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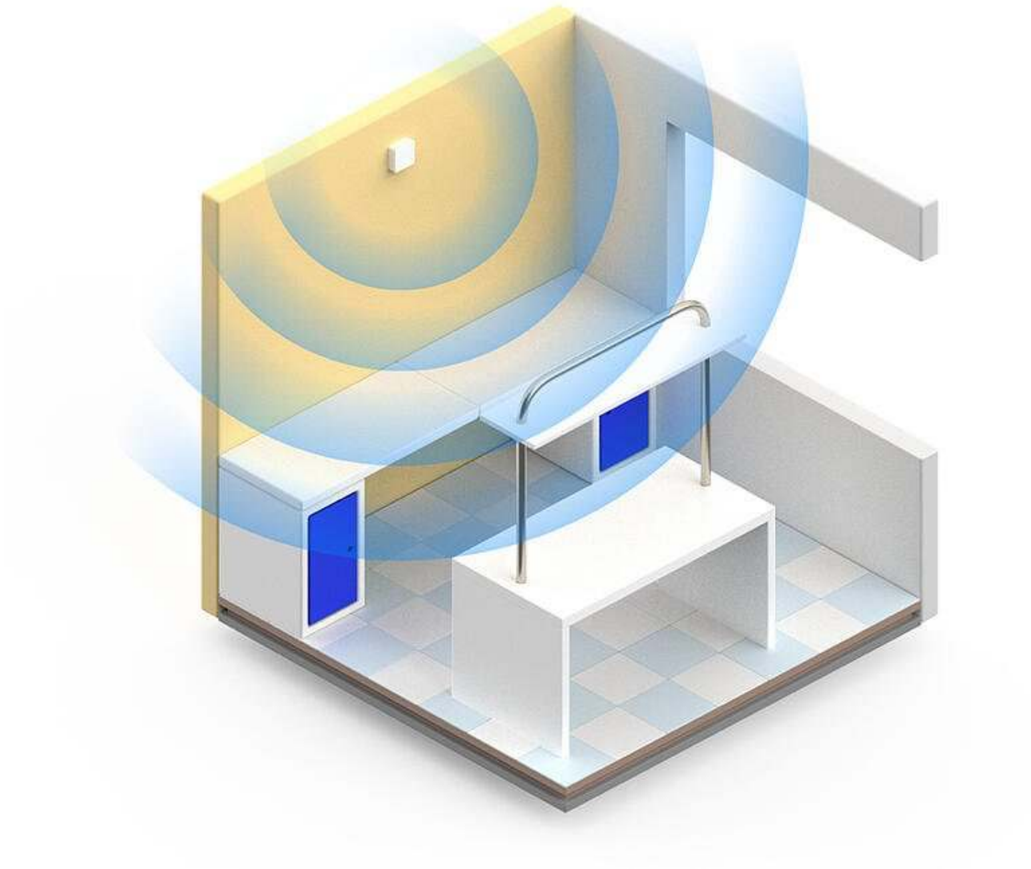
The Lab Walls Speak

Why Context Holds the Key to Experimental Reproducibility

A LabOps Whitepaper



Improving reproducibility first requires conquering the common enemy of the scientific community.

From chemistry and biology to materials science and manufacturing, lack of reproducibility is a common enemy, hindering scientists' ability to confidently and reliably repeat protocols and achieve identical outcomes. This industry-wide crisis costs billions of dollars, wastes massive amounts of researchers' time, and delays time-to-market for life-saving innovations.

The good news? Reproducibility failures are no longer the research community's whispered secret. Focus on the issue is widespread across sectors as stakeholders remain determined to increase transparency and improve outcomes, and new technological innovations (rise) to meet the challenge.

Unmasking the Enemies of Reproducibility

While there is no single variable compromising reproducibility across all fields of research, every scientist knows that invisible environmental factors – ambient temperature, humidity, light levels, sound, vibration, and equipment performance – can affect his or her work. Simple contextual factors surrounding cell cultures, mouse studies, a specific molecular synthesis, tissue studies, or a polymerization processes can play a significant role. Most researchers have first-hand anecdotes, but lack the precise data and intelligent insights about the culprits to blame.

Why not? Data about ambient issues has been challenging and cost-prohibitive to acquire, analyze, and integrate into research methodology, making its impact on experiments virtually impossible to understand – until now. By unlocking access to that information, researchers are empowered to:

- Rapidly identify issues contributing to experimental outcomes
- Rule out suspected factors that are not actually playing a role
- Get alerts if any readings are out of range
- Refine protocols by specifying precise environmental and instrument requirements
- Improve reproducibility

Little did he know, Steve Jobs changed the research landscape.

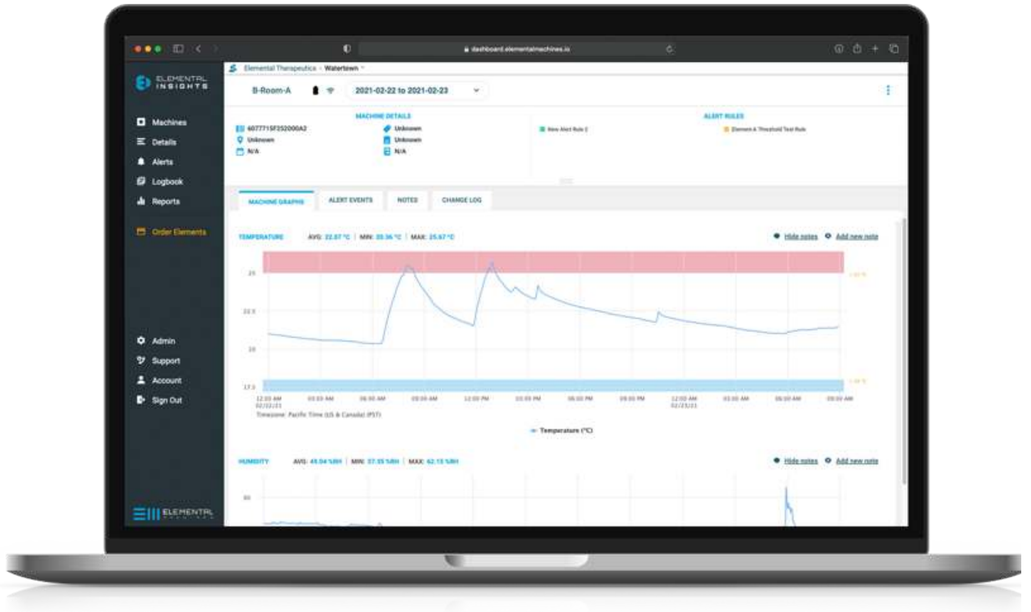
How? The same technologies embedded in cell phones and personal fitness trackers – combined with cloud-based computing, and sophisticated analytics capabilities – are now being applied to the Reproducibility Challenge.

Often referred to as the "peace dividend of the smartphone wars," the miniaturized component technologies that were first brought to market in smartphones are enabling new applications when applied to new markets. Experimental research, and its many variants, is now the beneficiary.

While Internet of Things (IoT) technologies – sensors, wireless networking capabilities, cloud computing, and advanced analytics – have been harnessed to create applications as diverse as personal fitness and fleet management and optimization, they are now being leveraged to give scientists and facility management teams the ability to:

- Monitor the research environment for variations in temperature, humidity, light levels, sound, vibration and more
- Monitor laboratory equipment performance to verify performance and identify any variations from expected behaviors
- Visualize data patterns and spot issues
- Receive alerts if any readings are outside of specified ranges
- Correlate environmental factors with results
- Improve research processes and outcomes

Easy access to this information is poised to rapidly change the field of experimental research by helping scientists 'debug' the physical environment that they work in. Just as software engineers 'debug' their code, understanding the physical variables in the laboratory environment and performance of key equipment makes it possible for research scientists to identify factors that frequently play a contributing role in research outcomes.



Case Studies

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Introduction

For leading research teams, **granular environmental data provides a new level of visibility into experimental outcomes – without changing how they work.** These solutions are helping researchers identify culprits, document findings, and associate data with outcomes in high throughput screening, materials science, genomics, and synthetic biology.

Case Study #1

Leader in High-Definition Diagnostics Monitors Critical Equipment

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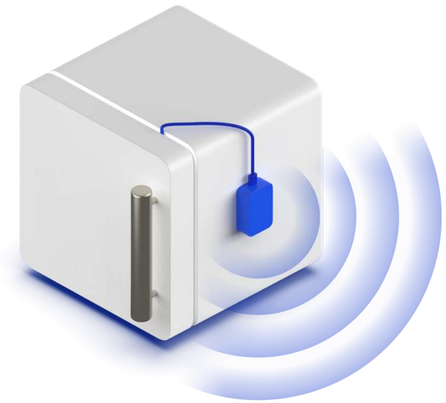
A Massachusetts-based company that is a recognized pioneer in the diagnostics field wanted to monitor a variety of equipment, including freezers (-80°, -20° and walk-in), refrigerators (standard and walk-in), as well as analyzers and their own custom equipment, to help meet their commitment to operational excellence. In addition, they wanted immediate notifications if any readings were outside of specified ranges – at any time of day or night. They are able to:

- Ensure that all equipment is performing according to specifications
- Receive email or text alerts about changes to the environment or equipment
- Document environmental conditions
- Have insight into operational patterns for equipment



Results

Initially a pilot project, the team has found real-time monitoring and notifications to be a key strategy for achieving performance objectives, and has adopted the technology as part of ongoing quality control efforts.

Case Study #2

Materials Science Company Increases Reproducibility

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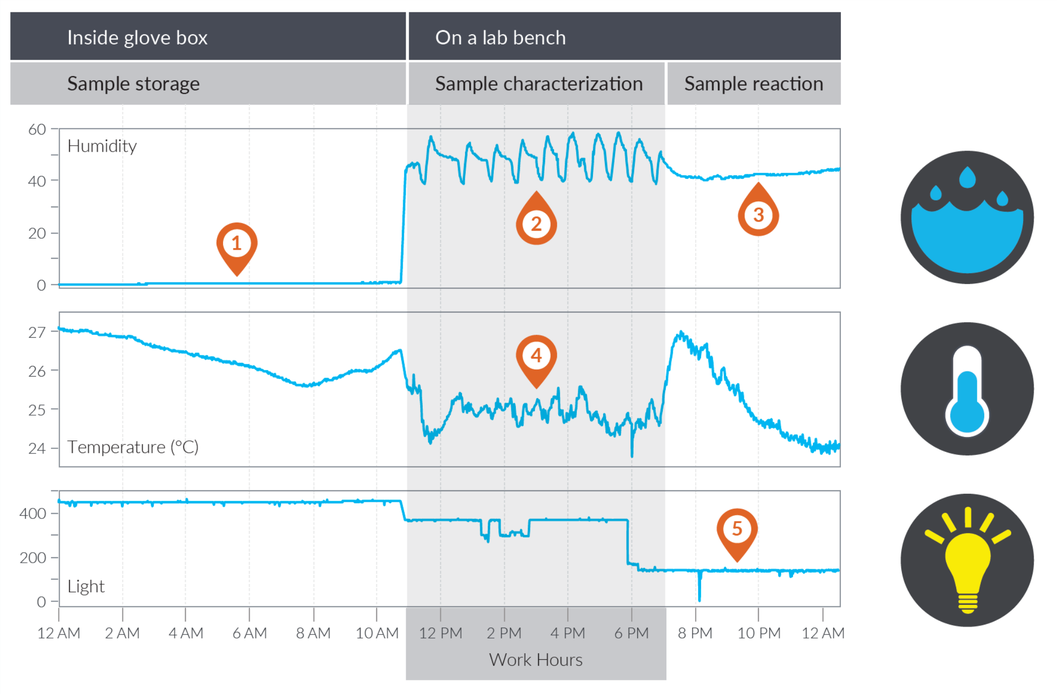
For this Silicon Valley-based company, controlled environmental settings are essential for reproducibility of materials required for their products. Complexity of the experimental protocol, the variety of benchtop locations for successive experiments on samples, and significant differences in outcomes made the team curious about the influence of fluctuating ambient conditions, particularly across different workspaces. The team needed to monitor conditions:

- Inside a glove box
- On the lab bench
- Inside the fume hood

By monitoring humidity, temperature, light and air pressure levels in real time – both inside the glove box and on the lab bench – the team was able to pinpoint ideal ambient conditions for performing their experiments. They also tracked samples and associated them with specific ambient conditions from storage to characterization to experimental reaction.



Humidity - Inside the Glove Box, humidity was maintained at 0% all times (1), but the lab bench (2) was much more susceptible to changes in ambient humidity based on the HVAC and thermostat settings. But when the HVAC system shuts off (3), fluctuations decrease.

Ambient Temperature - The lab bench was also susceptible to changes in ambient temperature (4), according to HVAC and thermostat settings.

After hours - Lights off (5)

Results

The team had not anticipated the high fluctuations in temperature and humidity in their facility and was able to identify the role that these factors played (especially as related to the different locations within the lab). They further refined experimental protocols to reflect the ideal conditions and equipment specifications, and successfully improved reproducibility, saving several months of development time.

Case Study #3

DNA Diagnostics Company Debugs Critical Polymerization Process

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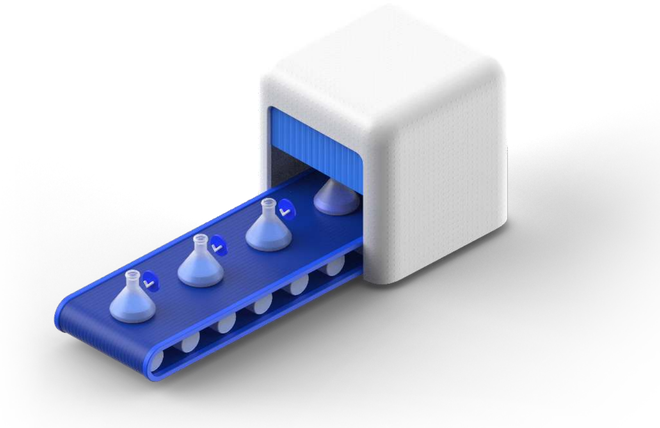
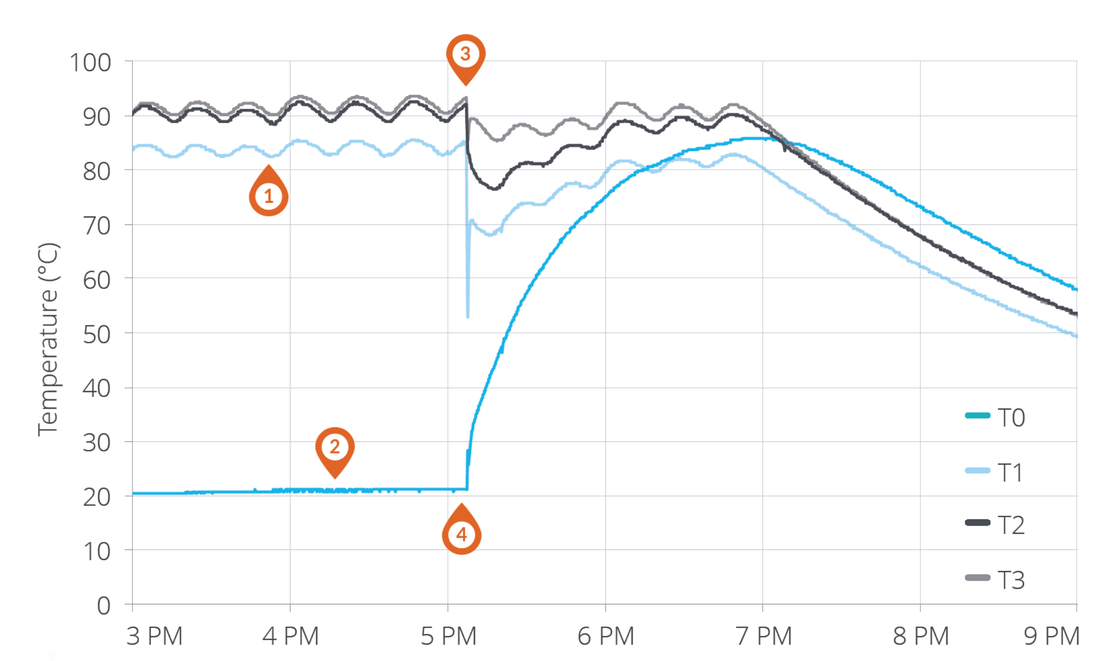


An innovative California-based company is developing a new technology for identifying genetic biomarkers using rapid and fully automated testing. Their specialized sensor device is a complex system of different materials, including polymers and biomolecules. During the R&D phase, the team encountered challenges in making reproducible sensors due to one particularly tricky step in the polymerization process, which needed to be completed before binding a costly biomolecule. While the team had successfully narrowed the issue to the polymerization step, they could not determine the exact problem. By gathering real-time data about the various conditions in their convection oven, they found:

- Significant variability in temperatures across the usage cycle and sensor-placement locations
- Greater disparity in temperature readings in various locations in the oven (front/back/top/bottom) than anticipated
- Much slower warm-up than assumed
- A larger oscillation pattern than expected created by the oven controller.



Sensor placement – Intelligent sensors placed in 4 different locations in the oven (1) and (2): T1 – front, T2 – middle, T3 – back, T0 – attached to metal reaction plate (between T1 + T2)
Temperature variations – As oven temperature rises, sensors show variations in readings by location (3) and longer-than-expected warm-up time for reaction plate (4).

Results

With real-time and historical streams of oven temperature data, the team was able to identify the temperature fluctuations that were compromising the polymerization process and improve the protocol, itself. They also saved money by conserving costly biomolecules that had previously been wasted because they couldn't be combined successfully.

Case Study #4

Synthetic Biology Company Identifies Optimal Conditions with Real-Time Monitoring

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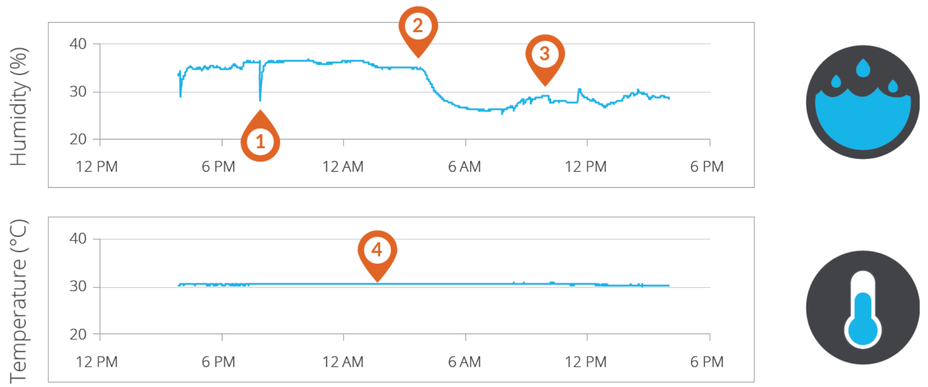
A Silicon Valley-based company needed to monitor conditions in their fermentation incubator to ensure rapid and consistent cell growth. Ideal conditions included a constant temperature of 30°C and a high humidity level, but the team had not determined the exact humidity level required. Additionally, the research team needed to add water manually to the incubator's water bath, but the precise rate at which water needed to be added was also unknown.



Humidity – At beginning of experiment, incubator door opened for long period of time (1), then when water runs out (2), humidity within the incubator decreases. Staff open and close incubator door quickly several times (3), causing small fluctuations in levels.

Ambient Temperature – Ambient temperature in the incubator remains consistent during the experiment.

Results

By tracking humidity and temperature levels in real-time and setting alerts to notify staff when levels dropped below a preset threshold, the team was able to understand exact conditions at all times and pinpoint the optimal humidity level to ensure for cell growth.

What can contextual data unlock for you?

While there's no single solution to the Reproducibility Crisis, systematically leveraging every available advantage is critical. Contextual data is an obvious piece of the puzzle, and now cost-effective and easy-to-deploy solutions are available to give researchers – and their facility management teams – new insights. With access to precise information about numerous contextual factors that can impact experimental research, the question is what you can learn? And how can you use those new insights to:

- Manage the laboratory environment and equipment
- Fine-tune protocols
- Increase yields
- Reduce costs
- Accelerate research
- Improve reproducibility

Take Action

Optimize your lab operations with Elemental Machines.

Elemental Machines is the trusted data collection and reporting technology supplier to researchers and clinicians around the world. The Cambridge-based company equips labs with universal cloud-based dashboards and turnkey sensors that unite data from every asset, every metric, and every location, enabling universal collection, seamless sharing, and turnkey reporting.

Designed specifically for scientific research environments, the Elemental Machines Universal LabOps Platform is a powerful and cost-effective solution that empowers scientists and laboratory staff to identify environmental factors and improve both the research process and overall reproducibility.

To learn more about how Elemental Machines can help you improve reproducibility in your lab, contact us at info@elementalmachines.com.