Looking Ahead

The Lab in a Box, or the Evolving Laboratory

In the flood of things flowing through my office everyday, a striking picture stopped me cold. It was a decapitated infant, lying on its back, with no legs below the knees. The two technicians or researchers, whichever they were, were smiling as they talked with each other. There were nine or so of these babies lying there. Now what was this? It was a diaper laboratory with the mannequins truncated for convenience in manipulation.

This laboratory was doing research in the conventional dedicated place, on a commodity. But as more and more products become commodities, either by expanding sales or by consolidation, the need for a different kind of laboratory work will increase because bigger and more competitive global markets will demand greater research attention to the product line.

I expect that by the time the U.S. National Academy of Engineering's "Engineer of 2020" project has been completed and documented, we will have seen a radical transformation in that engineer's laboratory. A dozen or more forces at play will radically alter all laboratories-their location, their size, their functions, their ownership, and the fields and topics for research.

Traditionally, the industrial laboratory is best illustrated by a chemistry or physics or engineering lab, a place where specific things are explored in a specially structured environment. Other sciences usually had little or nothing to do with laboratories and bench research. Their primary commitment was field or observational research or the collection of samples and the recording of their sources. That group is best illustrated by astronomy, geology and the largest portion of biological research through the early part of the 20th century. Events have changed all of that.

Information Technology

The most powerful and universal force for change in the laboratory and its functions is and has been information technology. I sometimes feel that the changes it forces are in a way regrettable, almost melancholy. I spent a decade in lab research, ending 40 years ago. When I walk into a chemical laboratory today, I truly am a stranger in a strange land. The instruments are unrecognizable. I am unable to figure out what is analyzed in them; it is beyond my knowledge and conjecture.

All in all, there have been marvelous changes in more or less traditional laboratory functions in all of the relevant sciences and especially dramatic in improving quality, speed and shrinking sample size. Much of the instrumentation is optical or spectral, and as the analytical or catalytic spectrum bands widen they are incorporated into laboratory equipment, The range of phenomena that will be analyzed or processed will, in turn, increase.

Information technologies' effects are not limited to the traditional laboratory. Tracking, for example, is among the tasks that infotech is making practical, cheap and widespread, particularly in fields that were previously observational. The ability to attach tiny electronic devices to animals is making tracking routine, from elephants to mosquitoes. The collection of weather data, by spreading out 5,000 or 10,000 devices on the riverside or hillside, will give unprecedented intimacy of detail about weather and what is going on. It will drastically change warning about such things as flooding. What these changes illustrate is that the laboratory is going outdoors in many regards. Successful field monitoring will inevitably move on to interventions and to small and large open environment experimentation.

Remote consulting will become more common. There is no compelling reason for most consultants to ever show up at a facility; it is just customary. Efficiency, effectiveness and cost and time saving will encourage more frequent and rapid exchange of visual imagery and interpretations. The parallel to remote consulting will be remote collaboration, where people on the same project will be in full real-time audio, video and data communication.

Learning from SETI

The search for extraterrestrial intelligence, SETI, has opened up a new concept in research data interpretation. There are now thousands of people dedicating the down time on their computers to processing data collected in connection with SETI. The same information technology that allows them to deal with the complexity of thousands of people working on relatively small bits of the problem and then bringing it all together to a central focus is much like the main problem today in protein research, which is understanding protein folding. There is little doubt that the shape that a protein takes as it folds is a primary factor determining its function. The SETI model may apply here as well as to a host of other biological research problems

Information technology is also changing the nature of experimentation, particularly the =handling of materials. We see this in pharmaceuticals, we know about it in electronics, and many of us view it in the forensic laboratories on TV. Information technology has led to miniaturization of sample size and the appropriate accommodations in analytical instruments and vice versa. Today experiments that might take a scientist a day or two to run, can be run a hundredfold or more, through the improved micro stuff.

Accompanying that micro sample size is a more general feature of the automation of the laboratory with two effects. First, the scientist's assistant may be the person far more involved with the setting up and managing of an experiment. If it is at all elaborate, that assistant will be activating the automation process to set up the experiment, test it with a dry run, and monitor it as it is goes along. Months or years later, that process could be fully planned, designed and executed without human assistance. Today's scientist is fast becoming a desk worker, designing experiments, interpreting data, planning for the next round of experiment. And won't that be better than wasting time and space to have him appear at the laboratory? Increasingly, more laboratory scientists, especially the most talented ones, will work from home or wherever else they wish.

Taking that notion of working away from the laboratory, one can foresee another quite dramatic change. There are a tiny number of fully independent scientists in the U.S. and England who have sufficient resources of their own that they work for no one and can plan, design and execute their own experiments. (Two striking developments coming out of work by the same independent scientist were the development of gas chromatography and the conceptualization of Gaia, the notion that the surface of the globe is such a complex set of interactions that it can be almost seen as organic.)

Outsourcing Research

Cooperation between and among laboratories will become more and more a general practice not limited to cooperation within a fixed company or organization, but across lines to suppliers, government agencies, specialized consultants, academics, and independent research organizations. That kind of cooperation will lead to substantial change in the laboratory itself, and to the outsourcing of research. To some extent, it could be the outsourcing of an entire project; it could be the outsourcing of some kind of new material preparation, or some model-making or parts manufacture.

Much of that outsourcing will favor highly-skilled countries with a low-cost labor structure, as in the recent emergence of India as a first-class provider of outsourced services. However, the outsourcing will not be driven by price alone, but by convenience, scheduling, and those most elusive of all factors, experience and reliability. Good experience in outsourcing will enable companies to seek out the “right” price, cost structure, talent, and accessibility.

One can also look at outsourcing as a form of rent-a-lab. The operator working alone in his or her home laboratory might be a focus of outsourcing for highly specialized capabilities and functions. Or they could be part of a worldwide virtual team of such solo researchers.

Voting on the Lab Director

Electronics in the laboratory will have other interesting effects. As a totally wired facility, with everyone able to communicate with everyone else, the notion of holding frequent assemblies to hear the word from the hierarchy will become quaint. Moreover, as the word is received about new plans, new concepts and new products from laboratory directors it should become routine for those who would be affected by the anticipated changes to vote electronically on what they have just heard in terms of clarity, desirability, utility, appropriateness, etc. This process would for the first time give the laboratory director direct, anonymous, and not always congenial evaluations of his or her plans from the staff.

Responding to Society

Concerns for social responsibility will create new laboratory functions and, to some extent, new kinds of laboratories. For example, the current fashion of ethanol as automobile fuel will stimulate an enormous amount of biological research-to be able to take other plant materials, trees or otherwise, and the now non-fermentable part of grains, like corn, and figure out how to convert them into alcohol, primarily by biochemical processes. Other social responsibilities will give us laboratory research to facilitate recycling construction and other materials.

As research creates social pressures on laboratories, I also see the crème de la crème of researchers employing professional agents just as ball players and movie stars do. They will look for the best bid in terms of what they want, including ready access to their children at the R&D facility. I am not suggesting playland and kindergarten rooms, but something much more stimulating: a place where the child and adult can see each other and, importantly, where the child can watch the adult pursue his or her professional work.

Research Above and Below Earth

More dramatic shifts of the locus of laboratories will be to the Moon and planets, notably Mars and perhaps even Venus. Those laboratories will be autonomous and, once they are established, probably have no humans in attendance, simply because extended time in space and weightlessness is injurious. The movement to other places in the solar system will also require autonomous facilities onboard spacecraft, although the materials, labor and time to construct them cannot now be estimated reliably.

We may find it convenient to do the same things with the largest unexplored space on earth-the ocean and its bottom. Our oceanographic ships are already floating laboratories, but that capability will expand as oceanography becomes more focused on economically useful research at all depths from the surface to the bottom.

Sites for Simulation

The laboratory will become the focus of simulation of almost anything that turns out to be interesting. Simulation of outdoors involving large numbers of people, and patterns of interaction and movement will be routine. The Smart Car, for example, will get loads of simulation as we look to the question of how to integrate it with human-driven vehicles and how to set up a strategy to make that integration. Even before a structure or a device has been built, a simulated walk-through and an operational experience will be commonplace in laboratories.

Robots will undoubtedly playa much more important part in dealing with highly toxic or risky materials, in dealing with unusual new stuff, or perhaps more significantly, in the most routine of laboratory tasks. Robots do not suffer from boredom. Many fields of social significance are on the border between research in the lab and research in the field and, as I see it, there will be a dynamic exchange and interaction between those two domains. Examples are devices for the handicapped, drug treatment, volunteer programs, and social-psychological experiments. This generalization involves physical interaction with social or economic components.

With the increasing automation of laboratories, as well as their robotization, there will be vigorous growth of capabilities for voice-operated systems, in which both people and robots speak in natural language.

The first portable computer I saw was bulky and heavy to lug around, but it was marvelous in what it could do. Now, 25 years later, all of that can be reduced to something that I can use while holding it in my hand.

Miniaturization in chemical; physical and biological fields will probably follow a similar path and carry us to the point where we will have a collapsible lab that you can carry as a suitcase and, ultimately, a pocket lab no bigger than a $25 hard cover novel, something you can take into the field and use effectively.

Virtual Worlds

Few of the forces for change act independently of one another. Therefore, in the spirit of systemic research, laboratory planners and designers should give consideration to an ever-expanding range and intensity of drivers of change.

For example, one of the most popular group activities on the Internet today involves virtual communities, the key feature of which is that each of the players buys into the game and owns a piece of property for which he or she has paid, and is thus entitled to develop within the game, in anyway they choose. As the game evolves, it is clear that some properties are worth more than others, and just as in the real world, a virtual economy evolves. These virtual communities may be a model for a laboratory to explore market needs, potential applications of a yet-to-be-developed product or service, to clarify research opportunities, and to improve the conceptualization of a laboratory assignment.

Perhaps more exciting will be the construction of virtual worlds, in which social scientists working with more traditional laboratory personnel, will be able to study and experiment with the sociological and behavioral components of a yet-to-be-developed product, service or system. For instance, The New York Times recently reported that the MacArthur Foundation has begun sponsoring events in the big online community of Second Life in order to learn how these virtual worlds are being used. Excitement about virtual communities is well justified if they can become a fresh source, a wellspring of creative scientific developments and their applications.