LA-13091-PR
Progress Report

New Mexico High School Supercomputing Challenge

1990–1995

Five Years of Making a Difference to Students, Teachers, Schools, and Communities

Los Alamos
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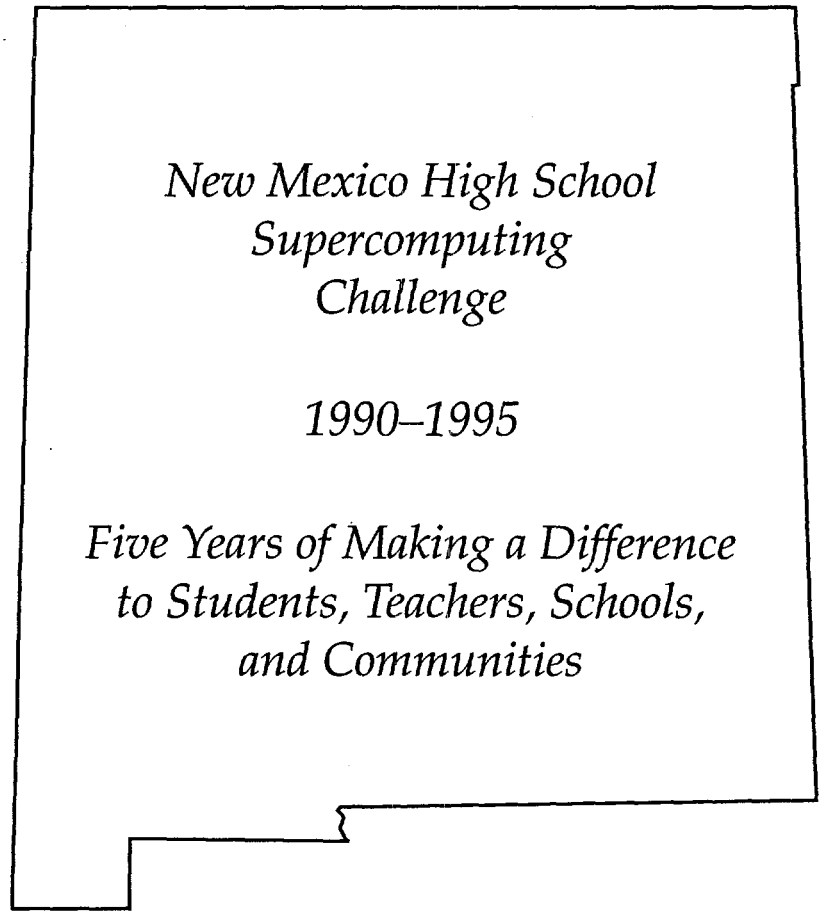
Marilyn Foster
David Kratzer

Los Alamos
NATIONAL LABORATORY
Los Alamos, New Mexico 87545



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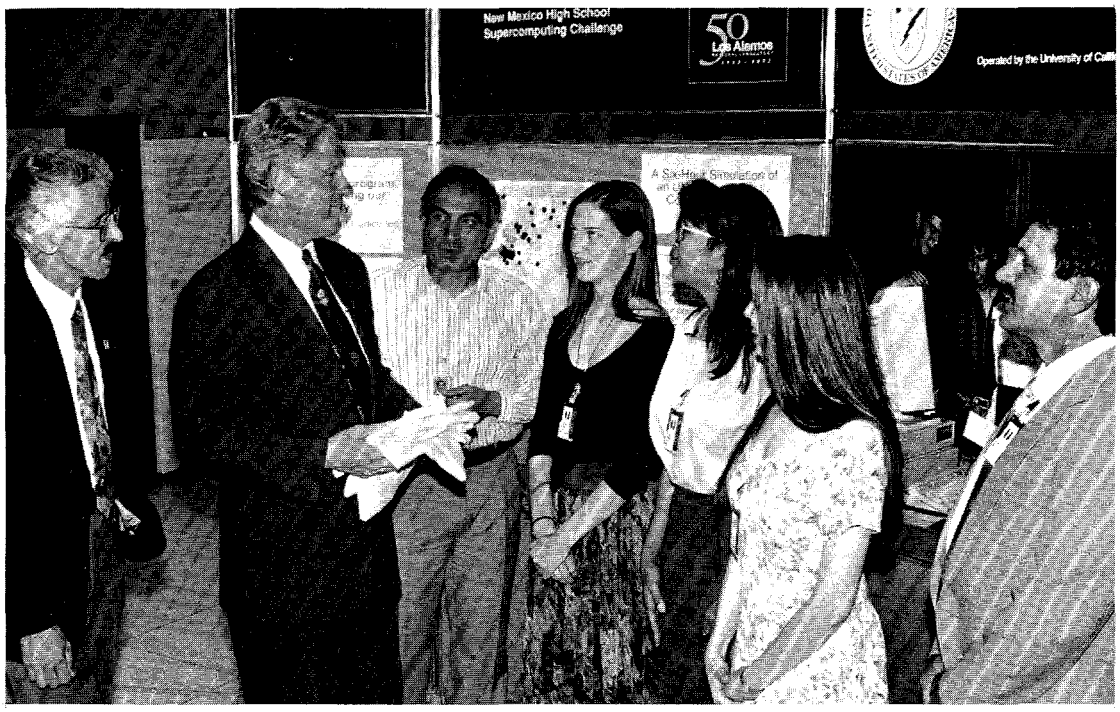


BSM-93-0096-L21

The 1992–93 winning team from Las Cruces presents President Bill Clinton with Challenge T-shirts for his family as LANL Director Sig Hecker and CIC Division Leader Hassan Dayem look on during the President's visit to Los Alamos National Laboratory in May of 1993.

> "I challenge business and industry and local government throughout our country to make a commitment of time and resources so that by the year 2000, every classroom in America will be connected."
>
> President Bill Clinton, September 21, 1995

New Mexico High School Supercomputing Challenge

1990–1995

Five Years of Making a Difference to Students, Teachers, Schools, and Communities

by

Marilyn Foster and David Kratzer

ABSTRACT

The New Mexico High School Supercomputing Challenge is an academic program dedicated to increasing interest in science and math among high school students by introducing them to high performance computing. This report provides a summary and evaluation of the first five years of the program, describes the program and shows the impact that it has had on high school students, their teachers, and their communities. Goals and objectives are reviewed and evaluated, growth and development of the program are analyzed, and future directions are discussed.

For more information about the current activities of the Challenge contact

David H. Kratzer
CIC–6 MS B251
Los Alamos National Laboratory
Los Alamos, New Mexico 87545
(505) 667–2864
dhk@lanl.gov

and visit the Challenge Web sites.

`http://www.education.lanl.gov/RESOURCES/NMSCC/scc.html`
and
`http://www.nm.org/challenge.html`

SUMMARY

The 1994–1995 academic year marked the fifth anniversary of the New Mexico High School Supercomputing Challenge. During these five years, the program has consistently met its goals and objectives and has made a difference in the lives of more than 2500 students and their teachers, schools, and communities.

In 1990 when the Challenge began, both the education and scientific communities expressed concern about the need for improving science education. Publications such as *Nation at Risk* from the National Commission on Excellence in Education and *Report of the Panel on Large Scale Computing in Science and Engineering* by Peter Lax called for action. In response to this concern, a number of innovative programs aimed at exceptional students were begun, but only the New Mexico High School Supercomputing Challenge was open to all interested students regardless of their academic status.

From the very outset, the New Mexico High School Supercomputing Challenge has reached out to students in metropolitan and rural regions, to students from affluent areas with well-equipped schools as well as those from areas with a low tax base and fewer advantages, and to students of all cultural backgrounds. The multifaceted population of the Challenge has made the program unique in its concept and design.

Data in this report confirms that the Challenge has positively impacted the participating students. They have gained knowledge and skills, advanced in their personal development, and established attitudes and goals that will guide them toward a successful future. The Challenge has influenced a significant number of its participants to choose careers in science or engineering.

Through the Challenge, teachers have become more knowledgeable about computing and scientific research. The majority now feel comfortable with using technology in their classrooms. Schools have upgraded their computer equipment, added technical classes to their curricula, and discovered an opportunity for academic achievement through the program.

The Challenge is sponsored by a partnership of businesses, universities, and national laboratories. Over the years the program has grown and evolved to meet the needs of diverse participants and help them to achieve excellence in an academically rigorous program.

Los Alamos National Laboratory (LANL) has played a key role in the Supercomputing Challenge with support coming from both the institution as well as from individual members of the staff. The Laboratory has provided hundreds of hours of computing time to Challenge participants, developed and implemented the educational component of the program, and sponsored the final judging and Awards Day activities. The Challenge exemplifies LANL's good neighbor policy of reaching out to improve educational opportunities in New Mexico.

The Supercomputing Challenge is proud of its accomplishments during the past five years. However, many more students are looking for the opportunity offered by this excellent program. Fewer than half of the school districts in New Mexico are participating. The Challenge must continue to build on its already-established solid base and encourage every school district in New Mexico to participate.

1 THE PROGRAM

The Supercomputing Challenge is an academic-year-long program that gives high school students the opportunity to do original computational science projects using high-performance computers. The idea for the program was conceived in 1990 when Los Alamos National Laboratory Director Siegfried Hecker commented to Tom Thornhill, President of New Mexico Technet, Inc, that the Laboratory would like to give high school students the experience of working on a supercomputer. With New Mexico Technet providing the networking and LANL the supercomputers, a partnership was formed with other federal laboratories, state universities, and businesses to quickly develop and set in motion the program, which has been enthusiastically received.

The Challenge is sponsored and conducted by a partnership of New Mexico businesses, universities, and federal laboratories. There is no direct cost to participating teachers or students, and schools are responsible only for phone lines and substitute teachers to allow Challenge teachers to attend program events.

Opportunity is the hallmark of the New Mexico High School Supercomputing Challenge. Participants can take advantage of educational training at workshops, access powerful supercomputers, and tap the expertise of scientists and technical consultants who are available throughout the program. The Challenge also offers an opportunity for the members of the scientific, academic and business communities to become directly involved in a program that supports, encourages, and nurtures the scientists and engineers of tomorrow.

1.1 Features of the Program

Features unique to the Supercomputing Challenge have fostered its success. These include nonselective participation, instruction and ongoing support, access to a variety of computer architectures, and competition.

Participation. The Challenge is open to all students in grades 9 through 12 on a nonselective basis. Participants come from public, private, parochial, and home-based schools in all areas of New Mexico. The program has no prerequisites of grade point, class enrollment, or computer experience. The key requirement for participating is an earnest desire to learn about science and computing.

Participating schools form teams of one to five students with a sponsoring teacher and a project advisor from business, academia, or a research laboratory. Each team defines and works on a single computational project of its own choosing. Projects represent all areas of science and mathematics with many teams choosing problems that impact their local environments.

Instruction and Support. Throughout the duration of the program, teams are assisted with instruction, educational materials, online and telephone consulting support, and help in finding a project advisor. The Kickoff Conference and Regional Training Workshops provide instruction on a number of topics, hands-on computer experience, and help from scientists in defining a feasible project. Whenever a problem arises, assistance is available from a number of sources.

Computer Access. The program provides computing time on CRAY, Connection Machine, DEC, IBM, and nCUBE computers. New Mexico Technet provides state-wide network access to these computers and to the Internet via local and long distance (800) phone lines.

Competition. The Challenge is both an educational program and a competition. Teams can compete for scholarships and savings bonds for individual team members and computing equipment for their schools. More than 170 individuals and their schools have received awards during the five years of the program.

Teams can choose to submit their final reports in either the competitive or noncompetitive category. Frequently teams concentrate on gaining knowledge and skill during the first year of participation and then enter a competitive project when they have gained experience. If noncompetitive teams wish, they may continue working on their projects for a second year.

1.2 Program Goals

The main goals of the Challenge are to foster creativity in devising computational solutions to original scientific problems and to make a positive difference in students' lives, motivating them to prepare for the workforce of the future. To meet these goals, the Challenge State Executive Committee, which oversees the program, developed the following objectives.

- Provide access to high-performance computers.
- Increase students' interest in science-related disciplines and promote careers in those areas.
- Develop students' confidence to perform complex problem solving.
- Institute electronic networking among all schools.
- Provide an educational experience unavailable in the regular curricula.
- Design a science and math program that can be replicated in other parts of the United States.

Section 3 discusses how the Challenge has consistently met these goals and objectives over the years.

1.3 Program Design

Throughout the program year, which spans September through April, the Challenge provides events and services to support students, teachers, and advisors.

Call for Participation. Early in the school year, all high school administrators and math and science teachers receive information about the Challenge and a registration packet.

Team Formation. Students form a team, either as part of a class or as an extracurricular activity. Each team must have a teacher as its sponsor and is encouraged to find a project advisor.

Kickoff Conference. The Challenge experience gets its primary impetus in late October with a two-day multitrack conference. The conference, which is held at a large residential conference center, presents numerous opportunities for students to learn about the Challenge process at both the beginning and advanced level. More than 14 hours of instruction are presented to expose participants to computer networks, supercomputers, software development methods, and programming. Hands-on computer laboratory sessions give students and teachers an opportunity to try new skills in both a structured and unstructured setting. Students have an opportunity to talk with scientists about their particular area of interest.

Project Advisors. Volunteer scientists and engineers from the national laboratories, industry, and academia advise teams on both the science and computing aspects of their projects. A number of former Challenge participants who are now enrolled in college also advise teams.

School Visits. A Challenge staff member visits each team at its school during November to answer questions and ensure that all necessary hardware and network connections are in place.

Consulting. Los Alamos National Laboratory, New Mexico Technet, and Sandia National Laboratory (SNL) provide electronic and telephone consulting to solve problems when they occur.

Network Support. New Mexico Technet supplies either a local or long distance (800) phone number for students and teachers to access electronic mail, the Internet, and the supercomputers at the participating laboratories.

Regional Workshops. Students and teachers attend a midyear, one-day workshop at a college or university in one of the six regions. Workshop content is tailored to address project and technical questions. As part of the training in 1994–95, teams wrote and analyzed sample computer programs and competed in answering basic computing questions.

Interim Reports & Project Evaluation. Each team submits a written interim report in January. The report describes the project and relates the progress made. Judges assigned to each region review the reports and, in Febru-

ary, listen to presentations by the teams and give each team a preliminary evaluation of their project.

Final Reports & Judging. Teams submit written final reports in April, and a panel of judge-scientists from throughout the state determines a group of finalist teams. Each of these teams is invited to come to Los Alamos on the day before the Awards Ceremony to present its project to the judges who listen and question the team members. The judges select the overall winners by consensus. They are guided by the following criteria and rating system.

Scientific Content	30%
Effectiveness of Approach	30%
Creativity	20%
Originality	10%
Clarity	10%

Sponsors and groups awarding prizes in special categories choose the winners in their particular area.

Awards Day. The Challenge concludes with participants visiting LANL to see the supercomputers on which they have worked, hear about current scientific and industrial applications, and attend the Awards Ceremony. Challenge sponsors supply numerous awards. First and second place team members receive savings bonds, and their schools gain new computer equipment. Outstanding team leaders receive scholarships; while trophies, plaques, or computing supplies are presented to winners in many different categories.

Evaluation & Feedback. Feedback is continually gathered and monitored to meet the needs of all participants and fine-tune each year's program.

1.4 Sponsors

The Challenge is sponsored by a statewide partnership that includes business and industry, institutions of higher education, and scientific laboratories. Members of the partnership work in conjunction with the education community throughout the state. The generous support of the sponsoring groups is invaluable. They provide major funding as well as equipment, awards and scholarships, and instructors and support personnel. Representatives of the sponsoring organizations sit on the Challenge State Executive Committee, which oversees the general operation of the program.

LANL provides supercomputing capability for all participants, develops and coordinates the educational component of the program, and hosts the final judging and Awards Day. New Mexico Technet handles program administration and network connections. The University of New Mexico provides administrative support for the Kickoff Conference and throughout the year. SNL coordinates the project advisors for the teams. The universities and colleges host the Regional Training Workshops and the preliminary project evaluation sessions.

A number of other organizations throughout the state contribute funds, in-kind services, and awards. Personnel from these organizations often volunteer as project advisors. Strong grassroots support has always been an important part of the Challenge. Sponsors and contributors are listed in Appendix A.

2 EVOLUTION AND GROWTH

While the basic design of the Challenge has remained constant, some details have changed over the years. As a result of observation and assessment by the program directors and evaluation of participant feedback, procedures have been refined and new strategies have been devised. Changes have been made to control the cost per participant (especially critical with increased enrollment), ensure a smooth running program, improve the educational experience of the participants, and initiate special training for teachers.

2.1 Cost Control

With enrollment increasing each year, it is imperative that costs be controlled both by the State Executive Committee and by the partic-

ipating sponsors. Both groups search for ways to give participants a quality experience within the constraints of money, personnel, and time.

One cost-control measure has been to give schools the responsibility for monitoring educational material so it remains at the school for future participants and does not need to be reissued. Moving the Kickoff Conference from an expensive metropolitan hotel to a self-contained conference center has also reduced costs.

Each sponsor contributes in its particular area of expertise and according to its own constraints. All sponsors are strongly committed to the program.

2.2 Program Administration

The Supercomputing Challenge is administered by the members of the State Executive Committee and the Challenge director. Strong and effective management is essential to a program the size of the Challenge. LANL and New Mexico Technet have helped to strengthen the administration by committing resources to that area of the program. Technet has dedicated a member of its staff to be program director, and LANL has assigned staff to the Challenge.

Administration of the program has been reinforced by applying strict deadlines at regular intervals throughout the year. With periodic check points, participants are better able to organize their time, and teacher feedback tells us that the deadlines are a positive motivation for continued work—students do not want to be dropped from the Challenge and lose their computer accounts.

2.3 Educational Experience

The Challenge strives to give each participant the opportunity for a quality educational experience. Curriculum content and pedagogy have been guided by personnel from LANL who have knowledge of the state-of-the-art in computing and who have access to scientists practicing this technology. This input combined with feedback from the participants makes the educational program both practical and exciting. Student and teacher requests have led to increased hands-on opportunities at the Kickoff Conference and classes geared to the different skill levels of the participants.

In the very first Challenge, the need for additional instruction and support during the year became apparent. Five midyear regional workshops were established in the second year of the program, and a sixth workshop was added in the fifth year to accommodate the increase in enrollment.

During the early years, some confusion was caused by the availability of computers with different operating systems. The current computers all run the UNIX operating system so participants need to learn only one operating system, besides their own PC or Macintosh system. In addition, to make it easier for participants to interact with the machines and each other, software, such as the PINE electronic mail program, has been incorporated.

2.4 Teacher Training

From the inception of the Challenge in 1990, everyone involved in the program realized that systemic change could best be achieved by educating the teachers. During the first three Challenges, many students knew more about computers than their teachers did. By the fifth year, a number of teachers had been involved long enough to be more knowledgeable than their beginning students, but new teachers and those with advanced students were still at a disadvantage. While special classes for teachers were added to the Kickoff Conference, these did not provide the intensive training that was needed.

In fiscal 1995, LANL procured funding to conduct a long-anticipated Summer Teacher Training Session, and in August of 1995, 27 teachers came to Los Alamos for two weeks of intensive training. While a few were from the metropolitan centers, most came from small rural high schools. Session participants attended classes in C++ programming language, UNIX operating system, Internet navigation, and HyperText Markup Language (HTML). The teachers also received hands-on experience

with the National Education Supercomputer Program at Lawrence Livermore National Laboratory and designed a course curriculum for their own computer students.

At the outset of the workshop, teachers took a pretest to measure their knowledge of the subjects to be taught. The test was repeated at the end of the two weeks with markedly different results, as shown in Figure 1. In addition to the test scores indicating a gain in knowledge, the teachers submitted evaluations that showed they definitely felt an increased confidence in their own computing skills.

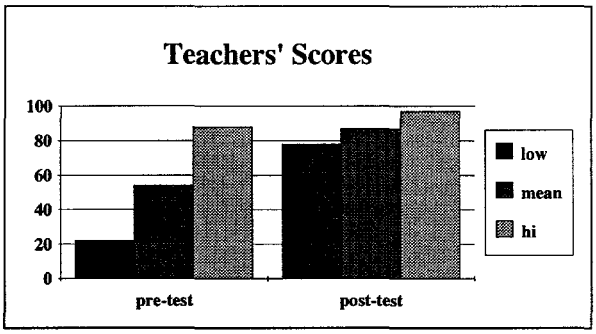


Figure 1: This shows the increase in knowledge that the teachers gained during their two week session at Los Alamos.

Teachers attending the 11 days of training were provided with housing and a stipend. They earned three units of credit from the University of New Mexico, Los Alamos Branch. Many of the participants requested another workshop. In this first Summer Teacher Training Session, 27 of the 118 Challenge high school teachers were reached; the future goal is to continue training additional teachers each year.

3 GOALS AND OBJECTIVES MET

At the inception of the Challenge in 1990, its aim was to enhance science education by enticing high school students to pursue scientific academic studies and consider science or engineering as possible careers. Just as the program itself has expanded and been refined, the goals have been further defined as the following:

> **To foster creativity in devising computational solutions to original scientific problems and to make a positive difference in students' lives, motivating them to prepare for the workforce of the future.**

These goals have been met year after year. In 1993 and 1995, follow-up surveys were conducted among students who had participated in the Challenge two years prior (1990–91 and 1992–93). Questions were asked about the current situation as well as the future plans of these former participants. The results showed that the Challenge had made a positive difference in their lives and that it helped prepare the majority for their current jobs or schooling. The 1995 survey showed that among the participants from two years earlier, 89% were attending college, and 80% of that number were majoring in science or engineering.

The Challenge State Executive Committee has developed six objectives to support the program's goals. Each objective is listed and is followed by a discussion of its achievement.

Provide access to high-performance computers so that teams can conduct complex scientific inquiry, experimentation, and visualization.

New Mexico Technet's statewide network provides all participating students, teachers and project advisors access to the supercomputers. New Mexico Technet has added local phone numbers in many communities around the state to support the Challenge. Participants use this network to connect to LANL's supercomputers at the Kickoff Conference and to work on them throughout the year. Access is also provided from New Mexico Technet's network to supercomputers at SNL, New Mexico State University, the University of New Mexico, and other locations as needed by the participants.

Increase high school students' interest in science related disciplines and pro-

mote careers in science and engineering by instilling enthusiasm for science in students, their families, and their communities.

Data from questionnaires and interviews show that the Challenge positively influenced students in their attitudes toward computing, science, math, and advanced education. In the 1995 survey of 1992–93 students, 80% of the respondents were attending a university, and 80% of that number were majoring in science or engineering.

The Challenge has also helped some students to realize that their interest lay elsewhere. When asked about the long-term effect of the Challenge, one student replied, "It gave me the knowledge that I did not, after all, want a career in computing."

Develop students' confidence to perform complex problem solving through their participation in a rigorous academic competition.

Many students said that as a result of their experience in the Challenge, they felt confident they could achieve success in a scientific field. When the 1995 survey of students asked if the Challenge positively influenced their self confidence, 85% responded that they had been positively affected, and 71% of that number measured the effect as "very much" or "a lot."

Institute electronic networking among all schools to reduce the isolation of students and teachers in remote locations.

This objective was unquestionably met! When students were asked on the evaluation form for the January 1995 Regional Training Workshop to rank their ability to use e-mail, 89% of teachers and 93% of students responded with the highest rating of 5 on a scale of 1 to 5. Students not only use electronic communication between team members, but also with project advisors, LANL and New Mexico Technet computer consultants, and scientists studying the research problems internationally. During the fifth year, some SLIP (Serial Line Internet Protocol) accounts were available, and plans for the future include expanding the use of SLIP to improve the networking capability of the schools.

Provide an educational experience that is otherwise unavailable in the regular curricula.

Teachers emphatically point out that the Challenge provides an educational experience unavailable to students through the regular curricula. The Challenge has positively affected schools to offer better technological support for students by providing software, hardware, phone lines, and courses of study. Teachers as well as students have indicated that they have become more excited about learning because of the Challenge.

Design a science and math program that can be replicated in other parts of the United States.

The Challenge has always encouraged other areas of the country to implement similar programs. Papers describing the program have been published, and representatives from the Challenge executive committee have attended a number of national computing and education meetings and conferences to share information about the program.

Several states have requested information about the program. In October 1995, three people from the Maui High Performance Computing Center attended the Kickoff Conference to observe its organization and implementation. They were very impressed and are planning their own version for the Hawaiian Islands.

An unwritten goal of the Challenge has been to encourage students to remain in New Mexico for their college education and future employment. Several scholarships are given each year by the institutions of higher education in New Mexico. Regional Training Workshops are held at college and university campuses to acquaint students with the local schools. In the 1995 survey, 56% of those pursuing post-high school education were attending in-state schools.

4 SCOPE OF PARTICIPATION

Since the initial announcement of the Challenge in 1990, the program has been enthusiastically received. In the first year, organizers hoped for a response of at least 10 teams—65 teams applied. By the fifth year, 182 teams were participating. Figure 2 shows the number of students who have participated in each year of the Challenge.

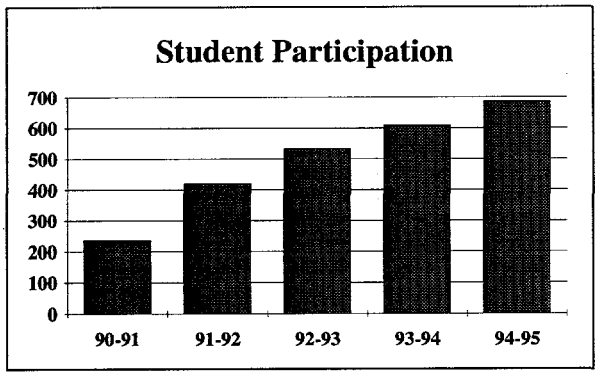


Figure 2: Student participation has increased each of the five years of the Challenge.

This trend of increasing participation will undoubtedly continue. In long-term follow-up surveys taken in 1993 and 1995, former participants unanimously recommended the Challenge for high school students. In the 1995 survey, a number of respondents mentioned that they were encouraging siblings and friends to participate.

While enrollment increases are significant, the number of teams completing the Challenge is even more important. This number has increased each year in both the competitive and noncompetitive categories. Over the years, organizers have developed guidelines and strategies to promote successful participation through the entire year.

With the nonselective policy of the Challenge, it is expected that some students will be unable to participate for the entire year. In the fifth Challenge (1994–95) the completion rate was 80% of the teams eligible to submit final reports. This number is more than 50% of the initial enrollment. Even though some students cannot complete the entire program, they benefit from the introduction to computer technology, networking, and problem solving. Many of those who must withdraw early reenter the following year and successfully complete the program.

4.1 Female and Ethnic Minorities

The Challenge reaches many students who are historically under-represented in scientific fields. Figure 3 shows the ethnic distribution for the years 1991–92 through 1994–95, and Figure 4 shows the enrollment by gender for each of the five years. Female and ethnic minority students have discovered that with the instruction and support that is provided, they can successfully participate in the program. In the third Challenge (1992–93), 77% of the members of the six winning teams were female, and 83% were ethnic minorities. Of the 15 scholarships awarded for team leadership over the five years, seven of the recipients have been female.

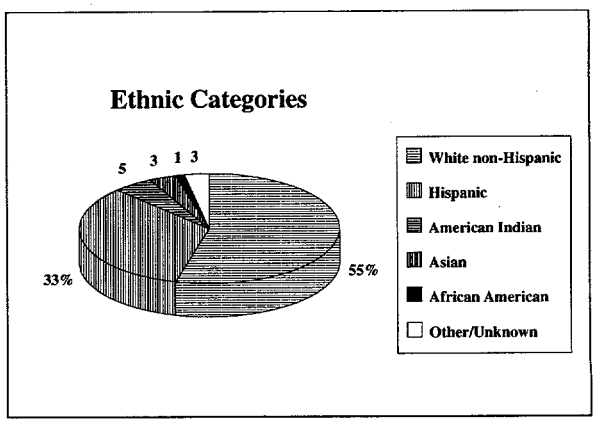


Figure 3: Ethnic data summarized over the last four years.

4.2 Remote Schools

Over half of Challenge participants are from small towns and rural areas. Because New Mexico is a state of vast land area but low population, a large number of high schools are located far from the metropolitan or technical centers.

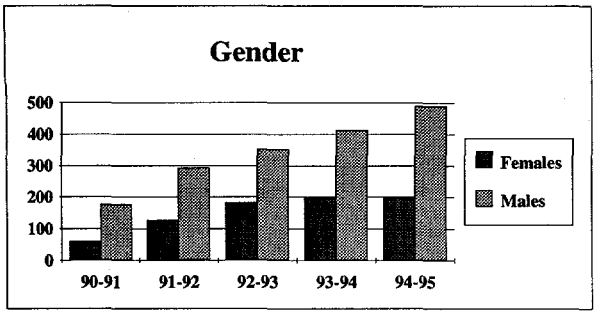


Figure 4: Over the entire five years, 31% of the participants have been female and 69% have been male.

Isolation is a real problem for these schools; however, with electronic connections, students in these schools can access the same supercomputing capability as students in the urban areas.

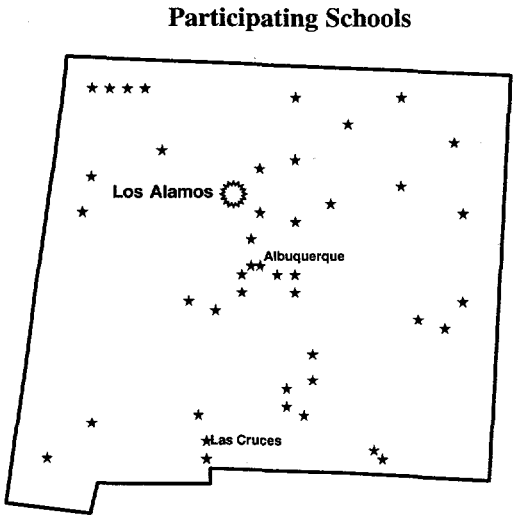


Figure 5: Schools are spread out over the entire state but connect to supercomputers at Los Alamos, Albuquerque, and Las Cruces via New Mexico Technet.

On the map of New Mexico in Figure 5, you can see that many schools are located far from the sponsoring institutions or the major cities.

4.3 Knowledge Base

There is a wide variation of knowledge among participating students—from students who do not know any programming language to those who have broad and diverse knowledge and experience in the use of computers. One of the participants commented, "Before beginning the Challenge, I could have been classified as virtually computer illiterate. In the end, I could understand a number of the things that computers are capable of doing and the things that I could do with them." As shown in Figure 6, data measuring the level of computer-related skills at the conclusions of the 1995 Challenge shows that, other than debugging a program, more than 60% felt confident of their ability to successfully use computers.

5 IMPACT OF THE PROGRAM

Participating students and their parents, teachers, and school administrators have expressed high praise for the Supercomputing Challenge. At least once in each of the five years, a student has said "Thanks for the Challenge. This is the best thing that ever happened to me!" The impact of the program goes beyond the immediate academic environment of the participants and reaches into the community, state, and nation.

5.1 Evaluating the Impact

To substantiate the impact that five years of the Supercomputing Challenge has had on the lives of more than 2500 participants, data was gathered and analyzed during each year of the program, and previous participants were surveyed by mail and telephone. The evaluation design targeted the following areas:

- **Direct affective domain measures** to determine participants' perception of the Challenge impact,
- **Indirect cognitive domain measures** to determine the learning cultivated by the Challenge experience,

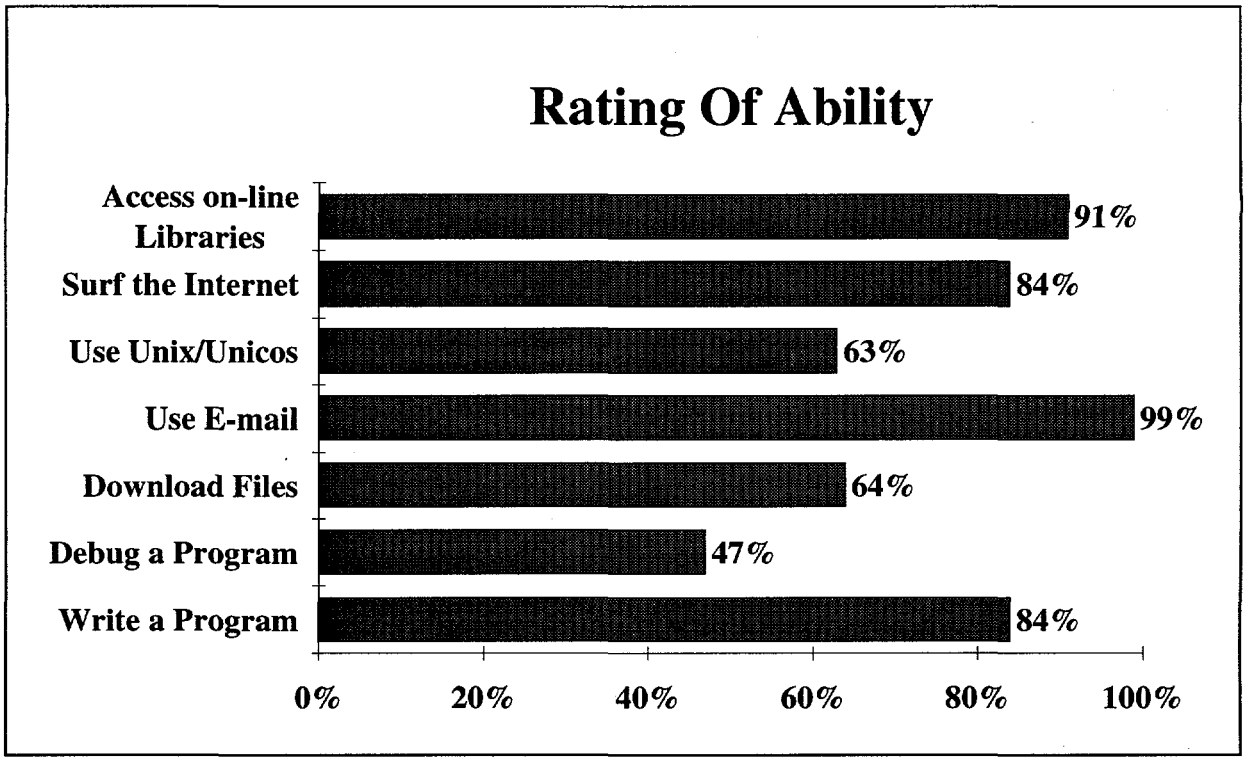


Figure 6: After completing the Challenge, students feel that they have gained the ability to do many computer related tasks.

- **Formative evaluation data** to use in planning future directions for the Challenge, and
- **Summative evaluation data** to determine the impact of the Challenge experience on students, teachers, schools, and communities throughout the state.

Over the five years of the program, a variety of sources and tools have been used for gathering data. Most summative data came from the 1993 follow-up survey mailed to 225 participants of the first Challenge and the 1995 survey sent to 450 participant of the third Challenge. These surveys researched the Challenge's long-term impact on participants' perceptions and career plans.

Other measurement tools used during the five years include:

- Student and teacher background questionnaires
- Student and teacher formative evaluation questions
- Assessments from Challenge staff
- Student and teacher post-event questionnaires
- Student and teacher critiques
- Interviews with students, teachers, and project advisors

5.2 Impact on Students

All data confirms that the Supercomputing Challenge has had a significant impact on high school students—those who participated successfully, those who for various reasons did not complete the program, and even students who did not directly participate. The successful participants gained knowledge and experience beyond the normal realm of the high school curricula. Students who did not complete the entire year learned some very practical lessons in teamwork and persistence along with an increase in computing knowledge. Non-participating students benefited from the program's spinoff of better equipment and net-

work connectivity, additional class offerings, and a changed attitude toward the importance of technology.

Influence on Attitudes. In long-term follow-up surveys done in 1993 (1990–91 participants) and in 1995 (1992–93 participants), respondents indicated that the Challenge had a positive influence on their attitudes toward science, math, and computing as well as other areas. The 1993 study had a return of 26% of 225 surveys sent, and the 1995 study had a 13% return from 450 surveys mailed. (The variation in return rate may be a factor of the time of the year when the surveys were conducted. The 1993 survey was done in December, and the 1995 survey was sent out in August.)

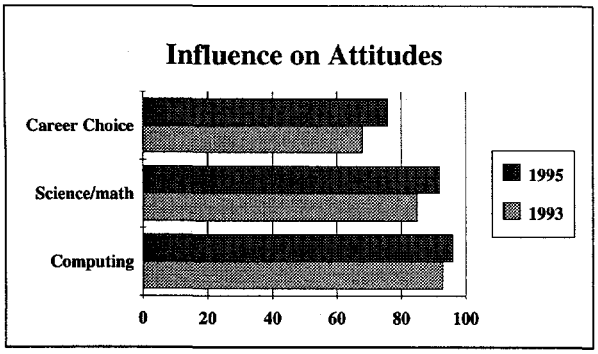


Figure 7: The Challenge has had a positive influence on students' attitudes in their career choices and their feelings about science, math, and computing.

The 1995 survey also queried the former participants about their attitude toward advanced education. Most (86%) said that the Challenge had a positive influence in this area. The majority of the respondents (80%) had completed their high school education with 87% of that number presently enrolled in college.

Education/Career Choice. In both surveys, the majority of college students (87% in 1993 and 73% in 1995) listed their majors as engineering, science, or computer science. In interviews, former award winners pointed out that the Challenge had helped to define their career paths. One said, "I leaned toward studying engineering, but I didn't really know how engineering worked...the Challenge gave me an insight into computer science, engineering, and math that I didn't have before." A Civil Engineering student observed, "I was impressed by the contact with scientists and engineers who helped with our project. These contacts influenced my career path."

Interest in Scientific Subjects. Science, math, and computing take on new meaning through Challenge participation. A former participant, who has also been a project advisor to an award winning teams, stated, "Most kids see science as dull and mundane. The Challenge gives a 'face lift' to science. Many students have learned to love science and embrace it." Another prize winner commented, "The Challenge taught me that science was not mysterious; it is something I can do."

Intellectual Achievement. Along with an increased interest in math, science, and computing, Challenge participants report the benefit of being involved in a mind-stretching endeavor. One award winner said, "I learned a new way of thinking: examining options, working with others and considering their ideas, and carrying the project through to completion." Another participant commented, "I learned new techniques of solving problems. It was an opportunity to work on large sized, complex problems. We learned to take the answers we got, find if they were useable, and keep them in the context of the problem. We learned to analyze what we put in and the results we got back."

Personal Development. Improved self-confidence, character development, and expanded horizons are added benefits of Challenge participation. With the extra work and enthusiasm for learning generated by the program, grades improve, and this success carries over into other areas. Comments such as the following confirm these gains: "Gave me confidence to explore new worlds," "The personal feeling of achievement when we turned in our final report was awesome," and "Sparked an interest in a scientifically oriented career. Whereas, I hadn't previously considered it seriously."

Teachers attribute many successes to Challenge participation. One teacher said "I come

from an isolated area with many Navajo students. The Challenge lets these students see that they can do it too. It lets them see what is available; it expands their horizons." A number of teachers have related experiences with students who discovered their strengths and blossomed as a result of their participation. One teacher concluded such a story by saying, "The Challenge has taken a very shy, quiet, uninvolved individual and turned him into a confident, self-assured, involved member of our student body."

Job Opportunities. Technical skills, learned and refined while working on Challenge projects, have led to part-time technical jobs for many participants while still in high schools or in college. One former participant told us, "The Challenge exposed me to the Internet, and now I'm working to get an Internet service provider up and running as a business." In the 1995 survey of former participants: part-time jobs held by students included computer consultant (2), computer programmer (2), systems integrator/network manager, technical assistant, computer sales person, designer (CAD), administrator of a discovery lab at a children's museum, and a number of summer intern positions at the scientific laboratories.

Teamwork Skills. A significant number of previous participants noted the benefits of teamwork. They considered this to be one of the most beneficial aspects of their Challenge experience. In the 1995 survey, 26% of the replies mentioned this aspect. The comments included, "Teamwork is used in all professions; I'm glad that we were introduced to that aspect." and "I learned the importance of group effort and teamwork. We found our individual strengths and divided the tasks. We developed real team solidarity."

Influence on Nonparticipating Students. An unanticipated finding was the positive effect that the Challenge has had on nonparticipating students. One teacher commented, "It is amazing to see how the Challenge has changed the lives of students who are not in the program. Challenge students have had an influence in our area, and now local electronic bulletin boards are springing up because of these students. More regular (nonparticipating) students are convincing their parents to buy computers AND modems." Another teacher said that because the Challenge gives weight and credibility to other technology-based classes, he was able to start a computer class for at-risk students. Participation in this class led to a complete turnaround for one student who had been considered incorrigible. During four years in the computer class, this individual went from failing grades, truancy, and a police record to the honor roll.

5.3 Impact on Schools

Words abound about the need for reform and systemic change in education, especially in the areas of science and technology. Many theories and plans have been proposed about how to best do this. One point that is consistently expressed in these proposals is the need for an influx of significant science and computing expertise into the high schools. The Challenge uses scientific and computational expertise existing in research laboratories, businesses and universities to work in collaboration with the education community to make a difference in high school science and mathematics education. The Challenge has impacted New Mexico's schools in the areas of equipment, curricula, and opportunity for academic achievement.

Equipment. During the first year of the Challenge, 82% of the participating schools needed to borrow equipment in order to take part, and dedicated phone lines were almost nonexistent. A teacher told of having to bring his personal computer to school and taping down the disconnect buttons on the phone in the school office when they wanted to connect to the network. By the fifth Challenge, 70% of the teachers who had participated previously felt that the equipment at their school was adequate and another 15% said that the situation was improving. A teacher stated, "We have built our system up because of the Challenge." Another said, "Yes, compared to previous years." One expressed the hope, "No, but soon." Only two of

the 54 schools in the 1994–95 Challenge needed equipment loans.

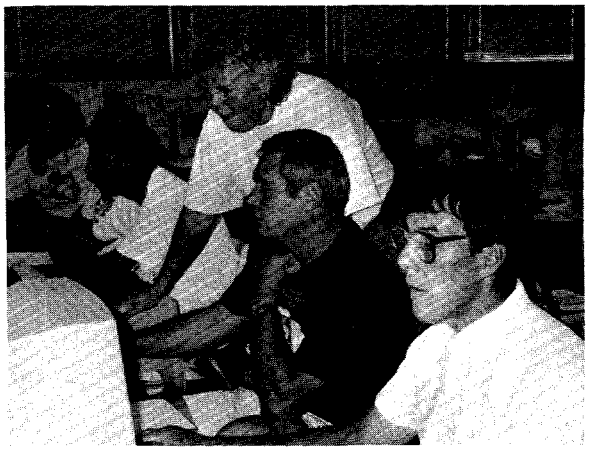
Challenge awards have helped schools acquire equipment. Winning teams receive computing equipment for their schools in addition to the personal prizes to the team members. One student remarked, "Our school has been gifted with excellent teams that have won computers, modems, etc. that are hard to come by in public schools." A number of schools have taken advantage of the expertise of team project advisors to help them choose the best type of new equipment and to get it installed and operating. A number of schools also are acquiring direct connections to the Internet.

Curricula Expansion. Both students and teachers attest to the Challenge prompting the offering of new and higher level technical classes in many schools. One teacher mentioned, "The Challenge has helped in getting the backing of the administration for advanced classes. Computers are now used in science and math classes, especially physics and chemistry."

Pride in Academic Achievement. Participants report that the Challenge promotes a feeling of school pride and increases faculty confidence in the ability of the students. These attributes seem to be especially important in small rural schools. One student of a winning team said, "While our school had competed well in some sports in the past, it had never had any sense of academic achievement before winning the Challenge." Another student observed, "The Teachers realized that just because we were from a small school didn't mean we couldn't compete." A student from another part of the state remarked, "It was nice to have our school recognized for its academic achievement instead of all its problems."

5.4 Impact on Teachers

Even though Challenge participation adds extra hours to already busy schedules, teachers have enthusiastically supported and taken part in the program from the beginning. At the 1995 Awards Ceremony, 11 teachers were honored for five years of continuous participation. Teachers



RN96-058-02

Figure 8: Teachers help each other during the computer laboratory session at the Summer Teacher Training Session.

see the Challenge not only as an advantage for their students but also as an opportunity for themselves to learn and improve their skills.

Of the teachers completing an evaluation form at the end of the fifth Challenge, at least 83% were confident in their ability to use e-mail and find information on the Internet. More than 50% had some confidence in writing and debugging a computer program. This is a significant change from the early years of the program when the typical comment from a participating teacher was, "I don't know anything about computers, but I think my students should know about them."

Teachers value the opportunity the Challenge provides for interacting with their peers from other parts of the state and with practicing scientists. Teacher participants report that they have an increased confidence and enthusiasm for teaching. One student observed, "It gave the teachers more of an insight into what is going on with computers, how they are changing, and how they will affect us, the students." A teacher who has been in all five Challenges said, "The Challenge has had a tremendous effect on my teaching career. It encouraged me to learn programming, UNIX, and the Internet on my own. I now teach a class on supercomputing at my high school and teach a class on the Internet at the Community College."

5.5 Impact on Communities

The impact of the Challenge extends beyond the school into the families and communities of the participants. Through the participating students, many nontechnical people have been introduced to the uses and importance of computer technology. One teacher said, "I can attest to the effect the Challenge has had on a small computer illiterate community. The change has been wonderful to see. America Online is now considering supplying the area with a local telephone number because of the demand for the service in just the last year (mainly from high school kids)."

Many Challenge projects focus on local problems. Teams have tackled such diverse topics as pollution caused by smelter emissions, ground water contamination from fuel storage tanks, breaching of a local dam, and even the sports stadium's parking lot configuration. In a number of cases, the solutions proposed by the students have been presented to local officials for consideration. Such activities instill community responsibility and pride.

Local communities are impressed to see Challenge sponsors and contributors working directly with their students. One project advisor to a small-town team said "The community became aware of LANL and the other sponsors helping in their community. They saw the effort and money spent to get their kids involved."

5.6 Impact on State and Nation

The economic competitiveness of both the state of New Mexico and the nation is dependent on a citizenry that is knowledgeable in scientific and technical matters. To maintain a technically literate workforce, we must have an adequate supply of trained workers in the science pipeline. High school students are eager for the opportunity to learn about computers and how they will affect the work environment of the future.

The Challenge increases both the quality and number of students entering technical careers. The results of the 1993 and 1995 follow-up surveys indicate that the Challenge positively influenced participants' attitudes toward science, engineering, and math, and that it had a definite effect on their choice of academic major or career area. See Figure 7, Section 5.2.

In addition to the statistical evidence, comments from participants also support the effect of the Challenge. "I changed my major from nonscience to computer science. The Challenge gave me an interest in computers," is a commonly heard remark.

6 LANL AND THE CHALLENGE

Los Alamos National Laboratory has strongly influenced the Supercomputing Challenge, and the Laboratory has benefited from its participation in the program. From the initial conversation of LANL Director Siegfried Hecker and New Mexico Technet President Tom Thornhill in which the idea was conceived to use supercomputers as a way of attracting high school students to science and math, LANL has given whole-hearted support to the program. The Laboratory sees participation in the Challenge as a part of its commitment to increasing science literacy and to broadening the pool of scientists and engineers in the United States. LANL's responsibilities include designing and implementing the program's educational component, providing supercomputer access, and hosting Awards Day.

6.1 Educational Component

The main focus of the Challenge is education. In this area, LANL contributions have benefited both students and teachers. The learning process extends over the entire program year. Formal teaching is done at the Kickoff Conference and at the Regional Training Workshops, and informal instruction is given whenever questions or problems are addressed by LANL and New Mexico Technet computing consultants.

Laboratory personnel have developed a curricula to address the needs of beginning as

well as experienced participants. The curriculum gives participants a good grounding in the basics of computing and also enables the advanced students to explore and develop new skills. Many of the classes are taught by LANL staff. In addition, a large number of Laboratory employees have volunteered their personal time as team project advisors.

LANL introduced special classes and hands-on laboratories for teachers at the Kickoff Conference. In addition to this training, the Laboratory has sponsored one Summer Teacher Training Session and hopes to hold additional ones in the future.

6.2 Computer Access

Over the five years of the Challenge, more than 2500 high school students and teachers have had the opportunity to work on a supercomputer. The dream of Director Hecker has flourished. Providing this kind of experience to such a large number of people is not duplicated anywhere else in the United States.

Each participant in the Challenge has an account on a Cray supercomputer at LANL. Records of computer use were kept during the first three and a half years and showed that the usage time increased dramatically. During the fourth Challenge, a Cray YMP-EL was dedicated to educational programs, and computer use for Challenge participants was no longer recorded.

Through the Advanced Computing Laboratory (ACL) at LANL and the Massively Parallel Computing Research Laboratory at SNL, teams whose projects could take advantage of parallel computing technology, have been given access to parallel processing machines. The ACL has provided access to massively parallel Connection Machines, and SNL has made an nCUBE machine available. Some teams have used a Cray YMP at New Mexico State University and the IBM SP2 at the Maui High Performance Computing Center, which is operated by the University of New Mexico.

6.3 Awards Day

The Laboratory has hosted the two-day project judging and awards event for each of the five Challenges. Finalist teams spend the first day at the Laboratory presenting their projects to the judges. The second day is Awards Day. The finalists join other participants to tour the Lab's computing facilities and hear presentations about the latest scientific advances. The event closes with the announcement of the prize winners at the Awards Ceremony.

At recent Awards Day activities nearly 100 LANL employees participated by giving talks and demonstrations or escorting groups of participants on the tours. The staff looks forward to taking part in the event each year because they see the value of the Challenge and how it positively affects the participants.

6.4 Attitude toward LANL

The Laboratory's involvement in the Challenge has had a positive effect on participants' perception of the institution. In the 1995 follow-up survey, 88% of the respondents said that the Challenge had positively influenced their attitude toward the Laboratory, and 73% of that number indicated that the influence was "very much" or "a lot."

Interviews with former participants also confirm this fact. One said "LANL stopped being a 'mystical hilltop.' Instead I began to think of it as a mecca of technology where people shared my interest and worked on projects that were large scale versions of what I worked on in the Challenge. LANL finally became relevant to me. It became a place that produced things that I cared about, that interested me, that affected me."

7 FUTURE PLANS

While the Challenge is proud to have reached the five year mark, the leaders and sponsors are even more excited about the future of the program. They have a vision in which every secondary school in the state is connected elec-

tronically to supercomputers, and all students have the opportunity and support to do scientific problem solving on that equipment. Efforts to achieve this vision will focus on the areas of increasing the number of schools as well as the participation by female and minority students, offering additional teacher training, and locating project advisors for teams

The Challenge executive committee would like to see at least one school from every school district in the state taking advantage of the Challenge. New Mexico has 89 independent school districts, and in 1995, only 39 of those districts had schools participating in the Challenge. Many of the nonparticipating districts are in remote parts of the state and will require extra attention so that they can be electronically connected.

Increasing participation by female and ethnic minorities will continue to be a priority. Strategies to increase not only the number enrolling, but also the number successfully completing the program are critical. Frequently the successful strategies in this area are subtle in nature: using promotional materials that show women and minorities actively participating, having a significant number of women and ethnic minority instructors for technical classes, and alerting instructors, lab assistants, and project advisors to include every participant in the activity, not just the assertive ones. Continuing to work in conjunction with other LANL sponsored programs that target female and minority participation in technical areas can also increase participation in the Challenge.

The first Summer Teacher Training Session was an outstanding success. This opportunity must be extended to more teachers. The training that the teachers receive benefits not only Challenge students, but all the subjects and classes taught by those teachers in future years. Technically knowledgeable teachers also have a positive impact on their peers and the curricula of their schools.

Having a project advisor can be a critical factor in a team's success. Teams in remote regions are frequently at a disadvantage because they do not have access to people knowledgeable in the scientific areas of their projects. Strategies must be devised to expand the pool of project advisors in all areas of the state. These strategies may include recruiting from professional societies, tapping the retiree community, making a concerted effort to locate potential advisors in rural areas, and encouraging electronic communication between a team and its advisor.

8 CONCLUSIONS AND IMPLICATIONS

The five years of the New Mexico High School Supercomputing Challenge prove that a program that has strong grassroots support and is nonselective, academically stimulating, and relevant can be successful in attracting participants and in affecting the lives of those participants. The program is a link between the education and the scientific communities. Funding for programs such as the Challenge cannot be considered a luxury or extravagance. The Challenge and programs like it are vital to the future of the United States.

Our country needs a technologically literate population if it is to compete in the world market. The Challenge has proven that it positively contributes interested and trained students to the scientific pipeline feeding the workforce of the future. Evidence shows that participants not only gain immediate personal and academic benefit from the experience but also realize a definite advantage in pursuing future career success. The program positively impacts the educational environment by enhancing equipment, curricula, and teacher knowledge.

In the five years of its existence, the Supercomputing Challenge has made a difference in the lives of students, teachers, schools, and communities. The Challenge looks forward to its contributions to the future participants and the world in which they will live.

Appendix A. SPONSORS AND CONTRIBUTORS

We are grateful to the following organizations who, over the years, have sponsored the Supercomputing Challenge. These sponsors provide funds, awards, computing time, equipment for educational sessions and to lend to schools, and personnel to conduct training and advise teams.

Sponsoring Organizations 1990–1995

New Mexico Technet, Inc.
Los Alamos National Laboratory
Phillips Laboratory
Sandia National Laboratory
University of New Mexico
New Mexico State University
The Albuquerque Tribune
Cray Research, Inc.
CHECS, Inc.
Eastern New Mexico University
Digital Equipment Corporation
Intel Corporation
National Education Supercomputing Program
New Mexico Institute of Mining and Technology

Contributing Organizations 1990–1995

Apache Peak Observatory
Aquila Technologies
Computer Science Corporation
Fort Lewis College
General Telephone Company
Hewlett-Packard
IBM
KOAT TV, Channel 7
KOB TV, Channel 4
KRQE TV, Channel 13
New Mexico Highlands University
New Mexico School for the Visually Handicapped
New Mexico State Department of Education
New Mexico State General Services Dept.
New Mexico State Human Service Dept.
New Mexico State University at Grants
San Juan College
Santa Fe Community College
Thinking Machines Corporation
University of Arizona
University of New Mexico, Gallup
University of New Mexico, Los Alamos
Very Long Baseline Array
Western New Mexico University
White Sands Missile Range

Appendix B. LIST OF WINNING SCHOOLS

First Annual Challenge
Albuquerque Academy
Career Enrichment
Los Alamos High School
Valley High School
Portales High School
Silver High School

Second Annual Challenge
Espanola Valley High School
Moriarty High School
Del Norte High School
Los Alamos High School

Third Annual Challenge
Las Cruces High School
Albuquerque Academy
Espanola Valley High School
Hatch Valley High School
Moriarty High School
Socorro High School

Fourth Annual Challenge
Albuquerque Academy
Highland High School
Los Alamos High School
Espanola Valley High School
Moriarty High School
Pecos High School

Fifth Annual Challenge
Albuquerque Academy (3 Teams)
Espanola Valley High School
Albuquerque High School
Highland High School

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