TRAINING SCIENTISTS AND ENGINEERS FOR THE YEAR 2000

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Mr. Chairman and Members of the Subcommittee, I am pleased to have the opportunity to testify before this Subcommittee to present my views on training of scientists and engineers for the year 2000. I look forward to this appearance because the topic of training our nation's scientists and engineers is clearly one of critical importance to our competitive posture. This is also an area in which I have had a long-term personal commitment having spent much of my adult life involved in science education. For nearly twenty years, I taught at the university level; while at the American Association for the Advancement of Science, I was actively involved in a broad range of educational activities. Now, as director of Oak Ridge National Laboratory, I have a vital interest in a highly qualified scientific and technical workforce. Finally, as chairman of the Mathematical Sciences Education Board, I am working to build a consensus for a national strategy of mathematics education. My testimony will provide my perspective on the effects of a projected shortfall of scientists and engineers, and then comment on challenges faced by the university research community.

Many studies over the past several years have indicated that our country's changing demographic profile, under present conditions, will not produce enough scientists and engineers in the next two decades. White males have traditionally been the largest segment of the population in the science and engineering work force. But time marches on and they retire and leave the work force. The new entrants to the workforce will largely be composed of minorities, women, and immigrants. As new scientists are needed to replace them, other population groups will have to take their place. But it just isn't happening fast enough. We are heading for a shortfall that could exceed a half-million in twenty years.

Oak Ridge National Laboratory and the nation's other Department of Energy laboratories are, according to the Secretary of Energy, "home to some of the world's brightest and most innovative scientists and engineers. Their creative minds are a precious asset and will be encouraged not only to continue their basic research, but also to improve the process by which new technologies are transferred to American industries, small businesses, and universities." Historically, our involvement in education has been focused in higher education with emphasis on research appointments at the faculty and postdoctoral level. Eventually, undergraduate programs were developed which also focused on research opportunities for students. Educational links between the laboratories and the academic institutions are seen as beneficial to both in that faculty, staff scientists, and students have access to research facilities that may not be available at the base institution and contribute to the ongoing

research at that guest facility. Faculty, students, and the staff scientists interact with professional personnel beyond that of the base institution. Students that participate in the research programs provide an experienced set of hands and a pool of capable students to be encouraged to pursue graduate degrees or to consider employment at the national laboratories. These arrangements are attractive to the Laboratory.

I believe it is the national laboratories that hold the key to America's scientific competitiveness. Our emphasis on fundamental research requires advanced degrees: over 50% of ORNL's research staff have doctoral degrees. We recruit across the nation for our professional and research staff and rely on local markets for other job categories. We are now feeling the effect of the shortfall in selected areas. Environmental and chemical engineers and materials scientists with advanced degrees are in short supply. I attribute this to the significant financial opportunities available to people with a bachelor's degree. There is little incentive to attend graduate school and obtain a doctorate when you can earn almost as much, and start earning it five years earlier, entering the workforce after your senior year. The shortage is also severe in other disciplines. The nationwide emphasis on radiation protection and industrial hygiene places qualified individuals with these backgrounds in great demand. Health physicists are essential for our work with radiation sources and we constantly searching the marketplace for individuals that are the very best in this field. Yet during a recent survey of ORNL, we had to request support from other DOE facilities for the loan of

several health physicists. Recruitment in some disciplines is difficult, and hiring qualified women and minorities, the logical source of new scientists and engineers, is even tougher.

In the years ahead, it is easy to predict that the competition for the top graduates will increase. As in most bidding wars, the wealthy and prestigious institutions will be the winners and the losers will be the other research centers. Unless alternatives are found to increase the number of qualified graduates, there will be fewer of them in industry, research, and education. Our nation's immediate competitive position, as represented by industrial needs, will suffer. Our long-term growth prospects will also suffer, as represented by education and research. If fewer scientists and engineers are on the staff of universities, future growth of qualified personnel will not be easily accommodated.

If Department of Energy facilities continue under their present budgetary stringencies, I am not sure of the extent of the immediate impact of the decline in availability of scientists and engineers because I am not sure the full effect would be felt at ORNL. This past year we narrowly avoided a layoff of scientists because of unanticipated costs associated with waste management. ORNL was able to transfer these scientists from their specialities to other areas where increased staff levels could be used. The Laboratory's overhead rate has risen dramatically to cover increased environmental charges that were not anticipated in the budget. Budgetary considerations are affecting our competitiveness more

than a shortage of scientific manpower. When we are in a state of declining research budgets,the cutting of research subcontracts is considered along with other options. ORNL currently has approximately $20 million of subcontracts and procurements with 100 universities. While ORNL values these connections, we recognize there may be little alternative to our actions. Increased budgets for research will allow the university-laboratory connection to be expanded.

In a 1988 study, the Department of Energy's Energy Research Advisory Board reported (Science and Engineering Education, report DOE/S--0065) on the Department's role in meeting its future manpower needs. The Board found that the Department has a continuing, critical requirement for a broad spectrum of highly educated and trained scientists, engineers, and technicians. They recommended that DOE continue and strengthen its role in the education and training of these human resources. In this context, the Board found that DOE has established a clear leadership role in graduate and postgraduate education in many fields of science and engineering related to its primary mission in energy research and development. They also found that this program makes a great contribution to other science-based, high- technology industries so vital to our nation's economic strength, and especially to our international competitiveness. The Board further noted that DOE's greatest contribution to science and engineering education is in supporting research in the universities, and in bringing the

university professors and students into close working relationship with the DOE laboratories and energy-industry professionals.

ORNL and the Department of Energy have a strong commitment to science education and educational outreach activities that will impact the supply of the future technological workforce. About 1,000 college and university students and faculty from throughout the nation visit ORNL annually. In addition to university interactions a significant number of precollege participants also visit the Laboratory for various "hands-on" research experiences. During the past few years, ORNL's involvement and commitment to science education and educational outreach has continued to expand, and now is developing a plan for a Science Education Center. This plan, encompassing all facets of the DOE-supported University-Laboratory Cooperative Program, provides an integrated focus for program development at all levels from precollege (K-12) students and teachers through students at the undergraduate, graduate, and postdoctoral levels and college and university faculty. The document reflects new emphases and initiatives from the DOE-sponsored Math/Science Education Action Conference convened in October 1989 by Secretary Watkins in Berkeley, California. It also incorporates and expands the Laboratory's strong continuing emphasis on increasing opportunities in science, engineering, and mathematics for women and minorities as well as people with disabilities.

Two new proposals were recently developed to strengthen and provide greater continuity in the Science Education Center activity at ORNL. One of these initiatives would increase the opportunities for informal science instruction and for science and engineering career counseling available to young women of junior and senior high age. The second would fill a "gap" that exists in opportunities for young people to maintain contact with DOE laboratories during a critical period of their development. This is during the first two years of undergraduate study. It would provide a continuing avenue for summer research participation for students who, as secondary students, have participated in the DOE High School Science Honors Workshop, Project SEED, or special honors study opportunities and who later as college juniors and seniors will be candidates for the Science and Engineering Research Semester, Undergraduate Research Training, and Professional Internship programs.

The Department of Energy recognizes the important role that minorities have in the future competitiveness of the United States. To this end, ORNL continues to expand program interactions with Minority Educational Institutions (MEIs). The main thrust of the program is to develop opportunities through internal and external interactions. Internally the program emphasizes communication of Energy Systems' MEI program objectives; externally, attempts are made to encourage MEI participation in research through workshops, established contact networks, mutual visitations, and professional assistance. Program activities and initiatives are underway with a number of institutions toward the overall goal of increasing the

number of scientists and engineers to help contribute to the manpower needs projected for the future.

The Memorandum of Understanding (MOU) with the University of Puerto Rico (UPR) established in FY 1988 continues to be a highlight toward increased interactions with Hispanic institutions. During FY 1989 this Memorandum provided a mechanism to support eight faculty and students to conduct research in various ORNL divisions. Also while subcontract activities are not funded through the Memorandum, subcontract activity through ORNL divisions also provides another mechanism for collaboration.

Also in FY 1989 as a part of the Historic Memorandum of Understanding and Intent, forming support for the DOE/OER Science and Technology Alliance, ORNL established a subcontract with North Carolina A&T State University (NCA&TSU). NCA&TSU, New Mexico Highlands University, and the Ana G. Mendez Educational Foundation along with ORNL, the Sandia and Los Alamos National Labs make up the Alliance whose intent is to develop a sustained program with the combined efforts of the participating institutions, to increase the representation of Blacks, American Indians and Hispanics in the scientific and engineering programs of the U.S. Department of Energy. ORNL established an initial subcontract with NCA&TSU in the amount of $372K for program administration, faculty development, student development, curricula development and other direct/indirect components as needed. While ORNL selected NCA&TSU as its prime contact, other activitgies will also be ongoing

with the other Alliance Educational Institutions, which included assistance to New Mexico Highlands University in the establishment of an R&D library in support of a planned program in technology. ORNL will donate books and magazines totalling over $17K. Also, ORNL is assisting the Ana G. Mendez Educational Foundation in the establishment of a five-year plan for the Computer Center. ORNL is providing a staff member to consult with the Mendez Foundation in the creation of the operating plan for the Center.

Another component of the Historic Science and Technology Alliance is a collaboration between the ORNL Metals and Ceramics Division and NCA&TSU in the development of a sustained program, with the combined efforts of the participating groups, in the materials engineering programs of NCA&TSU. Interaction between NCA&TSU and the Metals and Ceramics Division dates back several years through collaborative research subcontracts totalling more than $1.5M. These research projects are credited with aiding several minority students to obtain graduate degrees in mechanical engineering. This collaboration has also led to the inclusion of NCA&TSU as a partner along with the Metals and Ceramics Division, the University of Dayton, and the National Bureau of Standards in a DOE-sponsored research program on the study of ceramic technology for advanced heat engines.

Efforts have been successful during the period to extend university subcontracts beyond the traditional ORNL R&D base. These efforts include interactions with Winston-Salem State University in mass

communications, Coppin State College in contracts management, and North Carolina A&T State University in technical editing. This has proven particularly useful in support of institutions who don't have R&D capabilities to support DOE/ORNL missions. The total estimated dollars committed to Higher Education Institutions for the first half of FY 1990 is $8 million. The total commitments to MEIs for Energy Systems is $1 million which included $0.9M for ORNL.

ORNL is also a member of the National Consortium for Graduate Degrees for Minorities in Engineering (GEM). GEM is a consortium of universities and industry, both private and federally-formed, to help increase the pool of minorities receiving graduate degrees in engineering. GEM has a graduate rate of 86% of those who enroll in graduate school. ORNL will sponsor two graduate students in a semester research experience during FY 1990 and FY 1991.

By reaching teachers who are in daily contact with young students, it is possible to excite their interest in science at an early age. Students interest in science has been shown to drop during the latter portion of elementary school. Many are "turned off" by science at an even earlier age. Teachers must be a vital connection in any national program to increase the science and technology abilities of the United States.

The joint ORNL/Oak Ridge Associated Universities Project SMART (Science/Math Action for Revitalized Teaching) was initiated in partnership with administrators and teachers of the two

participating Tennessee school systems--Roane County and Chattanooga along with the State of Tennessee and private industry. The goal is to strengthen science and math teaching capabilities in these two selected systems that serve primarily economically disadvantaged and minority student populations, respectively. This will be done through joint planning by teacher teams at all levels within each system, by special opportunities for summer teacher research participation, and by providing access to Oak Ridge resources--both technical staff members and equipment--to assist in curriculum development and educational enrichment activities.

ORNL is serving as the lead Laboratory in a partnership with five other national laboratories, Los Alamos, Lawrence Livermore, Pacific Northwest, Argonne and Fermi National Accelerator Laboratory, and Oak Ridge Associated Universities in a multidisciplinary training program for teachers in grades K-8. Education and networking are key components of this initiative. The program is expected to serve over 400 teachers in a 3-year period involving "hands-on" activities that will impact conventional science curricula.

ORNL's base program in the precollege area, the Ecological and Physical Sciences Study Center, during the past fall semester passed the 20,000 mark in the number of students and adults served during its first five years of operation. Twenty-two (22) field and laboratory study units now are offered on a year-round basis.

ORNL is also participating with the local school system in an effort to help it recruit and retain quality minority teachers by providing the opportunity for summer employment. This relatively new program, Summer Teachers As Resources (STAR), differs from other teacher programs in that participants are drawn from all academic levels and disciplines.

ORNL during the 1989-90 academic year supported establishment and initial operation of the 130-acre environmental study center and wildlife sanctuary being developed by three area school systems--Oak Ridge, Clinton, and Anderson County--through the Clinch River Environmental Studies Organization (CRESO). Among the accomplishments have been: arrangements for (and installation of) an on-line NOAA Atmospheric Turbulence and Diffusion Laboratory meteorological reporting station at the site; assignment of a DOE Teacher Research Associate (DOE-TRAC) to work full-time during the Summer of 1990 on site survey activities and development of curriculum packages and resource kits for class use; and assistance in the organization and conduct of two teacher orientation workshops.

Special educational outreach activities centered on the new "Science-by-Mail" tutorial assistance program, the PALS (Partners at the Laboratory in Science) "adopt-a-school" network, and ORNL's Ecological and Physical Sciences Study Center were carried out as part of local efforts in support of National Engineers Week and this spring's planned National Science and Technology Week observance.

These activities linked the Laboratory's precollege program, local professional societies, and the East Tennessee Discovery Center. They involve both elementary and secondary students in area schools as well as adults. A special conference was held for undergraduate women on graduate study and career opportunities in science and engineering The keynote speaker for this conference was NASA Astronaut, Dr. Shannon Lucid, a biochemist. Dr. Lucid served as a mission specialist on the crew of the space shuttle Discovery in June 1985, and the Atlantis in October 1989.

Under the partnership agreement with the Oak Ridge Schools, the first three after-school "Science Seminars for Students" led by ORNL research staff members were offered.for junior high and high school students.

The Council on Research and Technology presented its ideas in its 1989 report Meeting the needs of a growing economy: the CORETECH agenda for the scientific and technical workforce. They recommend increasing federal financial support for both graduate and undergraduate education. In part, this involves grants to graduate students at a monetary level that can serve as a counter-incentive to substantial industry salaries. CORETECH also recommends that academic research facilities and instrumentation be modernized. I concur with both of these recommendations. From my experience at Oak Ridge National Laboratory, I am aware of the need to constantly upgrade the infrastructure of a facility. The phrase "penny wise and pound foolish" is certainly appropriate when you don't have the funds

to perform periodic maintenance and repair. Delays in updating facilities and equipment, in the long run, can only result in loss of competitiveness.

On an individual basis, each of our organizations must take the initiative in solving the shortfall in the kinds of skilled people we will need. Particular attention must be given to women and minorities. We must enhance our interactions with high schools, colleges and universities. In February 1990, President Bush, Secretary Watkins, and Secretary Cavazos visited The University of Tennessee at Knoxville. While he was there, it was announced that contributions of $1 million each will come from the state of Tennessee, Martin Marietta Corporation (the operating contractor of Oak Ridge National Laboratory for the Department of Energy), and the Department of Energy to establish a Summer School of the South for Science and Mathematics for precollege students. An Academy for Teachers of Science and Mathematics will also be established as part of this program. It will be an advanced training ground for 200 of the region's most outstanding teachers. This overall UT/ORNL initiative will also explore and implement alternate paths for certification of science and engineering professionals who wish to enter teaching as well as provide summer laboratory research experience for science education majors as part of their undergraduate and/or graduate-level academic preparation for teaching careers.

At last week's first meeting of the Secretary's Advisory Board, Secretary Watkins reiterated his commitment to education. The recently issued Interim Report - National Energy Strategy (report DOE/S-0006P) states that implementation of a National Energy Strategy requires two types of educated people. Professionals and technicians with excellent mathematical and scientific skills are needed to carry out energy-related research and technology development. Similarly, it is vital that a general public be scientifically and technically literate to make well-reasoned decisions about national energy options. The report identified obstacles and options in precollege education, teacher training, underrepresented groups, university research and instruction, and the scientific and technical literacy of the public.

Direct interactions with colleges and universities are only part of the answer. Apprenticeship programs and technical training programs for skilled workers should be strengthened. Internal training and education can be enhanced and opportunities for advanced degrees might be increased through liberalization of educational allowances.

For many years, educators have decried the lack of parental involvement in education. Our schools are working diligently to eliminate the "hands-off" attitude held by too many parents by seeking input and attempting to involve parents in more decision-making. In the same way, our organizations must create the proper environment in research and development and other technical

activities that will be "appropriate" for the changing work force. An analysis of management styles and organizational values must be included in any strategy for recruiting and retaining women and minorities. Cafeteria-style benefit plans may be appropriate to deliver the benefits to a socially and culturally diverse work force. Perhaps ORNL needs a day-care center, like Brookhaven National Laboratory and the Forrestal Building of the Department of Energy.

Science and technology are playing an increasing role in economic development, both in the United States and elsewhere in the world. Robert Solow of MIT, the 1987 Nobel Prize winner in economics, has studied the economic impact of science. In an interview, he has stated, "What I got interested in was the question of what makes a modern industrial economy grow...we owe it all to the growth of science and technology." This comment reflects the important role science and technology has in our economic well-being. Solow demonstrated that only a small portion of annual growth could be explained by increases in labor and capital. The key factor was always technology. If technology is the engine for increased economic growth, then education is certainly the fuel for the engine.