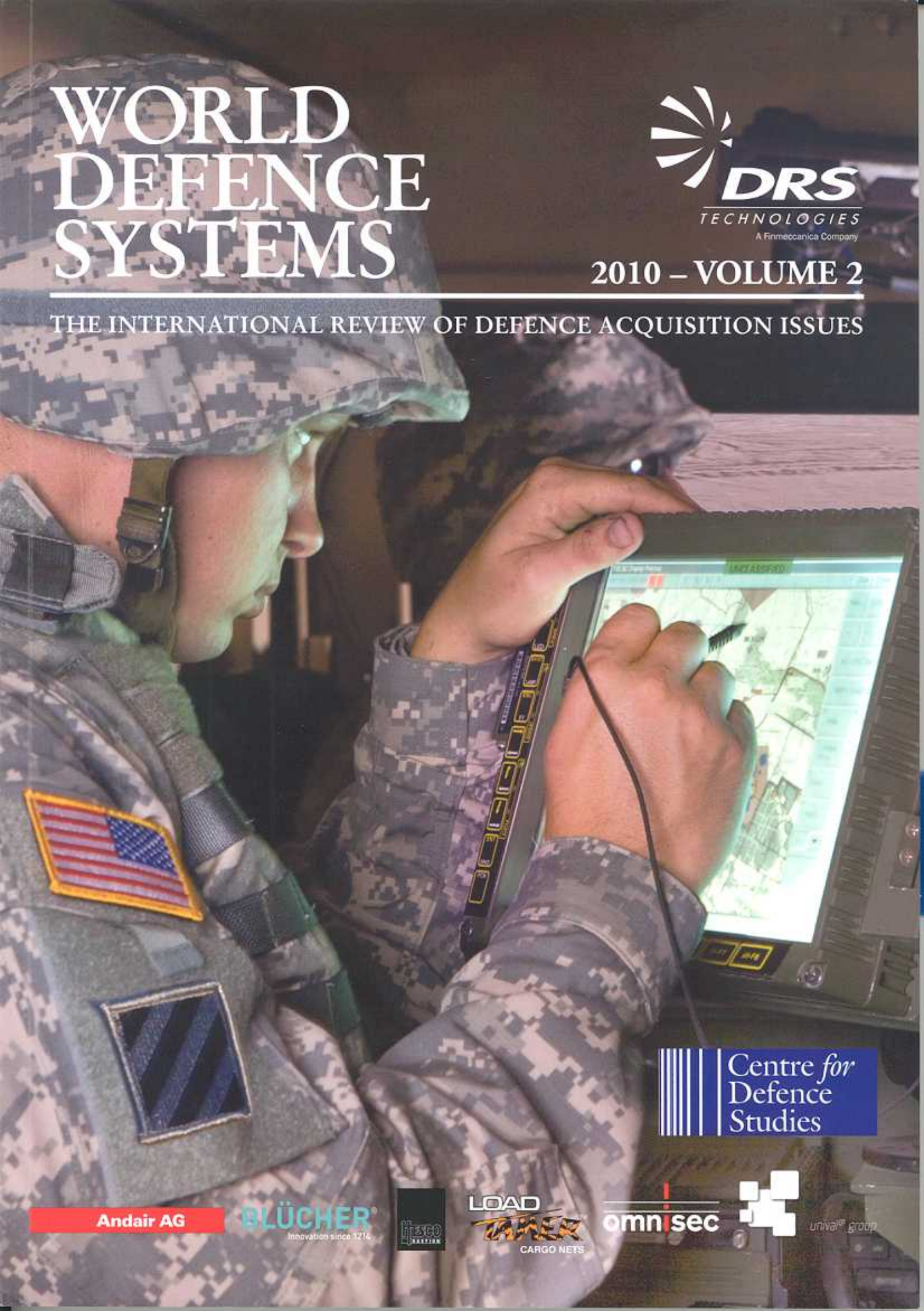


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MEMS Motion Sensors, the Solution for Harsh Environments in Defence Applications

[Colibrys](#)

MEMS accelerometers are precise even in harsh environment. One of the best example of utilization of the MEMS sensor technology in a very rugged defence environment is the M982 Excalibur, a 155mm extended range guided artillery shell, developed by United States based Raytheon Missile Systems and BAE Systems Bofors, a Swedish defence company and a subsidiary of BAE Systems Land and Armaments. This product includes a inertial control system with the goal to increase accuracy and to minimize collateral damages and to improve the efficiency when complex terrain limits the effectiveness of conventional projectiles and makes it difficult in term of logistic and supply. A major challenge for the control system is the inertial sensor that has to operate at full accuracy even after the extremely harsh launch environment.

This smart munitions, integrating Colibrys MEMS accelerometers, is capable, after an initial launch characterized by a gun hard shock of about 20'000g, to be guided by a GPS and/or an inertial unit to the target within a precision of few meters or less at a distance of approximately fifty kilometers.

This concrete example is the ideal illustration of how MEMS accelerometers penetrate more and more high end applications in the defence and aerospace market replacing the well established, expensive and fragile electromechanical devices. It is also the demonstration that the technology is enabling new applications thanks to both technical and economical advantages.

Many other applications in various Mil Aerospace and Civilian domains are taking advantage of this technology and contribute to the success of MEMS. They can be classified in three main families:

Inertial and tilt defence applications:

These applications are characterized by excellent long term stability (bias, scale factor, misalignments...), very low rectification error, good signal to noise, low power and high robustness.

Concrete examples are the inertial measurement units (IMU) for air, land and sea guidance and navigation and for attitude heading reference systems (AHRS). Such sub-systems are integrated in fix wings, helicopters, UAV and smart munitions but are also largely used for GPS backup or dead reckoning navigation as well as war fighter navigation. Civilian applications such as fire fighter navigation or underground miners' localization are directly inspired and taking advantage from such solutions.

The tilt control, range finding and stabilization of platforms such as antenna, radar, camera or gun stations represent a second family of applications requesting advanced and performing tilt sensors and where high end MEMS can offer definitive advantages.

Vibration and shock defence applications:

These applications require an accurate and stable monitoring of vibrations over a wide bandwidth and a wide g range, combined with high shock survivability and minimum impact on specifications.

Out of a large variety of applications, the most obvious are vibration control and preventive maintenance on moving vehicles such as helicopters, planes or land vehicles. These measurements can be performed in situ during operation or during the phase of qualification and test. Other typical examples of vibration and shock applications are the monitoring and control of transportation conditions of critical components such as missiles or instruments, mine-sweeping equipments or the latest intelligent emergency egress[1] systems.

Seismic defence applications:

Applications using seismic sensors are still emerging and taking slowly advantage of the very low noise, extreme resolution, high dynamic range and large bandwidth capability of the seismic sensors initially developed for earthquake monitoring and seismic imaging.

Typical example of applications are unattended ground sensors (UGS) used to secure a perimeter or track movement of troupes or vehicles and all kind of homeland security applications requiring very sensitive sensors for perimeter, border or building security.

Selection of the right solution

A majority of these applications have been traditionally served by electromechanical solutions, extremely performing but expensive and relatively limited in term of resistance to harsh environments. Such high end solutions can only survive shocks of few hundreds g, far from the 20'000g described in the

previous example. To address these market requirements, some people always try using upgraded versions of automotive and consumer sensors but with relative low success. It turns out that the basic technologies developed for these high volume applications, mainly driven by cost requirements, are not adequate to reach the required performance levels. This technical limitation is generally completed by a different business model with limited commitments to qualification requirements, fixed design principle and engagement to long term supply.

In the world of motion sensors, Colibrys has a very clear and relative unique positioning on the market and focuses fully on the high-end markets with the appropriate business model and with technologies specifically designed for performance. High end MEMS products are already on the market and find growing success in a wide range of defence applications. To enter this market, one the first barriers is technical with the required stability (1 to 100 ppm of the full range) and the resolution (16 to 24 bits). The other success factors for MEMS accelerometers are lower cost, excellent performance, sometimes even surpassing those of the traditional electromechanical devices, robustness, power and size.

Technology

The three key ingredients needed to make a high performance accelerometer are a highly stable MEMS sensor element, a good assembly and packaging technology and high-quality electronics. The advantage of this technology over the traditional electromechanical solutions comes mainly from the lower manufacturing cost of MEMS devices induced by the possibility to proceed in batches. Performance such as stability relies on the excellent quality of the raw material (silicon wafers) and capability of the design to meet the performance with manageable manufacturing tolerances

and manufacturing processes, avoiding lengthy and expensive burn-in and selection procedures.

MEMS sensor element

The basic structure of the acceleration detector is constituted of a proof mass with a surface of few mm² and a thickness of few hundreds microns, attached by a silicon spring to a frame and separated from the detection plates on each side by a narrow gap of few microns. This sensor element is realized by a so called bulk micromachining MEMS process inspired from the standard microelectronic technologies. The three layers are manufactured independently and are then hermetically bonded under vacuum and at very high temperature to form a wafer stack of hundreds finished sensors. Such components are extremely stable over time, temperature and environmental conditions. It has been demonstrated that after 10 years of storage, temperature up to 200°C and shock larger than 20'000g, the silicon proof mass returns to its initial position within 0.03nm, which represents 1/30 of the radius of a silicon atom.

Assembly and packaging

The sensor assembly is extremely critical for high precision under harsh environments. Colibrys has chosen a multi chip module (MCM) approach combining the MEMS device and electronics in a hermetically sealed ceramic package, qualified against MIL standards and insuring long term stability and reliability. The MEMS die is attached with a propriety low stress process assuring that the intrinsically good performance of the MEMS is not degraded by the assembly process.

Electronics

The electronics associated with the MEMS sensor is crucial to get high performance. There are two ways to operate a Capacitive MEMS sensor. For the open loop approach, the mechanical

plate deflection is measured through the associated capacitance change. This concept gives excellent results and is small and low power. However it has limitations in terms of the ultimate noise and linearity. Typically open loop sensors are good where 16 to 20 bit resolution is needed. For closed loop (or servo) accelerometers, the proof mass is maintained in a fixed position and the inertia is compensated by electrostatic forces. With this concept the ultimate limits of MEMS sensors can be pushed further in terms of stability, noise, linearity. Closed loop sensors are covering the resolution range of 20 to 24 bits and beyond in the future.

Conclusion

MEMS accelerometers penetrate more and more high-end defence applications replacing the well established, expensive and fragile electromechanical devices. The driving forces for this revolution are the need for devices offering the same or even better performance, at lower cost, lower power and smaller size and significantly more robust. The success of high end MEMS accelerometers is completed by their unique capability to serve harsh environment applications characterized by extreme temperature, vibrations or shock conditions in the Mil Aerospace, Industrial, Instrumentation and Energy markets. ■