Roop L. Mahajan

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Shandong University -Virginia Tech Symposium on Bat Biophysics & Bio-inspired Technology
August 14-18, 2010

Session on "Innovation Concepts"

August 15, 2010
Chair Zuo-tang Liang,
Shandong University

Innovation concepts

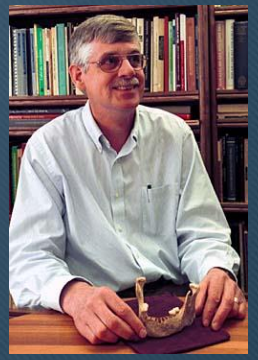
Human Spark

- **Neanderthals and modern humans evolved from the same ancestors.**

- **Neanderthals left Africa and spread to Europe where they lived for about 200, 000 years before they became extinct.**

- **Those left behind successfully evolved to modern humans and occupied the planet.**

DO YOU KNOW WHY?



Innovation

"Just as energy is the basis of life itself, and ideas the source of innovation, so is innovation the vital spark of all human change, improvement and progress."

Ted Levitt; Marketing Guru, Harvard Business School

1. Invention vs. Innovation

Invention vs. Innovation

INVENTION

- an idea made manifest
- the creation/embodiment of something new
- the first occurrence of an idea for a new product or process
- ***i****s the conversion of cash into ideas*

INNOVATION

- an idea applied successfully in practice
- is the conversion of ideas into cash

(Etymological origin of word INNOVATION – creation of something new)

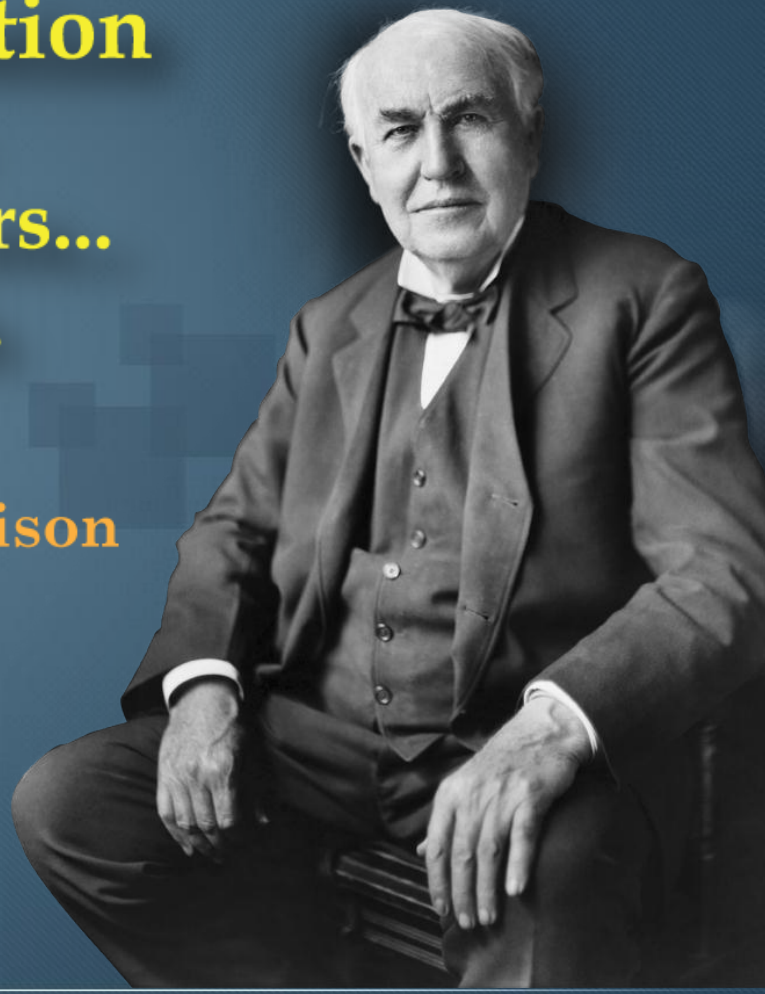
Invention vs. Innovation

Innovators produce, market and profit from their innovations

Inventors may or may not profit from their inventions

"I never perfected an invention
that I did not think about in terms of the
service it might give others...
I find out what the world needs,
then I proceed to invent."

-- Thomas Edison



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2. Sources of Innovation

Sources of Innovation

- **Inventor(s) –driven**
  - **Recent research suggests that the most successful innovation occurs at the boundaries/interfaces**
- **End- User –Driven**
  - **Need-based**
  - **Increasingly assuming more importance**

Sources of Innovation

- **Inventor(s) –driven**

  Recent research suggests that the most successful innovation occurs at the boundaries/interfaces

- **End- User –Driven**

  need-based
  increasingly assuming more importance

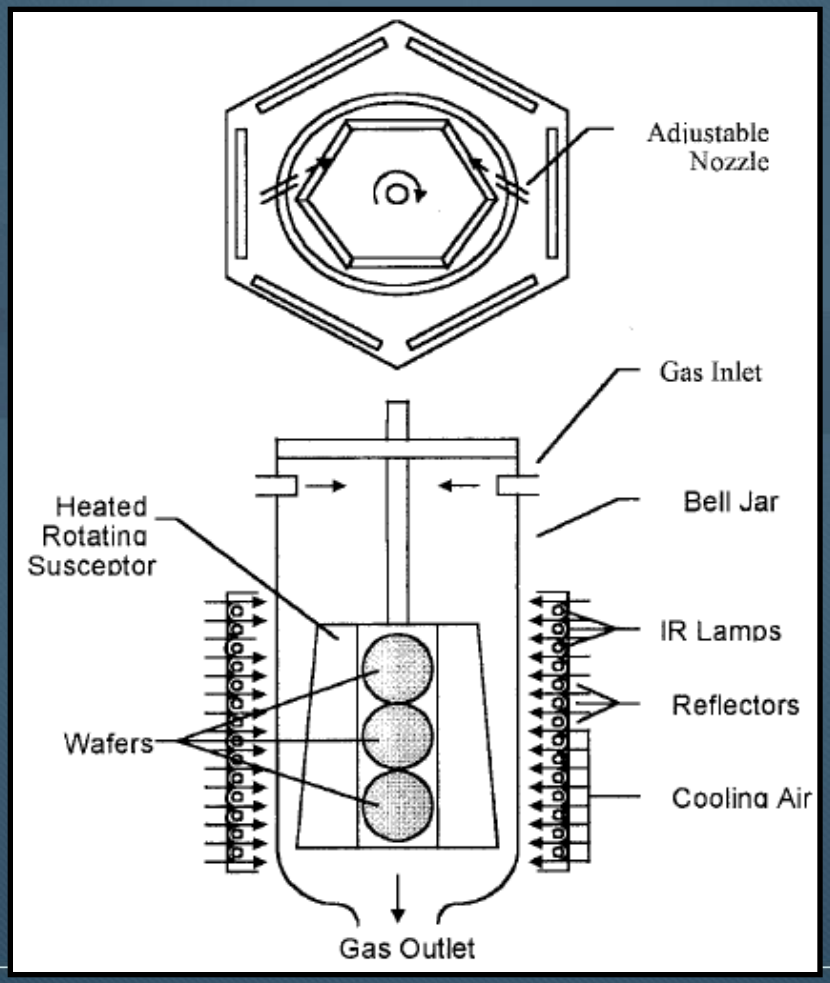
3. Linear vs. disruptive Innovation

3. Linear vs Disruptive Innovation

- **Linear**
  - **Incremental**
    Ex: Cost reduction

➢ **Barrel reactor silicon epitaxy**

CVD: Barrel Reactor

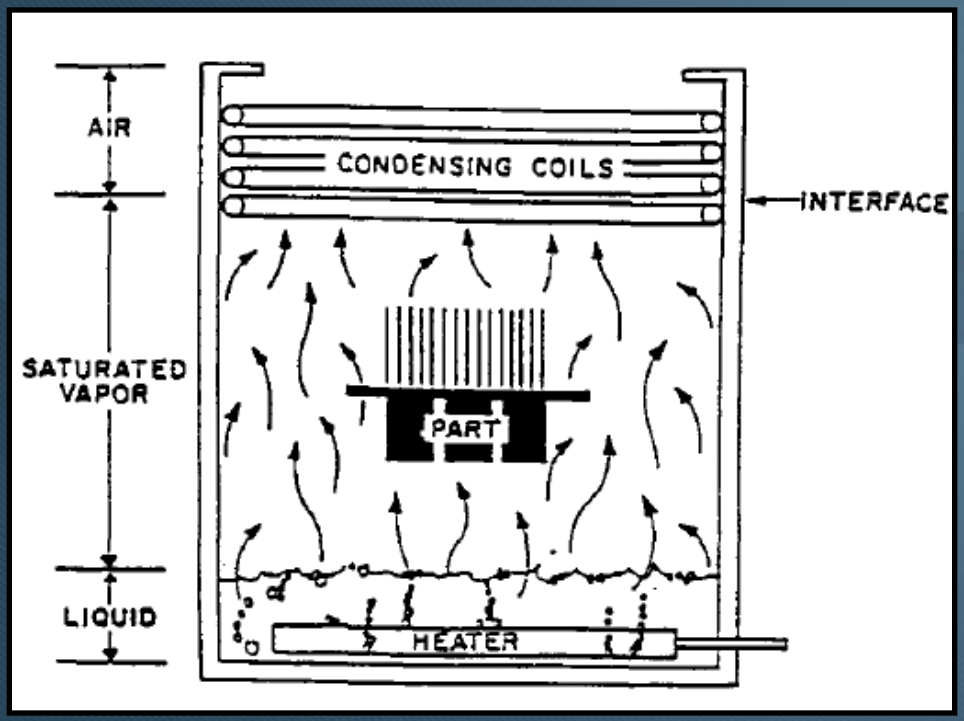


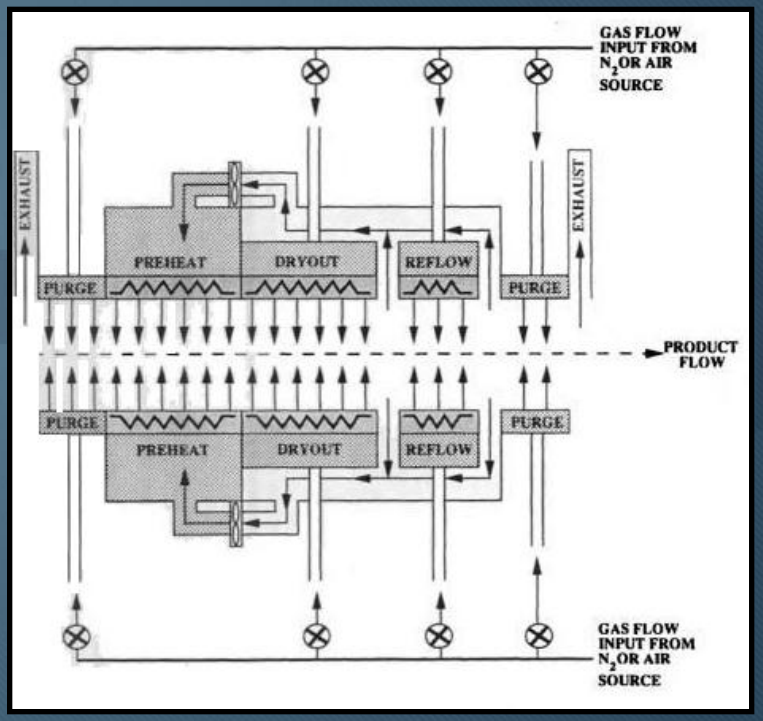
3. Linear vs. Disruptive Innovation

- **Disruptive**
  - **Game-changer**
  - **EX: Digital vs analog watches**

➢ **Condensation Soldering vs IR soldering**

Condensation and IR Reflow Soldering





3. Linear vs. Disruptive Innovation

- **Disruptive**
  - **Game-changer**
  - **EX: Digital vs analog watches**

Condensation Soldering vs IR soldering

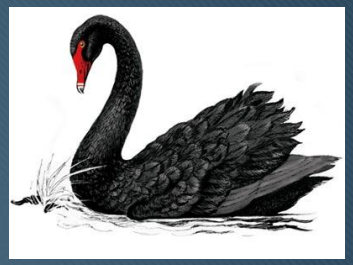
- **The Black Swan**

Disruptive Innovation and a Black Swan

A Black Swan is an event that has three characteristics;

- it is an outlier
- it carries an extreme impact
- it has retrospective predictability.

"The Black Swan", by Nassim Nicholas Taleb

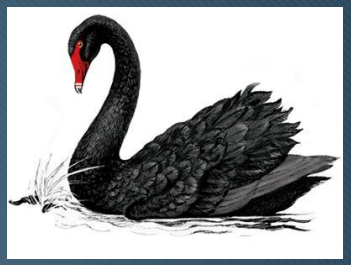


- Our world is dominated by Black Swans.
  - the internet
  - the computer
  - the laser

All three were unplanned, unpredicted, and unappreciated upon their discovery, and remained unappreciated well after initial use.

Disruptive Innovation

A powerful exercise for disruptive innovation



WHAT WILL MAKE YOU UNEMPLOYABLE IN 7 YEARS?

Or

WHAT WILL MAKE YOU IRRELEVANT IN 7 YEARS?

4. Promoting innovation

Promoting Innovation

- promoting interdisciplinary research

Buds of creativity bloom at intersections

- encourage risk-taking
  - Celebrate successes and failures
- constantly examine existing paradigms
  - Look for the next **Black Swan**

Promoting Innovation

Additional ingredients for success

- ❑ Technical competency
- ❑ Resources
- ❑ Recognition

Innovation Concepts

1. Invention vs. Innovation
2. Sources of Innovation
3. Linear vs. disruptive innovation
4. Promoting innovation

- **ICTAS as an agent of Innovation**

ICTAS

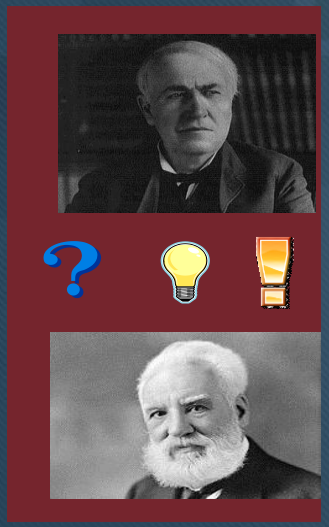
INSTITUTE *for* CRITICAL TECHNOLOGY *and* APPLIED SCIENCE *Virginia Tech*

VISION

To be among the top-ranked global institutes in transformative technologies for a sustainable future

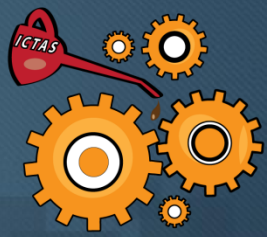
MISSION

To stimulate, catalyze and promote interdisciplinary / trans-disciplinary research at the intersection of science, engineering, biology and social sciences.



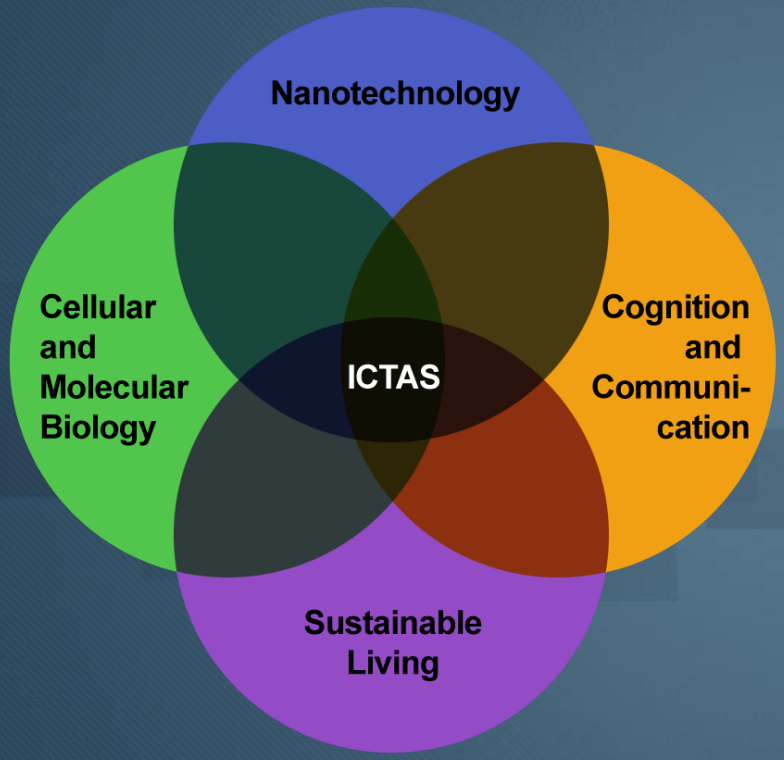
critical emerging areas

transformative thinking



NBIC Tetrahedron

Defining Research Thrusts



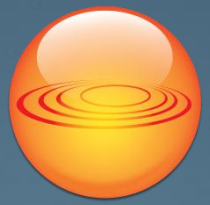
ICTAS research is at the NBIC interfaces with a focus on A SUSTAINABLE FUTURE

"The most incomprehensible thing about the world is that it is at all comprehensible."

Albert Einstein

ICTAS *Thrust Areas*

Nanoscale Science and Engineering



Sustainable Water

Nano-Bio Interface

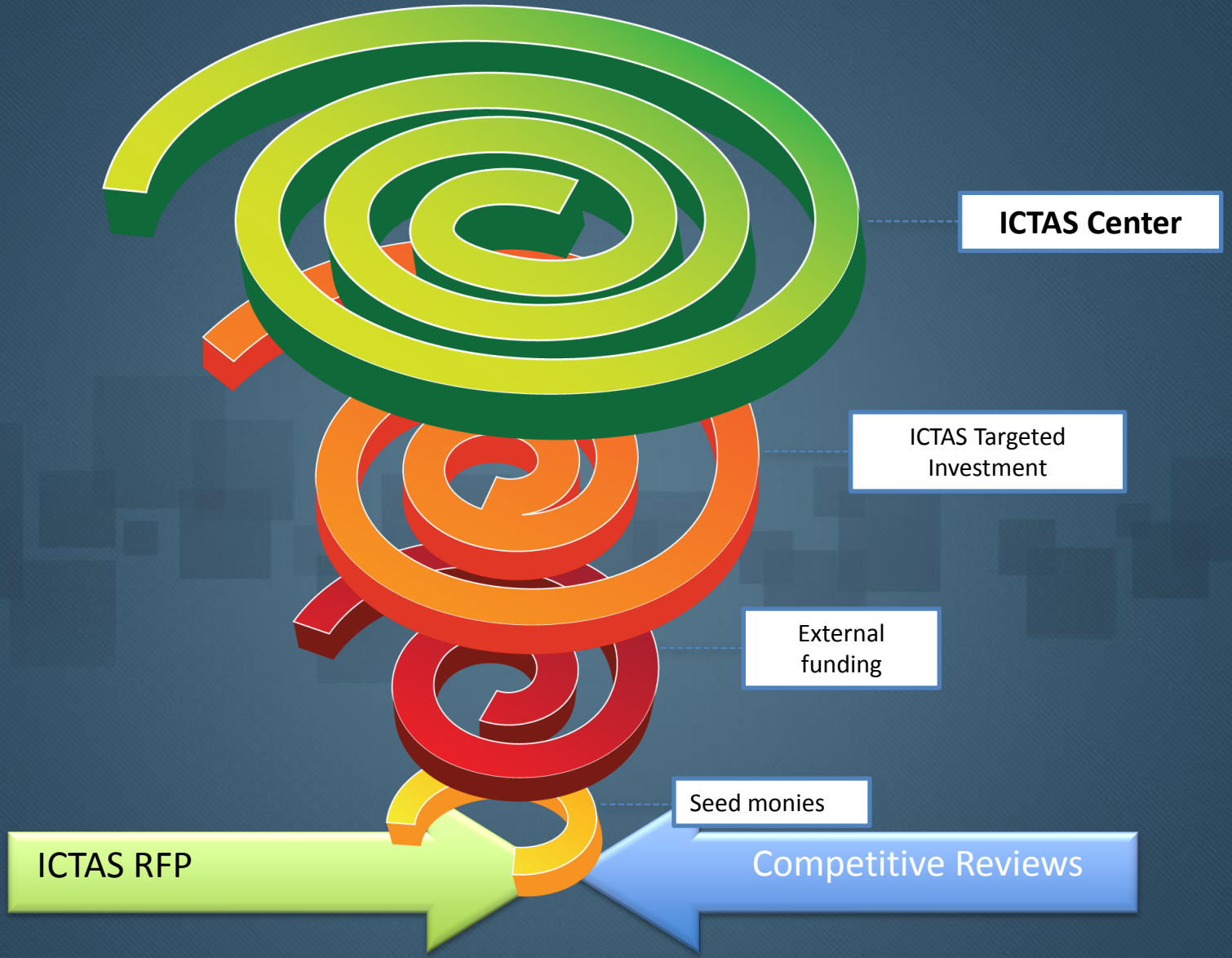
Cognition & Communication

Sustainable Energy

Emerging Research

Renewable Materials

National Security



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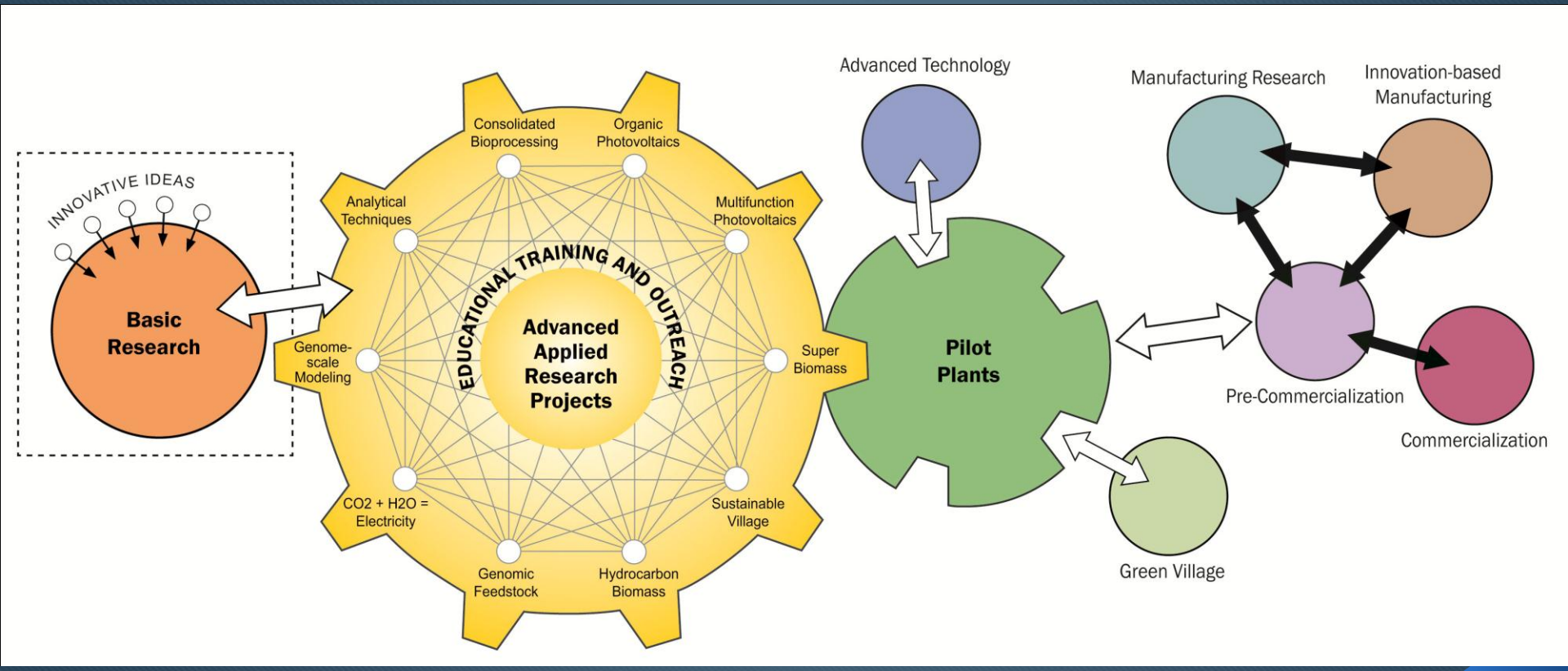
SUN2Fuels Hub



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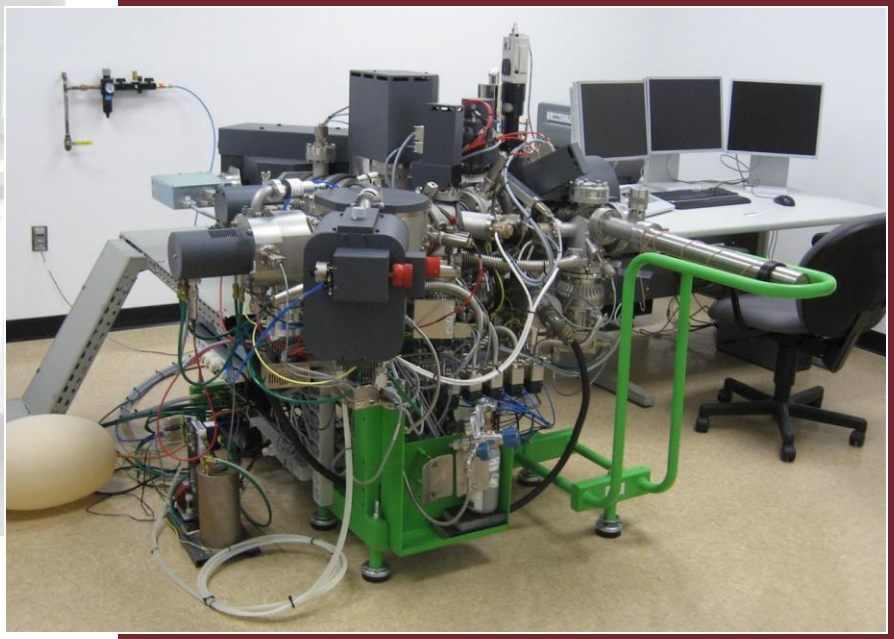
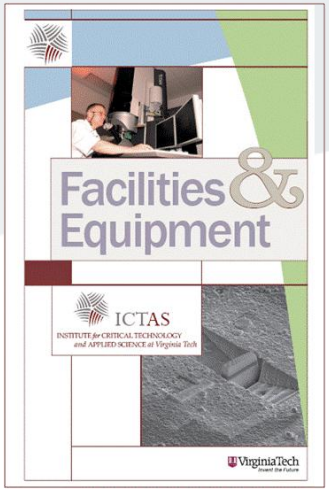
Laboratories and Collaborative Space



- http://www.ictas.vt.edu/ncfl

NCFL Director Bill Reynolds

NCFI

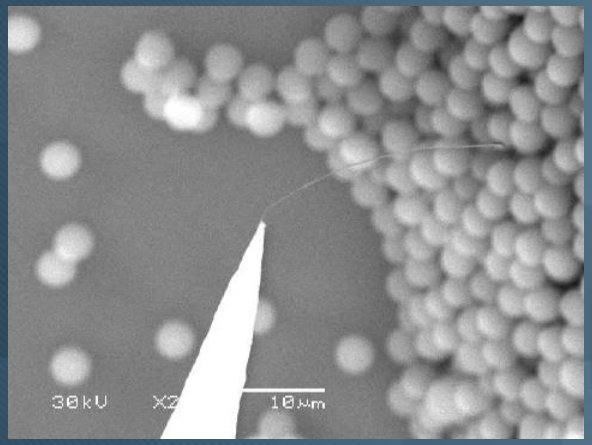


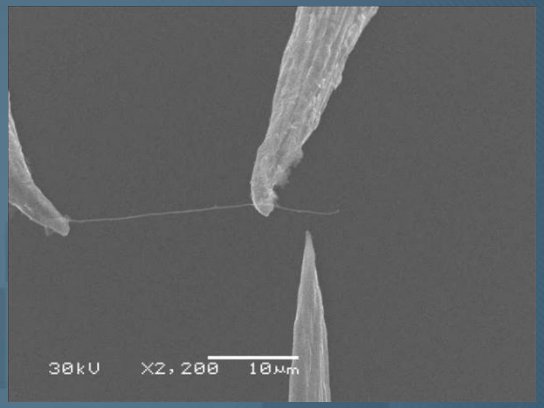
FEI Helios 600 NanoLab

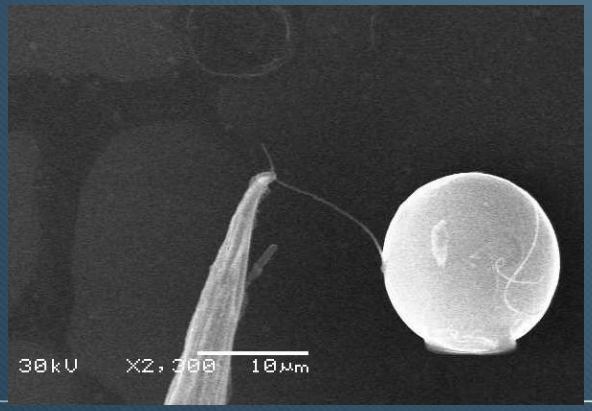
- **Field-emission SEM: LEO (Zeiss) 1550**
- **Focused Ion Beam: FEI Helios 600 NanoLab**
- **Environmental SEM FEI: Quanta 600 FEG**
- **Transmission Electron Microscope : F**EI Titan 300
- **Secondary Ion Mass Spectrometer:** Cameca IMS 7f GEO
- **XPS PHI Quantera SXM:** Scanning Photoelectron Spectrometer Microprobe
- **Confocal laser scanning microscope:** Zeiss LSM 510 NLO + VIS
- **BioAFM, TriboIndenter, AFM : NanoMAN**

FEI Titan 300

Nanoscale Fabrication: NT/Sphere Device

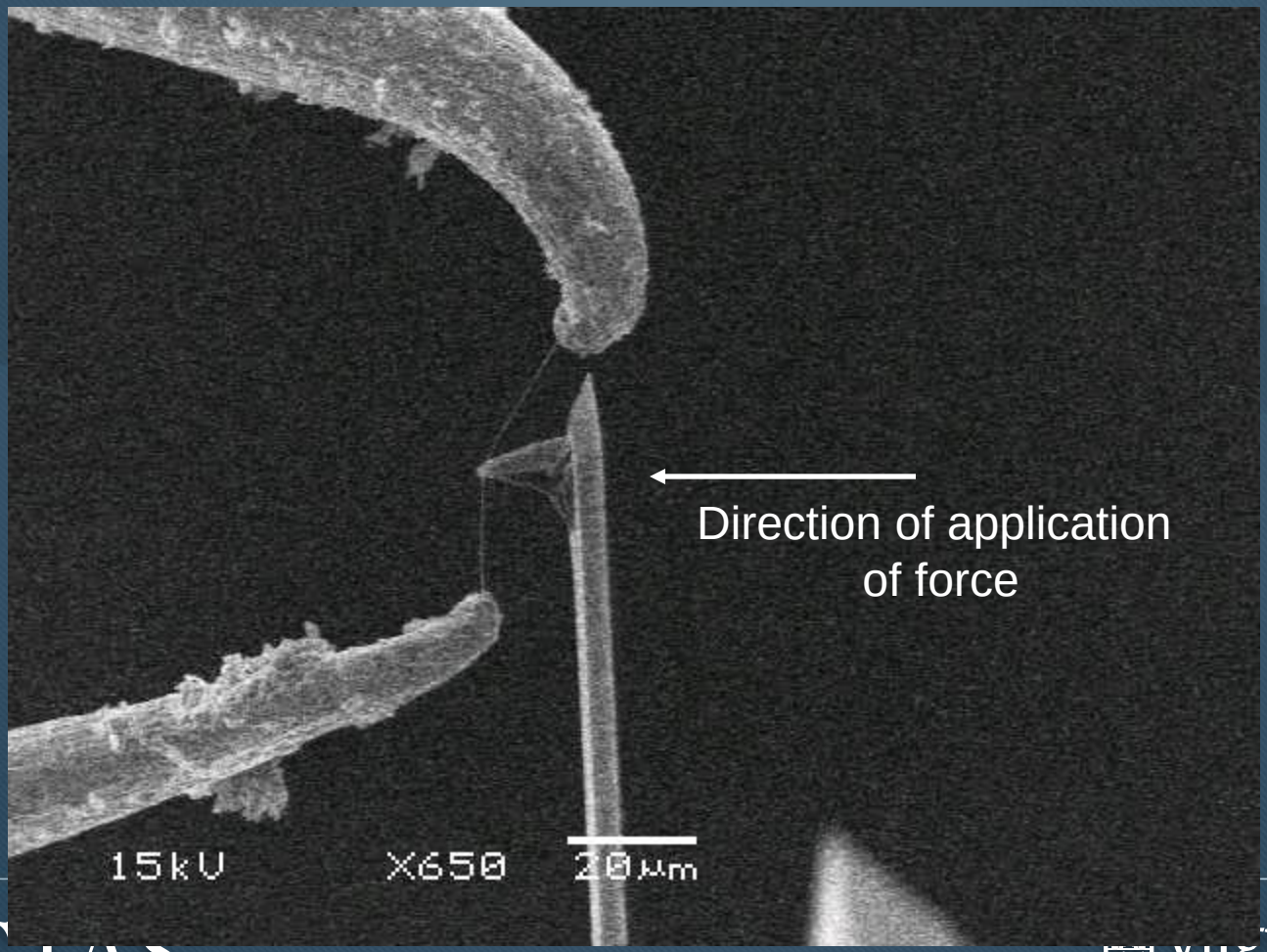






Mechanical Characterization

(B) Mechanical Testing



ICTAS Laboratories

ICTAS-NCFL: The Nanoscale Characterization and Fabrication Lab opened in the Corporate Research Center in July 2007.

ICTAS-HQ: The institute headquarters and home to the School of Biomedical Engineering and Sciences opened on Stanger Street in March 2009.

ICTAS-LSP The facility in the Life Sciences Precinct is under construction and will open at the end of this year.

ICTAS-NCR: ICTAS will utilize 7,000 ft^2 in the new facility near Washington.

ICTAS *Thrust Areas Populated*

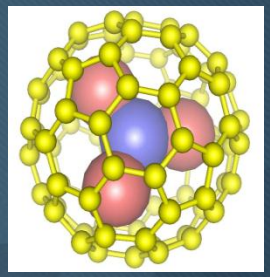
Nanoscale Science and Engineering	Environmental Nanoscience and Technology | Nanomaterials including carbonaceous materials | Nanosensors
Nano-Bio Interface	Targeted Delivery of Nano-medicine | Cellular Engineering Microsystems |Non-invasive Sensing and Diagnosis | Inflammation | Bio-Imaging
Sustainable Energy	Fuel Cells | Organic Photovoltaics | Biologically Derived Fuels | Energy Harvesting | Clean Coal Energy
Renewable Materials	Bio-based Materials: Design and Processing
Sustainable Water	Water Infrastructure Management | Sustainable Ecosystems and Urban Infrastructure | Water & Health
Cognition and Communication	Cognitive Radio Networks | Autonomous Secure Communications | Human Computer Interface
Homeland Security	Naval Surface Warfare Center Dahlgren Division (NSWCDD) | DARPA, NASA
Emerging Research	Complex Network Systems | Accelerating Scientific Discovery through Data Mining | Personal Health Informatics | Humanoid Hospital

Nanoscale Science and Engineering

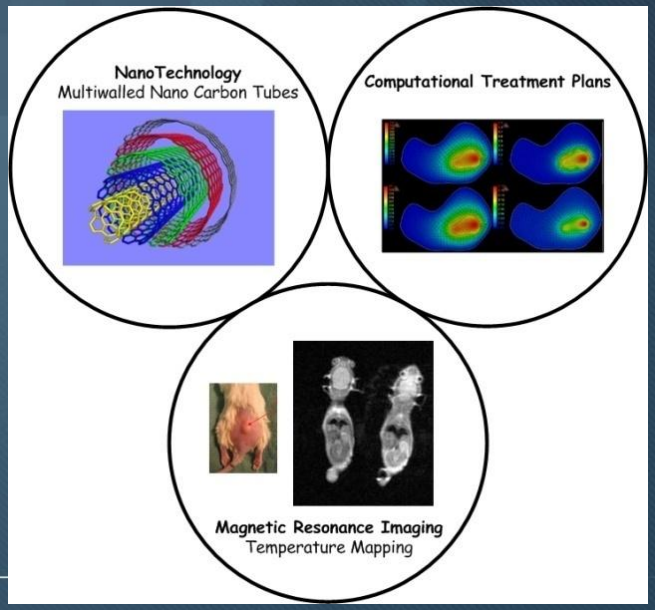
- Continues to grow in scholarship and external funding- beyond Environmental Nanoscience and Technology

  - $7.05 million new research funding related to NSE (21 awards: NSF, NIH, DoD, VCOM, AFOSR, other).
  - IMI: International Multifunctional Materials Research Institute (IMMRI)
  - New Center for Sustainable NT (SUN)
  - Nanofibers
  - **Nanomanufacturing : Discussion with Aneesh Chopra/ Dr Kota**
    - **Innovation-based manufacturing**

Novel nanomaterials for engineering and medical applications



- New material discovered by Prof. Harry Dorn of Chemistry, 1994
  - Metal encapsulated in a fullerene cage
  - More discoveries followed
  - Many applications in bio-imaging, energy, optoelectronics
- Grants:
  - $6m from NIH and NSF; 2005-09
  - $200,000 from the Commonwealth Technology Research Fund (CTRF), March 2008
- Has spurred new collaborative research
  - Novel nanostructures (peapods and nanohorns) as improved imaging agents and therapeutic enhancers (hyperthermia, drug delivery)



Sustainable Water

- **One of the eight thrust areas, with three sub-areas**
  - **S**ustainable Water Infrastructure Management (SWIM)
    - Pipe restoration, rehabilitation, renewal
  - Water and Health
    - Pathogens, Water treatment, Aesthetics
  - Sustainable Ecosystems and Urban Infrastructure
    - Stormwater runoff/recovery, nutrient cycling, natural systems

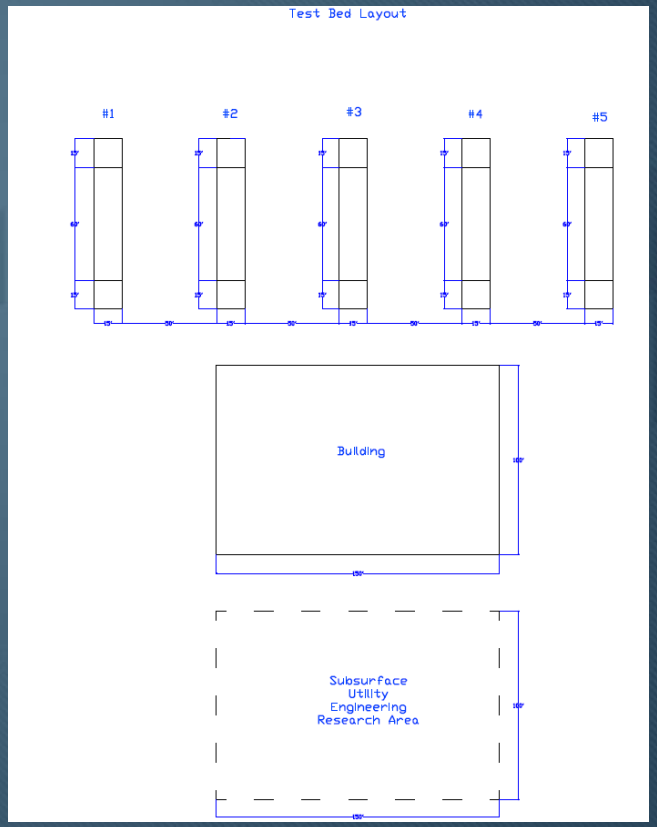
PROPOSALS:

- **NIST/EPA "SMART PIPE" FACILITY $10-15 million**
- NSF EFRI "SUSTAINABLE WATER BUILDINGS" $2 million
- NSF IGERT (2011) *DESAL Water: ACES- Discovering Environmental and Sustainable Alternatives for Water: Aesthetic, Community and Engineering Solution*

Smart Pipe Test-Bed Facility

NIST External Construction Grant Proposal (to submit April 26, 2010): $10-15 million with $2-3.0 million cost share

- A platform for conducting controlled-condition research on the benefits of using innovative technologies (e.g., new measurement sensors) to assess the condition of pipe infrastructure systems and to rehabilitate aging water and wastewater pipelines.



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New Energy Sources *for a* Sustainable Future

Research in energy cells, photovoltaics, and other technology areas lead the way to sustainability for future generations.

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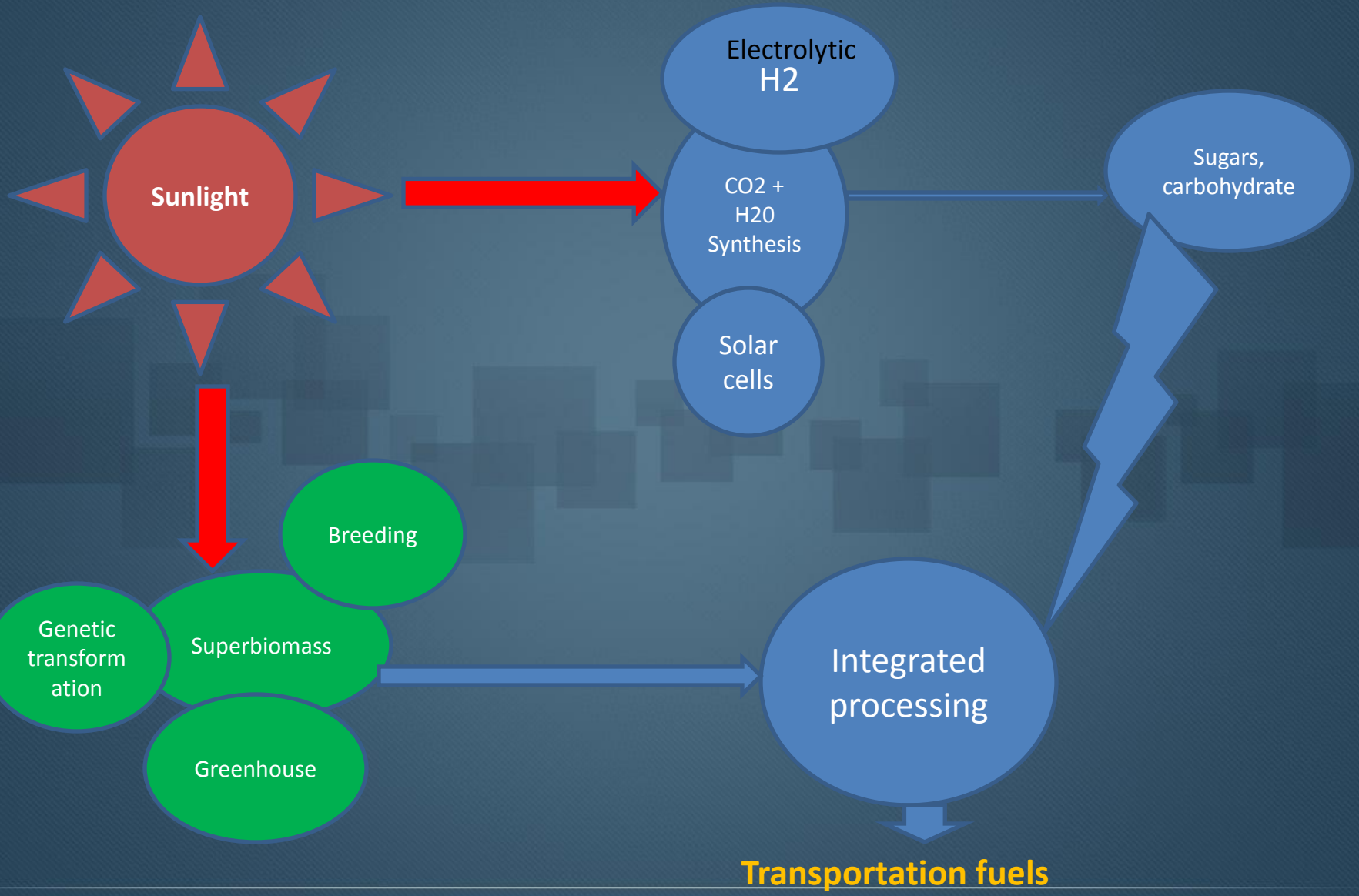
Sustainable Energy

Southeastern Regional SUN2 Biofuels Hub

- A major effort, VT Lead University ; $125 m over 5 years
- Partners: ORNL, Columbia U., SUNY-Syracuse, Baylor U., U. of Delaware , CIT, BASF, Applied Materials, Inc., Luna nanoWorks…
- P.I. : Dr. Foster Aglevor; Roop L. Mahajan: Chair, External Advisory Committee
- 33 Faculty from COE, COS, VBI, CALS, IALR, CNR
- Significant help from PAG, OSP, ICTAS Team, Burruss Hall

Sun2Fuels Process Pathways



Sustainable Energy

E-RIC (Energy Regional Innovation Cluster)

- **Another major effort; $129 m over 5 years**
- **Two potential partners**
  - CCI/ PSU led teams; politics
  - VT as a core university with PSU/CMU/UT/ IBM…..
  - P. I. : **Professor John Burns**
  - Faculty from COS, COE, College of Architecture, College of Arts & Humanities

Nuclear Energy Hub: Led by ORNL; VT as a user-institute

Nano-Bio Interface: VT Center for Inflammation

- **A theme area under ICTAS; Expanded to a VT Center, with support from Fralin**

Integrative team

- Experimental biologists; Computational and engineering scientists; Chemists Clinicians (Cardiologists, neurologists, infectious disease experts)

Core Areas

- Mechanism of irreversible and chronic inflammation
- Computational simulation and prediction of inflammation network
- Target identification and chemical intervention of inflammation
- Translational studies of human atherosclerosis, infection and neurological inflammation

Key grant support

- Collective funding from NIH totaling $2.5 million annually
- Additional grant application from NIH, NSF totaling $2.5 million annually

Collaborative networks

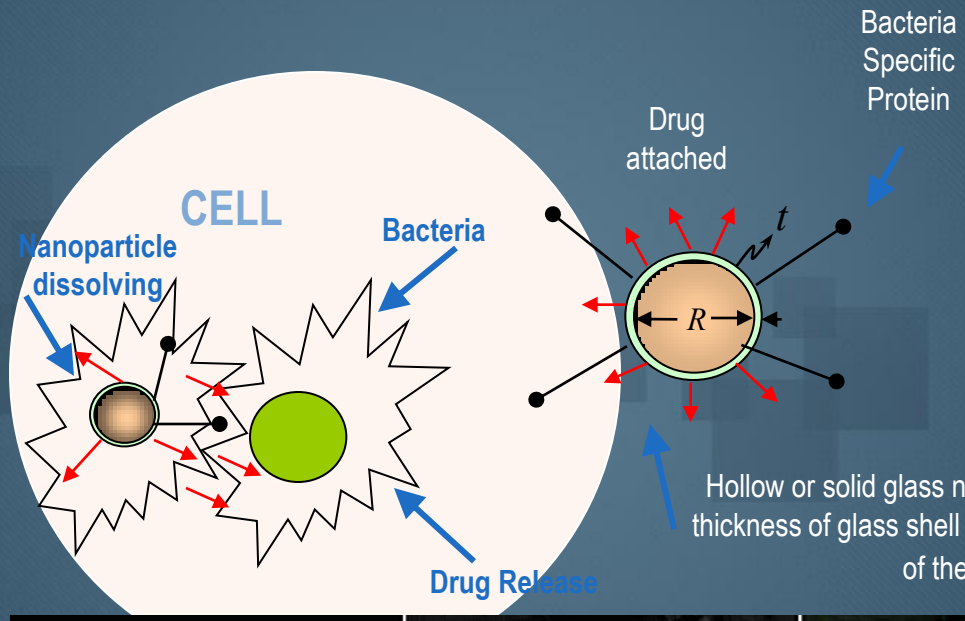
- Wake Forest, Georgetown, NIEHS, Carilion Clinic, Celgene, Amgen, BD Bioscience

Nano-Bio Interface

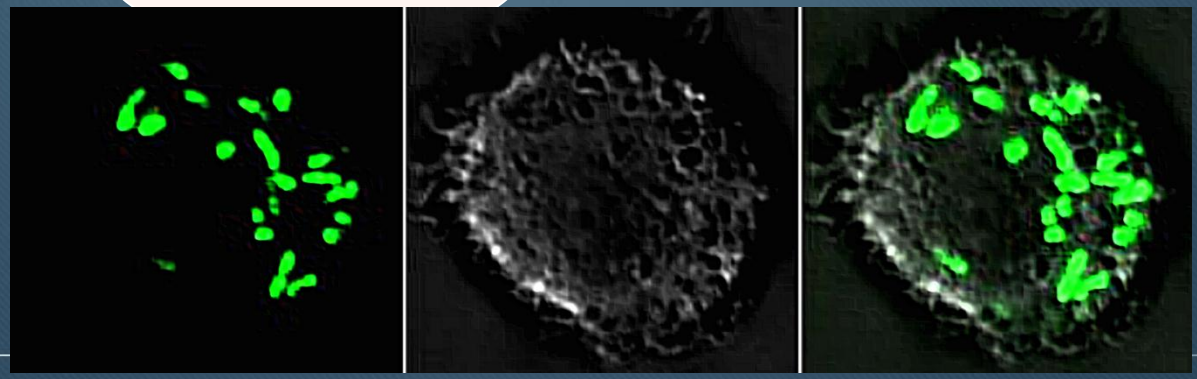
Targeted delivery of nano-medicine

Targeted drug delivery for the treatment of infections due to intracellular pathogens

- Work is currently underway into all aspects in a systematic manner with encouraging results
- Will define the ideal system which can be used for the control of intracellular bacterial infections like *Tuberculosis Brucellosis* and *Salmonellosis* with targeted drug delivery system using nanoparticles



Hollow or solid glass nano particle where *t* is the thickness of glass shell and *R* is the internal radius of the particle.



Macrophage cells infected with *Brucella* expressing green fluorescence protein. Confocal image of J774 A.1 cells

Nano-Bio Interface

ICTAS M-BEDS

- *yet another example of spiral growth*

Multiscale Bio-Engineered Devices and Systems

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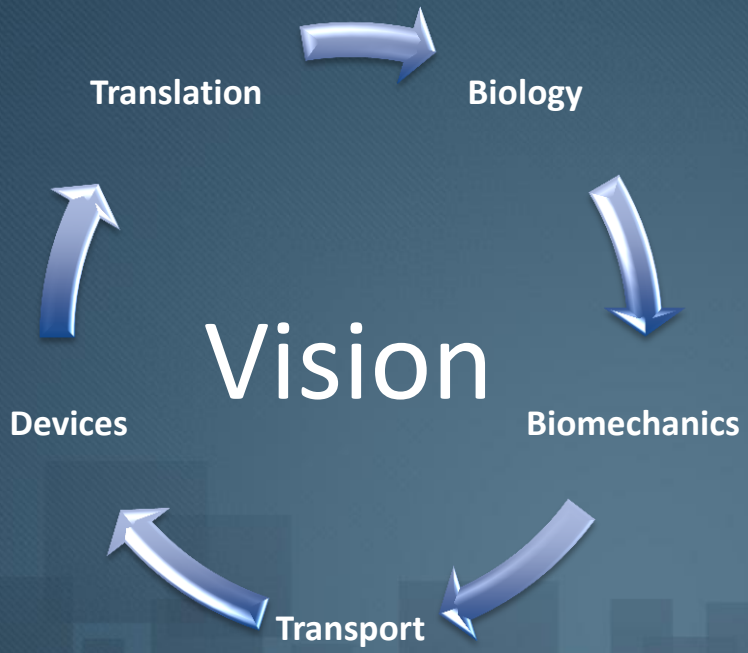
Background

- ✓ MBEDS is the grandchild of several ICTAS and COE initiatives:
  - ✓ CEMS/CarDia ICTAS theme areas
  - ✓ NSF IGERT: MultiSTEPS
  - ✓ NSF-EFRI: Complex Microsystem Networks Inspired by Internal Insect Physiology



ICTAS-MBEDS envisions to realize novel biomedical devices or systems that serve as enabling or platform technologies for the efficient and effective diagnosis and treatment of acute or chronic diseases.

MBEDS will bridge the "bench-to-bed" gap by developing a framework that will enable technology translation to clinical practice.

MBEDS will be a "grassroots" initiative that will be shaped by and contribute to the research aspirations, desires, and goals of its stakeholders.

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M-BEDS Role within ICTAS

- ✓ MBEDS will exist at the intersection of engineering, physics and biology, cutting and connecting across ICTAS theme and thrust initiatives within the "nano-bio interface", biomedical engineering and sciences and physics of disease.

ICTAS Bio-Based Materials Center

- Formally established as an ICTAS Center
  - Added 6 new faculty members
  - Awarded first round of interdisciplinary research grants; each student will be mentored by at least two center faculty members in different disciplines to facilitate interdisciplinary learning
  - Proposed new graduate certificate in Bio-based Materials Science
  - Hosted first annual Bio-based Materials Symposium
  - Entire BBMC faculty won the only USDA Educational Center grant awarded ($0.5M, 4 yrs)

Cognition and Communication

VT-Cornet Status

- 48 high performance servers are installed in a server room and accessible from outside

- Currently have 10 RF nodes, full 48 RF needs by summer

VT-CORNET to be connected to NEW MOBILE TESTBED

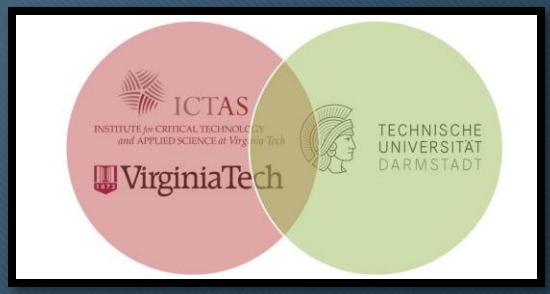
- Can study interoperability between mobile and fixed cognitive radio and to enhance the capability of VT-CORNET.

- A unique and premier infrastructure

Expansion to advanced security

- Potential collaboration with TUD
  - ➢ Security of data, services , imbedded systems

- Ted & Karyn Hume Center for National Security &Technology



Ted & Karyn Hume Center for ***National Security and Technology***

- **Mission:** To create a capability and framework that provides a sustainable pipeline of science and technology leaders for the Intelligence Community

- Key role and investment by ICTAS

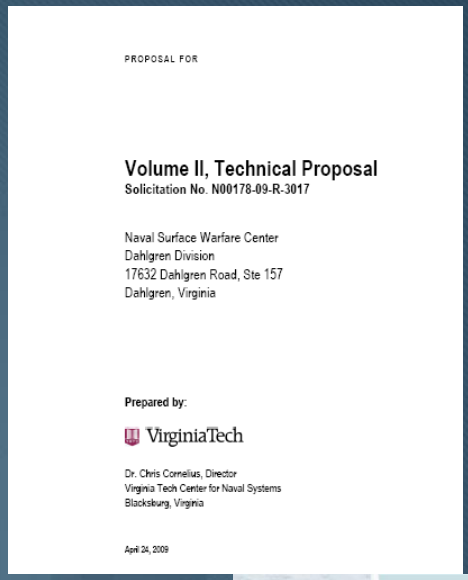
- Interim Director: Dr. Jeff Reed

- $5 million over 10 years, first installment of $2 million received

- Center announcement to the IDEA group in DC on April 8 by President Steger

Dahlgren Initiative

- Sole-Source IDIQ awarded, June 2009 (Indefinite Delivery Indefinite Quantity, 5yr, $7.5M)
- CRADA (Cooperative Research and Development Agreement) signed, August 2009
- **Tasks Awarded June through December 2009 ~ $4M**
- **Increase of IDIQ Ceiling to $11.25M**
- **Another IDIQ in progress with APL:**
  - **Expected contract : $1.5 m**


PROPOSAL FOR

Volume II, Technical Proposal
Solicitation No. N00178-09-R-3017

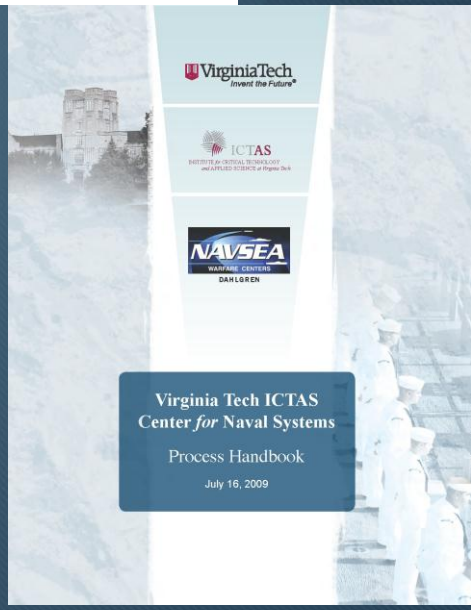
Naval Surface Warfare Center
Dahlgren Division
17632 Dahlgren Road, Ste 157
Dahlgren, Virginia

Prepared by:

VirginiaTech

Dr. Chris Cornelius, Director
Virginia Tech Center for Naval Systems
Blacksburg, Virginia

April 24, 2009



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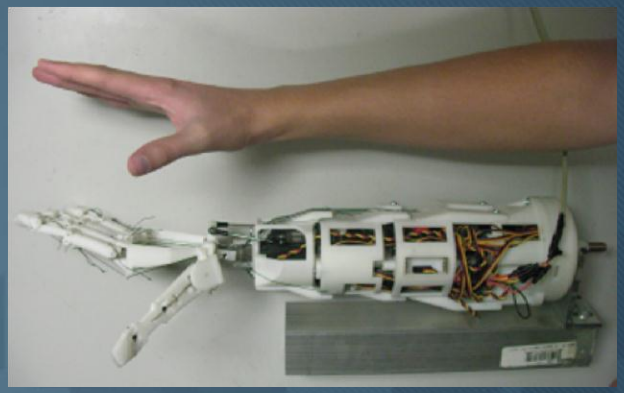
Incubator/ Emerging Technologies:

Humanoid Hospital

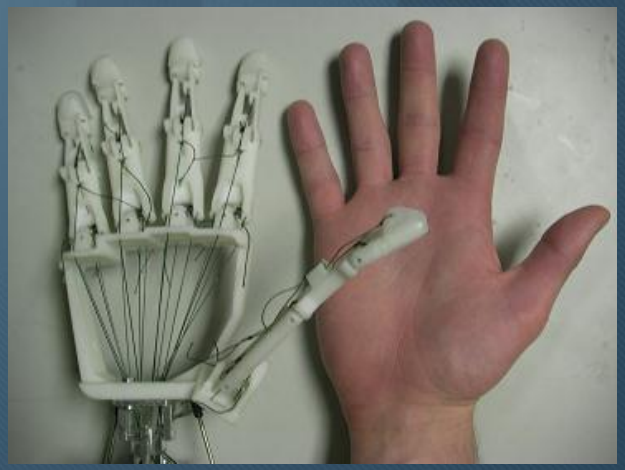
GOAL:

Develop fully functional human-like patients (robots) tailored to mimic any specific or combined state of the healthy/diseased body.



Example of research in progress: Dexterous Humanoid Hand

	Robot	Human (male)
Hand Size	180 x 90 x 50 (mm)	189 x 84 x 48 (mm)
Forearm Size	315 x 100 x 85 (mm)	275 x 88 x 75 (mm)
Hand Weight	0.09 kg	0.4 kg
Forearm Weight	0.96 kg	1.113 kg
Degrees of freedom	23	24
Joint ranges of motion	70, 90, 90 (degrees)	90, 100, 110 (degrees)
Grasp Speed	0.35 sec	0.15 sec
Typing Speed	20 words/minute	33 words/minute



Incubator/ Emerging Technologies:

Discovery Analytics

Mission: Extract interesting/actionable knowledge from exabyte-scale data

Current targeted activities with rich application contexts

- Mining data from massive sensor networks
  - Data centers, neuroscience
- "Storytelling" for unstructured data exploration
  - Cyber-intelligence
- Probabilistic graphical models
  - Protein design, electronic medical records

A highly successful research program

Ideal candidate for NCR

Incubator/ Emerging Technologies:

VT Center for Ethics and Scholarship Integrity

A campus-wide Collaborative Center

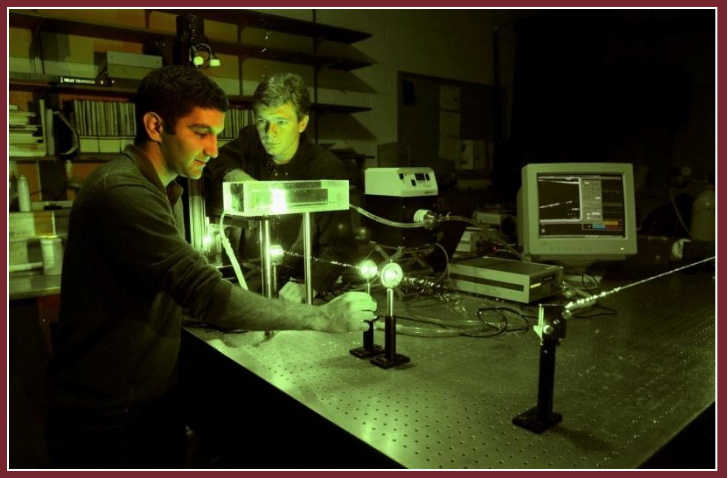
- ICTAS, ISCE, Graduate School, Fralin, Philosophy Dept, OVPR

- The Center will serve as a university-wide structure:
  - to coordinate efforts throughout the university to enhance our knowledge and understanding of ethics and scholarly integrity
  - to foster research identifying ethical issues and concerns throughout the discovery process and addressing ethical issues in the advancement of new knowledge and practices
  - to help educate faculty, staff and students about ethics and scholarly integrity

- Executive Committee in place; seed monies, charter under development

Students and Faculty

- **ICTAS Doctoral Scholars**
- **New Faculty Hires**
- **ICTAS Faculty Fellows**



Doctoral Scholars 2010-2014

COE (3)
1.School of Biomedical Engineering and Sciences (SBES), pending
2.Aeronautic and Ocean Engineering (AOE), pending
3.Civil and Environmental Engineering (CEE), pending

COS (3)
1.Mathematics, declined
2.GeoSciences, pending
3.Mathematics, pending
4.Biological Sciences, pending

CALS (2)
1.Plant Pathology and Weed Science, declined
2.Biological Systems Engineering, pending
3.Plant Pathology and Weed Science, pending

CNS (1)
1.Wood Science and Forest Products, ACCEPTED

CVM (1)
1. ACCEPTED

ICTAS Doctoral Scholar Program:

Four-year summary

	COE	COS	CNR	CALS	CVM	Total
Class of 2007	3	3	2	2	1	11
Class of 2008	3	2	1	2	1	9
Class of 2009	2	3	0	1	0	6
Class of 2010	3	3	1	2	1	10
Total	11	11	4	7	3	36

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Learning Domain: Other Graduate Student Initiatives

IGERT programs

PI: Gerardo W. Flintsch (CEE): Uncovering network Interdependencies and Synergies (UNIS)

P.I. Mark Stremler (ESM): Multi-STEPS

PI Tamal Bose (ECE), USDOE *proposal*, $30,000

PI Robert Moore (Chemistry), IGERT *award*, $30,000/yr. for 3 years

PI Jeff Kuhn (Biology), IGERT *proposal*, $30,000/yr. for 3 years, space in NCFL

PI Tamim Younos, NSF IGERT *proposal*, Roop will chair the internal advisory panel.

Learning Domain: Other Graduate Student Initiatives

26th Annual Graduate Student Assembly Research Symposium: $3500 in support

Participation in Graduate Student Appreciation Week

Undergraduate Student Initiatives

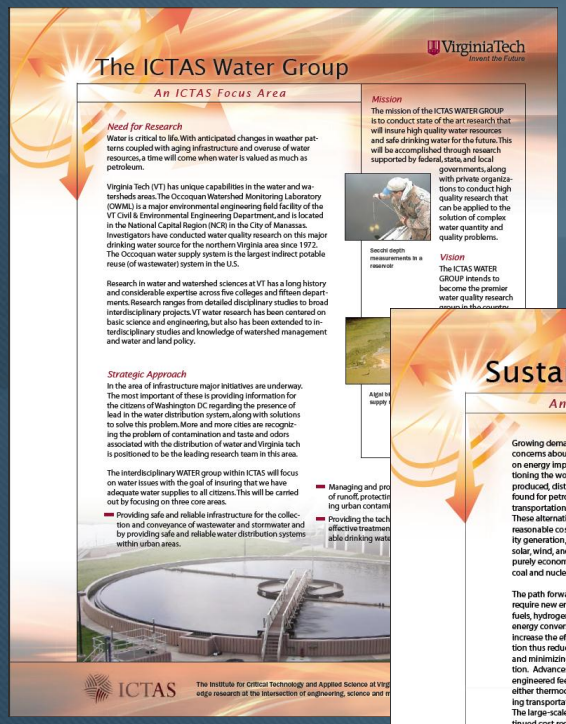
- Staff participation in the university search committee charged with selection of a *Director for Undergraduate Research*
- Research Experience for Undergraduates (REU), NSF Award, P.I.: I. Puri
- NCFL faculty plan to submit an NCFL-based REU
- Summer internships at NCFL; considering AY internships

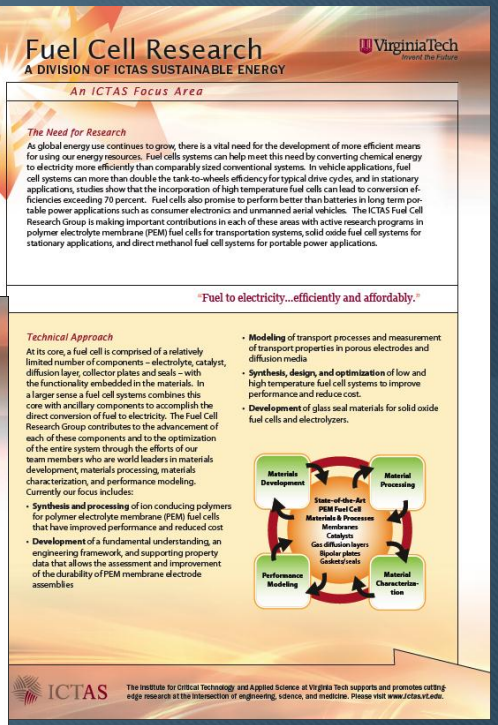
Outreach and engagement

ICTAS Newsletter twice annually, SBES newsletter once annually

Outreach and engagement

2-page flyers for initiatives underway at ICTAS, 22 in circulation





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Outreach and engagement

Seminar Series

Bill Reynolds
Virginia Tech

Roop Mahajan
Virginia Tech

Claudia Cardona
Luna Innovations

Masoud Agah
Virginia Tech

Carolyn Elfland
UNC Chapel Hill

Hrishikesh Panchawagh
Eastman Kodak

W.S. Sampath
Colorado State U.

Skip Garner
Virginia Tech

Jeffrey Nelson
Sandia National Labs

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Outreach and engagement

A New Seminar Series to start later this month

"The Black Swan and Disruptive Technology":

An informal discussion of the future

Where ? Café X located in the main ICTAS building.

Objectives

Create an environment for engineers, scientists, and humanists to come together to move *beyond the predictable and incremental advances* in the current technologies to the ***disruptive technologies*** of the future.

Features:

No tyranny of power point

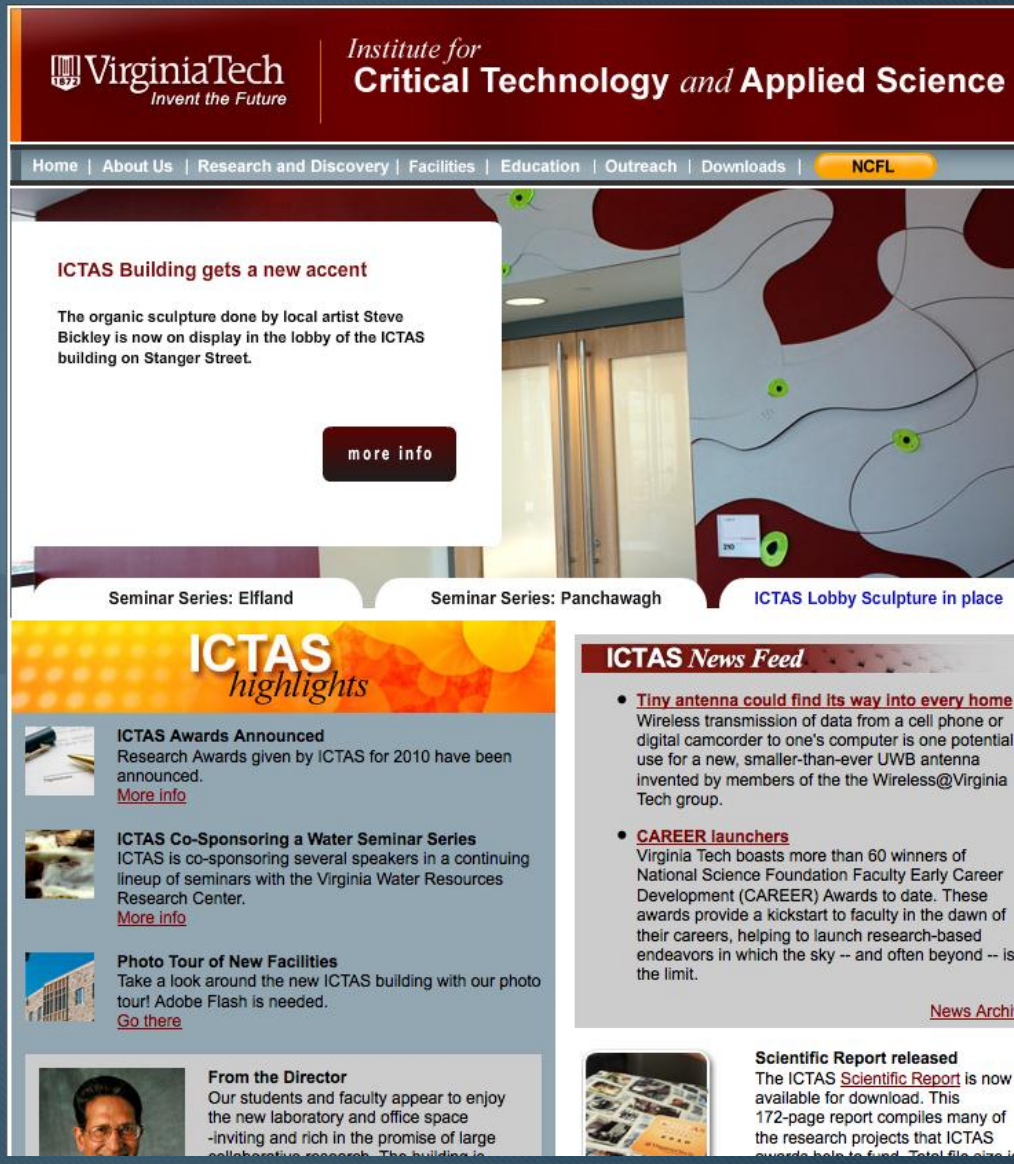
Focus on one general area with invitees from outside the field

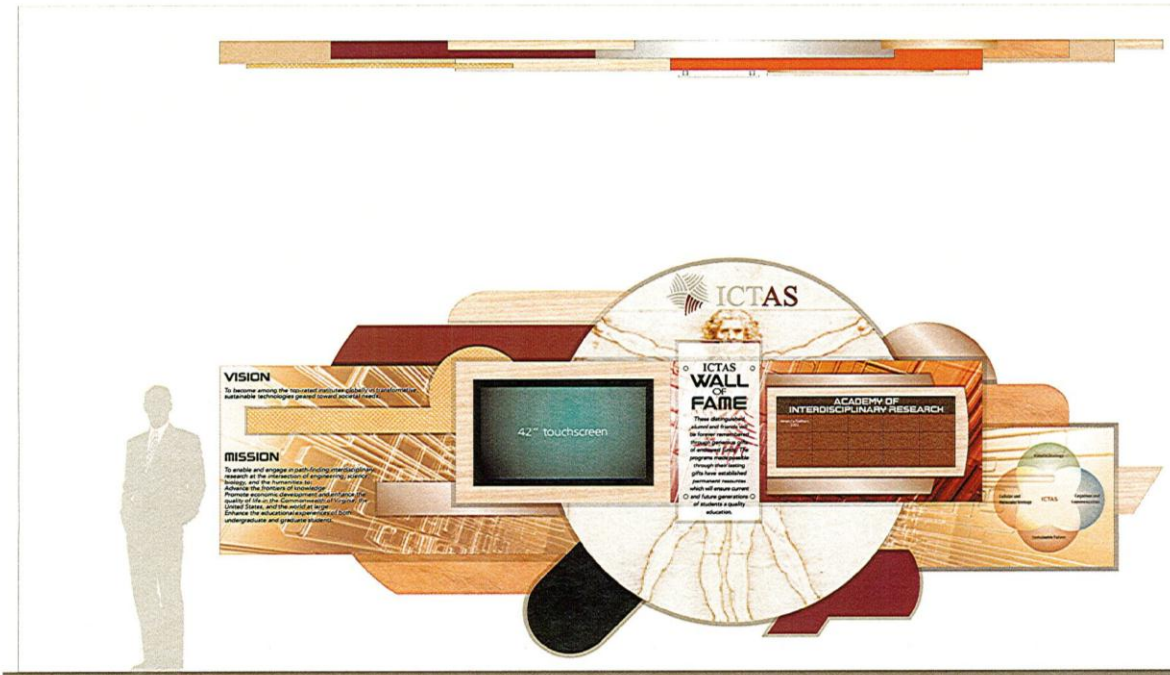
Outreach and engagement

Website

Between Feb. 23 and March 25, 2010, Google website analytics logged the following for ICTAS website:

- 6,188 page views
- Helps give a boost to other organizations affiliated with ICTAS
- Top page after homepage: **research**
- A user's average time on a page: 1:05





FOR CONCEPT ONLY

Virginia Tech / ICTAS

Date: 3.31.10 / all / #71890 / Overall Size: 211.125" x 88.5" x 6.75"

1157 designconcepts

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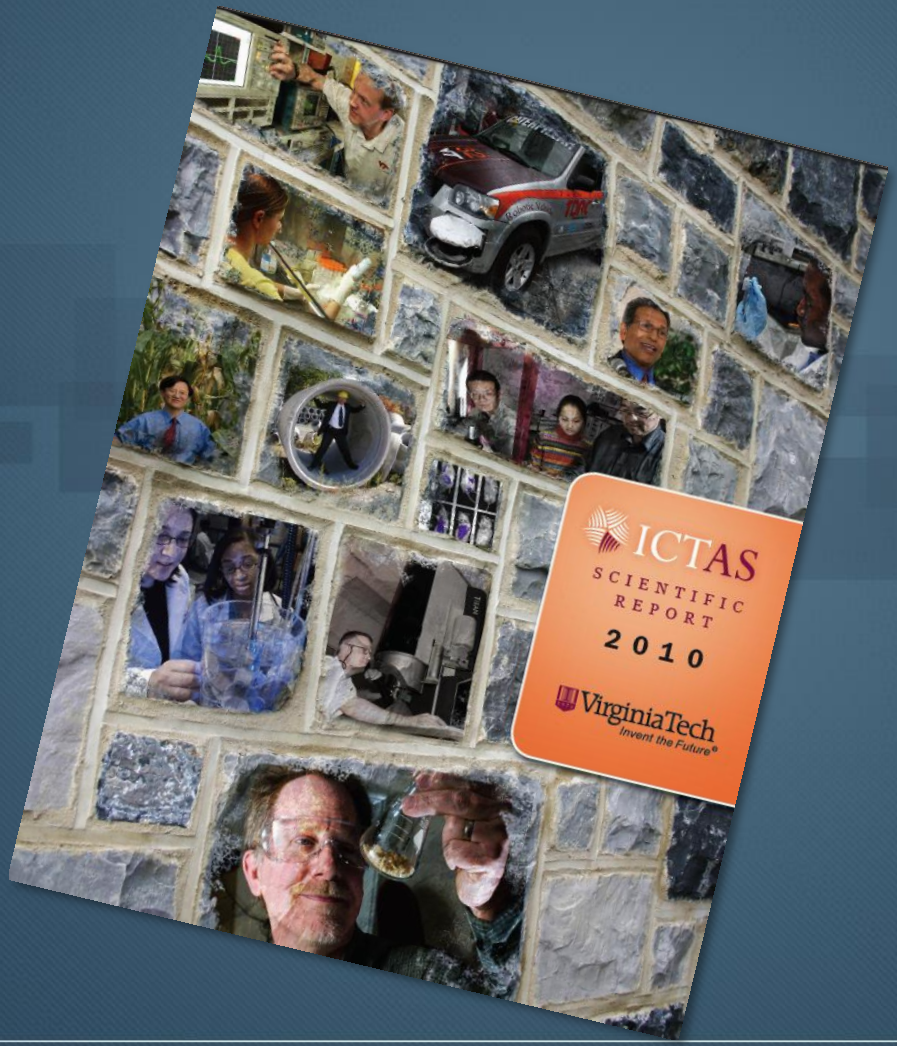
Outreach and engagement

Scientific Report



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Outreach & Engagement - *National Labs*

Oak Ridge National Laboratory (ORNL)

•Discussions underway to strengthen the relationship, as previously established in Oak Ridge Association of Universities (ORAU) agreement with Virginia Tech

•Two User Access projects active on nanobiotechnology

•Talks underway to embed a graduate student in Center for Nanoscale Materials Science (CNMS) labs

National Institute of Standards and Technology (NIST)

•Strengthening collaborative discussions in area of Sustainable Water research (*e.g.,* Smart Pipe Test-Bed Facility)

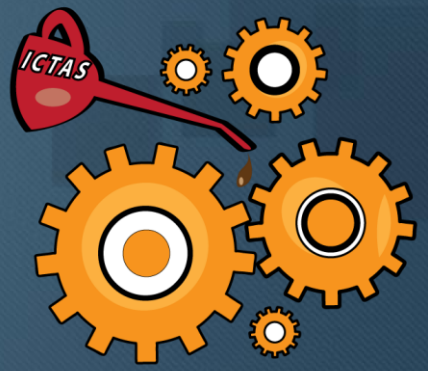
•Multiple visits to Gaithersburg and Boulder, NIST staffers visiting Blacksburg for conferences and further discussion

Outreach & Engagement- Research Day

- ICTAS Research Day scheduled for September 28, 2010
- Dr. Anthony Atala from Wake Forest University / SBES is a confirmed keynote speaker
- Aneesh Chopra (invited), Vinod Khosla (on list), Regina Dugan (on list)
- Tours, student poster session with competition, and other activities are being planned
- Participants will be invited from a large list of key players in the federal agencies (DOD, NIH, NSF, ARPA-E, DARPA, etc.), as well as VT faculty, students

ICTAS –An agent of Innovation

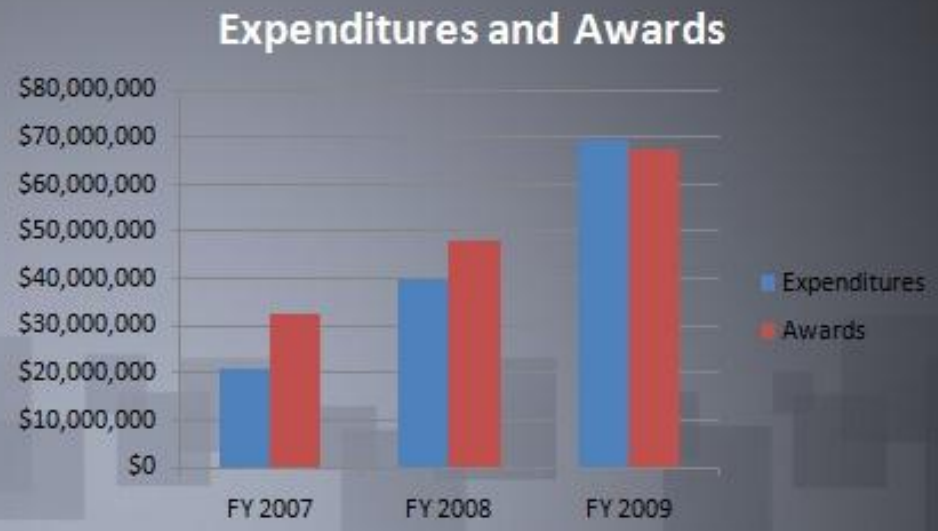
- **Interdisciplinary research**
  - Recall "Buds of creativity bloom at intersections"
- **Identify/ Recognize need**
  - NBIC for sustainable growth
  - Thrust areas
- **Match need with technical expertise**
  - Interdisciplinary teams; 227 faculty
- **Provide resources**
  - NCFL, Collaborative space, financial resources
- **Promote transformative thinking**
  - The Black Swan Seminar Series



- ***Results have far exceeded our expectations***

Proposals/awards/expenditures

- steady increase



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