Arizona Institute for Nanoelectronics: Kick-Off

4 April 2008
David H. Guston, Director
Center for Nanotechnology in Society at ASU

CNS-ASU research, education and outreach activities are supported by the National Science Foundation under cooperative agreement #0531194.

Sec 2(b)(10):

- Establish societal implications research program
- Require NSECs address societal implications
- Integrate societal concerns with nano R&D for benefit of all
- Provide for public input
Network for Nanotechnology in Society

- **NSEC/Center for Nanotechnology in Society at Arizona State University**
  - $6.2 million (Oct 2005 – Sept 2010)
- **NCEC/Center for Nanotechnology in Society at UC Santa Barbara**
  - $5 million
- **Projects:**
  - Harvard/UCLA ($1.7 million)
  - University of South Carolina ($1.4 million)
NSEC/CNS-ASU Network

- Arizona State University
- University of Wisconsin-Madison
- Georgia Tech
- North Carolina State University
- Rutgers University
- University of Colorado, Boulder
- University of Georgia

CNS-ASU involves the activities of more than 80 individuals at seven major collaborating institutions, as well as other collaborators, partners, and consultants.
NSEC/CNS-ASU Mission

- **Research** the societal implications of nanotechnologies
- **Train** a community of scholars with new insight into the societal dimensions of nanoscale science & engineering (NSE)
- **Engage** the public, policy makers, business leaders, and NSE researchers in dialogues about the goals and implications of NSE
- **Partner** with NSE laboratories to introduce greater reflexiveness in the R&D process
Real-Time Technology Assessment

- Research and Innovation Systems Analysis (RISA)
- Public Opinion and Values (POV)
- Deliberation and Participation (D&P)
- Reflexivity Assessment and Evaluation (RAE)

Thematic Research Clusters

- Equity and Responsibility (E&R)
- Human Identity, Enhancement & Biology (HIEB)
Clearing Up Some Jargon

**Reflexivity**

- A capacity for social learning (by individuals, groups, institutions, publics) in the NSE enterprise narrowly, and society broadly, that expands the domain of and informs the available choices in decision making about nano.

**Anticipatory Governance**

- A broad-based capacity extended through society that can act on a variety of inputs to manage emerging knowledge-based technologies while such management is still possible.
Partnerships: Teaching

- Teaching with:
  - (UG) Learning Community
  - (UG) InnovationSpace
  - NSE Ethics & Responsibility
    - Woodbury lab
    - Eng Ethics course development

- Teaching for:
  - Professionals – NNIN and CINT
  - Grads
    - Summer sessions – DC and IPNS
    - Courses – STSO, NB&F, Nano Law, K-12
  - Undergrads – Perspectives, HE&D, J&F
Partnerships: ISE & Outreach

- **Science Cafés**
  - Off-campus events for lay public
  - Matching natural scientists & engineers with social scientists & humanists

- **Ten Big Ideas**
  - For informal science educators
  - Describing societal perspectives on nano

- **National Citizens’ Technology Forum**
  - 6 panels of lay citizens across country
  - Expert-informed deliberations and recommendations
Partnerships: Research

- Scenario Development
  - NSE scenes
  - Doc-in-a-box
  - Cancer vaccine

- Tubes in the Desert
  - “embedded” researcher and grad student

- Public Value of Organic Photovoltaics
  - Partial embed
  - Structured workshops

- STIR Proposal

- Training NSE grad students
  - CNS/Biodesign Fellows/PhD+
Find Out More About CNS-ASU

- Web address: 
  http://cns.asu.edu

- CNS-ASU and its research, education and outreach activities are supported by the National Science Foundation under cooperative agreement #0531194. Any opinions, findings and conclusions are those of the author and do not necessarily reflect the views of the National Science Foundation.
More on *Anticipatory* Governance

"Competent social scientists should work hand-in-hand with natural scientists, so that problems may be solved as they arise, and so that many of them may not arise in the first instance."

- Understand beforehand the political and operational strengths and weaknesses of such activities
- Imagine sociotechnical futures that might inspire their use
More on Anticipatory *Governance*

- Not government but governance
- Not “do” or “ban”
  - “Science finds, genius invents, industry applies, man adapts”
  - Moratoriums proposed by ETC Group and Friends of the Earth
- Wide array of mechanisms
  - Licensing, restrictions
  - Liability, indemnification
  - IP
  - Testing
  - Treaties
  - PUS – FSE, ISE
  - Public engagement
  - Public action
RTTA 1: Research and Innovation Systems Analysis

Research Program Assessment
- Data-mining, interviews, etc.
- To ID core thrusts and actors

Public Value Mapping
- Conceptual development
- To connect research to promised public values

Workforce Assessment
- Supply and demand analysis
- To assess regional nano workforce
## RTTA 1: Research and Innovation Systems Analysis

### Defining nano

<table>
<thead>
<tr>
<th>Search</th>
<th>Terms</th>
<th>2005 SCI Hits</th>
</tr>
</thead>
<tbody>
<tr>
<td>MolEnv-I (inclusive)</td>
<td>(monolayer* or (mono-layer*) or film* or quantum* or multilayer* or (multi-layer*) or array* or molecul* or polymer* or (co-polymer*) or copolymer* or mater* or biolog* or supramolecul*)</td>
<td>&gt;100000</td>
</tr>
<tr>
<td>MolEnv-R (more restrictive)</td>
<td>(monolayer* or (mono-layer*) or film* or quantum* or multilayer* or (multi-layer*) or array*)</td>
<td>78390</td>
</tr>
<tr>
<td>nano*</td>
<td>nano*</td>
<td>39101</td>
</tr>
<tr>
<td>Quantum</td>
<td>(quantum dot* OR quantum well* OR quantum wire*) NOT nano*</td>
<td>3633</td>
</tr>
<tr>
<td>Self-Assembly</td>
<td>(((SELF ASSEMBL*) or (SELF ORGANIZ*) or (DIRECTED ASSEMBL*)) AND MolEnv-I) NOT nano*</td>
<td>3532</td>
</tr>
<tr>
<td>Terms to include as Nano without other delimiters</td>
<td>(molecul* motor*) or (molecul* ruler*) or (molecul* wir*) or (molecul* devic*) or (molecular engineering) or (molecular electronic*) or (single molecul*) or (fullerene*) or (coulomb blockad*) or (bionano*) or (langmuir-blodgett) or (Coulomb-staircase*) or (PDMS stamp*) NOT nano*</td>
<td>3550</td>
</tr>
<tr>
<td>Microscopy - terms to include but limit to the molecular environment</td>
<td>((TEM or STM or EDX or AFM or HRTEM or SEM or EELS) or (atom* force microscop*) or (tunnel* microscop*) or (scanning probe microscop*) or (transmission electron microscop*) or (scanning electron microscop*) or (energy dispersive X-ray) or (X-ray photoelectron*) or (electron energy loss spectroscop*)) AND MolEnv-I) NOT nano*</td>
<td>11665</td>
</tr>
<tr>
<td>Nano-pertinent; Limit to the Molecular Environment - More Inclusively</td>
<td>(pebbles OR NEMS OR Quasicrystal* OR (quasi-crystal*)) AND MolEnv-I) NOT nano*</td>
<td>128</td>
</tr>
<tr>
<td>Nano-pertinent; limit to the Molecular Environment - More Restrictive</td>
<td>(biosensor* or (sol gel* or solgel*) or dendrimer* or soft lithograph* or molecular simul* or quantum effect* or molecular sieve* or mesoporous material*) AND (MolEnv-R) NOT nano*</td>
<td>2104</td>
</tr>
<tr>
<td>1 or 2 or 3 or 4 or 5 or 6 or 7</td>
<td></td>
<td>61173</td>
</tr>
<tr>
<td>Additional Items in Nano Journals</td>
<td>fullerene* or ieee transactions on nano* or journal of nano* or nano* or materials science &amp; engineering C - biomimetic and supramolecular systems (in JOURNAL title field) NOT nano*</td>
<td>506</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>61479</td>
</tr>
</tbody>
</table>
RTTA 1: Research and Innovation Systems Analysis

- **ISI Web of Science** (Science Citation Index – SCI)
  - ~407,000 articles
  - Representing ~2.7% of SCI over the period and 4.1% of SCI for the 2005-06 period

- **EI Compendex**
  - ~381,000 articles & conference papers

- **INSPEC** (Engineering Village 2 website)
  - ~334,000 articles & conference papers

- **EKMS** searched MicroPatent, INPADOC and their proprietary U.S. Patent Citation database
  - ~61,000 patent families (from ~70 patent authorities)
Nano Districts

Drill down into any of them, by institution or investigator

Development of U.S. Nano Districts over time

Publication & Patenting intensity by Nano District

Regional concentrations and subject drivers

Cities With Nanotechnology Publication Records of 1,000 or Greater

Source: Science Citation Index 1990 to Mid Year 2006

This material is based upon work supported by the National Science Foundation under grant #0531194. Any opinions, findings, and conclusions or recommendations expressed are those of the author and do not necessarily reflect the views of the NSF.
Comparison of “Generality Index” Scores Across Three Technologies, 1990-1993

<table>
<thead>
<tr>
<th>Nanotechnology</th>
<th>Variable</th>
<th>Count</th>
<th>Mean</th>
<th>Drugs</th>
<th>Count</th>
<th>Mean</th>
<th>Computers</th>
<th>Count</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1990</td>
<td>Gen US</td>
<td>287</td>
<td>0.620</td>
<td>2188</td>
<td>0.386</td>
<td>1961</td>
<td>0.612</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Gen IC</td>
<td>287</td>
<td>0.642</td>
<td>2187</td>
<td>0.385</td>
<td>1961</td>
<td>0.443</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Gen TC</td>
<td>287</td>
<td>0.540</td>
<td>2187</td>
<td>0.273</td>
<td>1961</td>
<td>0.424</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1991</td>
<td>Gen US</td>
<td>293</td>
<td>0.623</td>
<td>2405</td>
<td>0.394</td>
<td>2306</td>
<td>0.610</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Gen IC</td>
<td>293</td>
<td>0.617</td>
<td>2405</td>
<td>0.389</td>
<td>2306</td>
<td>0.445</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Gen TC</td>
<td>293</td>
<td>0.507</td>
<td>2405</td>
<td>0.278</td>
<td>2306</td>
<td>0.431</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1992</td>
<td>Gen US</td>
<td>411</td>
<td>0.596</td>
<td>2349</td>
<td>0.387</td>
<td>1956</td>
<td>0.612</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Gen IC</td>
<td>411</td>
<td>0.582</td>
<td>2349</td>
<td>0.388</td>
<td>1956</td>
<td>0.405</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Gen TC</td>
<td>411</td>
<td>0.487</td>
<td>2349</td>
<td>0.268</td>
<td>1956</td>
<td>0.417</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1993</td>
<td>Gen US</td>
<td>364</td>
<td>0.608</td>
<td>2499</td>
<td>0.380</td>
<td>2999</td>
<td>0.609</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Gen IC</td>
<td>364</td>
<td>0.605</td>
<td>2498</td>
<td>0.376</td>
<td>2999</td>
<td>0.398</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Gen TC</td>
<td>364</td>
<td>0.511</td>
<td>2498</td>
<td>0.264</td>
<td>2999</td>
<td>0.423</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Variable definition:
Gen US = Generality based on USPTO-classes
Gen IC = Generality based on International Patent classes
Gen TC = Generality based upon NBER patent database technology classes (Hall et al., 2001)
RTTA 2: Public Opinion and Values

Public Opinion
- Longitudinal surveys, linked to themes
- To assess changes in public opinion

Media Influence
- Experimental science news stories
- To assess media influence

Scientists’ Opinions
- Surveys of nano researchers
- To assess & compare scientists’ values
Has Outreach Made a Difference?  
Nano Knowledge, 2004 vs. 2007

Economic implications  |  Basic nano knowledge  |  Specific nano knowledge

This material is based upon work supported by the National Science Foundation under grant #0531194. Any opinions, findings, and conclusions or recommendations expressed are those of the author and do not necessarily reflect the views of the NSF.
Perceived Risks: Aware vs. Unaware Respondents

![Bar chart showing perceived risks compared between aware and unaware respondents](image)

- Loss of privacy
- Lead to arms race
- Loss of jobs
- Self-replicating robots
- May be used by terrorists
- New health problems
- More pollution

This material is based upon work supported by the National Science Foundation under grant #0531194. Any opinions, findings, and conclusions or recommendations expressed are those of the author and do not necessarily reflect the views of the NSF.
Perceived Benefits: Aware vs. Unaware Respondents
Perceived Risks: 2007
Scientist and Public Opinion Surveys

- Loss of Privacy
- Use of the Technology by Terrorists
- An Arms Race
- Loss of Jobs
- Self-replicating Robots
- More Pollution
- New Health Problems

Percent of respondents agreeing

Scientists
Public

This material is based upon work supported by the National Science Foundation under grant #0531194. Any opinions, findings, and conclusions or recommendations expressed are those of the author and do not necessarily reflect the views of the NSF.
Perceived Benefits: 2007 Scientist and Public Opinion Surveys

This material is based upon work supported by the National Science Foundation under grant #0531194. Any opinions, findings, and conclusions or recommendations expressed are those of the author and do not necessarily reflect the views of the NSF.
RTTA 3: Deliberation and Participation

**Scenario Development**
- Deliberative exercise among experts
- To provide plausible technological futures

**InnovationSpace**
- User-centered research and design course
- To create new products/scenarios

**CriticalCorps**
- Critical Theory
- To engage critically nano products and scenarios

**National Citizen’s Technology Forum**
- Six interlinked citizen’s panels
- To deliberate on nano issue of their framing

What are plausible nano-enabled futures?
How can we envision responsible NSE products?
What are the cultural resonances of NSE futures?
How can the public be engaged in NSE decision-making?
This material is based upon work supported by the National Science Foundation under grant #0531194. Any opinions, findings, and conclusions or recommendations expressed are those of the author and do not necessarily reflect the views of the NSF.

Scenario Development

Upon chip integration, the implantee will need to attend nine months of intensive classroom-based courses, where they are taught new ways to think, process thoughts, and to categorize memories and data.

The cranial cage is light and comfortable during sleep. The disruption of the chip improves ‘sleep’, removing restlessness, annoying dream sequences, or sedative needs.

The implantee will just ‘wake up’ in the morning knowing what was streamed into their head from the previous night. The data feed does not disrupt or alter the ‘sleep’ of the implantee.

This data feed feature dramatically decreases the amount of time needed to assimilate data each day.

The 4.0 chips are a sandwich of carbon nanotubes and gate molecules that are covered in neural growth promoters.

The use of rare earth magnets in a wide net around the cranium makes for a thorough disruption of the chip.

The new disruptor cages only need to lock onto the head and upper vertebrae of the neck.

‘Sleep’

Cranial chip disruptors allows data transmission directly to the implantee’s brain during resting time. The data feed does not disrupt or alter the way of ‘sleep’ for the implantee.
RTTA 3: Deliberation and Participation

InnovationSpace Current
RTTA 4: Reflexivity, Assessment and Evaluation

Reflexivity Assessment

- Intensive interviews with nano researchers
- To understand change in Identity, Knowledge and Practice
  - High familiarity & high involvement associated with significant changes in knowledge & initial changes in practice

Boundary Organizations

- Comparative case studies to assess capacities to bridge “ways of knowing”
- Report of BORGs workshop (9 Nov 06)
TRC 1: Equity and Responsibility

To explore ways in which NSE research interacts with ideas of social and economic equity and responsible innovation

- Laboratory interactions
- Workshops
- Public Value Mapping
- Broader impacts of NSE
TRC 1: Equity and Responsibility

- **Nanotechnology and Religion**
  - Survey of religious statements finds religions more interested in equitable distribution of benefits than "playing God" type issues
  - Workshop on Nano and Religion

- **Nanotechnology and "Able-ism"**
  - Wolbring – how converging technologies will make us all disabled

- **NSE Co-Lab**
  - Responsible nanotechnology in the Woodbury lab on BioOptical Nanotechnology

- **Public Value Mapping – dissertation in NSE for developing world**

- **NSE and Broader Impacts**
  - NSE applications show minimal attention to equity, societal outcomes
TRC 2: Human Identity, Enhancement and Biology

To investigate the historical, philosophical, cultural and political dimensions of the interactions between human biology and human values in the context of nano

- Philosophical/Ethical analysis
- Personnel exchange and collaborative deliberation among scientists and ethicists
- Develop and assess case studies and scenarios for participatory analysis
Neural Interface Systems
“I can’t put it into words. It’s just – I use my brain. I just thought it. I said, “Cursor go up to the top right.” And it did, and now I can control it all over the screen. It will give me a sense of independence.”

Mind control: Matt Nagle’s neuroprosthetic lets him move a cursor using thought alone

Images reproduced from Hochberg et al. (2006)
Some Exemplary Research Questions

- What is the state of the art of NIS R&D? How do NSE researchers think about this work? Why do they do it?
- Who funds NIS R&D? Why? In what institutional practices and systems is the research embedded?
- What are the relevant values (ethical, religious, scientific, political, economic) at stake in NSE-enabled NIS R&D?
- How should NSE researchers, companies, funders and regulators navigate and negotiate the regulatory terrain?
- What are the specific identity and enhancement concerns, and how should they be addressed?
- How can we, as citizens in a diverse, pluralistic, global society with competing visions of the good, begin to grapple with nano-enabled neural interface systems?
Neural Implants and Interfaces Raise Ethical, Social, Legal & Policy Questions

- Moral acceptability of research with nonhuman primates
- Determination of appropriate risk/benefit ratio for clinical studies in brain-damaged humans and healthy volunteers
- Clinical decisions to undergo personality-changing procedures
- Threats to the moral and legal identity of humans (and of non-human animals)
- Allocation of scarce research dollars for high-tech treatments
- Social desirability of civilian application of military applications