MEMS Program
Precision Guided Weapons Aim for Increased War Impact

Precision guided weapons have made a significant impact in recent armed conflicts in the War on Terrorism. These weapons offer increased accuracy resulting in a greater percentage of enemy targets destroyed with less chance of collateral damage. It is estimated that 70% of the bombs used in the recent War in Iraq (Operation Iraqi Freedom) were guided. Precision guided weapons frequently use the Global Positioning System (GPS) to home in on a target in conjunction with an inertial measurement unit (IMU) that is internal to the weapon. These guided munitions are presently the weapon of choice, and ongoing DOD funding efforts indicate a trend toward the production of smaller guided weapons with enhanced accuracy. The increased use of smaller, more accurate precision guided weapons will rely on electronics manufacturing improvements that enable high-g survivability at reasonable cost.

Efforts are underway to produce a new class of precision guided munitions. Examples include the Army's Excalibur and the Navy's Extended Range Guided Munition (ERGM). Extending the precision guidance capability to munitions fired from Navy ships would allow precision strikes on enemy targets that are within range of the shoreline. The ERGM round will be fired from a gun barrel on a Navy ship, have the ability to travel a distance of around 40 miles, and impact within meters of its target. The ERGM round is approximately 5 feet long and includes a rocket motor that fires briefly after leaving the gun barrel. The round will be guided by GPS, but will also have a form of inertial guidance (inertial meaning functions without external reference or communication), known as an IMU (Inertial Measuring Unit). The IMU is used initially and potentially during the final stages of the mission. Upon approach to the target, the GPS signal can be lost or jammed by the enemy. In this scenario, the IMU can complete the mission by leading the round to the target. Guidance information is processed and used to adjust aerodynamic fins on the side of the round in order to change its flight course.

One enabling path to producing precision guided weapons such as ERGMs is to produce functional, gun-hardened IMUs at a reasonable cost. IMUs are units containing both accelerometers to measure linear acceleration, as well as gyroscopes which measure angular rates. IMUs based on Micro Electro-mechanical system (MEMS) technology are being considered due to their small size, low-cost and expected long-term reliability. MEMS technology typically refers to small mechanical elements micro-machined into a silicon substrate, which also contains circuitry.

The U.S. Navy, Army and Air Force are currently committing funds to industry to develop low-cost MEMS IMUs for precision guided munitions. The EMPF is involved with a Navy Manufacturing Technology program to produce low-cost IMUs for precision guided munitions applications (Figure 1). The objective of this project is to achieve cost reduction through manufacturing improvements on Micro-electromechanical System (MEMS) based Inertial Measurement Units (IMU) for precision guided munitions such as the U.S. Navy's Extended Range Guided Munition (ERGM) as part of the Extended Range Munition (ERM) program organized by PMS 529. Previous efforts focused on improving yields of MEMS fabrication as well as automating testing for the MEMS sensor and the IMU for a candidate supplier, L-3 Communications. Current efforts are focused on integrating a lower cost MEMS accelerometer into the IMU of the current ERGM baseline MEMS IMU supplier, BAE Systems. In addition, long-term IMU storage issues will be addressed and high-g packaging guidelines will be established.

One of the main technical challenges associated with precision guided munitions is the need for the electronic hardware to operate after withstanding the high g forces (g's) associated with the gun firing. Munitions of this type typically experience gun shocks of 10,000 to 20,000 g's. Future applications for the Advanced Gun System [AGS] and the 105mm & 120mm rounds for the Future Combat System [FCS] will see environments producing a pull in excess of 20,000 g's.

In addition to high-g survivability, reduced size packaging will enable next generation guidance electronics such as the Deeply Integrated Guidance/Navigation Unit (DIGNU), which combines the Inertial Measurement Unit (IMU) and the GPS receiver into a four to five cubic inch unit. Achieving smaller, gun-hardened electronic systems can also enable new classes of guided weapons such as Helicopter fired missiles. Beyond control electronics lies the DOD need for micro-electronic packaging that can be utilized in new fuze programs [MOFA, MFF, HTSF to name a few], seekers and sensors for missiles. The need for the high-g survivability, along with the ever-increasing demand for higher performance and smaller electronics systems in PGMs, presents the need to establish and demonstrate electronics packaging guidelines for gun-hardened applications.

As part of the effort to manufacture gun-hardened IMUs and related PGM electronics, ACI has proposed to develop a set of gun-hardened packaging guidelines based on high-g test data. This guide could be used by numerous DOD manufacturers that make subsystems such as IMUs, GPS receivers, SAASMs, fuzes, and control electronics. ACI would select, assemble, and test packaging and interconnection approaches not currently proven in high-g applications that provide a definable benefit in terms of high-g survivability, size reduction, and/or cost. ACI can leverage its current involvement in the MEMS IMU area as well as its internal packaging capability, knowledge, and industry contacts. The work performed here would establish failure mechanisms of packaging currently being tested in high-g electronics such as wire bonding and flip-chip. Further investigation can include more advanced packaging approaches for consideration that would enable size reduction such as 3-D chip stacking, stud-bumping of MEMS, or use of a folded flex-rigid circuit board.

The selected packages would be assembled into test articles on The EMPF 's demonstration factory floor. The test articles would be tested off-site at an established high-g testing facility. The EMPF would use its in-house testing and analysis equipment to perform functional check-out and any associated failure analysis. In addition to the high-g survivability data, The EMPF could include the corresponding manufacturing guidelines for package assembly.

Establishing guidelines for gun-hardened electronics would allow all the manufacturers of high-g systems and subsystems to draw from a single source of packaging information. The intent would not be to completely mimic the gun-environment, but instead provide high-g test data to allow better electronic design, component, and material decisions by the DOD industrial base. The high-g test data for packaging would provide a basis of confidence that a packaging approach has merit and should be investigated further as next generation products are developed. In the end, this would not only contribute to the fielding of current and next generation PGMs, but it would do so with an emphasis on low cost, manufacturable packaging solutions.

Precision guided munitions have made a significant impact in recent armed conflicts. The level of investment from multiple DOD branches demonstrates the current interest in precision guided munitions. Through the efforts of the EMPF and programs such as Navy ManTech, the technology needed to expand and enhance the attributes of precision guided munitions can lead to their increased availability and affordability, thus meeting the Battlefield needs of today and tomorrow.