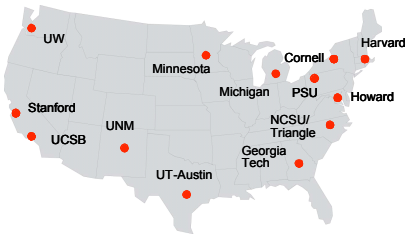
National Nanotechnology Infrastructure Network (NNIN)

NSF Grant ECS-0335765

PI: **Sandip Tiwari**
Cornell University

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 is now in the scone year of its operation. 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. NNIN's staff includes PhD level experts that facilitate cross-disciplinary propagation of know-how and NNIN provides remote support for many processes and for characterization where a visit may not be necessary. The key to success in this effort is openness and equal access to all, commitment to service, low costs, and rapid interchange. The network usage is currently growing at ~30%, and success with serving the diverse user community is encapsulated in Fig. 3 which shows the breadth of our user

Figure 2: Network scope and activities.

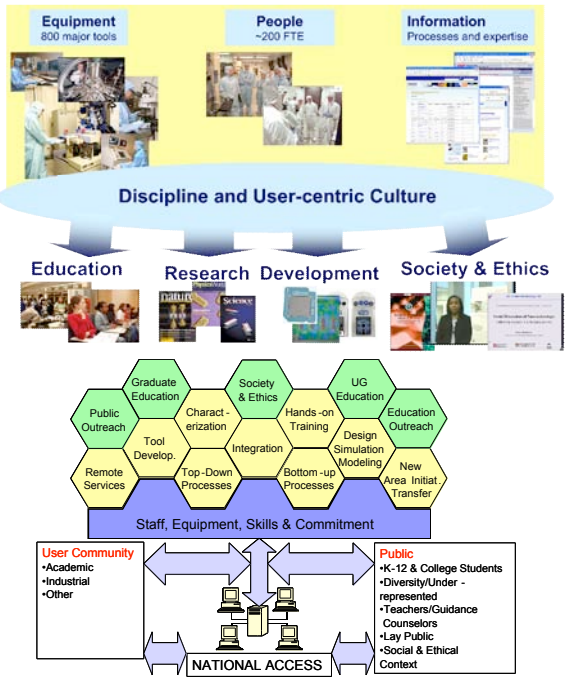
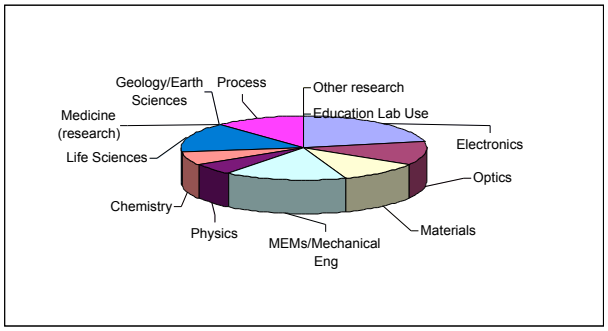


Figure 3: Discipline breakdown, from the first 12 months (3/2-2/28/05) of the network operation, of 3564 users. Current research group is 20% larger.



community. An average of nearly 200 new research users per month are being trained and accessing the network currently. The network is also employed as a precious resource by more than 250 small companies. 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. As an infrastructure network, an efficient continuous transfer and cross-fertilization of the knowledge of these techniques and new developments is an important task for us. Our Technical Liaison staff (domain experts) support research at the boundaries of disciplines by day-to-day interactions and hosting site visits, and we organize regular workshops. Examples of areas where this has been very successful 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.

Our web-site (www.nnin.org) [1] is a major link and store-house of information to technical and non-technical community. It provides, technical know-how to the national community, provides detailed information of our resources (processes, tools, training media, for users, technical talks, a search engine) and is a web-portal for outreach activity for education and social and ethical discussion. 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 and through focus on user service. 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 beam techniques, are available through the network, alongside traditional and non-traditional synthesis and fabrication tools for integrated processing. 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.

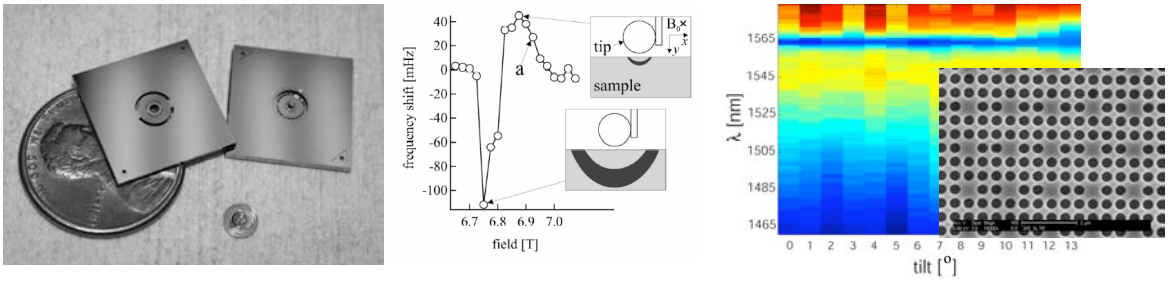
In order to assure that the network remains dynamic in its support and capabilities and makes judicious use of resources, the network sites have assigned technical focus areas for leadership. These areas correspond to the areas of exceptional strength of the local research and allows us to selectively apply precious financial resources towards maintaining the most advanced capabilities for 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. We organize local and national workshops that tie technical areas to research and to practicing knowledge. 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 and a program for teachers. During 2005, 81 interns from 66 different institutions across the United States and representing 37 fields of study participated in the 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. In time, we will have courses and an open text-book available on the web. The workshops conducted by the network during the past year included hands-on three-and-a-half day lectures coupled to fabrication, computation and modeling, movement of ideas and technologies from research to manufacturing, and workshops for small institutions for an immersive laboratory experience. The network has also extensive international cooperation that take the form of joint workshops as well as web-based Nanotechnology International Cooperative for knowledge and experience interchange. Reports of such activities are available on the web. Nearly 700 attendees participated in our workshops during the year.

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: Several examples of research from NNIN are available on 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 a multi-stage microturbine from Frechet et al. that produce 0.1 W of power at 1.1 atm pressure. The middle shows measurements from a new force-gradient magnetic resonance microcscopy developed by Marohn et al. for ultra-sensitive spin detection. The last shows photonic bandgap structure by Altug et al. for x100 reduction in light group velocity.



Summary: NNIN, in its second year of operation, is now reaching out to nearly ~4000 research users nation-wide, ~250 small companies, and has been instrumental in several major recent successes in research – ranging from spin detection, ultra-small electronics to biological characterization. The educational, health and safety, and societal and ethical consciousness efforts of NNIN are also reaching out to a wide audience.