Trend report: Laboratory 4.0—The smart laboratory of the future

The modern laboratory is experiencing a paradigm change. As laboratory processes increase in complexity, automation solutions are becoming indispensible. In addition, the constant increase in statutory and regulatory requirements makes needs-oriented networking necessary. Smart laboratory equipment will be a driving force behind innovation in the smart laboratory of the future.

From May 10–13, 2016, analytica in Munich will allow experts to make user-oriented presentations of integrated automation and digitalization solutions. Corresponding tools, software and networking solutions that satisfy the prerequisites for the "smart laboratory" will be presented in theory and in practice.

So far, future-oriented information technology solutions have opened up unimaginable opportunities and challenges in the laboratory. Optimized levels of automation and integrated device modules with dynamic application capabilities are making it possible to develop processes that are efficient and reproducible—i.e. that can be validated—and ensure holistic data management. The task now is to transform manual processes into automated ones and to integrate laboratory information management systems (LIMS) to make the laboratory a more efficient "think factory". Intelligent laboratory systems, individual networking and integrating laboratories into company structures in a sustainable manner not only increase a company's flexibility, but significantly improve its profitability, as well.
Particularly in the case of growth-oriented industrial laboratories, it is important to improve efficiency, optimize structures and increase flexibility. Essential prerequisites and factors of success for reaching these objectives include state-of-the-art, high-resolution, communication-capable analysis systems, functional automation solutions to monitor reaction parameters and product quality and ensure rapid data availability and efficient data management.

Important future technologies have their place in the laboratory value chain. Against the backdrop of increasing digitalization, various processes and structures in the laboratory of the future must be rethought. Launching this new phase of development in the laboratory calls for complex holistic automation solutions. The number of network-capable laboratory devices with so-called smart functions will continue to grow at a rapid pace. Lab 4.0 is about to become a reality.

The laboratory of the future requires that laboratory systems be able to communicate with one another without restriction. The objective is to guarantee various flexible additional functions including monitored inspection processes through continuous data availability. Intelligent modules already control equipment systems, switch on laboratory devices automatically and regulate various processes in the laboratory. For example, a safety cabinet can now automatically monitor and regulate the overflow of collection containers or communicate with other cabinet parts and devices. Cameras that are built into various laboratory technology tools intelligently control things in their surroundings. In the future, communication between laboratory devices will continue to increase in importance.

The smart laboratory stands for a new era in the laboratory. Existing
equipment technologies must be made future proof, and high-availability data networks are urgently needed. The gigantic flow of data must be used sensibly. The quick and reliable transfer of huge quantities of data and IP-based networks make it necessary to handle that data efficiently.

Bridge between the life sciences and automation technology
The team of researchers who work with Andreas Traube, Head of the Department of Laboratory Automation and Biomanufacturing Engineering at Fraunhofer IPA, has developed new approaches for networking laboratory and analysis processes in the value chain that covers everything from sample logistics to documentation. They took their experiences with LEAN management and process optimization and incorporated them into the laboratory, the objective being to sustainably improve the efficiency of all processes and overall laboratory performance. By successfully implementing their objectives, the team of researchers did an exemplary job of bridging the gap between the life sciences and automation technology. "We are convinced that interaction between organizational and technological solutions can make life-science laboratories considerably more efficient. Fraunhofer IPA offers customer-specific solutions for the entire LEAN Lab workflow and provides support during implementation and with technical developments," explains Traube.

"We live in an age of increasingly personalized products. As a result, laboratories that are used to research and test products in various branches of industry are becoming a key factor in the product development process," predicts Traube. "Networking key laboratory elements such as laboratory processes, data analysis, equipment and operating personnel are key elements for an efficient smart laboratory," explains Traube, looking forward to the future. "The technological foundation for this is already available. These technologies will have an enormous influence on and change laboratories in the years to come!"

Lab 4.0 from the industry’s vantage point
Generally speaking, one can differentiate between two types of laboratories, i.e. the academic research laboratory and the industrial research and quality assurance laboratory. According to Dr. Frank Schleifenbaum, Marketing Director at Berthold Technologies, the first has little need for laboratory automation because applications are not standardized or repetitive enough. He feels that the preferred approach here would be to network laboratory equipment, which covers everything from a fully automated procurement system for chemicals and labware and the direct exchange of data between individual analysis devices (LIMS) to fully automated lab records. "This type of integration calls for corresponding interfaces in the hardware, electronics and software," explains Schleifenbaum. "Ideally, all devices have access to the network and communicate via a standardized protocol such as SILA. However, in the research sector, the user must be able to intervene in the process at any time. Uniform footprints for the devices might also be a topic."
For instance, standardized dimensions with defined graduated sizes are conceivable because they make it easier to adapt a laboratory to the procedure in question—e.g. through the use of adjustable lab benches.” He goes on to explain that the demands placed on routine and analysis laboratories in industry emphasize different aspects. Instead of flexibility, the priority here is on reliability, throughput and avoiding errors. “In any event, sample handling must be automated and data documentation must be fully automatic. Individual devices exchange data and samples among one another, and manual intervention is not necessary. At the same time, standardized interfaces make it possible to combine centralizing and decentralizing laboratories. Complex data evaluation (big data) can be outsourced to high-performance computer clusters, and data can be stored centrally and correlated with one another,” continues Schleifenbaum. Despite all the standardization of laboratory processes, uniform interfaces make it possible to quickly convert the laboratory for other routine tasks.

**Big data**

Lab 4.0 makes it possible to collect and link large quantities of data. “That is why innovations must be triggered that can automate and quickly generate these large quantities of data (high-throughput screening and big data). However, the interfaces must be defined. To do that, binding specifications from a regulatory authority are needed. A loosely knit consortium of laboratory equipment suppliers will probably not suffice,” explains Schleifenbaum. “Data protection will be an important topic and a challenge that network technology must deal with. Communication between individual devices must be kept simple enough so that the user can create and adapt it on his own.” Which is why data evaluation must be capable of learning, i.e. of independently searching for relationships and detecting and depicting dependencies. Then it would not just reflect the user's manual actions, but expand on them. According to Schleifenbaum, on the one hand that would give the user a flexible laboratory environment that could be adapted to current requirements. At the same time, he would see an increase in the quality of the analysis results and be able to collect, organize and automatically evaluate larger quantities of data.

**Sector-specific solutions at analytica in Munich**

At analytica, which takes place in Munich from May 10–13, more than 1,100 exhibitors from around the world will present their latest products and methods—including those for the laboratory of the future. According to Dr. Gunther Wobser, Managing Partner at LAUDA, the challenges of Lab 4.0 lie in the fact that "devices must communicate with one another.” LAUDA sells thermostats and circulation chillers with various interfaces. "We make integrated laboratory-automation systems available free of charge and use remote maintenance to ensure permanent availability," LAUDA is presenting a new product line at analytica. “The major device innovation that we are presenting at analytica is called PRO. For the first time ever, we have optimized thermostats for bath applications and circulation thermostats for external applications. The operating unit is completely independent of the thermostat and is flexible enough to be placed wherever it is needed,” explains Wobser.

**Conclusion**

Lab 4.0 is revolutionizing the laboratory community, from sample logistics to data management, and is allowing new approaches for personalized processes. In the future, next-generation technologies such as big data, cloud computing, the Internet of Things and the mobile Internet will place an essential role in securing future growth.
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