Department of Energy and National Science Foundation
Status Review of QuarkNet
May 2006

A joint Department of Energy (DOE) and National Science Foundation (NSF) status review of the QuarkNet project was held on May 15, 2006 at the National Science Foundation in Arlington, Virginia. The review committee was co-chaired by Marvin Goldberg (NSF) and Kathleen Turner (DOE). A complete list of the attendees is attached. The committee reviewed the project status in terms of scope, management, costs, schedule, responses to the previous review recommendations and future plans. This review follows reviews held in March 2004 and May 2005.

Introduction

The QuarkNet project began in 1999 as a joint NSF/DOE research-based high-energy physics teacher education project. Marjorie Bardeen (Fermilab) serves as the spokesperson and is one of four managers shown in the attached organization chart. Staff members are an integral part of running the QuarkNet project. QuarkNet is a partnership of high school teachers and mentor physicists working in the field of high-energy physics at universities and laboratories across the country. It provides long-term professional development for local high school physics teachers through research experiences and workshops as well as sustained support over many years. Through these activities, the teachers enhance their knowledge and understanding of science and technology research. They transfer this experience to their classrooms, engaging their students in both the substance and processes of contemporary research as appropriate for the high school classroom. The teachers get academic credit towards their professional development for participation in this program.

The project, starting its eight year of activity, has been jointly supported by the Department of Energy (Office of High Energy Physics) and the National Science Foundation (Directorate for Elementary, Secondary and Informal Education [ESIE], the Directorate for Mathematical and Physical Sciences [MPS] through Elementary Particle Physics [PHY/EPP] and the Office of Multidisciplinary Activies [OMA]). The QuarkNet project was originally based on university and laboratory "centers" with physicist mentors who are participating in the Large Hadron Collider (LHC) experimental collaborations (ATLAS and CMS) at CERN in Geneva, Switzerland and the Tevatron experimental collaborations (DZero and CDF) at Fermilab. It has since expanded to also include centers with participation in eleven experiments at seven DOE laboratories as well as foreign laboratories that are broadly representative of the field of high-energy physics.

The QuarkNet project has four measurable goals that relate to teacher development:

1) To increase teachers' knowledge of scientific process, particle physics and relationships to curriculum.
2) To increase teachers' knowledge of and ability to implement inquiry based teaching methods.
3) To increase teachers' contributions to quality and practice of colleagues within the field of science education.
4) To support teachers as they facilitate student understanding of and ability to solve science related problems.

The outcomes of the QuarkNet project are to improve high school students'

- abilities to understand and appreciate measurements
- abilities to engage in scientific investigations
- knowledge of basic physics concepts
- positive attitudes towards science and science literacy.

QuarkNet offers programs designed and conducted according to "best practices" reported in the National Science Education Standards prepared by a National Research Council (NRC) committee and published by the National Academy Press in 1995.

Development and Status of the Centers

In order to become a QuarkNet center, at least two experimental physicists must make a long-term commitment to participate for the duration of the project. The teachers who are recruited by the physicist mentors to participate in the centers also make a long-term commitment. The physicist mentors provide the initial research experiences in the summer and also maintain frequent contact with the teachers during the academic year.

A center has two stages of development, termed Center I and II, before getting to its steady-state level termed Center III or Center IV. The roles of types of centers are described below.

Center I

In the first year of a center's participation, the physicist mentors go through an orientation process and also recruit two "lead" teachers for the project. The teachers attend a one-week high-energy physics orientation workshop (institute) arranged by the QuarkNet staff and usually held at Fermilab. The teachers then participate in a seven-week research project with the physicist mentor, either at the center or at a laboratory where the experiment is conducted.

Center II

In the second year of a center's participation, the physicists and the lead teachers recruit up to ten "associate" teachers. The full complement of teachers attends a three-week research-based institute at their local center, developed by the physicist mentor and lead teachers and focusing on teacher professional development. The new teachers learn about high-energy physics, research methods and inquiry-based teaching and learning, tailored to their needs.

Center III

In the third and subsequent years of a center's participation, QuarkNet provides support for teachers to spend the equivalent of one-week in follow-on activities. In 2004 and 2005, Center III included a one-week refresher institute for two associate teachers. Starting in 2006, a new three week institute, termed the "Teaching and Learning Academy", is being held for teams of Center III teachers interested in developing instructional materials. This was set up in response to teacher requests. The team works one week at their home center and two weeks at Fermilab.

Center IV

In addition to the above stages, NSF has funded a stage, termed Center IV, with four high school student-researchers supervised by one of the teachers. This stage started in FY 2004 and will apply to those centers that have reached the Center III level.

During each year of the ramp-up, the QuarkNet staff recruited up to twelve new Center I's, and the previous ones move to the next stage. The original plans called for QuarkNet to reach a steady-state of participants within five years involving 60 centers, 120 physicists, 720 high school teachers, and potentially reaching 100,000 students. Note that individual centers have varying numbers of mentors, teachers and high school students.

In September through December of each year, new Center I's are recruited. In January through May of the next year, the project gets ready for the summer program. The main QuarkNet sessions for the year are held in the summer.

The original plan was to have a full complement of 60 centers in 2003, though currently there are only 51 on board. This is due principally to the rate of applications. The project would rather have strong centers than growing to 60 in a set time. Between 2005 and 2006, three underperforming centers were retired and two new ones have joined the project. The numbers of centers of each type are shown in the table below as a function of year.

As of 2006, the project has 70 lead physicist mentors, with approximately 230 mentors who have worked on the project at some point. There are approximately 520 teachers in the program. There has been some turnover in teachers and in mentors at the centers due to other commitments. Some of the centers have, in effect, only one mentor, and other centers are effectively led by the teachers. There are approximately 75 high school students participating in the project as part of stage IV centers.

Number of QuarkNet Centers in Each Project Year

Project Year	# Center I	# Center II	# Center III	# Center IV	Total # centers
1999	11				11
2000	13	11			24
2001	8	13	11		32
2002	7	8	24		39
2003	9	7	32		48
2004	4	9	33	6	52
2005		4	36	12	52
2006	1	2	35	13	51
2007		1	27	24	52
2008			22	30	52

Note: Values for 2007 and beyond are planned and are based on support for 52 centers.

Project Materials and Services

The QuarkNet staff members provide services to the centers and teachers as well as guidelines for center performance. They have weekly meetings via telecon and a face-to-face meeting every other

month. To maintain quality control and support for the centers, they visit each center yearly as well as some of the high schools associated with the center. When new centers are being recruited, a staff member visits to ensure that roles and responsibilities are understood and can be met.

Some of the other services provided include:

- Maintaining the QuarkNet website and collecting data for the independent evaluations.
- Developing and implementing a teacher orientation institute and physicist mentor orientation session each summer.
- Developing an online database with example classroom activities, workshop ideas and other resources for teachers.
- Developing program materials to assist mentors and teachers as they develop local programs.
- Building cosmic ray detectors for teachers to use in the classroom.
- Providing community-building activities for the teachers locally and across the country.
- Enabling teacher meetings and presentations at conferences.
- Visiting the centers to check status and progress.
- Participating in effort to get experimental data into e-lab environments that use the Open Science Grid as the IT structure.

The QuarkNet project staff has put a lot of effort into the cosmic ray shower studies for teachers and students. They have 138 teachers in 135 high schools doing these studies. There are 170 detectors currently in schools and 70 new detectors are being assembled. They held a meeting of all the cosmic ray education collaborations across the country (QuarkNet, CROP, CHICOS, WALTA) to share ideas.

In the last year, the staff has coordinated workshops, teacher reunions and teacher participation in conferences such as the American Association of Physics Teachers (AAPT) meeting and the Linear Collider Physics workshop. In addition, they have been disseminating their knowledge about the program to other areas of physics and other countries. For example, they have worked with groups in condensed matter physics to broaden the participation in this type of education program. They have given presentations and held workshops at a number of conferences to show others how the program works. Examples are presentations at a high school teacher conference at CERN and a workshop for local teachers in Bangalore, India and Vancouver, Canada as part of International Linear Collider (ILC) workshops. They are planning to attend several more conferences and workshops in the next year to broaden teacher participation and disseminate information about the QuarkNet project and help local people start up such a program.

Response to Previous Recommendations

The project has addressed recommendations from previous reviews and their advisory group as described below. They have retired underperforming centers in order to release resources for and provide more attention to productive centers. They have worked to bring the online data analysis tools to maturity. As recommended by the reviews and also by teachers, they have worked on continued teacher development and products by starting a Teaching and Learning Academy as described above. They have worked on disseminating the QuarkNet model to other areas of physics and broadened participation by holding teachers workshops at meetings as described above.

Another recommendation was to do more detailed evaluations of the project and the centers. In response to this, there are in-depth case studies of 3-4 centers with classroom visits taking place this year. Next year, they plan to implement the recommendation to evaluate the teachers' professional development.

Panels

Part of the review was devoted to having panel discussions, with separate panels for the mentor physicists, high school teachers and students. Their comments and concerns are summarized here.

There were three mentor physicists on the mentor panel. They commented that they are participating in QuarkNet because it is personally rewarding. Their original plans were to use actual high energy physics experimental data and they want to make sure this will be done because some of the teachers are getting tired of cosmic ray data-taking. There were concerns raised such as running the center takes a lot of work and it's not appreciated by their university or in the peer reviews of their grant.

There were four high school teachers on the teacher panel. They described differing amounts of activity at their centers with some getting a lot of support and interactions with the mentor physicists and others describing low level or tailing off of support and activity. All the teachers were very positive about their participation in the program. They had learned a lot and felt they could take some of it back to their classrooms. It was mentioned several times that being in the program has been extremely helpful in allowing them to make contact with other physics teachers in their area and has made their work more important in the eyes of the school administration.

There were five high school students on the student panel. Several were already deeply interested in science before joining this program but one had never had a physics class before this and now is very involved and excited. They were all happy with being part of the project and described the work they have done, including building detectors, taking data, writing software and analyzing the data. Several commented that having to figure things out on their own was a very positive experience.

Cost and Schedule

QuarkNet is a build-to-cost project. The cost per year to run each type of center, mostly for teacher stipends, travel and mini-grants, is shown in the table below. The planned schedule of reaching the full complement centers in the program and of moving them to the steady state, Center III, IIIa, or III-TLA (for DOE) and Center IV (for NSF), is shown in the table in the "Development and Status" section above.

The high school student research component is planned to last at least through 2008. The costs for the research teams of up to 4 students and a research teacher include student and teacher stipends and support for the teacher to attend a lead teacher institute.

***Costs for 2006 for a QuarkNet center**

	Center I	Center II	Center III	Center IV
Costs in ($k)	19.7	16.5	4.5	14.9

* DOE G&A costs are not included.

Other costs include support for the staff members, the outside evaluators, the advisory group, the TLA, teacher reunions and the cosmic ray detectors. DOE funds are used to support the staff members at LBNL and Fermilab and NSF funds are used to support fund those at Hampton University and Notre Dame. The evaluators and advisory group are funded by NSF. Support for the QuarkNet management team, the physicist mentors, and resources at the laboratories and universities are not part of the project costs, and are contributed separately. An administrative assistant at Fermilab was supported on the project, but as of last year, is supported by Fermilab. With the funds made available by this, a new QuarkNet staff member was hired at Fermilab.

The breakdown of costs each year is shown in the table below, including full G&A costs. These costs are based on a full complement of teachers at each center. Costs are as-allocated at the beginning of the year. Remaining funds available (see table on next page) are used to support reunions, the new Teaching and Learning Academy and additional classroom materials and detectors.

QuarkNet Project Costs per FY ($k) - includes full G&A

Year[5]	**FY03**	**FY04**	**FY05**	**FY06**
Staff[1]	711.5	740.3	767.8	773.3[6]
Center I (#centers)	119.4 (9)	85.2 (4)	49.6 (4)	19.7(1)
Center II	70.4 (7)	128.1 (9)	59.6(4)	33.0(2)
Center III	127.2 (32)	187.7 (27)	171.1 (24)	129.4(35)
Center IIIa[2]	--	66.8 (6)	133.7 (12)	0
Center IV	--	109.2 (6)	218.4 (12)	195.2(13)
Misc[3]	68.9	102.1	95.5	54.0[7]
Classroom Equip[4]	--	130.0	25.0	244.1
TOTAL	**1,097.0**	**1,549.5**	**1,481.4**	**1,466.7**

1. Staff costs consist of salaries for the staff teachers, fringe, overhead, travel, and G&A.
2. Beginning in FY04, this includes the additional one-week Fermilab institute as described above.
3. Miscellaneous expenses include funds for outside evaluators, advisory group, M&S and teacher reunions.
4. Classroom cosmic ray detectors
5. Costs are as-allocated at the beginning of the year.
6. Includes evaluators and advisory group.
7. TLA and reunions

Management

The QuarkNet management team organizes the project, works to secure funding, provides reports to the funding agencies, responds to requests for information and represents the project at reviews. The project management is lead by five PI's with a very active and competent staff. They have included an advisory panel to help prioritize their goals and provide further direction.

Funding

After the December 2001 review, NSF approved a planned funding profile for FY 2002 through FY 2006 that matched the planned costs. The NSF funding to date has been provided by the Directorate for Elementary, Secondary and Informal Education (ESIE) and the Directorate for Mathematical and Physical Sciences (MPS) through the Office of Multidisciplinary Activities (OMA) and Elementary Particle Physics (PHY/EPP). The NSF grant is up for renewal in FY 2007. DOE approved a planned funding profile starting in FY 2003 that was shown at the review. The funding for FY 2006 and beyond is planned to remain flat at $750k. The DOE funding is provided by the Office of High Energy Physics. The planned funding levels from each agency are shown in the table below. When the planned funding is less than the costs (shown above) for a particular year, the QuarkNet management works to secure funds elsewhere as needed and/or changes the scope of work.

Planned Funding Profile ($K)

(FY 1998 – FY 2006 are actual funding amounts)

Fiscal year	NSF-ESIE†	NSF-MPS‡	DOE-HEP*	TOTAL
1998	--	188.8	--	**188.8**
1999	317.4	250.0	152.8	**720.2**
2000	353.2	275.0	261.0	**889.2**
2001	324.8	361.0	316.0	**1,001.8**
2002	290.5	530.9	375.0	**1,196.4**
2003	169.0	682.0	475.0	**1,326.0**
2004	220.2[1]	756.6	575.0	**1,551.8**
2005		801.5	675.0	**1,476.5**
2006		889.9	750.0	**1,639.9**

† Award goes to Fermilab; QuarkNet's FY runs from June through May

‡ Funds are from the PHY/EPP Division and OMA at NSF. The award goes to Notre Dame. The NSF-ESIE funds are included in this column, starting in FY 2004. The NSF grant expires 9/30/06 and is up for renewal in FY 2007.

* DOE funding in FY 2006 and beyond is planned to remain flat at $750K.

1 Supplement. No-cost extensions due to change in staff provided some funds for FY05 and FY06.

Summary and Recommendations

QuarkNet is an excellent project which should be continued and supported. The strength of QuarkNet is the cooperation of the physics research community and every effort should be made to continue this strong participation. The project's center status, services and materials provided are progressing well. The mentors, teachers and high school students at the review reported having positive experiences in QuarkNet.

The project management was encouraged to maintain the continued strength of the core program of teacher research and professional development. A strong focus of QuarkNet needs to continue

to be the LHC. The cosmic ray detectors, e-labs and planning for future efforts such as the ILC are an important part of the project, but should not detract from the LHC focus.

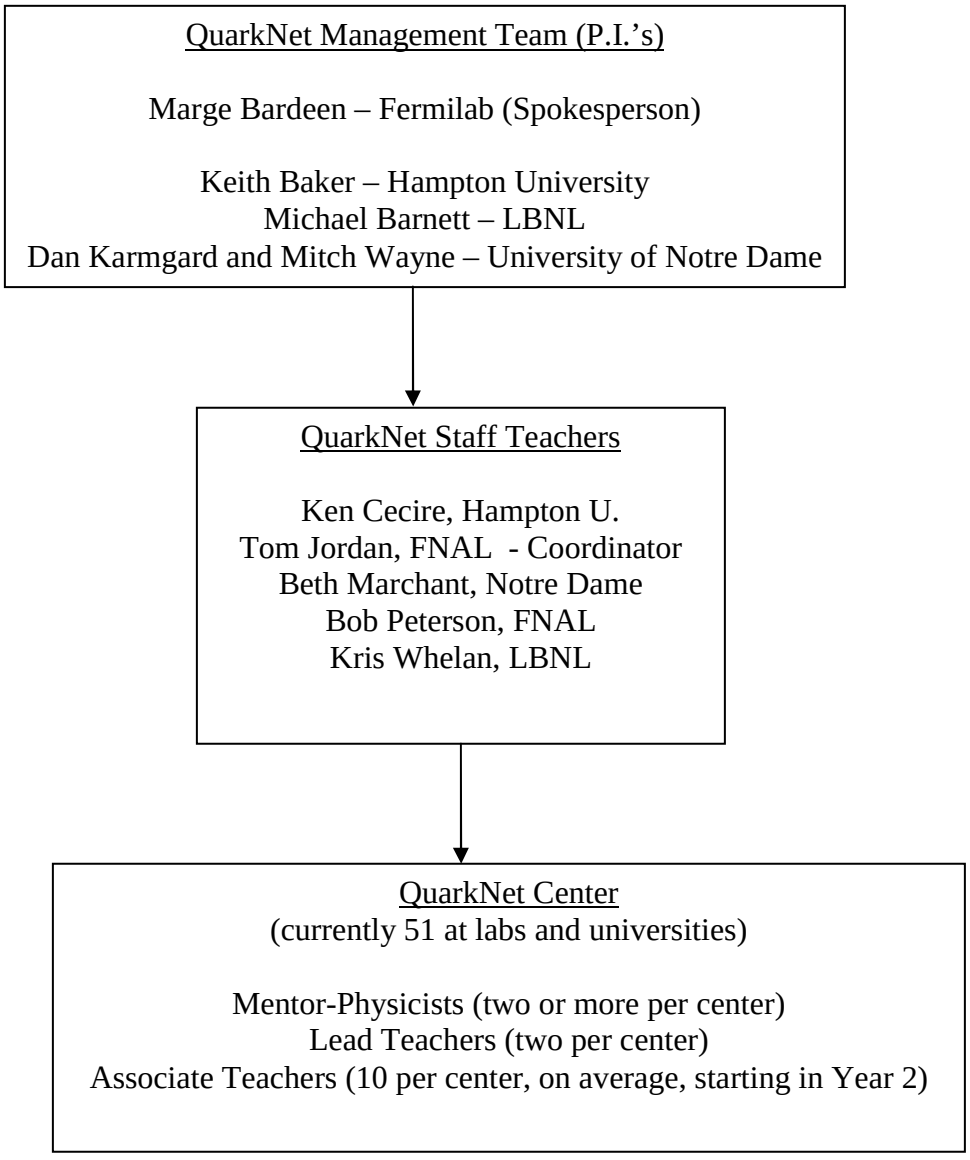
The agencies plan to facilitate a meeting between QuarkNet and the Open Science Grid (OSG) management so that they can develop a working relationship to advance the computing infrastructure needs of QuarkNet and to provide potentially broader impacts for the OSG.

The new plan for their outside evaluations to measure the outcome of their project goals by delving more deeply into several centers is good. A report on the project evaluation will be provided to the agencies in summer 2006.

The current NSF grant for QuarkNet ends in 2006. DOE's funding from 2006 on is planned to remain flat at $750k and the project should tailor the DOE part of their program to this flat budget. A new 5-year proposal for QuarkNet should be submitted to NSF by late October 2006. Though the proposal will be to NSF, DOE will also use it to evaluate future plans. The proposal will be sent out for ad hoc mail-in reviews in late 2006. A joint DOE/NSF review panel is planned for January 2007 to evaluate the proposal.

In conclusion, the committee found the QuarkNet project to be strong and progressing well. The QuarkNet model is successful as evidenced by other physics fields and countries interest in the project. QuarkNet is making a positive impact on the high school physics community and providing a needed link between the high energy physics research community and the nation.

QuarkNet Organization Chart



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