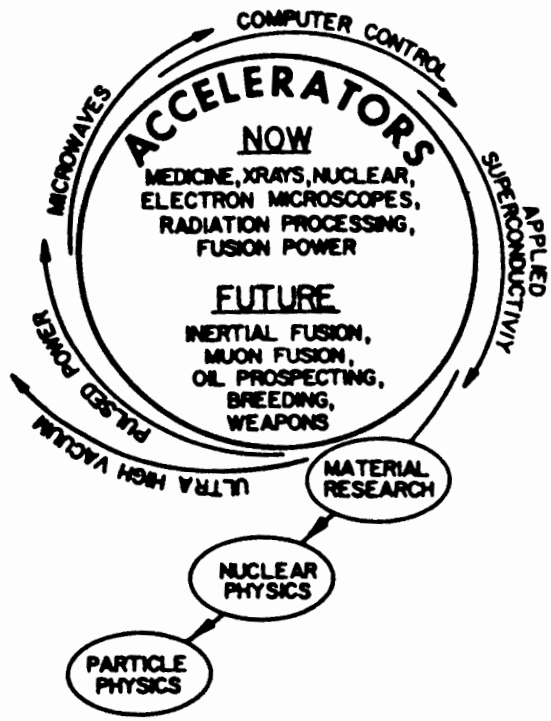
What Has Fermilab Done for Me Lately?
or
". . . but What Is the Practical Goal of Your Program?"

Reported by Richard A. Carrigan, Jr.

A superficial observer of a laboratory like Fermilab engaged in very basic research might jump to the conclusion that there were too few superconducting toothbrushes and quark power generators coming out of the program. A more insightful picture is that much of modern technology has been built upon the foundation provided by the direct antecedents of the basic research now under way at Fermilab. This situation is graphically illustrated with the trail of scientists, shown in the chart on the next page, that have led to our present level of high technology. The figure below illustrates the same sort of effects for accelerator science where a multitude of new and associated technologies, as well as new techniques for allied sciences, have flooded out of what was originally a search for tools for basic science investigations.



Intellectual Heroes of Basic Frontier Physics

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Democritus
 Archimedes
   Ptolemy
    Copernicus
     Galileo
      Brae
       Newton                    CLASSICAL MECHANICS
        Ampere
         Faraday
          Maxwell                 RADIO
           Hertz                  TELEVISION
            Curie
             Thomson
              Rutherford
                Einstein
                 Bohr                  TRANSISTORS
                  Schrödinger           CHEMISTRY
                   Heisenberg            DNA
                    Pauli
                     Fermi                ATOMIC POWER
                      Anderson              MEDICAL TRACERS
                        Yukawa
                         Dirac
                          Lawrence              ACCELERATORS
                           Lamb
                            Schwinger
                              Feynman
                               Bardeen
                                Yang
                                  Gell-Mann
                                   Salam
                                    Weinberg            COSMOLOGY
                                     Glashow
                                      Cronin
                                       Fitch
                                        K. Wilson
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An anecdote related by George Zweig, co-inventor of the quark hypothesis, at the recent Fermilab Industrial Affiliates annual meeting shows how important basic research can be. During the latter part of the last century, Gustaf Hertz, a very prominent physicist of his day, and the discoverer of radio waves, tried in vain to find the particle we now know as the electron. In the process, he invented the cathode-ray tube. He published his null results in 1883. Because of his enormous reputation, no one pursued the matter for 15 years until J. J. Thomson came along. All of modern electronics including oscilloscopes and television flowed directly out of Thomson's discovery of the electron. What would our century have looked like if Hertz had found the electron 15 years earlier?

Last year, Fermilab Director Leon Lederman published an article entitled "The Value of Fundamental Science" in *Scientific American* that discussed many of the practical results that have come out of fundamental physics. This was part of a serious program on his part to make more widely known the substantial benefits accruing from basic research and the ways these benefits reach the public. This article grew out of an earlier *Viewpoint* article, a more detailed review of the same point. Lederman's *Scientific American* article speaks directly to the ways benefits flow out of fundamental science.

> "...the support of fundamental science - mathematics, astronomy, the physical and the biological sciences - yields profoundly significant benefits. They can be classified roughly according to the time it takes for them to be transferred to society. The most important benefits are cultural; the cultural benefits also require the longest and most complicated maturation process. Direct benefits, in which the object of scientific inquiry is put to some practical use, typically require about 30 years to be realized. For example, nuclear magnetic resonance (NMR) was discovered in the 1940's, and its commercialization as an imaging device in medicine began in the 1970's. The most rapidly realized social benefits are usually indirect, such as technology spin-off. They arise when some solution to a problem in a fundamental discipline is perceived to have application in an unrelated field."

With this in mind it is obvious that any report of current efforts to spin-out technology misses the main long-term benefits. If Katz-Moody algebras are to string theory what calculus was to classical mechanics, then the most important contribution of particle physics in the next millenium could be mathematics. Nevertheless, the more immediate spin-offs are also interesting.

The major thrust of the technology transfer program at Fermilab is the Fermilab Industrial Affiliates. The Affiliates organization is comprised of industrial concerns interested in the research and development work underway at the Laboratory. Affiliates receive a monthly tailored distribution of reports. An annual meeting gives the Affiliates an opportunity to visit the Laboratory and review ongoing work and future projects. The most recent meeting had as its major topic "Applications of Particle Physics, Out on the Limb of Speculation." This Round Table attracted outstanding participants--Sheldon Glashow of Harvard University, George Zweig of Los Alamos National Laboratory, two very interesting industrial scientists from the General Electric Company and Hughes Research Laboratory , and Stephen Jones, then at Idaho National Engineering Laboratory and now at Brigham Young University. Walter Sullivan of the *New York Times* served as moderator. An "Intense Briefing on Superconductivity" was held in February. This was well attended by interested industries in the cryogenics and superconductivity fields. That meeting helped to illuminate the practical side of large scale superconductivity.

The Laboratory is also involved in the more traditional forms of technology transfer. Many technical articles are published and papers presented at meetings based on the work of the Laboratory. These papers represent a very effective means for transferring the work of the Laboratory. The field of particle physics is also an exporter of highly trained manpower to other technical areas. Staff and graduate students trained at Fermilab have gone on to such activities as telephone switching systems, oil exploration, and medical imaging where they have made direct use of Fermilab science and technology.

These technology transfer activities are superimposed on another traditional, on-going, and historically very effective natural process of technology transfer. This is the process whereby Fermilab specifications are met by vendors only after considerable effort, usually collaborative, between Laboratory and industry. The result is often a new product or a new skill which results in a new product. A prime example of this is the development of the superconducting cable that was used in the Tevatron. That cable solidified and aggregated the present superconducting cable industry. Similar illustrations hold for several important electronic products. It is this "standard" activity that probably accounts for an overall payback which is a significant fraction of the annual budget of all the basic research laboratories. An interesting analysis of this type of activity has been carried out recently at CERN. A similar study at Fermilab would strongly support the CERN picture.

A recent activity at Fermilab that shows this process in action is the Advanced Computer Project (ACP). That project is developing a special super computer that can analyze many experimental particle events in parallel. The system goals are to be able to process an enormous number of events at a modest cost in an environment that is user-friendly. One important element of this program has been to maintain close working relationships with microprocessor chip manufacturers and software developers. The thrust of the Fermilab program, in turn, acts back on the suppliers. To quote comments received from a person at a prominent corporation in the computer field, "I applaud your progress on the ACP microprocessor. You deserve credit for helping us all realize the benefits of multiprocessing systems."

Recently the Laboratory has also been serving as a lightning rod for interest in the possibility of developing a proton accelerator for medicine. Several meetings have been held here as a forum for the interested parties from medicine, industry, the universities, and the accelerator community. At this stage the dust has not yet settled but it has been vigorously stirred. Discussions have been underway with the State of Illinois about the possibility of a small center at Fermilab to facilitate commercialization.

These two activities represent broad areas with substantial potential. Progress has also been made in exploiting some of the

individual inventions at the Laboratory. This year the Laboratory has started to use the Technology Commercialization Center at the University of Illinois-Chicago to assess some of these inventions. Currently a design class at the University is studying an interlocking component system devised here by Carl Lindenmeyer in the Physics Department for drift chamber fabrication. Interestingly, one of the applications they are considering is for decorative panels. Another Laboratory-developed modification on a Bendix coordinate measuring machine by Greg Kobliska and his colleagues in Technical Services was featured recently in the magazine *Quality*, the trade publication of the quality control industry.

This fall the Laboratory was awarded an IR-100 award for a magnetic wire position transducer developed by Hans Jöstlein. About 20% of these IR-100 awards went to DOE Laboratories this year. This is certainly a tribute to the enormous diversity of the Department of Energy's (DOE) program.

The Laboratory has redoubled its efforts to patent appropriate technologies. In the process a complete technology inventory has been put in place. It now contains more than 300 technology items in a computer data base. An application assessment along the lines of a standard DOE reporting form has been prepared for each of these. In the next year, hopefully, ways will be found to effectively exploit these innovations.

These developments discussed here arose directly out of the Laboratory's single mission of conducting research in fundamental physics. These technologies either have or could have wide practical use. On the other hand, new technology is not the primary purpose of the Laboratory. While science leads to technology, technology is not the aim of the Laboratory. Basic research is!