SECURING SAFETY WITH SENSORS

ORIGINATING TECHNOLOGY/ NASA CONTRIBUTION

The Robot Systems Technology Branch at NASA's Johnson Space Center collaborated with the Defense Advanced Research Projects Agency to design Robonaut, a humanoid robot developed to assist astronauts with Extra Vehicular Activities (EVA) such as space structure assembly and repair operations. By working side-by-side with astronauts or going where risks are too great for people, Robonaut is expected to expand the Space Agency's ability for construction and discovery.

NASA engineers equipped Robonaut with human-looking, dexterous hands complete with five fingers to accomplish its tasks. The Robonaut hand is one of the first being developed for space EVA use and is the closest in size and capability to a suited astronaut's hand. As part of the development process, an advanced sensor system was needed to provide an improved method to measure the movement and forces exerted by Robonaut's forearms and hands.

Astro Technology, Inc., of Houston, Texas, rose to the challenge by developing a new sensor system that could measure the bending of the fingers, tactile forces at the finger tips, and tendon forces in the forearm. The company based the sensors on fiber-optic sensing technology and developed a small, high-rate data signal conditioning and acquisition system. With this new system, measurements that could not be accomplished with conventional methods were now possible.

Astro Technology's Fiber-Optic Sensor System (FOSS) overcomes the technical limitations of the previous method of using conventional strain gauges, such as susceptibility to electrical noise, difficult attachment techniques, cable handling limitations, and the need for a large data acquisition system to support a large number of sensing elements. The fiber-optic sensors are immune to electrical noise since the sensing element and cable require a light source rather than an electrical current. Cabling needs are significantly reduced, requiring fewer cables to pass through the wrist and forearm where space is limited. The small size of the fiber-optic sensors provides superior attachment methods relative to conventional sensors, and the miniaturized data acquisition system can reduce the size and weight for space flight and operation with the Space Shuttle and International Space Station.

PARTNERSHIP

NASA Johnson granted Astro Technology a Phase II **Small Business Innovation Research (SBIR)** contract to develop the FOSS, which will be used to instrument the Robonaut hand aboard the International Space Station. The contract followed Astro Technology's completed Phase I SBIR contract with Johnson, which tasked the company with applying the technology to robots used on the Space Shuttle. Astro Technology's advancements from its Robonaut development efforts paved the way for the application of new sensing methods in the oil and gas industry.

PRODUCT OUTCOME

Astro Technology engineers miniaturized and ruggedized the FOSS to meet the needs not only of NASA's Robonaut program, but for solid rocket motor testing applications and oil and gas subsea monitoring as well. The company has contracted with major oil companies to apply its FOSS technology to evaluate fatigue on subsea pipelines, risers, and offshore drilling and oil production rigs.

Astro Technology, Inc.'s Fiber-Optic Sensor System has applications ranging from deepwater drilling risers to the instrumentation of NASA's Robonaut.

Over the past decade, new oil reserves have been discovered in deepwater environments around the world. These deepwater reserves are capable of providing a constant stream of fossil fuel energy for many years, making their development increasingly important as energy consumption pressure increases.

Extensive technology requirements are necessary to develop the deepwater reserves, since many of the oil fields are in water depths of 7,000 feet or greater. Oil pipelines or risers must be greater than 1 mile in length and are unsupported from a well head to the water surface. Once the pipelines are in place, water currents flowing past the pipeline create a vortex-induced vibration that can cause the riser to fail from fatigue damage. Additional high-stress areas that could fail are located where the pipeline touches down on the ocean floor. Predictive monitoring is essential where failure could be catastrophic both economically and environmentally.

Astro Technology engineers adapted the FOSS technology to monitor and determine the service life of these subsea pipelines. The company developed risk management software to calculate real-time service life evaluations and cumulative fatigue using rain-flow analysis techniques. By calculating total fatigue based on the logged history of real-time strain measurements, the system is able to perform predictive failure analysis in order to determine which riser sections need to be replaced. As a result, costly repair and downtime are reduced and potential environmental contamination from hydrocarbon spillage is eliminated. Optimized for harsh operating environments, the sensor system has been deployed in deepwater fields in the Gulf of Mexico.

The FOSS technology is also suited for applications such as high-speed data acquisition systems for measuring strain and temperature in wind tunnel tests, structural monitoring of aircraft, and sensors in automobiles. In the meantime, the technology is bringing value to NASA, as Astro Technology's FOSS can be applied to both the current Robonaut version and its next-generation design.

One of the large oil rigs to which Astro Technology, Inc., is applying its sensor technology is now installed in the Gulf of Mexico.

The accurate, robust, and reliable sensors can integrate into a Robonaut hand with minimal interference with the mechanical design. The company's predictive failure analysis software could also be adapted to monitor space vehicle structures and subsystems, including propellant lines.