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?
“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
Innovation Concepts

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
- is 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
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
Innovation Concepts

3. Linear vs. disruptive Innovation
3. Linear vs Disruptive Innovation

- Linear
  - Incremental
    - Ex: Cost reduction
  - Barrel reactor silicon epitaxy
CVD: Barrel Reactor

Diagram of a Barrel Reactor

- Adjustable Nozzle
- Gas Inlet
- Bell Jar
- Heated Rotating Susceptor
- IR Lamps
- Reflectors
- Cooling Air
- Wafers
- Gas Outlet
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?
Innovation Concepts

4. Promoting innovation
Promoting Innovation

- promoting interdisciplinary research
- 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
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
“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
ICTAS RFP

Competitive Reviews

ICTAS Targeted Investment

External funding

Seed monies

ICTAS Center
SUN2Fuels Hub
Laboratories and Collaborative Space

• [http://www.ictas.vt.edu/ncfl](http://www.ictas.vt.edu/ncfl)

NCFL Director Bill Reynolds
- Field-emission SEM: LEO (Zeiss) 1550
- Focused Ion Beam: FEI Helios 600 NanoLab
- Environmental SEM FEI: Quanta 600 FEG
- Transmission Electron Microscope: FEI 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
Nanoscale Fabrication: NT/Sphere Device
Mechanical Characterization

(B) Mechanical Testing

Direction of application of force
ICTAS Laboratories


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 ft² in the new facility near Washington.
### ICTAS Thrust Areas Populated

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<thead>
<tr>
<th>Thrust Area</th>
<th>Activities</th>
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<tbody>
<tr>
<td><strong>Nanoscale Science and Engineering</strong></td>
<td>Environmental Nanoscience and Technology</td>
</tr>
<tr>
<td><strong>Nano-Bio Interface</strong></td>
<td>Targeted Delivery of Nano-medicine</td>
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<tr>
<td><strong>Sustainable Energy</strong></td>
<td>Fuel Cells</td>
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<tr>
<td><strong>Renewable Materials</strong></td>
<td>Bio-based Materials: Design and Processing</td>
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<tr>
<td><strong>Sustainable Water</strong></td>
<td>Water Infrastructure Management</td>
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<tr>
<td><strong>Cognition and Communication</strong></td>
<td>Cognitive Radio Networks</td>
</tr>
<tr>
<td><strong>Homeland Security</strong></td>
<td>Naval Surface Warfare Center Dahlgren Division (NSWCDD)</td>
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<tr>
<td><strong>Emerging Research</strong></td>
<td>Complex Network Systems</td>
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</table>
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)
• **One of the eight thrust areas, with three sub-areas**
  - **Sustainable 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.
New Energy Sources for a Sustainable Future

Research in energy cells, photovoltaics, and other technology areas lead the way to sustainability for future generations.
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
CO₂ + H₂O → Synthesis → Solar cells → Electrolytic H₂ → Sugars, carbohydrate → Integrated processing → Transportation fuels

- Sunlight
- Genetic transformation
- Breeding
- Superbiomass
- Greenhouse
- Integrated processing
- Transportation fuels

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.

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
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.
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.
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)
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
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
**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**

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

<table>
<thead>
<tr>
<th>Class</th>
<th>COE</th>
<th>COS</th>
<th>CNR</th>
<th>CALS</th>
<th>CVM</th>
<th>Total</th>
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<tbody>
<tr>
<td>Class of 2007</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>11</td>
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<tr>
<td>Class of 2008</td>
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<td>2</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>9</td>
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<tr>
<td>Class of 2009</td>
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<td>3</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>6</td>
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<td>Class of 2010</td>
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<td>3</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>10</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>11</td>
<td>11</td>
<td>4</td>
<td>7</td>
<td>3</td>
<td>36</td>
</tr>
</tbody>
</table>
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
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
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
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


- Proposals: A steady increase from $200,000,000 in FY 2007 to $450,000,000 in FY 2009.
- Expenditures and Awards: A steady increase from $10,000,000 in FY 2007 to $70,000,000 in FY 2009.