Superconductivity
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Over the past few months, a series of scientific developments have occurred that could provide a tremendous opportunity for dramatizing and accelerating the President's goal of assuring American competitive preeminence into the 21st Century. During this time the scientific community has put out a series of announcements of technological breakthroughs in the development of superconductors, affecting the basic science of transmission and use of electric power, and electronic technology. The applications of these breakthroughs could be much broader and have as much or more economic impact as development of the transistor.

Superconductivity is the ability of a substance to transmit electricity with almost no resistance, which means little loss of power to heat in the transmission process. In a matter of months, scientists, building upon work that has been ongoing worldwide since the turn of the century, have been able to produce various metallic alloys that exhibit superconductivity at increasingly warmer temperatures than had been possible in the past. Until recently, superconductivity was observed in certain metals only at ultra cold temperatures approaching absolute zero (-459°F). The cost of the refrigeration needed to reach such temperatures, involving the use of liquid helium, is very high, and has severely limited the practical usefulness of the early discoveries. Now, technological advances point to the possibility of superconductivity at temperatures well above the temperature of liquid nitrogen, a fairly cheap coolant. If superconductivity becomes practical, potential economic applications could include revolutionary microelectronics, "superchips", and super fast computers; trains that operate at high speeds by floating on magnetic fields; less costly power generation and transmission; dramatic reductions in the size of electric motors; improved prospects for electric vehicles; and greatly enhanced, higher resolution medical imaging machines.

The rush of discoveries streaming from laboratories around the world has been breathtaking, but it is expected that it may take 20 years or more before the full potential of these discoveries is realized. When the potential is realized, however, the economic impact will be substantial, and almost entirely on the plus side.

As an example, superconductivity could produce substantial benefits in the energy area. Currently, long distance transmission of electricity is made more expensive by resistance in the wires, which results in 15 to 20 percent power loss. If electricity could be transmitted over vast distances without loss because of the development of superconducting wires that provide little or no resistance, there would be considerable savings. The country's electricity needs could be met using less fuel than at present, saving several billion dollars per year. Furthermore, power plants could become more efficient by using generators made with superconducting magnets, and power could be stored cheaply and easily for use during peak load periods.

Looking further ahead, if we allow for changes in the pattern of energy production and use, the benefits could be even greater. The country's energy demand could be satisfied to a significant extent by using cheaper, cleaner, safer and more secure energy sources and production methods than at present.

For example, superconductivity could lead to greater use of coal to generate electricity. Power plants could be located where the coal is mined, e.g., the Western States or the Appalachians, rather than shipping the coal at great expense to localities where power plants are presently located. Use of low sulfur western coal could reduce the cost of controlling acid rain and other forms of pollution, as would locating power plants farther from urban areas.

The ability to locate plants farther from urban areas might also improve prospects for nuclear power from a safety standpoint. It is even conceivable that super-magnets could be created to produce "magnetic bottles" strong enough to contain nuclear fusion reactions. This could lead to virtually unlimited electric power without most of the safety and hazardous waste products of fission plants.

Coal and nuclear power are domestic energy resources that could reduce our dependence on oil imports from insecure foreign sources in the production of electric power. On the demand side of the energy sector, the development of much smaller but far more powerful superconducting electric motors could make it feasible to produce and use efficient electrical cars rather than vehicles that require gasoline made from crude oil. The reduction in the cost of electricity might increase the use of electric heating and also reduce the demand for heating oil. These developments could be especially important as domestic production of oil declines in the years ahead.

Outside of the energy area, superconductivity could enhance national security through its application in supercomputers. These would have significant advantages in the development of the Strategic Defense Initiative, in addition to obvious commercial uses.

There may be some concern over the prospect of a significant decline in the demand for the products of certain industries, e.g., reduced demand for gasoline for transportation, reduced demand for cars powered by internal combustion engines, and reduced use of copper wire and traditional motors or generators. Theoretically, a sudden decline in the demand for such products could injure firms which are heavily invested in capital which is specific to production of these products. However, there does not appear to be any reason to think that this will be a significant problem in practice, for several reasons.

First, there will be no sudden shocks to major industries. While some breakthroughs have been made in the basic science, large scale commercial applications remain years in the future. Consequently, it is unlikely that any displacement of existing industries could occur in the near future, or come so rapidly as to create major adjustment problems.

For one thing, the new superconducting materials are basically ceramics, and are brittle. For use in power transmission, motors, and computer chips, the materials must be drawn into wires or thin films, which requires considerable ductility. In addition, extensive experimentation to reach higher temperatures with cheaper materials is needed, and a multitude of design and development problems must be overcome. A critical initial problem that needs to be resolved is that the amount of electrical current that can be pushed through the new superconductor is so small that in their present state they have only limited practical usefulness. Scientists seem confident that they can solve this current-density problem but it will take time. Even after the current-density problem is solved, it will take time for scientists and engineers to come up with a way to design and produce the new superconductor materials in the form and quantity needed for practical applications.

Second, in most cases, the new technologies and products will be developed and produced by companies currently in the field. Companies now producing gasoline-powered cars will have significant expertise and capital advantages in the production of electric-powered cars. Leading computer firms will have substantial advantages in using new "superchips" to produce new supercomputers. These firms are also likely to be leaders in the research leading to commercial applications. Other firms with limited research capabilities may become end users, acquiring access through purchase, licensing, merger or acquisition. In most cases, the transition to new products will be accomplished gradually. In most cases, old capital will continue to wear out before becoming technologically obsolete, and firms will gradually introduce the new technology in the normal course of replacing old plant and equipment.

In the case of the oil and gas industry, a number of factors must be weighed. Petroleum and natural gas will always be essential as feedstocks for petrochemicals. Although superconductivity may bring about some reduction in the demand for gasoline, it is unlikely that electric vehicles will dominate the market for long distance transportation. There may be some relative shift in favor of coal and nuclear fuel to generate electric power, and some shift in favor of electricity for home heating. However, energy companies are often diversified, with interests in several fuels. In fact, these developments may induce them to shift exploration funds into diversification and research into the new technologies. There is ample time for them to do so. Most importantly, U.S. oil production is gradually declining as old fields become depleted. Thus, fuel-saving and fuel-switching technologies based on superconduction are likely to coincide roughly with the natural decline in U.S. petroleum output, with no disadvantage to the petroleum industry, and with major benefits to the nation in terms of the balance of payments and energy security.

In brief, superconductivity is likely to be of major economic benefit to the nation. Negative impacts, if any, should be minor. This landmark scientific advance should be viewed as expanding our economic horizons, pushing back limits on our standard of living and creating greater opportunities for growth and employment.

Federal Involvement

The scientific community and others are urging the Federal Government to move expeditiously to optimize its efforts at research and development in the superconductivity area and to facilitate the transfer and commercialization of its direct efforts, and the integration of its efforts in this area with those in the private sector. Unless we move with great speed, there is apprehension that other countries, and in particular Japan, will move ahead quickly to organize their research capabilities into a program with strong commercial goals that would enable them to gain the edge on the U.S. in commercializing the superconductivity research to date done largely, although not exclusively, in Federal and private U.S. laboratories. By achieving this edge in an area that promises to have revolutionary scientific and economic impacts, the concern is that this country would again lose out to others by failing to capitalize on the advances resulting from our pioneering basic research and innovation.

Exploiting the benefits of science and technology is fundamental to U.S. competitiveness. President Reagan has announced a number of measures to help generate new knowledge in the sciences and advanced technologies and to transfer swiftly technologies to the marketplace.

One key measure is Executive Order 12591 issued on April 10, 1987. This Executive Order directs Federal agencies to implement programs that will encourage their scientists to facilitate the commercialization of their research and innovation; help the private sector exploit fully foreign science and technology; seek out "science entrepreneurs" to act as conduits between the public and private sectors for technology transfers and commercial spin-offs from Federal research and development efforts; and facilitate the prompt and efficient dissemination of information on foreign research and technology developments to the private sector.

Federal research activities on superconductivity provide a timely opportunity for testing the usefulness and effectiveness of Executive Order 12591. The Federal Government has been involved in superconductivity research for many years, particularly in the Department of Defense, Department of Energy, NASA, and the NSF. No single Federal agency is coordinating the Government's efforts to exploit the most recent developments, nor do we know how much the U.S. in the aggregate, or the Federal Government by itself, is spending on superconductivity research. The following summarizes the current efforts of the Federal Government in this area.

<u>Department of Energy</u>

- The Department of Energy (DOE) has traditionally had the largest Federal program in superconductivity, spanning the basic research on theory and structure to the actual construction and use of engineering devices. The DOE role in this effort has been to: a) enhance our understanding of the properties of materials and the phenomenon of superconductivity through programs at DOE laboratories and universities; b) apply the technology of superconductivity to the department's programs in fusion, accelerator physics, and electrical energy transmission, generation and storage; and c) involve industry to the maximum extent possible through the manufacture of superconducting materials and the design of devices.

  - The major DOE labs have redirected about $10 million of their existing resources into team efforts to attack various aspects of producing and testing the new superconducting materials.

  - DOE also spends another $15 million on research and development associated with more conventional superconductors. This research is directed at metallic superconducting alloys and at developing techniques for fabricating these alloys into practical conductors.

  - The Department is publishing a newsletter to disseminate to investigators outside DOE the flow of information that is being generated among all the DOE-supported investigators.

Department of Defense

- Following the breakthrough last year in high temperature superconductivity, DOD doubled its research effort to around $10 million. Current DOD efforts involve DOD labs, universities and non-DOD Federal Research Centers; DOD is coordinating with laboratories and research programs of other Federal agencies, and participating in symposiums with other agencies, industry and universities.

- DOD research objectives are to achieve higher transition temperatures, greater current carrying capacity and improved flexibility of material.

National Science Foundation

- The National Science Foundation (NSF) has allotted an additional $1 million for research on superconducting materials by teams at three of the Materials Research Laboratories (MRLs) it supports. The teams will involve chemists, physicists, materials scientists, and engineers.

- The NSF has also initiated a program of rapid turnaround grants for researchers with promising ideas for processing superconducting materials into useful forms, such as wires, rods, tubes, films, and ribbons. This program will provide $600,000 primarily for research in engineering.

- Together, these programs will bring NSF's total research effort on superconducting materials to more than $6.5 million in FY 1987.

- Finally, NSF has commissioned a special study by the National Academy of Sciences to review recent progress in superconductivity research and recommend needed actions. The report is scheduled to be completed by mid-summer.

NASA

- NASA, along with NSF and DOE, helped fund a significant breakthrough by University of Houston/University of Alabama scientists in February 1987. Additional NASA plans include: redirecting in-house research at several NASA Centers; collaborating with private firms; and increasing university and industrial involvement in exploring potential space applications.

Commerce

- National Bureau of Standards scientists are working on two major scientific problems related to superconductivity:

1) how to fabricate superconductive material in pliable form as opposed to its present ceramic form which is brittle.

2) how to increase the amount of electric current that can be carried by the high temperature superconducting material.

° The Patent Office reports that hundreds of inventions in the superconductor field have been patented over the years. However, following the recent dramatic breakthrough in this area only two patent applications have been identified, as of 2 months ago. Both were filed in November 1986, and both were of Japanese origin. Others, if any, filed in the last 2 months may be in a "pre-processing" status.

Other Countries

° The present superconducting technology is available throughout the industrial world (U.S., Japan, Western Europe, Soviet Union, China) and work on new superconductors is proceeding in all these countries.

° The high temperature superconductivity discovery in Houston meshes well with technology Japan has worked on for years.

  - Japan has been developing an experimental train using superconductivity; it travels at more than 250 mph while hovering five inches above a track on a magnetic cushion created by superconducting coils.

  - Japan's shipbuilders have spent $23 million to develop a fast ship propelled by superconducting magnets.

  - NEC and others have produced prototypes of superconducting computer chips.

  - Japan supplies the U.S. with superconducting wire.

  - MITI hopes to have a working model of a superconducting power plant by 1992.

° Eleven days after the February announcement in Houston of the high temperature superconducting breakthrough, Japan's Science and Technology Agency had in place a research consortium of companies, universities and government labs. The government agency " . . . gathered all the leading edge researchers in superconductivity in Japan . . . to share information and decide how to move." It is reported that "the objective is to organize industry to get the jump on the West in applications and commercialization for a huge new market."

- The Soviet Union has worked on superconducting for many years, particularly in seeking a means for low loss transmission lines.

Additional Federal Initiatives

Potential commercialization of emerging superconducting technology depends not only on significant additional scientific developments enabling commercial application of these materials, but also the speed at which processes are subsequently developed by the U.S. private sector to mass produce new and improved products using the technology.

- Bipartisan legislation, H.R. 2069, introduced April 9, would establish a four-month national commission on commercialization of superconductivity technology. The Congressional Office of Technology Assessment is planning a study on the issue as well.

- OSTP in conjunction with the Department of Energy is planning a government-industry conference this summer targeted towards the commercial application of superconductors. In addition the Federal Coordinating Council for Science, Engineering and Technology (FCCSET) will coordinate interagency technical activities involving superconducting materials and their applications. FCCSET, chaired by the President's Science Advisor, was created by the National Science and Technology Act of 1975, and has as members the heads of eleven Federal Departments and agencies responsible for science and research and development: USDA, DOC, DOD, DOE, HHS, DOI, State, DOT, EPA, NASA and NSF.

Areas for further study by the Working Group on R&D include:

- Develop a plan to use this issue to test and publicize the Executive Order;

- National initiative to highlight U.S. progress in superconductivity and encourage U.S. commercialization and collaboration efforts;

- Clarification of intellectual property rights protection both in the U.S. and abroad for superconducting discoveries and options for reform, if necessary. Potential domestic initiatives could include:

  - Priority by the Patent and Trademark Office for handling patent applications and disputes involving superconductivity discoveries;

- Redoubling efforts to enact H.R. 1155, the Administration's legislation to remove disincentives for patent licensing, in particular "blocking" or closely related patents;

- Explore the merits of proposing legislation to strengthen the National Cooperative Research Act of 1984 that modified the antitrust treatment of joint R&D ventures. Potential reforms could provide additional protection covering certain advanced development and manufacturing activities.