CASE STUDY: Extending Emissions Probe Durability

5× Life Increase, 70 % Cost and 80 % Lead-Time Reduction, and Proven Measurement Integrity

Project Snapshot

Industry: Aerospace / Combustion Emissions Testing
Challenge: Frequent emissions-probe failures (~100 hr life) caused unexpected test interruptions and data variability.
Result: New 3-D-printed probe and field-representative mount achieved > 500 hr life, cut manufacturing time from 12 weeks to 2 weeks, eliminated CO-burnout concerns, and lowered lifecycle cost by ≈ 70 %.

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1. Opening Hook – The Challenge

A leading combustion-test organization faced **recurrent emissions-probe failures** during high-value engine tests. Each probe—used to sample exhaust gases from multiple points at the combustor exit—lasted only about **100 hours**, often failing mid-test with no warning.

While the **individual cost ($1.5 K)** was modest, unplanned breaks jeopardized test assets worth tens of thousands of dollars, creating an unacceptable operational risk.

Each test used **five probes per setup** (≈ $7.5 K per set) and **five sets per year**, totaling **$37.5 K annually** or **$375 K across 10 years**—for hardware that routinely underperformed.

A secondary client concern involved **CO burnout within the probe**, where CO might continue reacting into CO_2 inside the probe cavity and skew true exhaust reading accuracy.

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2. Problem Definition

We identified three root causes:

1. **Limited durability** of the probe body and tip (~100 hr average life).
2. **Non-representative acoustic boundary conditions** at the combustor exit, accelerating fatigue.
3. **Potential in-probe CO oxidation**, raising measurement-integrity doubts.

customer's core objective was not cost savings—it was **durability, realism, and ntific confidence**. Our team saw an opportunity to address all three—and do it faster.

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3. Our Approach

Our process combined diagnostic testing, fluid-mechanic modeling, and additive manufacturing to deliver an agile redesign.

1. Correcting Acoustic Boundary Conditions

During teardown reviews, we discovered that the **mounting structure distorted the acoustic loading** seen by the test article. We created a new, representative mounting assembly that mimicked real engine exit conditions—improving both test fidelity and probe longevity.

2. Design Innovation through Additive Manufacturing

Leveraging **1-D design calculations and CFD simulation**, we produced a **3-D-printed probe geometry** optimized for thermal balance and structural endurance.

- **Probe cost:** $1 K each (vs $1.5 K baseline).
- **Mount cost:** $10 K, reusable for thousands of hours.
- **Predicted life:** > 500 hr (5× improvement).
- **Fabrication time:** Cut from **12 weeks to 2 weeks** for probes, enabling rapid replenishment during campaigns.

The additive process allowed agile iteration—minor adjustments could be implemented in days rather than months.

3. Validation and Testing

Durability testing confirmed the new probes ran **> 500 hours** without failure.
Mount assemblies proved stable for long-term repetitive use, requiring replacement only every **~3 years**.

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4. Results and Impact

Metric	Baseline	New Design	Improvement / Insight
Probe life	~100 hr	> 500 hr	+400 %

Metric	Baseline	New Design	Improvement / Insight
Manufacturing lead time	12 weeks	2 weeks	**− 80 % faster**
Annual part cost	$37.5 K	~$15 K	− 70 %
10-year total (no inflation)	$375 K	≈ $100 K	≈ $275 K saved
Acoustic realism	Limited	Field-representative	Major gain
CO burnout inside probe	Not evaluated	Proven negligible	Concern removed

Even though **cost reduction wasn't the main goal**, the lifecycle economics improved dramatically due to fewer replacements and reusable mounts—proof of how our **systems-thinking approach** naturally drives effectiveness and efficiency.

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5. Verifying Measurement Integrity

To address the CO-burnout question, we ran a targeted experiment:

- Instrumented the probe to record **internal temperature, pressure, and flow residence time**.
- Compared results with **chemical-kinetic models** for $CO \rightarrow CO_2$ conversion.

Findings:

- Gas residence time inside the probe was roughly **10× shorter** than the period required for meaningful CO oxidation.
- Once gases entered the **350 °F sampling line**, all species effectively "froze," halting any further reaction.
- Measured CO and NOx trends matched baseline tests within repeatability limits.

This validation not only **eliminated the client's primary measurement concern**, it provided **new quantitative insight** they lacked even for the old design.

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6. Takeaway & Forward Value

This project highlights our team's **innovative and agile engineering mindset**—we don't just fix components, we **rethink the system**:

- **5× durability** through physics-based redesign.
- **80 % faster manufacturing** via additive methods.
- **Validated chemical integrity** ensuring emissions accuracy.

- **70 % lower lifecycle cost** through intelligent reuse.
- **Realistic acoustic boundary integration** for better test correlation.

By questioning assumptions and using fast-cycle engineering, we turned a recurring reliability issue into a platform solution—**smarter, faster, and technically superior**.