



# Sustainable Nanotechnology Organization

Research | Education | Responsibility



## Sustainable Nanotechnology as a Platform for Interdisciplinary and Holistic Graduate Education

Matthew Y. Chan, Michael F. Hochella, Jr., Peter J. Vikesland

The Virginia Tech Center for Sustainable Nanotechnology

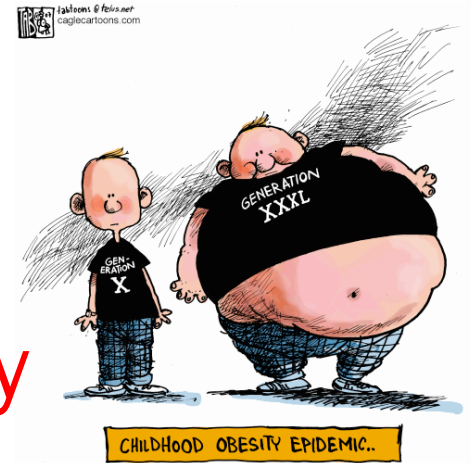
NanoEarth: National Center for Earth and Environmental Nanotechnology Infrastructure

November 5, 2017.

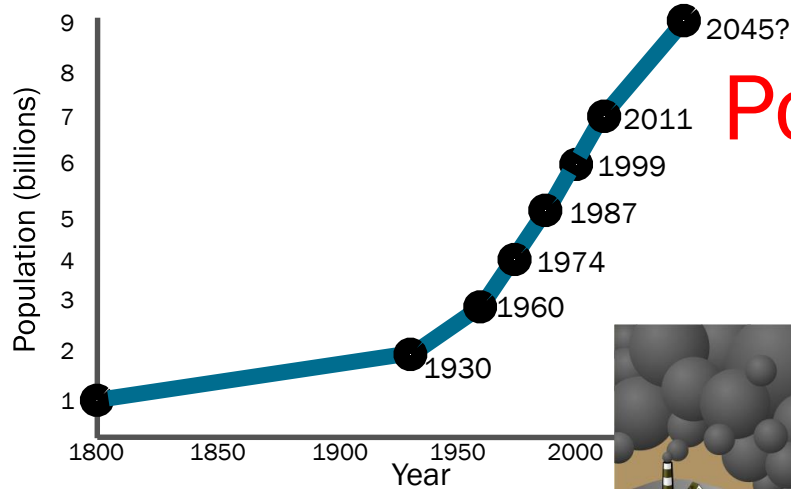
# We live in a world beset by complex problems



Climate Change



Obesity



Population



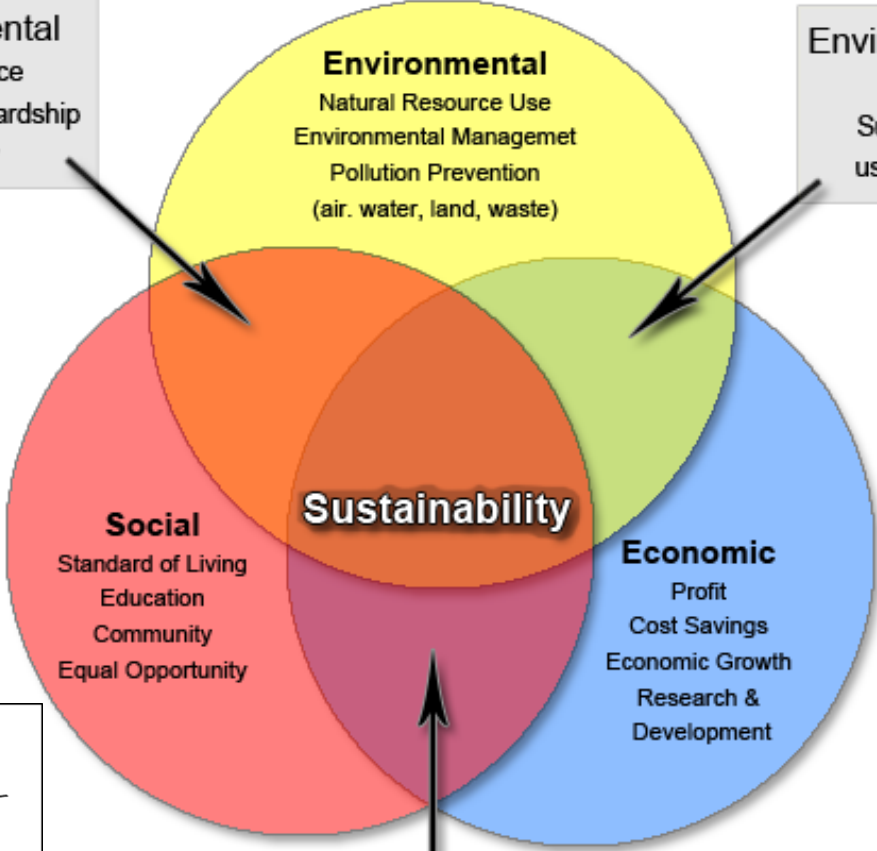
Water

Energy

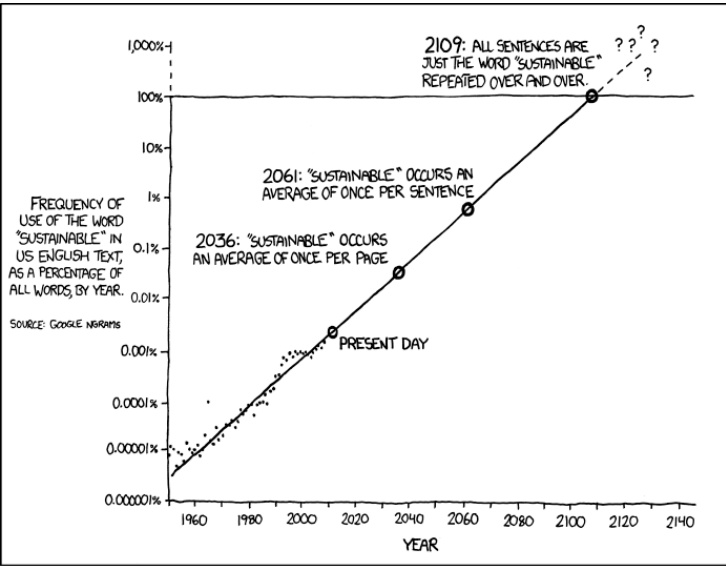


**Social-Environmental**  
 Environmental Justice  
 Natural Resources Stewardship  
 Locally & Globally

**Environmental-Economic**  
 Energy Efficiency  
 Subsidies / Incentives for  
 use of Natural Resources



**Economic-Social**  
 Business Ethics  
 Fair Trade  
 Worker's Rights



THE WORD "SUSTAINABLE" IS UNSUSTAINABLE.

# Sustainability

# Wicked problems...

- 1) Difficult problem **formulation**
- 2) Multiple but **incompatible** solutions
- 3) Open ended time frames
- 4) **Novelty**
- 5) **Competing** value systems or objectives

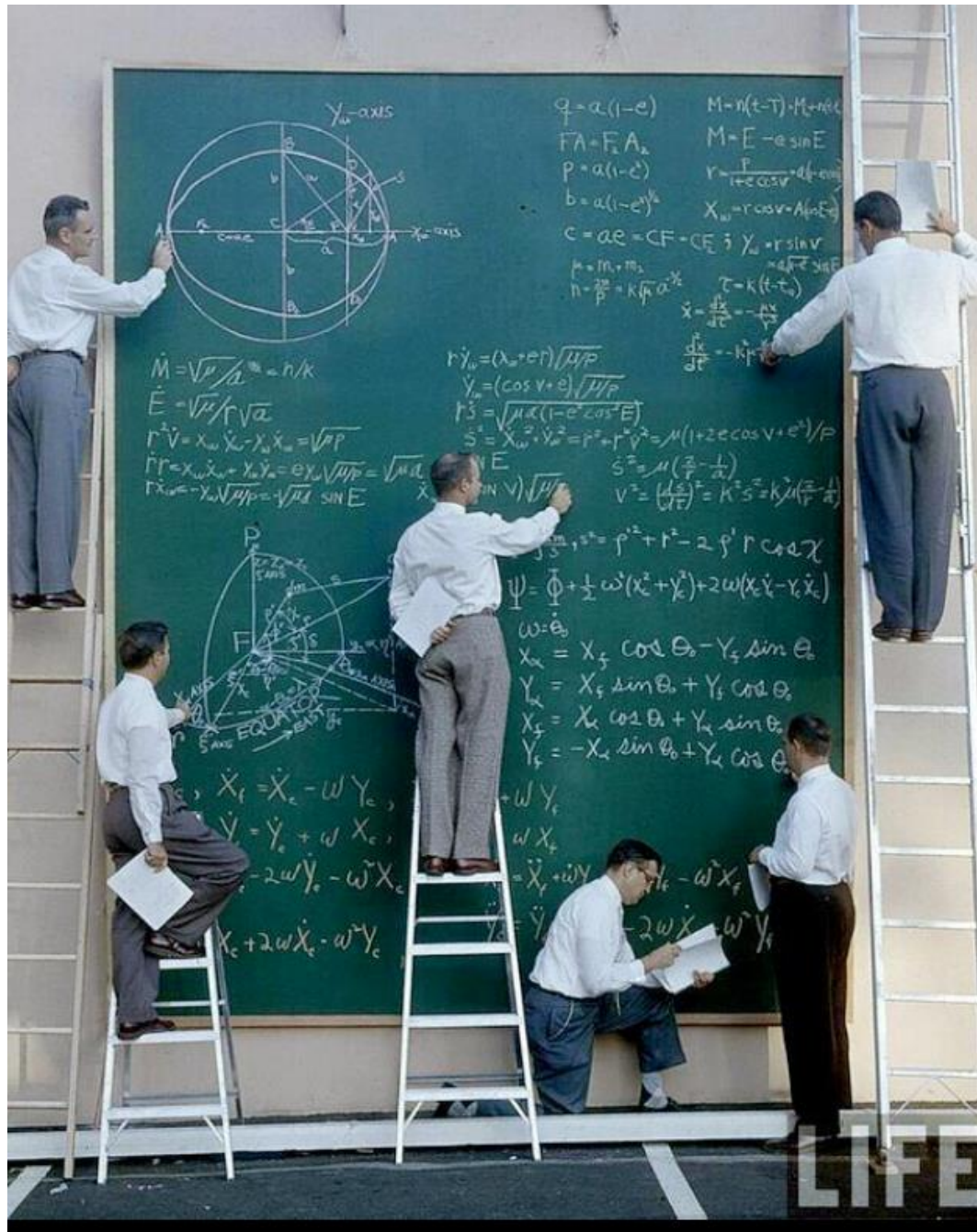
...requires new approaches

Rethinking development of next generations of scientists, engineers, and other professionals

# Interdisciplinary and Holistic Graduate Education

- Bringing together established disciplines (isolated domains of human experience and community of expert) to tackle wicked problems with new knowledge, research, education, and theory.
- Pushing boundaries of traditional disciplinary education by intentionally developing transferrable skillset and overarching growth in areas such as knowledge, leadership, social responsibility, and scholarly inquiry.



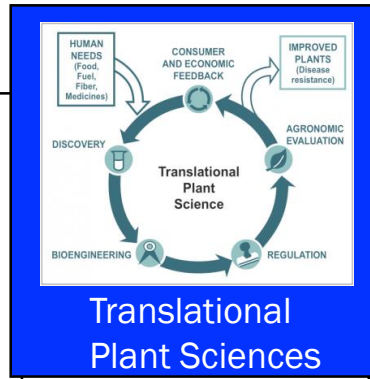
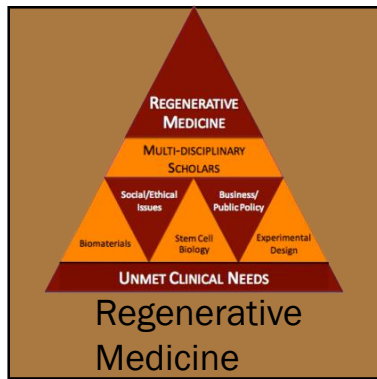


# Interdisciplinary Team Science

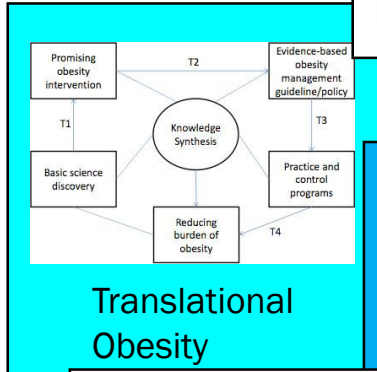
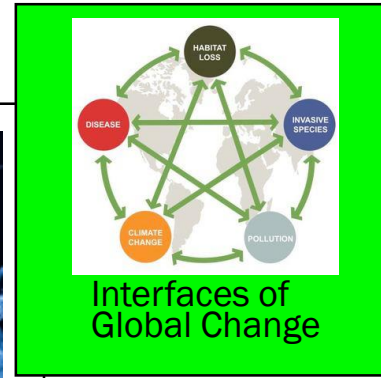
Teams have  
always been  
required to  
solve complex  
problems

Rocket Scientists  
at NASA

LIFE



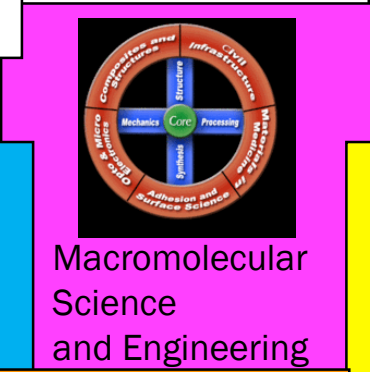
Water INTERFACE



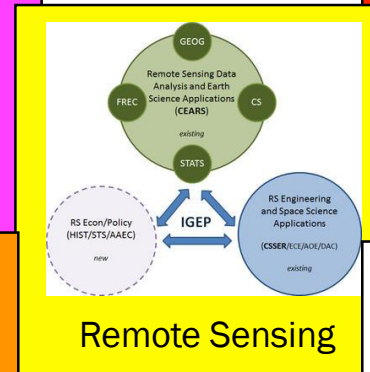
Translational Obesity



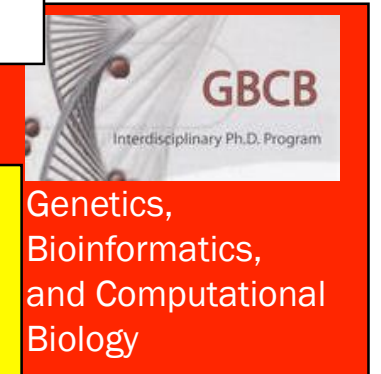
BioBuild



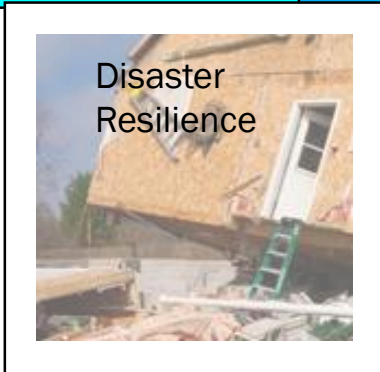
Macromolecular Science and Engineering



Remote Sensing

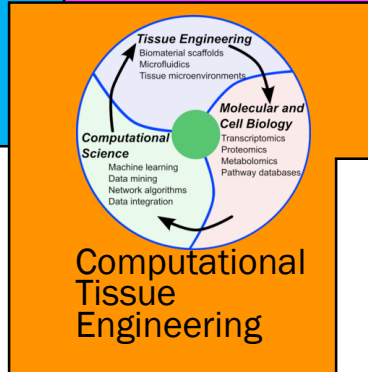


Genetics, Bioinformatics, and Computational Biology



Disaster Resilience

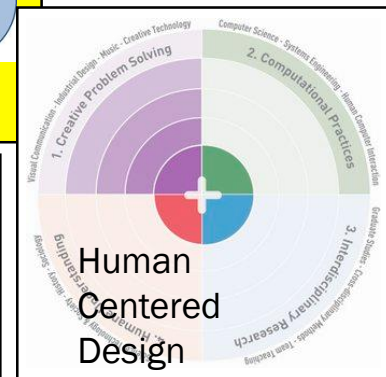
Bio-Inspired Buildings



Computational Tissue Engineering



Sustainable Nanotechnology



Human Centered Design

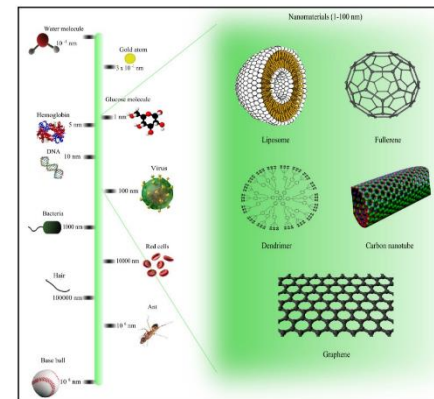
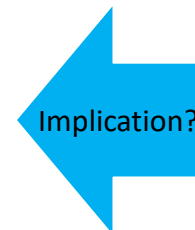
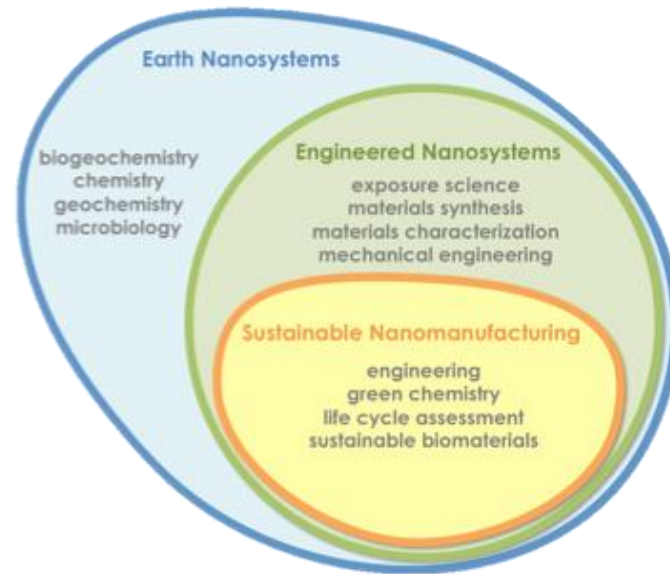
# Interdisciplinary Graduate Education Program (IGEP) at VT

# VTSuN

Virginia Tech Sustainable Nanotechnology

VTSuN supports:

- Scholarly applications of nanoscale science and engineering to improve our understanding of nanomaterial **interactions within the environment**
- Enhance our ability to **apply** nanotechnology to solve global environmental challenges.





# Chemistry



Mike  
Hochella

Greg  
Liu



Tijana  
Grove

# Computer Science



Liqing  
Zhang

# Geosciences



Marc  
Michel

Maren  
Roman



# Sustainable Biomaterials



Peter  
Vikesland



Lindsay  
Marr

# Green Engineering



Sean  
McGinnis

# Civil and Environmental Engineering



Matt  
Hull



Matt  
Chan



Weinan  
Leng



Amy  
Pruden

Mitsu  
Murayama



Johan Foster

# Material

# Science & Engineering



Chemistry

Computer Science

Sustainable Biomaterials

Civil and Environmental

Material

Science & Engineering

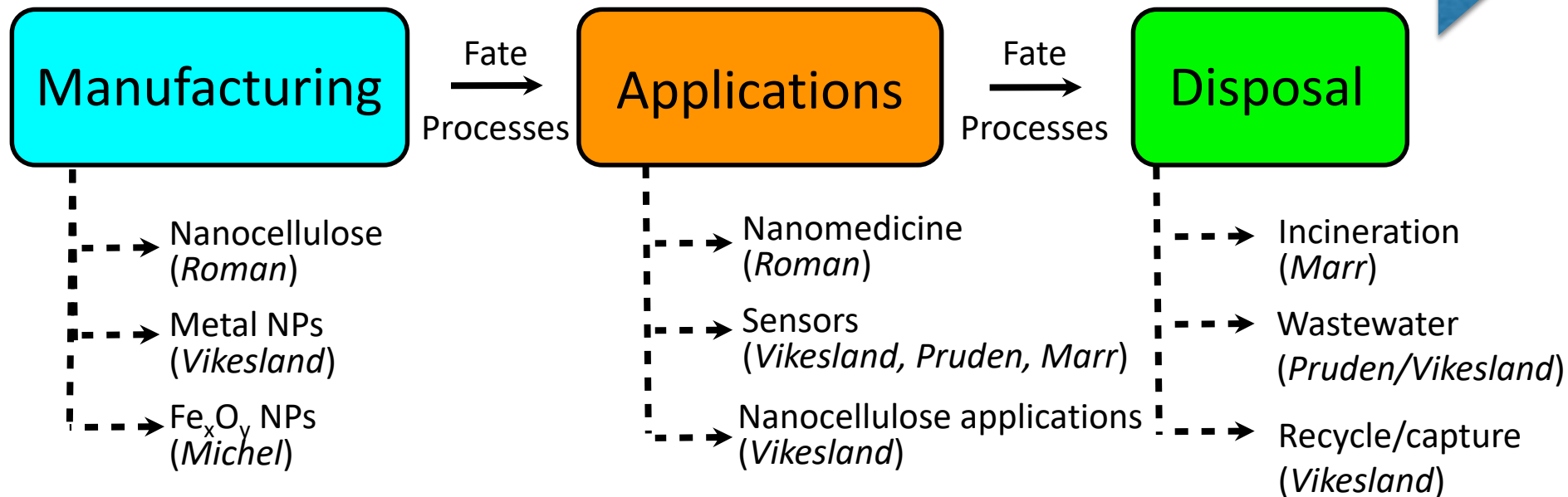
- 2009 – 2017 (now)
- 3 Colleges
- 6 Departments
- 15 Faculty
- 18 Graduates
- 18 Current students

- Aspiration: Faculty from humanities?

NanoEarth  
ICTAS

# Sustainable nanotechnology: an illustration on interdisciplinarity

## Earth Nanosystems (Hochella)



### Fate Processes

*n*C<sub>60</sub> (*Vikesland, Marr*)      CeO<sub>2</sub> (*Hochella, Marr*)      Virus (*Marr, Pruden*)

Metals/Metal oxides/sulfides  
(*Chan, Hochella, Marr, Michel, Pruden, Vikesland*)

### Life Cycle Assessment

AuNPs CeO<sub>2</sub>  
(*McGinnis, Vikesland*)

Nanocellulose  
(*McGinnis*)

# IGEP PROGRAM

## Formal Courses

Sustainable Nanotechnology

Interdisciplinary Team Science

Holistic Development Elective

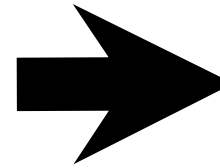
Technical Elective

Seminars, brown bags, and workshops

Co-advising of students

Financial support (via Grad School)

Outreach and public engagement



## GOAL

A **cohort** of students, faculty, and affiliates with the collective expertise to address the complexities of sustainable nanotechnology



# Interdisciplinary education DO NOT replace disciplinary approach, but rather, AUGMENTS it

## Disciplinary Degree Program

### IGEP PROGRAM

#### Formal Courses

Sustainable Nanotechnology

Interdisciplinary Team Science

Holistic Development Elective

Technical Elective

Seminars, brown bags, and workshops

Co-advising of students

Financial support

Outreach and public engagement

### GOAL

A **cohort** of students, faculty, and affiliates with the collective expertise to address the complexities of sustainable nanotechnology

Disciplinary courses

Research and publications

Dissertation/thesis

## GOAL

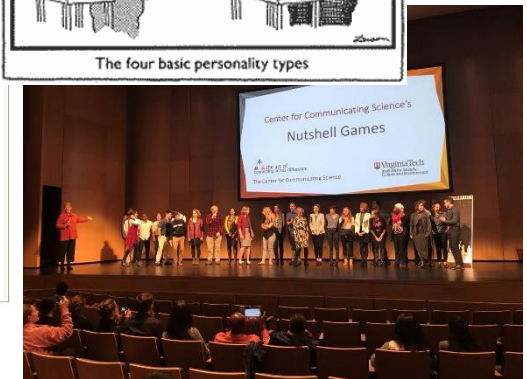
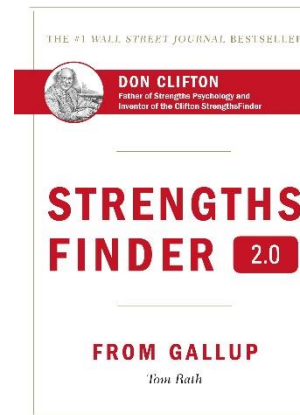
Degree credentials

Holistic development

Transferrable skills for a diverse career field

# GRAD 5134 Interdisciplinary Team Science

- Partner with Student Affairs and Career Services
  - **Understanding yourself and others;** differences and strengths
  - Anticipating differences and potential conflicts; best practice in resolution and communication
- Partner with the VT Center for **Communicating Science**
  - Communication with: peers from other disciplines, general public, different age groups
- **Interdisciplinary** grant writing
  - Course capstone
  - Identifying common research questions
  - Leveraging strengths from different disciplines
  - **“The sum is greater than the whole”**



**the art of**  
connecting across difference





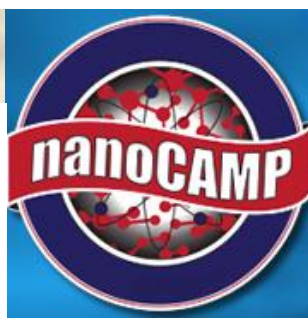
**TEDx**  
VirginiaTech  
x = independently organized TED event




**PULSE  
OF THE  
PLANET**



**n p r**



  
**Montgomery-Floyd Regional Library**  
*One stop, unlimited possibilities*



# Communicating the significance of sustainable nanotechnology in a relatable way

- Audience-dependent
  - Elementary school students
  - High School students
    - aka. prospective undergrads
  - Prospective graduate students
- Adults
- Beyond Virginia Tech
- Beyond STEM-H



# Other forms of **holistic** development in **VTSuN**

## Teaching



### ACADEMY OF INTEGRATED SCIENCE NANOSCIENCE

Nanoscience is the study of materials, phenomena, properties, and applications at the smallest length scale at which we can control matter. A nanometer is one-billionth of a meter, just slightly larger than individual atoms.

Nanoscience and nanotechnology have rapidly growing applications in a wide range of technology areas including electronics, information technology, medicine, renewable energy, aerospace, and advanced materials. The National Science Foundation predicts that by the year 2020, **\$1 trillion of products in the U.S. will contain nanotechnology**. The Bachelor's degree program in Nanoscience at Virginia Tech is **one of only two such programs in the U.S.**

#### Careers in Nanoscience

Electronics and Semiconductor Industries,  
Energy Generation and Storage, Pharmaceuticals,  
Auto and Aerospace Industries, Sporting Goods,  
Materials Science Medical Devices, Biotechnology,  
Environmental Monitoring and Remediation,

**Nano Major** **Nano Minor** **Nano Flyer**

#### Nanoscience Course Offerings

HANO 1015-1016 Introduction to Nanoscience	▼
HANO 2024 Quantum Physics of Nanostructures	▼
HANO 2114 Nanoscience Research Seminar	▼
HANO 2124 Nanoscience Research Rotations	▼
HANO 3015-3016 Nanoscale Synthesis, Fabrication, & Characterization	▼
HANO 3114 Professional Dissemination of Nanoscience Research	▼
HANO 3124 Nanoscience & the Environment	▼
HANO 4124 Advanced Nanomaterials & Devices	▼

## Entrepreneurship



**DUE:**  
December 1<sup>st</sup>  
2017

Virginia Tech Students: Tell us about your business concept that uses nanotechnology to solve sustainability challenges in areas like public health, agriculture, clean water, renewable energy, and beyond, and **win \$2,500 to help make it happen!**

### NanoTechnology Entrepreneurship CHALLENGE

Nanotechnology for global sustainability

www.nanoearth.org | (540) 231-1922 | NanoEarth@vt.edu | @NanoEarthVT

## VT KnowledgeWorks

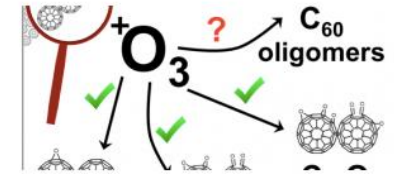
**VIRGINIA TECH  
CORPORATE  
RESEARCH CENTER**

## Writing



HOME VTSUN WEBSITE ICTAS VTSUN IGEP VT GRAD

### C60 fullerenes are oxidized by levels of ozone found in ambient air



### Learning In



For the last y  
Virginia Tech  
Nanotechnol  
VTSuN. Check  
website here  
VTSuN is (als

(This is a post by VTSuN member, Andrea Tiwari. You can reach Andrea at [ajtiwari@vt.edu](mailto:ajtiwari@vt.edu)) As we know, carbon is the basis of life on Earth – we are all “carbon-based life forms.” The carbon ...  
[Continue reading →](#)

Posted on February 25, 2014 by [coffeemug](#) · [Leave a comment](#)

Posted on Febr  
[comment](#)

### My first research experience



### Your one sto consumer p



# Quantifying our successes



Rebecca French  
PhD 2011  
AAAS  
Congressional  
Fellow



Andrew Whelton  
postdoc 2010  
Assist Prof  
Purdue



Bojeong Kim  
postdoc 2013  
Assist Prof  
Temple

Rebecca Lahr  
PhD 2013



Assist Prof  
Michigan State

## Graduated 13 PhDs

3 EPA STAR Fellows

5 NSF Student Fellows

8 ACS Student Awards

3 ICTAS Fellows

Nina Vance  
PhD 2012



Assist Prof  
U of Co Boulder



Manuel Monge  
postdoc 2013

Assist Prof  
Univ Santiago  
Chile



Jose Cerrato  
PhD 2010

Assist Prof  
U of New  
Mexico

Assist Prof  
UT El Paso



Gail Xi  
postdoc 2016

Jake Metch  
PhD 2017  
Scientist  
US Water



Matt Hull  
PhD 2011

ICTAS  
Program Manager

Yanjun Ma  
PhD 2014

Assist Prof  
China Univ  
Mining & Technology



Takuya Echigo  
postdoc 2010  
Assist Prof



Shiga Univ, Japan



Param Pati  
PhD 2015  
Assist Prof  
Smith College

# Keys to success

Fruitful **faculty-faculty** interactions



Fruitful **student-faculty** interactions

Fruitful **student-student** interactions



**Communication** AND **buy-in** from both faculty and students is essential



## Lofty Goals for the future

- Incorporate more opportunities for holistic development: leadership, social responsibility, and beyond, within the framework of sustainable nanotechnology
- Remain agile and responsive to student and alumni feedback, and especially to the rapidly evolving field of career and professional opportunities
- Sustainable nanotechnology is inherently interdisciplinary and suitable as a framework for holistic graduate education; can we be an example to other similar endeavors to tackle *wicked problems*?



# Acknowledgement

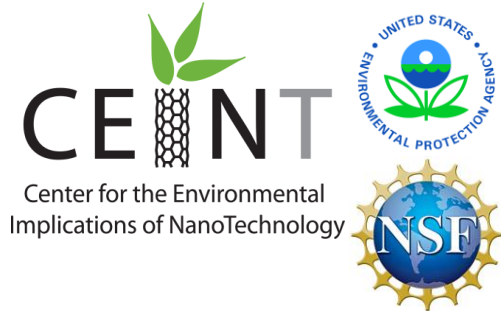
The Charles E. Via, Jr.

**Department of Civil and Environmental Engineering**  
**Environmental and Water Resources Engineering**



**ICTAS**

INSTITUTE *for* CRITICAL TECHNOLOGY  
*and* APPLIED SCIENCE *Virginia Tech*



Center for the Environmental  
Implications of NanoTechnology

**VTsuN**  
Virginia Tech Sustainable Nanotechnology



**Sustainable  
Nanotechnology  
Organization**

Research | Education | Responsibility



 **VirginiaTech**<sup>®</sup>  
Graduate School



“How do we make the world work for 100% of humanity in the shortest possible time through spontaneous cooperation without ecological damage or disadvantage to anyone?”

Buckminster Fuller



**VTSuN**  
Virginia Tech Sustainable Nanotechnology

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@VTSuN