

Leveraging the Nation's Nanotechnology Research Centers: True Interdisciplinary Buildings Foster a Seamless Transition from Lab Bench to Consumer

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ABSTRACT:

Spearheaded by the National Nanotechnology Initiative, the United States government has funded the construction and operation of several new research centers located at national laboratories. Additionally, state and local initiatives and private donors have funded higher education institutions to build a new breed of laboratories and cleanrooms supporting the nation's infrastructure for nanoscale research. Now operational, the Center for Functional Nanomaterials at Brookhaven National Laboratory and the Birck Nanotechnology Center at Purdue University are two examples of such facilities that offer private industry incubator space and/or operate as open access centers for use of their laboratory equipment. Interdisciplinary buildings are designed to provide a built environment that delivers "high end" laboratory space, true interdisciplinary research environments, and integration with the commercialization process.

keywords: facility design, economic development, infrastructure, nanotechnology, metrology

1. INTRODUCTION:

The ultimate goal of the National Nanotechnology Initiative (NNI) is new technology and industry that benefits society. NNI Program Component Areas include "Establishment of user facilities, acquisition of major instrumentation, and other activities that develop, support, or enhance the National scientific infrastructure for the conduct of nanoscale science, engineering, and technology R&D" [1]. The Birck Nanotechnology Center (BNC) in Discovery Park at Purdue University and the Center for Functional Nanomaterials (CFN) at the Brookhaven National Laboratory (BNL) are key examples of the many new nanotechnology research facilities. BNC and CFN successes owe much to their architectural designs and the support those designs provides for managing the challenges of nanotechnology research and its commercialization process.

This paper presents the BNC, CFN, and its sister facility, the Center for Integrated Nanotechnologies (CINT) at Sandia National Laboratories, as case studies to illustrate how architectural design contributes to programmatic success and

to provide a more detail understanding of the opportunities available for leveraging the investment represented by these facilities.

2. INTELLECTUAL FUSION:

Nanotechnology is part of today's electronic devices, automobile catalytic converters, infection-fighting bandages, and leading-edge sports gear. It will be part of tomorrow's biomedical devices, pharmaceuticals, renewable energy and many, many other technologies. These and other end-user products are the combination of technologies from many disciplines. Their development requires the integration of basic science discipline knowledge from chemistry, physics, biology, and other fields; with engineering design that combines principles from electrical, mechanical, chemical, materials, and other fields; all taken forward by diverse entrepreneurial teams with access to leading-edge prototyping and characterization facilities.

Because nanotechnology is so diverse and pervasive a multidisciplinary team in proximity is a necessity for effective research, development, and commercialization. An interdisciplinary approach from "lab bench to business" is critical for successful economic development.

Scientific collaboration can be encouraged and enabled by architecture. Purdue University demonstrated the execution of this concept by merging 145 faculty members from 36 schools and departments including science, engineering, agriculture, pharmacy, and the liberal arts to create a "Birck Nanotechnology Community". Forty-five of these faculty, about 200 graduate students, and 30 technical and support staff members reside in the BNC building.

The building layout fosters dynamic and interactive collaboration spaces within the building while keeping within the 20-25% ratio of circulation space and without adding a cost premium to the overall project. There are many interaction spaces: seating in public areas, 10 small conference rooms, an office design that encourages leaving doors open, open-format student offices immediately



adjacent to laboratories, glass vision walls for many conference rooms and labs.

These spaces are intended to foster the informal meetings that are leading to collaborations, and they do. However, with this architectural support in place, BNC management has enacted planned personnel policies including placing faculty from different departments in adjacent offices and assigning graduate students working on different, but potentially synergistic research projects to the same multi-person office.

These graduate students report high satisfaction with close proximity to those working on different projects. Further, they note that high degree of interaction among students from different research projects leads to the rapid diffusion of best practices for experimentation and scientific instrument operation and, thus, more rapid progress.

Faculty research groups with aligned interests but based in different departments would, if housed in different buildings, formerly have rarely or never interacted. After spending time in the collaboration-supporting spaces of the BNC building, several such groups have entered into highly productive mergers. Figure 1 illustrates a portion of the web of such collaborations as of Dec. 2007.

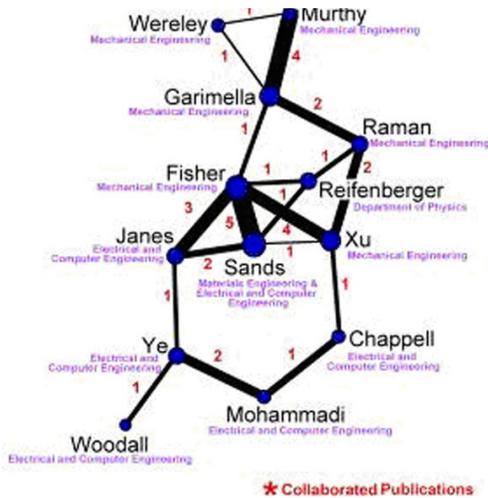


Figure 1: Each research group is represented by a disk with diameter proportional to the number of collaborations. Shorter, thicker lines between hubs indicate closer collaboration as measured by jointly authored publications [2].

The goal of providing the best support possible for the personnel involved in interdisciplinary nanoscale research and empowering a cultural change from individual laboratory facilities to shared spaces containing shared equipment thus directly informed BNC and CFN architectural design in anticipation of the desired operational policies.

3. QUALITY OF SPACE:

Recruitment of talent and grant funding are two major indicators of a successful program. Within the design and construction of appropriately specified “high end” laboratory space, both BNL and Purdue have recruited leading researchers as anchors to their programs. The facilities’ aesthetically pleasing designs also provide natural mitigation of environmental “contaminants” affording dramatically better technical spaces and greatly improving researcher efficiency. The page of photographs shows the aesthetic aspects and collaboration spaces of CFN, BNC, and CINT. Researchers quickly feel at home in these buildings.

The CFN provides state-of-the-art capabilities with an emphasis on atomic-level tailoring to achieve desired properties and functions. CFN is a science-based user facility with the overarching theme of addressing challenges in energy security, consistent with the Department of Energy mission. Like its four sister DOE nanoscale science research centers, CFN works collaboratively with university, industry, and government laboratory researchers seeking breakthroughs in energy research as enabled by nanocatalysis, biological and soft materials, and electronic materials.

The \$81M CFN facility (construction and major equipment) opened on May 21, 2007. The building features cleanrooms; general, dry, and wet laboratory space; office space for users and staff; and a wide range of materials-focused scientific fabrication tools and characterization instrumentation.

There is great promise for nanotechnology-based products comprising, for example, a multidisciplinary combination of NEMS/MEMS and biological molecules and/or organisms to create sensing/diagnostic devices with environmental and health care applications. Nano-MEMS devices require a semiconductor-style cleanroom for fabrication. Working with biological molecules and/or viable organisms and prototype materials, structures, or devices for health care use requires a pharmaceutical-grade cleanroom with biosafety containment. These two cleanrooms are not compatible in design or operational protocols [2]. These conflicting needs provide one example of the challenges of nanotechnology facility design. For the BNC, the design of the cleanrooms begins with a structure for a semiconductor fabrication cleanroom and modifies a portion of this area for the bio-pharma cleanroom. The semiconductor cleanroom requires the more complex infrastructure, so an incorporating bio-pharma section within the fabrication envelope is simpler design. Providing adjacency of the two spaces allows for materials transfer and enables research.

The BNC building was completed in October 2005 at a cost of \$58M, of which, \$42M came from three generous private gifts. The 187,000 sq. ft. building includes the



Birk Nanotechnology Center
Purdue University



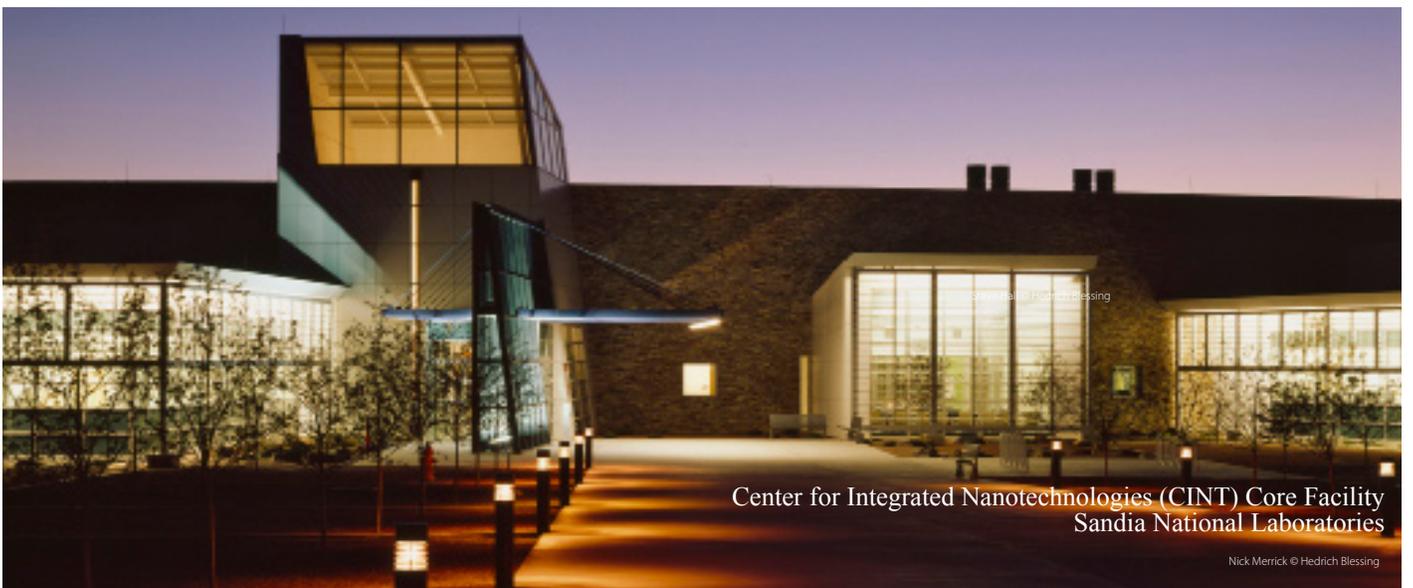
Birk Nanotechnology Center
Purdue University



Center for Integrated Nanotechnologies (CINT) Core Facility
Sandia National Laboratories



Center for Functional Nanomaterials
Brookhaven National Laboratory



Center for Integrated Nanotechnologies (CINT) Core Facility
Sandia National Laboratories

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Scifres Nanofabrication Laboratory (SNL), a 25,000 sq. ft. cleanroom with research space rated at 1, 10 and 100 microparticles per cubic foot, an extraordinary level of cleanliness.

Within the SNL is a bio/pharma cleanroom that facilitates research at the juncture of nano- and bio-technologies. This unique capability puts the BNC at the forefront of facilities designed for research at this important frontier.

Another 22,000 sq. ft. of dedicated laboratories outside the SNL provide specialized spaces with features such as temperature control to ± 0.01 °C, floating inertial-mass floors for vibration isolation (NIST A-1 standard), and shielding from electromagnetic interference. BNC process water is the purest in the world, exceeding that of the best used for the manufacture of silicon integrated circuits.

The BNC project came in on time, on budget, and exceeds its extremely challenging technical specifications. Careful monitoring to ensure construction per design by the project management team lead to laboratories that exceed design goals by (1) a factor of 10 in cleanroom airborne particle count, (2) a factor of 30 in 60 Hz magnetic field generated by the building electrical power system, and (3) a factor of two in cleanroom floor vibration (yielding the lowest vibration for an elevated cleanroom floor ever measured by the project vibration consultant, a major vibration consulting firm to the worldwide semiconductor industry). This commitment to quality means that the scientific instruments in the facility routinely reach the limits of their performance capabilities.

The BNC design is supporting research in nanoelectronics, nanophotonics, nanobiotechnology and nanomedicine, energy conversion, heat transfer, surface science, nanomaterials, nanomanufacturing, MEMS/NEMS and micro/nanofluidics, and nanometrology. More information about BNC research activity is available [3] at www.nanoHUB.org.

CFN, BNC, and CINT planned for flexibility in their facility designs. Planning for the future and change reduces cost and down time.

4. GATEWAY TO INDUSTRY

Purdue University is a land grant university. Economic development for the State of Indiana is an important element of Purdue's mission. BNC, working with the Burton D. Morgan Center for Entrepreneurship, Purdue's Office of Technology Commercialization, and the Purdue Research Park has contributed to 702 new jobs with an overall increase in payroll of more than \$36 million from 2003-2007. Companies that emerge from the BNC may find a place to grow in the nearby Purdue Research Park, currently home to 7 start-up companies in the Purdue Research Park based on nanotechnologies from BNC researchers.

The BNC laboratories are open to outside users. Companies making use of BNC facilities include ExxonMobil, Honda, Med Institute, and Cummins. BNC also features Nanotech Accelerator lab space for lease by companies investigating the promise of nascent nanotechnologies.

With an estimated 300 users from academia, industry and national laboratories, Brookhaven CFN serves as a hub to nanoscience studies in our national energy challenges.

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