Perspectives: The lab of the future

Tomorrow's researcher can expect to work at the intersection of reality and science fiction

By Michael P. Conroy, National Aeronautics & Space Administration

[+]Enlarge

Credit: Shutterstock

The lab of the future. This phrase calls to mind a place where scientists, engineers, or, frankly, researchers of any discipline, can step around the mundane aspects associated with having a lab—that is, planning, performing maintenance, scheduling, and preparing—and get straight to the process of experimentation. Imagine a place with floating displays, information at the tip of a finger, and few barriers to analysis, synthesis, or creativity.

We've seen something like this already in the basement work space of Tony Stark, the businessman alter ego of Stan Lee's comic book and movie superhero Iron Man. The lab of the future is all about bringing this vision closer through modern information technology. But where can we find this ideal basement?

In the real world, we still have to build it. So let's start with a list of what we'll need, beginning with the basics: data, data management systems, and knowledgeable research teams. These need to be arranged in such a way that researchers can collaborate from anywhere, introducing the notion of the lab of the future being a global network of labs. This approach also introduces the need for networking technology as a foundation to build from.

Visualizing a blueprint for the final structure, I suggest our project will entail six technology areas, call them Lab of the Future Technologies, or LOFTs. LOFT 1 is broadly made up of networking technology, which is the array of hardware and software necessary to craft our global network. Some LOFT 1 technology is already commercially available, and some is still on a wish list. We will find that some mix of available and emerging technologies exists for all six LOFTs, with the balance shifting from available to emerging as we move upward.

When we speak of moving upward, it is not to suggest that each LOFT is a physical layer of technology that we must achieve before moving to the next one. Work will be done across our blueprint at all six LOFTs simultaneously, with each LOFT taking us to a higher level of technological capability.

Now, let's look at LOFT 2, where we have automatic retrieval of data and displays made possible by personal-assistant technology. Imagine our LOFT 1 network is equipped with a programmer, logistics manager, planner, and assistant—in essence, a robotic information technology manager.

Much of the technology required at LOFT 2 has caught on in consumer electronics. The man on the street is getting directions, just as the man on the couch is ordering pizza, using personal computers and cell phones with applications such as Google Assistant, Amazon's Alexa, Microsoft's Cortana, Apple's Siri, and Samsung's Bixby.

Even more capable versions of this technology are on their way. NASA's Ground Systems Development & Operations (GSDO) program, for example, is evaluating the Assistant for Understanding Data through Reasoning, Extraction & Synthesis (AUDREY), a humanlike assistant developed by the Jet Propulsion Laboratory with funding from the U.S. Department of Homeland Security. GSDO is also looking at NASA's Kennedy Automated Test Engineer (KATE). Both are intended to work as data agents with the goal of becoming intelligent virtual partners.

Studies are also under way at the Kennedy Space Center's IT Advanced Concepts Lab of the viability of the "internet of things" (IoT), a technology concept in which intelligent devices in individual instruments in laboratories are linked via the internet. The goal for IoT elements is that they will be supervised by our intelligent partners. It's hoped that one day an IoT-enabled autonomous system will be able to manage equipment and ultimately participate as an automated member of the research team, not unlike the HAL 9000 computer in Arthur C. Clarke's and Stanley Kubrick's "2001: A Space Odyssey" (though we aren't ready to turn over control of certain air locks).

The role of the human information technology manager and data analyst is significantly elevated at LOFT 2. Here, I submit the Kennedy Space Center's launch team, which operates within the GSDO program, as an analog for the lab environment we are constructing. The team's laboratory architects and engineers have integrated a range of tools, data models, and disciplines. These include flight simulators, process protocols, planetary physics, audio/video data, atmospheric physics, and planning systems that

provide enterprise visualization of multidecade projects, such as a Mars landing. This work has required a look forward to the needs of future researchers with knowledge of historical experimental results and decisions of impact to a global, if not interplanetary, network of labs in the future.

Our next LOFT need is for display technology able to represent new information and knowledge. Putting Iron Man comics aside, we turn to a broader entertainment sphere, the multi-billion-dollar digital-game industry, for inspiration as we conceptualize LOFT 3. Here we encounter virtual- and augmented-reality systems, pivoting to a practical question that has been waiting in the wings: What does our visualization system need to display?

For an answer, we advance to the first of our data technology LOFTs, where we apply existing technologies to locate archived information, such as reports, graphs, tables, or images cataloged in legacy data systems, and communicate this information across our network. Large data sets are entering research, but so are “big data” management tools that can handle them at LOFT 4.

At LOFT 5, we anticipate a higher level of data, made up of emerging and undiscovered information and knowledge—the unknown unknowns of the research domain. The relevance of these data, which could exist in media ranging from the unfamiliar to the inconceivable, may come to light only in the future when studied in contexts that are also in an emergent state. And they can be handled only with the introduction of machine-learning techniques. These methods include algorithms that significantly enhance the data network with the ability to “learn from experience” about the likely trajectory of new data entering the system as it crafts pathways for the unknowns into the evolving managed database. LOFT 5 is a giant step into the realm of the unsolved, where no drop-in tools are yet ready.

As we develop visualization at the frontier of science and technology, we will focus on devising data representation techniques suitable for both humans and intelligent machines. We are conscious of the fact that the machines operate at an astronomically higher capacity than humans in most regards. A 40,000-line table of results is manageable for a computer and floats through the computing cloud with no problem. But it would overwhelm a human researcher.

In search of such techniques, Kennedy Space Center worked with temporal-spatial data and metadata formats to develop its Distributed Observer Network (DON) environment, in which multiple users can simultaneously assess simulation results, and the Model Process Control language through which DON operates. The hard work is to develop protocols that can be rapidly understood by both the human and machine teams and that are sensitive to the elements of future interest as they arise. That brings us to LOFT 6, technologies that support a rich human-to-machine engagement, which will pay great dividends but are still far away from the “solved” side of the page.

The lab-of-the-future interface will certainly resemble Stark's artificial-intelligence platform, Just A Rather Very Intelligent System (JARVIS), the enabler that Iron Man introduced to the world. An archetype, JARVIS represents an environment of amazing efficiency and effectiveness in research, one in which the researcher is freed from all the old-fashioned "lab stuff," which is taken care of in the network.

NASA is pushing forward to that end. But LOFT 1 through LOFT 6 also need to be developed across the research universe and shared among all disciplines, certainly in chemistry-intensive fields such as materials science and drug discovery. NASA, hoping to build on its heritage of passing technologies into the world at large, is interested in sharing its tools and experiences at the new frontier of the laboratory.

But without a vision of the ultimate lab of the future—a blueprint that extends several steps beyond the science and technology that can easily be deployed today—new developments are as likely to burden as they are to free the researcher. In Stark's world, success comes not from a random assemblage of cool tools, lasers, and robots, but from their integration with JARVIS, the intelligent system that enables Stark to achieve breakthroughs.

[+]Enlarge

Conroy

Credit: NASA

Michael P. Conroy is simulation technology manager at NASA's Kennedy Space Center.

Learn how to write for C&EN Perspectives. Submit your ideas to cenperspectives@acs.org.

Chemical & Engineering News
ISSN 0009-2347