# Resolution to Approve B.S. in Nanoscience

Documents included:

1. Resolution to Approve a B.S. in Nanoscience
2. B.S. in Nanoscience Degree Proposal
3. Professor JP Morgan – Introductory Presentation
4. Professor Randy Heflin – Degree Presentation

# RESOLUTION TO APPROVE THE BACHELOR OF SCIENCE DEGREE IN NANOSCIENCE

**WHEREAS**, nanoscience is a rapidly emerging field and encompasses areas within biological sciences, chemistry, geosciences and physics (disciplines that lie at the core of Science Technology Engineering and Mathematics (STEM) education); and

**WHEREAS,** nanoscience is an integral part of the discovery, development and delivery of new pharmaceutical compounds, is foundational to the discovery and the development of nanomaterials, is a key area in the discovery and development of new devices for the production, storage and delivery of energy, and plays a foundational role in modern information and communication technology; and

**WHEREAS,** the College of Science is in an excellent position to initiate a bachelor of science in nanoscience, due to its strong base of senior faculty who are actively engaged in research at the nanoscale, in addition to 15 faculty members hired in this area since 2004 with particular strengths in novel nanomaterials and devices, nanomedicine, and environmental nanoscience; and

**WHEREAS**, the bachelor of science in nanoscience will provide students with the base of knowledge in the theoretical aspects and experimental tools and techniques in nanoscience; and

**WHEREAS**, the bachelor of science in nanoscience will prepare graduates for interdisciplinary research and education, with employment in the private sector, employment in state and federal government agencies, and for post-baccalaureate training; and

**WHEREAS**, the undergraduate degree in nanoscience is unique in the Commonwealth of Virginia, and will join four other nanoscience/nanotechnology undergraduate degree programs in the United States, and will establish Virginia Tech and the Commonwealth as key leaders in education for one of the most critical technologies of the future;

**NOW, THEREFORE BE IT RESOLVED,** that the bachelor of science in nanoscience be approved effective spring 2015 and the proposal forwarded the State Council of Higher Education for Virginia (SCHEV) for approval, and to the Southern Association of Colleges and Schools – Commission on Colleges (SACS-COC) for notification.

**RECOMMENDATION:**

That the resolution to approve the bachelor of science degree in nanoscience be approved.

March 24, 2014

# Virginia Tech Degree Proposal
## Bachelor of Science (B.S.) Nanoscience
## (CIP: 40.9999)

**Type of degree action (circle one)**: (New) Spinoff Revision Discontinuance

**Program description**

The College of Science at Virginia Tech is proposing a new Bachelor of Science (B.S.) in Nanoscience degree, to commence in Spring 2015. This will be one of only a few such degree programs worldwide. Nanoscience and nanotechnology lie at the very foundation of our world. A nanometer is simply a billionth of a meter, and a typical atom is about $1/10^{th}$ of a nanometer in size. At this length scale, atoms and molecules follow the laws of quantum physics, and the processes of life (DNA and proteins are naturally-occurring nanoscale materials, for example) and the properties of materials emerge. Due to a combination of profound theoretical insights, advances in scientific instrumentation, and massive computing power, we are now capable of imaging and steering single atoms with unprecedented precision, opening a window towards a world in which materials, chemical compounds, devices, and even small organisms can be built atom by atom and molecule by molecule, tailored towards desired properties and applications.

Already, modern information and communications technology, the discovery and delivery of new drugs, and our energy supply are critically dependent on nanoscale phenomena. Public and private partners have recognized the need for continued innovation in this critical field. In 2000, the Clinton administration launched the *National Nanotechnology Initiative* (NNI, http://www.nano.gov), which prioritizes and coordinates the nanoscience and nanotechnology research and development efforts of 25 federal agencies. The cumulative investment in this initiative now stands at $18 billion. In response, several leading universities have started graduate programs in nanoscience and technology. However, *undergraduate* degree programs in this field are still very rare with four B.S. programs in nanoengineering and one in nanoscience, even though strong interest and demand, both from students and employers, can be documented. Virginia Tech, and especially the College of Science, is in an excellent position to initiate such an undergraduate program, thanks to a strong base of senior faculty who are actively engaged in research at the nanoscale. In addition to this senior base, the College of Science established Nanoscale Science as a key Cluster area for faculty hiring, with fifteen faculty members hired in this area since 2004. Particular strengths include novel nanomaterials and devices, nanomedicine, and environmental nanoscience. *We are presented with a unique opportunity to become one of the first and leading institutions in undergraduate education in the field of nanoscience.*

**Curriculum summary**

The B.S. in Nanoscience at Virginia Tech is designed to provide a strong background in the theoretical aspects as well as experimental tools and techniques of nanoscience with an additional key requirement of completion of eight hours of

undergraduate research. The undergraduate research component ensures that students will have direct exposure to the frontier of nanoscience research and be competent in advancing that frontier. An additional crucial component of the degree program is a sequence of seminar courses that gradually introduce the students to the research frontier. This is accomplished first through a series of guest lectures by researchers (Nanoscience Research Seminar), followed by a set of research laboratory rotations (Nanoscience Research Rotations), and completed by a course on scientific dissemination skills (Professional Dissemination of Nanoscience Research). This focus on research skills will yield students who are excellently prepared for directly entering the workforce with their B.S. degree as well as for pursuit of a graduate degree. A total of eleven new courses (thirty-two credits) have been developed for the degree program, five of which have been taught as a pilot course at least once as of Spring 2013. As nanoscience is by its very nature a highly interdisciplinary field, the students will be required to have a good foundation in biology, chemistry, mathematics, and physics. They will develop additional skills in these disciplines, as well as geosciences, through the specific courses of the nanoscience degree itself.

As there are currently few undergraduate degree programs in nanoscience and nanotechnology, we will for the first several years strongly encourage the students to carry out a minor degree with their Nanoscience major, preferably in biology, chemistry, geosciences, or physics. As Virginia Tech and the Commonwealth will be at the vanguard through creation of the B.S. in Nanoscience, it will be valuable for the students to have a component of their degree with which employers and graduate programs are quite familiar. Furthermore, the training in a more traditional discipline combined with the interdisciplinary breadth of the Nanoscience degree will be an especially powerful combination for our graduates and will position them for the highest levels of success in their employment and/or graduate education. As undergraduate degree programs in nanoscience and nanotechnology proliferate, and as employers and graduate programs learn what to expect from and appreciate the value of students with a B.S. in Nanoscience from Virginia Tech, we will not as strongly advocate that all students in the program carry out the additional minor, though we will continue to educate the students on the power and added value of doing so. The program is designed for a compatibility with completion of the Nanoscience major / traditional science minor in four years.

The B.S. in Nanoscience comprises 120 credits, distributed among the following categories of courses:

**I. Curriculum for Liberal Education (38 credits)**
Area 1: Writing and Discourse (6 credits)
Area 2: Ideas, Cultural Traditions, and Values (6 credits)
Area 3: Society and Human Behavior (6 credits)
Area 4: Scientific Reasoning and Discovery (8 credits - Physics 2305-2306)
Area 5: Quantitative and Symbolic Reasoning (6 credits - Math 1205-1206)
Area 6: Creativity and Aesthetic Experience (3 credits)

Area 7: Critical Issues in a Global Context (3 credits)

**II. Nanoscience Core Courses (40 credits)**
NANO 1015 - Introduction to Nanoscience* (3 credits)
NANO 1016 - Introduction to Nanoscience* (3 credits)
NANO 2024 - Quantum Physics of Nanostructures* (4 credits)
NANO 2114 - Nanoscience Research Seminar* (1 credit)
NANO 2124 - Nanoscience Research Rotations* (2 credits)
NANO 3015 - Nanoscale Synthesis, Fabrication, and Characterization* (4 credits)
NANO 3016 - Nanoscale Synthesis, Fabrication, and Characterization* (4 credits)
NANO 3114 - Professional Dissemination of Nanoscience Research* (1 credit)
NANO 3124 - Nanoscience and the Environment* (3 credits)
NANO 4124 - Advanced Nanomaterials and Devices* (3 credits)
NANO 4314 - Nanomedicine* (4 credits)
NANO 4994 - Undergraduate Research (8 credits)
(* indicates new course developed for this degree program)

**III. Math/Science Required Courses (18 credits)**
CHEM 1035/1045 - General Chemistry (4 credits)
CHEM 1036/1046 - General Chemistry (4 credits)
CHEM 2514 - Survey of Organic Chemistry (3 credits)
MATH 1114 - Linear Algebra (2 credits)
MATH 2214 - Differential Equations (3 credits)
BIOL 2124 - Cell and Molecular Biology for Engineers (2 credits)
(*Note: Two semesters each of Introductory Physics and Calculus are also required and satisfy the Curriculum for Liberal Education requirements above.*)

**IV. Free Electives (24 credits)**
As an alternative entry point to the degree program, students can participate in the Integrated Science Curriculum rather than traditional introductory courses in science. The ISC is an 8-hour classroom/laboratory experience for a total of four semesters. These 32 credit hours are a direct substitution for the 32 hours of BIOL 1105/1106/1115/1116, CHEM 1035/1036/1045/1046, MATH 1114/1205/1206, and PHYS 2305/2306 listed above.

**Relevance to university mission and strategic planning**
The development of the B.S in Nanoscience degree is especially well-matched to the mission of Virginia Tech to create and disseminate new knowledge and prepare our students to be leaders in their fields. The program will establish Virginia Tech and the Commonwealth as key leaders in education for one of the most critical technologies of the future. The program ties in with a major research focus area for the College of Science and the university, and it involves undergraduate students in those research efforts that are creating new knowledge in the area of nanoscience. Such discoveries in nanoscience will enable the enhancement of current technologies and the creation of new ones that will benefit the Commonwealth, the

nation, and the globe in essential areas such as medicine, energy, communications, and sustainability.

Through its involvement of students in laboratory experiences and exposure to nanoscience research at Virginia Tech beginning in the sophomore year and continuing through the end of the degree, the Nanoscience degree program exemplifies the "hands-on, minds-on" model of education called for in the Virginia Tech strategic plan *A Plan for a New Horizon: Envisioning Virginia Tech 2012-2018* (http://www.president.vt.edu/strategic-plan/strategic-plan.html). Furthermore, the strategic plan identifies science, technology, engineering, mathematics and health sciences (STEM-H) as a key focus area of education, which is clearly well-aligned with development of the Nanoscience degree. The strategic plan also states that the university will leverage existing and emerging strengths in areas such as energy, materials, ecosystems, and environmental quality along with increased focus on the health sciences, all of which are impacted by nanoscience education and research.

**Justification for the proposed program**

The World Technology Evaluation Center, Inc. (WTEC) is the nation's leading organization in conducting international technology assessments, and an expert review reported that US public awareness of nanotechnology is low (~30%), despite the fact that most US citizens own or operate a device that is enabled with nanoscience and nanoscale components, *e.g.* smart phones. Moreover, nanotechnology is viewed as the next general purpose technology with nanostructures as safer, more efficient substitutes for commonly used compounds, and nanoscience and nanotechnology will infiltrate virtually every aspect of human existence in modern societies around the world. The globalization of nanoscience is evident in the level of funding across the globe, ensuring opportunities in the international workforce and opportunities for undergraduates to study abroad in the undergraduate curriculum. Thus, an undergraduate degree in nanoscience is critical to educate students (and the public at large) in the unique nanoscale elements of self-assembly in chemistry, quantum mechanics in physics, nanoscale confinement in biology, and treating large data sets with statistics and mathematics where traditional theories, physical property measurements, and design strategies no longer function. Undergraduates must understand sustainable practices, impacts on humans and the environment, and full life cycle assessment of nanostructures and their elemental constituents. Education at the undergraduate level with a degree that clearly navigates our students is vital for training students with sensitivity to these societal learning outcomes prior to joining a burgeoning industrial workforce. A few other universities have begun to answer the national call for an educated undergraduate in nanoscience and nanotechnology as described in the Program Overview section. Virginia Tech will be the first university in the Commonwealth to offer a B.S. degree in Nanoscience, and only the second in the United States, although we expect that the number of dedicated programs like these will start to increase rapidly.

There is a clear need to have students trained at the undergraduate level with a firm foundation of nanoscience that are capable of understanding, designing, and manipulating nanostructures at these increasingly complex levels. The graduates of such a program will be exceedingly well-prepared for working for nanotechnology companies and for graduate school. We no longer can effectively educate undergraduates in nanoscience with a complicated maze of courses. We must provide a clear degree path, and we must nurture thinking and teaming in transdisciplinary domains that are unique to the field of nanoscience.

**Student Demand**

The College of Science at Virginia Tech held a NanoCamp for upper-level high school students on August 4-5, 2012. Registration for the event rapidly reached its maximum capacity and was attended by 41 students. A variety of faculty and graduate students introduced the participants to the concepts and tools of nanoscience through presentations, demonstrations, laboratory tours, and hands-on exercises. The program was an overwhelming success and will be continued each summer for the foreseeable future. The enrollment in NanoCamp is one indicator of potential student interest in nanoscience. We polled the NanoCamp participants electronically in February, 2013 to determine their interest in enrolling in our proposed Nanoscience degree program. We received a quite limited response from these high school students despite a follow-up request to them and a request to their parents to encourage student response to the poll. Nonetheless, of the seven students who responded to the question *"Virginia Tech is considering creating an undergraduate degree program in Nanoscience. How likely would you be to enroll in a B.S. in Nanoscience program at Virginia Tech?*" one student (14%) responded "*definitely*", two (29%) responded "*highly likely*," and three (43%) responded "*somewhat likely*."

We also surveyed students at Virginia Tech enrolled in the calculus and non-calculus based introductory physics courses in February, 2013. All science and engineering students are required two take one or the other of these two courses, so it was considered to be a good proxy for the types of students who might be most interested in such a program. We received a reasonably good response to the poll with 452 responses from the approximately 2000 students enrolled in the courses at the time. The questions were phrased slightly differently than for the high school students as "*Virginia Tech is considering creating an undergraduate degree program in Nanoscience. How likely would you have been to enroll in a B.S. in Nanoscience program at Virginia Tech if it had been available when you were a freshman?*" Of those respondents, 21 (5%) responded "*definitely*," 49 (11%) responded "*highly likely*," and 147 (33%) responded "*somewhat likely*." These numbers suggest that it should be quite reasonable to meet our enrollment goals.

**Market Demand**

At the request of the National Science and Technology Council (NSTC) (through a subcommittee on Nanoscale Science, Engineering, and Technology: NSET), a workshop from September 28-29, 2000 by the National Science Foundation was

organized. The opinions of leading experts from academia, the private sector and government were discussed during the workshop. NSTC, which is the principal means for the U.S. President to coordinate science, space and technology policies across the Federal Government, reported:

*"Advances in nanoscience and nanotechnology promise to have major implications for health, wealth, and peace in the upcoming decades. Knowledge in this field is growing worldwide, leading to fundamental scientific advances. In turn, this will lead to dramatic changes in the ways that materials, devices, and systems are understood and created. The National Nanotechnology Initiative (NNI) seeks to accelerate that progress and to facilitate its incorporation into beneficial technologies. Among the expected breakthroughs are orders-of-magnitude increases in computer efficiency, human organ restoration using engineered tissue, "designer" materials created from directed assembly of atoms and molecules, and the emergence of entirely new phenomena in chemistry and physics".*

Nanoscience and nanotechnology are interdisciplinary research and educational areas. Therefore careers exist in a vast array of disciplines. The National Nanotechnology Infrastructure Network has identified the following career areas:

- Electronics/semiconductor industry
- Materials science including textiles, polymers, packaging, among others
- Auto and aerospace industries
- Sports equipment
- Pharmaceuticals including drug delivery, cosmetics, among others
- Biotechnology
- Medical fields
- Optoelectronics
- Environmental monitoring and control
- Food science including quality control and packaging
- Forensics
- University and federal lab research
- National security and Military
- Energy capture, storage, & use; fuel cells, batteries

**Resource Needs/Savings**

The B.S. in Nanoscience degree program will be administratively situated within the Dean's office of the College of Science at Virginia Tech. Courses will be taught by existing faculty members from the Departments of Biological Sciences, Chemistry, Geosciences, and Physics. Established faculty from each of these departments have participated in the development of this new degree program and have active research programs in the field of nanoscience.

Two graduate teaching assistants (GTAs) will adequately cover the laboratory courses throughout the curriculum.

One part-time (50%) administrative assistant will be required to assist in coordination of the curriculum, student advising, student recruiting, programmatic assessment, and student undergraduate research and internship opportunities.

No additional library or telecommunication resources will be required for the program beyond those that already exist.

In terms of space and equipment, we will be using a synergistic combination of existing resources, including faculty research laboratories and nanoscale characterization facilities:

- The college has recently constructed three interdisciplinary and dynamic lab spaces, which will be shared in the initial stages of the program. This space is uniquely positioned within Biological Sciences and Geosciences, and adjacent to Physics and Chemistry for proximity.
- The laboratory space that is available to the Nanoscience students comprises chemical hoods, instrumentation, team bench spaces, cell culture facilities, and team data discussion spaces.
- Existing equipment includes electron and atomic force microscopy, surface analysis centers, X-ray characterization centers, and nanoscale fabrication facilities.
- The university has instituted a mechanism by which lab fees can be collected to help maintain equipment and supplies.
- As the program matures, the expectation is that the planned science research lab building will house these laboratory courses.

| RESOURCE | ESTIMATED COSTS (use NA if not applicable) |
|---|---|
| **Faculty** | NA |
| **Administrative Staff** | $24,500 (salary + fringe) |
| **Graduate Teaching/ Graduate Research Assistants** | $43,200 (stipend + fringe); $21,480 tuition costs |
| **Space** | NA |
| **Library** | NA |
| **Equipment** | NA |
| **Other** | NA |

# Academy of Integrated Science

**Virginia Tech Board of Visitors**
**Academic Affairs Committee**
**March 24, 2014**

AIS
ACADEMY OF INTEGRATED SCIENCE
Integrated Science Curriculum | Computational Modeling & Data Analytics
Nanoscience | Neuroscience | Systems Biology | Science, Technology, & Law

COLLEGE OF SCIENCE
10th ANNIVERSARY

# Quote from a Canadian Philosopher

## A good hockey player plays where the puck is.


## A GREAT HOCKEY PLAYER PLAYS WHERE THE PUCK IS GOING TO BE.

**Wayne Gretzky**

AIS
ACADEMY OF INTEGRATED SCIENCE
Integrated Science Curriculum | Computational Modeling & Data Analytics
Nanoscience | Neuroscience | Systems Biology | Science, Technology, & Law

# Education for the Future:
## Multi-departmental Degrees and Programs

Being presented today:

- Computational Modeling and Data Analytics (CMDA)
- Nanoscience

In the near future:

- Neuroscience
- Systems Biology

Already under way:

- Science, Technology, and Law (minor)
- Integrated Science Curriculum (portal program)

The Academy is the administrative unit for these programs.

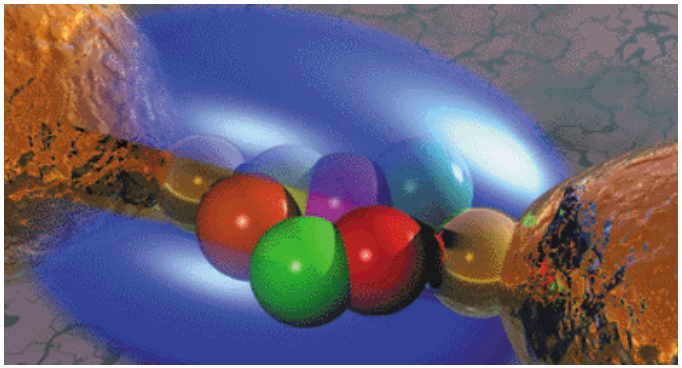
# Functions of the Academy

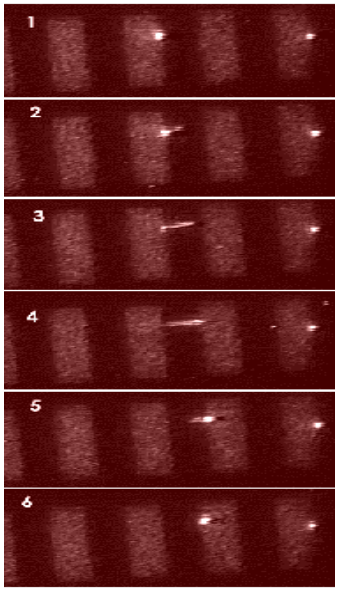
- House and manage multi-departmental degree programs, minors, and the Integrated Science Curriculum
- Schedule classes and secure faculty to teach those classes
- Recruit and advise students
- Track student progress
- Evaluate program success and modify as needed
- Provide a “major home” for students (a focal point for their education, including clubs and other program related activities)
- Organize faculty for program support and development
- Provide an interdisciplinary home for associated faculty
- Enhance research in alignment with these new programs; foster collaboration across departmental lines


AIS
ACADEMY OF INTEGRATED SCIENCE
Integrated Science Curriculum | Computational Modeling & Data Analytics
Nanoscience | Neuroscience | Systems Biology | Science, Technology, & Law

# B.S. in Nanoscience
# Academy of Integrated Science
# College of Science

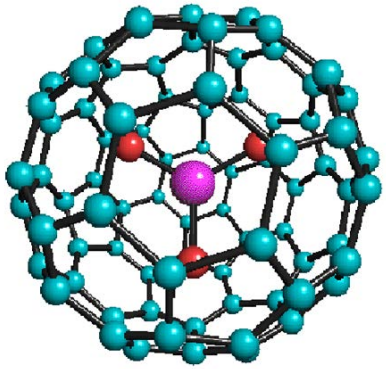
Prof. Randy Heflin
Department of Physics

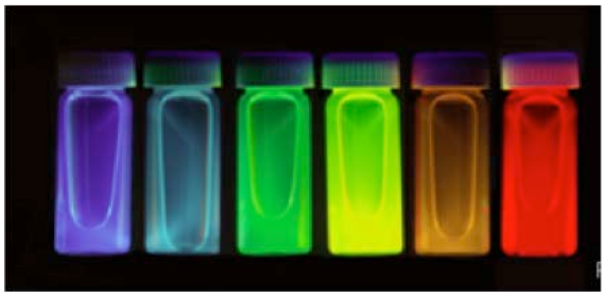


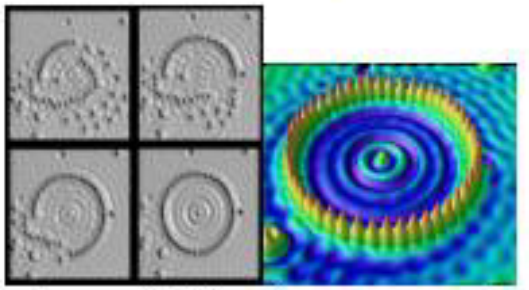


# What is Nanoscience?

- Just as most engineering technologies build on fundamental scientific principles, nanoscience is the firm foundation of nanotechnology.
- Nanoscience and Nanotechnology refer to control of matter at the nanometer (one-billionth of a meter) length scale.
- 1 nm ~ 5-7 atoms side-by-side
- Degree program will focus on:
  - Synthesis of nanomaterials (e.g. fullerenes, nanotubes, quantum dots)
  - Fabrication of Nanostructures (e.g. electron beam lithography, nanoimprint lithography)
  - Characterization techniques of nanomaterials and nanostructures (e.g. scanning probe microscopy, diffuse light scattering)
  - Properties of nanomaterials (e.g. electronic and optical properties, environmental impact, nanomedicine)



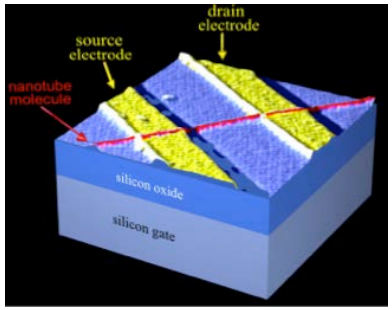




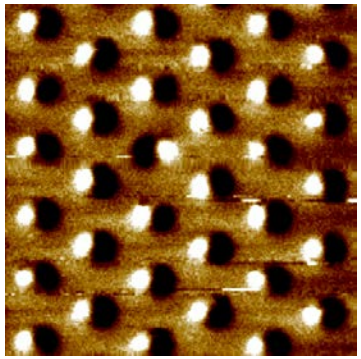
Quantum corral of 48 iron atoms on copper surface positioned one ata time with an STM tip
Corral diameter 14nm

# Background

- National Nanotechnology Initiative has invested >$19 billion through 20 federal agencies since 2000 (www.nano.gov).
- National Science Foundation estimates a market of $3 trillion by 2020 for nanotechnology products with a U.S. workforce of 2 million.
- National Science and Technology Council (NSTC) reports : "*Advances in nanoscience and nanotechnology promise to have major implications for health, wealth, and peace in the upcoming decades…Among the expected breakthroughs are orders-of-magnitude increases in computer efficiency, human organ restoration using engineered tissue, "designer" materials created from directed assembly of atoms and molecules, and the emergence of entirely new phenomena in chemistry and physics"* and states that it is a national imperative to "*Educate and train a new generation of scientists and workers skilled in nanoscience and nanotechnology at all levels.*"




- National Nanotechnology Infrastructure Network identifies that nanoscience and nanotechnology will have major impact in career areas that include: Electronics/semiconductor industry; Materials science including textiles, polymers, and, packaging; Auto and aerospace industries; Pharmaceuticals including drug delivery and cosmetics; Energy capture, storage, & use; fuel cells, batteries; and Environmental monitoring and control.
- There currently exist only one B.S. in Nanoscience in the U.S. (SUNY-Albany) and three in Nanotechnology/Nanoengineering (SUNY-Albany, UC-San Diego, Louisiana Tech).
- Virginia Tech and the Commonwealth have the opportunity to be pioneers in nanoscience education.



# Why Virginia Tech and the College of Science?

- Excellent alignment with hands-on/minds-on and STEM-H emphases of VT strategic plan.
  - Four lecture/laboratory courses
  - Lab rotations course (four weeks each in three different research labs)
  - 8 credits of undergraduate research (expected to result in journal publication and conference presentation)
- Senior Faculty Leadership with expertise in nanoscience education, leading large research projects, conference organization, administration, and commercialization.

- Prof. Mike Hochella (Geosciences)
- University Distinguished Professor
- VT PI of NSF Center for the Environmental Applications of Nanotechnology
- Director of ICTAS Center for Sustainable Nanotechnology

- Prof. Tim Long (Chemistry)
- Associate Dean for Research and International Outreach
- Co-Chair of 2012 World Polymer Congress (held on VT campus)
- Co-Leader of ICTAS Nano-Bio Interface Thrust

- Prof. Randy Heflin (Physics)
- Co-Editor of first undergraduate textbook "Introduction to Nanoscale Science and Engineering"
- Assoc. Editor of International Journal of Nanoscience
- Co-founder of Virginia nanoTech, LLC

# Why Virginia Tech and the College of Science?

- Cluster Hiring in Nanoscience in COS has resulted in hiring of 15 faculty members since 2004. Those participating in Nanoscience degree program development include:

Carla Finkielstein
*Biological Sciences*

Tijana Grove
*Chemistry*

John Matson
*Chemistry*

Amanda Morris
*Chemistry*

Marc Michel
*Geosciences*

Giti Khodaparast
*Physics*

Vinh Nguyen
*Physics*

Kyungwha Park
*Physics*

Hans Robinson
*Physics*

Chenggang Tao
*Physics*

# Student Interest

- In August 2012, the College of Science held a two-day NanoCamp that was attended by 41 high school students.
- In February 2013, we surveyed all students in introductory physics at Virginia Tech with the question: "*Virginia Tech is considering creating an undergraduate degree program in Nanoscience. How likely would you have been to enroll in a B.S. in Nanoscience program at Virginia Tech if it had been available when you were a freshman?*" 21 (5%) responded "*definitely*," 49 (11%) responded "*highly likely*," and 147 (33%) responded "*somewhat likely*."
- As of Spring 2014, we have offered all but one of the eleven new courses that comprise the proposed degree program.

  Nano 1015: 42 students (Fall 2013)

  Nano 1016: 25 students (Spring 2014)

  Winter Session Course on *International Perspectives on the Nanoscience of Macromolecule*s: 20 students (January 2014 in France, Germany, and Switzerland)

  The students in 1016, 2114, and 3015 have all stated an interest in declaring a major in Nanoscience upon approval. We expect high enrollment, including many elite students from both Virginia and around the nation, when the degree program is approved and we are able to advertise it.