Centurion Harbor Surveillance Program for Homeland Security Applications

Northrop Grumman's FOAS technology is a key element in the Centurion Port-Harbor Anti-Terrorism/Force Protection system which provides the operator with a complete status of the harbor he is monitoring.

The integrated sensor and display product shows the harbor vicinity and potential threats on a standard Navy display system located at the test site. During a demonstration, divers with a battery-powered underwater propulsion device were easily detected attempting to penetrate the harbor. Surface craft traveling in the test area, and entering the restricted Port of Hueneme, were also detected and tracked.

The proof-of-concept demonstration was completed within three months of the contract award by the U.S. Navy's Maritime Surveillance Systems Program Office, utilizing passive fiber-optic sensor arrays and support equipment delivered by Northrop Grumman's Navigation Systems Division, coupled with commercial-off-the-shelf equipment provided by Northrop Grumman's Sperry Marine business unit in Portsmouth, Virginia.

The equipment provided by Sperry Marine included the marine radar, Automatic Identification System (AIS) shipboard identification system, and the digital electronic charting system that provided the common integrated harbor picture.

The Northrop Grumman team completed a threat analysis for the port and determined the most effective locations to place the underwater arrays. The array installation was performed with the assistance of Naval Facilities Engineering Support Center and the team's ocean engineering subcontractor, Sound and Sea Technology, Inc. of Edmonds, Washington and Ventura, California.

Performance benefits of this technology include unattended detection, identification and tracking capabilities for the harbor defense applications. Since no electronic components are in the water, the fiber-optic arrays provide a highly reliable solution that also offers reduced acquisition and maintenance costs. The arrays employ glass fibers instead of older technology piezoelectric hydrophones to convert sound to modulated light for efficient transmission to shore.
Fiber-Optic Acoustic Sensor Array Systems.

Northrop Grumman is a leading developer of fiber-optic acoustic sensor array systems. FOASs are designed to simplify the detection of acoustic energy by using fiber-optic elements in an array configuration. FOASs are not operated on a reference mandrel, and changes in the distance the light travels through the optical fiber wrapped around the sensor are used to detect acoustic energy. Optic fibers wrapped around the sensor mandrel, which is located far from the sensor to stretch or relax. When light is projected through the optic fiber wrapped around the sensor mandrel, the acoustic energy is detected by changes in the distance the light travels through the optic fiber. The distance the light travels through the optic fiber is a reference measurement, and differences between the two are used to detect acoustic energy. Immunity to high radiation, electromagnetic interference, and mechanical vibration are advantages of fiber-optic acoustic sensors. FOASs are superior to equivalent ceramic arrays and have several advantages, including:
- Superior reliability due to a simpler array design
- Reduced maintenance costs
- Lower cost to manufacture
- No underwater electrical components
- Light weight and small cable diameter
- Reduced maintenance and recovery of the array
- Immunity to electromagnetic interference (EMI)
- Immunity to high vibration

Other advantages of fiber-optic acoustic sensors include:
- Critical to detect since the fiber-optic sensor array contains no non-metallic materials.
Northrop Grumman’s Optical Navigation Systems Division has applied its expertise in fiberoptic technology to develop a line of acoustic sensors it calls Fiber-Optic Acoustic Sensors (FOAS). FOAS originated in 1981 as part of a major effort to develop both fiberoptic gyroscope and fiberoptic hydrophone sensor technologies. This effort, which has required investment of over $140 million, has established Northrop Grumman as the world’s leader in optical acoustic sensor technologies.

FOAS Description and Capabilities
Northrop Grumman can produce fiberoptic acoustic sensor arrays for a variety of applications. Northrop Grumman builds these FOAS systems in two arrays: the Light Weight Wide Aperture Array (LWWAA) and the Centurion Acoustic Evaporative Sensor (CAES). The LWWAA system currently on USS Virginia-Class Submarines, transmits sound to submarine ammunitions and other applications, and transmits waveforms for deep-sea and shallow-littoral sonar systems.

The arrays themselves comprise only passive fiberoptic elements, and contain very few parts and no electronics. One remote transmitter/receiver station houses all the necessary optoelectronics. The data are transmitted on a low single mode fiber, over distances of more than 100 kilometers.

Over the past 15 years, Northrop Grumman and the U.S. Navy have made significant strides in developing fiberoptic sensor technology for precise acoustic monitoring. This work has focused on demonstrating the advantages of fiberoptic over conventional piezoelectric sensor arrays.

One of the primary advantages of fiberoptic acoustic arrays is their simplicity. Conventional acoustic arrays require precise, complex electronics and signal processing to be located close to the sensor to overcome resistance losses. Ceramic sensors also have numerous connectors and mechanical joints that introduce variability. The electronic processing elements of a fiberoptic array are located in a dry environment and are not affected by mechanical or environmental shifts, which is not possible with legacy ceramic arrays.

FOAS sensors are standard interconnect equipment. The acoustic signal is wrapped tightly around a fiber optic transmission standard. As pressure from the acoustic event moves across the sensor mandrel, it changes shape causing the optical fibers to stretch or relax. When light is projected through the optical fiber wrapped around the sensor mandrel, the acoustic energy deforms the fiber and changes the distance from the light to the fiber.

The resulting change in optical path length is detected and measured. The optical path difference between the two, representing the acoustic energy, can easily be measured and passed on to the signal processing equipment.

The performance of these arrays has been superior to equivalent ceramic arrays, and its ruggedness and flexibility have been exceptional. It is expected that future towed arrays systems will transition to fiberoptic technology to take advantage of the lower cost, reliability and ruggedness.

Surveillance Systems
FOAS systems are operational in all types of terrain and marine environments, including perimeter security, harbor monitoring, and ground surveillance. Depending on the application, these arrays may contain optical geophones, fiberoptic hydrophones, and other optoelectronic components.

Other advantages of fiberoptic arrays over conventional arrays include:

- Lower power requirements
- Increased reliability due to a simplified array design
- Reduced maintenance costs
- Lower cost to manufacture
- No underwater electrical components or cabling
- Light weight and small cable diameter, which facilitate concealment and recovery of the array
- Immunity to electromagnetic interference (EMI)
- Inability to sink or be hit by foreign objects
- Optimal for use in all types of terrain and marine environments
- Accommodation to accommodate such applications as navigational security, harbor monitoring, and ground surveillance. Depending on the application, these arrays may contain optical geophones, fiberoptic hydrophones, and other optoelectronic components.

The Centurion Harbor Surveillance program demonstrates our FOAS capabilities in the area.


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**B key Principle of FOAS Operation**

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**Ceramic Arrivals**

Ceramic acoustic arrays require power, complex electronics and signal processing to be located close to the sensor to overcome resistance losses. Ceramic sensors also have numerous connectors and mechanical joints that introduce variability. The electronic processing elements of a fiberoptic array are located in a dry environment and are not affected by mechanical or environmental shifts, which is not possible with legacy ceramic arrays.

**Arrays for Deep Ocean and Shallow/Littoral Applications**

Northrop Grumman builds FOAS array.

**Arrays for Submarine and Other Applications**

FOAS technology has been applied to a variety of applications, including submarine and underwater acoustic arrays.

**Arrays for Underwater Acoustic Applications**

FOAS sensors have been designed and developed high channel count fiber optic arrays for submarine applications.

**Arrays for Underwater Surveillance**

The performance of these arrays has been superior to equivalent ceramic arrays, and its ruggedness and flexibility have been exceptional. It is expected that future towed arrays systems will transition to fiberoptic technology to take advantage of the lower cost, reliability and ruggedness.
Northrop Grumman Corporation’s Navigation Systems Division has applied its expertise in fiber-optic technology to develop a line of acoustic sensors it calls Fiber-Optic Acoustic Sensors (FOAS). FOAS originated in 1981 as part of a major effort to develop both fiber-optic gyroscope and fiber-optic hydrophone sensor technologies. This effort, which has required investment of over $140 million, has established Northrop Grumman as the world’s leader in optical acoustic sensor technology and exclusive manufacturer of Department of Defense fiber-optic acoustic sensor array systems.

FOAS Description and Capabilities

Northrop Grumman can produce fiber-optic acoustic sensor arrays as a service to any customer. A Northrop Grumman Fiber-Optic Acoustic Sensor Array (FOAS) array is an all fiber-based advanced acoustic detection system. The FOAS array is a set of arrays, each of which is mounted on either side of the submarine, which transforms acoustic energy by converting ultrasound into light energy. The optical signals are transmitted and passed on to the signal processing equipment.

Light Weight Wide Aperture Array on Virginia Class Submarines

The Navy’s newest Virginia-class submarine employs a Light Weight Wide Aperture Array (LWWAA) on its hull for advanced underwater surveillance. The LWWAA system is designed, developed and manufactured by Northrop Grumman. The LWWAA system is a fiber-optic acoustic sensor array that has been developed by the U.S. Navy and Northrop Grumman as part of a major effort to develop both fiber-optic gyroscope and fiber-optic hydrophone sensor technologies. This effort has required investment of over $140 million, has established Northrop Grumman as the world’s leader in optical acoustic sensor technology and exclusive manufacturer of Department of Defense fiber-optic acoustic sensor array systems.

FOAS Architecture and Capabilities

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Basic Principle of FOAS Operation

FOAS sensors are standard interferometric sensors, optimized for applications in a large variety of submarine environments. As pressure from the acoustic event moves across the sensor mandrel, it changes shape causing the optical fiber to stretch or relax. When light is projected through the optical fiber wrapped around the sensor mandrel, the acoustic energy deforms the optical fiber. The resulting change in the position of the light beam is converted into an electrical signal.

The arrays themselves contain only passive fiber-optic elements, and contact very few parts and no electronics. One remote transmission station houses all the necessary electronics, the data are transmitted on a single mode fiber, over distances of more than 100 kilometers. Over the past 11 years, Northrop Grumman and the U.S. Navy have made significant strides in developing fiber-optic acoustic sensor technology for passive acoustic monitoring. This work has focused on demonstrating the advantages of fiber-optics over conventional piezoelectric sensor arrays.

One of the primary advantages of fiber-optic acoustic arrays is their simplicity. Passive acoustic arrays require no power, no complex electronics and signal processing to be located near the sensor to overcome resistance losses.

Ceramic sensors also have numerous connectors and mechanical joints that reduce reliability. The electronic processing elements of a fiber-optic array are located in a dry or controlled environment or on a submarine or on shore. Their location at these sites is known for maintenance purposes and technological advances, which is not possible with existing ceramic arrays.

Other advantages of fiber-optic arrays over conventional arrays include:

- Lower power requirements
- Increased reliability due to a simplified array design
- Reduced maintenance costs
- Lower cost to manufacture
- No underwater electrical components or wiring
- Light and small size, which will facilitate installation, deployment and recovery of the array
- Insensitivity to electromagnetic interference (EMI)
- Improved modularity in size and shape
- Reduced maintenance costs

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Performance benefits of this technology include unsurpassed detection, identification and tracking capabilities for the harbor defense applications. Since no electronic components are in the water, the fiber-optic arrays provide a highly reliable solution that also offers reduced acquisition and maintenance costs. The arrays employ glass fibers, instead of older technology piezoelectric hydrophones, to convert sound to modulated light for efficient transmission to shore.
Centurion Harbor Surveillance Program for Homeland Security Applications

Northrop Grumman's FOAS technology is a key element in the Centurion Port-Harbor Anti-Terrorism/Force Protection system which provides the operator with a complete status of the harbor in near-real-time.

The integrated sensor and display product has the harbor security and potential threats on a standard Navy display system located at the test site. During a demonstration, divers with a battery-powered underwater propulsion device were easily detected attempting to penetrate the harbor. Surface craft traveling in the test area, and entering the restricted Port of Hueneme, were also detected and tracked.

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