



WHITE PAPER

Pressure and vibration sensors for the aerospace industry and other extreme environments

INTRODUCTION

Modern aerospace, energy, and industrial systems increasingly operate in environments that exceed the limits of conventional instrumentation. From jet engines and liquid- or solid-fuelled rockets surpassing 1,200 °F (649 °C) to the unique stresses of nuclear small modular reactors (SMRs) and high-vibration automotive systems, accurate pressure and vibration measurements are mission-critical.

Capturing accurate data in extreme conditions has historically required compromises. Engineers resorted to workarounds such as standoff tubes or infinite tube systems for pressure measurement, or accepted the signal drift inherent in pyroelectric materials. These approaches often masked critical events like combustion instabilities or rotor vibration signatures, leaving operators with incomplete insight into high-value systems.

HBK's approach removes these compromises by offering direct-mount, high-temperature vibration and pressure sensors. These solutions are designed not only to survive but to thrive in conditions that defeat conventional instrumentation, ensuring continuous, high-fidelity monitoring that supports better design, testing, and operational safety.



THE AEROSPACE INDUSTRY

The aerospace industry is among the most demanding test and operational environments for sensing technologies. Aircraft engines, rocket engines/motors, and rotorcraft gearboxes combine high thermal loads with extreme vibration and limited installation space. Measurement technology must therefore deliver absolute reliability while maintaining the smallest possible footprint.

HBK addresses these challenges through a unique combination of technologies. Piezocryst by HBK dynamic pressure sensors enable flush-mounted installation directly in combustors and afterburners, capturing thermoacoustic instabilities without the signal distortion common in tube-based systems. At the same time, Dytran by HBK's Silver Window™ accelerometers withstand high

vibration and thermal shock in oxygen-starved environments such as engine cores. Together, these tools provide aerospace engineers with unmatched visibility into propulsion dynamics, structural integrity, and flight test data.

Key applications include: monitoring jet engine combustors for flame instability, capturing hydrogen combustion acoustics, tracking rotorcraft gearbox vibrations for Health and Usage Monitoring Systems (HUMS), and safeguarding spacecraft structures during launch and re-entry.



Dytran by HBK's Silver Window technology and Piezocryst by HBK's pressure sensors.

BEYOND AEROSPACE – OTHER EXTREME ENVIRONMENTS

While aerospace is often the proving ground, many other industries face similarly punishing conditions where HBK's solutions provide decisive advantages.

In energy and power generation, gas turbines and nuclear reactors demand pressure and vibration monitoring at temperatures and radiation levels that challenge conventional sensors. Piezocryst by HBK's GaPO₄ sensors are widely deployed in turbines, delivering more than 200 million operating hours, while Dytran by HBK's radiation-tolerant accelerometers support vibration monitoring in nuclear systems.

In the automotive industry, sensors are used for power-train noise, vibration and harshness (NVH) analysis, exhaust system development, and electric vehicle (EV) battery enclosure testing under extreme thermal stress. Dytran's miniature accelerometers and Piezocryst's compact CP501 pressure sensors allow engineers to capture accurate data even in confined test setups.

Industrial applications such as hot rolling, sealing, and heavy machinery monitoring also benefit from the combination of high-temperature endurance and compact packaging, enabling predictive maintenance and safer operations.

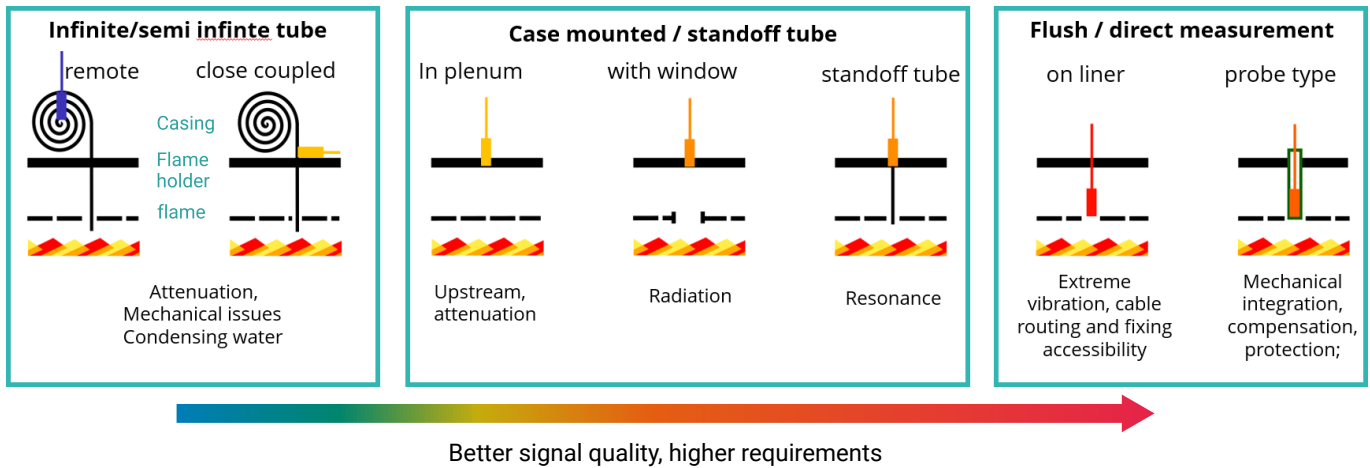
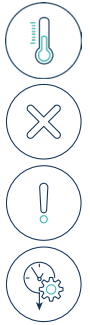
DISADVANTAGES OF LEGACY SENSOR APPROACHES

Before advanced piezoelectric solutions, engineers were forced to accept the shortcomings of legacy setups. Pressure measurements often required long standoff tubes that introduced damping, condensation, and resonance problems, reducing signal bandwidth. Pyroelectric effects in older materials caused false signals during thermal cycling. To mitigate poor reliability, test teams resorted to redundant sensors or frequent recalibration – both costly in time and resources.

By contrast, HBK’s direct-mount approach, leveraging GaPO₄’s inherent stability and Dytran by HBK’s Silver Window™ technology, eliminates these compromises. The result is cleaner data, longer operational life, and reduced downtime across critical industries.

Limitations of Legacy Sensors

- Unable to withstand extreme vibrations, temperature, or pressure conditions
- Can fail or become disruptive to the measurement response
- Catastrophic failures can result in missed fault detections, due to low-fidelity data
- Impacts of unplanned downtime include:
 - Delayed Projects
 - Missed Deadlines
 - Budget Issues
 - Unplanned turbine downtime can cost millions



HBK’S HOLISTIC EXTREME ENVIRONMENT SENSOR PORTFOLIO

HBK’s offering spans both vibration and pressure sensing, giving engineers a complete measurement toolkit for high-temperature and high-stress environments.

On the pressure side, Piezocryst by HBK’s CP5 series includes miniature probes for R&D and high-sensitivity differential models for turbine combustors. The portfolio also features the NTS sensor platform, a modular architecture designed for adaptation to rocket engines/ motors, sCO₂ plants, and other extreme applications.

On the vibration side, Dytran by HBK’s portfolio ranges from ultra-miniature accelerometers for tight aerospace applications, through triaxial packages for comprehensive structural monitoring, to radiation-tolerant models for nuclear and space.

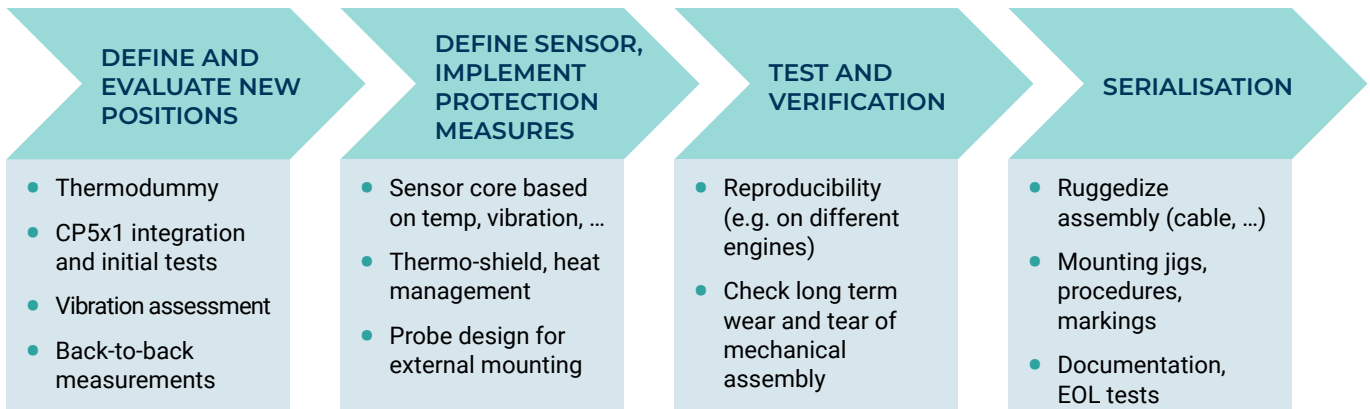
The integration of these technologies under HBK ensures not only technical breadth but also consistency – from sensor head through to data acquisition with HBK’s CAN-MD® smart networks. For example, the 4785A Charge to CAN Adapter adds smart sensor capabilities to standard charge-mode sensors.



IMPLEMENTATION METHODOLOGY

Deploying HBK solutions follows a structured methodology to maximise performance and reliability. Engineers begin with a detailed application analysis, mapping out thermal gradients, vibration loads, and physical constraints. Prototype testing with CP5 series sensors or Dytran compact accelerometers validates feasibility in real-world conditions. Based on results, solutions are customised for mounting, shielding, and cabling. Finally, comprehensive verification and ruggedisation ensure reproducibility and qualification for serial deployment.

This approach balances cutting-edge performance with long-term dependability, providing original equipment manufacturers (OEMs) and operators with confidence from concept through operational life.



Changing or setting up a new measurement is a process and typically not straight forward.

CONCLUSION

Whether in the combustor of a hydrogen-fuelled jet engine, the containment vessel of a nuclear SMR, or the exhaust system of a high-performance automobile, Dytran by HBK and Piezocryst by HBK sensors provide trustworthy, long-life solutions for environments that defeat conventional technologies. By uniting pressure and vibration measurement under one portfolio, HBK empowers engineers to operate more safely, design more efficiently, and innovate with confidence.

COMPETITIVE ADVANTAGES

HBK's combined pressure and vibration portfolio offers several decisive advantages over legacy and single-domain solutions:

- Field-proven with more than 200 million turbine operating hours
- Reduced recalibration needs, minimising downtime
- Backed by HBK's global support, ensuring availability and expertise for aerospace, energy, automotive, and industrial customers alike
- Certified to AS9100, ISO 9001, ISO 14001, meeting aerospace and industrial standards

