UCRL-JRNL-203792

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LLNL Microsensors Program

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April 26, 2004

LLNL Engineering Review

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This work was performed under the auspices of the U.S. Department of Energy by the University of California, Lawrence Livermore National Laboratory under Contract No. W-7405-Eng-48.

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Introduction

The Microsensors Program was born out the need for enhanced sensor technology in support of the Weapons Program. In the interest of expanded diagnostic capabilities to provide true performance characteristics of weapon assemblies in flight and ground tests, a suite of sensor requirements was proposed. These potential new sensor technologies were envisioned to be completely unobtrusive and allow for the development of test vehicles (mock warheads and bomb assemblies) that were designed to mechanical and electrical specifications as close to the stockpile weapon design configuration as possible. The closeness of a test vehicle design to the respective stockpile weapon design is referred to as "fidelity," with the term "high-fidelity" to mean all components are designed to emulate, very closely, the true system design. These efforts were in line with many activities associated with Stockpile Stewardship and were intended to enable better modeling and performance assessment without the need for underground testing. Several weapons are currently undergoing Life Extension Programs (LEP) to lengthen each weapon system's respective service life. The ability to assess the projected life of these complex assemblies is crucial to the success of the LEP activities.

Main Focus

The Microsensors Program is a collaboration between W Program and the Engineering Directorate to leverage institutional capability and facilitate the development of new sensor technologies in a time frame necessary to support the design and fielding of a new family of Joint Test Assemblies (JTA). JTA assemblies are test vehicles used in the weapon certification process and are one of the primary performance assessment tools available for stockpile certification. Each JTA and associated flight test is an expensive exercise; therefore, it is highly desirable to leverage as much information a possible from each event. The ability to design and field high fidelity JTA assemblies that include a comprehensive suite of sensors and on-board diagnostic capabilities has tremendous benefits, and it is this goal that provides the primary motivation for the Microsensors Program.

In the interest of supporting the stockpile certification process across the weapons complex, the Microsensors Program looks for opportunities to involve and collaborate with other national laboratories in an effort to accelerate these developments. Additionally, commercial technology advancements and industry capabilities are continually monitored to ensure that duplication and misdirection are avoided.

Additionally, in the interest of facilitating complex-wide collaborations and dialog, the Microsensors Program organizes an annual on-site, multi-laboratory Sensors Workshop. This workshop is intended to foster the sharing of information and activities associated with weapons-related sensor developments, as well as to provide a forum for discussing current needs and evolving requirements. The workshop is held in an environment that allows for classified discussions and has been quite successful, attracting participants

from LLNL, LANL, SNL/NM, SNL/CA, KCP, and AWE. This year's workshop was also expanded to include related sessions on bio-sensors and homeland security technology.

Technologies

The Microsensors Program continually looks to leverage any technology that has potential applications in its mission to develop new sensor technology. Though many potential sensor technologies are being pursued, the primary focus is on optically-based sensor technology. Optical technology provides several significant benefits that cannot be realized with conventional analog sensor technologies. The main concern with respect to the deployment of embedded sensors and weapons system is safety. Optically-based sensors are considered to be intrinsically safe and can be readily employed in environments that also include hazardous or volatile elements such as high explosives (HE). The ability to embed sensors in an assembly that contains HE allows for performance characterization of complex assemblies not previously pursued due to safety concerns. As an example, we have been working together with LANL to develop optical shock sensors to measure HE performance in a weapon assembly. These sensors are intended to determine information about the shock wave from an HE detonation as it passes through a mechanical assembly. The performance requirements are a significant challenge in terms of extremely fast response and timing specifications, as well as the environment that must be survived.

Fiber optics and optical sensor technology has seen dramatic advancements in recent years. We have leveraged these advancements and new technologies, as well as developing new, unique capabilities and optical sensor technologies. We have been working with a commercial optical sensor manufacturer (FISO, Inc.) to deploy both COTS devices and LLNL-developed sensors based on technology developed at FISO. Off-the-shelf sensors include strain gauges, temperature sensors, and pressure sensors. We have used FISO strain gauges in the development of a gap gauge designed to measure up to 2 mm gaps in nm increments. In addition, we are using white light Fabry-Perot interferometry techniques in advanced designs for micro accelerometers, strain gauges, and gap gauges. These sensors combine advanced micromachining and white-light interferometry to realize extremely small geometry sensors.

A unique method of using coherent light polarization as a means for sensor design has been demonstrated. Using a unique magneto-optical assembly, the polarization of laser light traveling through a fiber can be controlled, and therefore employed as a sensor. Practically any mechanical, and even a few electrical, phenomena can be measured by the appropriate application of this technology.

It can be readily shown that sensor development is focused on small geometries. Though we have realized and witnessed significant advances in this area, one technology that is consistently overlooked is the signal processing component. Our needs dictate that the signal processing components also be small, low power, and unobtrusive. To satisfy this requirement, we have demonstrated a 3 channel solid-state optical processor that

measures approximately 1 cm^3. This device converts optical information into quadrature analog signals and leverages thin-film technology for advanced optical filter design.

In addition to optical sensor developments, we have made advancements in several analog sensor applications. These sensor developments have been pursued with the intent to maintain high fidelity mechanical assembly designs. An example of this work is the demonstration of an acoustic sensor technology developed specifically to provide the ability to "look through" complex geometries or take advantage of existing assembly structure to evaluate the dynamic performance of internal sub-systems. The acoustic sensor is being designed into the next generation W80 JTA.

We have also developed a new force sensor technology that was initially being developed for medical applications. Using single-crystal silicon micromachining techniques, we have developed a 2 dimensional array of sensors that measures about 3 mm thick that is used to examine the contact force profile at the interface between two surfaces. The motivation for this sensor was to be able to perform this measurement in real time while not compromising the high-fidelity assembly design. Conventional load cells are quite large and obtrusive. These sensor arrays are assembled in a 3-layer kapton frame and is intended to provide the ability to conform to complex surface curvatures. This sensor array is also identified as a component in the next generation W80 JTA. The intent is to embedded the force sensor array in the existing assembly as a replacement component (pad, spacer, or shim) with similar mechanical dimensions as the component being replaced.

Other sensors that have been developed include capacitive proximity sensors, time domain reflectometry (TDR) sensors, and resonant cavity sensors. Each technology that is pursued has the common goal of small size, unobtrusive geometry, and robust performance.

We are engaging in a series of captive carry flight tests to evaluate the first products from the Microsensor Program in a flight environment. Intended as a survivability test (the combination of environments is not attainable elsewhere), the sensors will be evaluated in a true flight environment as well as being compared to conventional analog sensors from a performance perspective.

Organizations

Electrical engineering – EETD, DSED
Mechanical engineering – DTED, MMED
W Program

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Web Site

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