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What Makes Cornell NanoSmart?

The Cornell faculty have proven that they can collaborate effectively in nanoscience and nanotechnology research. The success of several interdisciplinary faculty groups in winning support to carry out innovative work in the research centers described in this issue shows this. However, how did Cornell actually become *nanosmart*? A deeper question is: Why is Cornell able to collaborate so effectively across the disciplines? How did this develop, and why can Cornell do it? Does it happen spontaneously, and why does it happen when it does? How fragile is this culture, and how can Cornell sustain it?

As a longtime faculty member at Cornell, my answer to these questions reflects a particular view of the history and the people who brought us to this point. I arrived at Cornell in August 1961 at the time when the Materials Science Center (now the Cornell Center for Materials Research) was just getting underway. I believe that the manner in which that center was formed had a great influence on the development of the interdisciplinary culture we enjoy today at Cornell and provides the basis for Cornell's success.

A pleasant memory, for example, of the initial days of the center was the lunch-time practice of the founding director of the Materials Science Center, Robert L. Sproull. If he was free, Sproull would head for Statler Hall early to be first in line and grab the round table in the little room at the back of the Rathskeller, a favorite dining area of the faculty. Tactically, the Rathskeller was located centrally on campus and was equidistant from the Physics, Chemistry, and Engineering Physics departments in one direction and the engineering departments in the other direction.

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Research in Focus
The NanoCulture Has Taken Root at Cornell

“If new approaches or extensions are developed by one user, the presence of permanent staff allows those developments to become part of the repertoire of the facility and available to other users.”

Charles Harrington/CU



Members of the Materials Science Center knew this, and they would join Sproull for lunch. The result was that on most days, the problems and opportunities of the day for the fledgling center were discussed and debated over lunch. The effect, over the long term, was to create an awareness of the faculty skills, capabilities, and resources among members of the center and thereby establish a solid base for future collaborative efforts on materials problems and issues.

Another factor in the development of this interdisciplinary culture was early federal support. The center operated as an Interdisciplinary Laboratory under support from the Advanced Research Projects Agency, which was able to provide 60 graduate research assistants, additional postdoctoral associates, technical staff, and laboratory rental charges, as well as to purchase major pieces of equipment such as electron microscopes. The cost of a similar venture now would be approximately \$10 to \$12 million per year. The inspiration for this program was the success of major industrial laboratories such as Bell Telephone Laboratories, where the ability of chemists, physicists, metallurgists, and engineers to collaborate on problems in materials research had become legendary. Since these labs had been so effective, the goal was to create this environment within universities for the training of graduate students in materials research. This significant federal support enabled Cornell to plan and develop an optimum program.

A critical part of the support for these new centers was targeted for the purchase of major equipment for experimental work. This formed the origin of shared facilities that are part of the Cornell Center for Materials Research today, driven by an underlying force—the need for equipment too costly for an individual faculty research group to purchase. An even more important element in the success of shared equipment is the support given by permanent staff specialists who maintain the equipment, improve and extend it, as well as teach operational details and ensure disciplined behavior around the instruments. If new approaches or extensions are developed by one user, the presence of permanent staff allows those developments to become part of the repertoire of the facility and available to other users. At its

best, a shared facility is much more than the instruments located within the walls of the laboratory. It is a resource of skill and expertise that is able to force nature to give up her secrets by skillful exploitation of the arts of the experimental approach.

A scanning electron microscope in one of these facilities played an important role in the initiation of the Cornell Nanofabrication Facility—the cornerstone of Cornell work in nanoscale science and technology.

When Joseph M. Ballantyne, Electrical and Computer Engineering, learned of the

National Science Foundation's request for proposals to host a facility capable of providing fabrication technology on an academic campus serving the academic community, he used the Materials Science Center's experience in operating this kind of facility and in generating the cross-disciplinary interest able to take broad advantage of this capability. Among the interested faculty members at Cornell was Robert A. Buhrman, then new to the Cornell faculty in Applied and Engineering Physics. Buhrman had been making superconducting device structures using the Materials Science Center's scanning electron microscope to create small structures, one of the few examples of microfabrication outside the electronic device community. Ballantyne was relentlessly optimistic, identifying possible collaborators, important research topics, and writing the proposal, which identified a broad sweep of research activity in materials science, applied physics, solid state physics, and electrical engineering.

The proposal won the award. The dean of Engineering at the time, Edmund T. Cranch, persuaded Dale R. Corson, president of Cornell, in an extremely short time to commit to a building for housing the effort. The estimated cost was impossibly small but the venture was so important that it was “full steam ahead” regardless. Edward D. Wolf joined Cornell's Electrical and Computer Engineering Department and served ten years as director of the facility. Wolf propelled the project through the difficult construction stage and formed a substantial service facility. Buhrman served for two years as associate director to solidly establish the user program.

Wolf was part of the team that invented the “gene gun,” an early harbinger of the interest in biology. Succeeding directors solved various problems and moved the center forward. When the National Science Foundation decided to establish a network of these facilities across the nation, through hard work, Cornell and Stanford became the anchors of what is now the National Nanofabrication Users Network (NNUN).

The director of Cornell facility during much of the transformation to the network was Harold G. Craighead, Applied and Engineering Physics. As director, Craighead

began to see the potential value of the technology for biological research at the microscopic and molecular levels. As a result, he began to orient his research in this direction. He and Lynn W. Jelinski, then director of Cornell's Biotechnology Institute, teamed up to present a case for a new interdisciplinary science area, nanobiotechnology. After many workshops and lengthy reports, a proposal came out of Cornell in this area. It obtained funding as a Science and Technology Center in the National Science Foundation portfolio. In double-quick time, a team from Cornell and the University of Rochester located additional Defense Advanced Research Projects Agency (DARPA) support for a Center for Biochemical Optoelectronic Microsystems with a focus on biological sensors.

The most recent of the centers to arrive at Cornell is the Center for Nanoscale Systems. Robert A. Buhrman, director, cleverly positioned the center to take advantage of the fabrication capabilities at Cornell, basic research in materials in the Cornell Center for Materials Research, and new faculty with strength in nanoscience and technology. This faculty will tackle the research needed to find out which parts, if any, of the discoveries that are currently reported in nanoscience can be eventually utilized in manufacturable units. Filling the gaps so that manufacturers can eventually make logical decisions about where to best focus their interests is central to the work in the center.

John Silcox

Vice Provost for Physical Sciences and Engineering and the David E. Burr Professor of Engineering, Applied and Engineering Physics

What Makes Cornell NanoSmart?

- A history of successful interdisciplinary collaboration among the faculty in Cornell's early centers such as the Materials Science Center
- Knowledge among the faculty of each other's skills and expertise
- Shared equipment and facilities too costly for individual faculty research groups to attain
- High technology resources embodied in the staff and the instruments of the facilities
- Faculty success in winning support for research in nanoscience and nanotechnology

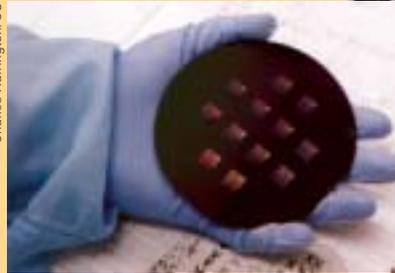
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Cornell Nanofabrication Facility