DOE/NSF
Review Committee Report

on the

Review

of the

QuarkNet Project

December 2001

EXECUTIVE SUMMARY

A joint Department of Energy (DOE) and National Science Foundation (NSF) committee conducted a review of the QuarkNet project on December 13-14, 2001, at NSF headquarters in Arlington, Virginia. QuarkNet is a joint NSF/DOE research-based physics education project aimed at high school teachers and their students. In this project, active researchers in high energy physics at university and laboratory centers are partnered with high school teachers.

There are four principal investigators of the project: Keith Baker (Hampton University), Marjorie Bardeen (Fermi National Accelerator Laboratory), Michael Barnett (Lawrence Berkeley National Laboratory) and Randy Ruchti (University of Notre Dame). Marjorie Bardeen serves as the project spokesperson. Participating physicists in QuarkNet are working on projects funded by the Division of High Energy Physics in the Office of Science at DOE (DOE-HEP) or by the Elementary Particle Physics (NSF-EPP) program in the Division of Math and Physical Sciences (NSF-MPS) at NSF. Funding for the project is being provided by the NSF Elementary, Secondary and Informal Education (NSF-ESIE) program for a five-year start-up period, and by NSF-EPP, NSF-MPS and DOE-HEP.

At the request of the John O'Fallon, Director of DOE-HEP, and Marvin Goldberg, Program Director of NSF-EPP, the review was organized by Kathleen Turner, Program Manager at DOE-HEP. The Committee consisted of ten expert review members from a variety of backgrounds, including physics, astrophysics, astronomy and education. Individual comments and opinions were provided by each of the Committee members during the review. These individual reports were summarized by the Chair of the Committee, Professor Ken Heller, University of Minnesota, to form the basis of this report.

The Committee was charged with evaluating the progress of the QuarkNet project to date with respect to the original goals as well as future plans and goals. In its assessment of the project, they also evaluated the management and commented on whether it is meeting the needs of the participating physicists and teachers. They were asked to comment on the funding levels and profile for this project as well as giving guidance on whether these levels are feasible and reasonable.

The Committee felt that QuarkNet is an excellent project and gave its unanimous recommendation that it be continued and expanded to its original planned scope. Details of specific recommendations made by the Committee are included in the text of the report.

It is the view of the Committee that the project is well on its way to accomplishing the goals of the original proposal. The management and staff of QuarkNet were seen to have done an excellent job of modifying and refocusing the project as needed. If the project is functioning smoothly at the end of its original plan, the Committee recommends that the funding agencies should consider expanding the original proposal to also allow participation by high school students.

The Committee looks forward to more extensive outside evaluations of QuarkNet, employing the use of

measurable outcomes of the project. More direct involvement in the evaluation process and in defining the measurable outcomes by the Principle Investigators and the project staff was advised. The Committee recommended that the project work with the funding agencies to determine the appropriate level of evaluation consistent with the budget and effort available.

The Committee has reviewed the budget and believes that the funding profile over the life of the budget is reasonable and should be well within the capability of DOE-HEP and NSF to fund. This funding should cover at least the level of its original plan and its future expanded plan if possible. The Committee does not make these recommendations lightly, realizing that funding for the project could be a drain on both the modest scientific manpower and budget of the physics research program. The Committee recommends that both agencies allocate funds to QuarkNet from sources other than the universities research program, whose recent funding has not kept pace with the costs of inflation.

The Committee noted that additional outreach functions and funding sources could be explored by the QuarkNet project. Outreach to more of the community could be accomplished by expanding the presentations by the participating teachers to a variety of conferences. They are encouraged to assist the centers in incorporating other available funding programs and sources in order to enhance the impact of the QuarkNet project.

It is clearly perceived by the HEPAP Subpanel on Long Range Planning that the missions of both the NSF and the DOE encompass outreach and education components. Projects of this type are a necessary function of the particle physics research divisions of both DOE and NSF. QuarkNet is seen by the Committee to be a project that strongly supports both education and scientific research. The Committee, as well as the QuarkNet management, believe that it should not be the only outreach project for high energy physics supported by NSF and DOE, but should be viewed as a successful example. The Committee urges that QuarkNet be supported at, or slightly above, the level proposed and that the funding agencies also support other types of outreach projects that can use QuarkNet as an inspiration if not a model.

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1. INTRODUCTION

The Department of Energy (DOE) and the National Science Foundation (NSF) share the mission to support continued United States leadership in science and technology. Their mission also includes the realization that for our society to enjoy the fruits of that technology, we must have a continuous supply of young people who understand and are interested in science. For example the Office of Science of the Department of Energy recognizes that[(1)]:

> "The Office of Science has a long-standing and critical role in ensuring the flow of young scientists, engineers and technicians into the U.S. workforce."

One of the most important elements in determining that flow is the Nation's science teachers. It could be said that every experimental or theoretical contribution to the field of High Energy Physics has invisible but essential collaborators, the teachers of the scientists. The precarious human links that form the science and technology chain have become so threatened that it has been stated as a National Security issue, most recently by the U.S. Commission on National Security in the Twenty-First Century[(2)].

> "The nation is on the verge of a downward spiral in which current shortages will beget even more acute future shortages of high-quality professionals and competent teachers. The word "crisis" is much overused, but it is entirely appropriate here. If the United States does not stop and reverse negative educational trends—the general teacher shortage, and the downward spiral in science and math education and performance—it will be unable to maintain its position of global leadership over the next quarter century."

> "Resolving these cumulative problems will require a multi-faceted set of solutions. Educational incentive programs are needed to encourage students to pursue careers in science and technology, and particularly as K-12 teachers in these fields. Yet such incentives alone will not be adequate to avert the looming teacher shortage. Therefore, a set of additional actions must be taken to restore the professional status of educators and to entice those with science and math backgrounds into teaching. Only by addressing the systemic need to increase the number of science and math teachers will we ensure the supply of qualified science and technology professionals throughout our economy and in our national security institutions, both governmental and military."

The events of September 11^{th} , 2001 have, if anything, added cogency to the Commission's analysis of the strengths of our country and the dedication of its people to meet the future's challenges. This tragedy has reinforced the importance of a defense based on the most advanced technology with a population educated to solve problems as they arise from unexpected sources. We see clear evidence of the usefulness of the most esoteric physics such as General Relativity, that makes possible precision guidance using the Global Positioning System (GPS), and Quantum Mechanics, without which there would be no lasers or computer processors. The bravery and confidence of our citizens must be supported with the tools of education, science, and technology.

The country needs teachers who not only understand the basics of their subject but also know the excitement of contemporary science. Teachers are needed who communicate to each generation the enthusiasm, values, and processes of scientists engaged in fundamental research at the frontiers of knowledge. Unfortunately, frontier research has become so remote from the everyday experiences of students and their teachers that, by the time they reach college, not enough young people have the desire or skills to pursue a career in science. The most direct way to remedy this situation is to involve teachers in the research process in as many fields of physics as possible. Teachers could then use their skills to communicate their interest, excitement, and experiences to students.

High energy physics is an excellent candidate for this experience since it is unquestionably one of the most fundamental fields of science. Its exploration of the very nature of space and time and of matter and its interactions using instruments that push the technology frontier seems to naturally interest students, especially at the high school level. Involving teachers in this research requires their participation in research funded by either DOE-HEP (DOE, Office of Science, Division of High Energy Physics) or NSF-EPP (NSF, Directorate of Mathematical and Physical Sciences [NSF-MPS], Experimental Particle Physics program [NSF-EPP]).

The necessity of a DOE and NSF partnership in science education was recognized by Congress in the Department of Energy Organization Act of 1977(3):

> "The Department's involvement in mathematics, science, and engineering education should be consistent with its main mission and should be coordinated with all Federal efforts in mathematics, science, and engineering education, especially with the Department of Education and the National Science Foundation (which have the primary Federal responsibility for mathematics, science, and engineering education)."

The most recent joint DOE and NSF High Energy Physics Advisory Panel (HEPAP) Subpanel on Long Range Planning for U. S. High Energy Physics report (January, 2002) recognizes the joint needs of dissemination and education as being a responsibility of those who do research on the frontiers of physics. Their very first recommendation directly addresses the education and outreach mission of QuarkNet(4):

> "We recommend that the United States take steps to remain a world leader in the vital and exciting field of particle physics, through a broad program of research focused on the frontiers of matter, energy, space and time.
>
> The U.S. has achieved its leadership position through the generous support of the American people. We renew and reaffirm our commitment to return full value for the considerable investment made by our fellow citizens. This commitment includes, but is not limited to, sharing

> our intellectual insights through education and outreach, providing highly trained scientific and technical manpower to help drive the economy, and developing new technologies that foster the health, wealth and security of our nation and of society at large."

The elaboration of that recommendation most relevant to the QuarkNet project is given below:

> "Public education is both a responsibility and privilege of our field. …Individual physicists at universities and laboratories reach a geographically diverse public through face-to-face contact.
>
> … we believe that as a field we can and should do more in this area. … We believe we can broaden our impact in K-12 science education through additional direct partnerships with educators. We can offer assistance as states and local districts struggle to improve science education. Increased educational efforts will raise our profile in the community, draw the public into the excitement of our future discoveries, and foster pride in our society's investment in science.
>
> To strengthen the impact of our field on science education, we urge that all current and future large particle physics experiments incorporate project-specific education and outreach programs as part of their mission. Such efforts, linked very closely to the research programs, represent key investments in the future and must be given sufficient priority. More specifically, the level of activity on education and outreach in the field should be doubled, in order to ensure a viable, effective and sustainable program. This extra effort will significantly increase our impact on education and society without adversely affecting our research program."

Building the interface between a physics teacher and high energy physics research would seem to be a daunting task considering the chasm in knowledge and skills. A typical high energy physics graduate student has at least two years of graduate physics courses and three years of apprenticeship during the time that a teacher spends learning about and practicing teaching. Even if the necessary bonds of mutual trust and communication between teacher and researcher could be established, the next difficulty would be to involve enough teachers to make a significant impact on the educational system. The QuarkNet collaboration, funded by the team of the DOE-HEP, the NSF-MPS, NSF-EPP and NSF-ESIE (NSF, Division of Elementary, Secondary, and Informal Education) in a manner envisioned by Congress when it established the Department of Energy, has developed and tested a model that has the potential to meet this challenge.

The Committee (Appendix B) was charged (Appendix A) with evaluating the QuarkNet project in light of the following 4 questions:

1. Evaluate the progress to date and the level of meeting the goals set forth in the original proposal. Are the laboratory and separate site programs aligned with "Best Practices"? What is the level of the high school teachers' satisfaction with the project? How have the high school teachers

and their students benefited from this project? What components need to be modified or refocused?

2. Evaluate the future plans and goals of the project. Can the project successfully expand to the proposed size?

3. Evaluate the management of the project and comment on whether it is adequately integrating the needs of the teachers with participation of the mentor physicists and support by the project staff teachers.

4. Comment on the proposed project funding profile over the life of the project. Are these funding estimates feasible and reasonable for DOE-HEP and the NSF team of MPS, ESIE, and Experimental Particle Physics Division?

The findings of the Committee are given in section 3 and a summary of its recommendations are in section 4.

2. Description of QuarkNet project

QuarkNet is a partnership of schools and their physics teachers, universities and their physics faculty, and national laboratories and their staff to provide long term professional development for high school physics teachers based on participation in frontier high energy physics research. The project, starting its fourth year of activity, is jointly supported by the Department of Energy (HEP division) and the National Science Foundation (MPS, EPP and ESIE divisions). The QuarkNet project is based on experiments that either exist or are in the construction stage and was planned to run through the life of the Large Hadron Collider (LHC) program at CERN. During the first five years the project will ramp-up to its steady-state that will continue for the next ten years.

There are four PI's associated with each of the four institutions running the project; two are DOE-funded (Marge Bardeen, Fermi National Accelerator Laboratory [Fermilab] and Michael Barnett, Lawrence Berkeley National Laboratory [LBNL]) and the other two are NSF funded (Randy Ruchti, University of Notre Dame and Keith Baker, Hampton University). There are five (four full-time equivalent) QuarkNet staff teachers, one associated with each institution listed above, plus a staff secretary located at Fermilab. Marge Bardeen is the spokesperson for the project.

<u>Scope of the Project – Initial Proposal</u>

The original proposal (1997) describes this project as partnering high school teachers and students with active researchers in high energy physics. It was expected that teachers would enhance their knowledge and understanding of science and technology research through research experiences. Then they would transfer this experience the classroom and engage their students in both the substance and processes of contemporary research as applied to the high school curriculum.

The Five-Year Initial Plan for QuarkNet

The initial focus of interaction between physicists and high school teachers was partnerships established at university and laboratory "centers" 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.

Each year of the initial five-year period, the QuarkNet staff teachers and PI's would select 12 new university/laboratory high energy physics departments to be added as a QuarkNet center. In five years, it was hoped that all of the 60 U.S. groups in 28 states participating in LHC experiments would be involved. At each center, there would have at least two physicists that provide initial research experiences for the teachers at the center and then mentoring over the entire project period. The number of teachers each year at each center would be steady. The start-up of each center begins with summer research experiences for the two lead teachers with their two associated physicist mentors (seven weeks), usually at the center, and their attendance at a fundamental physics orientation workshops (one week), usually held at Fermilab. In the second year of a center, there is a three week session at the center that includes the two lead teachers and approximately ten associate teachers. The focus of this session is teacher professional development. In subsequent years of a center's participation, there is a one week refresher session each summer. During the academic year, the teachers keep in contact through frequent meetings with their mentors.

The staff teachers, working with the PI's and other physicists, develop guidelines for assisting the teams of teachers and physicists at each center to develop and implement programs, create prototype activities for the students to use in the classroom, maintain the WWW site, provide online support for teachers and help teachers create experiments for classroom use. One of the staff teachers will facilitate an instructional materials development component. The staff works with center-based mentor physicists and teachers to help them develop a portfolio of programs within the QuarkNet framework, based on their own needs.

The staff teachers joined the project in June 1998 and the staff secretary started in July 1999. In June 1999, the first group of lead teachers began the project. They attended the Fermilab workshop and participated in the research experiences during the summer. The second year of teachers and centers began in June 2000. The QuarkNet project year runs from June 1 to May 31. Year 1 of the QuarkNet project is defined as June 1999 through May 2000.

At the end of the initial five year plan, a steady state of participants is expected to be reached, involving 60 centers, 120 physicists, 720 high school teachers, and reaching 100,000 students. The QuarkNet project, through its staff teachers and mentors, will provide sustained support for the high school teachers.

Originally, the centers that were part of QuarkNet were limited to those having physicist mentors on one of the four experiments: Atlas, CMS, DZero or CDF. Starting this year, the project has been opened to allow centers with physicists on the experiments more representative of the field of high energy physics. Currently there are participants from the following additional high energy experiments: BaBar, BTeV, CDMS, CKM, CLEO, GLAST, E907, Milagro, MINOS, Auger, Super-Kamiokande.

A table describing number of centers and participating teachers in each year of the project is shown below.

Project Year	# University/Laboratory Centers	# Participating High School Teachers*
1999	13	~26
2000	25	~140
2001	34	~225

* Includes lead and associate teachers. In the first year of a center's participation, only lead teachers are involved, leading to the dramatic increase of teachers between 1999 and 2000.

<u>New Proposal</u>

A new proposal was recently submitted by Professor Randy Ruchti to NSF for the next five years of the project. Though submitted to NSF, this proposal addresses plans for the entire project. In addition to the original scope of QuarkNet, in which funds are provided for the project staff teachers plus the high school teachers at the centers, they have perceived the need for more extensive participation of the high school teachers after their second years at the center than originally planned. They also propose to add participation by high school students along with their supervising high school teachers in research at the center. This modification of the scope of the project would require additional funding and an increase of the number of weeks participation by each center each year.

<u>Evaluations of Project</u>

Currently, evaluations of the project are provided by:

?? Annual reports prepared by an outside evaluator
?? Bi-annual updates on the activities of each center
?? Any other reports required by the funding agencies

3. Committee's Program Evaluation

QuarkNet is an innovative project that successfully brings together university groups working on frontiers of high energy physics research and high school physics teachers. It has solved the difficult problem of creating an organization that can be an interface between university based researchers and

K-12 teachers. This project incorporates a decentralized organizational structure with centralized support and guidance similar to that used by high energy physics experiments. In physics research this type of organization enables individual university research groups to operate within a larger collaboration at a national or international laboratory. In the realm of education, it is used by QuarkNet to give the support, guidance, and flexibility necessary to connect researchers to high school teachers to accomplish the project's primary goal: "to engage teachers, and subsequently their students, with scientific investigations." In addition to its benefit to high school education, QuarkNet also makes an effective interface for informing the general public of the fundamental research program in High Energy Physics conducted at the national level. This outreach function occurs because of the close connection of teachers and high school students with their local communities.

The review Committee commends the management and staff of QuarkNet for an excellent presentation and candid answers to questions during the two day review process. It also applauds the Department of Energy, Office of Science, Division of High Energy Physics and the National Science Foundation team of the Office of Multidisciplinary Activities and Experimental Particle Physics in the division of Mathematical and Physical Sciences and the division of Elementary, Secondary, and Informal Education for cooperating to fund a project that transcends so many institutional boundaries and directly addresses the separate but related missions of each agency. The QuarkNet project directly addresses some of the most pressing needs of our country.

In the presentations by high school teachers in the QuarkNet project, the Committee was struck with its positive effect on the professional status of the teachers from their own point of view and that of their students and local community. It was clear that this was a consequence of the long term professional development strategy inherent in QuarkNet. This is precisely the need recognized by the U.S. Commission on National Security in the Twenty-First Century[(2)]:

> "Professional development that involves a substantial number of contact hours over a long period has a stronger impact on teaching practice than professional development of limited duration. Today, however, more than half of all science teachers in the United States report receiving no more than two days of professional development per year."

In addition to giving our unanimous recommendation that the QuarkNet project be continued and expanded to its original planned scope, we will directly respond to the questions put forth in the charge to the Committee by given below:

1. Evaluate the progress to date and the level of meeting the goals set forth in the original proposal. Are the laboratory and separate site programs aligned with "Best Practices"? What is the level of the high school teachers' satisfaction with the project? How have the high school teachers and their students benefited from this project? What components need to be modified or refocused?

To date, the project has met most of its original goals. Where a technique did not work, the plan was modified to accomplish the same goals in a different manner. The primary goal of the original proposal was to engage teachers, and subsequently their students, with scientific investigations. It was very clear from the presentations of informal case studies that the goal is being met for the teachers. There were examples of this ranging from some to a great deal of impact on classroom practice. The project management realizes that transfer to the classroom will take time and constant effort. The primary mechanism for encouraging this transfer is the building of a relationship of trust between the teacher and the university researcher and the communication among teachers. They recognize that what can and should be transferred to a classroom depends on local constraints. Teachers in the project are anxious to have specifics that transfer immediately to the classroom and the project is working to accomplish this by writing a handbook which communicates classroom activities that have been used by teachers in the project. Although adding these activities into existing classes will make them more interesting and exciting, at least for some students, this alone will not change the way that science is taught at a fundamental level in those classrooms.

True reform in changing the pedagogy used by the teachers is a long-term venture. It will not be accomplished by this project alone and that is recognized by the QuarkNet project management. Advances in pedagogy including clarification of the goals of a high school physics course are happening and will continue to happen largely based on other projects sponsored by the NSF and the Department of Education. For example, standards based science education is a national trend but the standards, although typically derived from the American Association for the Advancement of Science (AAAS) Project 2061: Science for All Americans and the National Academy of Science[(5)], are often modified by state and local school boards. The specific standards directly addressed by the QuarkNet project are: Actively participate in scientific investigations (Science as Inquiry); Collect evidence, use models and develop explanations based on their work (Unifying Concepts and Processes); and Study the structure and properties of matter and interactions of energy and matter (Physical Sciences).

Unfortunately at this time there does not exist even a small range of exemplar high school science curricula that are based on modern pedagogy, modern technology, and modern goals that can have been demonstrated to work in the real world of a teacher. QuarkNet cannot and does not intend to provide these. They will probably be generated by other NSF curriculum projects, such as Constructing Ideas in Physical Science[(6)] (CIPS) in the middle school, as well as by NSF sponsored research efforts in physics education. QuarkNet will continue to make its lead teachers aware of these projects through presentations by their proponents in the QuarkNet workshops. The project management recognizes that QuarkNet is only a piece of the solution that will give teachers confidence that the pedagogical changes advocated by others are both necessary and in keeping with the actual practice of scientific inquiry. They are satisfied with small, steady steps in this arena and the Committee concurs.

Another goal specified by the group was to confront particle physicists with issues in science education. The mentors certainly had to deal with secondary education. They met with the high school teachers in lunch hour discussions, as advisors on a research project, and in informal discussions. As an example, the syllabus for one center’s workshop was completely rewritten when the level of the high school teachers was discovered. Quantifying the success at meeting this goal is difficult without access to the evaluation data for the project. However, the interaction of the teachers and mentors as described in the presentations will lead to better understanding of secondary school education on the part of university researchers.

In the final analysis, it is the view of the Committee that the project is well on its way to accomplishing the goals of the original proposal. In the original five year proposal, the project goals were to have 60 centers at universities throughout the country. Currently, after three years, the project has 36 different university centers. This is excellent progress toward the goal. The management of the project has decided to widen their target group of centers from only those participating in collider experiments at LHC and Fermilab to all high energy experiments. The Committee concurs with this change as both necessary and useful. They still plan to increase to 60 centers but believe they will be able to accommodate 720 teachers while staying with their original plan. Each of the current 36 lead teachers has had a 7 week research experience. The lead teachers then help conduct a 3 week research experience for the associate teachers from their center during the first year followed by a 1 week workshop every summer thereafter. This process will be continued for the next 24 centers. The Committee believes that achieving the goal of 60 centers using this model of teacher involvement has a strong probability of success based on the experience of the existing 36 centers.

It was recognized by the project management that entropy is at work in human systems such as professional development so that energy must be added to the system at regular intervals. The original plan to accomplish this energy transfer by electronic communication has not been successful and has been replaced by more personal contact. The project is still investigating how to make electronic communication effective among their teachers. The same increase in entropy makes the workshops conducted by the lead teachers and mentors for the associate teachers less effective than the workshops for lead teachers conducted by the staff and the management. This situation is common for professional development plans of this type. As a result the project uses more staff input into the associate teacher workshops at the centers than originally planned. Because the teachers are expected to remain in the project for a long time, an initial below optimum workshop for associate teachers is not a serious problem.

The plan for teacher development used by QuarkNet is fully aligned with the "Best Practices" as very usefully outlined in the document "Profiling Teacher Research Participation Programs: An Approach to Formative Evaluation" prepared by the National Center for Improving Science Education with support from the Department of Energy. The Committee was less well able to determine how well the project followed a similar document "Profiling Teacher Development Programs: An Approach to Formative Evaluation" which deals more with the focus of the program on pedagogy. The informal case study information given did indicate that many of these "Best Practices" were indeed being followed.

It was very clear from the presentations and the data summarized by the evaluator that the high school teachers' satisfaction with the project was extremely high. The benefits to all participants in the project and their students are numerous and include: an appreciation of the goals of high energy physics, incorporation of contemporary physics topics in the high school curricula, increased student interest in science, increased student interest in science as a career, and hands-on research experiences by both students and teachers. The most important benefits were to the professionalism of the teachers. They were especially enthusiastic about the establishment of a community of physics teaching and the increased respect they received from students, parents, administrators, and the general public because of their involvement in cutting edge research in particle physics. Whether the benefits reach beyond the outstanding students in the class remains a subject for future evaluation. However, if only a few outstanding students in each class are influenced to pursue a career in science or science teaching, the project will be a great success.

In general, the management and staff of QuarkNet have done an excellent job of modifying and refocusing the project as needed. Two issues were raised in the review. The first is a request to broaden the project to serve more significantly teachers who are themselves underrepresented groups in physics or teaching students who are. We recognize that this project cannot by its structure serve at-risk teachers and students but it can target those members of underrepresented groups who are not academically at-risk. These groups should include teachers in rural schools and resource-poor schools as well as those from inner cities. The second is possibly a related issue. Recruiting teachers from underrepresented groups probably require paying the teachers a living wage for the summer workshops. Teachers are practically the only profession employed for only part of the year and expected to seek outside employment to support their family during the summer months. QuarkNet requires a sizeable commitment of time during the summer that precludes holding another job. To insure a higher participation of underrepresented minority teachers, as well as those teaching in underserved areas of the country, this project should strive to give teachers a stipend equal to their regular salary. If teachers are going to implement any of the QuarkNet experience into their curriculum, this requires additional time for which teachers need to be compensated.

2. Evaluate the future plans and goals of the project. Can the project successfully expand to the proposed size?

The future plans and goals are modest given the great success of the project thus far. The Committee has no doubt that the project structure can easily accommodate 60 centers using their model of an initial 7 week workshop for the new lead teachers, an initial 3 week workshop for the associate teachers, and then a 1 week workshop for the associate teachers for all future summers. The management proposes to expand the project by adding another 7 week workshop for the lead teachers periodically. The review Committee also believes that the longer recurring workshops for lead teachers at regular intervals are a necessary feature of any project that will have a lasting impact. The Committee does worry that the excellent staff may be stretched thin. The expanded project might suffer a setback if any staff member were out of action for any extended period of time. We suggest that an additional staff person would add the contingency necessary for a project of this importance. The additional staff would reduce the stress on the existing staff and allow some more effort on materials development and communications.

The Committee looks forward to a more extensive evaluation by the outside evaluators than was available in time for this review. The QuarkNet proposal outlines some potentially measurable outcomes of the project for which data would be interesting. Significant measurement in the realm of education is not easy nor is it inexpensive. We would like to see more direct involvement of the Principle Investigators and the project staff with these measurements. Perhaps a person familiar with the scope and limitations of such measurements could be added to the QuarkNet advisory group.

The project management proposes in the future to expand the project to include high school students in the summer research experience. The Committee understands this as a tactic to keep the lead teachers periodically engaged in an extended (7 week) research experience by allowing them to supervise high school students in the research environment. This plan is reasonable because the primary focus of these teachers is teaching high school students not doing high energy physics research. Specific teaching modules for the classroom may also develop from this interaction involving high school students, the lead teacher, and the research mentor. We caution that involving high school students in meaningful research will be a very challenging task. However, the management and staff of QuarkNet are experienced and prudent and we would trust their judgment in this matter. The periodic summer research experience of lead teachers working with high school students in high energy physics research would be a key element in maintaining the momentum of the project and keeping its focus current. Other directions, suggested by the Committee, that are also compatible with the current project include using additional resources to involve the associate teachers in extended periods (7 weeks) of high energy physics research and, at the same time, more deeply ground them in research based pedagogy or to use the QuarkNet staff and outside experts to more fully introduce research mentors to modern research based pedagogy. The challenge facing the QuarkNet management, and the funding agencies, is how to keep such a successful project from being asked to do more than its means allow.

3. Evaluate the management of the project and comment on whether it is adequately integrating the needs of the teachers with participation of the mentor physicists and support by the project staff teachers.

The management of this project is superb. The genius of their structure is that it can and does respond to any needs that arise. We expect that problems will continuously arise and that they will continue to do an excellent job in this respect.

4. Comment on the proposed project funding profile over the life of the project. Are these funding estimates feasible and reasonable for DOE-HEP and the NSF team of MPS, ESIE, and EPP?

The Committee has reviewed the budget and believes that the funding profile over the life of the budget is reasonable and should be well within the capability of DOE-HEP and NSF to fund. As remarked earlier, we believe that the project would be strengthened by a modest increase in the budget to fund one additional staff person and to raise the stipends of teachers to be equal to their salaries.

The Committee does not make these recommendations lightly. We understand that currently the physical sciences, and particularly high energy physics is underfunded to accomplish its mission. The U.S. leadership in this field, that Congress has specifically charged the DOE to maintain, is moving to Europe and Japan. The number and frequency of experiments has been reduced to a point that it is difficult to maintain a coherent project closely connected to the universities that provide the vast majority of the scientific effort. Meanwhile the number of U.S. citizens studying physics in graduate school has been steadily decreasing as has been the number of those remaining in the field after graduation. Despite the recommendations of numerous HEPAP panels, the funding for high energy physics research at universities has not even kept pace with the very real costs of inflation. Indeed, university groups in DOE are currently facing significant cuts to their funding even without accounting for inflation. Both NSF and DOE are faced with the classic conundrum of maintaining the present or providing for the future. The QuarkNet project could be a drain on both the modest scientific manpower and budget of the physics research program in this country. Clearly, the Committee recommends that both agencies allocate funds to QuarkNet from sources other than the universities research program. However, no enterprise, including physics research can survive if it does not look to its future. In the worst case scenario for funding, we believe that the NSF and DOE support for QuarkNet should continue at the level of its original plan.

QuarkNet is one very cost effective way to address the responsibility of both agencies to communicate the importance of the research funded by them to the citizens of this country and to replenish the supply of young scientists, engineers, and technicians needed by the country. In its steady state, QuarkNet will provide a structure to high energy experiments that will have a minimal overhead in effort for the individual research groups. As the project has already demonstrated, high school teachers make excellent spokespeople for high energy physics. Their stories and the research in which they are involved are much in demand by local newspapers and local groups.

Additional outreach functions could be accomplished by expanding the venues for presentations of the QuarkNet high school teachers to additional professional meetings. They have begun to give talks at the annual Winter meeting of the American Association of Physics Teachers (AAPT). We encourage the management to have the teachers make presentations at the Summer AAPT meeting. Not only are these meetings significantly larger than the Winter meetings but high school teachers from around the country tend to populate the Summer AAPT meeting. We also believe that presentations should be made at the April American Physical Society (APS) meeting that has a significant number of education sessions and high energy physics sessions and at the Division of Particle and Fields meeting.

It is clearly perceived by the HEPAP Subpanel on Long Range Planning that the missions of both the NSF and the DOE encompass outreach and education components. The subpanel recognized that projects such as QuarkNet will not only benefit high school teachers and students, but through the communication skills and the sheer numbers of the teachers and students affected, it will serve a very important role in bringing science in general and particle physics in particular into the homes of every-day Americans. QuarkNet has already demonstrated that projects of this kind bolster the professionalism of teachers encouraging them to stay in teaching and giving an incentive for new people to join it. Better and more committed physics teachers will result in more students considering careers in science and technology. QuarkNet is a project that strongly supports both education and scientific research. Projects of this type are a necessary function of the particle physics research divisions of both DOE and NSF.

A doubling of the education and outreach program funding as recommended by the HEPAP panel is a modest investment in the future of the field. The QuarkNet project should not be the only one supported by NSF and DOE but should be viewed as a successful example. If we have learned one thing in the past half century it is that rigid centralized planning of any complex social enterprise is a blueprint for failure. The strength of the U.S. research program is its recognition of the importance of the individual researcher, including the formation of loose confederations of individuals in collaborations, that initiate their own investigations and are supported by funding agencies. We believe that this model is applicable to the role of outreach of these same research programs. The QuarkNet management does not propose that they should be the only outreach project for high energy physics. The Committee supports this outlook and urges that QuarkNet be supported at, or slightly above, the level proposed and that the funding agencies also support other types of outreach projects that can use QuarkNet as an inspiration if not a model. We note that a small amount of additional funding and official sanction can be used to encourage high energy physics researchers to use existing projects such as the NSF sponsored Research Experience for Undergraduates (REU), Research Experience for Teachers (RET), and educational partnerships, as well State administered block grants from the Department of Education, and individual University funds for Undergraduate Research Opportunities (UROP).

4. Committee's Recommendations

QuarkNet is an excellent project that serves as a model for insuring that the country has a continuing supply of young scientists, engineers, and technicians by enabling a partnership between researchers at geographically widespread universities and physics teachers in their area. In addition QuarkNet enables the flow of information about the fundamental research funded by DOE and NSF in high energy physics to the citizens of the country. Below we summarize the specific recommendations of the Committee:

1. Continue the QuarkNet project as designed and modified over the first three years and fulfill its plan within the next two years to reach its original scope of 60 centers with 720 high school teachers and 120 physics mentors. At the end of that time, if the project continues its successful path, the funding agencies should consider additional expansion.

2. Directly involve the PIs and staff in the evaluation process to define more carefully the measurable outcomes of the project. Work with the funding agencies to determine the appropriate level of evaluation consistent with the budget and effort available.

3. Attempt to involve more well-prepared teachers from underrepresented groups as well as from underserved population areas. This will probably require raising the teacher stipend to match their regular wage with a subsequent increase in the QuarkNet budget.

4. If more funding is available, add one additional staff member to assure the smooth functioning of the centers.

5. Attempt to increase the information transfer among teachers in QuarkNet by continuing to investigate electronic methods that teachers can and will use. Increase the information transfer to teachers outside of QuarkNet by increasing the number of presentations at appropriate AAPT and APS meetings.

6. Assist each university center to incorporate other funding sources such as the NSF research experience for teachers (RET) or Department of Education block grants to the states for science and mathematics partnerships to enhance the QuarkNet project at the university centers.

7. If the at the end of its original plan, the project is functioning smoothly, the funding agencies should consider expanding the original proposal to allow the teachers to work directly with high school students during the summer.

APPENDIX A – Charge for Review

To: Kathleen Turner, Program Manager, U.S. Department of Energy

Date: 12/7/01

Re: Request to Conduct a Review of the QuarkNet Project

The National Science Foundation (NSF) Elementary Particle Physics (EPP) Program and the Department of Energy (DOE) Division of High Energy Physics (DHEP) requests that a joint independent peer review of the QuarkNet project be conducted on December 13-14, 2001, at the National Science Foundation Headquarters in Arlington, Virginia.

QuarkNet is a joint NSF/DOE research-based physics education project aimed at high school teachers and their students. The original proposal was received in 1997, and the first year of the program was 1999. It is funded by the NSF Elementary, Secondary and Informal Education (ESIE) program for a five-year start-up period, by NSF-EPP and by DOE-DHEP. There are four principal investigators of the project: Keith Baker (Hampton University), Marjorie Bardeen (Fermi National Accelerator Laboratory), Michael Barnett (Lawrence Berkeley National Laboratory) and Randy Ruchti (University of Notre Dame). Marjorie Bardeen serves as the project spokesperson. Further information about the project is available on the QuarkNet WWW site at http://quarknet.fnal.gov.

The Committee is asked to review the progress of the QuarkNet project to date and plans and goals for future directions. A key issue is the proper funding level and profile for this project and how the funding from NSF-EPP and DOE-DHEP should be increased as the NSF-ESIE start-up funding ramps down.

Specific charges directed to the Committee are:

1. Evaluate the progress to date and the level of meeting the goals set forth in the original proposal. Are the programs through the laboratories and sites aligned with "Best Practices"? What is the level of the high school teachers' satisfaction with the project? How have the high school teachers and their students benefited from this project? What components need to be modified or refocused?

2. Evaluate the future plans and goals of the project. Can the project successfully expand to the proposed size?

3. Evaluate the management of the project and comment on whether it is adequately integrating the needs of the teachers with participation of the mentor physicists and support by the project staff teachers.

4. Comment on the proposed project funding profile over the life of the project. Are these funding estimates feasible and reasonable for DOE-HEP and NSF-EPP?

One member of the committee will be designated as the report coordinator and is asked to collect and summarize all individual member's opinions and findings. Individual committee members are asked to contribute draft opinions and findings for a report by the end of the review, December 14, 2001. A written report, summarizing these findings, is due to DOE-DHEP and to NSF-EPP by February 14, 2002.

Marvin Goldberg	John R. O'Fallon
Program Director	Director
Elementary Particle Physics Program	Division of High Energy Physics
National Science Foundation	U.S. Department of Energy
Arlington, VA	Germantown, MD

APPENDIX B – Review Committee Members

Dr. Julie Callahan	University of Utah
Professor Elliott Cheu	University of Arizona
Professor Sarah Eno	University of Maryland
Dr. Lucy Fortson	University of Chicago and Adler Planetarium
Dr. Ken Heller (*Chair of Committee*)	University of Minnesota
Dr. Michael Kenney	ASM International
Dr. James Madsen	University of Wisconsin, River Falls
Professor Mats Selen	University of Illinois
Dr. Fred Stein	American Physical Society
Dr. Joseph Stewart	Formerly of the National Science Foundation

APPENDIX C – Review Agenda

AGENDA for the
Joint NSF and DOE Review of the
QuarkNet Project
December 13-14, 2001 at NSF Headquarters

Thursday

8am – Executive Session (Committee & Agencies Only)

8:30-10:15am – General Session (Open)
- Introductions - Michael Barnett
- The QuarkNet Collaboration - Marge Bardeen
- Notre Dame QuarkNet Center" - Randy Ruchti
- The Future of QuarkNet - Michael Barnett, Randy Ruchti

10:15-10:45am – Break

10:45am-12:15pm – General Session (Open)
- The Role of the Staff - Tom Jordan
- Teachers, Mentors and Research - Ken Cecire, Darren Carollo, Fred Olness
- Associate Teachers - Beth Beiersdorf, Marshall Mosesson, Carl Telly, Rick Van Berg

12:15 -1:30pm – Break

1:30-3pm -- General Session (Open)
- Classroom Transfer - Tom Jordan
- Impact in a High School Classroom - Bob Grimm,
- How a High School Activity Gives a Glimpse of Particle Physics - Aaron Mertz
- Impacting High School Physics Curriculum - Deborah Roudebush, Katherine Kovar
- How I Learned Excel to Analyze Data - Pete Bruecken

3-3:15pm – Break

3:15-4:30pm -- General Session (Open)
- QuarkNet at Ames High School - Jeff Dilks, Jonathan Russell
- The QuarkNet Community - Andi Erzberger

4:30-7pm? – Executive Session (Committee & Agencies Only)

- discussion
- write up questions
- draft report

Friday

8:30-10 - Project Session (QuarkNet Project, Agencies and Committee Only)

- how finances work
- budget history and request for future

10-11am – Project Session (QuarkNet Project, Agencies and Committee Only)

- breakout session

11-1pm Executive Session (Committee & Agencies Only)

2pm Closeout Report (QuarkNet Project, Agencies and Committee Only)

3pm Review Ends

APPENDIX D – Cost Tables

QuarkNet Project Costs ($k)

	FY99	FY00	FY01	FY02	FY03	FY04	FY05	FY06	FY07	FY08
Staff[1]	380.3	446.8	606.8	687.8	715.4	737.3	764.8	793.1	834.2	853.4
Center I[2] (#centers)	256.3 (13)	232.6 (12)	197.2 (12)	185.0 (12)	246.7 (12)	--	--	--	--	--
Center II[3] (#centers)	--	165.6 (12)	179.4 (12)	138.0 (12)	131.1 (9.5)	172.6 (12)	--	--	--	--
Center III[4] (#centers)	--	--	39.6 (11)	112.6 (24)	204.7 (36)	247.7 (36)	247.7 (36)	165.1 (24)	82.5 (12)	--
Center IV[5] (#centers)	--	--	--	--	--	237.7 (12)	475.4 (24)	713.0 (36)	950.8 (48)	1,188.4 (60)
Misc[6]	83.6	44.2	36.7	89.9	149.0	131.0	131.0	131.0	131.0	131.0
TOTAL	**720.3**	**889.2**	**1,059.8**	**1,211.4**	**1.447.0**	**1,527.4**	**1,620.0**	**1,803.4**	**1,998.5**	**2,173.0**

1. Staff funding consists of salaries for the staff teachers and secretary, fringe, overhead, travel, and G&A costs.
2. Center I: costs for a center in its first year of operation. Costs include support and expenses for two lead high school teachers (8-week program).
3. Center II: costs for a center in its second year of operation. Costs include support and expenses for two lead high school teachers plus ten associate teachers (3-week program).
4. Center III: costs for a center in its third and following years of operation. Costs include support and expenses for two lead high school teachers plus ten associate teachers (1-week program).

5. Center IV: costs for a center in its third and following years of operation with additional scope of high school students now included. Costs include support and expenses for two lead high school teachers plus ten associate teachers (1-week program) plus one supervising teacher and four high school students.
6. Miscellaneous expenses include funds for outside evaluations, advisory group, summer institute (FY04 and after) and M&S.

APPENDIX E – Schedule Charts

	FY99	FY00	FY01	FY02	FY03	FY04	FY05	FY06	FY07	FY08
	Growth----------------------->					Operation-------------------->				
Cntrs C-I	12	12	12	12	12					
Lead Teachers	24	24	24	24	24					
7-week Research+Summer Institute										
Cntrs C-II		12	12	12	12	12				
Lead Teachers		24	24	24	24	24				
Associate Teachers		120	120	120	120	120				
3-Week Summer Institute										
Cntrs C-III			12	24	36	36	36	24	12	
Lead Teachers			24	48	72	72	72	48	24	
Associate Teachers			120	240	360	360	360	240	120	
1-Week Summer Institute										
Cntrs C-IV						12	24	36	48	60
Lead Teachers						24	48	72	96	120
Associate Teachers and 1-Week Summer Institute						120	240	360	480	600
Supervising Teachers, 7 Wk Research + Summer Institute						12	24	36	48	60
High School Student Researchers						48	96	144	192	240
Total Ctrs	12	24	36	48	60	60	60	60	60	60
Total LT	24	24	24	24	24	0	0	0	0	0
Total AT3	0	144	144	144	144	144	0	0	0	0
Total AT1	0	0	144	288	432	576	720	720	720	720
Total ST	0	0	0	0	0	12	24	36	48	60
Tot Tchrs	24	168	312	456	600	732	744	756	768	780
Total Student Researchers						48	96	144	192	240

APPENDIX F – Funding Tables

Current Funding ($k)

	Actual FY98	Actual FY99	Actual FY00	Actual FY01	Request FY02
NSF-ESIE & EPP[1]	--	317.4	353.2	324.8	290.5
NSF-EPP & MPS	188.8	250.0	275.0	361.0[2]	530.9
DOE-HEP	--	152.8	261.0	316.0	390.0[3]

Planned Funding Requests by the QuarkNet Project ($k)[4]

	FY03	FY04	FY05	FY06	FY07	FY08
NSF-ESIE	169.0	--	--	--	--	--
NSF	682.3	757.6	802.6	890.9	990.5	1,068.9
DOE-HEP	595.7	769.8	817.4	912.4	1,008.0	1,104.0

1. Grant Year begins in June.
2. FY01 funding from NSF-EPP/NSF-MPS was funded in FY02.
3. Planned funding from DOE-HEP in FY02 is $375k.
4. Funding for increased scope of project (funding for adding high school students to the project) is included in planned request to NSF & DOE-HEP starting in FY04.

APPENDIX G – References

1. A Diverse Research Portfolio for the Nation's Future, U.S. Department of Energy, Office of Science, TEID 3605, http://www.science.doe.gov, February, 2002.

2. Road Map for National Security: Imperative for Change, The Phase III Report of the U.S. Commission on National Security/21st Century, The United States Commission on National Security/21st Century, http://www.nssg.gov/Reports/reports.htm , February, 2001.

3. Department of Energy Organization Act of 1977, Public Law 95-91, http://www.sc.doe.gov/henp/congress.htm, August, 1977.

4. DOE/NSF High Energy Physics Advisory Panel (HEPAP) Subpanel on Long Range Planning for U. S. High Energy Physics report, http://doe-hep.hep.net/lrp_panel/, January, 2002.

5. Science for All Americans, Rutherford and Ahlgren, Oxford University Press, 1990. Benchmark for Science Literacy, American Association for the Advancement of Science Project 2061, Oxford University Press, 1994, http://www.project2061.org/. National Academy of Science: National Science Education Standards, National Research Council, National Academy Press, 1996, http://books.nap.edu/html/nses.

6. http://cipsproject.sdsu.edu/

cc:
JRO'Fallon, SC-22
RWoods, SC-222
SPRosen, SC-20

Copy mailed to:
Marvin Goldberg, NSF

KRT:slp:3-4829:3/7/02
Q:Kathy/QuarkNet/Review-Reports-Dec01/QuarkNet-Final-6Mar02.doc

SC-221	SC-223
PKWilliams	GCrawford
/ /02	/ /02