Military system applications of superconductors

In October of this year, the Pentagon's Defense Science Board (DSB) issued a general report on the deterioration of the U.S. industrial and technological base, and a report on the U.S. failure to take the lead in the development of a crucial new technology, high-temperature superconductors.

Last week, EIR *presented an analysis of the DSB's more general study,* The Defense Industrial and Technology Base, *together with Marsha Freeman's analysis of the Avtex Fibers case, thus documenting the collapse of existing technological capabilities, and with them, America's potential for future technological leadership. In that first installment, we also began our analysis of the DSB study,* Report of the Defense Science Board Task Force on Military System Applications of Superconductors, *October 1988.*

In the final section of last week's report, we noted that in 1986, Jane's Fighting Ships *had put forth the hypothesis that the Soviets "had developed a wide range of advanced submarine systems, including super-cold, absolute-zero cryogenic electric superconducting motors and propellerless propulsion based on electromagnetic and MDS drive." The DSB report of October 1988 finally admits that this hypothesis might be right, and continues:*

"Another application of well-known laws of physics is the principle of electromagnetic thrust (EMT). In this case, a magnetic field is set up by passing an electric current between this field and a second field set up by a line of electromagnets placed on the center-line develops a forward thrust in the water. This option is currently being developed in Japan and has also received careful attention in the U.S.S.R.

". . . Thus, the Gorshkov forecast of the need for colossal electric power output may well have been met by one means or another. . . . In some cases, those with MHD or EMT propulsion, there will be no need for propellers or pump jets, both of which are liable to damage, particularly under ice, and both of which emit radiated noise. As well as increased speed, these developments would decrease the sonic signature and could have an effect on the magnetic signature. The second of these would also be reduced by the use of titanium alloys for the hull and fittings, an advantage to be added to the increased diving depth." These last characteristics have been demonstrated by the Soviet Alpha nuclear submarine.

In the concluding part of EIR's *report below, we quote extensively from the DSB report's findings, which, we believe, speak for themselves.—Charles B. Stevens*

Executive summary

In 1911, a Dutch scientist discovered a class of materials which, at temperatures near absolute zero, could conduct electricity with no resistance and therefore zero loss of power. In spite of the revolutionary potential of this superconducting material, the difficulty in producing engineered materials and in maintaining low operating temperatures precluded practical applications for many decades. The recent dramatic discoveries of high temperature superconducting materials (up to 125° Kelvin) have prompted an intense international surge in superconductivity research and development.

This surge of research and development activity, particularly that of the Japanese, combined with the promise of revolutionary performance improvements in many applications, prompted President Reagan to establish a national program in high temperature superconductors. The Defense Science Board was tasked to study the military system applications of superconductors. The attached report presents the findings of this study.

The Task Force found a number of superconductivity applications that could result in significant new military capabilities, including electronics and high power applications. In particular, superconducting materials could enable significant military improvements in:

- *Magnetic Field Sensors* with greatly increased sensitivity for improved detection and identification capability
- *Passive Microwave and Millimeter-wave Components* enabling increased detection range and discrimination in clutter
- *Staring Infrared Focal Plane Array* sensors incorporating superconducting electronics permitting significant range and sensitivity increases over current scanning IR sensors
- *Wideband Analog and Ultra-Fast Digital Signal Processing* for radar and optical sensors
- *High Power Motors and Generators* for ship and aircraft propulsion leading to: decreased displacement; drive system flexibility; increased range; or longer endurance on station
- *Magnets/Energy Storage* for high power microwave, millimeter-wave or optical generators (e.g., free electron laser); capability for powering quiet propulsion systems
- *Electro-Magnetic Launchers* capable of launching hy-

pervelocity projectiles for anti-armor weapons and close-in ship defense weapons

- *Magnetohydrodynamic (MHD) Propulsion* enabling ultra-quiet drives for submarines, torpedoes, and surface ships.

As these examples illustrate, superconducting materials have potential for significant military applications. It is important to note that many of the applications have high value for commercial and scientific applications as well. However, an extensive program of basic and applied research and materials development will be necessary to make these applications possible. The present R&D level in the U.S. is below critical mass to achieve the desired applications in a timely way. By comparison, the Japanese effort in superconductors is substantially greater than that of the aggregate U.S. commercial and government effort. If these trends continue, the U.S. may fall so far behind in this field that defense and important commercial applications will be achieved only by using foreign source materials and designs as they become available to the U.S. It is the judgment of the DSB that such dependence on foreign sources is an unacceptable position for the U.S.

We have recommended a significantly expanded superconductor R&D program for the Department of Defense which increases the 1989 effort by 50% and triples the current effort by 1992. The Task Force members believe such an aggressive program is required to assure U.S. leadership in the many high leverage superconductivity applications. This recommended R&D effort is balanced between exploitation of old (LTS) materials and development of new HTS materials. It includes a vigorous program of building engineering models that will demonstrate the substantial performance advantages achievable with superconducting materials. The demonstration programs recommended include engineering models of a space surveillance system, mine detector, hypersonic tank gun, undersea MHD propulsion system, and a millimeter-wave radar. Most of these efforts involve old (LTS) materials. To achieve the very real cost, weight, and logistic benefits of the new (HTS) materials in these applications, substantially more progress must be made in the U.S. R&D program, particularly in the development of new material processing techniques. We have also recommended the development of improved militarized cryogenic devices, because even the new HTS materials will require cooling. In the near future we do not anticipate room temperature operation of superconducting materials.

In summary, superconductor materials represent a major opportunity to significantly improve performance in important defense missions as well as in commercial applications. To achieve these benefits, we will need to make substantial, focused increases in R&D over a sustained period. While U.S. superconductivity research is competitive with that of other countries, we cannot count on our commercial developments providing this capability for defense. In fact, U.S. industry is already well behind Japanese industry in the development of superconductivity applications. . . .

Section 2: Findings

(. . .)

U.S. and foreign research expenditures in high temperature superconductivity. With the discovery of high temperature superconductivity, substantial R&D efforts have been undertaken in the U.S., Europe, Japan, and very likely in the U.S.S.R. It is very difficult to make estimates of national R&D efforts. 1988 estimates of U.S. and foreign high temperature superconductivity research, as drawn from CIA and NSF inputs to the Task Force, are as follows:

	FY88 FUNDING ($M)	# OF PROFESSIONALS
U.S.		
Government	95	500
Industry	50	250
Japan	135*	1,000*
U.K.	25	300
France	20	200
West Germany	15	150

*See Appendix H for more detailed information. The above estimates for Japan do not include salaries of the researchers. All other funding numbers do include such costs.

. . . It is estimated that in 1988 approximately 500 professionals are supported by U.S. government funding. Most of the U.S. industrially-funded research is concentrated in a few large research laboratories (e.g., IBM, AT&T, etc.) In addition, several start-up companies have been formed. The rest of U.S. industry is investing relatively little and maintaining a wait-and-see attitude.

The intensity and emphasis of the Japanese effort is not-

Abbreviations

DARPA—Defense Advanced Research Projects Agency
DSB—Defense Science Board
LTS—Low Temperature Superconductors
HTS—High Temperature Superconductors
MHD—MagnetoHydroDynamic
R&D—Research and Development
IR—InfraRed
FEL—Free Electron Laser
DDR&E—Defense Development Research and Engineering
SDIO—Strategic Defense Initiative Organization
DoD—Department of Defense

U.S. Department of Defense, "Soviet Military Power"

A Soviet OSCAR class submarine. The October 1988 Defense Science Board report suggests that Soviet submarines may be driven by MHD rather than by propellers.

able. Both basic research and rapid industrialization are emphasized. Single crystal materials with significant current carrying capacity at 2 tesla fields have already been achieved. In contrast to the U.S., Japan is already applying significant effort toward the industrialization of both LTS and HTS. According to a recent OTA [Office of Technology Assessment] report,

> Japanese companies have been more active in pursuing the commercial potential of HTS. They have more people at work, many of them applications-oriented engineers and business planners charged with thinking about ways to get HTS into the marketplace. . . . As the scientific race becomes the commercial race, Japanese firms could quickly take the lead. Indeed, they may already be doing so.[6]

The European efforts are mainly concentrated in universities and emphasize basic research.

At the present time, it seems clear that high-temperature superconductivity research is geographically widespread and that the U.S. is not the principal focus of research.

Section 3: Conclusions

Based on these findings, the Task Force came to the following conclusions:

1. The new high temperature superconductors are of great signficance because of their high operating temperatures and magnetic fields.

6. *Commercializing High Temperature Superconductivity*, OTA Report Brief, June 1988.

2. The discovery of high temperature superconductors has rekindled interest in low temperature applications which have not been exploited.

3. There are superconductor applications of potentially significant military impact. . . .

4. To make these military applications possible, intensive research and development in the following areas will be required:

- Expanded efforts in superconductor theory and basic research should provde the fundamental understanding of the new materials to guide applied research. Such basic research (theory and experiments) could also lead to the scientific breakthroughs which will make the speculative applications feasible.
- Thin HTS film fabrication, with emphasis on lower processing temperatures, perfecting surfaces/interfaces, reducing RF surface losses, minimizing electronic noise, and increasing environmental stability, including radiation hardness.
- HTS composite films/conductors/wires with emphasis on increasing current densities in high magnetic fields to useful levels, minimizing persistent current creep and AC losses, and attaining requisite mechanical strengths and flexibility.
- Militarized cryogenic coolers with long lifetimes and increased reliability, especially portable, miniaturized coolers.
- High strength structural materials for magnet support systems.

FIGURE 4-1
Suggested DoD superconductivity funding*
(Dollars in millions)

	88	89	90	91	92	93
6.1 Basic Research including Theory	17	20	20	25	25	30
6.2 Applied Research on Processing of New Materials, Manufacturing Sciences, Cryogenics, and High Strength Composites	22	50	60	70	70	75
6.3 Engineering Demonstrations of Electronics Applications of New Materials (e.g., Magnetic Sensor, IR Sensor, and Microwave Antenna)	13	10	20	30	40	50
6.3 Engineering Demonstrations of High Power Applications of New Materials	0	0	0	0	10	20
6.3 Early Exploitation of High Power Engineering Test Models Using LTS (e.g., Quench Gun, MHD Torpedo for Quiet Propulsion)	22	30	50	70	80	70
6.3 Early Exploitation of Electronics Engineering Test Models Using LST (e.g., digital signal processing, squids, millimeter-wave sensors)	5	10	10	20	20	15
TOTAL	79	120	160	215	245	260

*This funding is over and above that being invested by agencies and organizations outside of the Department of Defense

5. DoD sponsored developments in basic research, materials, and manufacturing processing will provide direct benefit to commercial manufacturing organizations.

6. Some applications of great military significance could be embodied in engineering models in the near future. The following programs, which combine a high degree of significance with a reasonable expectation of technical success, could be started in parallel with the efforts to develop improved high temperature superconducting materials:

- Space Surveillance System. Build an IR focal plane array demonstrating high resolution and low power consumption by combining detectors using existing extrinsic silicon materials with signal processors employing LTS materials. In parallel, a 6.2 program could develop sensor elements with HTS materials.
- Mine Detector. Build and demonstrate a magnetic field sensor with LTS materials suitable for use as a mine detector. In parallel, a 6.2 program could develop sensor elements with HTS materials.
- Hypersonic Tank Gun. Build and demonstrate an electromagnetic projectile launcher using LTS materials. This launcher should achieve hypersonic velocities capable of penetrating reactive armor and modern composite armor.
- Undersea MHD Propulsion. Build and demonstrate a small-scale MHD propulsion system with LTS materials. This engineering model would be designed to power a torpedo. Later models would be scaled up for submarine applications.
- Millimeter-wave Radar. Build and demonstrate a millimeter-wave radar. This radar would embody HTS materials in its filters, transmission lines, phase shifters and possibly the reflector.

7. Foreign investment in superconductivity research and development is increasing rapidly and significantly exceeds that of the U.S. Japan is currently spending considerably more than the total U.S. effort in superconductivity research and has targeted superconductivity as an important commercial area.

Section 4: Recommendations

Based on this evaluation, the following recommendations are made:

- DDR&E should implement a focused plan for superconductivity basic research (theory and experiments), materials development, and application demonstrations. This plan should include cooperation with industrial organizations in order to build a strong industrial base in the area of superconductivity. This plan should also incorporate substantial funding which increases over the next several years. A model funding profile is shown in **Figure 4-1.**
- The Services, SDIO and DARPA should implement an aggressive plan for early exploitation of high-temperature superconductivity in electronic applications, including sensors and data processing, as well as weapon and propulsion systems. Initial emphasis should be placed on electronic applications. A suggested funding profile is included under the high-temperature 16.3 lines of Figure 4-1.
- To facilitate the earliest military applications of superconductivity, the Services, SDIO and DARPA should build a number of engineering test models exploiting existing low temperature materials. Estimates for funding of these efforts are shown in Figure 4-1 under the last two 6.3 lines.