Overview
Michael B. Silevitch
Director

NSF
Year Two Site Visit
May 21, 2002
Outline of the CenSSIS Overview

- Vision and mission
- The CenSSIS team
- Research strategy and program
- Organization and management
- Education program
- Industrial collaboration
- Summary
The CenSSIS Vision and 10 Year Mission Will Impact Research, Education and Industry

Top Level Goals

- Attack important Real World Problems
- Create a Systemic Approach Using the Engineered Process I-PLUS
  - Incorporate a unifying framework
    - *Diverse Problems - Similar Solutions*
      - Incorporate General Purpose Simulation and Validation Tools for Rapidly Assessing New Ideas
- Tech Transfer Proof of Concept Designs of new multi-sensor instruments
- *Educate Students to Address Multi-disciplinary Challenges*
Why Are There Similar Solutions?

- Physics Based Signal Processing
- Reusable Hardware & Software Tools
- Parallel Computation Resources

Complex Subsurface Medium

Surfaces

Probes

Detectors

Target
Wave Probes of Subsurface Media Unifies the CenSSIS Approach to a Wide Range of Problems

**Subcellular Biology**

- 100nm - 100 μm

**Tissues & Organs**

- 10 μm - 10 cm

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**Underground Diagnosis**

- 1 cm - 100 m

**Underwater Exploration**

- 10 cm - 1 km

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**Optics**

**Ultrasound**

**Radar**

**Sonar**

Wave Probes of Subsurface Media Unifies the CenSSIS Approach to a Wide Range of Problems

- 100nm - 100 μm

- 1 cm - 100 m

- 10 μm - 10 cm

- 10 cm - 1 km
There is a Broad Taxonomy of Subsurface Sensing Characteristics and Phenomena

Probe(s) → Detectors

Medium

Target

Probe:
- Electro-magnetic
- Acoustic
- Optical/IR
- X-Ray
- CW
- Pulsed
- Modulated
- Coherent
- Partially Coherent
- Multi-spectral
- Classical
- Quantum
- Outside
- Inside
- Auxiliary

Medium:
- Absorption
- Dispersion
- Scattering
- Diffusion
- Clutter
- Inhomogeneous/Layered
- Rough Surface

Target:
- Absorption
- Fluorescence
- Nonlinear Absorption
- Scattering
- Nonlinear Scattering
- Diffusive
- Phase Object
- Depolarizing
- Stationary
- Moving
How can we Organize the Many Existing Subsurface Information Extraction Methods?

Localized Probing & Mosaicing (LPM)

Focused or Pulsed Probe
Focused or Gated Detector

Multi-Spectral Discrimination (MSD)
Wide Band Probe
Narrow Band Detectors

Multi-View Tomography (MVT)
Sources
Object
Detectors
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What is the CenSSIS Team?
What is the Role of the CenSSIS Strategic Affiliates?

- Massachusetts General Hospital
- Brigham and Women's Hospital
- Lawrence Livermore National Laboratory
- Woods Hole Oceanographic Institution

Important Biomedical Problems

Important Environmental & Civil Problems
Outline of the CenSSIS Overview

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A Top Down Approach Motivates Our Strategic Plan

System Goal: Solve Real World Subsurface Problems

Use a Validated Physics-Based Approach

Identify Barriers & Research Thrusts

New Methods for Subsurface Problems

Testbeds to Validate Framework

Develop Physical/Math Framework

Level 3 Engineered System

Level 2 Enabling Technology

Level 1 Fundamental Science

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Use a Validated Physics-Based Approach
The Barriers Stem from the CenSSIS Top Level Goals

Level 3 (L3) Engineered System

Level 2 (L2) Enabling Technology

Level 1 (L1) Fundamental Science
What Fundamental Science Barriers Crosscut Application Areas?

**Barrier 1**
Inadequate understanding of the physics of subsurface sensing and imaging

**Barrier 2**
Unreliable inversion methods for inhomogeneous and cluttered subsurface media

**Barrier 3**
Lack of robust, physics-based recognition and sensor fusion techniques
What Barriers Prevent the Development of an Integrated Engineered System?

**Barrier 4**  
Lack of computationally efficient, realistic physical models

**Barrier 5**  
Lack of optimal end to end sensor design methods

**Barrier 6**  
Lack of rapid processing and management of large image databases

**Barrier 7**  
Lack of validated, integrated processing and computation tools

**Barrier 8**  
Lack of a unified framework for diverse sensing and imaging modalities
Overview of the Research Program

- **Fundamental Science**
  - Subsurface Sensing and Modeling
  - Physics-Based Signal Processing and Image Understanding
  - Image and Data Information Management

- **Enabling Technologies**
  - Validation Testbeds

- **Engineered System**
  - Bio-Medical Applications
  - Environmental-Civil Applications

I-PLUS
A Long Range Goal: An Engineered System

Integrated Process for Looking Under Surfaces

“I-PLUS”

Enables Rapid and Efficient Development of New Subsurface Technologies and Solutions

- Leverages Lessons Learned - Similar Solutions
- Solutionware for effective modeling & processing
- TestBEDs for validation with measured data
- Demonstrated on Important Societal Problems
The I-PLUS Process Incorporates Our Unifying Framework

Information Extraction Strategies

- LPM
- MVT
- MSD

Subsurface Sensors
Physical Models

Reconfigure for Optimal Performance

R1: Subsurface Sensing & Modeling
R2: PBSP & Image Understanding
R3: Image & Data Info. Management
Four Validating TestBEDs Help Enable the Evolution of the Engineered Process I-PLUS

- **BioBED**: 100nm - 100 µm
- **MedBED**: 10 µm - 10 cm
- **SoilBED**: 1 cm - 100 m
- **SeaBED**: 10 cm - 1 km
The Fundamental Science Project Areas Stem from Our Strategic Barriers

- **Thrust R1: Subsurface Sensing & Modeling**
  - R1A - Nonlinear and Dual Wave Probes
  - R1B - Effective Forward Models

- **Thrust R2: Physics Based Signal Processing & Image Understanding**
  - R2A - Multi-View Tomography (MVT)
  - R2B - Localized Probing and Mosaicing (LPM)
  - R2C - Multi-Spectral Discrimination (MSD)
  - R2D - Image Understanding & Sensor Fusion

- **Thrust R3: Image & Data Info Management**
  - R3A - Parallel Hardware Implementation
  - R3B - Solutionware Tools
How Can CenSSIS Achieve Integration of Research Effort?

Important Outcomes - Center Deliverables at All Three Strategic Levels

- **Fundamental Science Level**
  - Thrust R1, R2, R3 State of the Art Advances

- **Enabling Technology Level**
  - Re-Usable Validating BEDs
  - Re-Usable Solutionware Products

- **Engineered System Level**
  - Unifying Framework Demos
  - 1st Generation I-PLUS Engineered Process
  - Multi-Sensor Instrument Demos
  - Advances in Solving Real World Problems

- **Multi-Institutional Collaboration**
### "Quilt Chart" Organization & Integration of Year Two CenSSIS Research Program

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### Relative Contribution to Outcomes

- **Fundamental Science Level**
- **Enabling Technology Level**
- **Engineered System Level**

![Image of Quilt Chart with colors indicating contribution levels]
“Quilt Chart” Organization & Integration of Year Two CenSSIS Research Program

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Relative Contribution to Outcomes

Important Outcomes

CenSSIS Research Areas

Multi-Institution Collaboration

Multi-Sensor Instrument Demos

1st Generation I-PLUS Process Advances in Solving Real World Problems

Unifying Framework Demos

Solutionware Products

Usable Validating “BEDs” Thrus R3 SOA Advances

Thrus R2 SOA Advances

Thrus R1 SOA Advances
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### Important Outcomes

- **CenSSIS Research Areas**
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### Notes

- **Important Outcomes**
  - **CenSSIS Research Areas**
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**“Quilt Chart” Organization & Integration of Year Two CenSSIS Research Program**

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**CenSSIS Research Areas**

**Relative Contribution to Outcomes**

- **Fundamental Science Level**
- **Enabling Technology Level**
- **Engineered System Level**

**Important Outcomes**

- **R1A Nonlinear and Dual Wave Probes**
- **R1B Effective Forward Models**
- **R2A MVT Methods**
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- **Fast pre-conditioners for conjugate gradient Helmholtz solvers**
- **Gaussian beam models for GPR scattering**
- **Modeling Underground Strata for use with EIT Algorithm**
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### Relative Contribution to Outcomes

- **Fundamental Science Level**
- **Enabling Technology Level**
- **Engineered System Level**

**Important Outcomes**

- Implement Born Approximation processing on MedBED data.
- BU-NU team works to ensure MedBED usage for MVT applications
- MVT Toolbox Development
### “Quilt Chart” Organization & Integration of Year Two CenSSIS Research Program

#### Important Outcomes

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#### Initial TestBED Facilities
- Bio, Med, Soil, SeaBEDs

#### I-PLUS Development
- Bio, Med, Soil, Sea (Real Problems)

#### Relative Contribution to Outcomes
- Fundamental Science Level
- Enabling Technology Level
- Engineered System Level

- **EIT Near Field Algorithms Adapted to Underground Assessment**
- **Pseudo-Inverse Methods applied to Underground and Undersea Detection**
- **Radial Diffraction Tomography applied to Underground and Medical Domains**
## "Quilt Chart" Organization & Integration of Year Two CenSSIS Research Program

### Important Outcomes

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**Relative Contribution to Outcomes**

- **Fundamental Science Level**
- **Enabling Technology Level**
- **Engineered System Level**
# Proposed Changes in Emphasis for Year Three Research Program

## CenSSIS Research Areas

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## Relative Contribution to Outcomes

- **Fundamental Science Level**
- **Enabling Technology Level**
- **Engineered System Level**

Delta values indicate changes in emphasis for each area.
## Proposed Changes in Emphasis for Year Three Research Program

### CenSSIS Research Areas

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### Relative Contribution to Outcomes

- **Fundamental Science Level**
- **Enabling Technology Level**
- **Engineered System Level**

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**Important Outcomes**

- Multi-Institution Collaboration
- Multi-Sensor Instrumentation Demos
- 1st Generation I-PLUS Process
- Advances in Solving Real World Problems
- Unifying Framework Demos
- Solutionware Products
- Usable, Validating “BEDs”
- Initial TestBED Facilities Bio, Med, Soil, SeaBEDs
- I-PLUS Development Bio, Med, Soil, Sea (Real Problems)

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**CenSSIS Research Areas**

- R1A Nonlinear and Dual Wave Probes
- R1B Effective Forward Models
- R2A MVT Methods
- R2B LPM Methods
- R2C MSD Methods
- R2D Image Understanding & Sensor Fusion Methods
- R3A Parallel Hardware Implementation for Fast Subsurface Detection
- R3B Solutionware Tools
- Initial TestBED Facilities Bio, Med, Soil, SeaBEDs
- I-PLUS Development Bio, Med, Soil, Sea (Real Problems)
A Research & Technology Roadmap Leads to Our Engineered System — The Process (I-PLUS)

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- **Quantitative Underground Multisensor Diagnosis Testbed (Radar, Acoustic, Induction Arrays)**
  - LLNL
  - RPI
  - NU
  - MGH

- **SoilBED**
  - LLNL
  - NU
  - BU

- **MedBED**
  - RPI
  - NU
  - NU

- **BioBED**
  - BioBED
  - Entangled 2 Photon Microscopy
  - Quadrature Phase Retrieval Microscopy
  - High Resolution Confocal Microscopy
  - Ophthalmic Subretinal 3D Visualization and Navigation
  - Dual Wave Ultrasound/Optical Soft Tissue Imaging
  - Combined Impedance & Passive Source Tomography
  - Nonlinear Ultrasound Mechanisms
  - Phase Conjugation Time Reversal Beam Forming

- **Quadrature Phase Retrieval Microscopy**
  - BU

- **High Resolution Confocal Microscopy**
  - RPI

- **Ophthalmic Subretinal 3D Visualization and Navigation**
  - BU

- **Coherent X-Ray Protein Molecular 3D Imager**
  - LLNL

- **Civil Infrastructure and Buried Waste Characterization**
  - RPI
  - NU
  - LLNL

- **Laser-Acoustic Dual Wave Probe**
  - NU/BU

- **Cluttered Environment Modeling**
  - NU/BU

- **Indoor Hyperspectral Measurements**
  - NU
  - UPRM

- **Acoustic Camera Array**
  - WHOI

- **SeaBED**
  - WHOI
  - UPRM

- **Multisensor Medical Imaging Testbed**
  - LLNL

- **Multisensor Medical Imaging Testbed**
  - RPI

- **Hi-Contrast Tomographic Ultrasound Testbed**
  - BU

- **Hi-Res Environmental Hyperspectral Imaging/ Detection**
  - UPRM

- **Hi-Res Environmental Hyperspectral Imaging/ Detection**
  - NU

- **Shallow Ocean Distributed Sensing Imaging/Monitoring Testbed**
  - UPRM

- **Deep Sea Observatory**
  - WHOI

- **Multisensor Imager for Groundwater Contamination & Buried Waste**

- **Distributed Multi-Sensor Mariculture Monitoring System**

- **Solutionware**
  - Efficient Scalable Computation Methods
  - Image Database
  - Integrated Tomographic Feature Visualization and Sensor Fusion Tools

- **DNA Structure EUV/X-Ray Imager**

- **Multisensor 3D Medical Scanner**

- **Important Real-World Problems (System Testbeds)**

- **Primarily ERC Supported Effort**

- **Collaboration with non-ERC Effort**

- **Location of Experiments**
Key Milestones for the Research Program Over the First 5 Years of Operation
Examples of Year 2 Research “Nuggets”

- BU CenSSIS team Developed concept of “Quantum Holography”—Designated by American Institute of Physics as one of the top stories of 2001
- Dept. of Energy funds an RPI--LLNL demonstration that Near Field EIT medical imaging algorithms can be used for underground assessment
- LPM algorithms developed at RPI (retinal) & WHO (undersea) applied to improve proton beam therapy at MGH
- NU—WHOI—UPRM CenSSIS Team Implemented first generation feature searchable database of images and testBED data
These Examples Further Illustrate the CenSSIS Approach & Some Accomplishments During Year 2.

- **3D Fusion Microscope Under Construction**: This Instrument will Enable New Biological Discoveries—2004 Completion Antic.
  - Keck Foundation $750K Award to ERC (Jan. 2002)
  - Key Concept Stems from Laser- Radar Environmental Use
  - Initial Applications to Mouse Embryo Viability and to Zebra-fish Stem Cell Development

- **First Use of Diffraction Tomography to Create 3D Images of the Pit 9 Buried Waste Site**: DOE Nat’l Lab Collab.-- INEEL & LLNL
  - Assess Contaminants and Prevent Pollution to the Water Table!

- **Better Ultrasound Diagnostics Conceived to Prevent Sudden Heart Attacks**: Extension of Pit 9 Buried Waste Imaging Method
  - Detection of Vulnerable Plaque Deposits Inside Arteries
  - Simulations and Experiments Ongoing
  - $5 Million NIH Proposal to Create Clinical Demonstration

- **March 2002: Validating Testbed Data Collection Campaign Aims to Demonstrate Ability to Remotely Monitor Coral Reef Health**
  - A Major Marine Science-Ecological Concern
  - 3D Biomedical Tools Will be Used in Data Analysis
First Results From UOK-NU-INEEL-LLNL Teamwork to Assess Buried Waste in Pit 9
Students Building the AUV SeaBED at WHOI
BU-WHOI Team Explores Another Dimension of Coral Reef Assessment
Outline of the CenSSIS Overview

- Vision and mission
- The CenSSIS team
- Research strategy and program
- Organization and management
- Education program
- Industrial collaboration
- Summary
The Board of Directors Helps Bind Together Our Distributed Center

Chairman: Allen Soyster
NU Dean of Engineering

- 8 senior university administrators
  - Dean level or higher
- Highly committed industrial partners
- Board defines partnership policies
  - Academic & industrial agreements (IP, internal match, etc)
- Board provides strategic oversight
  - Bi-monthly meetings
- Yearly evaluation of the center
CenSSIS Retreat at Mayaguez Puerto Rico—March 3-5, 2002

- **22 Attendees**
  - Board of Directors (Including Industry Reps)
  - CenSSIS Executive Committee
  - Other senior research and education leaders
  - Admin and Industrial Liaison Directors

- **Impact**
  - Refined the Elements of I-PLUS
  - Addressed Board, NSF, and Industry SWOTs
  - Defined Year 3 Research & Education Priorities
  - Launched UPRM—WHOI Coral Reef Project
  - More Emphasis on Pipeline & Diversity Issues
    - CenSSIS Scholars
    - UPRM PhD Bridge Program
Board of Directors, Executive Committee
2002 Retreat in Mayaguez, Puerto Rico
Our Project Evaluation Process is Aligned With CenSSIS Goals and Mission.

- Annual RFP Process
- Progress Reports
- Proposals Submitted
- Panel Review
- Assess Alignment
- Proposed Funding Plan
- NSF Site Visit
- Feedback: Incorporated?

- Strategic Planning Consultation
- CenSSIS Research & Education Leaders
- Director & Exec. Comm.
- Final Funding Plan

UPRM Retreat
What is the Impact of this Year 2 Process?

- Thrust Area R3 Significantly Modified
  - Research on Massive Data Compression and Transmission Eliminated
  - Collaborative Work Environment Will Make Use of Available Technology
  - Reallocation of $500K in Year 2

- A New RPI Associate Director and Co-PI Appointed

- Additional $150K Reallocated for Year 3

- Clearer Alignment of Project Areas with Center Level Important Outcomes
  - Gaps In Year 2 Effort Addressed for Year 3
### Year 2 vs. Year 3 Core Program Allocations Reflect Strategic Priorities

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Year 2 Accomplishments: Management and Infrastructure

- Moved into New Headquarters - Suite 302 Stearns Center
  - 3rd Floor Stearns Building
  - Part of University Strategy to Link With industry
- Created Project Management Tools
  - “Quilt” Project integration Chart
  - Project Spending Report
- Dr. Phil Cheney Joins Team
  - Recently Retired Senior Raytheon Executive
- Cemented Shadow Accounting and IT Support Systems
  - Full time people in place
- Maintained Weekly Management Meetings
  - All Partners Attend
  - 20 People Average Attendance
  - Maintains Communications and Shared Vision
The New CenSSIS Headquarters Will Poise CenSSIS For Future Growth
Outline of the CenSSIS Overview

- Vision and mission
- The CenSSIS team
- Research strategy and program
- Organization and management
- Education program
- Industrial collaboration
- Summary
The CenSSIS Education Program Works at all Levels

- Engineering Profession
- Continuing Ed.
- Grad. (Interdisc. Learning, SSI Topics)
- I/UROP (Jr./Sr. 3-Course SSI Conc., Undergrad. Modules)
- I/UROP (Fresh./Soph. Hi-Tech Tools&Toys)
- K-12 Outreach
- K-12
There is Active Student Involvement

- Motivated by ERC’s Vision and Mission
- Local Chapters and center-wide Council
- Services Provided by CenSSIS Staff Member
- Monthly Meetings and Field Trips
Student Poster Presentations at the January 2002 Research and Industrial Collaboration Conference
High Tech Tools and Toys Lab: A common theme for all CenSSIS partners
CenSSIS Course Developments

- **NU Undergraduate SSI Course:** Jan. 2002
  - Junior/Senior technical elective
  - Instructors: D. Brooks, C. DiMarzio
  - Overview of SSI
  - Work with real data
  - Pilot SolutionWare modules
  - Extend to Other Partners - Fall 2002

- **2 Distance Learning Graduate Courses**
  - **NU:** Tony Devaney ECE3300:
    - Special Topics—Inverse Problems (Videotapes to 4 sites + Boston)
  - **RPI:** Badri Roysam ECSE-6963:
    - Bio-medical Image Analysis (WEB)
How Does Diversity and Gender Equity Become Embedded Within CenSSIS?

- **Involve More PhD Level Women**
  - Mischa Kilmer (R1 - Tufts)
  - Sara Wadia-Fascetti (R1 - NU)
  - Anne Morgenthaler (R1 - Cons.)
  - Margaret Cheney (R1 - RPI)
  - Miriam Lesser (R3 - NU)
  - Sandra Pol (Educ - UPRM)
  - Carol Warner (Bio - NU)
  - Betty Salzberg (R3 - NU)
  - Karen Tompko (R3 - UCin)
  - Magda El-Shenawee (R1 - UAK)

  *Anticipated involvement in Yr 3*
  - Anne Cohen (Ocean - WHOI)
  - Jennifer Dy (R3 - NU)
  - Ingrid Padilla (Envir - UPRM)

- **Outreach to Under-Represented Groups**
  - Research Experiences for Undergraduates (REU)—8 Students
    - Morehouse College (2), Simmons College (1), Smith College (1), UPRM (3), Other (1)
  - CenSSIS Scholars
    - Year 3 Target 50 Freshman for Pipeline
    - Board of Directors “Buy-In”
  - UPRM PhD Bridge Program
  - K-12 Urban Programs

- **Overall Diversity Co-ordination**
  - Dr. Paula Leventman (NU) Chair
  - Prof. Lueny Morell (UPRM) Co-Chair
K-12 Outreach

CenSSIS Challenge

- 300+ Urban Students participated in their schools
- Second challenge was held May 2002
- Funded by Massachusetts Department of Education
- $50K/Year
Research Experiences for Teachers -- RET
Outline of the CenSSIS Overview

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Year 2 Industry Support is $1.97 Million

- In-Kind: 35%
- Cash: 28%
- I-UROP: 8%
- Sponsored Research: 29%
The 5 Year CenSSIS Financial Plan Will Lead Towards Sustainability

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Outline of the CenSSIS Overview

- Vision and mission
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Our Long Range Mission - A Systemic Means to Attack Important Subsurface Problems

- Functional Deep Brain Imaging
- Early Tumor Diagnosis
- Real-Time Vascular Imaging
- 3D Subretinal Diagnosis
- Heart Attack Prevention
- Humanitarian Demining
- Underground Bunker Discovery
- 3D Pollution Assessment
- Real-time Roadbed Assessment

Our Long Range Mission - A Systemic Means to Attack Important Subsurface Problems
CenSSIS Has Addressed the NSF, IAB, & BOD SWOT Concerns To Date

- **Resources Spread Too Thinly**
  - Pruned the R3a and b areas--$500K per year

- **I-PLUS is not Clearly Defined**
  - A Shared Vision Has Been Achieved

- **Leaders don’t have Meaningful Authority**
  - Budgetary Authority Linked to Important Outcomes

- **Need more Rigor in parts of the Research Program**
  - 80+ peer-reviewed publications in journals over past two years
  - Sharpened focus on important strategic outcomes

- **Enhance the Distributed Education Program**
  - Graduate and Undergraduate Pilots Completed

- **Only NU has Initiated Industrial Partnerships**
  - Engineering Dean’s Challenge Established
Some Key Year 3 Research Plans

- **Unifying Framework Demonstrations**
  - EIT Medical Tools applied to Soil
  - Undersea Mosaicing Tools applied to Medical
  - Soil Modeling Tools applied to Tissue

- **ReUsable Solutionware Toolboxes**

- **Working testBEDs**

- **Multi-Sensor Solutions & Instruments to Help Refine the Developing I-PLUS Process**
  - 3D Fusion Microscope—Multi-cell Structure
  - Ultrasound + Optical Tomography—Coronary Artery Assessment
  - Acoustics + Induction--Buried Waste Assessment
CenSSIS is on Track in Year 2!

Our Shared Vision Ties The ERC Together