team students to work with a successful college student, senior enough to be a good role model but close enough in age to be accessible. Effectively the scientists, the SST teams and SURF/REU student will form a larger research group with the observatory. The research tasks are complementary to other research by LIGO collaborators at Caltech, MIT, Louisiana Tech University and Pennsylvania State University, who will be in close communication as the research progresses. This allows our program to put special emphasis on presentation skills with frequent seminars on related research topics and frequent reporting of results. We will also place special emphasis on the importance of developing good mentoring skills which are essential both to successful transfer of experience to the school and to career development by the students and teachers involved.

The research techniques developed and used by the teams will have general applicability, bringing important skills to the school that can find many other applications. Researchers will learn firsthand the importance of teamwork and coordination in the performance of technically challenging research tasks and the role of collegial scientific debate in ensuring the validity and robustness of scientific conclusions. Teams will gain skills in using the internet and teleconferencing to break down spatial separations between researchers and facilities. They will acquire expertise in the areas of statistics, data analysis and computation which are the foundation of effective scientific analysis across all fields of science. We expect these lessons to be replicated throughout the school district by personal interactions, improved lesson plans and the development of many of the research tools as a consequence of making the school a research site.

Observatory staff participation is possible using NSF research money because the products of this research for the observatory are real. (Cost sharing estimates include: approximately $30K of

Cost-Sharing Contributions ($K)

Year	*NSF ESIE*	*NSF LIGO*	*Schools*
Pilot		46.8	5.0
1	42.1	18.0	10.0
2	25.5	16.8	5.0
3	29.5	16.8	5.0
Equipment		5.0	
Totals	*97.1*	*103.4*	*25.0*

operating funds for the pilot; in-kind contributions of $9K/yr of supervisory time and summer supplies for a full team and $7.8K/yr for a teacher only; high school contributions of $5K/yr in matching funds to support team research at the school.) Data on man-made sources of noise near the LIGO site are important for dealing with local land-use issues to protect the viability of a significant infrastructure investment (> $120 million at Hanford) by the NSF. Local government agencies are tasked with developing lands adjacent to LHO to optimize employment, income and

cultural opportunities as the DOE role at Hanford wanes in a manner that does not endanger assets already in place, such as LIGO. The Kamiakin High School team's data will be important input into future planning decisions and will guide observatory management in ways to mitigate activities already in place that could affect the sensitivity of detectors at this site. Data on earth tides and other low-frequency seismic displacements and tilts will be used to develop feedforward adjustment of the seismic isolation in LIGO's interferometers. Successful implementation of this scheme promises to reduce demands on LIGO control systems and improve performance. Collaboration with the existing PNNL-SST program brings tremendous resources and strength to this LIGO-based effort at low cost. Associated Western Universities (AWU), a partner in the PNNL program, will provide administrative services for the LIGO-SST program, handling teachers stipends, insurance matters, etc. Research transfer will be facilitated by special meetings on Fridays of each week of the summer program where the teams, PNNL-USEP staff and Washington education specialists will develop comprehensive plans to transfer research experiences into improved instructional practices in the classroom. PNNL staff have extensive experience in promoting such transfer from many years of experience in the U.S. D.O.E.'s Teacher Research Associates Program. SST teams will return to their schools with explicit plans for transfer of the research experiences into the classrooms.

5 EVALUATION PLANS

The LIGO-SST program will share evaluation resources (at incremental cost) and procedures with the PNNL-SST program, which includes both formative and summative evaluation. An annual report of progress will be provided to NSF. This will include project management information that will be used to strengthen the project in future years. Pre-assignment evaluations will occur before each summer research team begins their designated assignments. Continuous monitoring will occur during the progress of each research assignment. Evaluation of the quality of research assignments will be made by studying the responses from a variety of resources including scientists, students, teachers, school administrators, etc.

An outside evaluator from the Northwest Regional Education Laboratory in Portland, Oregon will assess the classrooms of the scientist/student/teacher research teams before and after the summer research experiences to identify changed classroom practices in each school. Assessment in the classrooms of each research team will continue throughout the project, with special emphasis regarding the actual practice of research activities in the classroom after the summer assignments.

6 DISSEMINATION PLANS

Information illustrating this project will be disseminated through publications targeted at educators (such as the Science Teacher), through coauthored technical publications with observatory staff and through dissemination in special reports at meetings of the LIGO Science Collaboration and the Topical Group on Gravitation within the American Physical Society. Teachers involved in the program will be encouraged to present reports on their work to their colleagues at regional, state and/or national meetings as such opportunities arise. A valuable tool in this effort will be presentations on this program to workshops conducted through internet teleconferencing facilities, such as Washington's K-20 network. Information on the LIGO-SST program will be fully shared with the PNNL-SST program and disseminated to the appropriate state offices that cover public instruction for the schools in question. LIGO-SST web pages will be linked to the LIGO web pages and to the web pages of the associated high schools.

7 BUDGET

Requested funding from NSF ESIE:

Year 1			
Stipends for 2 teachers	8,240		
Stipend for 6 students	9,888		
Gladstone Teacher housing allowance	1,030		
Gladstone Students housing allowance	1,854		
Matching research support at 2 schools	10,000		
Evaluation Costs	4,000		
Travel (dissemination related)	1,500		
Subtotal Direct Costs		*36,512*	
*Overhead charges**		*5,568*	
Year 1 Total Costs		*42,080*	
Year 2			
Stipends for 2 teachers	8,487		
Stipend for 3 students	5,092		
School A Teacher housing allowance	1,061		
Matching research support at 1 school	5,000		
Evaluation Costs	1,000		
Travel (dissemination related)	1,500		
Subtotal Direct Costs		*22,140*	
*Overhead charges**		*3,376*	
Year 2 Total Costs		*25,517*	
Year 3			
Stipends for 2 teachers	8,742		
Stipend for 3 students	5,245		
School A Teacher housing allowance	1,093		
School B Teacher housing allowance	1,093		
School A Students housing allowance	1,967		
Matching research support at 1 school	5,000		
Evaluation Costs	1,000		
Travel (dissemination related)	1,500		
Subtotal Direct Costs		*25,639*	
*Overhead charges**		*3,910*	
Year 3 Total Costs		*29,549*	
Total Direct Costs			**84,292**
Total Indirect Costs*			**12,854**
Grand Total			**97,146**

*A/WU Rate = 15.3%

8 VITAE

Barry Barish (Principal Investigator): Barry Barish received his BA in Physics from U.C. Berkeley in 1957. He also did his graduate studies in Berkeley and received his Ph.D. in Experimental High Energy Physics in 1963. Barry Barish came to Caltech directly from Berkeley in 1963 where he has pursued high energy physics as a researcher and a faculty member. Barry Barish was named the Maxine and Ronald Linde Professor of Physics in 1991.

Barry Barish conducted experiments at Fermilab using high energy neutrinos that were important in demonstrating the quark substructure of the nucleon. These experiments were also among the first to observe the weak neutral current which was vital in establishing the validity of Electroweak Unification theories of Glashow, Salam, and Weinberg. Over the past decade, Barry Barish has led an ambitious effort to search for the magnetic monopole predicted in theories of Grand Unification. A large experiment (MACRO) to make this search is being conducted underground below the Gran Sasso mountain in Italy. Barish also served as co-spokesman of a large international collaboration to develop the GEM detector, one of two major detectors that were planned for the Supercollider. In 1994, Barry Barish became the Principal Investigator of the Laser Interferometer Gravitational-Wave Observatory (LIGO) project. Professor Barish became Director of the LIGO Laboratory in 1997 and was instrumental in the establishment of the LIGO Science Collaboration. Internationally, he is regarded as a leader in the field of elementary particle physics, is often an invited speaker at international conferences, and serves on many important international committees.

Frederick J. Raab (Co-PI): Fred Raab received his B.S. in Physics from Manhattan College in New York in 1973. He did his graduate studies at S.U.N.Y., Stony Brook and received his Ph.D. in Experimental Atomic Physics in 1980. From 1980 to 1988, he was a member of the research faculty at the University of Washington, where he developed a number of precision experiments to test fundamental symmetries using atoms as a sensitive probe of the underlying physics. This led to a number of strong bounds on violations of time-reversal symmetry and local Lorentz invariance. During this time he also became involved in torsion-balance experiments to provide stringent tests of the equivalence principle over a range of distances from centimeters to one astronomical unit. In 1988 he joined Caltech as Assistant Professor of Physics and coauthored the LIGO Construction Proposal. His research with his graduate students and scientific collaborators at Caltech has led to key developments that appear in the LIGO-1 optical control configuration and mirror suspensions. He was named Head of LIGO Hanford Observatory in 1997.

Raab's interest in education began with his work as a laboratory assistant at Manhattan College, where he co-developed an introductory optics laboratory and participated in a summer laboratory training program for teachers from secondary schools in the greater New York metropolitan area. He has gainfully employed dozens of student workers in his research laboratories, and mentored undergraduates, graduate students and professional engineers in a variety of research endeavors, from REU projects to Ph.D. dissertations. As Head of LIGO Hanford Observatory, he has networked with professionals in the local education community to develop plans for an extensive outreach effort in gravitational physics (see www.ligo-wa.caltech.edu/~fjr/vision.pdf). He actively directs the day-to-day activities of resident observatory staff and resources, which allows him to ensure laboratory commitment to successful completion of the research endeavors of this proposal.