National Nanotechnology Infrastructure Network (NNIN)

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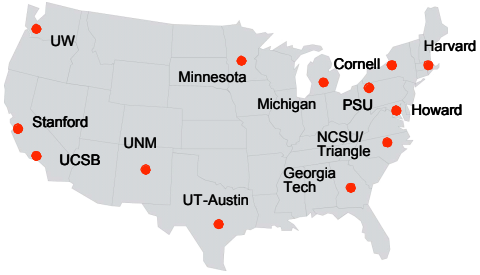
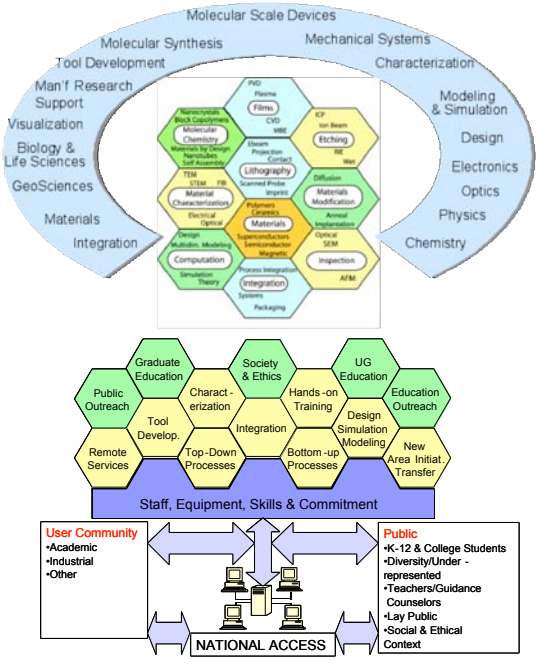
Figure 1: Member institutions of NNIN.



The National Nanotechnology Infrastructure Network (NNIN) provides access to infrastructure within open shared facilities to enable the national science and engineering community to pursue research, education and technology development within all the many disciplines that can benefit from nanotechnology. NNIN formally started operation on Mar. 1, 2004 with the mission to bring to fruition the promise of nanoscale science, engineering and technology. We are a partnership of 13 university-based laboratories, each of whom while serving broader needs, provides leadership in specific technical focus areas so that the advanced techniques, instruments, and knowledge can be efficiently utilized. The network also has in place a national and local effort in support of education, public outreach, safety, and a thrust in examining the societal and ethical implications of nanotechnology.

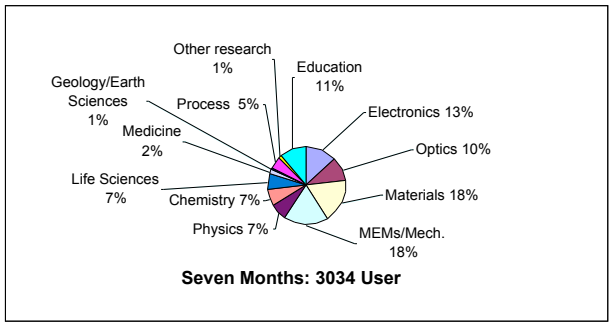
Science, Engineering and Technology Support: The network's current technology scope and activities are summarized in Fig. 1. We make continuous efforts through workshops, advertising, presence at professional society conferences to assess needs of new directions developing through the worldwide nanotechnology activities, and to actively develop infrastructure and technical support for these new directions. Supporting hands-on nanoscale research so that graduate researchers, industrial and national laboratory professionals, as well as smaller institutions can build and explore materials, structures, devices, and systems using a combination of bottom-up and self-assembly techniques and top-down fabrication techniques is our central mission. The user support for these tasks is accomplished through rapid technical interchange via user-support staff, arranging the visit to the appropriate facility, and a rapid initiation to the experimental work through training and staff-researcher interactions. The key to success in this effort is openness and equal access to all, commitment to service, low costs, and rapid interchange. While the network has been in operation since March of this year, as Fig. 3 shows, our outreach and success with serving the diverse user community has been very successful. An average of nearly 200 new research

Figure 2: Network scope and activities.



users per month are accessing the network currently. One of the key challenges to nanotechnology, as a multi- and inter-disciplinary area where many of the exciting ideas require cross-discipline use of techniques, is finding an efficient way for cross-training. For the infrastructure network, one of the best ways that we can support the research community is through an efficient continuous transfer and cross-fertilization of the knowledge of these techniques and new developments. Recognizing this, in addition to the staff for user support, we also have Technical Liaison staff (domain experts) at our sites to support research at the boundaries of disciplines. Examples of this include the interface between life-sciences, chemistry, and the major disciplines of engineering. Use of soft-lithography, tools and techniques of biology and chemistry, and connecting them to electronics, optics, and MEMS are some examples where the staff provides strong support.

Figure 3: Discipline breakdown, from the first seven months of the network operation, of 3034 users.



Our web-site (www.nnin.org) [1] is a major link and store-house of information to technical and non-technical community. It features a number of links, including recent examples of research made possible through the network. A number of these examples, which have received extensive recognition as important contributions, came about due to the ability of bringing diverse techniques together through the staff. Increasingly, characterization is also an important part of the research since observation of properties and structures at the nanoscale is non-trivial. Thus, various forms of microscopy (cryo-tem, tem, stem, etc.) and preparation of samples, such as through focused-ion bema techniques, are available through the network. We are also placing increasing effort in support of technical usage through remote means. This support activity ranges from critical electron-beam lithography and processing of nanoscale features, providing membrane structures used in a variety of nanoscale experiments, to integrated processing of more complex device and systems.

In order to assure that the network remains dynamic in its support and capabilities and makes judicious use of resources, the network sites have assigned technical focus areas for leadership. These areas correspond to the areas of exceptional strength of the local research. This allows us to provide the best resources and knowledge to the national community. Cornell and Stanford provide extensive support across disciplines as well as for complex integration projects. For biology and life-sciences, Georgia Tech and U. Washington; for chemistry at nanoscale, Penn-State, Harvard and Texas; for Geosciences, New Mexico and Minnesota; for integrated systems, Michigan; for tool development and manufacturing research support, Texas; for remote use and characterization, Minnesota and New Mexico provide the focus technical area leadership.

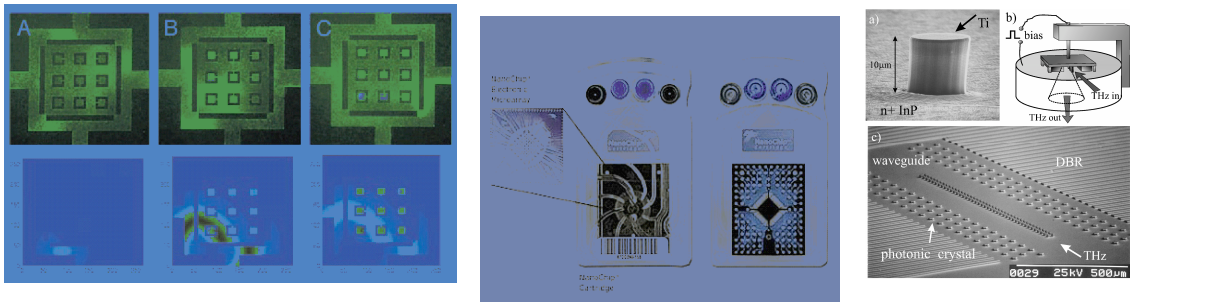
Education, Development and Outreach: Education and outreach at the local and national scale is a very key component of the network activities. These activities encompass the needs of public and of the education community. Our web-site features a number of multi-media offerings related to education and outreach. There are lectures on the practice of nanotechnology, there are a variety of graduate-level discussions related to specific disciplines – nanomagnetics, e.g., and

there are more practical lectures related to mentoring (art of scientific presentation or writing of scientific papers), as also instructional material related to social and ethical considerations. The network also conducts a very successful REU program, which had 72 participants in the current year, and a smaller RET program. Sites also have activities focused on local needs, ranging from attracting underrepresented high school students through rewarding experiences, and support for local teaching community – high school, community college and other small colleges. We are also active in workforce development through hands-on practical training. As the network activities build up, we will have courses and an open text-book that will become available on the web. As part of outreach and development activities, the network conducts many workshops. To name two, a workshop in August brought together educators and researchers from US and India to explore questions related to incorporation of nanotechnology developments in undergraduate and graduate curriculum, and one in December to discuss the safe operation and conduct of nanotechnology research in facilities with large and diverse community of users. Reports of such activities are available on the web.

Societal and Ethical Implications: Integrated into our network activities are activities fostering the awareness of societal and ethical issues for practicing researchers, as well as creation of the archives and collection of data as the nanotechnology area evolves for future studies. These activities are centered at Cornell, Stanford, Washington and Georgia Tech. Discussions and seminars from these activities are available as multi-media presentation from the NNIN web-site.

Example Research: A number of examples of research from NNIN are available for viewing from the web-site. To provide a breadth of the activities made possible, a few examples are provided in Fig. 4.

Figure 4: Example projects from NNIN. The left set shows work from Austin et al. (Princeton) performed at Cornell leading to an understanding of quorum sensing during bacterial growth in confined spaces[2]. The middle set shows a DNA fragment identification unit developed by Nanogen at Stanford, and the right set shows a terahertz Bloch oscillator in InAs/AlSb superlattice effort of Agilent at UC Santa Barbara.



Summary: NNIN is a geographically diverse infrastructure network created to support advanced research and development, develop our understanding of the phenomena of nanoscale, and so that tools and techniques of nanotechnology can be rapidly used to support commercialization and economic development. The network is organized with focus on serving the external users and simple procedures in place so that users can come and become efficient users of our facilities in a very short time from the first contact. The network also offers remote support for projects that utilize well-understood and developed technology, and conducts national level activities in support of education, development, health and safety, and societal and ethical consciousness related to efforts in nanotechnology.

References

[1] For further information and to peruse the variety of activities, see: **http://www.nnin.org**
[2] S. Park et al. Science 301(2003) and Proc. NAS 13910(2003)