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TITLE GET HIGH SCHOOL STUDENTS HOOKED ON SCIENCE WITH A CHALLENGE

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# Get High School Students Hooked on Science with a Challenge


## Abstract

*Skilled scientists and engineers along with a public that understands science and technology are vital in today's technically competitive world. The United States must encourage its students to study and excel in scientific academic subjects and consider science and engineering as a possible career.*

*An academic program that progresses from a state-wide to a national competition is a way of developing science and computing knowledge among high school students and teachers, as well as instilling enthusiasm for science. This paper describes the New Mexico High School Supercomputing Challenge, a nonselective academic-year long program that was initiated in 1990. Teams of high school students from throughout New Mexico do a team computational science project using high-performance computers.*


## 1 Introduction

Since the launching of Sputnik by the USSR in the 1950s, the United States has realized the need for increased scientific knowledge at all educational levels to supply well trained scientists and engineers for research and industry. The nation also needs a scientifically literate public that can function in a technological workplace and will support technological progress.

### 1.1 Need to Enhance Science Education

While science education has made some progress, there is much yet to be done to meet the national goals of well trained scientists and a technologically literate public. This need has been described in many reports, including the Lax Report [1], *Nation at Risk* [2], *Science for All Americans* [3], and the National Science Foundation (NSF) report *A National Computing Environment for Academic Research* [4].

Furthermore, the need to enhance science education has been well documented, and strategies have been identified, most recently in an NSF study on the role of high-performance computing in science education [5,6].

### 1.2 Abundance of Existing Expertise

This country's universities and national laboratories have a wealth of scientific and technological expertise and many resources that can be brought to bear to enhance science education. These technical resources, combined with the expertise and interest of the education and business communities, can be brought together to create a cooperative educational environment that provides more effective science education.

Our approach is to capitalize on existing technology and business resources, the hunger for knowledge among teachers and students, the traditional role of nonselective extra-curricular activities in high schools as a motivator for additional academic studies, the model of competitive science fairs and sports, and the excitement that state-of-the-art computing can bring to students and teachers.

## 2 Method

In this paper, we describe the features of the New Mexico High School Supercomputing Challenge, explain how the program was conducted, outline the elements that have been most important for success, and delineate how this program is different from others [7].

### 2.1 Why Supercomputers for High School Students?

Although high school students may not need to use supercomputers for the size and complexity of their problems, supercomputers and high-performance computing methodology can be instrumental in getting the attention of teenagers, attracting them to science and technology, and ultimately hooking them on science. Just as teenagers are naturally interested in high-performance cars, giving them the chance to use high-performance computers can make a difference.

High school is the time when students develop career interests and lasting attitudes toward science and engineering. Successfully using supercomputers at this stage sets a foundation for future computing and scientific endeavors by

- giving confidence and enthusiasm to try academically challenging work,
- instilling excitement for science and computing, and
- providing the thrill of working on the best, most powerful equipment available.

The effects that supercomputers can have on students has been observed in a high school supercomputing program in Alabama [8]. Many students who previously voiced no interest in continuing their education beyond high school completed the supercomputing program with a strong desire to pursue a career in science, engineering, or computer science.

## 2.2 Goals

The goals of the New Mexico High School Supercomputing Challenge are the following:

- Increase science and computing knowledge at the high school level.
- Promote careers in science and engineering.
- Encourage students to compete academically and give them the experience and confidence to enter national competitions.
- Reduce the isolation of teachers in remote areas by putting them in electronic touch with their colleagues at other schools.
- Take advantage of existing science and computing expertise and resources for the benefit of high school teachers and students.
- Develop programs that can be replicated and may serve as models for other educational communities.

## 2.3 Features of the New Mexico Program

The New Mexico Supercomputing Challenge is an academic-year long program for high school students throughout New Mexico to do computational science projects using high-performance computers. It was conceived in the summer of 1990 by Senator Pete Domenici of New Mexico and John Rollwagen, chairman and chief executive officer of Cray Research, Inc., and was conducted during the 1990-91 academic year.

Each team is composed of 1–5 students, their sponsoring teacher, and a science coach from academia or a research laboratory. The team defines and works on a single computational project of their own choosing.

The Challenge is open to all students on a nonselective basis. In the first year of the program, 235 students on 65 teams with 55 teachers at 40 schools participated. More than 50 coaches and 10 judges volunteered their scientific knowledge and their time to provide a rewarding experience for the teachers and students. Awards include scholarships and savings bonds for winning students and computing equipment for their schools.

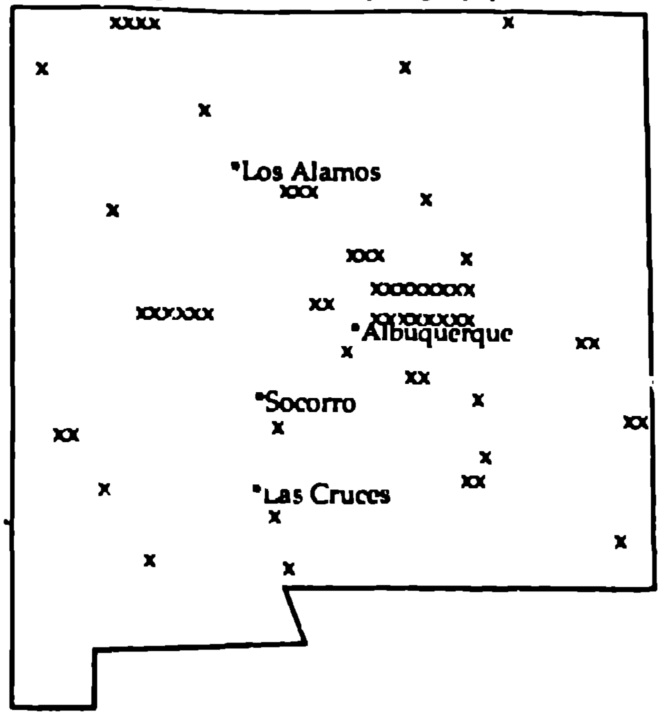


*Figure 1. On this map of New Mexico, you can see that the teams are located all over the state, far from the sponsoring institutions in the major cities.*

- **Participation on a Nonselective Basis**

The Challenge is open to students enrolled at any New Mexico high school (grades 9 through 12). It reaches students at schools where computing equipment and computing courses may not be available, as well as schools that have equipment and advanced-level computing courses. Because there is a vide variation of knowledge among the students, the emphasis is on achievement, or competition at each team's own level.

The program reaches many students who are historically underrepresented in scientific fields. In the initial program in 1990-91, women represented 25% of the students and 35% of the teachers, and three teams were all women. Many Hispanic students, students from several other ethnic groups, and students from the New Mexico School for the Visually Handicapped participated. We hope to increase participation by seeking the support of organizations that promote awareness and academic involvement for these groups.

- **Access to Computer Architectures and National Computer Networks**

Students are provided computer time on CRAY Y-MP/264, Connection Machine CM-2, Convex C220, IBM 3090-300E, and VAX computers, where they explore the different architectures in finding solutions to their problems. More than 125 hours of computer time were used by participants during the academic year.

New Mexico Technet provides state-wide computer network access to these computers via 1-800 and local telephone lines.

- **Ongoing Support**

Throughout the Challenge, a wide variety of support is provided—training and computer documentation, equipment loans, communications and computing troubleshooting and consulting, and scientific coaching. Students and teachers are brought together in October to receive two days of training to help them get started.

**Training**: At the October workshop, scientists talk about supercomputing and its application in different scientific fields. Computer consultants give a hands-on-workshop where participants log on to the computers through the communications network and use basic commands to compile and run a sample program.

**Equipment**: Because many schools do not have adequate equipment to access the network and supercomputers, terminals or workstations and modems are lent to those schools.

In the 1990-91 Challenge, 72 pieces of hardware and 9 software packages were provided to 33 schools (82% of the participating schools).

**Computer and Communications Consulting**: Throughout the year, computer consultants at Los Alamos are available to answer questions and solve programming problems, and personnel at New Mexico Technet handle communications questions and problems.

**Technical Coach**: Each team is assigned a technical coach from either academia or a scientific research laboratory. The coach is familiar with supercomputing and the scientific area of the project and helps the team design its project, suggests additional or alternate approaches to the topic, answers questions, and offers encouragement.

**Point of Contact**: A point of contact at Los Alamos National Laboratory helps teachers identify problems and hurdles and seeks solutions to eliminate these hurdles. The contact talks with teachers, takes requests for equipment and documentation, and answers questions or finds someone who can give the answer.

**Broad Base of Community Support**: New Mexico Technet created a partnership of universities, national laboratories, and businesses together with public and private high schools throughout the state to sponsor the Challenge.

### 2.4 Implementation

The Challenge proceeds through six phases during the academic year, with continuous evaluation and feedback throughout.

**Phase 1. Call for Participation**: The Challenge begins at the start of the academic year with a call for participation for teams to do computational science projects using high-performance computers. Teachers and students form teams and enter the Challenge by describing, in general terms, the scientific area and project they plan to work on.

**Phase 2. Introductory Workshop**: A two-day workshop is held in the fall for all students and teachers, where they are introduced to computational science and learn basic computing on supercomputers.

**Phase 3. Initial Work**: After the initial workshop, students return to their schools to begin tackling their problem. Many students must also learn a scientific programming language such as Fortran or C. With guidance from their technical coach and their teacher, the team members set up the problem and learn about what will be needed to solve it. At the end of this phase, students write a report of 200 words or less describing the team's project and their progress.

**Phase 4. Computing**: The computing phase of the project is the most exciting and frustrating to the students. The Consulting Office at Los Alamos is in great demand at this time answering programming questions and examining problems.

Students, with the help of their technical coach, define an algorithm to solve their problem. Then, they write a computer program to run on the supercomputer, or they may obtain an existing scientific application code and focus on simulation or data analysis.

**Phase 5. Final Report**: Students complete their project by late April, write a final report, and create a poster display. Because of the diverse computing background of students entering the competition, projects may be submitted in either of two categories.

Category 1 projects are for teams who have made progress in learning to work on a computer but were not able to make significant progress on their problem. Their report includes what they have learned about their project and what they have learned about supercomputers, programming, and communications on the super-computers. During next year's competition, these teams may continue working on their problem to carry it through to completion.

Category 2 projects are for teams who have more computing background and made significant progress with their computing projects. Their report includes a statement of the problem being investigated, description of the method of solution, results of the investigation, conclusions drawn from the analysis, and supporting evidence. In the next year, these teams may further define their projects and submit them to the national competitions. In addition, individual students submit reports describing their leadership, involvement, and accomplishments.

**Phase 6. Judging and Awards**: Leading scientific and computing experts drawn from research laboratories and universities in the region are asked to participate as judges. They are selected before the beginning of the Challenge and are kept informed of the directions and support given to the teams. The judges visit the teams at the schools to talk with the students about the projects.

The projects are judged according to the following criteria.

| | |
|---|---|
| Scientific content | 30 points |
| Effectiveness of approach | 30 points |
| Creativity | 30 points |
| Clarity | 10 points |
| Total | 100 points |

At the culmination of the competition, all teams attend a one-day awards ceremony and science tour in early May at Los Alamos where they get to see the computers they have been using. Each member of a team that completes the Challenge by submitting a report in Category 1 or 2 receives a scientific calculator for project completion.

Awards for Category 2 teams for the 1990-1991 competition included: first-place awards of a $1,000 savings bond for each student on the team and computer equipment for the school; second-place awards of a $500 savings bond for each student on the team and computer equipment for the school.

In addition, to team excellence, individual excellence is also judged. This is based on a separate report written by a student and substantiated by letters of recommendation from the teacher and technical coach. The report and letters describe the individual's involvement and leadership in the project. Three scholarships are awarded, one to each of University of New Mexico, New Mexico State University, and New Mexico Institute of Mining and Technology.

**Phase 7. Evaluation and Feedback**: In order to meet the needs of teachers, students, and coaches, feedback from all participants is continually monitored. We evaluate the quality of the projects relative to the computing background of the teams and observe computer usage time and number of participants, noting the involvement of groups that are historically under-represented in science.

## 3 Other High School Supercomputing Programs

There are several other well-known programs at the state and national levels that use supercomputers to enhance science education for high schools. Like the New Mexico program, the Alabama program [8] is nonselective and serves both average and exceptional high school students, but its community of involved schools and students is somewhat smaller and only the Cray supercomputer architecture is available. The Alabama program has a strong teacher education component.

Other competitions, such as the SuperQuest national competition [9] from Cornell National Supercomputing

Facility, et al; the National High School Supercomputing Honors Program [10] from Lawrence Livermore National Laboratory; and the North Carolina competition [11], are selective and serve the exceptional high school students.

## 4 Results

This project was undertaken with virtually no preplanning. From the beginning, the idea intrigued everyone, and we decided to try it. We had the scientific and computational resources, and the organizers had assembled people with administrative, educational, marketing, and technical expertise. We were aware of some of the other programs around the country and could draw on their experiences.

We were surprised and pleased by the level of interest among teachers and students from throughout the state, and we were delighted that 80% of the original participants completed the Challenge.

The students and teachers profited from the program in many ways.

- They learned about computing and science.
- Students' horizons were expanded, and science and technology have a greater place in their lives.
- Teachers' view of the role of computing in the classroom and science was widened.
- Students came away with a new interest in science and computing as a career.

Many people consider the Challenge a success. The broad base of community support—including New Mexico Technet, national laboratories, universities, computer vendors, businesses, and schools—were pleased with the program and its results. The judges were impressed with the quality of the projects and the creativity and resourcefulness shown by the participants. The participants gave the Challenge a vote of approval when all nongraduating students said they planned to take part again

Additional observations include the following:

- The goals of promoting interest in science and computing and increasing students' knowledge in these areas can be achieved through this type of program.

- Ongoing support is critical to identifying hurdles and addressing them rapidly. Teachers have little time to spend on troubleshooting and seeking solutions to problems.
- Technical coaches are necessary to give direction to the projects and individualized support in science and computing.
- A non ctive program is key to achieving broad participation leading to broad benefits.

### 4.1 Unanticipated Results

The high level of interest in the Challenge was totally unexpected—20% of New Mexico high schools participated in this first Challenge. Students and teachers have been very enthusiastic.

It is possible to put together a program such as this in a very short time. Solicitation and commitment of sponsors and resources was obtained in only a few weeks. The program was defined and structured in that same short time period.

## 5 Future Plans

We plan to offer the New Mexico High School Supercomputing Challenge as a yearly competition, and as students' and teachers' knowledge and experience grow, their projects will feed into the national competitions. By continuing to obtain feedback and evaluate results, we will adapt and improve the program to meet the needs of the participants and encourage a high level of academic excellence.

While we were pleased with the level of participation of the historically underrepresented groups (25% women, 30% minorities), we intend to take specific action to inform representative organizations of the Challenge and to identify ways to encourage greater participation.

Additional training and understanding of scientific computing and the use of supercomputers in science must be provided for teachers. Possible professional development programs include a six-week summer institute in computational science and several regional one-day in-service workshops.

## 6 Summary

The New Mexico Supercomputing Challenge is presented as a link between the education communities and the science communities, both locally and nationally. It enhances the knowledge of high school teachers and students in science and computing; it increases the understanding of education realities and opportunities by scientists; and it taps the potential for community benefits offered by scientists and the energy and desire to learn of teachers and students.

The Challenge is an effective way of encouraging students to discover the excitement of science and computing. The enthusiasm generated by academic success can provide the impetus to pursue a career in science and computing.

The Challenge may serve as a model that can be enhanced and adapted by other localities. A nationwide scheme of local programs leading to the national level will increase the level of interest and the number of students participating in scientific and computing endeavors and foster higher levels of academic achievement.

Without the influx of significant science and computing expertise and resources into high school educational communities, high school teachers cannot by themselves enhance science education. The Challenge uses scientific and computational expertise existing in research laboratories and universities, in collaboration with education communities, to make a difference in high school science and mathematics education.

By combining science and computing with a high school activity of high visibility and excitement, students, parents, and teachers are attracted and will learn more about scientific computation and the multidisciplinary approach to scientific problems.

## 7 Acknowledgments

This program was the result of state-wide support by businesses, national laboratories, and universities. It was made possible through the generous support and contributions of many people and organizations.

Terry Boulanger and New Mexico Technet have been instrumental in creating and coordinating the Challenge and in assembling a partnership of businesses, universities, national laboratories, and public and private schools throughout the state. New Mexico Technet also provided funds for advertising, food and lodging, workshop materials, training, computer equipment, awards, and transportation.

University of New Mexico, New Mexico State University, and New Mexico Institute of Mining and Technology donated scholarships for outstanding individuals in the competition, and they were involved in teacher support, coaching, judging, and administration. Art St. George and John Jenkins of UNM deserve special thanks.

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With the support of Sig Hecker, Norm Morse, and Hassan Dayem, Los Alamos National Laboratory contributed coaches and judges, speakers, computer consultants, teacher and student support, teaching assistants, and administrative support; network connections and high-performance computing resources; computer documentation, videotapes, and other instructional materials; computing equipment for schools; and facilities and food for workshops. We especially thank the support staff who handled the logistics necessary for meetings of 300 people.

We appreciate the advice and materials given by John Ziebarth of the Alabama Supercomputing Center and Helen Doerr of the Cornell Theory Center. They were very helpful.

Most of all, we thank the 40 coaches, 55 teachers, and 235 students, who devoted their time and energy to this effort, and the school administrators who had the foresight to support it. Without these people, there would have been no Challenge.

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