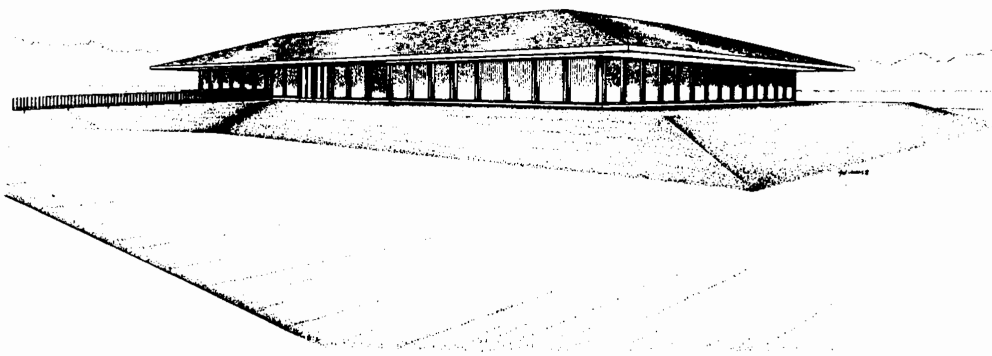
fermilab report

October
1989



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On the cover: *Conceptual drawing for the Fermilab Education Center. See the article beginning on page 16.*

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Update on Central and Data Acquisition Computing at Fermilab

by Jeffrey A. Appel

The Tevatron era and its associated computing is now nearly five years old. Al Brenner wrote the last review of computing to appear in these pages near the beginning of this era (*Fermilab Report* issue of December 1984). A lot has changed in computing in these five years! This has been a period of exponential growth, technological innovation, and great tension. All these are the result of dramatically expanding computing needs and the resultant competition with other Laboratory priorities in a period of limited resources. October 1st, 1989, marked the beginning of the era of the Computing Division at Fermilab. It's appropriate, therefore, to stop and review how far we have come during these first five years of the Tevatron era.

The changes and growth in computing at Fermilab are driven by the physics research requirements which must be satisfied in order to take advantage of the Tevatron potential. The Collider Detector at Fermilab (CDF) is the most well known of the new class of experiments. However, it is only one of seven experiments which already count between 1500 and 3000 modules provided by the electronics pool. In each of these experiments, the purchase price of the pool electronics is between 1.5 and 3 million dollars. The increased size and complexity of the detectors has also led to an increase in the amount of data recorded. In the last fixed-target run, over 35,000 nine-track tapes of data were recorded, over 10,000 by one experiment alone. In the Collider run, CDF recorded almost 6000 tapes of data. These numbers all dwarf those of five years ago. It is no wonder that other changes in computing have been necessary.

Central and Distributed Computing

During the last two years, the Computing Department has implemented a three-pronged approach (Fig. 1, page 2) to the tremendous computing challenges of the experimental physics program. The three prongs include (1) the user-friendly, tools-rich VMS environment of the central VAX clusters and work stations; (2) eight production microprocessor farms for the running of stable, data reconstruction codes; and (3) the general purpose, fast turn-around,

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The author, having just completed a term as Head of the Computing Department, has now returned to full-time research on the series of heavy-flavor physics experiments at the Tagged Photon Laboratory. He is spokesperson of E-769 and Co-Spokesperson of E-791.

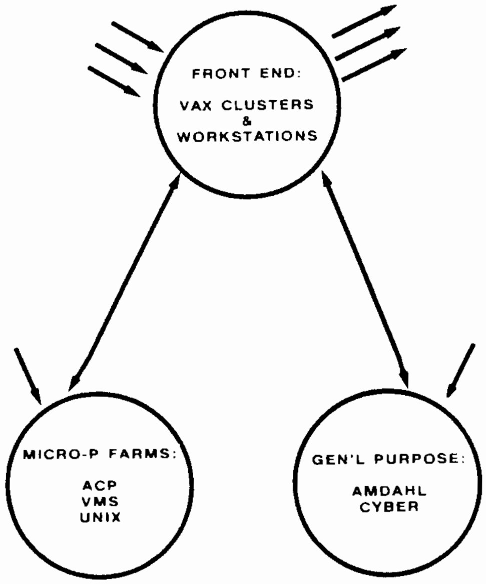


Fig. 1. Schematic representation of the three prongs of the Fermilab approach to scientific computing. Not fully shown are the interconnections and common file-serving components currently being implemented.

large-scale scientific computers, including the new Amdahl 5890 and outgoing CDC Cybers. Taken together, this triple platform provides over 1000 MIPS (millions of instructions per second) of computing power applied directly to physics research (Table I and Fig. 2). The increase in this power has been literally exponential, increasing a factor of two every six months during the most recent period (Figs. 3,4, page 4). Not only has the CPU power grown enormously, but the requisite numbers of disks and various types of tape drives and special input/output devices have grown, too. These must necessarily stay in balance with the CPU in order to make effective use of the tremendous raw computing power. Having the three platforms for computing has allowed these resources to be allocated in the most effective way, matched to the specific role of each of the platforms.

The microprocessor farms have been the major contributor to the growth of raw CPU power. During this period, the original Advanced Computer Program (ACP) system was turned into a computing center object. There are currently six ACP production systems in use. Seven different experiments have made use of these production systems, with as many as five experiments' programs operating at one time. This has required development systems, management software, and interfacing to the operators who mount the magnetic tapes of raw data. In addition, a great number of tools (e.g., librarian and linker routines) were written by Computing Department personnel. A beginning has been made on extending these capabilities to UNIX-based microprocessor farms in anticipation of using the newly available RISC (Reduced Instruction Set Computer) technology. One such farm, a commercially available system from Silicon Graphics, is in use by E-769 to help reconstruct the 10,000 nine-track tapes of raw data collected in the last fixed-target run.

The bulk of the new computing hardware and software resources were provided as part of the Central Computing Upgrade Project, first funded in FY86. However,

Table I. Scientific Computing at Fermilab
(Over 1000 MIPS of computing available)

A. LOAD:
700 tape mounts/day
3400 interactive terminal sessions/day
2000 batch jobs processed/day
500 users logged on in afternoon

B. CYBER COMPLEX:
approx. 30 MIPS (1-dual CPU 875)
36 gigabytes disk
20 tape drives

C. VAX COMPLEX:
approx. 65 MIPS (2 clusters)
65 gigabytes disk
20 tape drives

D. WORKSTATIONS AND LOCAL AREA VAX CLUSTERS:
Over 120 nodes, in 14 LAVC's
approx. 125 MIPS total
Additional 140 nodes in 12 LAVC's for mostly controls and engineering roles

E. MICROPROCESSOR FARM SYSTEMS:
6 ACP production systems
440 nodes total, approx. 312 MIPS
5 ACP development systems
46 nodes total, approx. 30 MIPS
CDF microVAX farm
22 nodes, approx. 60 MIPS
2 UNIX farms (physics + E-769)
approx. 320 MIPS

F. AMDAHL SYSTEM:
approx. 120 MIPS (5890/600E)
90 gigabytes disk
24 tape drives

G. Connected via hyperchannel, Interlink /DECnet intercomputer networks

H. CURRENT TAPE LIBRARY:
over 180,000 reels

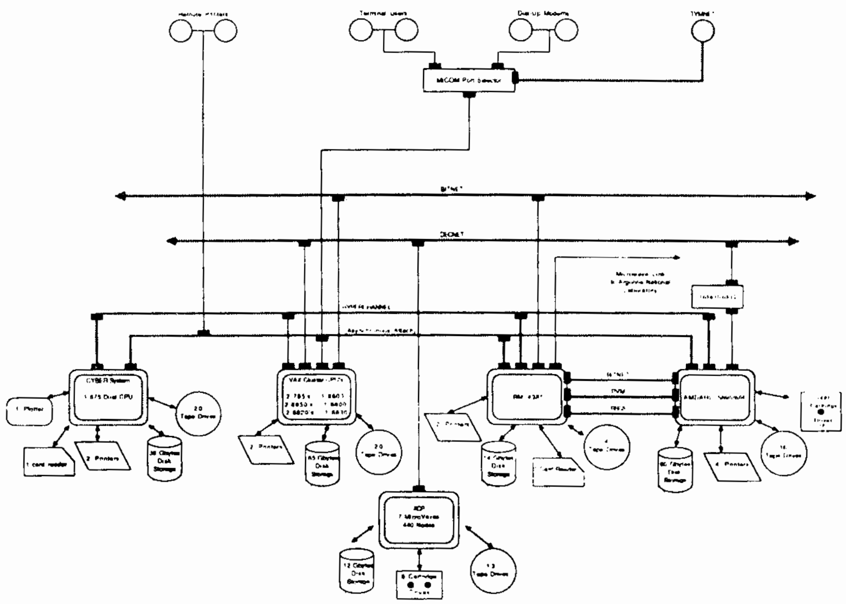


Fig. 2. Detailed schematic drawing of the computers in the Central Computing Facility at Fermilab.

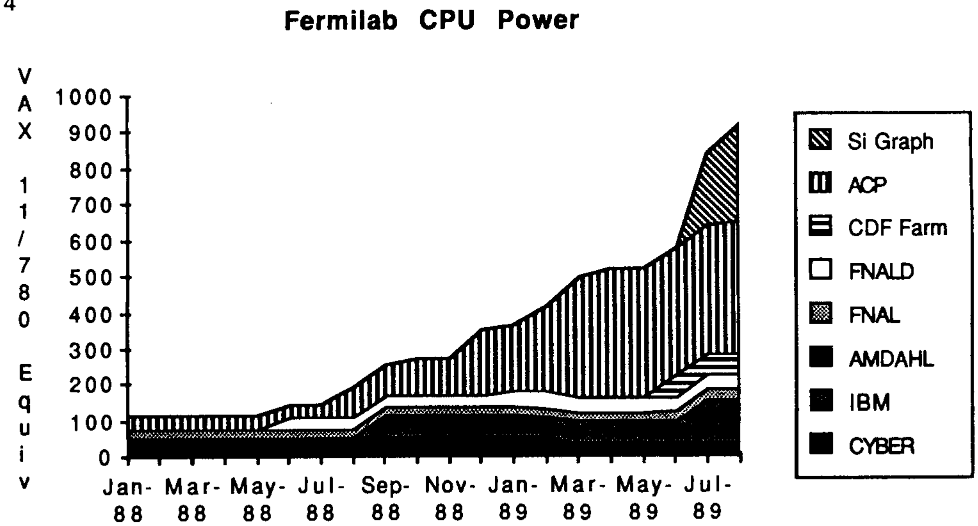


Fig. 3. Growth of the Fermilab CPU power over the last year and a half, showing the growth by system type.

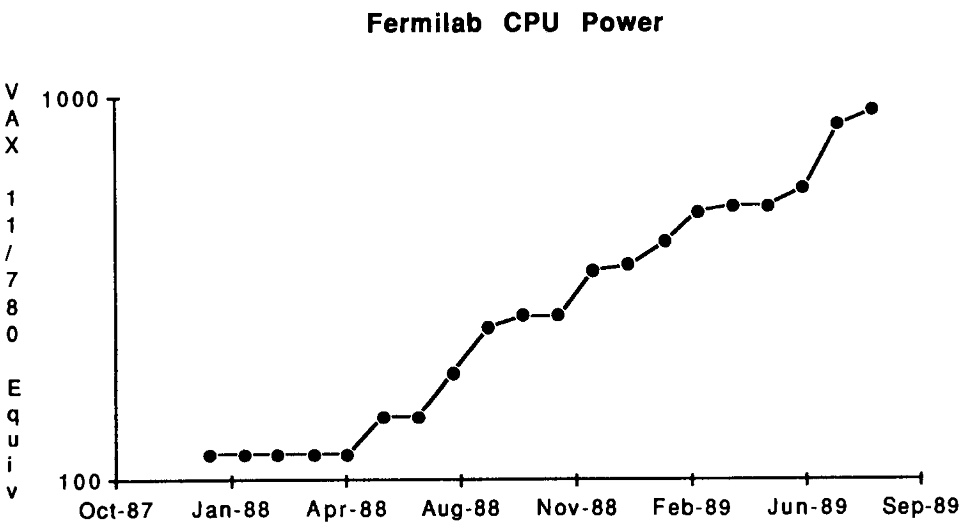
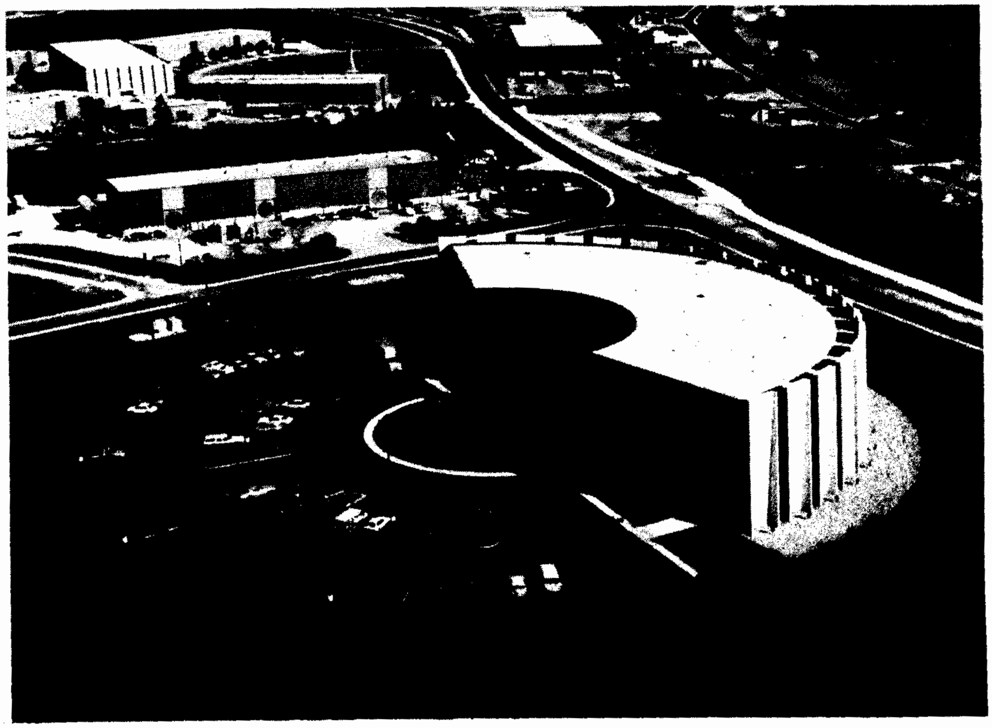


Fig. 4. Data from Fig. 3, plotted on a semi-logarithmic scale, showing the exponential growth of CPU power since May 1988.

a significant fraction of the resources have also come from the regular Computing Department equipment funds and from strong user groups. These user groups have wanted to increase the resources available to them at, and supported by, the Laboratory. In particular, the Japanese collaboration on CDF has added to the VAX cluster, many CDF institutions have provided nodes for a microVAX farm, and the INFN (Italy) has provided the base for one of the ACP farms.

In addition to its support of scientific computing at Fermilab, the Computing Department has continued to provide hardware and operating system support to the Business Section. This support of administrative needs is currently based on an IBM 4381-class machine. This administrative system has been upgraded several times in the last five years in support of the increased load of business activity at the Laboratory, the wider availability of data and reporting, and the development of wide-spread interactive data processing in this area.

In order to house all of the equipment associated with this tremendous growth, we have added the architecturally elegant new Feynman Computing Center (dedicated December 2, 1988, and shown in the photograph below) and additional operators and supervisors.



(Fermilab photograph 88-1033-5)

Aerial view of the Feynman Computing Center at Fermilab.

While the major part of our central computing resources are located in the Feynman Center, an increasing amount of computing resource is distributed elsewhere on the site. Not only is the hard-copy output from the computer available at many sites with traditional and laser printers, but the growth of local-area VAX clusters and workstations attached to the Center has been enormous (Fig. 5, page 6). In order to help support these local-area VAX clusters, the Computing Department has initiated an extensive program of help for the planning, installation, system management, maintenance, software distribution, and consulting with end users of these systems.

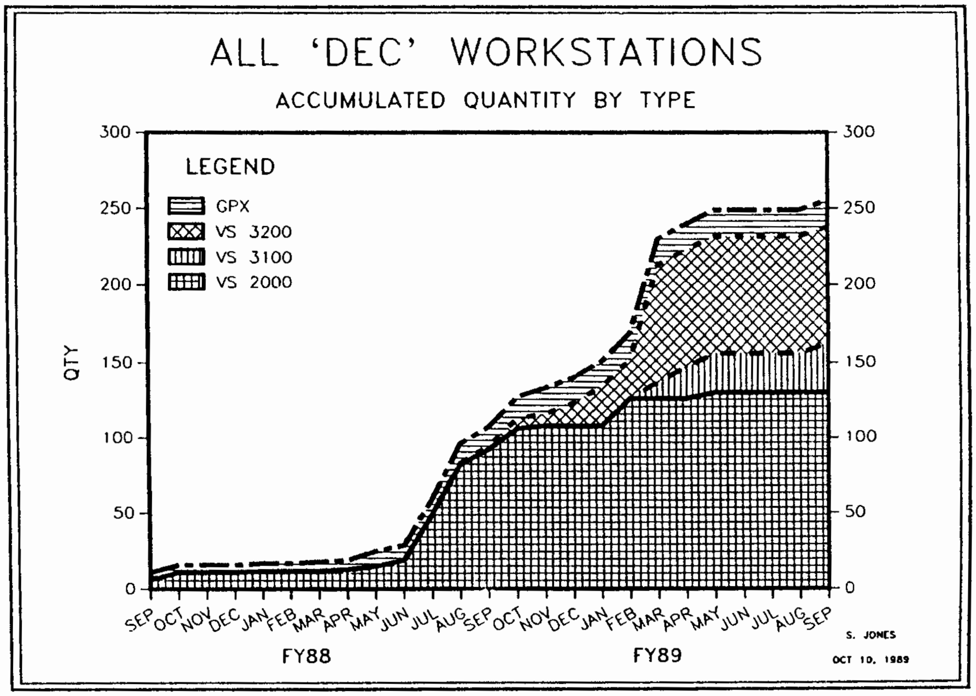


Fig. 5. Delivery dates of the most common workstations at Fermilab. The graph documents a very rapid growth in DEC workstations in FY 1988.

One of the less visible parts of distributed computing at Fermilab is that done by the engineering communities. The mechanical engineering community has coalesced around a common and unified approach, well positioned for centralized support. This has resulted in one of the major growth areas for the Computing Department. The support includes assistance with hardware and software selection, maintenance, and end-user consulting. When considering the use of workstations networked to data bases, file servers, and the central facility, the engineering computing is one of the most architecturally complex environments at the Laboratory. Yet it provides one of the most transparent environments to the end user.

In a sense, the most widely distributed computing organized by the Computing Department has been in support of several summer studies, most recently the Breckenridge Workshop on Physics at Fermilab in the 1990's. In conjunction with loans from several commercial vendors, the Department supplied a mini-Fermilab-computing environment, including access to the Fermilab site and wider HEPnet community. This was arranged with a minimum of funding, but provided a new high in capability for a remote high-energy physics location, the beautiful Rocky Mountains of Colorado.

Another innovation of this period has been the appearance of video technology for recording on 8-mm cassettes. The Department has taken a leadership role in developing applications of this technology. That role has included testing of the drives and various interfaces to computers, problem resolution in conjunction with the equipment vendors, and implementation of production copying facilities. At this point, video media are in use as input to microprocessor farm systems and as a distribution media for data summary information. Recently, the Department has been actively developing options for primary data recording from VME and VAXes at experiments and the capability of using these media on the VAX Cluster and Amdahl systems. Many problems remain to be resolved in this last area as the use of this capability is extended beyond the original disk backup function for which it was marketed. By the end of the last Collider run, CDF had started recording raw data on video media. It is anticipated that several experiments in the next fixed-target run will make use of the media as well. One experiment, E-769, has taken an approach which would have been unthinkable before the advent of this kind of cost effective data recording. Finally, we have just seen the last seven-track tape drives removed from the computing center. Can the last punched card be far behind?

Networking and Communications

The three-pronged approach to computing problems can only reach its full potential with the existence of a high throughput and transparent interconnection among the components. These are provided in the Fermilab system by DECnet and TCP/IP connections between the front ends and the microprocessor farms, and by Interlink hardware and software between the front end and the Amdahl. The Interlink product makes the Amdahl VM system appear as a DECnet node. Several experiments are using this feature in a fundamental way as they create their computing environment. Hyperchannel capability is also available among the larger systems.

Beyond the interconnected computers is a vast system allowing user access from next door and around the world. Fermilab has on site a segmented, but site-wide, Ethernet utilizing over 30 bridges. It's aggregate length is over 12 kilometers. One part of it is the beginning of a much higher bandwidth fiber optic capability. Users can connect to any of the major computers at Fermilab and to over 500 other devices on site.

Externally, the community is almost universally connected by DECnet and BITnet. These comprise what we have colloquially called HEPnet; that is, the network for high-energy physics. HEPnet has become one of the world's largest networks. Fermilab is an integral part of this. Fermilab maintains connections to Brazil, Canada, Europe (CERN in Switzerland and the INFN in Bologna, Italy), and via Lawrence Berkeley Laboratory to KEK in Japan. Much of this HEPnet backbone has been enhanced to 56 kilobaud and upgrades to T1 (1.544 Mbaud) will be in place this fall. All together, Fermilab has 39 direct DECnet links to universities and other laboratories, including the backbone. HEPnet now reaches 1500 systems in the U.S. alone. The Laboratory is also connected to the NSFnet, allowing the National Science Foundation-funded users a growing connectivity with increasing bandwidth. The Laboratory's role in networking has been recognized as a leading one, and the Department of Energy recently asked Fermilab to take on the overall management responsibility for HEPnet.

Data Acquisition Computing and Electronics

The move away from the old PDP-11-based Bison data acquisition systems began with the advent of the VAX-Online software environment. This widely used combination of standardized hardware and software incorporates the first distributed data acquisition system; multiple computers, each focusing on a part of the readout or monitoring of an experiment and interconnected for uniform system control and user interfacing. Like its predecessor, VAX-Online focuses on a single computer architecture. However, data acquisition needs have also grown rapidly and the VAX-Online system is evolving into a more universal and much more powerful PAN-DA system. Some claim the new name is meant to describe a sense of soft and fuzzy well being, but the name is also intended to convey the universality of the new approach (PAN DA). This approach opens the architecture to VME- and FASTBUS-based processors, as well as the more traditional VAX computers. It incorporates multiple levels of parallelism in readout and data collection. It anticipates UNIX as well as supporting VMS computers and the pSOS kernel operating systems run on Motorola 68K-series computers. A first implementation of the full PAN-DA system is scheduled for use in one experiment of the next fixed-target run. Many other experiments will use various components of the PAN-DA tools kit in support of their online system. Several experiments anticipate recording raw data on the new 8 mm video technology devices.

The wide variety of computer equipment in both the data acquisition and central computing systems have expanded the complexity of the maintenance job tremendously. While the largest computers are maintained by commercial vendors, the Fermilab maintenance groups have been enlarged and reorganized to handle everything from the more traditional mini-computer and its peripherals to distributed computer systems based in VME. The maintenance also extends to the hundreds of microprocessor farm nodes and system responsibility for the ACP farms in the Computing Center. Finally, the Department maintains 13 varieties of IBM and compatible PC's and Apple Macintosh computers, totaling over 1100 units! Over 540 repairs and upgrades were performed in the last year alone.

Two years ago microVAX 2000s and 3200s were only plans and subjects of interesting rumors. Today there are 130 2000s and nearly 100 3000-class workstations at the Laboratory. Exabyte 8-mm tape drives and Wren V disks were unknown two years ago. Today Fermilab provides repair service on about 150 of each of them. The approach to troubleshooting has also changed dramatically. Formerly, PDP-11 problems were investigated by chasing bits with octal switch panels. Now computers in the computers, using firmware-based tools, allow analysis of most problems from a terminal. Thirty percent of the Lab's PDP-11's have been retired. Versatec printers and 800-bpi tape drives are finally history. Where removable media hard disks were the primary program loading media at experiments two years ago, they have been largely replaced by electronic network distribution of software.

Front-end standardized electronics support has also grown tremendously to satisfy the needs of the Tevatron-era experiments. PREP (the Physics Research Equipment Pool) has grown to over 34,100 units with an almost $28 million purchase price, half of this in the last five years. The inclusion of processors and sophisticated controllers in many of the modern systems has added to the complexity of the distribution and maintenance jobs associated with this pool of modules. Continuous training and the use of more-powerful computerized test stands and a foray into the world of artificial intelligence have marked the efforts to keep up. The Department has added expert system technology in a prototype test stand for one of the more complicated FASTBUS modules, the Segment Interconnect.

Maintenance of the equipment in PREP is only one part of the repair effort provided by the Department. Over 53,000 instruments of 2500 different types are beneficiaries of this support. In the most recent year, over 7500 repairs were completed, with only 1-1/4 percent of these requiring return to the original manufacturer.

Personnel and Organization

It was evident rather early that all of these increasing technologies and support requirements would demand a larger staff and an organization that allowed people to focus their attention on the most crucial problems. Figure 6 shows the growth in each of the major parts of the Computing Department over the last five years. Overall, the Department has grown over 50 percent, and just before the reorganization into the Computing Division, it was recognized that the ongoing parts associated with the old Computing Department should grow by an additional 25 to 30 people minimum.

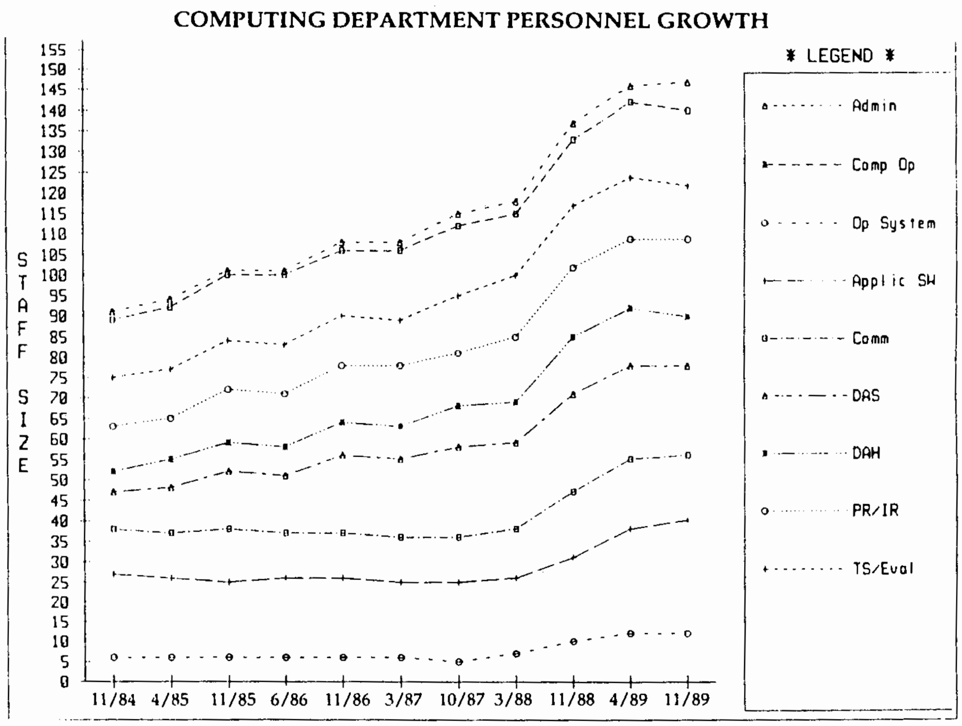


***Fig. 6.** Five-year growth of the size of the Computing Department by major activity area.*

The people in the Computing Department are only one of the human elements in the computing story. The end users are an equally crucial element. With this in mind, an aggressive program of consulting, training, and seminars has been an important part of the Department. The Department now publishes three newsletters and has organized a tutorial, seminar, or workshop at an average rate of one per week. Some of these training sessions have lasted as long as a week as well. These efforts are aimed at a wide audience, from the traditionally supported physics community to newer users from the office automation, engineering, and other communities. In addition, for the most rapidly changing areas, series of regular meetings with the most affected users have been set up. These include the "Early Bird" program for first use of the Amdahl system, meetings with engineering groups, and the newly instituted meeting to help users migrate off the Cyber systems and onto other available computing platforms at the Laboratory.

The number, size, and complexity of systems supported by the Computing Department has grown vastly faster than the number of people in the Department. Forging ahead has been possible only by the dedicated efforts and talents of the people who are so poorly represented by the statistics presented here. Based on the enthusiasm of these people and the demonstrated progress of the last five years, one can say that computing at Fermilab is poised for even greater success, success limited mostly by available funding and not by technological opportunity or talent.

"Workshop on Physics at Fermilab in the 1990's"

by Mark Bodnarczuk

High-energy physics workshops are designed to be highly focused ''brainstorming'' sessions where new ideas for ground-breaking physics can emerge. Consequently, they are often held in settings that are conducive to creativity. Such was the case with the ''Workshop on Physics at Fermilab in the 1990's'' recently held in the Rocky Mountains at Breckenridge, Colorado. The workshop was co-sponsored by the Fermilab Users Executive Committee and Fermilab.

When the majority of high-energy physics experiments moved from using incident beams that were ''naturally'' produced by cosmic rays, to beams created by high-energy particle accelerators, a symbiotic relationship was formed between the available accelerator parameters and the experiments that could be performed at the end of external fixed-target beamlines or in interaction regions within the accelerator itself. When designing a new accelerator, the physics community must carefully interweave state-of-the-art accelerator technology, existing experimental data, theoretical predictions, cutting-edge detector techniques, and ever-increasing demands for computing power into a tailored tapestry that will define the topography of the subsequent physics options. Consequently, the design decisions made early-on in the process of giving birth to a new machine are of fundamental importance to the direction of a laboratory like Fermilab.

The workshop was one of the most important in the 20-year history of Fermilab. Since 1985, the future of Fermilab has been intimately tied to the possibility of siting of the Superconducting Super Collider (SSC) in Illinois. With the recent siting of the SSC in Texas, Fermilab must now hammer out a unique identity in support of, but ultimately separate from, the new SSC Laboratory. This scenario created a high level of expectation at the workshop and a boundary-pushing intensity that was eloquently reflected in the quote from Einstein which hung on the wall of the workshop computing room: ''Great spirits have always encountered violent opposition from the mediocre minds.'' As many workshop participants labored long into the night in the computing room, there was often a waiting line for access to one of the 40 terminals which were part of a local VAX cluster totaling 27 MIPS of computing power.

In the workshop, participants addressed the physics that could be carried out over the next decade given the fact that Fermilab's Tevatron (at 2 TeV in the center of mass) will remain the world's highest energy accelerator well into the next decade. With the contemplated upgrade in luminosity, data samples of 100 inverse picobarns (and possibly 1000 inverse picobarns) will become a reality. There will be two large collider detectors, feeding on that unique data stream. With the goal of exploring the mass region beyond the W and Z and below that reached by the SSC in the collider mode, Fermilab has begun to define this new identity by proposing a three-phase upgrade of which the first phase (the Linac Upgrade) is already under way. In mid-May, interested physicists came together at Fermilab to study the second phase of the upgrade, called the Main Injector, in a workshop on physics at the Main Injector. The Main Injector will be located in a sub-surface enclosure separate from the Main Ring tunnel and is a 120-GeV, large-aperture, rapid-cycling proton synchrotron designed specifically to address the limitations inherent in the Main Ring when using it for Collider operations. The combination of the Linac Upgrade and the Main Injector will provide a factor of two more flux than is currently available, and most importantly, a luminosity increase to 5 x 10^{31} cm^{-2} sec^{-1} for the Collider. Increased luminosity is crucially important because when multiplied by the cross section for a given reaction, it gives the average number of events per second for that reaction. The increased intensity of the Main Injector will allow higher mass regions to be explored by Fermilab Collider experiments.

Another important feature of the Main Injector is the ability to extract 120-GeV protons to the fixed-target experimental areas simultaneously with Collider operations. This means that Fermilab will now have particle beams available year round. The Main Injector Workshop focused on the types of fixed-target physics that could be done with this higher intensity beam, including high-sensitivity K_L^0 decays, high-flux neutrino and pbar initiated processes, and detector and beamline design requirements. The Breckenridge Workshop was the next logical step because it more fully defined the future fixed-target and colliding-beams physics options that will be available with the Main Injector. Another topic that received some lively discussion was a "Dedicated Collider" proposal using 6.6-8.6 tesla superconducting magnets, yielding a center-of-mass energy of 6-8 TeV, depending on the magnetic field strength. This machine, called the LINCOLN (Large Independent Collider Nearby) would be a possible step beyond the Main Injector.

Emerging from the working group summaries was a multidimensional framework within which the upgraded accelerator and physics options at Fermilab could be defined during the next decade and beyond. Of major importance was clearly identifying the most pressing theoretical issues in the 1990s, the tell-tale signatures of those effects, as well as the methods for unambiguously detecting these low-cross-section events and extracting them from a background of stable but less interesting physics. In his workshop summary, Jonathan Rosner (Chicago) described an exciting menu of physics topics that emerged from workshop discussions, including studies on W, Z radiative corrections, new electroweak tests, precise measurements of $\sin^2\theta_W$, quark mixing parameters, and CP violation measurements.

The summary sessions began with Mitchell Golden (Fermilab) and Keith Ellis (Fermilab) laying out the theoretical geography of physics with the Main Injector and beyond. With the theoretical issues out on the table, discussions then moved to defining the myriad physics options made possible with a higher intensity and luminosity upgraded machine. There were some common questions which provided a focus for all the reports that were given. For example, what types of physics can be done only with the Main Injector? How can experiments accumulate large data samples with good statistics given the allowable parameters? What are the significant background problems and how can these be addressed? Are there other ways to measure an effect which give better resolution using a more cost effective detector design? Can more than one measurement be made in one detector? Can more than one experiment use the same detector to obtain different measurements? One of the main goals of the working groups studying future physics options was to take questions like these and look deeply into the realities of experimental design, given the parameters of the proposed machine.

One topic of major interest was future charm and B-physics experiments in both the fixed-target and Collider modes. Joel Butler (Fermilab) showed that, currently, fixed-target experiments dominate measurements of the lifetimes of charmed particles and are quite competitive with e^+e^- colliders for both rare decay modes and heavier charm states like the D**. His conclusion was that charm physics is still a viable route and that Fermilab experiments are quite competitive.

In the fixed-target beauty sector, the first high-sensitivity B experiments will begin taking data in the upcoming run. A key to future fixed-target B-physics at Fermilab involves the low signal-to-background ratio obtainable compared to e^+e^- and even high-energy hadron colliders. Because the available fixed-target "luminosity" is so high (1×10^{34}), the potentially large yields are tantalizing even though they are difficult to pull out of such high backgrounds. The answer that emerged is that continued and increased work on detector technology, triggering strategies, data acquisition speed and capacity, and data analysis capability is necessary. Interaction rates of order 100 MHz are expected, with a goal of examining 1 million tagged beauty events in an open geometry, yielding 10,000 fully reconstructed B's.

In his summary talk, Carl Haber (LBL) discussed two approaches to B-physics in the Collider mode. The first approach uses the existing Collider Detector at Fermilab and D0 detectors ("high-P_T" experiments) which can study B's produced on the tail of the B spectrum. The second approach is a proposed Bottom Collider Detector (BCD), a large-acceptance spectrometer designed to take advantage of the total B cross section for a broad study of B-physics, especially CP violation in the B system.

The working group summary on symmetry violations and rare decays was given by Bruce Winstein (Chicago) who summarized papers given at the workshop on rare K decays (Y.W. Wah- Chicago), ε'/ε Fermilab E-731 (B. Hsuing), $K_L^0 \rightarrow \mu e$ BNL E-845 (H. Greenlee), $K_L^0 \rightarrow \mu e$ KEK E-137 (T. Skinkaura) and CP at LEAR (J. Fry). An important point in this area centered on detector issues and the need for more development work in the areas of sophisticated Transition Radiation Detectors, EM Calorimetry (BaF2, CsI, PbF2 fibers), and high-rate wire chambers. Positive solutions to envisioned problems in future CP violation experiments were enhanced by the collaborative work done at the workshop between the CP violation working group and the detector working group.

There was much discussion about the place of fixed-target experiments at Fermilab in the light of the demand for SSC test beams and in an increasingly Collider-oriented environment. The sentiment of many workshop participants was that fewer, more carefully chosen fixed-target experiments should be approved and run, with the full resources of the fixed-target program being brought to bear on them. This approach would decrease the total time needed to bring an experiment from the proposal stage to the completion of data analysis.

In closing the workshop, Fermilab's Director, John Peoples, re-affirmed the wide variety of physics possibilities available and Fermilab's desire to carry out a finely focused, intensive assault on the most promising physics topics. He also re-affirmed the need for the next logical step in this process, the Main Injector.

The proceedings of the workshop will be published by World Scientific later this year.

The Science Education Center at Fermilab

Science education took center stage at Fermilab on Saturday, October 7, 1989. The new Science Education Center at Fermilab, a collaborative effort between the Laboratory and the education community, was launched with a symposium on "Science Education for the Entire Nation" in the Ramsey Auditorium, and a groundbreaking ceremony at the Center's future site. Building upon the strong foundation laid by the Laboratory's successful science education programs sponsored primarily by the Friends of Fermilab, the Center will offer a wide range of programs for students from kindergarten through high school. The Center, a Fermilab project supported by the Department of Energy's (DOE) Office of Energy Research, is the fruition of years of effort on the part of Stanka Jovanovic, Fermilab's Education Office Manager, and Marge Bardeen, Fermilab's Education Office Program Manager.

(Fermilab photograph 89-1120-24)

Secretary of Energy James D. Watkins at the podium in Ramsey Auditorium on the occasion of the symposium on "Science Education for the Entire Nation." Seated to the Secretary's left are John Peoples, Leon M. Lederman, Lourdes Monteagudo, Howard S. Goldberg, Roosevelt D. Burnett, and William E. West, all of whom spoke at the symposium.

Moderated by Fermilab Director John Peoples, the symposium featured an address by U.S. Deparment of Energy Secretary James D. Watkins; Leon M. Lederman, Fermilab Director Emeritus and Professor, University of Chicago, speaking on "Scientists and Science Education - The National View"; William E. West, President-Elect, Illinois Science Teachers Association and Science and Technology

Chair, Naperville Central High School, addressing the issue of "Science Education: The Fermilab Experience"; Lourdes Monteagudo, Deputy Mayor for Education, City of Chicago, on "Science Education: A View from the City"; Howard S. Goldberg, Professor, University of Illinois at Chicago, on "Integrating Math and Science in the Elementary School: Problems and Prospects"; and Roosevelt D. Burnett, Principal, Chicago Vocational High School, on "High School Science Education in the City: Needs and Prospects."

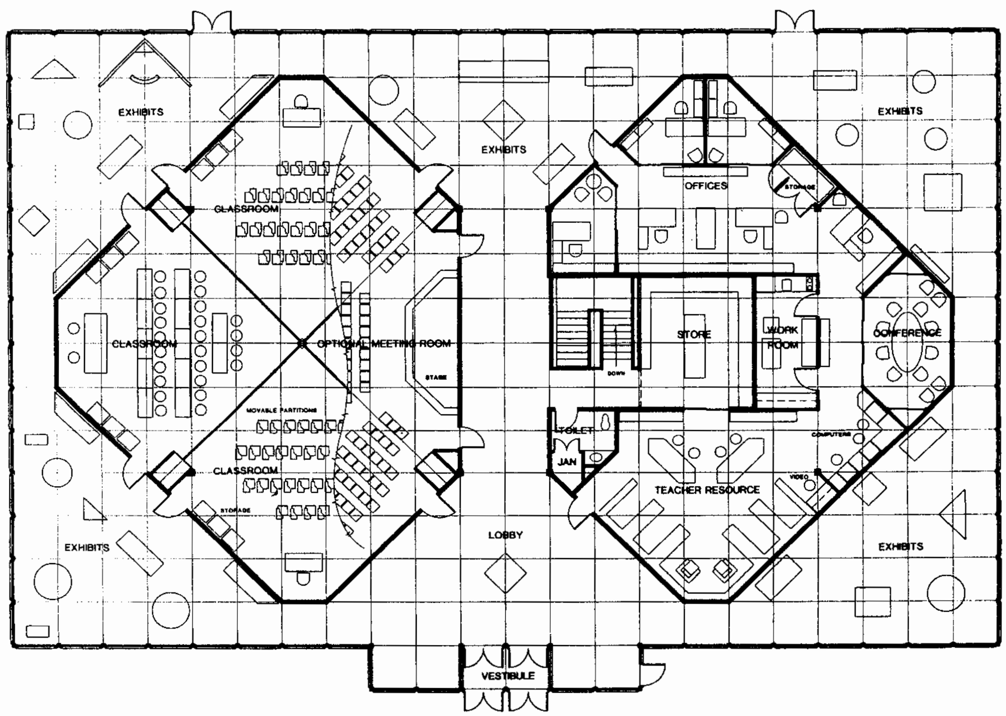
Secretary Watkins delivered the keynote speech at the ground-breaking ceremony, followed by Congressman Dennis Hastert (R.-Ill.). Then it was time for a series of luminaries to turn the ceremonial shovels of earth. Included were Secretary Watkins; Hilary Rauch, Manager, DOE Chicago Operations Office; Fermilab Director Emeritus Robert R. Wilson; John Peoples; Leon Lederman; Stanka Jovanovic and Marjorie Bardeen; and students Al'ishandrah Braneon, Samuel Byrd, Eric Dahl, Choudet Jhou, Clarissa Ramos, Clare Sammells, Aaron Smith, Laurent Stadler, and Jason Stevenson.

(Fermilab photograph 89-1124-20)

(L. to r.) Secretary Watkins, keynote speaker at the Science Education Center groundbreaking, John Peoples, Fermilab Director Emeritus Robert R. Wilson, and Leon Lederman do the ceremonial honors in front of more than 200 onlookers at the groundbreaking.

The building (shown in the conceptual drawing on the cover of this issue of *Fermilab Report*) is reminiscent of Frank Lloyd Wright's Prairie School of architecture. That aesthetic was foremost in Fermilab Director Emeritus Robert R. Wilson's design philosophy for the building's exterior. Wilson envisioned a low building, capped by a roof with a pronounced overhang, and set upon a plinth, or berm, to emphasize the structure. In the architect's drawings and models, the building seems to float above the ground while, at the same time, appearing to be firmly placed in its surroundings.

Wilson's concept was brought to the design stage by Fermilab's Construction Engineering Services group. The plans call for an 84 ft by 132 ft one-story structure with a partial basement. On one side of the building (see floor plan, below) are offices, a teacher resource area, a conference room, a work room, and a store where science education-related learning tools will be sold. The other side of the building is divided into four classrooms. The walls dividing the classrooms are movable partitions, allowing for conversion of the space into larger rooms or into one meeting room that can accommodate groups of up to 200 people. The two interior halves of the building are, in effect, islands surrounded by open space to be occupied by hands-on exhibits.



Proposed floor plan for the Science Education Center at Fermilab.

The building's roof will feature a concavity lined with windows. Daylight will pour through the windows, creating natural indirect lighting for the Center's interior.

Ed Crumpley, Jr., one of the Construction Engineering Services staff who worked on the design of the Center, found the project ''exciting for an architect. For one thing, this is a finished space, something we don't usually get a chance to work on here at Fermilab, where much of our work involves empty buildings and experimental halls that will be filled with experimental apparatus.

''The enthusiasm that Marge Bardeen and Stanka Jovanovic brought to this project was truly infectious. They looked at many similar buildings during their travels, and came into the project with so many fine ideas for utilizing the space.''

The Center's design will undergo some fine tuning just prior to the construction start. Construction Engineering Services will be refining the plan, seeking out additional economies in construction and materials choices. - *Richard Fenner*

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Three main program areas have been implemented by the Friends of Fermilab for the Science Education Center at Fermilab. Local school districts will be invited to become members of a program advisory group, which will play a role in determining the Center's programs.

The first of these programs, the Teachers' Resource Center (TRC), will ''generate a stimulating atmosphere for science education by providing materials and services to schools.'' Science educators and school librarians in Illinois' Kane and DuPage counties will form an education network with the TRC serving as a clearinghouse for ideas, materials, and resources. Teachers will have access to space in the Center where they can build classroom demonstrations and assemble science kits from supplies provided at cost. A pool of scientists, teachers, and others with science expertise will be accessible via hotline.

The formal-education programs include: the Department of Energy (DOE) High School Honors Research Program, which brings students to Fermilab from each state, Puerto Rico, the District of Columbia, and six Economic Summit countries for a two-week program of seminars with Fermilab scientists as well as to work on a Fermilab experiment; the DOE Teacher Research Associates Program, an opportunity for some 20 teachers selected from both regional and national schools to work with a scientist or engineer on a research project during the summer at Fermilab; and the Summer Institute for Science and Mathematics Teachers at Fermilab, which enables 45 high school biology, chemistry, and physics teachers, and 15 mathematics teachers, to spend four weeks at the Laboratory attending lectures by research scientists and mathematicians, as well as computer, laboratory, and mathematics sessions with master teachers. Other programs include: Chemistry West and Physics West, teacher networks that allow high school teachers to share skills, teaching strategies, and materials; and *Topics in Modern Physics*, a teacher resource manual containing curriculum materials.

Finally, the K-8 Programs include Beauty and Charm at Fermilab, a hands-on curriculum unit that has to date trained over 90 teachers and brought over 5000 students to tour Fermilab, and the Wonders and Magic of Science, a science show for outstanding area science students, grades three to six.

A variety of classroom materials, created in conjunction with precollege education programs, are made available free of charge or at cost to teachers. Included are Beauty and Charm kits, *Topics in Modern Physics* resource books, videotapes, and posters. Some of these materials have been translated into Spanish for Latin American scientists and teachers.

The Center's informal hands-on science programs, designed to encourage creative investigation and thoughtful questions, will include interactive exhibits, environmental exhibits, audio-visual materials, computers, and a science playground as part of Center's science education offerings.

The interactive exhibits will cover five areas: accelerators, detectors, scattering experiments, the structure of matter, and the structure of the Universe. ''Discovery rooms'' will include table-top interactive displays in many areas of science and mathematics related to the school curriculum.

Taken together, these programs form a solid foundation for the Science Education Center's future.

Lab Notes

On November 13, 1989, Universities Research Association, Inc. (URA), which operates Fermilab for the U.S. Department of Energy, announced that the URA Board of Trustees had appointed John S. Toll, Chancellor Emeritus of the University of Maryland, as URA's next president, effective December 1, 1989. Toll succeeds retiring President Edward A. Knapp, who is returning to Los Alamos National Laboratory to resume research in physics.

The announcement was made by John Marburger, Chairman of the URA Board of Trustees, at the November 13 meeting of the Board in Dallas. Marburger, who is President of the State University of New York at Stony Brook, said of Toll's appointment, ''URA is remarkably fortunate that Dr. John Toll has agreed to serve as URA President. He is one of the outstanding university administrators in this country and a highly respected physicist with great personal understanding of URA's mission. As Johnny Toll's successor at Stony Brook, I had a special appreciation for the caliber of the contributions he made to the university, and the Trustees' unanimous vote reflects our confidence in his leadership. He has had a career of exceptional achievement, which will now be turned to the benefit of URA, Fermilab, and the SSC. We are very pleased to welcome him to this new challenge.''

Fermilab Director John Peoples said of the announcement, ''Fermilab welcomes Dr. John Toll as the next President of URA. He will bring his energy and many years of experience to URA at the crucial turn in the history of Fermilab.''

John Toll received his Ph.D. in Physics from Princeton University. In 1953, he became Chairman of the University of Maryland Department of Physics and Astronomy prior to being named President of SUNY/Stony Brook in 1965. In 1978, he returned as President to the University of Maryland and was later named the first Chancellor of the newly reorganized 11-campus University of Maryland System. He continues to serve as Professor of Physics and Chancellor Emeritus at the University of Maryland.

John Toll has been actively involved in federal science advisory activities throughout his career, including terms as Chairman of the Federation of American Scientists and Chairman of panels for the National Science Foundation, the National Aeronautics and Space Administration, Princeton's Plasma Physics Laboratory, and the Congressional Office of Technology Assessment.

*("**Lab Notes**" continued)*

Norman F. Ramsey of Harvard University, first President of Universities Research Association, Inc., (URA) has been awarded the 1989 Nobel Prize for Physics for his role in the invention of the atomic clock. Ramsey shares the prize with Hans Dehmelt of the University of Washington and Wolfgang Paul of the University of Bonn, West Germany, both of whom were also honored for their work on precise atomic measurements.

Ramsey was a member of the Scientific Advisory Committee that first recommended the construction of the national laboratory that became Fermilab. He was instrumental in the decision to build the then National Accelerator Laboratory in Illinois, and in the formation of URA, which manages Fermilab for the Department of Energy. In 1981, Fermilab's auditorium was named for Ramsey upon his retirement from the URA presidency.

Fermilab's Tevatron continues to garner accolades as one of the premier technological accomplishments of its time. At a ceremony in the East Room of the White House on the afternoon of October 18, 1989, President George Bush presented the 1989 National Medal of Technology to Helen T. Edwards, Richard A. Lundy, J. Richie Orr, and Alvin V. Tollestrup for their work in the design, construction, and initial operation of Fermilab's Tevatron accelerator.

The National Medal of Technology (NMT) recognizes "those individuals or companies that have made exceptional contributions to the well-being of the nation through the development or application of technology." NMT winners are selected by the President based on the recommendation of the National Medal of Technology Evaluation Committee, appointed by Secretary of Commerce Robert A. Mosbacher and currently chaired by Robert White, President of the National Academy of Engineering.

J. Richie Orr, now Fermilab's Associate Director for Administration, was Project Manager for the Tevatron. From project start in 1979 until first acceleration of 512-GeV protons in 1983, and on through the improvement phase in 1986, Orr led the approximately 700 scientists, engineers, and technicians through the concurrent development and construction phases.

Helen Edwards, currently Head of the Accelerator Division at the Superconducting Super Collider Laboratory, served as Deputy Project Manager on the Tevatron. She is credited with providing "the basic intellectual talent required to design" the Tevatron. She specified the magnet acceptance parameters, and

("Lab Notes" continued)

supervised some 100 physicists and engineers in the design of the accelerator lattice, the high-power rf acceleration, the state-of-the-art computer controls, the beam diagnostics, and the technique for extracting and distributing accelerated protons.

Alvin Tollestrup, who is at present co-spokesperson of the Collider Detector at Fermilab experiment, was Manager of Research and Development for the Tevatron's superconducting magnets. He is credited with providing "particularly in the early stages of the effort. . . the intellectual stimulation, vision, enthusiasm, and expertise so crucial to the instigation of this ambitious project."

Richard Lundy, formerly Fermilab's Associate Director for Technology and now residing in White Salmon, Washington, where he is self-employed, served as Manager of the Magnet Assembly Facility for the Tevatron. He "provided the necessary 'practical' point of view which was essential to converting the many accelerator concepts into functioning hardware. He supervised all the engineering, tooling, testing, quality assurance, and documentation of the superconducting magnet components."

These awards represent the first NMT winners associated with a national laboratory.

Appointments:

J. Donald Cossairt has been appointed Head of the Safety Section. Cossairt received his Ph.D. in 1975 from Indiana University where he studied nuclear physics. After serving as a Research Associate at the Texas A&M University Cyclotron Institute, Cossairt joined Fermilab in 1978 as an Associate Scientist in the Safety Section, working in accelerator health physics research and health physics program administration. From 1982 until 1989, Cossairt was the Senior Safety Officer in the Research Division, responsible for operational health physics and the conventional safety program in the majority of the Lab's experiments. He is currently a participant in Fermilab Experiment 704 using the Polarized Proton Beam. Cossairt is an Associate Editor of *Health Physics* and a member of the National Council on Radiation Protection and Measurements Scientific Committee.

Peter H. Garbincius has been appointed Head of the Research Division. Garbincius received his Ph.D. in elementary particle physics from Cornell University in 1974. He was a post-doctoral Research Associate at MIT, working on Fermilab experiments using the Single-Arm Spectrometer. In 1976, he joined

*("**Lab Notes**" continued)*

Fermilab as a member of the Proton Department, where he led a group in the development of low-current superconducting dipole and quadrupole magnets for secondary beamlines. He also served as liaison physicist and beamline physicist for a series of experiments in the Tagged Photon Lab, and Deputy Head of the Proton Lab. With the formation of the Experimental Areas Department in 1982, Garbincius became head of the Cryogenics Group. After a five-month sabbatical at SLAC in 1984, Garbincius served as Head of the Experimental Areas Site Department as well as Assistant Head of the Research Division, and then Deputy Head before assuming his current role as Division Head. He has been involved in experiments with the Single-Arm Spectrometer, E-400 (Hadro-Production of Charm), and, since 1981, in the design and development of the Wide Band Beamline and E-687 (Photoproduction of Heavy Quarks).

E. Thomas Nash has been appointed Head of the Computing Division. Nash received his Ph.D. in 1970 from Columbia University. Between 1970 and 1972, Nash was a Research Associate at MIT working on experiments at DESY and the then National Accelerator Laboratory. Joining Fermilab in 1972, he served as Project Manager for the Tagged Photon Beam Facility until 1975. From 1976 until 1977, Nash was Head of the Internal Target Laboratory. He was Project Manager for the Tagged Photon Spectrometer and Spokesman for E-516 from 1977 until 1979, when he was named Deputy Chairman of the Fermilab Physics Department. In 1983, Nash became Head of the Advanced Computer Program. In 1988 he was named a Carnegie Science Fellow at the Center for International Security and Arms Control at Stanford University, returning to Fermilab in late 1989 to assume his present role.

Nash was named a Fellow of the American Physical Society in 1987. He is an Editorial Consultant to the *Encyclopedia of Applied Physics* and a Specialist Editor for *Computer Physics Communications*.

Manuscripts and Notes

prepared or presented from November 1, 1989, to November 30, 1989. Copies of Fermilab TM's, FN's, and preprints (exclusive of Theoretical Physics and Theoretical Astrophysics preprints) can be obtained from the Fermilab Publications Office, WH6NW, or by sending your request to (DECnet) FNAL::TECHPUBS or (BITnet) TECHPUBS@FNAL. For Theoretical Physics or Theoretical Astrophysics preprints, contact those departments directly. For papers with no Fermilab catalogue number, contact the author directly.

Experimental Physics Results

Experiment #581/704
N. Akchurin et al., ''Analyzing-Power Measurements of Coulomb-Nuclear Interference with the Polarized-Proton and Antiproton Beams at 185 GeV/c,'' (ANL-HEP-PR-89-82; Phys. Lett. B **229** 3, p. 299)

D. P. Grosnick et al., ''The Design and Performance of the FNAL High-Energy Polarized-Beam Facility,'' (ANL-HEP-PR-89-89; submitted to Nucl. Instrum. Methods A)

Experiment #632
V. Jain, ''Dimuon Production by 0-600 GeV Neutrinos in the Fermilab 15 ft. Bubble Chamber,'' (Ph.D. Thesis, University of Hawaii at Manoa, August 1988)

V. Jain et al., ''Dimuon Production by Neutrinos in the Fermilab 15 ft. Bubble Chamber at the Tevatron,'' (UH-511-685-89; submitted to Phys. Rev.)

Experiment #665
M. R. Adams et al., ''A Spectrometer for Muon Scattering at the Tevatron,'' (FERMILAB-Pub-89/200-E; submitted to Nucl. Intrum. Methods)

Experiment #741/CDF
F. Abe et al., ''A Measurement of D* Production in Jets from $\bar{p}p$ Collisions at $\sqrt{s}$ = 1.8 TeV,'' (FERMILAB-Pub-89/171-E; submitted to Phys. Rev. Lett.)

F. Abe et al., ''Psuedorapidity Distributions of Charged Particles Produced in $\bar{p}p$ Interactions at $\sqrt{s}$ = 630 and 1800 GeV,'' (FERMILAB-Pub-89/201-E; submitted to Phys. Rev. Lett.)

F. Abe et al., ''Two Jet Differential Cross Section in $\bar{p}p$ Collisions at $\sqrt{s}$ = 1.8 TeV,'' (FERMILAB-Pub-89/206-E; submitted to Phys. Rev. Lett.)

D. N. Brown, ''A Search for Double Parton Interactions in 1.8 TeV Proton-Antiproton Collisions,'' (Ph.D. Thesis, Harvard University, Cambridge, Massachusetts, June 1989)

R. M. Carey, ''Angular Distributions of Three Jet Events in Proton-Antiproton Collisions at the Fermilab Tevatron,'' (Ph.D. Thesis, Harvard University, Cambridge, Massachusetts, July 1989)

The CDF Collaboration (presented by S. Geer), "Recent Results from the CDF Experiment at the Tevatron Proton-Antiproton Collider," (FERMILAB-Conf-89/207-E; presented at the 8th INFN Eloisatron Project Workshop on the Higgs Boson, Erice, Italy, July 15-26, 1989)

B. L. Flaugher, "Measurement of QCD Jet Broadening in $p\bar{p}$ Collisions at $\sqrt{s}$ = 1.8 TeV," (Ph.D. Thesis, Rutgers, The State University of New Jersey, New Brunswick, New Jersey, October 1989)

BNL E-840
W. U. Wuensch et al., "Results of a Laboratory Search for Cosmic Axions and Other Weakly-Coupled Light Particles," (FERMILAB-Pub-89/185-E [BNL-43010]; submitted to Phys. Rev. D)

Accelerator Physics

A. Autin et al., "Calibration Beams at the SSC," (FN-518; [SSC-230])

W. N. Boroski et al., "Thermal Performance Measurements of a 100 Percent Polyester MLI System for the Superconducting Super Collider; Part I: Instrumentation and Experimental Preparation (300 K - 80 K)," (TM-1617 [SSC-N-660]; presented at the Cryogenic Engineering Conference, Los Angeles, California, July 24-28, 1989; submitted to Adv. Cryo. Eng.)

R. A. Carrigan, Jr. et al., "Beam Extraction from TeV Accelerators Using Channeling in Bent Crystals," (FERMILAB-Conf-89/162; contributed to the International Conference on Atomic Collisions in Solids, Aarhus, Denmark, August 7-11, 1989; to be published in Nucl. Instrum. Methods B)

J. D. Gonczy et al., "A Blanket Design, Apparatus, and Fabrication Techniques for the Mass Production of Multilayer Insulation Blankets for the Superconducting Super Collider," (TM-1619 {SSC-N-662]); presented at the Cryogenic Engineering Conference, Los Angeles, California, July 24-28, 1989; submitted to Adv. Cryo. Eng.)

J. D. Gonczy et al., "Thermal Performance Measurements of a 100 Percent Polyester MLI System for the Superconducting Super Collider; Part II: Laboratory Results (300 K - 80 K)," (TM-1618 [SSC-N-661]; presented at the Cryogenic Engineering Conference, Los Angeles, California, July 24-28, 1989; submitted to Adv. Cryo. Eng.)

A. J. Lennox et al., "Proton Linac for Hospital-Based Fast Neutron Therapy and Radioisotope Production," (TM-1622; presented at the International Heavy Particle Therapy Workshop, Villigen, Switzerland, September 18-20, 1989)

T. H. Nicol, "Structural Performance of the First SSC Design B Dipole Magnet," (TM-1623 [SSC-N-667]; presented at the Cryogenic Engineering Conference, Los Angeles, California, July 24-28, 1989)

T. H. Nicol and J. S. Kerby, "Superconducting Dipole Magnet Requirements for the Fermilab Phase III Upgrade, SSC High Energy Booster, and Fermilab

Independent Collider,'' (TM-1624; presented by T.H. Nicol at ''Physics at Fermilab in the 1990's,'' Breckenridge, Colorado, August 15-24, 1989)

D. E. Young and R. J. Noble, ''400-MeV Upgrade for the Fermilab Linac,'' (FERMILAB-Conf-89/198; presented at the XIV International Conference on High Energy Accelerators, Tsukuba, Japan, August 22-26, 1989)

Theoretical Physics

F. Brandstaeter et al., ''Critical Signal-to-Noise Ratio and Glueball Mass Calculations,'' (FERMILAB-Pub-89/199-T; submitted to Nucl. Phys.)

D. Chang et al., ''Gauge Hierarchy and Attractive Feeble Long Range Force,'' (FERMILAB-Pub-89/219-T; submitted to Phys. Rev. Lett.)

E. Eichten and B. Hill, ''An Effective Field Theory for the Calculation of Matrix Elements Involving Heavy Quarks,'' (FERMILAB-Pub-89/184-T; submitted to Phys. Lett. B)

H. Itoyama, ''Quantum Groups, Braiding Matrices and Coset Models,'' (FERMILAB-Conf-89/163-T; talk given at the XVIIIth International Conference on Differential Geometric Methods in Theoretical Physics: ''Physics and Geometry,'' Tahoe City, Nevada, July 3-8, 1989)

Theoretical Astrophysics

Z. G. Berezhiani and M. Y. Khlopov, ''Cosmology of Spontaneously Broken Gauge Family Symmetry,'' (FERMILAB-Pub-89/202-A; submitted to Phys. Lett. B)

Z. G. Berezhiani et al., ''Cosmic Nonthermal Electromagnetic Background from Axion Decays in the Models with Low Scale of Family Symmetry Breaking,'' (FERMILAB-Pub-89/203-A; submitted to Sov. J. Nucl. Phys.)

Z. G. Berezhiani et al., ''On the Possible Test of Quantum Flavor Dynamics in the Searches for Rare Decays of Heavy Particles,'' (FERMILAB-Pub-89/204-A; submitted to Sov. J. Nucl. Phys.)

P. Bhattacharjee, ''Cosmic Strings and Ultra-High Energy Cosmic Rays,'' (FERMILAB-Pub-89/196-A; submitted to Phys. Rev. D)

J. A. Frieman et al., ''Eternal Annihilations: New Constraints on Long-lived Particles from Big Bang Nucleosynthesis,'' (FERMILAB-Pub-89-190-A; submitted to Phys. Rev. D)

M. Y. Khlopov et al., ''Observational Physics of Mirror World,'' (FERMILAB-Pub-89/193-A; submitted to J. Sov. Astron.)

A. van Dalen, ''Cosmic String Induced Hot Dark Matter Perturbations,'' (FERMILAB-Pub-89/186-A; to be published in Astrophys. J.)

Computing

E. S. Lessner, ''Weighted Fit of Parametric Functions to Distributions - The New Interface of HBOOK with MINUIT,'' (FERMILAB-Conf-89/172; submitted to the 1989 Conference on Computing in High Energy Physics, Oxford, England, April 10-14, 1989)

Other

D. F. Anderson, et al., ''Lead Fluoride: An Ultra-Compact Cherenkov Radiator for EM Calorimetry,'' (FERMILAB-Pub-89/189; submitted to Nucl. Instrum. Methods A)

M. Bodnarczuk, ''New Directions for QA in Basic Research: The Fermilab/ DOE-CH Experience,'' (FERMILAB-Conf-89/194; presented at the DOE Quality Assurance Workshop, Department of Energy Idaho Operations Office, Idaho National Engineering Laboratory, Idaho Falls, Idaho, October 3-4, 1989)

Colloquia, Lectures, and Seminars

by Fermilab staff, at Fermilab, October 1989, unless otherwise noted.

October 3

K. Krempetz, ''The D0/IB4 Liquid Argon Test Dewar''

J. Strait, ''Recent SSC Magnet Testing Results''

E. Malamud, G. Goderre, C. Ankenbrandt, R. Gerig, ''Breckenridge Synopses''

October 5

V. Vigdorchik, ''Evaluation of the Distribution Function During the Quasi-Linear Relaxation of an Electron Beam in a Non-Uniform Plasma''

October 10

D. Harding, ''An Introduction to Relational Database Management Systems''

October 12

B. Hill, ''The Static Approximation for Heavy Quarks and the Measurement of f_B on the Lattice''

October 14

D. Ryu, ''Galactic Halos Made of White Dwarfs,'' at the 1989 Kingston Meeting, Victoria, British Columbia, Canada

October 19

J. Theilacker, ''F-Sector Low Temperature Power Testing''

October 26

A. Hahn, ''A Synchrotron Light Monitor for the Tevatron''

Dates to Remember

April 26-28, 1990

Workshop on Hadron Structure Functions and Parton Distributions, Fermilab, Batavia, Illinois. For information, contact Ms. Cynthia M. Sazama, Fermilab, P.O. Box 500, MS 122, Batavia, IL 60510, BITnet: PDFWKS@FNAL.