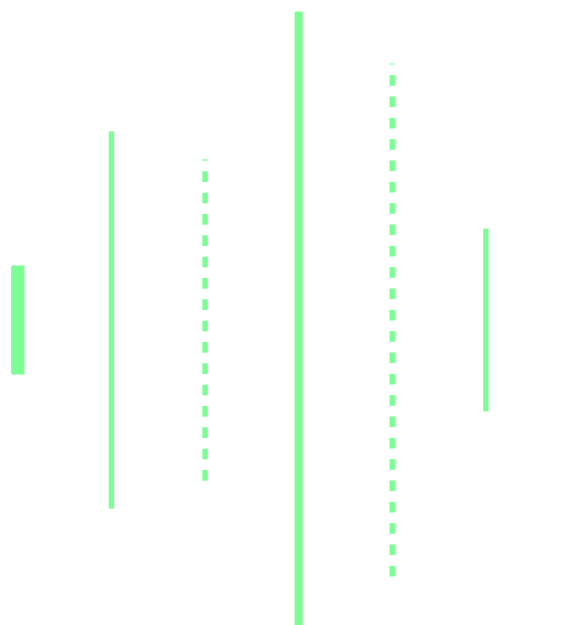


# The Sensing Gap:

Why precision measurement  
is becoming the strategic  
advantage industries  
cannot ignore



In early 2024, aviation authorities and industry groups warned that GPS interference had become a serious and growing problem for commercial flight operations in parts of the Middle East and the Black Sea ([Reuters, 2024](#)). Aircraft were not falling from the sky, and most flights still landed safely, but pilots were increasingly dealing with jamming and spoofing that could distort position data and erode confidence in a system modern aviation has treated as foundational for decades. The problem was not a dramatic failure. It was the loss of certainty.

**Modern systems rarely fail all at once; they degrade slowly, as the quality of their inputs deteriorates, navigation becomes less precise, detection thresholds slip, and margins compress.**

**The first point of failure is rarely the system itself. It is the fidelity of the measurement that informs it. This is the sensing gap.**

Quantum sensing deserves far more attention than it usually gets. Quantum computing still dominates headlines, but quantum sensing is closer to real industrial impact because it addresses an immediate operational constraint. It improves the quality of the input layer itself. If the last generation's strategic advantage came from data infrastructure, the next one may come from measurement infrastructure.

## Quantum sensing: Measuring at the level where noise begins

Quantum sensing addresses the problem at a different level. Instead of attempting to amplify weak classical signals, it uses systems that are intrinsically sensitive to external disturbances.

**“The underlying phenomena of quantum superposition and entanglement allow quantum sensors to achieve measurement accuracies that far exceed those of classical sensors. For example, quantum sensors can detect extremely small fluctuations in magnetic fields, enabling them to detect and measure even the most minute changes in material properties, equipment performance, and environmental condition.**  
([Panayaram, 2025](#))

Quantum computing is about processing information using quantum states. Quantum sensing is about using those same quantum effects to measure time, gravity, magnetic fields, motion, and electromagnetic signals. In certain applications, it can offer higher sensitivity or stability than conventional techniques. That distinction matters because quantum sensing is already much closer to deployment in several domains. Atomic clocks are the clearest example. They are not futuristic concepts. They are already embedded in critical infrastructure. DARPA's own material makes this point directly, noting that atomic clocks are among the few devices already operating very near fundamental physical limits.

So, the case for quantum sensing is not that it belongs to the broader quantum category. The case is that it solves a much more immediate problem: classical sensing approaches are beginning to encounter practical limits where precision is a strategic requirement

## Defining the sensing gap

The sensing gap emerges when measurement capability cannot keep pace with system demands. At a deeper level, the sensing gap is best understood through closed-loop control theory.

Every high-performance system depends on a continuous cycle:

Measurement → State estimation → Control → Feedback

The quality of control is bounded by the quality of state estimation, and state estimation is bounded by measurement fidelity. When measurement degrades, uncertainty enters the system at its root.

Systems are no longer judged by whether they function, but by how precisely they operate under constraint. Energy grids must balance intermittent supply in real time. Autonomous systems must navigate without reliable external signals. Defense platforms must detect weak signatures in deliberately obscured environments. Yet the sensors underpinning these systems remain constrained by classical physics. Noise, interference, and material limits define a ceiling on what can be detected and resolved.

Classical sensors perform reliably within known bounds, but those bounds are increasingly misaligned with operational reality. Improvements are possible, but incremental and costly. Each gain in sensitivity requires disproportionate effort in shielding, calibration, or signal processing.

The pressure points are consistent:

- Weak signals buried in noisy environments
- Systems operating without external references
- Subsurface or obscured detection
- Ultra-tight tolerances in advanced manufacturing

Systems demand higher fidelity inputs, while the tools used to generate those inputs struggle to deliver them consistently. That mismatch is the sensing gap in operational form.

## Three domains where the sensing gap is closing

### **Magnetometry: Sensing what cannot be shielded**

Quantum magnetometers, particularly those based on atomic systems and nitrogen-vacancy centers, can detect extremely weak magnetic fields, in some cases with reduced shielding requirements compared to traditional systems.

This has direct implications for defense, where non-acoustic submarine detection is being explored, and for energy systems, where current flows can be monitored with higher precision.

Research from [Sandia National Laboratories](#) shows that these systems maintain sensitivity in real-world environments, where noise can degrade conventional sensors.

### **Gravimetry: Seeing below the surface**

Quantum gravimeters measure minute variations in gravitational fields, enabling non-invasive mapping of underground structures.

This capability is already being deployed in geophysical surveying and infrastructure planning. It offers a way to detect what cannot be directly observed, from water reserves to tunnels.

Across the field, including at leading national labs and research institutions, efforts are underway to transition quantum gravimetry from laboratory setups to field-based applications.

### **Timing & navigation: Operating without signals**

The most mature and consequential quantum sensing category is precise timing. Atomic clocks, one of the most mature quantum sensing technologies, are already embedded in GPS and telecommunications networks.

The next frontier is quantum inertial navigation. These systems track motion with extreme precision, allowing navigation without reliance on external signals, which has become a strategic priority for defense. [The Defense Advanced Research Projects Agency](#) has supported programs to develop deployable quantum navigation systems capable of operating in GPS-denied environments.

Better measurement produces better decisions, tighter control, earlier warnings, and lower uncertainty. Over time, those advantages compound.

This is why precision measurement is beginning to resemble data infrastructure from a generation ago. At first, it seems technical, specialized, and somewhat peripheral. Then it becomes clear that the organizations with the strongest infrastructure are the ones making faster, better, more confident decisions. In the next decade, that advantage may increasingly go to those who can measure reality more accurately in challenging conditions, rather than just processing more data after the fact.

The firms and systems that can reduce uncertainty at the point of observation will operate differently from those that cannot. They are positioned to make faster decisions, require less redundancy, and tolerate tighter margins. For energy operators, that could mean more stable balancing and better fault detection. For manufacturers, it could mean tighter tolerances and less waste. For aerospace and defense, it could mean navigation and detection capabilities that remain reliable when conventional systems degrade.

In each case, the commercial logic is the same: reducing uncertainty at the sensing layer improves performance everywhere else.

## Systemic leverage: Why small improvements matter disproportionately

The sensing gap has disproportionate economic impact because measurement sits at the base of the system stack.

Improvements at this layer propagate upward

- Better measurement improves state estimation
- Tighter control reduces inefficiency and waste

Via a domino effect, this creates leverage. A small improvement in measurement fidelity can produce a large improvement in system performance.

In energy systems, even small efficiency gains can translate into significant cost savings in large-scale industrial systems. In semiconductor manufacturing, reducing measurement error by a fraction can significantly improve yield. In logistics and aerospace, improved navigation accuracy reduces fuel consumption and operational risk. These effects compound over time, making precision measurement a strategic variable rather than a technical detail.

This gap also points to significant untapped market potential. More conservative estimates place the quantum sensing market in the sub-billion to low-billion-dollar range by 2030, while broader analyses suggest it could grow into a multi-billion-dollar market over the following decade as adoption expands across timing, navigation, and measurement systems.

## How ready is it, really?

The honest answer is that readiness is uneven.

Some quantum sensing technologies are already deployed and foundational. Atomic clocks serve as the clear example. Quantum gravimetry is more advanced than many realize, with practical applications in surveying and infrastructure projects. Magnetometry shows promise and is becoming more capable, although deployment depends on specific applications. Other areas, especially portable quantum inertial navigation and widespread industrial use of NV-center systems, are still in the early stages and face common engineering challenges such as packaging, robustness, cost, and integration.

That is why the most important point in this discussion is also the simplest: the sensing gap is often more an engineering problem than a physics problem.

The science works. The race now is to make these systems smaller, tougher, more manufacturable, and more economical for deployment beyond specialist environments. DARPA's program language, along with the work emerging from NIST, Oak Ridge, and Sandia, all point in that direction.

### The next infrastructure race starts with the sensor

The sensing gap is a useful phrase because it captures a shift many industries are already feeling but have not fully named. The problem is not a lack of data, computing, or software sophistication. It is that the physical world is becoming harder to measure precisely at the exact moment when precision matters more.

Quantum sensing will not replace every classical sensor, and it does not need to. Its strategic value lies in closing the gap where conventional systems reach their limits and where the cost of uncertainty is highest. That makes it far more than an interesting branch of quantum technology. It makes it part of the next infrastructure race.

A decade ago, competitive advantage belonged to those who built the better data stack. The next advantage will belong to those who can measure the world with greater fidelity before anyone else can interpret it.