Virtual Testbed Framework for Civil Infrastructure & Geotechnical (CI&G) Applications

Research and Industrial Collaboration Conference
– 18 November 2003 –

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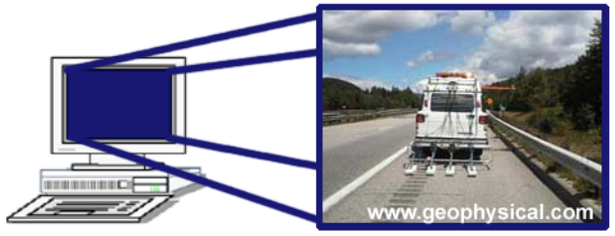
The Virtual Testbed

A set of software tools that model a physical structure and simulate a subsurface investigation.



Comparative Benefits

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How does the structure perform if perturbed?	time consuming	done with minimal effort

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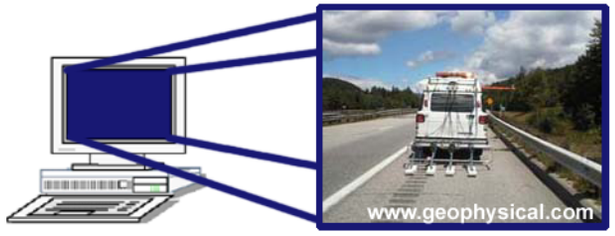

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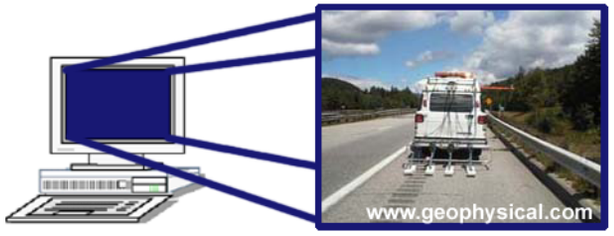

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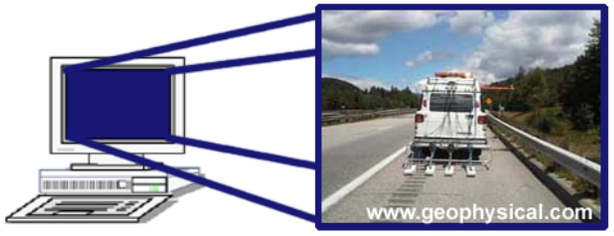

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How does structure test using different modalities?	requires time and equipment availability	requires simulation module for given modality
How do results compare to what is expected in field?	'real world' data	simulated data

Virtual Testbed Uses

- Increase the knowledge base for CI&G Applications of SSI
- Explore sensor fusion & the development of new sensors
- Improved signal processing for CI&G applications

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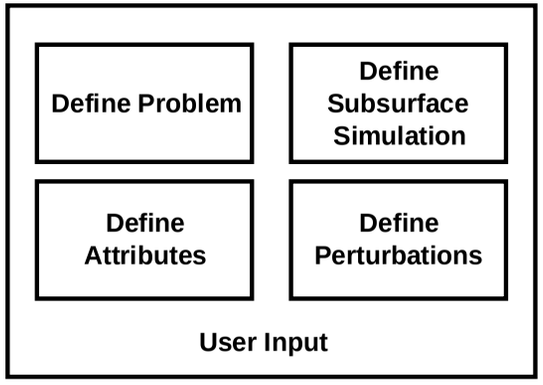
- Improved signal processing for CI&G applications
  - Better define 'rules' for data processing
  - Test new processing algorithms
  - Test inversion techniques (ground truth is inherent in model)

Virtual Testbed Framework Overview

- Virtual Testbed has 3 major components:
  1. Modeling tools for the physical structure (construction materials & defects)
  2. Simulation tools of subsurface investigation
  3. Simulation Control Program
- Components can function independently & are coded in MATLAB
- VTB will be open source



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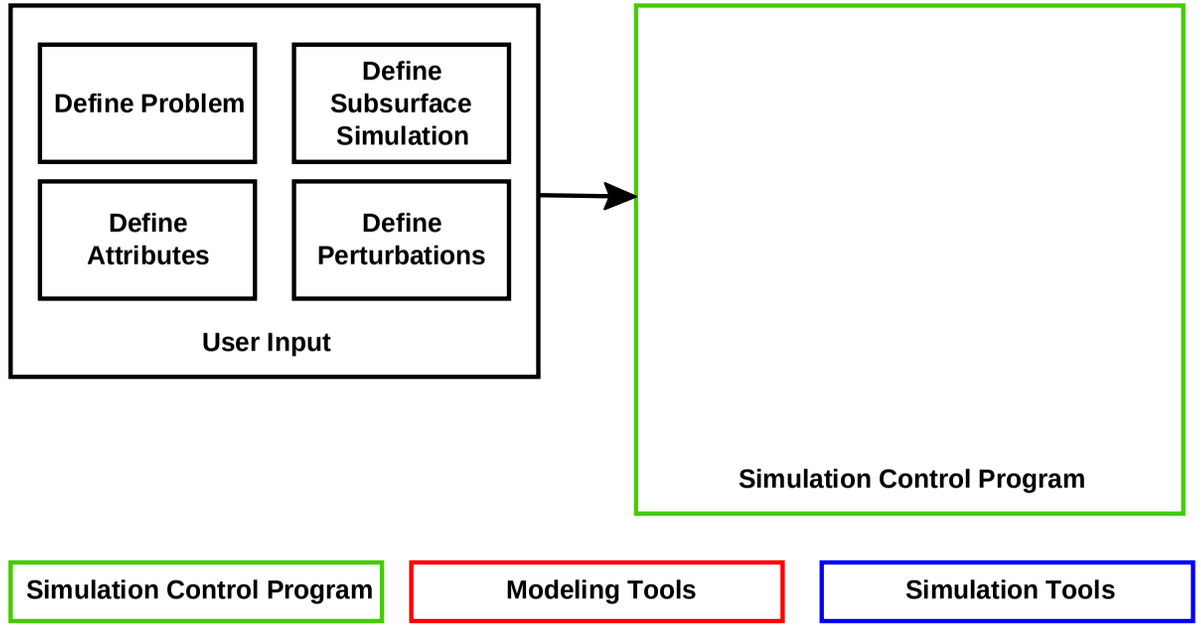

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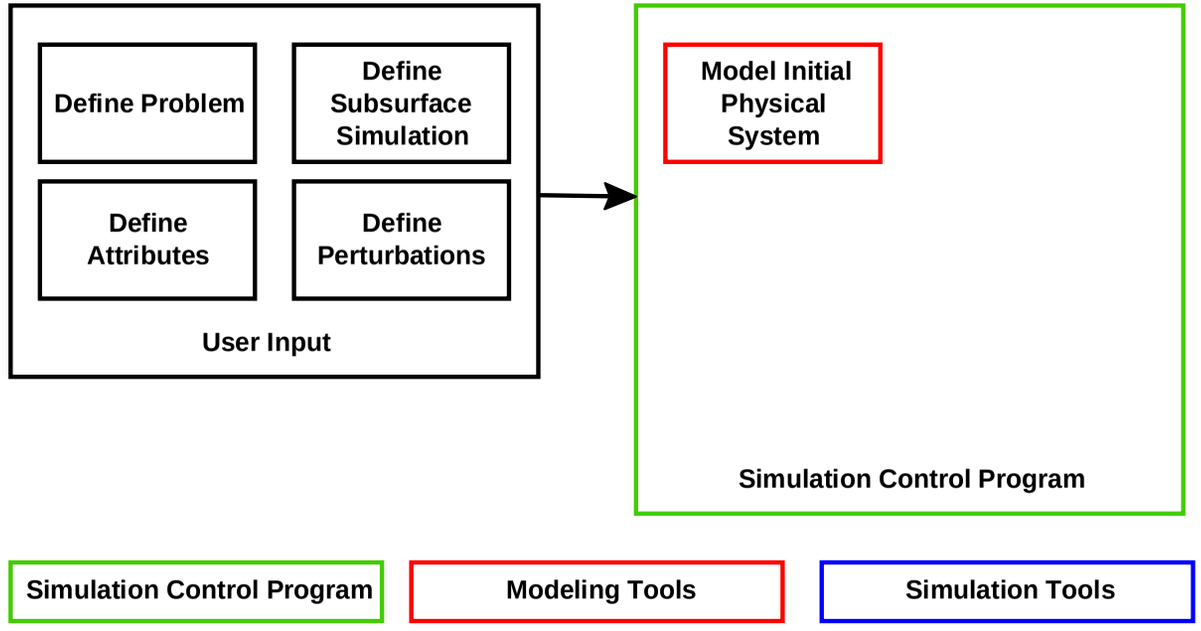

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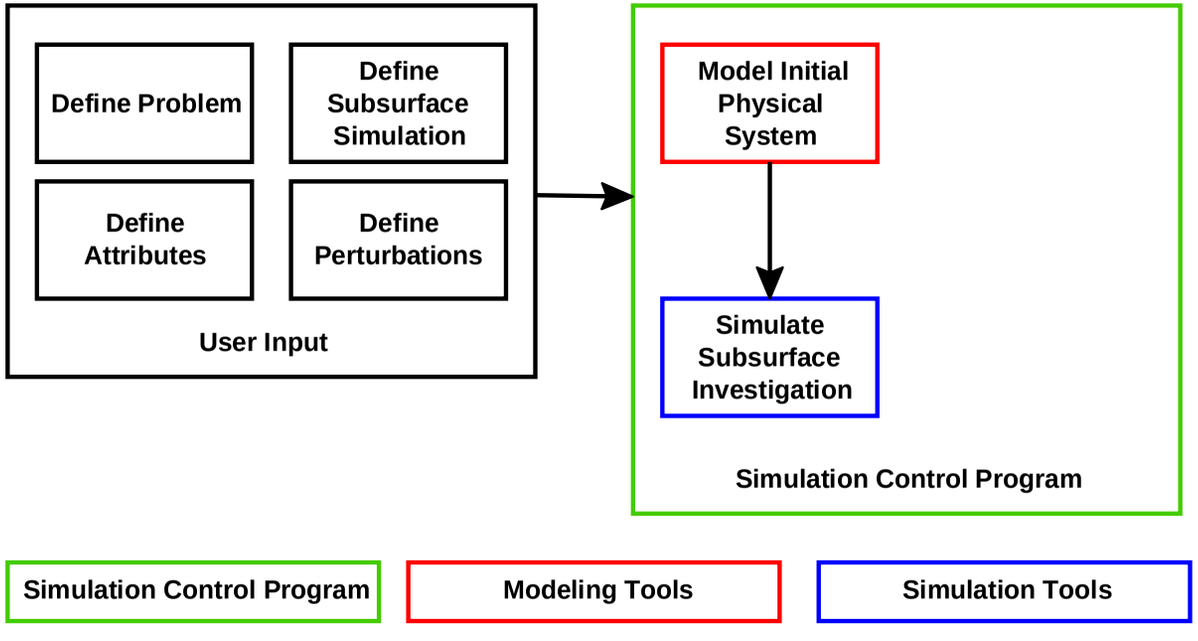

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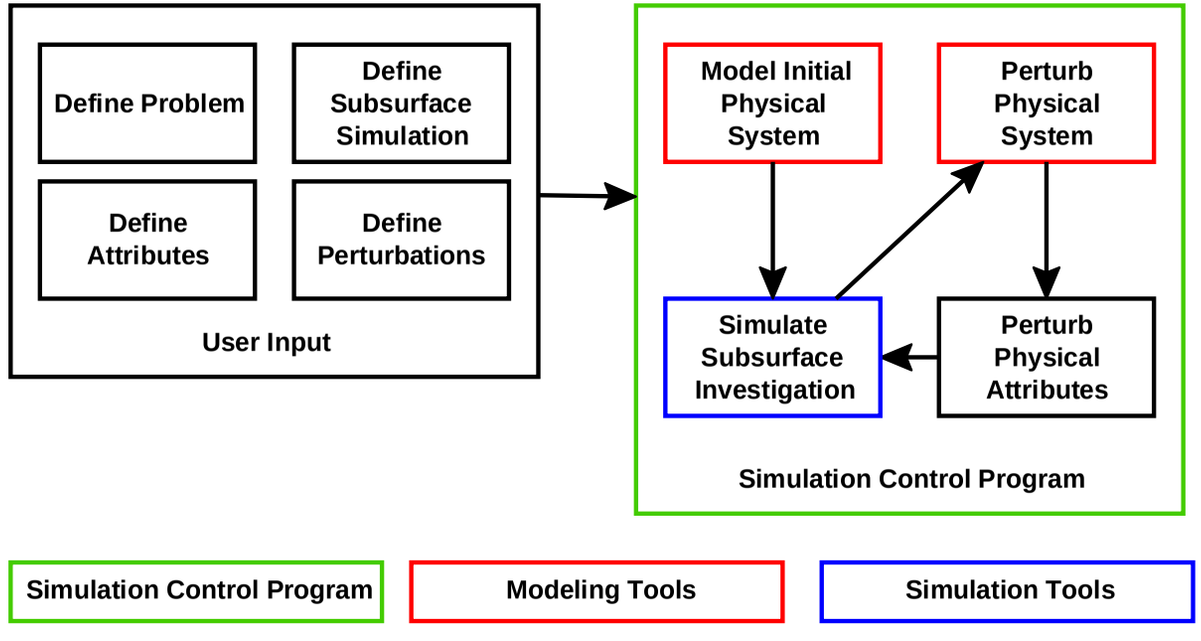

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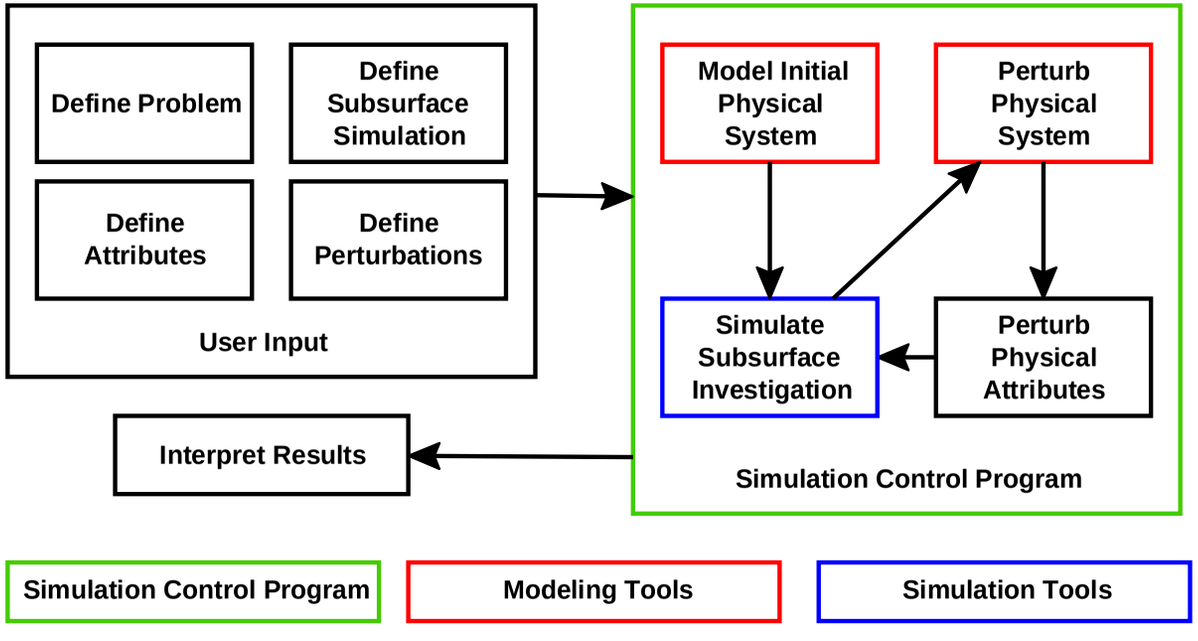
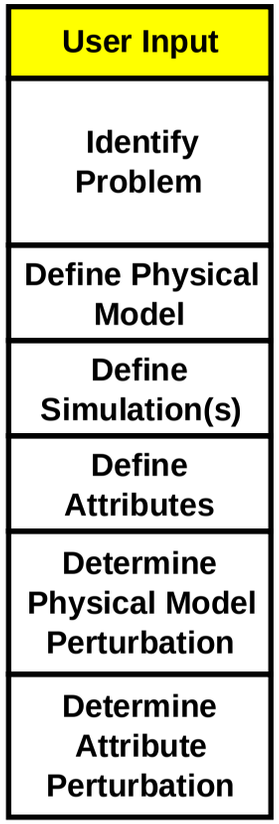


Some Civil Infrastructure Examples



Some Civil Infrastructure Examples

User Input	Case 1
Identify Problem	Study the variation of rebar depth on GPR simulation
Define Physical Model	- 9’ concrete deck - 1" asphalt overlay - #4 rebar - rebar grid 4"deep, 6" apart - Concrete 6% air content - Aggregate size info
Define Simulation(s)	GPR simulation using a 1GHz horn Antenna fixed in the center of the physical model and 18" above the deck
Define Attributes	DC of rebar: 20 DC of concrete: 7 DC of aggregate: 9 DC of asphalt: 5
Determine Physical Model Perturbation	Vary depth of rebar from 3-5" in 0.25" steps
Determine Attribute Perturbation	None

Some Civil Infrastructure Examples

User Input	Case 1	Case 2
Identify Problem	Study the variation of rebar depth on GPR simulation	Study the variation of dielectric constant of background material on GPR simulation
Define Physical Model	- 9’ concrete deck - 1" asphalt overlay	- #4 rebar - rebar grid 4"deep, 6" apart - Concrete 6% air content - Aggregate size info
Define Simulation(s)	GPR simulation using a 1GHz horn Antenna fixed in the center of the physical model and 18" above the deck	
Define Attributes	DC of rebar: 20 DC of concrete: 7	DC of aggregate: 9 DC of asphalt: 5
Determine Physical Model Perturbation	Vary depth of rebar from 3-5" in 0.25" steps	None
Determine Attribute Perturbation	None	Vary the dielectric constant of concrete from 7-10 in 0.5 steps

Some Civil Infrastructure Examples

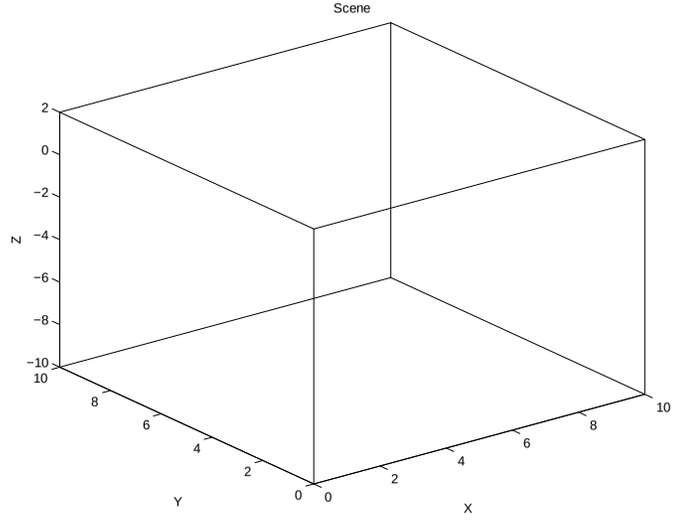
User Input	Case 1	Case 2	Case 3
Identify Problem	Study the variation of rebar depth on GPR simulation	Study the variation of dielectric constant of background material on GPR simulation	Study detection of various size delaminations on GPR simulation
Define Physical Model	- 9’ concrete deck - 1" asphalt overlay	- #4 rebar - rebar grid 4"deep, 6" apart	- Concrete 6% air content - Aggregate size info
Define Simulation(s)	GPR simulation using a 1GHz horn Antenna fixed in the center of the physical model and 18" above the deck		
Define Attributes	DC of rebar: 20 DC of concrete: 7	DC of aggregate: 9 DC of asphalt: 5	
Determine Physical Model Perturbation	Vary depth of rebar from 3-5" in 0.25" steps	None	Add air filled delamination 6" long varying from0.25" - 0.75" thick in steps of 0.25"
Determine Attribute Perturbation	None	Vary the dielectric constant of concrete from 7-10 in 0.5 steps	None

Some Civil Infrastructure Examples

User Input	Case 1	Case 2	Case 3	Case 4
Identify Problem	Study the variation of rebar depth on GPR simulation	Study the variation of dielectric constant of background material on GPR simulation	Study detection of various size delaminations on GPR simulation	Study detection of delamination by different NDT modalities (GPR & IE)
Define Physical Model	- 9’ concrete deck - 1" asphalt overlay	- #4 rebar - rebar grid 4"deep, 6" apart	- Concrete 6% air content - Aggregate size info	Same with addition of 0.25" delamination
Define Simulation(s)	GPR simulation using a 1GHz horn Antenna fixed in the center of the physical model and 18" above the deck			Same with addition of Impact Echo simulation
Define Attributes	DC of rebar: 20 DC of concrete: 7	DC of aggregate: 9 DC of asphalt: 5		Same plus acoustic properties
Determine Physical Model Perturbation	Vary depth of rebar from 3-5" in 0.25" steps	None	Add air filled delamination 6" long varying from0.25" - 0.75" thick in steps of 0.25"	None
Determine Attribute Perturbation	None	Vary the dielectric constant of concrete from 7-10 in 0.5 steps	None	None

Physical Modeling Tools

- Need to model materials (concrete, rebar, etc.) and defects (delamination, corrosion, etc.)
  - Shapes of individual physical components modeled using Object Oriented MATLAB.
  - Application specific shapes sit on top of 'basic' shapes. (Rebar is a 'grid' of cylinders)
  - Each component of the physical model references a library of information containing data needed for simulation (dielectric constant, acoustic impedance, etc.)
- Additional modeling objectives
  - Perturbation of physical model (increase diameter of rebar, move defect location)
  - Random & repeated insertion of shapes (randomly scatter aggregate or place crack)



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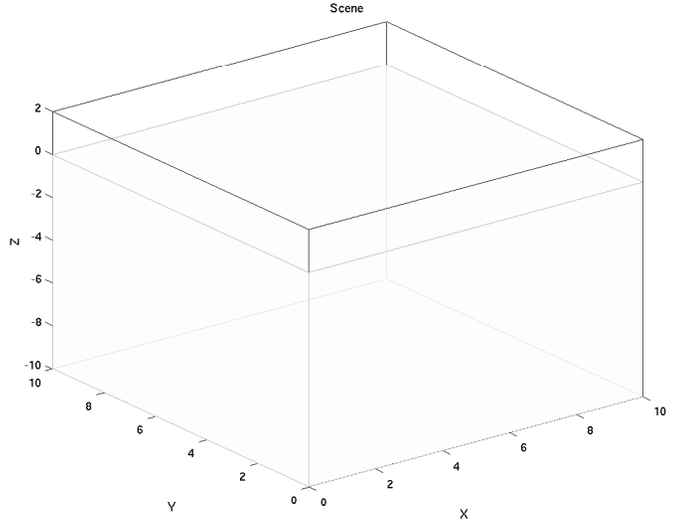

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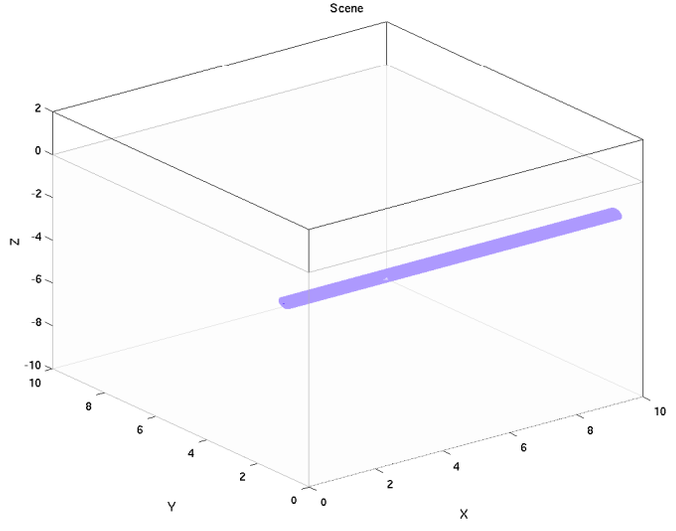

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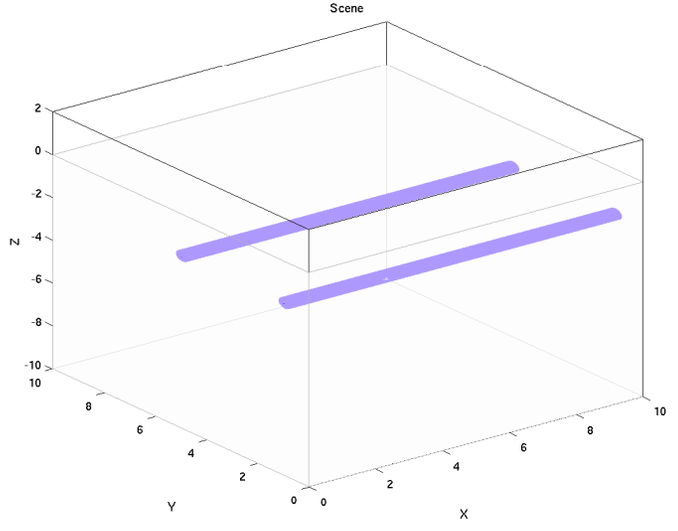

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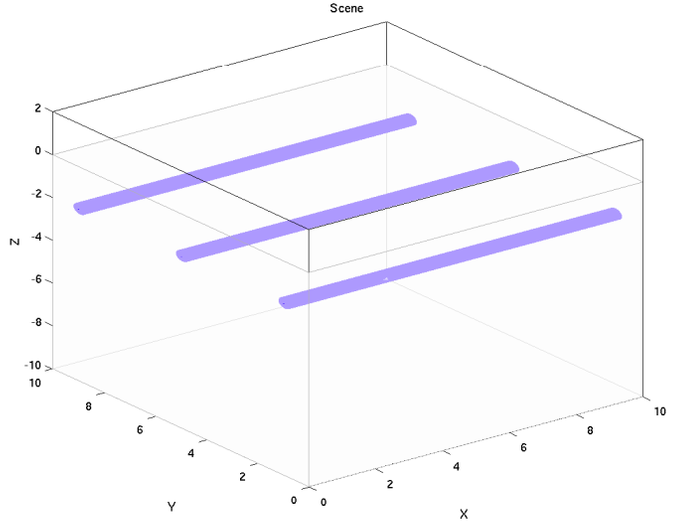

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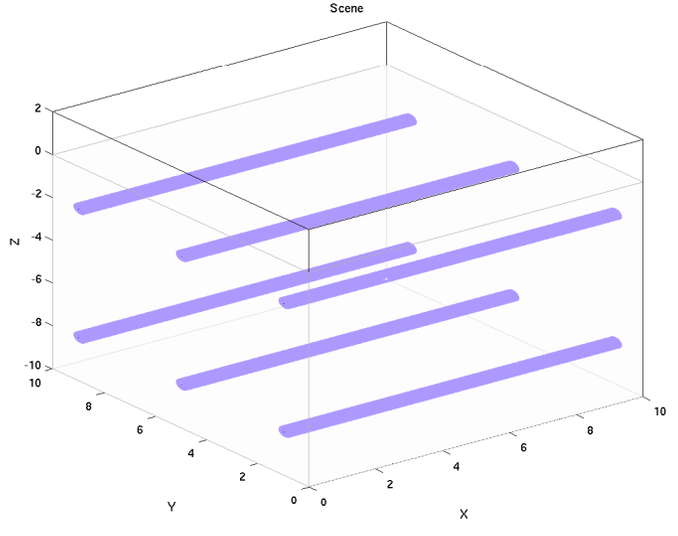

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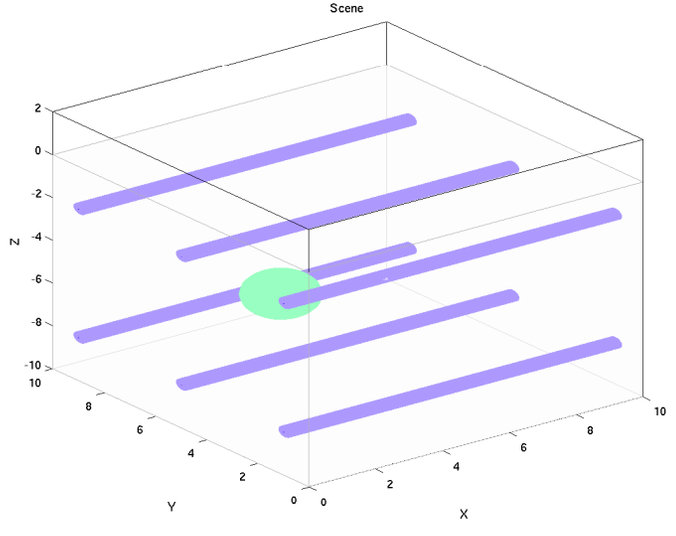
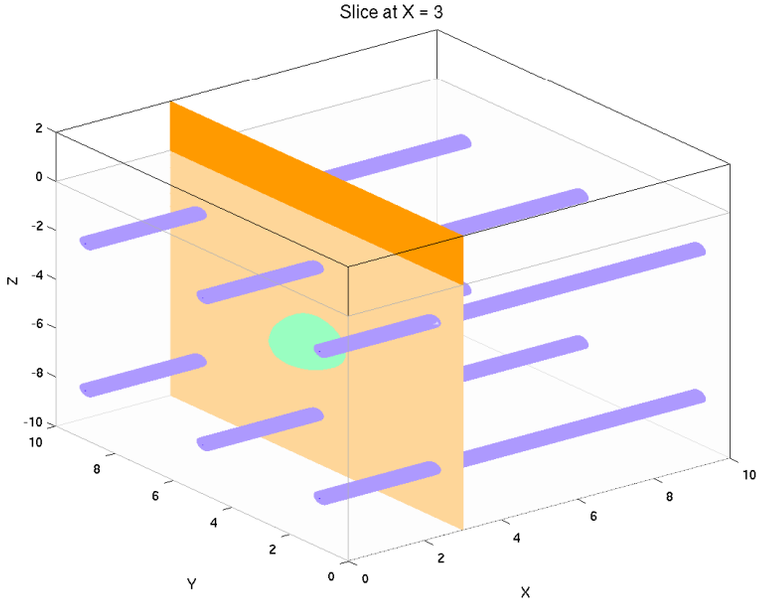
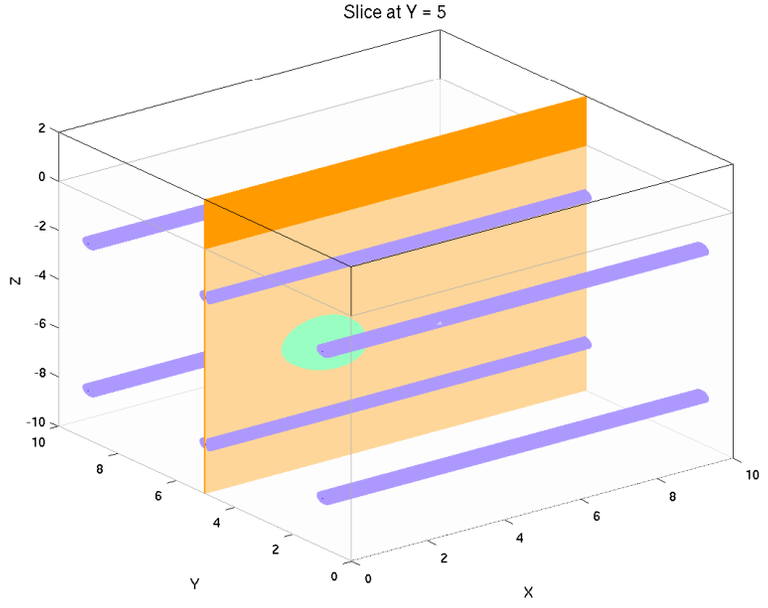


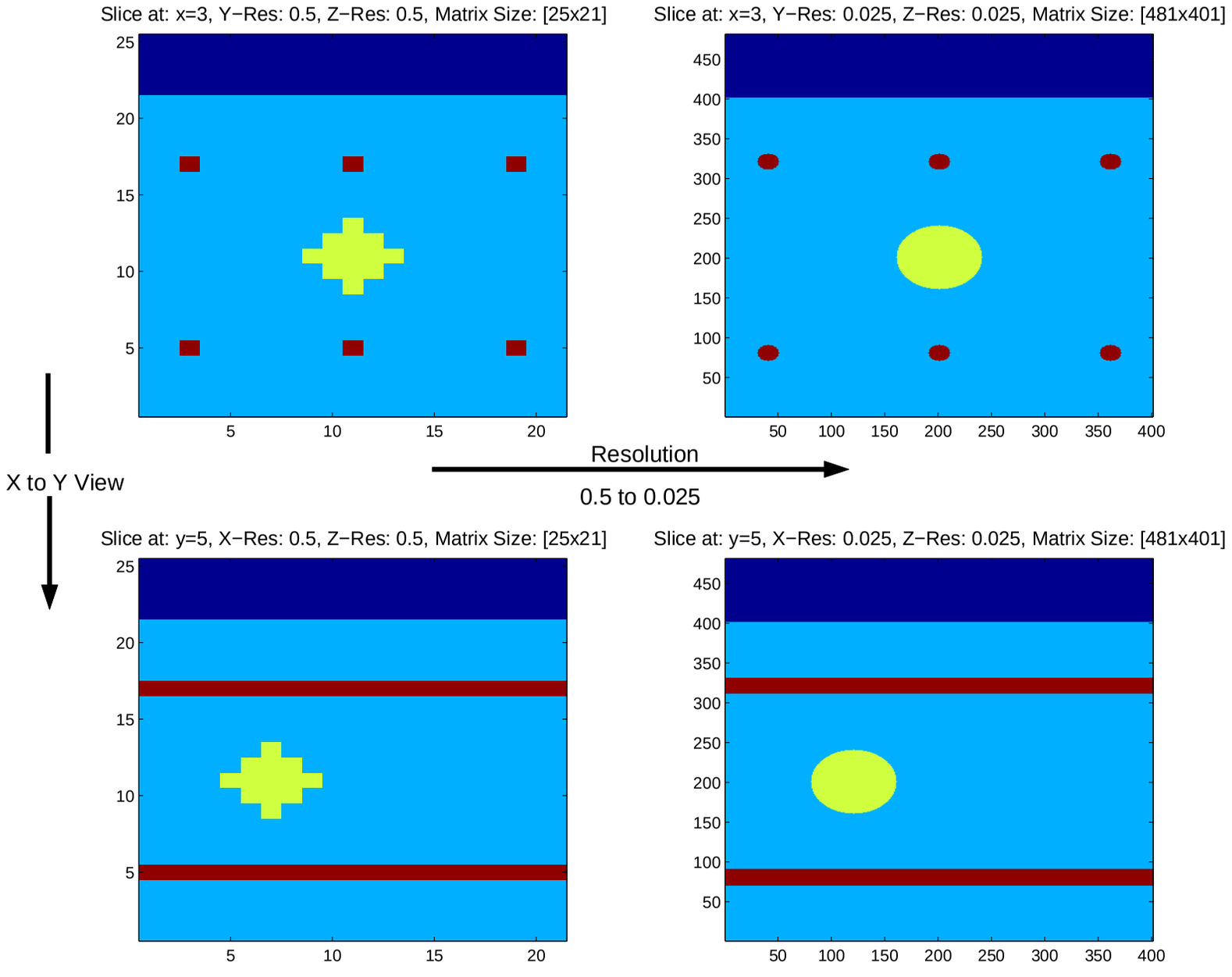
Physical Modeling Tools: Data Storage & Image Retrieval

- Shape information stored and displayed as a series of patch objects for quick rendering
- A slice (or series of slices in 3d) is taken of physical model
  - Roughness of slice determined by resolution
  - 2d matrix is output from slice (3d for series of slices)
  - Values of matrix are assigned at time of slice (Give me a slice at this location of dielectric constant values)





Physical Modeling Tools: Slice Resolution Example



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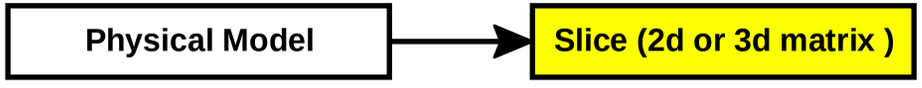
- 

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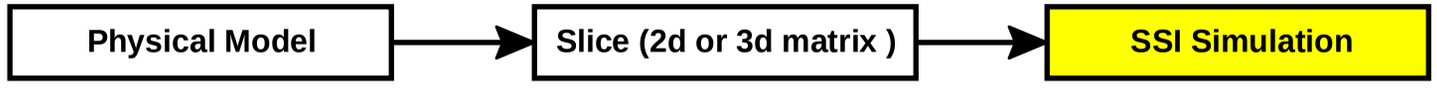
- 

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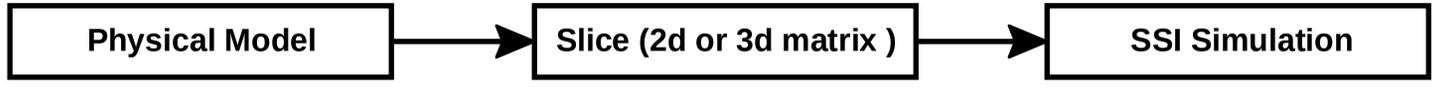
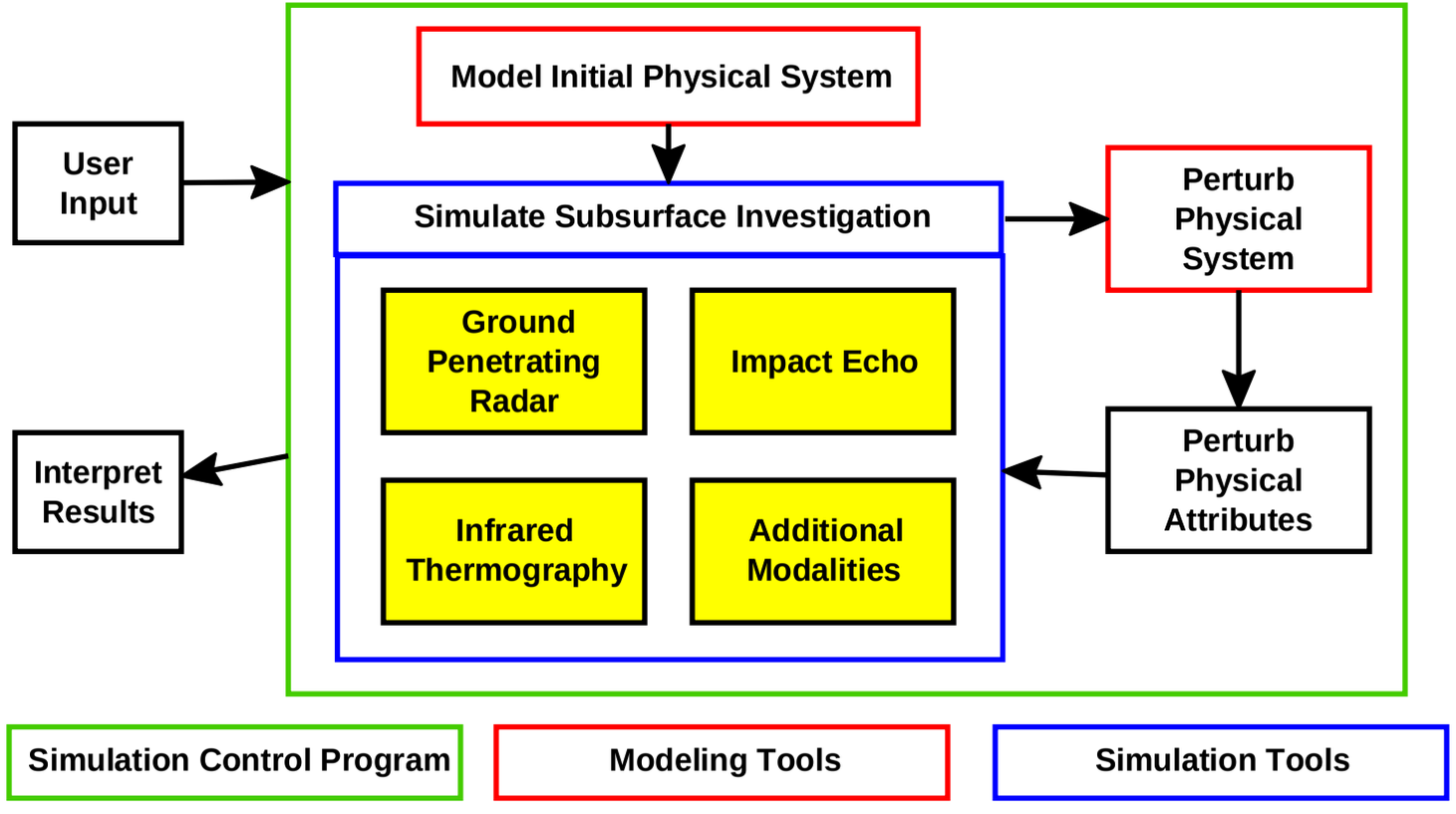
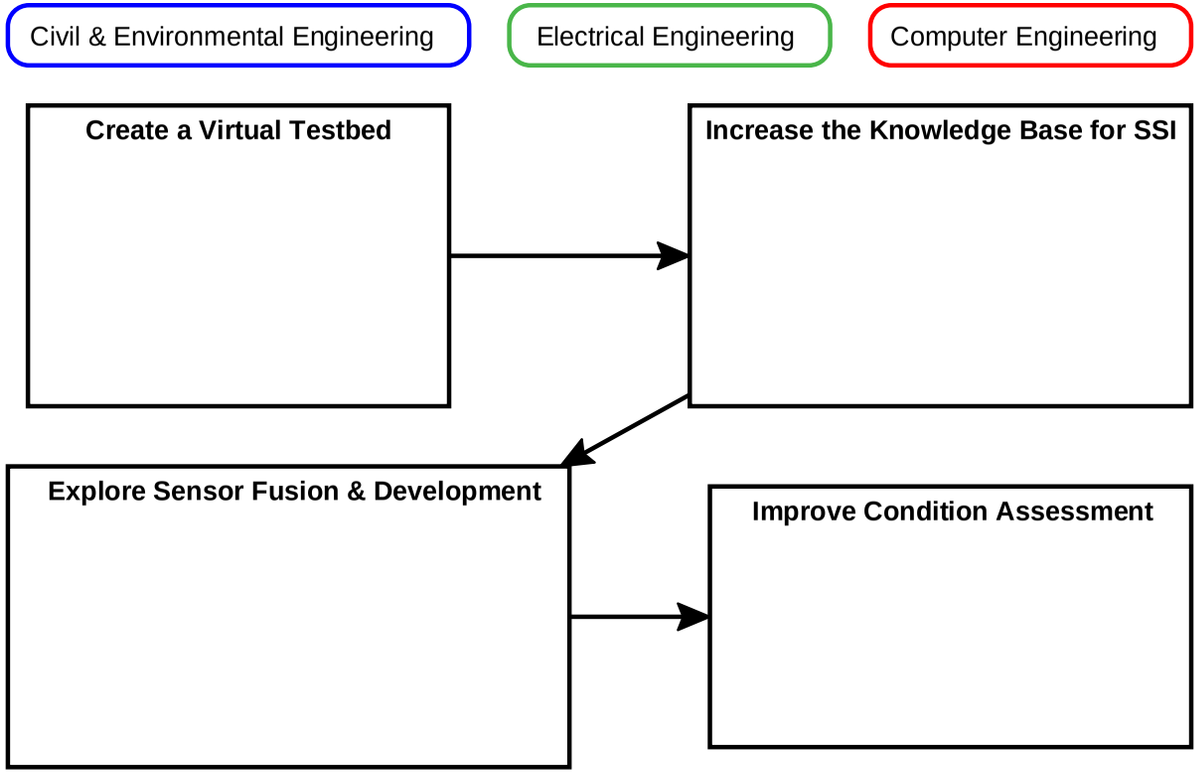
- 

- Each NDT modality is developed as a module - simulations of different modalities can be run on same physical model



Interdisciplinary Collaboration

- VTB relies on interdisciplinary collaboration



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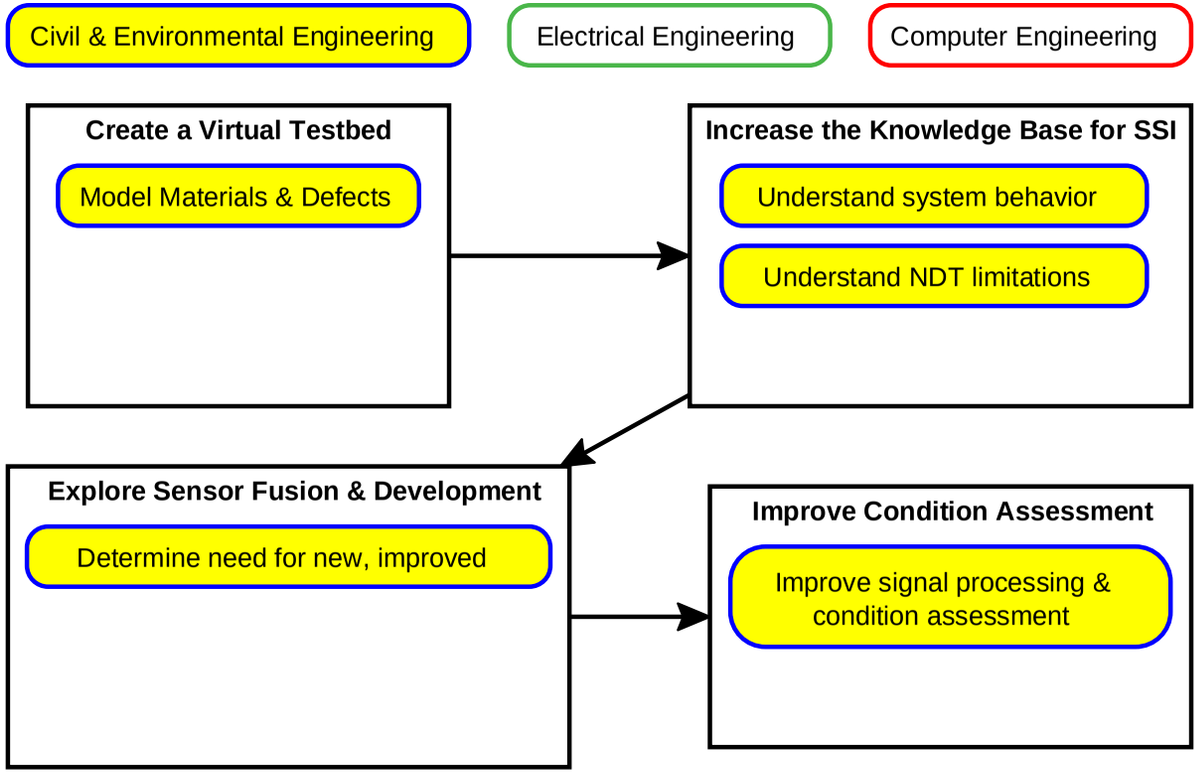

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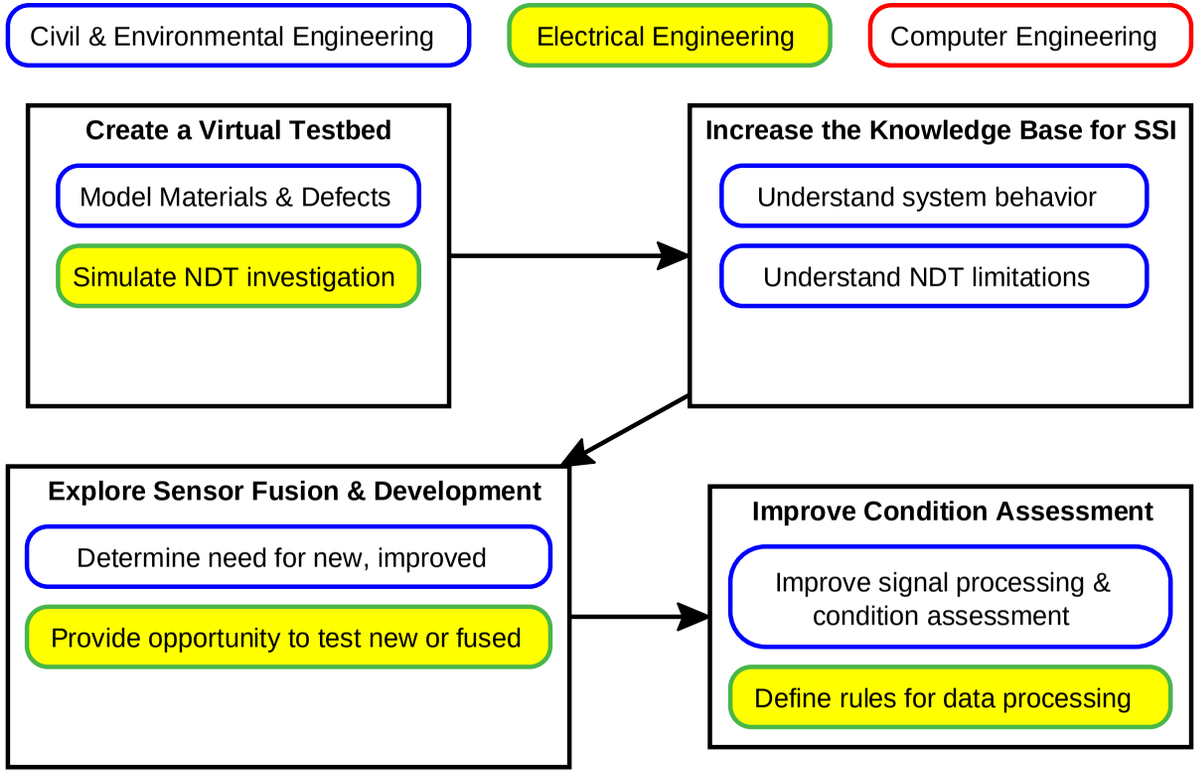

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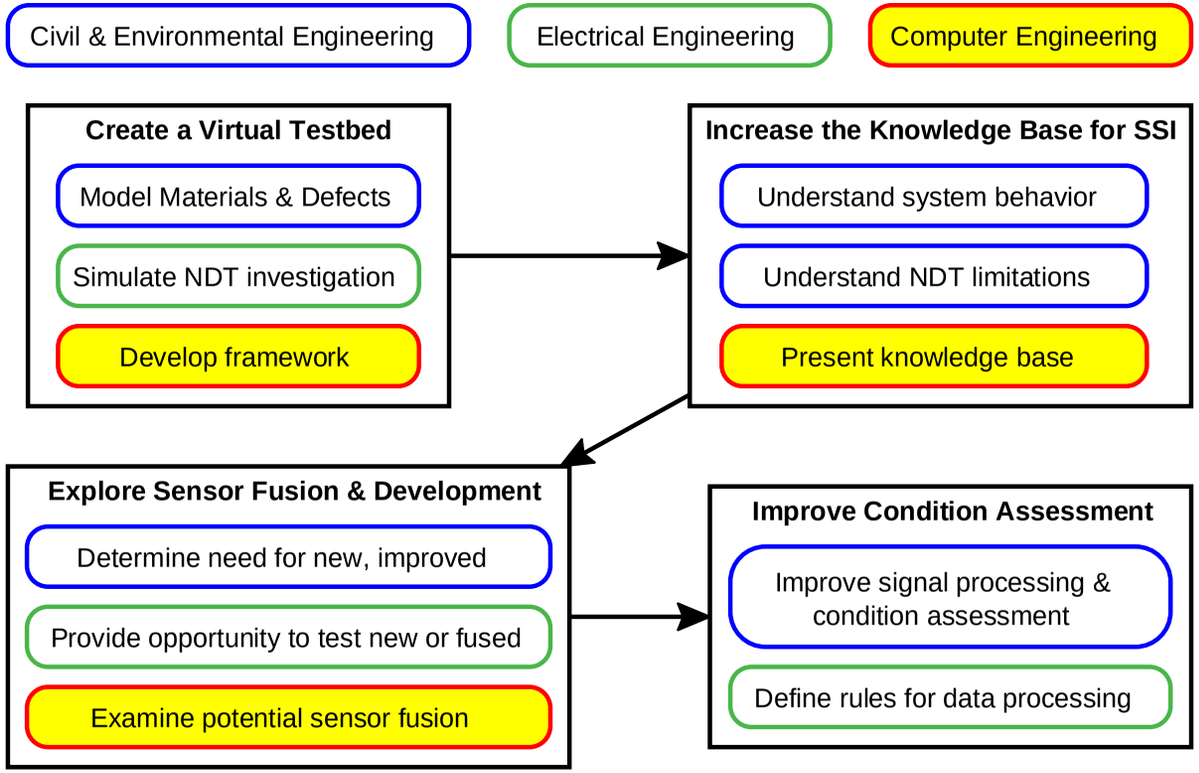

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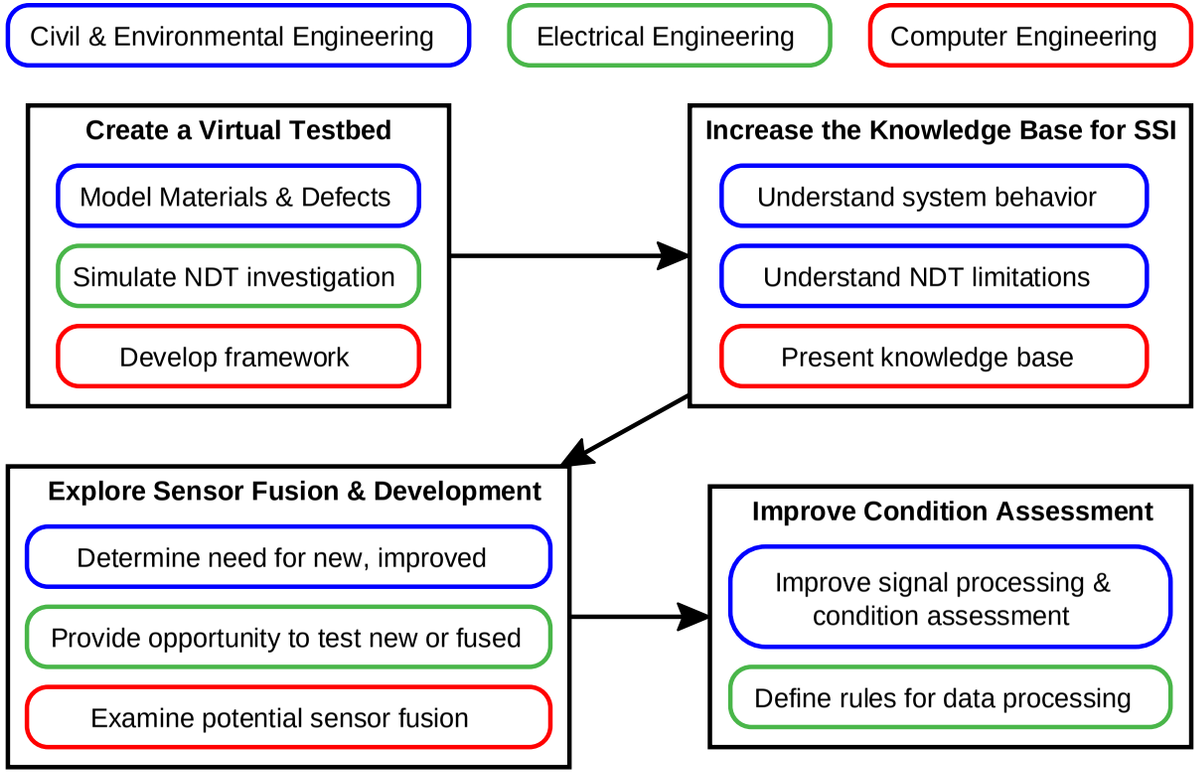
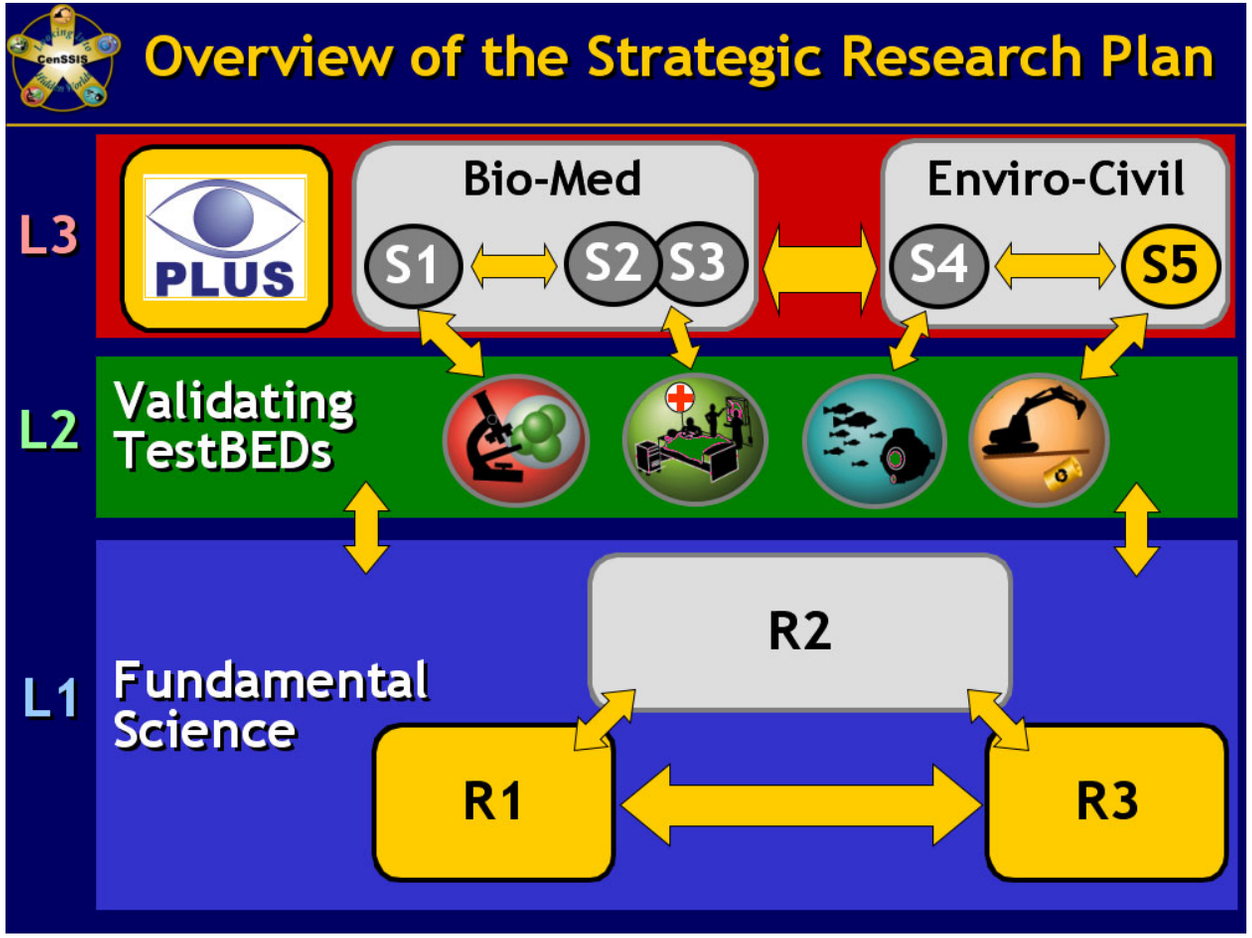


- VTB can be used in many applications other than Civil Infrastructure
  - Supports development of application specific modeling components
  - Supports development of simulation modules for additional modalities

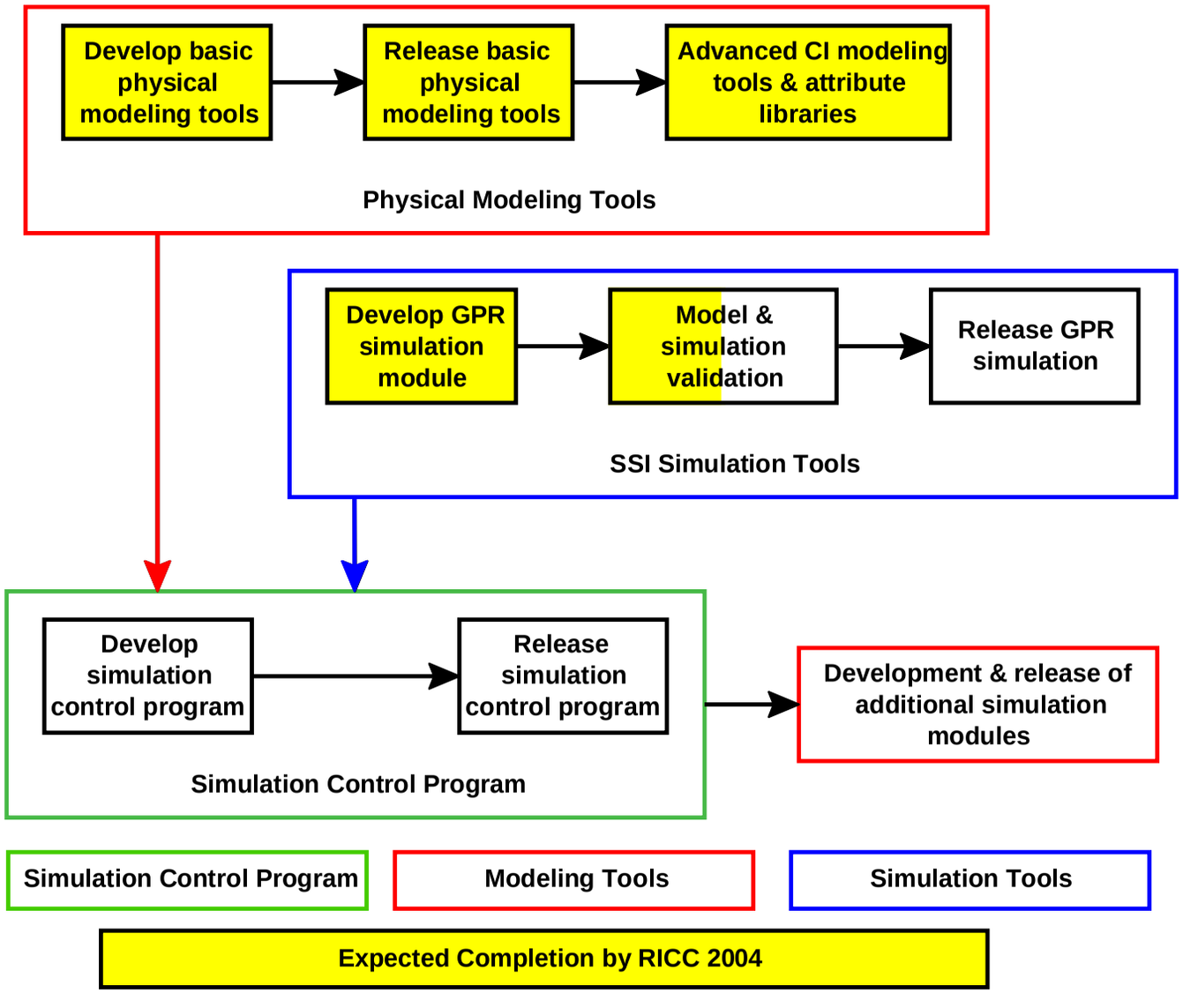
Relation to CenSSIS

Research Thrust R1 (Subsurface Sensing & Modeling) and S-Area 5 (Civil Infrastructure) as well as I-PLUS and Research Thrust R3 (CenSSIS Solutionware)



Future work has the possibility to move into Research Thrust R2 (Signal Processing & Image Understanding) and other S-Areas.

Plan of Attack



Contact Information

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