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## US NAVY SUPERCONDUCTIVITY PROGRAM

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The U.S. NAVY has had a long running and sustained program dating back to 1946 supporting superconductivity and its technology. This is due to a recognition of the enormous military benefits that could be achieved if the unique properties of superconducting materials could be tapped in field operating systems. The present NAVY's program is broadly based with an emphasis on field operational systems. The NAVY is committed to developing a science and technology base for superconducting materials, both high temperature superconductors (HTS) and low temperature superconductors (LTS), and to undertaking key system tests leading to the eventual implementation of the technology. The program is well integrated throughout the NAVY with four organizations leading the way in specific areas. Those organizations are: 1) the Office of Naval Research (ONR) and the Office of Naval Technology (ONT) [responsible for contract funding in all areas of Naval interest], 2) the Naval Research Laboratory (NRL) [responsible for fundamental property studies, materials research and development, and electronic and space applications], 3) the Naval Coastal Systems Center (NCSC) [responsible for SQUID magnetometer systems development], and 4) the David Taylor Research Center (DTRC) [responsible for power applications of superconductivity and ship propulsion]. Other NAVY organizations participate in the total program and all are coordinated by the Naval Consortium for Superconductivity (NCS).

The NAVY's superconductivity program includes work in HTS and LTS and is divided into 5 main thrust areas. They are: 1) Fundamental properties and materials research (mostly HTS), 2) SQUID magnetometers and gradiometers (mostly LTS), 3) superconducting ship propulsion (exclusively LTS), 4) electronic applications including digital circuitry and IR sensors (50% LTS and 50% HTS) and 5) Space experiment (exclusively HTS). About 2/3 of a total NAVY's budget of \$21M is split equally between fundamental properties/material research and the space experiment. SQUID research accounts for about 1/6 of the budget with the remaining going to power applications and electronic applications.

Almost half of the NAVY's program is focused on fundamental research and materials development. The NAVY believes this is essential if the technology is to meet its potential in Naval systems. The program is broad based with major efforts in theory, materials synthesis (primarily films),  $J_c$  and flux flow studies, surface resistance and noise studies, and radiation damage.

Superconducting electronics development in the NAVY began around 1966. Today the program is relatively broad based working on IR sensors (HTS), millimeter and micro wave devices (HTS and LTS), directional antennas (HTS), and digital circuit elements (LTS). Key to this program is assessments of the impact of the technology on specific systems performance vis a vis competing technologies. This program will develop, fabricate, and test device elements to certain their performance advantages and limitations. Close ties with industry and other DoD efforts in superconducting electronics gives the program an unusual breath.

The Space experiment at NRL began in 1988 and is designed to demonstrate the feasibility of millimeter wave and micro wave electronics for space use. The program includes material scientists, and electronic and spacecraft engineers. Various devices are being manufactured by over 15 different industries, made from a variety of HTS materials, and will be delivered to NRL by June 1990 for testing and evaluation. Devices which meet design criteria will be assembled into a space craft and launched into space sometime in the 1992 time frame. The tests are designed to demonstrate the virtues of superconducting electronics in space and to

space qualify the HTS devices. Space qualification means that the devices operate after the shock of space launch and exposure to space radiation environment.

The SQUID detection/surveillance systems development at NCSC began in 1969 and has focused on field operational demonstrations of the technology. Unanticipated problems associated with operation in motion while in the ambient earth's magnetic field had to be solved before the needed sensitivity levels could be reached. A gradiometer system designed to meet the requirements of Naval operation was built by Sperry Univac in 1985 and has been successfully demonstrated in field tests. This gradiometer is now being refurbished with newer sensors and electronics under a contract with IBM and will be used in subsequent tests. The original system as well as the refurbished system is based on bulk, niobium Nb technology. Advanced systems are now being designed which will use thin film technology, but still use Nb as the superconducting material. Thin film systems are expected to be smaller and less sensitive to certain types of system noise. Also under study is the eventual design as SQUID system based on HTS materials. Important issues of magnetic and thermal noise, flux motion, and hysteresis need to be improved before the HTS SQUID system becomes viable as a NAVY, field operational unit.

Superconducting ship propulsion systems development at DTRC began in 1969. This program has successfully demonstrated that industrially built (3000 Hp) superconducting motors can be installed in a small Naval vessel and operated at sea. NbTi wire was used in the magnet construction. The NAVY has been reluctant to take the next step to develop a larger scale demonstration on a mid sized Naval ship because 1) a reluctance to convert to a radically new drive system, 2) a reluctance to depend on a liquid helium technology, specifically in combat, and 3) cost of a mid sized Naval vessel demonstration would be large and particularly burdensome in times of budget austerity. Progress is being made, however, in that the NAVY has decided to make a major commitment to electric drive wherein superconductivity is seen as an advanced, but evolutionary concept. With this plan in mind, the NAVY has committed funds now to explore magnet stability for forces, strains, and vibrations anticipated in a Naval systems. The program will also explore advanced LTS conductor design (Aluminum stabilized matrix, and Nb<sub>3</sub>Sn conductors) as well as improved refrigeration designs and test. HTS materials are not considered in this program at the present time.

NAVY scientists and managers are actively involved with other major DoD efforts in superconductivity. They serve as reviewers, advisors, and in some cases as agents in a number of programs. In this manner the NAVY's program is thoroughly integrated into the overall efforts of the nation as a whole toward the rapid development of superconducting products, military or commercial.