2016 NNI Strategic Planning Stakeholder Workshop

Infrastructure Needs

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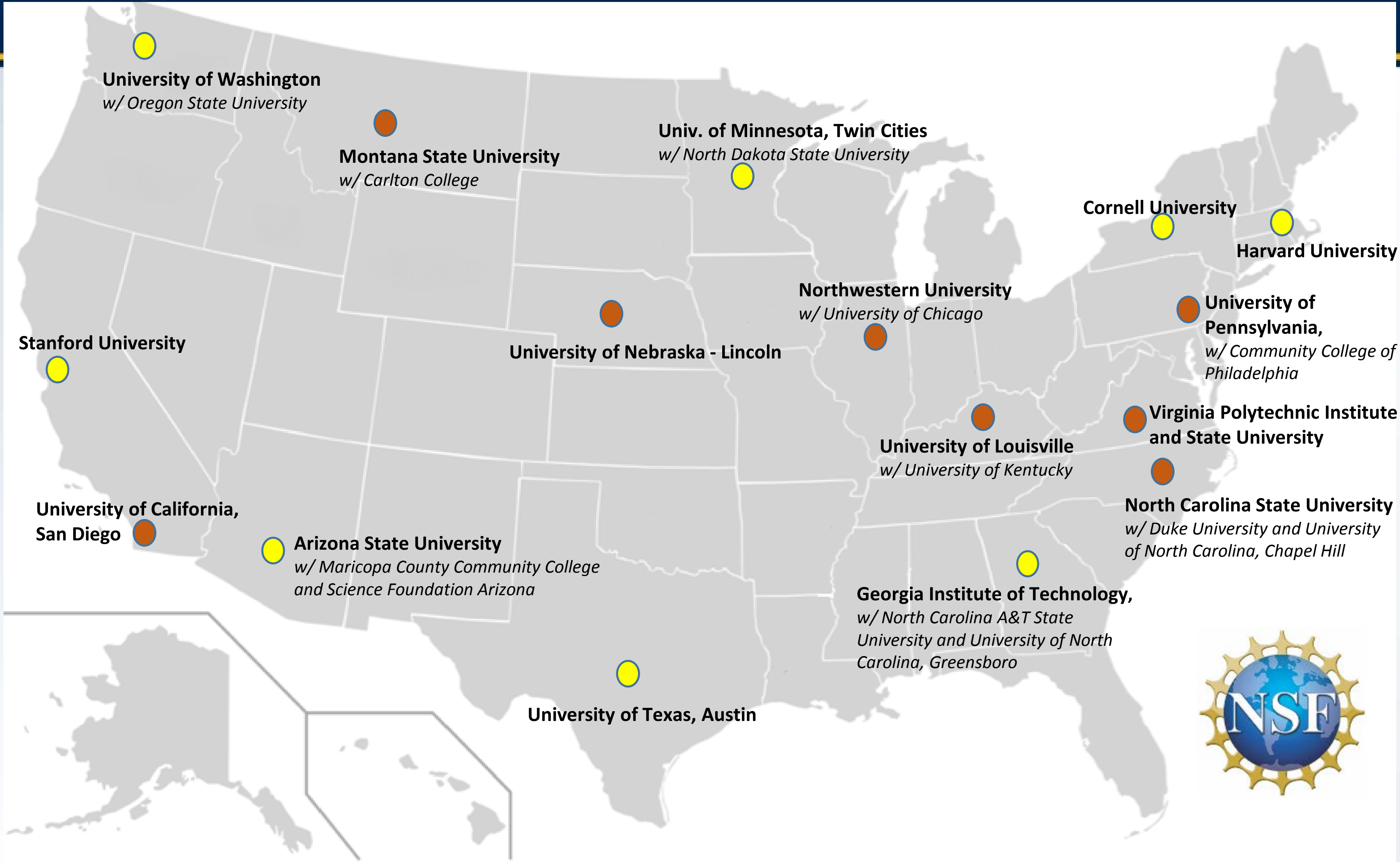
National Nanotechnology Coordinated Infrastructure

Georgia Tech Institute for Electronics and Nanotechnology

NNI Goal 3 and Objectives

- **Goal 3: Develop and sustain educational resources, a skilled workforce, and a dynamic infrastructure and toolset to advance nanotechnology**
- Objective 3.1: Expand **outreach and informal education programs** in order to inform the public about the opportunities and impacts of nanotechnology
- Objective 3.2: Establish and sustain programs that assist in developing and maintaining a **skilled nanotechnology workforce**
- Objective 3.3: Provide, facilitate the sharing of, and sustain the **physical and cyber R&D infrastructure**, notably user facilities and cooperative research centers

National Nanotechnology Coordinated Infrastructure (NNCI)



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NNIN (2004-2015) Facts & Figures

- NSF-funded network of shared-use, open access nanotechnology fabrications & characterization facilities
- 14 sites with >1,200 nanotechnology tools
- >6,000 individual users per year, ≈2,000 external users per year (year 10 data)
- 450 companies, 210 academic institutions served per year (year 10 data)
- >22,500 new users trained over 11 years
- E&O efforts grown from 75 individual directly reached in 2004 to >60,000 in 2014 (at 250+ events)
- >1,200 REU students (impact assessment shows >50% continue with PhD!)

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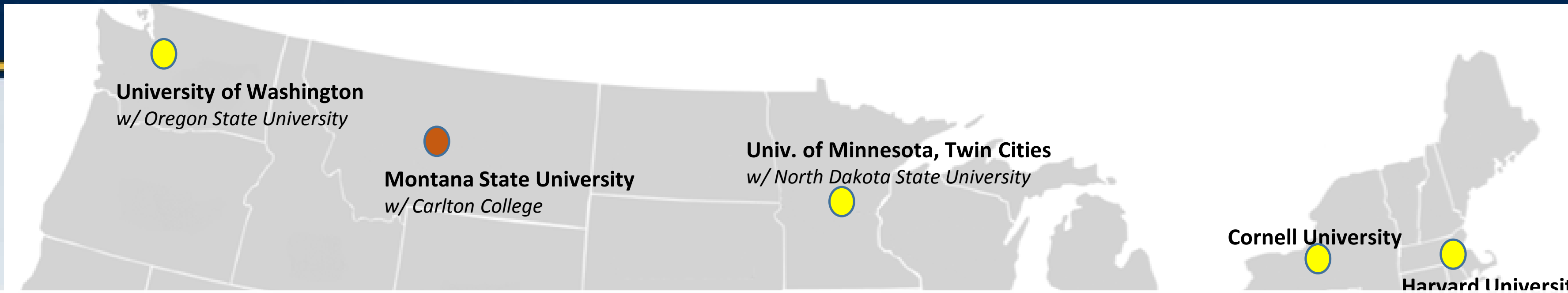
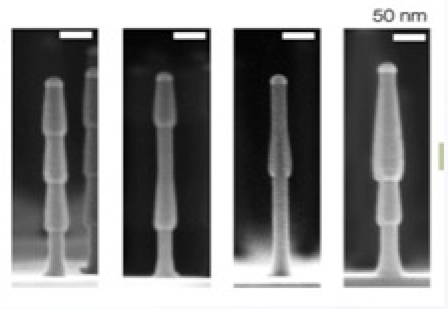
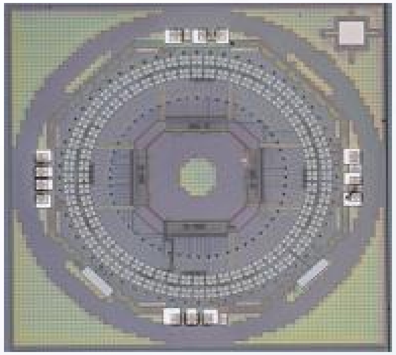


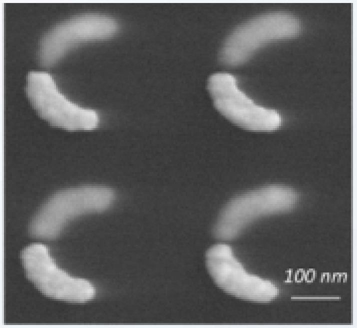
- *DOE Nanoscale Science Research Centers (NSRC)*
  - Molecular Foundry, Lawrence Berkeley NL
  - Center for Integrated Nanotechnologies, Los Alamos and Sandia NL
  - Center for Nanoscale Materials, Argonne NL
  - Center for Nanophase Materials Science, Oak Ridge NL
  - Center for Functional Nanomaterials, Brookhaven NL
- *NIST Center for Nanoscale Science & Technology (CNST)*
- *NCI Nanotechnology Characterization Laboratory (NCL)*
- *Network for Computational Nanotechnology (NCN) – nanoHub.org*
- **Plus 100+ academic shared-use nanotechnology facilities**

How are these Facilities used today?

- Top-down (lithography defined) and bottom-up (material synthesis) nanofabrication
- Nanoscale imaging and metrology
- Trend from materials & processes to complex devices, systems & their applications
- *Opportunity*: scale-up nano-manufacturing processes
- Large variety of disciplines: nanomaterials, nanoelectronics; MEMS/NEMS; energy; life sciences & health care; environmental & geo-sciences; food & water; IoT; defense; …….
- *Opportunity*: community forming activities that bring together experts from different disciplines







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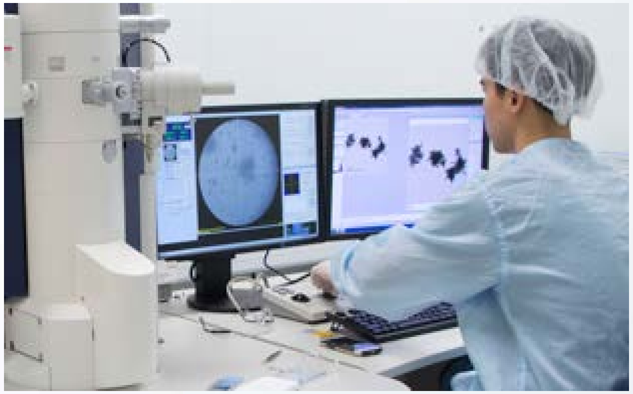
(1) Physical Infrastructure Needs

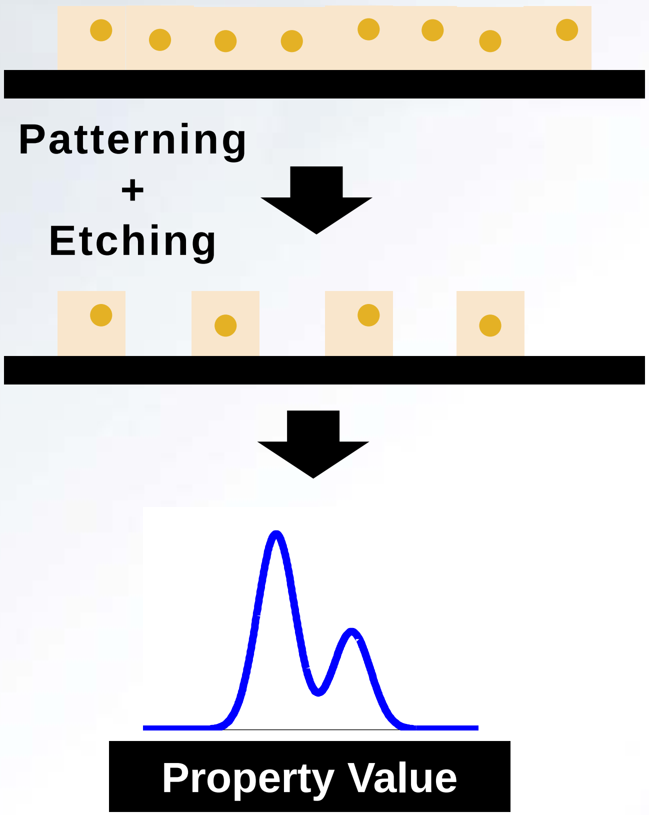
- **Evergreen Physical Infrastructure:** Recapitalization of particularly key/ workhorse/mission-critical tools (not suitable for equipment grants)
- Cost to acquire and **maintain** advanced nanotechnology tools, such as EBL, TEM, FIB, etc.



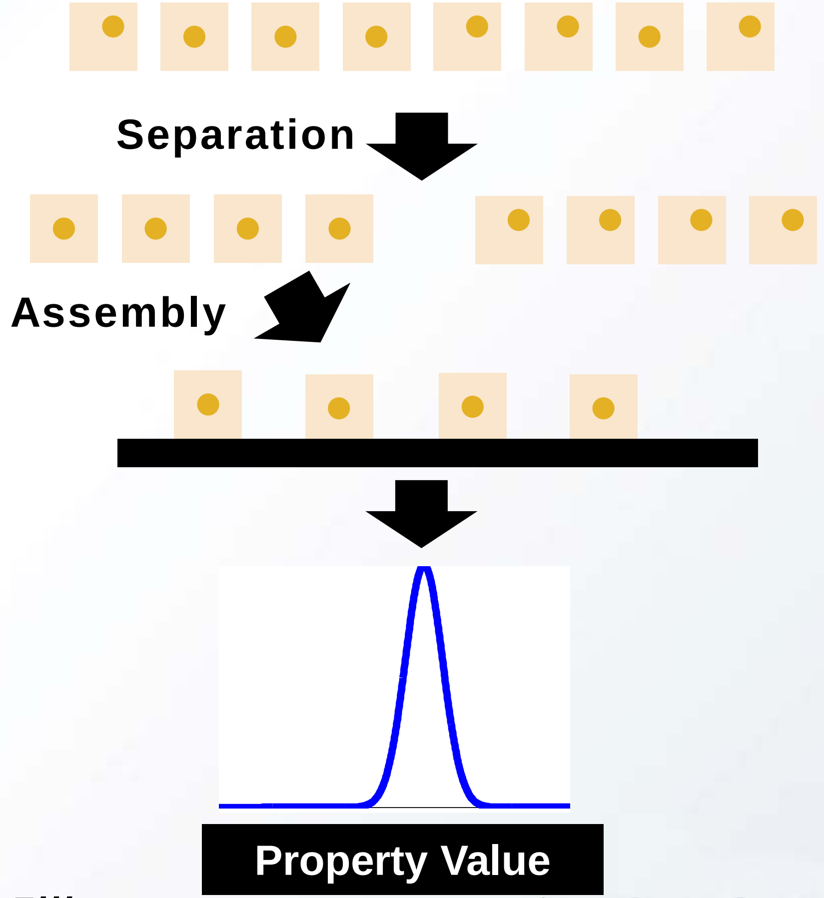
- *Opportunity*: Develop **skilled staff** (technicians, process & equipment engineers) that can maintain key/workhorse equipment, minimizing need for high-cost service contracts
- Ever **broadening/diversifying tool set** for top-down and bottom-up nanotechnologies (trend from materials/processes to devices/systems/applications)
- *Opportunity*: tools/processes for **scale-up nano-manufacturing**; explore links to Manufacturing Innovation Institutes

A Tale of Two Manufacturing Paradigms

Conventional Electronic Devices
(assumes fabrication can be near perfect)



Commodity/Specialty Chemicals
(assumes synthesis is always imperfect)



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Resulting Nanomanufacturing Needs

- **Novel synthesis methods**
  - Advanced function requires structural complexity
  - Nanoscale features within nanoscale objects
  - “One-pot” complete device fabrication
- **Novel separation methods**
  - At both the material and device level
  - Separate based on chemistry, structure, and properties (e.g., carrier density or turn-on voltage)
- **Nanoscale printing/assembly technologies**
  - “3-D printing at the nanoscale”
  - Printing of individual nanoscale objects/complete devices
  - Be careful: 10x10x10 µm is already a picoliter!

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(2) Outreach and K-12 Education Needs

- Continue to develop informed citizenry and encourage K-12 students to participate in STEM pipeline
  - Science festivals
  - School visits with hands-on demos
- Acknowledge and reward E&O staff
- Collect & disseminate E&O resources

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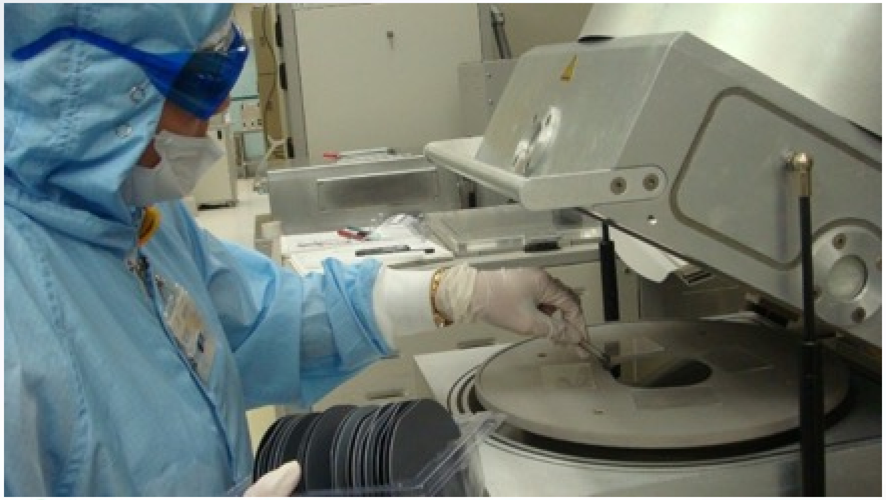
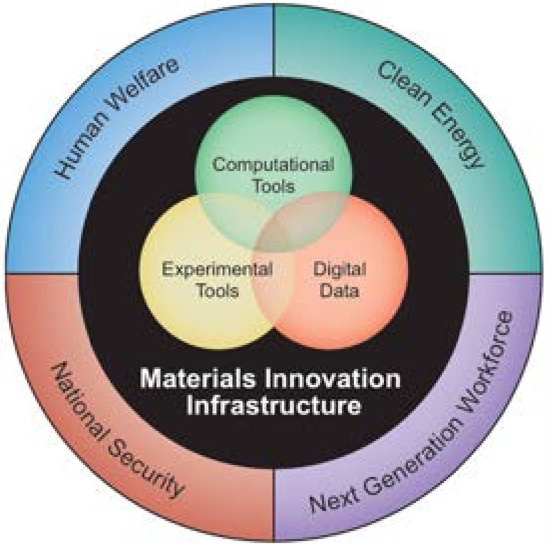
(3) Workforce Development Needs

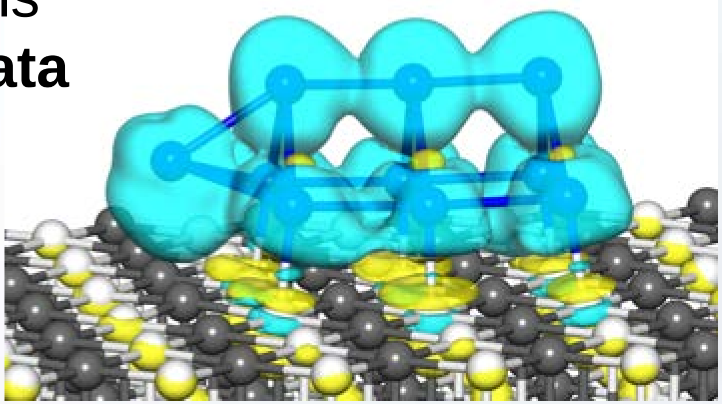
- **Continuing Education** (short courses, technical training)
- **Community Colleges** (training, internships, course work development, see e.g. NSF ATE)
- Undergraduates (REU programs, certificate programs)
- Graduates (facility users, seminars, workshops)
- *Opportunity:* Technical staff pipeline for our own facilities!



(4) Cyber Infrastructure Needs

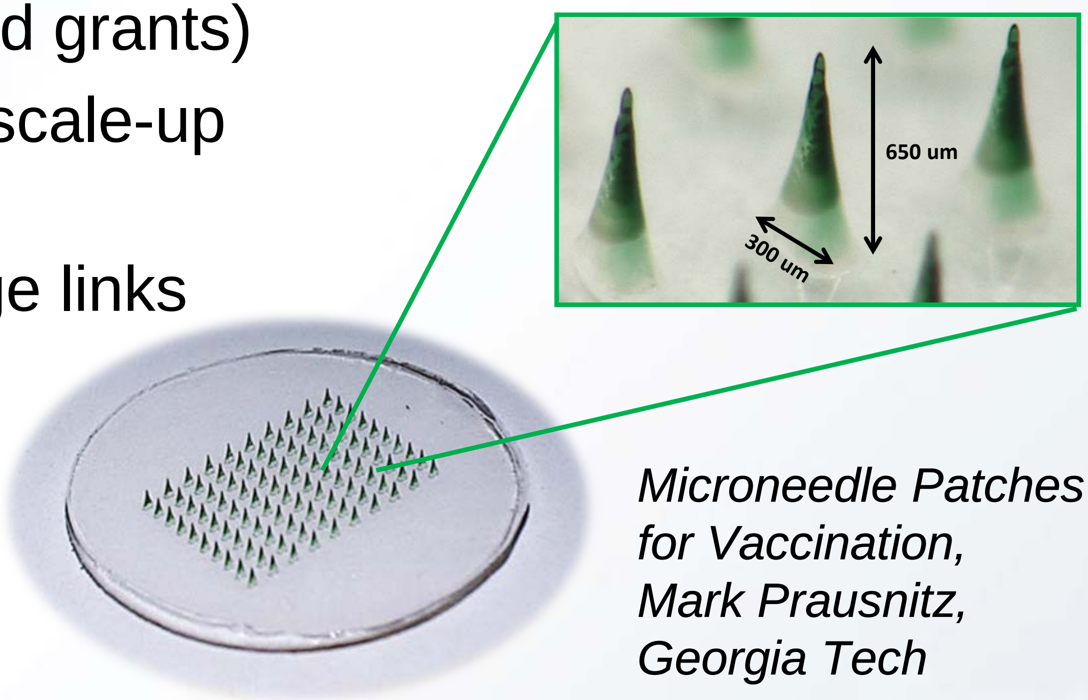
- Need for data & models to accelerate engineering design cycles
- Multi-scale data **generation/collection** (nanomaterial property data; process data; etc.), incl. real-time data for process control via feedback
- Strategies for **data management, sharing & access**
- Large-scale **simulations** (nanomaterials modeling, nano-Earth simulations) & **data analytics**
- *Opportunity*: tie-in with National Strategic Computing Initiative (NSCI)?





(5) Translational Activity Needs

- Promote/facilitate translational activities (entrepreneur in residence, incubators)
- Incentivize nanotechnology start-ups to use open-access facilities (e.g. commercialization seed grants)
- Invest in translational/scale-up technologies
- *Opportunity*: Encourage links with Manufacturing Innovation Institutes



Microneedle Patches for Vaccination, Mark Prausnitz, Georgia Tech

Panel Questions

- Are there any obvious gaps in the draft goals and objectives? Are there any objectives that are no longer among the top priorities that need to be addressed?
- What will be the new/hot areas of research or challenges in the next 5-10 years?
- Outside of additional funding, what can the Federal Government do to support activities or address challenges in the areas above?
- How will we know when the nanotechnology enterprise is successful in this area? How do we measure this?