ABSTRACT
Fiber optics is a new, rapidly developing technology that has the potential for improving the survivability and combat effectiveness of the Navy's ships and aircraft. Fiber optics is quickly finding potential application in almost every type of military weapon system, and the number of applications is growing daily. The Navy's requirements for fiber optics cover a wide range of applications, including data transfer, guidance and control, machinery control, damage control, communication, and sensing.

This paper will discuss why fiber optics is important to the Navy, how the technology is being used, the status of fiber optic standards, and the mission of the Navy's new Fiber Optics Standardization Office.

INTRODUCTION
Optical fibers have unique characteristics and capabilities that are extremely useful in military applications. First, the data-carrying capacity of the hair-thin fibers is thousands of times greater than that of coaxial cable. This huge capacity is being considered for several of our new weapon systems.

Second, optical fibers are essentially immune to electromagnetic interference from lightning and radio or radar transmitters, and they can survive electromagnetic pulses from nuclear explosions.

Third, fiber cables can be made very secure. In the military, we spend a lot of time and money ensuring that our classified data links are secure. A standard copper cable can be tapped by wrapping a coil of wire around it. To tap an optical cable, you must cut into the cladding and remove some of the light, causing a power loss that is easy to detect.

Fourth, optical fibers are made from either plastic or glass and thus do not conduct electricity. Because there is no electricity, and therefore no danger that a short circuit will cause sparks or high temperatures, we can safely use fiber cables in highly explosive environments such as fuel and munition storage areas. In addition, the nonconductive properties of fiber optic cables isolate the optical transmitters and receivers in the system. The isolation eliminates the need for a common electrical ground, with its attendant ground-loop and line-balancing problems. The isolation also decreases the noise in the electronic part of the system.

Fifth, glass fibers are rugged. The hair-thin fibers are being deployed from airplanes and missiles. They are being proof tested at tensile strengths of more than 1.4 gigapascal (200,000 pounds per square inch) and have survived accelerations greater than 2,000 g's.

MILITARY APPLICATIONS
The introduction of fiber optics into military systems is proving to be very cost effective. For example, installing coaxial cables in an aircraft carrier for one type of radar costs $130 per meter. The total installation cost is about $1,300,000. Comparable installation costs for a fiber optic cable would be about $30,000. In undersea fiber optic cables, repeaters can be spaced at 30- to 50-kilometer intervals, rather than the 2- to 3-kilometer intervals required by metallic cables. In land use, the Army's Fiber Optic Transmission System (FOTS) realized an 80% reduction in the number of repeaters and a 60% reduction in the number of cable reels in comparison to what is needed in a conventional system.

Military applications of fiber optics continue to increase. One projection is for over 125 applications of the technology in military systems by 1989. The Army and Air Force are conducting a variety of programs. The goal of a joint effort, the Tactical Generic Cable Replacement (TGC) program, is to develop an optical modem that will permit the use of optical fibers in a variety of 26-pair cable applications. In a separate program, the Army has demonstrated the size and weight advantages of fiber optics by deploying fiber optic cable from helicopters at speeds of up to 130 miles per hour. The rapid deployment system virtually eliminated reel weight and reduced cable weight to 25 pounds per kilometer.

The Navy's requirements for fiber optics cover a wide range of applications, including data transfer, guidance and control, machinery control, damage control, communication, and sensing. In sensor technology, the Navy is conducting research in the use of fiber optic acoustic, mag-
ment multiplexed communication aboard AEGIS-class cruisers. A fiber optic data link connecting the AEGIS Computer Center, Program Assurance Facility, and System Control Laboratory is also being considered.

STANDARDS AND SPECIFICATIONS

If the benefits of the unique characteristics of fiber optics are to be realized in military systems, standards and specifications must be written. In many fields, the need for standards has been recognized throughout history. In a recent (March 1985) Smithsonian magazine article titled "A Long, Arduous March Toward Standardization," author Achsah Nesmith presents many examples of man's attempts at standardization--and the difficulties encountered in those attempts. For example, the cubit--a measure widely used in the ancient world--was based on the length of a man's forearm, but the exact measurement varied greatly. Egypt used both a man's cubit, 17.72 inches, and a king's cubit, 20.62 inches. Yet, measurements for the Great Pyramid of Giza and other such structures were remarkable for their accuracy. The Roman mile equaled 1,000 paces, hardly a specific unit of measurement. The English Saxon yard was ostensibly based on a man's girth, but the measure varied so much that Henry I decreed that a yard would equal the length of his arm.

Closer to home, in 1789 the Constitution charged Congress with fixing standard weights and measures, and even George Washington urged action. Thirty years later, in 1819, Congress ordered a study and John Quincy Adams (then Secretary of State) was asked to conduct it. Two years later, Adams produced a booklength report documenting the discrepancies in America's weights and measures. Almost a decade later, nothing had been done, but another study was commissioned. Some progress was made during the next 25 years, and by then industrialization created even greater needs for standards. The Civil War also created new needs, and in 1863 the Secretary of the Navy established a standard gauge for screw threads and diameters of bolts and nuts used in Navy yards.

Examples of other standardization problems abounded in the United States through the following decades, perhaps the most well known being attempts to standardize rail gauges so the country's railroads could interconnect. Loss of life, unfortunately, was also a result of lack of standardization--in 1894 in Pennsylvania, 27 boilers exploded simultaneously, killing thousands of people. In 1910, with boiler explosions occurring at a rate of 1,400 a year, the American Society of Mechanical Engineers wrote a comprehensive boiler code that virtually ended explosions.

Of course, what these historical examples tell us is that the need for standards and the difficulties in establishing them are not new. In fiber optics, we are trying to address the same kinds of needs for the same reasons--efficiency, effectiveness, cost reduction, and safety. The development of standards and specifications has a direct bearing on increasing the acceptance and use of fiber optics in the Navy and the other services. Navy standards development must be conducted in coordination with other DOD organizations and with industry to maximize standardization of fiber optic components and systems where standards are appropriate and do not restrict technology's progress.

If the military is to reap the full benefits of using fiber optics, we need a full range of standards and specifications. The situation in connectors is an illustration of the disorder caused by lack of standardization. NATO has a written specification for single-fiber connectors corresponding to the Amphenol 905 SMA-style. In current US programs, the connector that the military has qualified for tactical communication systems is made by Hughes in formats from two to eight fibers. The use of the Hughes connector, however, is not universal--Magnavox's AN-GRC-206 tactical communication system uses the FOMC connector made by ITT. For the long-haul FOTS, the connector is made by ITT/STC, an English company. The problems caused by this kind of situation are obvious.

A commonly held view is that market forces will contribute to settling the fiber optic standards question ("Fiber Optic Trends: What's Happened to Standards," Photonics Spectra, February 1985). As they have in other technologies, those forces undoubtedly will play an important role. We cannot, however, rely on the market to solve all the problems--the process would take too long.

We must move ahead carefully but quickly to increase standardization everywhere that it is feasible and sensible to do so. Standards are not specific formulas for designs. They are instruments for eliminating unnecessary inconsistency and stimulating potential users to take advantage of technology. They must be broad enough to accommodate the changing technology, specific enough to be of use, and they must not be mere revisions of electrical standards.

Neither the military nor industry wants to be restricted by rigid standards, but they also do not want the chaos created by lack of standards or the confusion caused by using standards from other technologies as a basis for developing fiber optic standards. Because both groups want to see fiber optic standards development move more quickly, they are frustrated at the slowness of the pace. Each group can see in the other the causes of the slow pace, and each has valid points. If the objective--the development of useful standards--is kept in view, the two groups can work together to reach it.

NAVY FIBER OPTICS STANDARDIZATION OFFICE

Part of the Navy's effort to reach the goal, predicated on increased recognition of fiber optics' advantages, is the establishment of the Fiber Optics Standardization Office (FOSO). The office was established in October 1984 at the Naval Research Laboratory as part of the Fiber Optics Technology Program Office. The office charter from the Chief of Naval Material authorizes FOSO to "...act as the Chief of Naval Material's principal technical agency to expedite Navy acceptance of fiber optic technology."

3.1.2
The head of this new office is the Fiber Optic Standards Manager (FOSM), the position I assumed in December 1984. The FOSM is assigned functional responsibility for developing fiber optic standards and related specifications for the Navy. Specific responsibilities include (1) establishing and maintaining a Navy database of fiber optic standards and specifications, (2) supporting Navy program and acquisition managers in developing fiber optic standardization documents, (3) establishing and funding technical panels to draft fiber optic standards and specifications, (4) conducting technical reviews of draft fiber optic standards and providing comments to the cognizant Command Standardization Office, (5) providing validation testing, and (6) developing a user feedback system to evaluate and correct deficiencies.

To meet these responsibilities, my office will work in coordination with other organizations involved in fiber optic standards development. These organizations include the Defense Materiel Specifications and Standards Office (DMSSO), Defense Electronics Supply Center (DESC), Tri-Service Fiber Optic Coordinating Structure, the other services, and industry groups such as the Electronic Industries Association (EIA), Society of Automotive Engineers (SAE), American National Standards Institute (ANSI), Institute of Electrical and Electronic Engineers (IEEE), International Electrotechnical Commission (IEC), and International Telegraph and Telephone Consultative Committee (CCITT).

We are reviewing published fiber optic standards and those being developed. The review includes work being done by DOD and other Federal Government agencies and both American and international industry organizations. The result of this review will be a data base of standards and specifications organized by category (for example, fiber, cable, connector), originating organization, and development status. The data base will be used to determine what is needed to meet emerging requirements. This computerized data base will have versatile search capabilities and be readily accessible to Navy users to help them develop acquisition documents or specifications to meet their fiber optic requirements.

The Fiber Optics Standardization Office will also provide a variety of other services, including tutorials to familiarize program managers and engineers with fiber optics, briefings for military and industry groups on standards and specifications, and workshops for program managers on system design and engineering. As the Navy expands its use of fiber optics, the office will assist acquisition managers in identifying integrated logistic support requirements for implementing the new technology, and will help identify the needs for training personnel in the use of the technology and assist training organizations to meet those needs.

3.1.3

CONCLUSION

The Fiber Optics Standardization Office will play a major role in expediting the Navy's acceptance and use of fiber optics. By stimulating and coordinating development of Navy fiber optic standards and specifications and by encouraging and enabling Navy acquisition managers to take full advantage of the technology, the FOSO will help bring the benefits of fiber optics to the Navy. The "long, arduous march toward standardization" continues, but we in the Navy intend to shorten that march. The march may be no less arduous, but it will result in a more organized approach to solving the old problems of standards and specifications.