The Buyer's Guide for Life Scientists

# What Does the Lab of the Future Look Like?

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# YOUR LAB IS TALKING.
# ARE YOU LISTENING?


*Image courtesy of Paul Avis Photography*

The connected lab is now a reality. Monitor your cold storage equipment 24/7 and receive a text alert for any out of spec conditions. Track your environment to determine if it is having any effect on your equipment or processes. Extract data from OEM equipment and store it securely in the Cloud for easy access.

**WHAT IS YOUR LAB TRYING TO TELL YOU? WWW.ELEMENTALMACHINES.IO**

# The Shift toward a Data-Driven Smart Lab

by Jennifer Ellis

What new technologies will we see in the smart labs of the future? Technological innovations already abound in life sciences and clinical environments. They are applied to everything from automatable workflows and sample management to data analysis, expanding what labs can accomplish with more speed and simplicity. Yet, ideas around what the latest technology can do to further support and progress scientific endeavors are shifting focus from improvement to redesign.

Not only can technologies improve performance and simplify workflows, they are more recently opening the door to intuitive, scalable, and flexible infrastructure designs that enhance the user experience and enable new approaches like remote controls or predictive experimentation. Internet of Things (IoT) technologies and artificial intelligence (AI) platforms, for example, can support and connect lab functions for heightened monitoring and optimization of operations or experimental conditions. By digitizing the lab environment, these tools can help organizations achieve good laboratory practices (GLP), improve overall efficiency and data quality, and manage risk.

## Taking the next step

Automated procedures are common in labs that perform high-throughput or repetitive and routine operations. Machines built for liquid handling to compound storage can be implemented into processes like sample management and assay platforms to increase productivity, reduce error-prone manual handling, and enable users to focus on other high-impact work.

Beyond automation, strategies that expand lab connectivity provide greater experimental control and better decision-making capabilities based on more comprehensive information. Novel platforms connect everything from protocols and machines to data storage and records for complete confidence in not just the outcome of an experiment but the entire process itself, ensuring so-called verifiable science. For example, IoT intelligent sensors and analytics software can help optimize complex processes by collecting information generated by machines and instruments, or monitoring environmental conditions, like temperature, humidity, light, and vibration, all of which are variables that affect the quality of results. Historically, this information was not captured in a digital format nor analyzed by computational methods. This lack of information costs the industry billions of dollars in downtime, poorly manufactured product and yield loss, inefficiencies, and manual labor. Emerging tools strive to capture and interpret more of this type of information and offer insights in a way that has never before been possible.

## A data-driven world

One of the biggest challenges faced by organizations of all sizes is the integration of data from different sources. Connected systems that generate and manage the flow of data from experiment inception to completion are enabling a more strategic approach to lab management. Labs can address existing issues around siloed data and lack of information while still positioning to overcome future challenges. Having visibility to previously inaccessible data introduces new opportunities to gain insights on equipment performance, process output, timing of steps, and results generation, as well as how these parameters affect outcomes. By taking advantage of technologies like IoT and AI, labs of the future will enhance operational optimization and ultimately generate validated and more robust results.

Plug-and-play elements, such as wireless IoT add-on devices, can integrate seamlessly into operations to gather information and blend it in context to results. In the case of an unexpected outcome, this additional information provides a full picture of the conditions in which an experiment was performed, including machine operation, instrument calibration, and conditions under which reagents were used and stored. With the ability to control more of a process and reveal prior unknowns, visibility into how an experiment was performed can assist in troubleshooting issues, instill certainty in an outcome, and help prepare for future innovations.

Introducing cloud-connected software and the possibility of machine learning offers further visibility into machines, facilities, and processes, and the potential to automatically adjust small issues as they arise. While initially focusing on simple tasks like monitoring cold rooms and freezers, technology is advancing to more complex jobs like uploading data from machines and sending alerts if a problem is detected, providing an early warning before equipment breaks and samples are lost. By making the lab itself smarter, researchers are able to shift their focus to discovery and ensuring high-quality results, pushing the current limits of science exploration and development.

## Realizing the benefits

Data integrity, confidence in results, and reproducibility of experiments have been regularly questioned as of late in situations where publications and experimental methods cannot be validated. Fortunately, new technologies are reducing or even eliminating some of these issues. IoT and data science tools are gaining traction with their ability to manage equipment, automate experiments, and collect and interpret data, providing real-time results and information-sharing capabilities for better verification.

Furthermore, with comprehensive insights into big picture dynamics, labs are better able to manage risk, and thus save money. With extensive monitoring and advanced data collection along a pipeline, managers are empowered to identify issues sooner and make quicker decisions to resolve them, leading to greater efficiency and faster time to market to meet a greater demand for products.

As we write a new vision for the lab of the future, it is important to keep in mind the ultimate goal that this new lab will accomplish. Whether accelerating science with automation, increasing the reliability and reproducibility of connected research and development processes, or shifting from incident response to strategic planning, the lab of the future will surely benefit from the new wave of technology spreading in today's world.

# Data Management for Laboratory Equipment

by Harsha Jattani

## Background

Data is one of your company's most valuable assets. Scientific data, in particular, represents the output of countless hours of coordinated investment in resources such as equipment and time. The data collected takes on many forms, from simple (such as a weight measurement) to complex (such as HPLC data). Gathering and interpreting these complete data sets is necessary for troubleshooting reproducibility, improving workflows, and maintaining quality records.

There is growing interest in reliable data archival solutions. One study revealed that two years after a publication, the probability of accessing raw data from a scientific study drops by 17% and continues to drop by that amount year after year.[1] Scientists concede that the main cause of this is lost data, whether stored on paper documents or electronic media. So how can your organization implement robust data management solutions to ensure continued access to one of its most valuable assets?

## Introduction

Regardless of which approach you and your team use to capture raw data from your scientific studies, some important considerations for data collection systems include:

- Does the approach maintain data integrity?
- Is the data securely stored?
- Is the data readily available to team members?
- Can the data be accessed remotely?
- Is the method compliant with FDA 21 CFR Part 11 for electronic records?
- Does the data capture approach help meet compliance with other regulatory standards, such as the Food Safety Modernization Act

(FSMA), Joint Commission on Accreditation of Healthcare Organizations (JCAHO), and World Health Organization (WHO), as applicable?

There are four common methods for scientific data collection:

- Manual entry into forms or notebooks
- Equipment-generated records
- Manual entry into Electronic Laboratory Notebooks (ELNs) or Enterprise Resource Planning (ERP) systems
- Wireless Internet of Things (IoT) add-on devices

In this article we will briefly describe each method, how it's commonly used, and the advantages and disadvantages of each method.

## Manual entry into forms for notebooks

This is the most straightforward method for capturing scientific data. Typically a technician or other designated person writes down values that are output by various types of scientific equipment. These readings are manually entered into forms or laboratory notebooks. The cost to employ this approach is relatively low. Quality systems can also be set up to accept forms and laboratory notebooks as official records.

While it is easy to record data using this approach, there are several issues that might make this approach less desirable. This approach is the most prone to human error. As technicians, scientists, and engineers are consumed by the time-sensitive nature of their work, they may forget to write down equipment values or inadvertently write down incorrect values or units of measurement, thus compromising data integrity. Data security and accessibility can also be challenging when using manual data collection. Paper-based records, whether forms or notebooks, may be misplaced or lost.

Another downside of this approach is siloed data. Paper-based data records are not readily accessible by team members. Furthermore, remote access to data is also not possible when outside the office. Manual data capture may also fail to capture metadata such as equipment settings, maintenance, and calibration records, thus resulting in incomplete records. Finally, paper-based systems are not ideal to capture large, complex data sets.

**PROS**

- Simple, well-established method
- Cost-effective
- May be compliant with Quality Systems

**CONS**

- Most prone to human error
- Poor data security
- Data silos
- Incomplete data structure
- Not ideal for large, complex data sets

## Equipment-generated records

It is possible to print or export values or files from scientific equipment for data capture. Printed records are then affixed to forms or laboratory notebooks, while electronic files may be stored on USB memory sticks. This method offers an advantage over manual entry onto forms or notebooks. It improves data integrity as records are exported directly from the scientific equipment. Similar to manual entries, this approach is easy to adapt, and records may also be recognized as quality records.

While this method addresses a deficiency of the manual entry method, many of the issues from the manual entry method still persist. For example, poor data security continues to be an issue as paper-based records and USB memory sticks may still be lost or misplaced. Furthermore, staff may forget to print or export data while working on a complicated protocol, again resulting in lost data. Additionally, neither paper-based records nor USB memory sticks are adequate solutions for eliminating data silos. Lastly, this approach may not easily accommodate large, complex data sets, especially in the case of paper-based records.

**PROS**

- Simple, well-established method
- May be compliant with Quality Systems
- Reduced human error
- Cost-effective solution

**CONS**

- Poor data security
- Data silos
- Incomplete data capture
- Not ideal for large, complex data sets

## Manual entry into Electronic Laboratory Notebook (ELN) or Enterprise Resource Planning (ERP) systems

Some organizations utilize Electronic Laboratory Notebooks (ELNs) or Enterprise Resource Planning (ERP) systems to manage data collection and analysis. This approach successfully addresses some of the deficiencies of the previous methods. When data is input into an ELN or ERP system, data silos are alleviated as access to data may be granted to appropriate individuals. Remote access to data may also be available through web-based interfaces. As with previously mentioned approaches, this approach, too, may be compatible with quality systems.

The downside of ELN and ERP systems is that they tend to be more costly to implement than other methods. These solutions may also charge monthly subscription fees. Additionally, manual data entry into ELNs and ERP system does not safeguard from data integrity issues as this approach is still prone to human error.

**PROS**

- Maintain data security
- May be compliant with Quality Systems
- Reduce data silos
- Accept complex data sets

**CONS**

- More costly solution
- Prone to data entry errors

## Wireless IoT add-on devices

Using wireless IoT add-on devices is the newest approach to capturing data from scientific equipment. With this method, small IoT-equipped devices are attached to scientific instruments for data export. The IoT devices automatically collect equipment data and metadata (such as sample results, calibration, and QC data) and send them to a cloud-based dashboard for access anytime, anywhere. Since IoT-equipped devices are always available to capture data, staff can monitor data collection even when off-site, such as evenings and weekends. These systems even offer email and/or SMS alerts when data shifts from user-configured conditions. This allows for better troubleshooting and increased reproducibility. Even when staff is available on-site, automated data collection frees them up to perform other higher-value tasks.

One consideration for the implementation of wireless IoT add-on devices is the initial upfront cost. However, that must be balanced with the cost savings the solution provides throgh automated data collection.

**PROS**

- Maintain data security
- May be compliant with Quality Systems
- Reduce data silos
- Accept complex data sets
- Automated data collection
- Support 21 CFR Part 11 workflows and other regulatory standards

**CONS**

- Somewhat higher upfront cost

If you would like to learn more about your data management options please contact us at: sales@elementalmachines.io

## Reference


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# Guide to Ambient Environment Monitoring

by John Morgan

## Background

Monitoring of ambient environmental conditions, such as temperature, pressure, humidity, and light levels, is a vital requirement for many industries and applications. Life science labs can have millions of dollars of equipment that can be negatively affected by changes in ambient conditions. Materials and chemical processing plants often run processes that are sensitive to environmental conditions. Changes in humidity or pressure can have detrimental effects on yield and quality. Food service, storage, and transportation companies must ensure foods are properly stored and transported according to standards outlined in the Food Safety Modernization Act (FSMA). Incubators used for culturing medical, bio, and pharma should be constantly monitored to ensure optimal growth conditions are maintained.

## Introduction

Regardless of what specific quality standards or regulations apply to your industry, a proper environmental monitoring program should be able to answer the following questions. Are my environmental monitoring devices accurate? Are we paying proper attention to our environment—monitoring regularly and taking some action when an out-of-spec condition occurs? Are we keeping sufficient records to ensure our product safety and quality? If regulations exist for our industry, are we keeping sufficient records to satisfy these regulatory requirements? There are essentially five choices for monitoring ambient conditions:

- Manual thermometers, barometers, hygrometers, and light meters
- Chart recorders to record one or more parameters
- Data loggers
- HVAC facility monitoring
- Wireless IoT devices

In this article we will briefly describe each technique, how it's commonly used, and the advantages and disadvantages of each technique.

## Thermometers, barometers, hygrometers, and light meters


**PROS**

- Low capital cost
- Simple
- Well established

**CONS**

- Higher labor cost
- No continuous monitoring
- Record-keeping is cumbersome
- No real-time alarming
- Human error

These individual devices have been in use for decades and represent the most straightforward method for monitoring ambient conditions. Typically a technician or other designated person visits each monitoring station at least twice per day and records the readings from the various instruments monitoring the environment. These readings are manually entered into a logbook and can be stored for record-keeping.

While it is easy and straightforward to read these devices and record the temperature, humidity, pressure, or light level, there are some other issues that might make this technique less desirable. The initial capital cost of these instruments is fairly low, but don't ignore the cost of paying people to read and record all this information every single day. If you are monitoring several environments, it could take several hours per day for someone to make all these recordings. That can translate into relatively high operating costs.

In addition, while it's possible to keep records by storing the log sheets, this technique is also the most susceptible to human error. Are all your instruments positioned in a way that they can be easily read? Is lighting sufficient in all areas to be able to see the instruments clearly? Manual recordings are also easy to tamper with in the case of a regulatory or liability action, making them less reliable than other records.

## Chart recorders

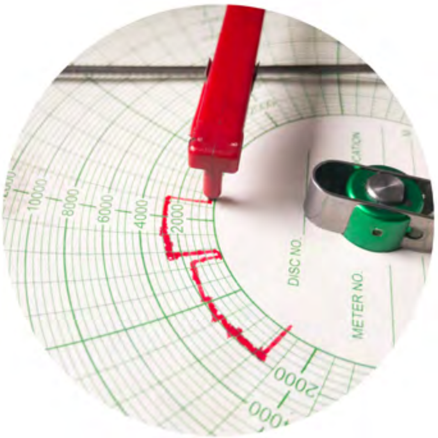


Chart recorders have been used for decades to keep a continuous record of various readings such as temperature, pressure, and humidity. They are reliable, fairly inexpensive, and easy to use. The charts can be saved and filed away to keep a comprehensive record of ambient conditions. For these reasons chart recorders have found wide usage for monitoring various environmental factors.

While they are reliable and easy to use, chart recorders still require someone to change out the chart paper, usually on a daily or weekly basis, and to file away the chart for compliance. If you want to get more resolution from your readings you will need to use a bigger chart recorder. Another thing to consider is operating cost. Charts and pens cost money and need to be replaced. If you have dozens of chart recorders the cost of paper charts and replacement pens can add up. It can also be cumbersome to find a place to store all the used charts.

**PROS**

- Continuous monitoring
- Data storage is straightforward
- Relatively simple

**CONS**

- Operating cost
- No real-time alarming and notification
- Record-keeping is cumbersome
- Poor granularity of data

## Data loggers

Data loggers are devices that measure and store readings electronically. They offer continuous monitoring of various parameters. Some data loggers measure several parameters at once, such as temperature, pressure, and humidity. Data loggers can be set up to alarm when readings are out of specification.

Data loggers can be more expensive than manual instruments, but they offer the advantages of continuous

**PROS**

- Continuous monitoring
- Data storage is straightforward
- Relatively simple

**CONS**

- No remote alarming and notification
- Data typically not available in the cloud


monitoring and storage of data. They can also be set up to alarm for out-of-range conditions. The data saved by a data logger can typically be downloaded and stored using a USB memory device, or they can be connected to a local area network.

Data loggers store a lot of information that can be easily saved and retrieved for regulatory compliance. What data loggers typically aren't set up to do is to alarm users remotely for out-of-spec conditions. They also are typically not set up to make data available in the cloud for easy access.

## HVAC facility monitoring

Newer HVAC systems have many options for monitoring and control. Oftentimes these systems are used to look for problems with the HVAC system itself, such as chillers that might need maintenance before they fail. However, these systems can also be used to monitor and control specific environments within a building.

These systems can be used to monitor ambient conditions in critical areas such as food storage or vaccine storage for temperature, humidity, and light levels. HVAC facility monitoring systems often allow for remote control and monitoring of out-of-spec conditions through cloud-based interfaces.

These systems are often pricey and may only be practical for new construction. Another downside for the researcher or lab manager is that the alarm system is often built for the facilities people and not for people running laboratories or doing the research, so an out-of-temperature alert is likely to get sent to a facilities manager rather than a lab manager. The facilities manager might not understand the criticality of the work being done in the environment that is being monitored and may not respond with the urgency required.

**PROS**

- Continuous monitoring
- Data storage in the cloud
- Remote alerting

**CONS**

- Can be very expensive
- May only be feasible for new construction
- May not alert the right person

## Wireless IoT monitoring and alarming


Wireless IoT monitoring is easy to set up, with no wires or connections needed. All elements are battery operated and seamlessly connect to the internet and to a personalized data portal in the cloud. The portal allows the user to monitor equipment in real time and to receive out-of-temperature alerts instantaneously via email or SMS alert.

This setup eliminates uncertainty caused by human error, stores data for years, continuously monitors equipment, and alerts designated users for out-of-spec conditions. Data is securely stored in the cloud and can be easily accessed for regulatory compliance. Users are also alerted to low battery conditions or connectivity issues, so no data gets lost.

**PROS**

- Continuous monitoring
- Data is stored in the cloud
- Simple installation
- Remote alarming

**CONS**

- Somewhat higher initial costs

## Regulatory compliance

There are numerous quality and regulatory standards across multiple industries requiring environmental monitoring, data storage, and alerting for out-of-spec conditions. Some of these standards include:

- FDA 21 CFR Part 11 compliance for electronic records to help ensure that electronic data collected is trustworthy, reliable, and equivalent to paper records.
- The Food Safety Modernization Act (FSMA) requires that proper temperatures of food are maintained throughout the supply chain.
- The Joint Commission on Accreditation of Healthcare Organizations (JCAHO) states that rooms that are considered critical, like those where invasive procedures are performed or where sterile items are stored, are to be in constant compliance when being used for their intended purpose.
- The World Health Organization (WHO) Technical Report Series No. 961, 2011, Annex 9 provides guidance for the storage and transport of time- and temperature-sensitive pharmaceutical products, which requires monitoring and alarming for temperature and humidity.

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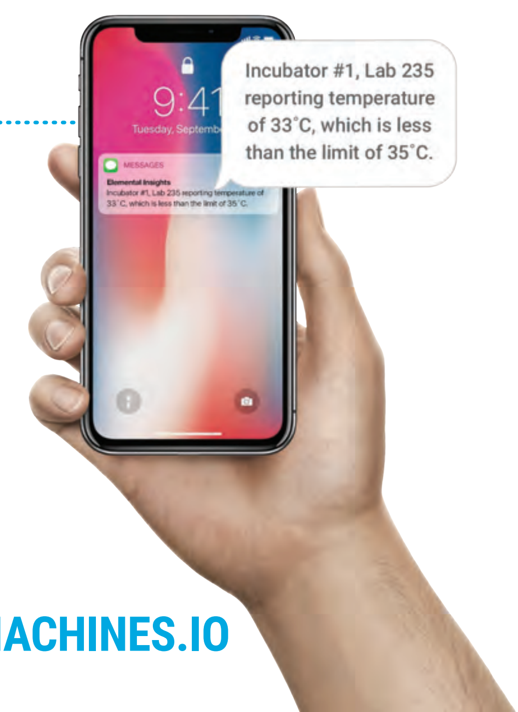


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**WHAT CAN WE DO FOR YOUR LAB? WWW.ELEMENTALMACHINES.IO**

# Automation in Bioprocess Development: Near-, Mid-, and Long-Term Opportunities

by Paul Denny-Gouldson and Claire Hill

Automation, combined with other technological advances such as the Internet of Things (IoT) and analytics platforms like machine learning, will be a major part of the future of bioprocess development, and will continue to make waves in the industry by removing mundane tasks from scientists while increasing accuracy and efficiency.

Liquid handling robots and high-throughput process equipment are already commonly found in development labs, and academic groups and technology vendors are pushing the boundaries of microfluidics to create "lab-on-a-chip" devices for process development applications. But, despite the interest and investment in these new technologies, very few labs can currently use them to their full potential.

## Shifting the bottleneck

Bioprocess development is very labor-intensive, particularly compared to small-molecule development, and there are many opportunities to take some of the manual handling burden off of lab scientists and technicians. When the speed of experiments is increased, however, the bottleneck shifts from equipment setup and manual operations to analytical assay turnaround and data analysis. This is especially true when processes are scaled down to bench or even microwell scale, because more experimental data is needed to account for potential variability.

## Automation is more than robotics

Only a few years ago automation was synonymous with robotics. And, initially, lab automation focused on wet lab requirements such as plate handling and pipetting. This led to the creation of assay platforms designed to be run on robotic systems that all but removed the need for human intervention. These platforms were designed to connect with corporate inventory and sample management and dispensing systems, which meant scientists could design experiments and let the robotic system run the assay.

While this type of system clearly brought many advantages, such as the ability to run experiments overnight and on weekends without manual supervision, it only covers part of the story. The definition of automation has now progressed to cover all aspects of the process development workflow, including automated data analysis and automated decision-making and progressive experiment design.


## Advances in technology

As the Internet of Things (IoT) makes its way from our homes into the laboratory, we are seeing many opportunities for the simplification and improvement of laboratory workflows. Companies such as BioBright (Boston, MA), TetraScience (Boston, MA), and Elemental Machines (Cambridge, MA) are leading the way in demonstrating what technology can deliver for next-generation "smart" laboratories. For example, the BioBright voice-recognition system and "hotfolder" software that automatically collects all experimental data including transcriptions of voice recordings were used in a neuroscience lab at New York University.[1] The system not only improved the accuracy of the delicate work by more than 20 times, but also meant that a single person could do the work of two scientists.

Most of the new instruments coming to market are now IoT-enabled and vendors are using this technology to help deliver a better service with features such as automated preventative maintenance and reagents delivered Just in Time (JIT). The benefits of advanced monitoring and alerting can be highly valuable when expensive long-term studies and instruments are involved.

A large pharmaceutical company used TetraScience's cloud-enabled monitoring technology to detect a potentially disastrous deviation in an accelerated lifetime experiment in time to take corrective action and avoid estimated costs of more than $30 million.[2] There are other examples, too. After failing to troubleshoot problems with a high-performance liquid chromatography (HPLC) instrument using traditional methods, a lab in Massachusetts installed a cloud-connected temperature sensor from Elemental Machines near the instrument and soon discovered that the problem was caused by the building's climate control system.[3]

So, while robotics will still form the foundation to automation, monitoring analytical instruments in real time, gathering data, and performing automated analysis and feedback loops all come into play with the concept of the totally connected lab.

## What comes after the connected lab?

With a fully connected and automated environment comes the next phase of development—a self-monitoring, self-regulating closed system that can make decisions on what to do next based on the results of the current experiment. Here, we see the importance of machine-learning techniques, where models can be developed and trained to allow systems to control themselves based on patterns they are seeing in real time.

In addition to academic research, companies such as LabGenius (London, U.K.) are already applying machine-learning algorithms to protein engineering with therapeutic applications in mind. The company developed EVA, an artificial intelligence-driven evolution engine, and is using this technology to learn how to enhance therapeutic protein stability with the potential to address unmet clinical needs.[4]

The foundations of this approach are IoT and robotics, but their development will require considerable optimization and testing. This also requires the ability to integrate data acquisition and process control strategies across different systems and vendors. There is some standardization in the industry, such as the use of the OPC for interoperability across process equipment, but more open-system architectures and better collaboration between vendors are still needed.

## Analysis, analysis, analysis

The final part of the system to consider for automation is the analysis and reporting aspects—all important parts of the decision-making process for scientists. Getting the fundamentals of data collection and analysis right is a key prerequisite to any automation effort, yet this isn't as simple as it sounds.

Typically, the process for data aggregation and analysis and reporting is still manual, despite automation of the instruments. There are different stages of data analysis, ranging from converting raw measured values into biologically meaningful parameters through comparing data across unit operations, across different analytical assays, and over extended time periods. Improvements at the instrument level can greatly enhance the quality and quantity of data analysis for individual unit operations, but there still needs to be a higher-level integration layer to link the results of each unit operation together and enable rapid and sophisticated root cause analysis across the entire process.

Great strides are being made in this area—the concepts of alerting, automated decision trees based on business rules and research and development project progress reporting are starting to emerge. This has the potential to not only reduce the burden of data administration faced by many scientists, but also enable greater visibility of the dependencies between process parameters and quality attributes leading to much more profound process understanding. The key with the analysis aspects is making sure that all the different parts of the system are integrated at the data level and this, in turn, will require collaboration from biopharmaceutical companies, instrument vendors, and software vendors.

By considering automation in this holistic manner, we can see great opportunities for new technology and a streamlining of research and development. The imperative to increase efficiency and reduce time to bring new biologics to market is forcing biopharmaceutical companies to reconsider the ways they interact with and leverage technology. With the advent of continuous processing and new types of biological products such as cell and gene therapies, these advances are now becoming more important than ever.

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4. https://www.labgeni.us/#markets-sectionAnchor



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# LabCentral Case Study

## LabCentral background

LabCentral, located in Cambridge, Massachusetts, is the nation's premier co-working laboratory launchpad for high-potential life-science startups. It offers everything young companies need to begin lab operations almost immediately upon move-in and propel their science forward faster and more cost-efficiently. While residents of the facility are developing breakthrough technologies, LabCentral's laboratory operations team manages all other details—from permitting and lab maintenance to administrative activities, such as ordering lab supplies. Elemental Machines has been a proud sponsor of LabCentral since 2015.

## Before Elemental Machines solution

The Elemental Machines solution has proved to be a valuable service for the LabCentral laboratory operations team. The platform comprises Elements, wireless sensor units that collect highr-resolution environmental data from lab equipment such as refrigerators, freezers, incubators, ovens, etc., and localized zones within the facility. Element data is


Figure 1. Prior to the introduction of Elemental Machines solution, regular walk-throughs of the 70,000-sq-foot LabCentral facility were the only ways to detect lab equipment issues. Photo courtesy: LabCentral © Paul Avis Photography.

aggregated onto the web-based Elemental Insights Dashboard for 24/7 monitoring and alerting.

Prior to deployment of the Elemental Machines solution, LabCentral did not have a comprehensive and centralized monitoring and alerting system. This resulted in three main pain points for the laboratory operations team:

1. Lengthy regular walk-throughs of the 70,000-square-foot facility to ensure its fleet of more than 300 pieces of equipment was in proper working order.
2. Communicating equipment problems to LabCentral residents.
3. Lack of transparency regarding utilization of laboratory equipment.

## After Elemental Machines solution

The Elemental Machines solution addresses LabCentral's pain points in the following ways:

1. **Eliminates the need for regular walk-throughs with the setup of customized alerts.**

   Highly valued by the LabCentral team, the Elemental Machines solution gives LabCentral team members the freedom to monitor equipment remotely. This functionality enables team members to take appropriate corrective action quickly, even when they are off-site. The end result is a reduction in the amount of scrapped materials due to equipment failures and power outages, the latter of which are common during New England winters. "Many of our residents produce time- and cost-intensive samples whose loss can impede the scientific advancement that our organization fosters."- Celina Chang, LabCentral Sr. Director, Laboratory Operations.

2. **Facilitates communication related to equipment issues/failures through shared access to the Elemental Insights Dashboard with LabCentral residents.**

   While LabCentral's laboratory operations

Figure 2a (left) and 2b (right): Elemental Machines solution monitors the LabCentral facility during inclement weather. Photos courtesy: David Van Horn licensed via CC and LabCentral © Paul Avis Photography, respectively.

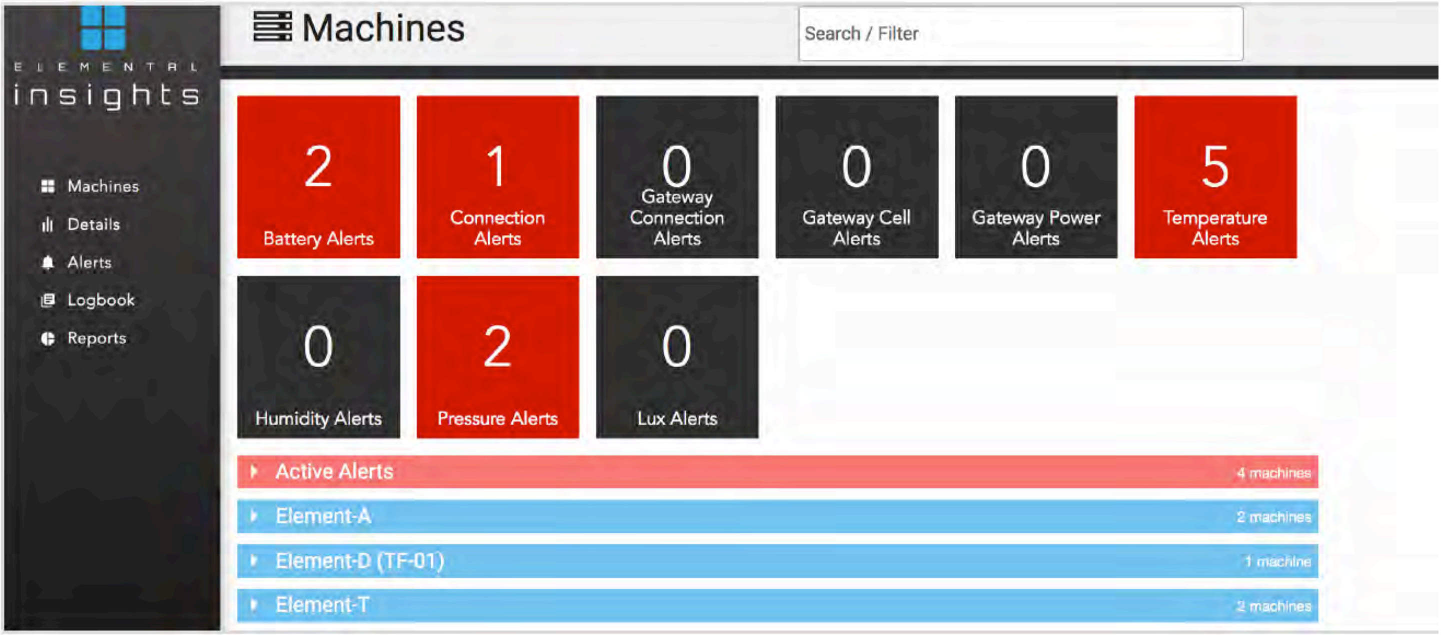


Figure 3. Elemental Insights Dashboard provides an overview of issues at the LabCentral facility based on user-defined parameters.

team uses the Elemental Machines solution to oversee the entire equipment fleet, its residents are granted access to the dashboard specifically for equipment and areas relevant to their specific company's operations. This allows resident scientists to monitor and receive alerts for environmental conditions pertinent to their studies. Each user, whether a resident scientist or LabCentral staff member, has the ability to configure unique alert parameters based on environmental parameters, equipment type, location, and other meaningful categorizations. Aberrant equipment performance is highlighted through color-coded views on the Elemental Insights Dashboard. Thus, the Elemental Machines solution also offers a large degree of customization for various groups within an organization that each have unique needs.

3. **Gained transparency and insight into the facility through machine details available on the Elemental Insights Dashboard.**

Once the LabCentral team had system-wide visibility into its laboratory environment, they were able to identify issues with the HVAC system that impacted different areas of the facility. Tracking the temperature and relative humidity of the affected areas was crucial in determining how the HVAC failure affected the day-to-day operations of resident companies. By monitoring both the equipment and its environment, they were able to detect the effects of poor operating conditions and prevent further damage. "Prior to this insight from Elemental Machines, we had challenges tracking the laboratory atmosphere in real time. This new data drove us to invest in temporary solutions while our HVAC system was repaired." - Lyndsey York, Senior Lab Manager.

In addition to addressing LabCentral's three main pain points, the Elemental Machines solution also offered LabCentral with the unforeseen benefits described below.

- **Scalability:** Elemental Machines has been able to offer LabCentral a scalable combined monitoring/alerting solution to accommodate a dynamic, fast-growing organization. As LabCentral has grown since its inception, Elemental Machines has also scaled its platform for LabCentral through seamless integration of new equipment and laboratory space onto the Elemental Insights Dashboard.

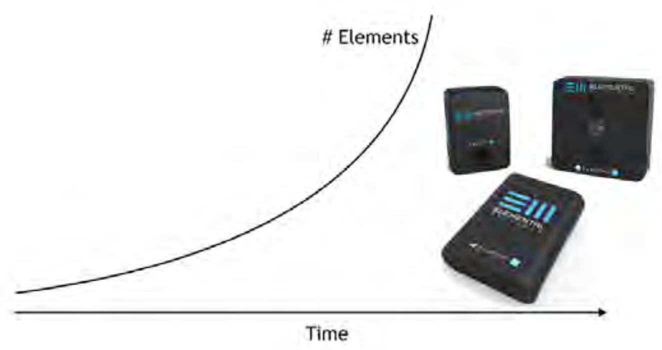


Figure 4. Both the number and types of Elements at LabCentral have grown with time. As LabCentral expanded, Elemental Machines equipped new facilities with additional Elements. Additionally, LabCentral has welcomed new Elemental Machines technology over the years. Clockwise from top left: Element-T (temperature), Element-A (ambient environment), Element-D (data capture from incubators, balances, etc.).

- **Facilitate repair or remediation decisions:** A close look at data from a particular freezer revealed a cyclic pattern indicative of an imminent compressor failure based on previous experiences. This insight allowed the laboratory operations team to act before the freezer failed and saved both time and money on the diagnosis of the issue. The contents of the freezer were safely moved to another freezer without the typical rush and stress of an emergency and no loss of material occurred.

- **Data for GLP:** One of LabCentral's resident companies was establishing formal Good Laboratory Practices. As a part of this program, the company established guidelines for storage of thermally sensitive materials. Like all scientists, the resident scientists sought data to justify decisions for material storage location, equipment maintenance plans, etc. Fortunately, this data was available to the team via the Elemental Insights Dashboard. Furthermore, the resident company plans to leverage this data for internal audits and the development of additional laboratory processes.

## Conclusions

Both the LabCentral team and residents view the Elemental Machines solution as an indispensable tool that enables them to focus on their core missions. Through scalable and customizable attributes, Elemental Machines has helped the LabCentral operations team manage a growing fleet of critical lab equipment while also providing peace of mind to its residents who are able to capture real-time data relevant to their high-stakes research. Elemental Machines is proud to support both small and large organizations that are catalyzing revolutionary scientific advancements.

Learn more about how Elemental Machines can help your team achieve peace of mind!

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# Resources

## The Smart Lab, IoT, and the Data-Driven Lab Manager

Laboratory managers are better equipped to manage data flows and monitor, record, and analyze increasingly large data stores by incorporating Smart lab solutions. The smart lab enables automated, high-resolution data acquisition; the ability to visualize large data sets; continual monitoring of lab equipment, processes, and environmental factors that may affect results; and integration of data from different instruments into a centralized system. As a result, organizations can increase operational efficiency and in turn accelerate research.

**Read more at https://www.labcompare.com/media/1/Document/Smart-Lab.pdf**

## Guide to Freezer/Refrigerator Monitoring and Alarming

Cold storage monitoring is critical to ensure the protection of precious samples such as pharmaceuticals and biologics. Four options for monitoring temperature in cold storage equipment are outlined here—manual thermometers, chart recorders, data loggers, and wireless IoT devices—with the advantages and disadvantages of each technique given. For example, data loggers provide continuous monitoring, but remote alarming and notifications are not possible, and data is not accessible in the cloud. Wireless IoT monitoring, on the other hand, delivers remote alarming and allows secure data storage in the cloud.

**Details can be found at https://www.labcompare.com/media/1/Document/Freezer-Monitoring.pdf**

## 4 Pillars of Laboratory Equipment Monitoring

Research advances rely on the ability to produce repeatable protocols and results, yet insufficient repeatability and data irreproducibility can impede progress. An effective laboratory monitoring system provides a simple solution to this problem by eliminating sources of error such as paper-based documentation. This article outlines four important factors that should be considered when integrating a monitoring system into the laboratory: 1) reliability and convenience, 2) compliance, 3) data integrity, and 4) risk management and cost savings.

**For more information, see https://www.labcompare.com/media/1/Document/Equipment-Monitoring.pdf**

## 10 Ways IoT Devices Can Help You Achieve Good Laboratory Practices (GLP)

Good Laboratory Practices are a set of management controls implemented to ensure the uniformity, quality, reproducibility, reliability, and integrity of experiments. The use of wireless IoT sensors in combination with cloud-based storage, retrieval, reporting, and data analytics can help organizations achieve regulatory compliance and Good Laboratory Practices. This paper shows how Elemental Machines' sensors and platforms meet the compliance standards for FDA 21 CFR Part 11B Electronic Records, 21 CFR Part 58D GLP Equipment, and 21 CFR Part 1271 Human Cells and Tissues.

**Read the article at https://www.labcompare.com/media/1/Document/IOT-Devices-and-GLP.pdf**

## Elemental Machines-Elements-T/A

Watch this video to learn how you can optimize your complex scientific processes using an effective line of software and precision sensors.

**https://www.biocompare.com/Life-Science-Videos/358473-Watch-Video-Elemental-Machines-Elements-Ts-As/**