SENG 331 - Modeling And Simulation with Python

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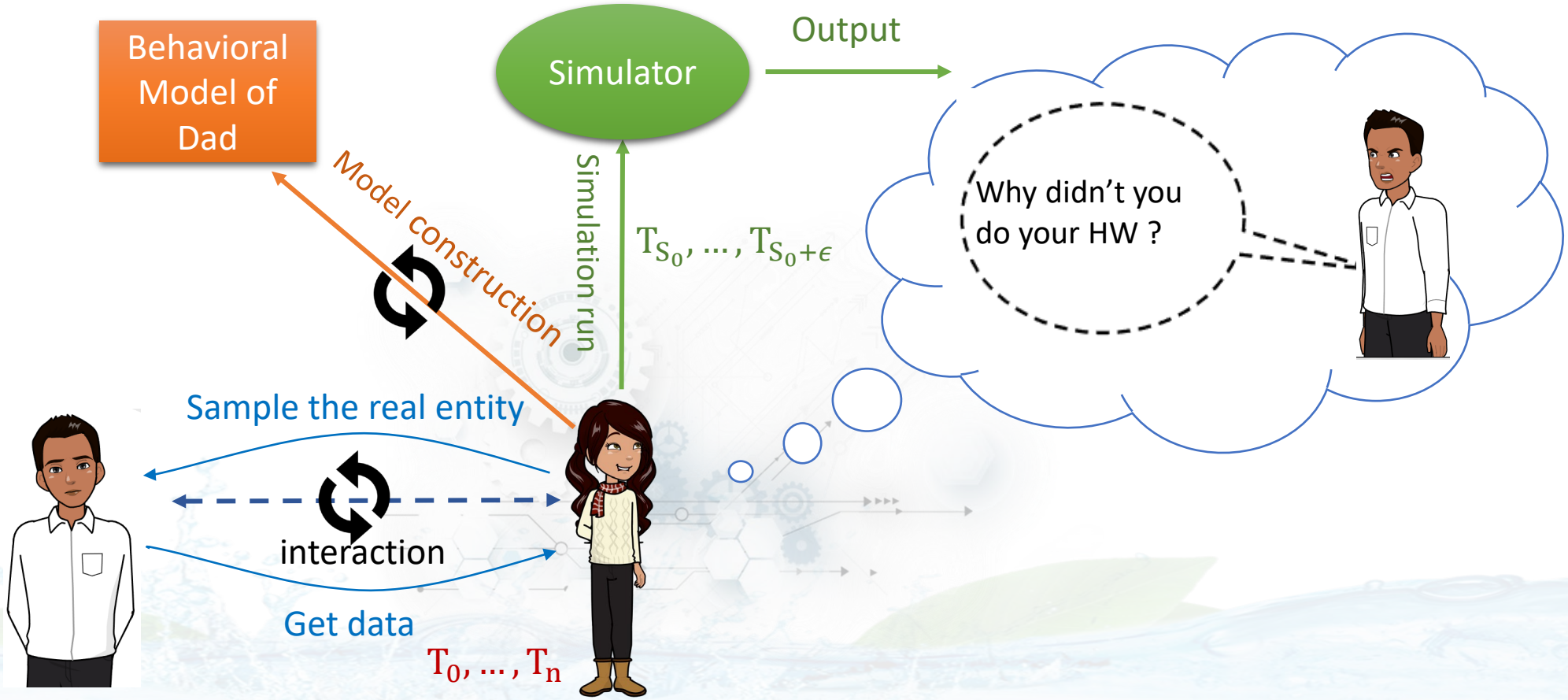
Essential Course Information

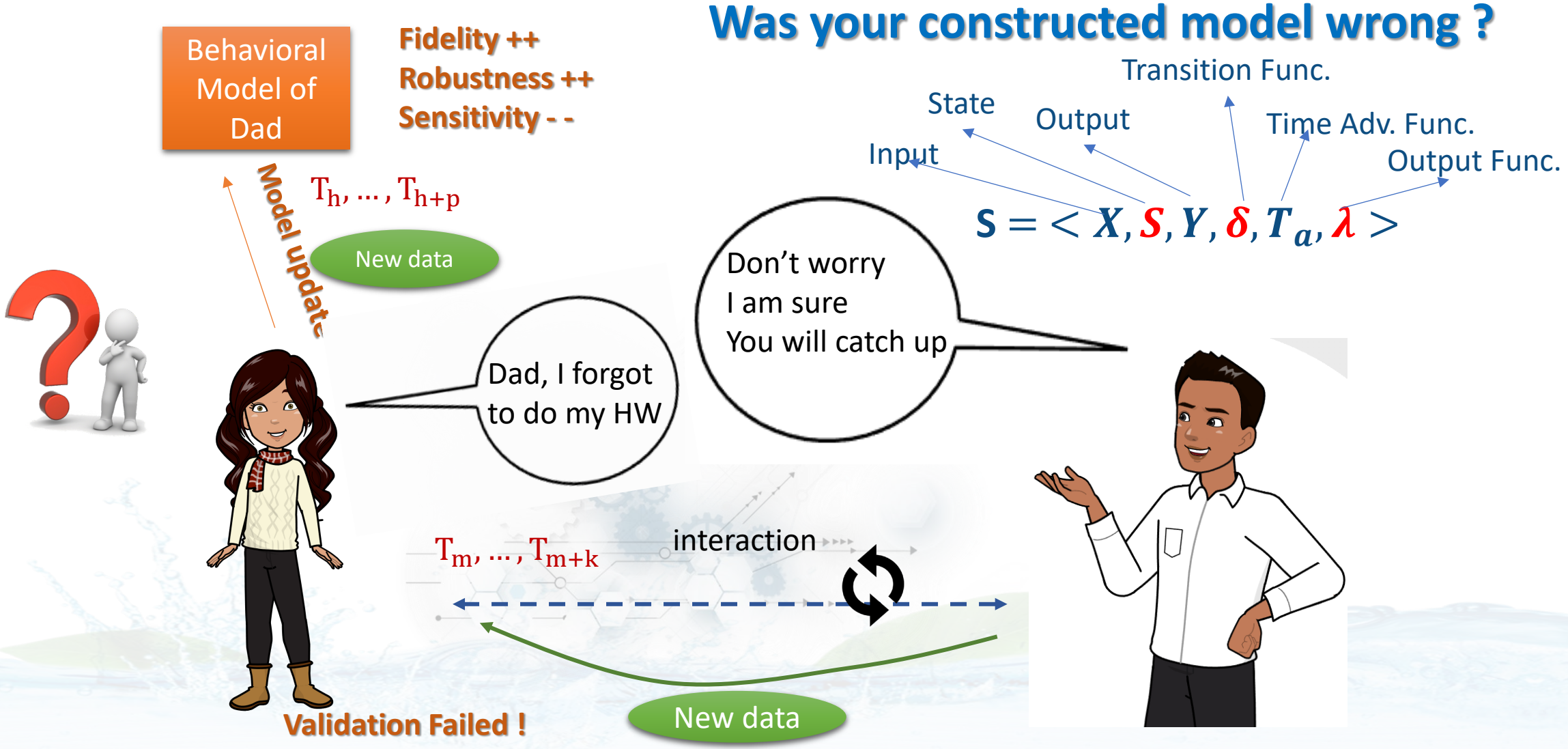
- Reference Material
  - Text Book: Simulation Modeling and Analysis, Averill M. Law, McGraw-Hill, 5th ed.
  - *Foundations and Methods of Stochastic Simulation* — Barry L. Nelson
- Programming Language for exercises: **Python**
  - You can download latest version of miniconda from (https://docs.conda.io/projects/miniconda/en/latest/)
- We'll use an open source and free Discrete Event Simulation package named **SimPy**
  - https://simpy.readthedocs.io/en/latest/
- A **tutorial** session will be provided for **Python & SimPy**
- Lab Exercises will be provided in Jupyter Notebooks
- Assessment
  - Project (%30) (delivery as jupyter notebook & demo in class);
  - Midterm %30
  - Final %40

Models and Simulations: A Story

Ayşe didn't do her homework, so she thinks that …



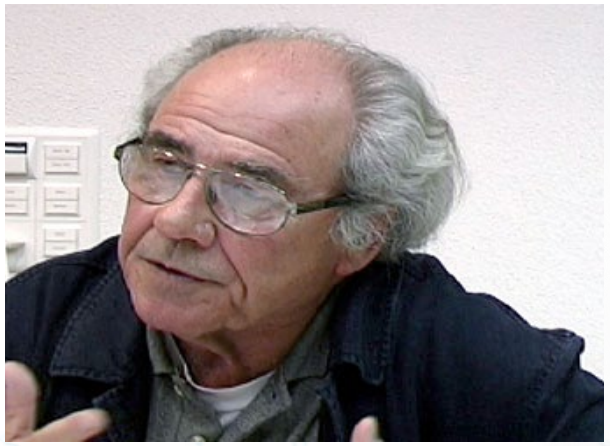
Models and Simulations: A Story



Some Philosophical Implications

Our mental abilities are inherently familiar with modeling and simulation enterprise.
This is how we deal with the complexity of the real world !

Jean Baudrillard



inspired

The Matrix Movie

- Simulacra, simulacrum, simulation
- The simulacrum is never that which conceals the truth — it is the truth which conceals that there is none.

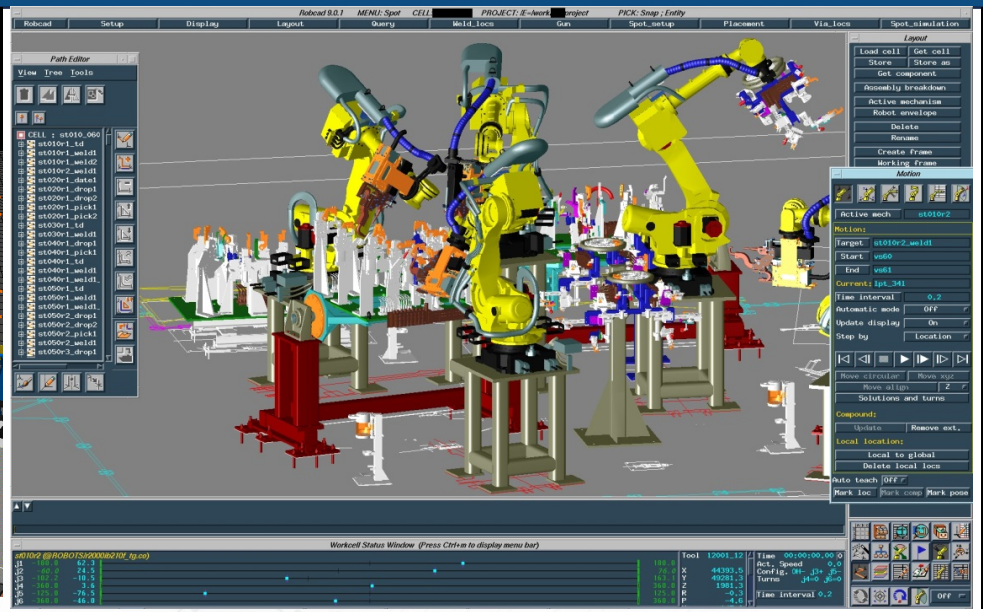
Morpheus: "your appearance now is what we call residual self-image. It is the mental projection of your digital self."

The Argument of MODSIM Community is …

- If we use the science of Modeling and Simulation in a systemmatic way:
  - We can design new systems in a much informed way because we can:
    - save money and time (by avoiding late, post construction anomalies)
    - use resources more efficiently
    - Try different design alternatives without actually building them (virtual prototypes)
    - investigate post deployment problems via user interaction in simulated (virtual) environments
  - We can improve and manipulate existing systems via their digital twins because we can:
    - Conduct detailed analysis on them
    - Optimize critical functions more easily via extensive experimentation
    - Test extreme cases which would be too dangerous to do with real systems, to identify vulnerabilities
    - make predictions about future behaviour via ‘What if?’ questions

Simulation Usage Areas

Manufacturing Systems

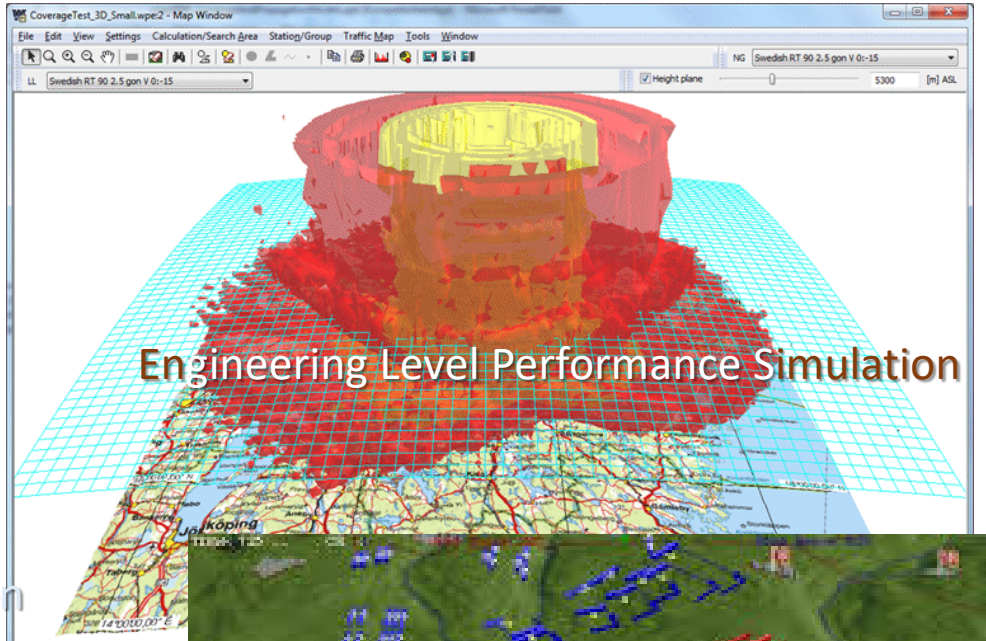


- Shop Floor Material Handling Simulation
- Specific Production Automation Simulation
- Overall Production Line Automation Simulation
- Stock and Inventory Control System Simulation

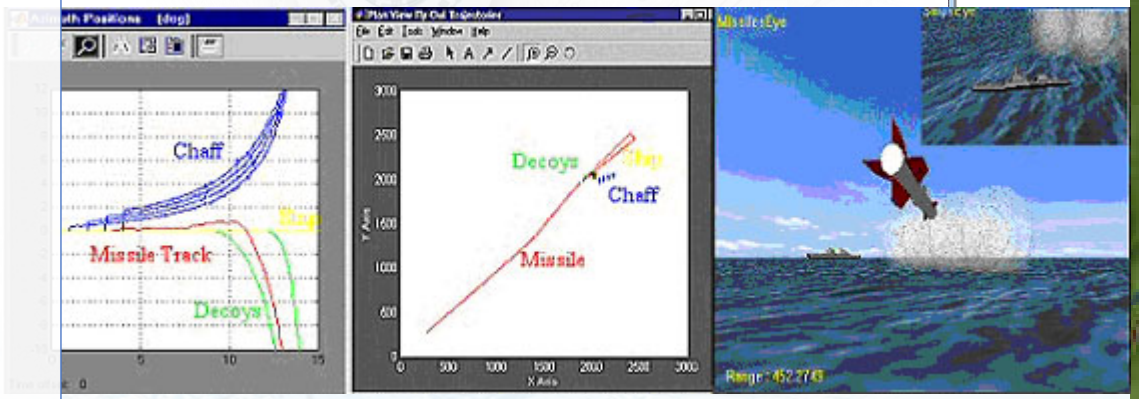
Military Weapon Systems

- Tactical weapon Engagement
- Tactical command and control Systems
- Strategic Level System/ Platform Performance / effectiveness
- War game
- Engineering level performance

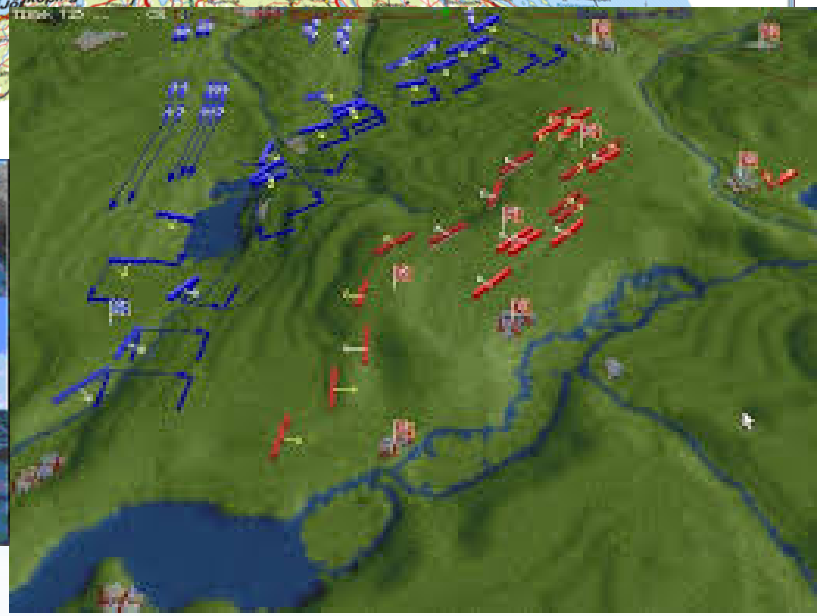
Strategic Level System Performance Simulation



Engineering Level Performance Simulation

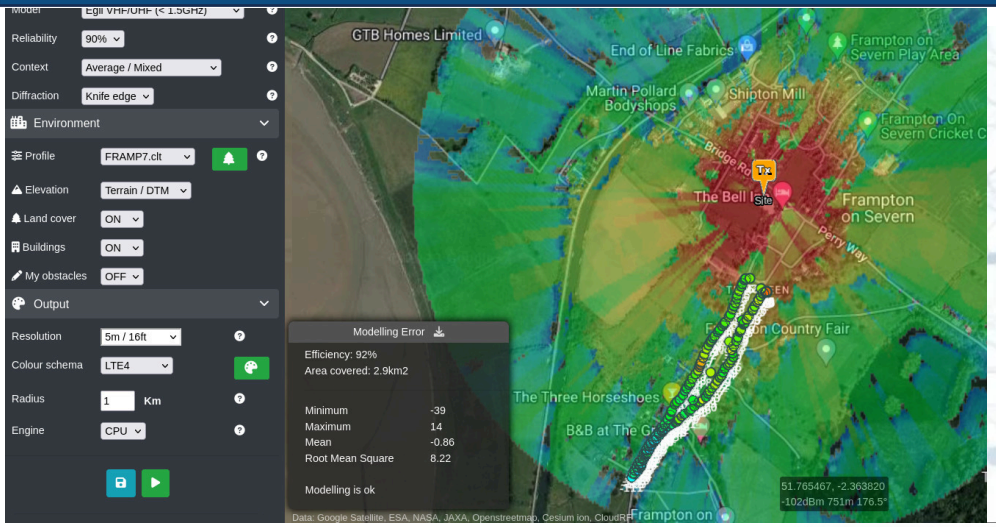


Tactical Engagement Simulation

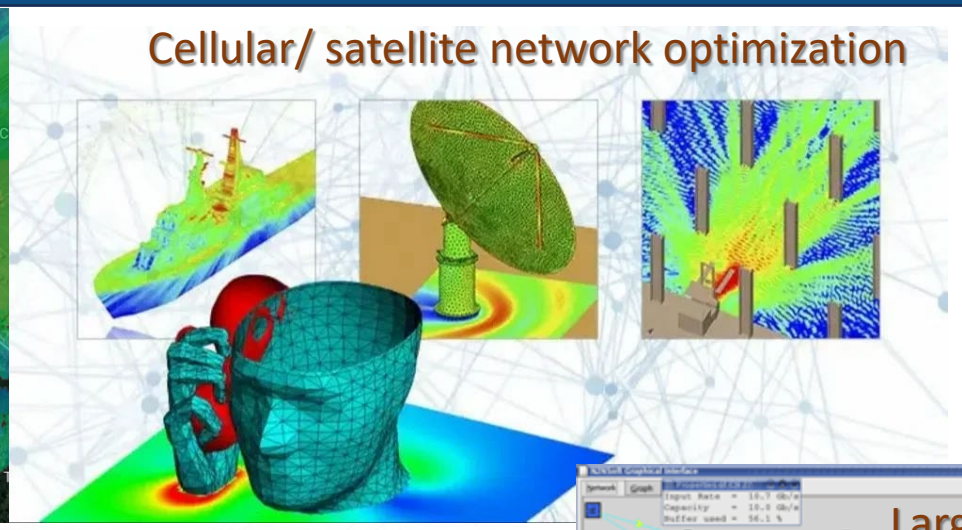


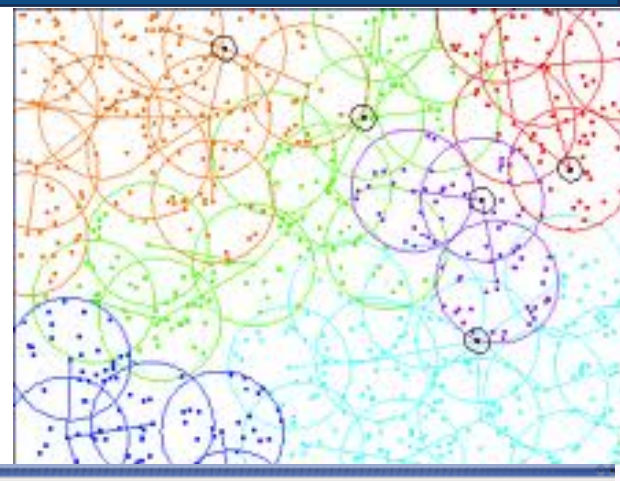
War game Simulation

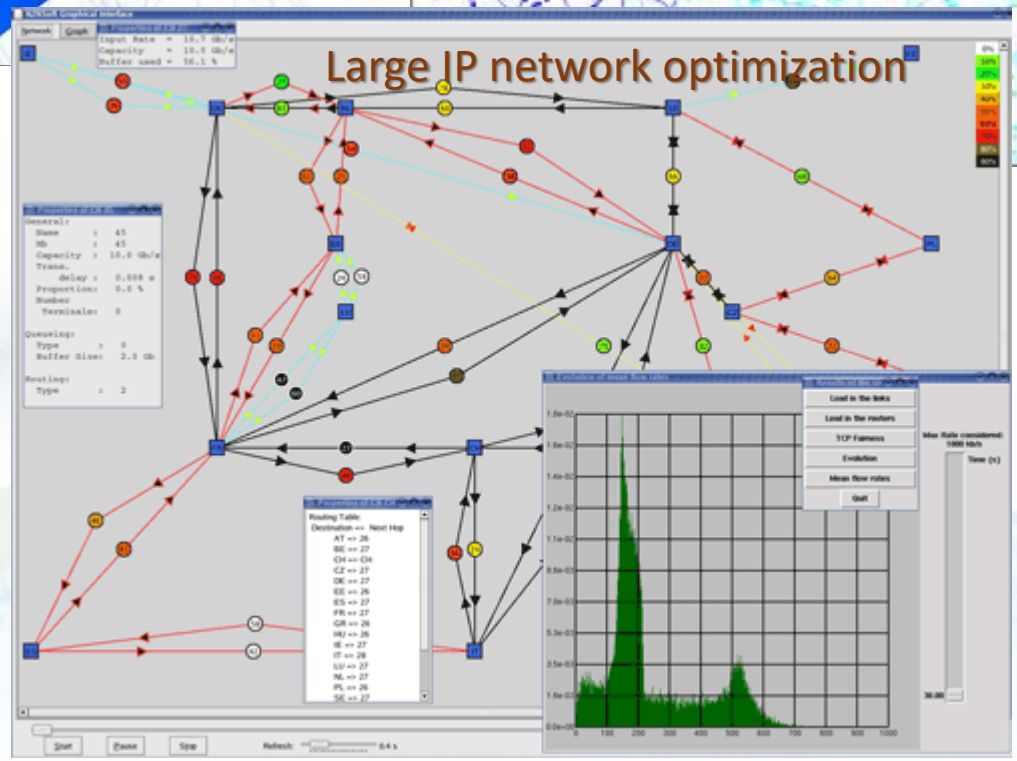
Communication Networks



Area Coverage Analysis



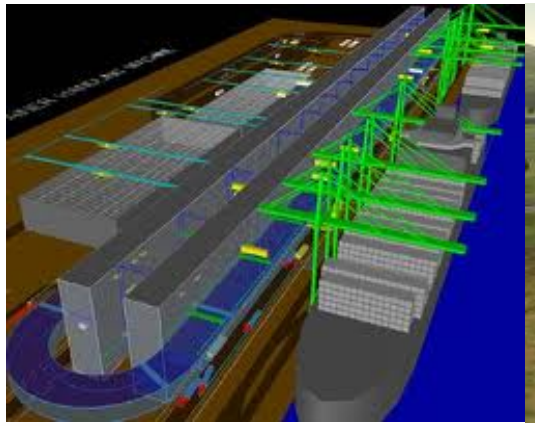


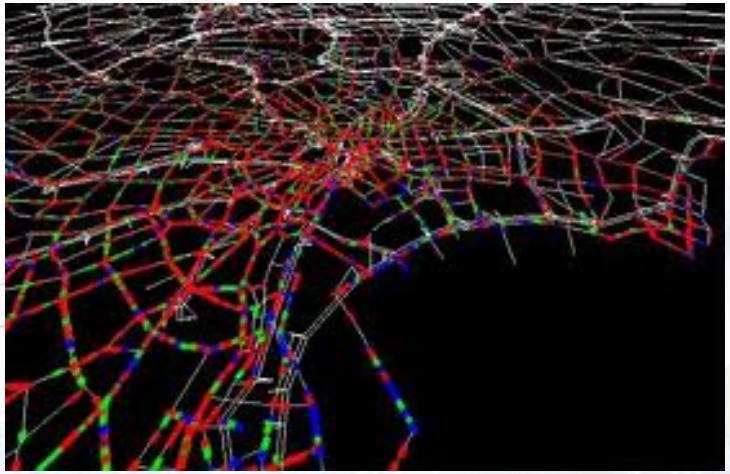


- network topology and coverage modeling
- application flow (traffic) modeling
- network performance metrics
- Technology/protocol evaluation and device designs
- Logging of packet/events for drill-down analyses/debugging

Transportation Systems

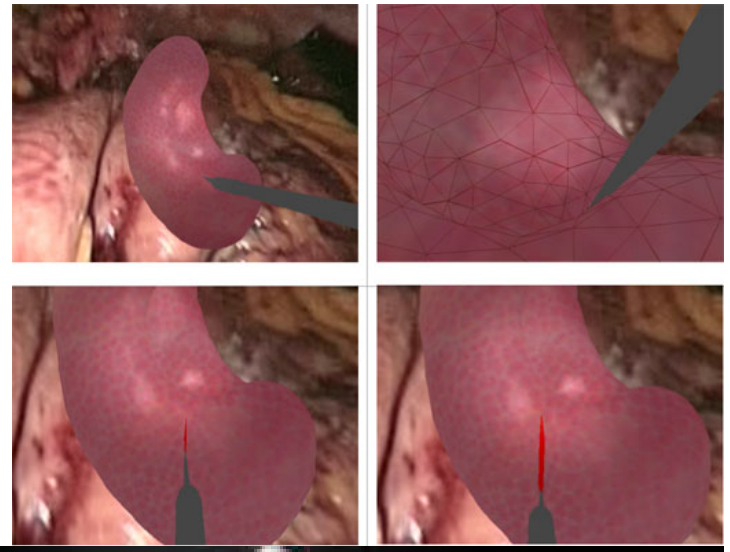
- Highway network design
- Traffic flow optimization
- Railway signalization design and optimization
- Airport/seaport/terminal capacity planning and optimization
- Platform training simulators





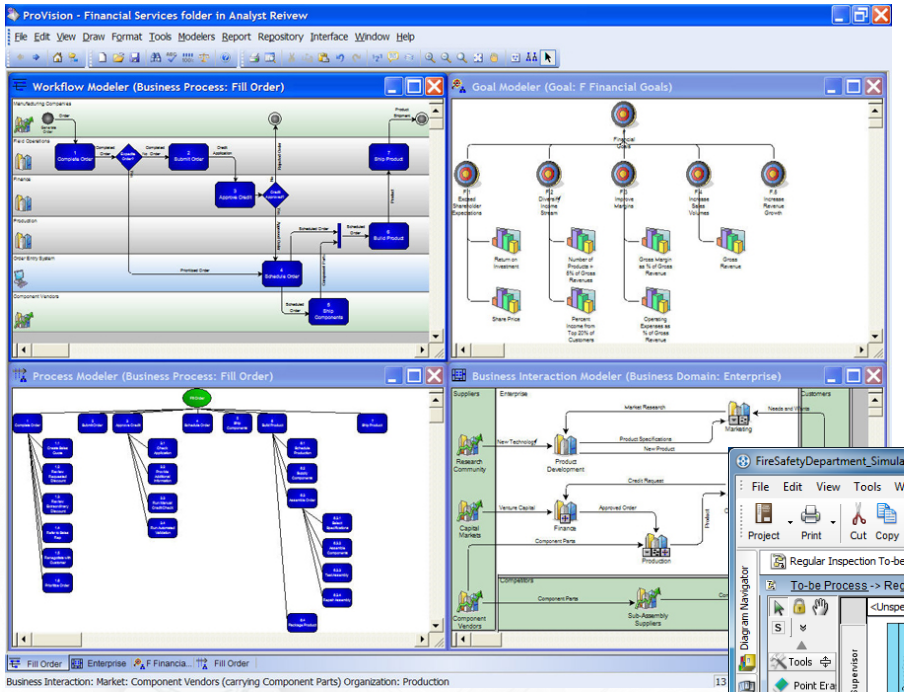
Health Industry

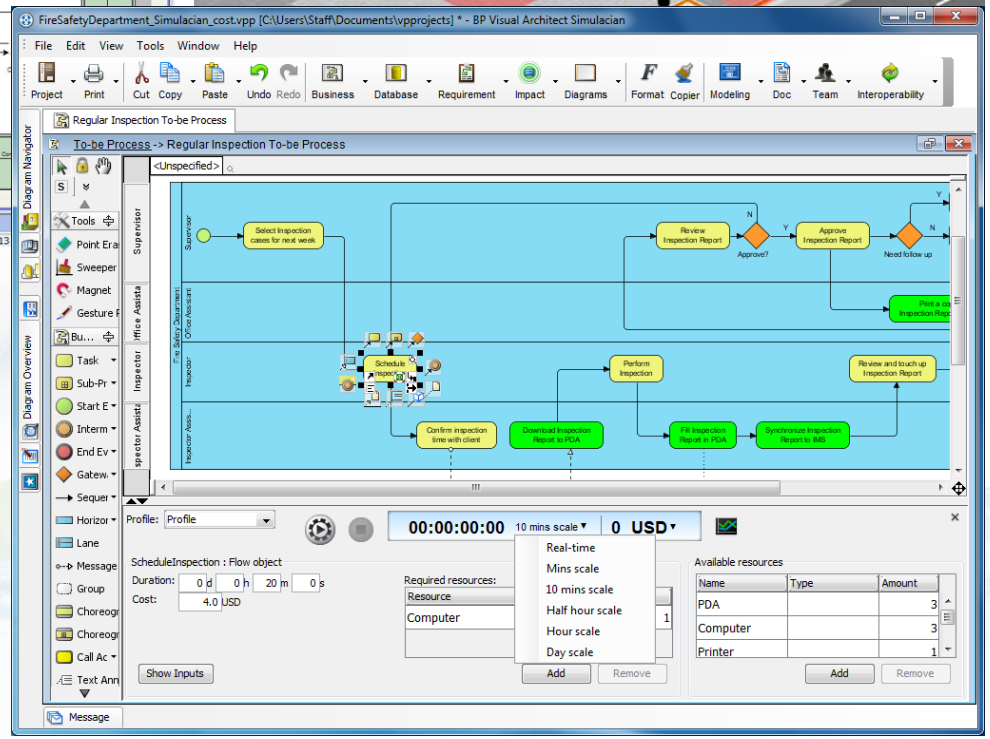
- Virtual surgery operations training
- Hospital capacity and equipment planning
- 3D inspection and analysis of anatomical processes
- Staff training and operational planning
- Patient handling process optimization
- Hospital facility location and architectural effectiveness analysis



Business Processes

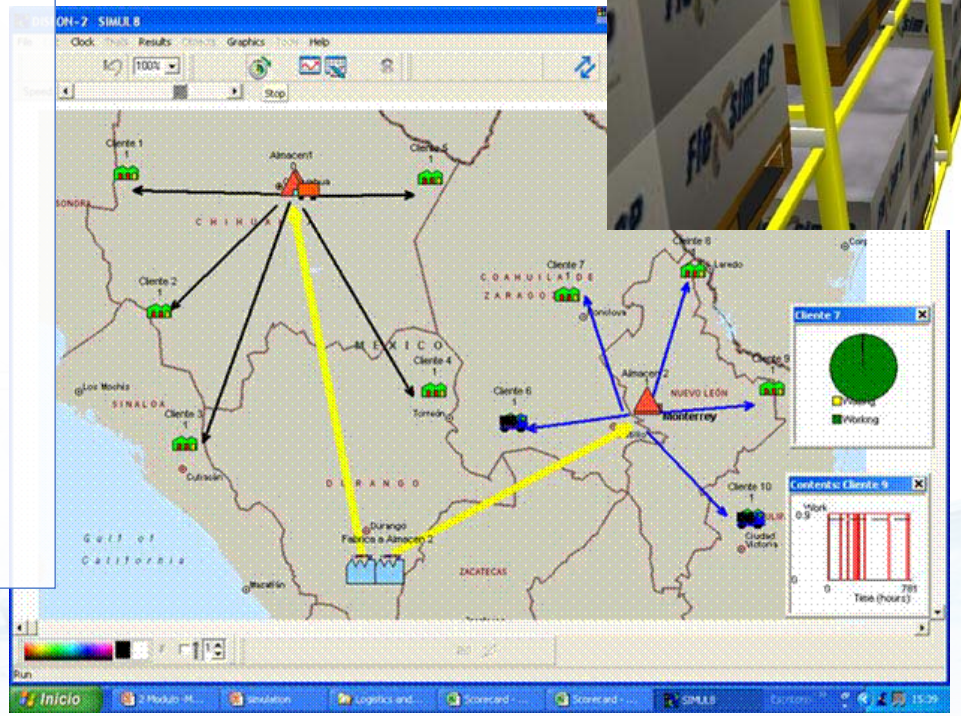
- Business process design, optimization and reengineering
- Workflow analysis and design
- Office work force location planing
- Staff training and operational planning

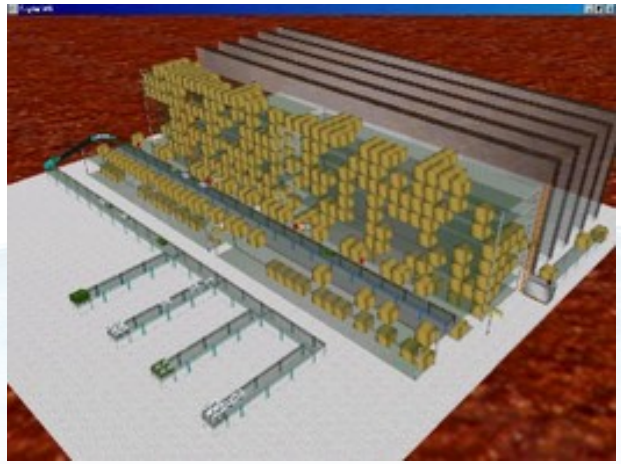




Supply Chain Management

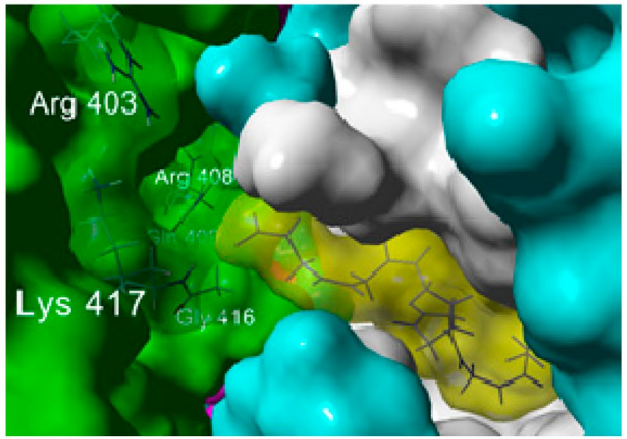
- Determine safety stock values
- Evaluate inventory policies
- Identify bottlenecks
- Cost service levels
- Ask what-if questions regarding new manufacturing facilities, or transport policies



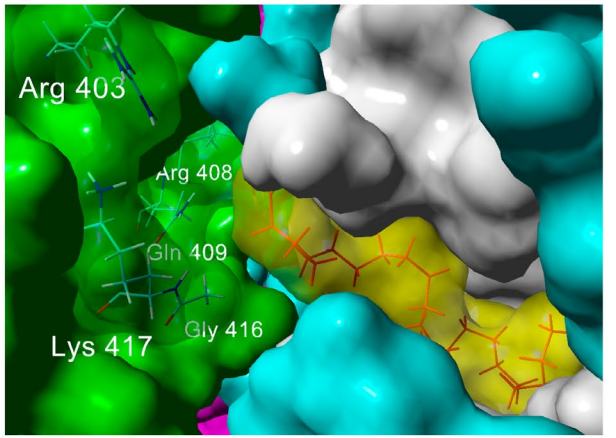


COMPUTATIONAL BIOLOGY

- New drug design
- Molecular Modeling of new bio materials
- analysis of protein and nucleic acid structure and function,
- evolutionary genomics and proteomics,
- Modeling gene-disease associations, and development and spread of disease

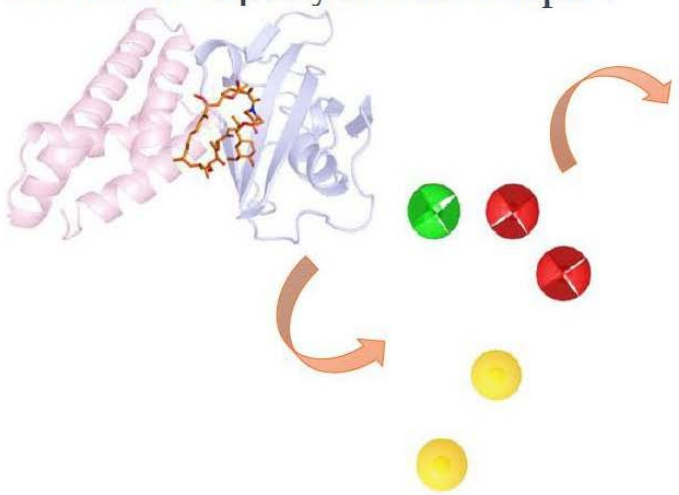


(a)



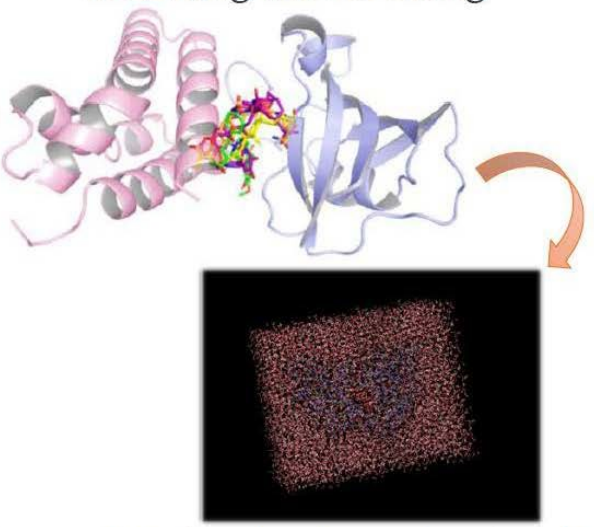
(b)

1.Molecular dynamics simulation of the FKBP12-rapamycin-FRB complex



2.Structure-based pharmacophore model generation and virtual screening

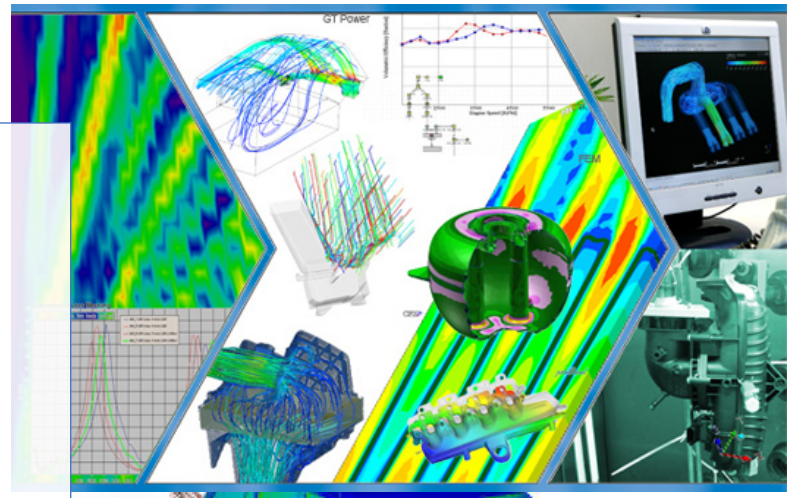
3.Docking and rescoring

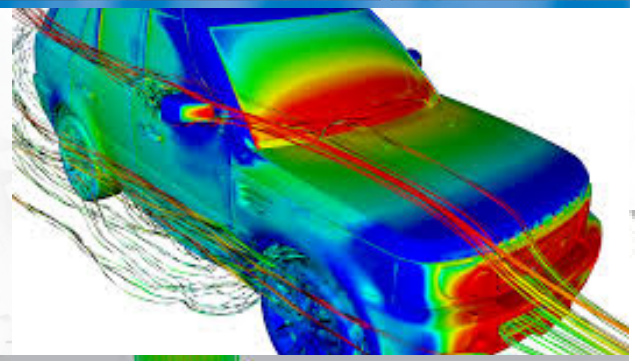


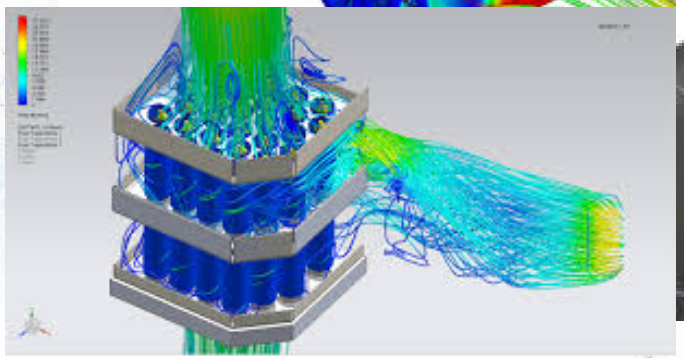
4.Molecular dynamics simulation of the docking complexes

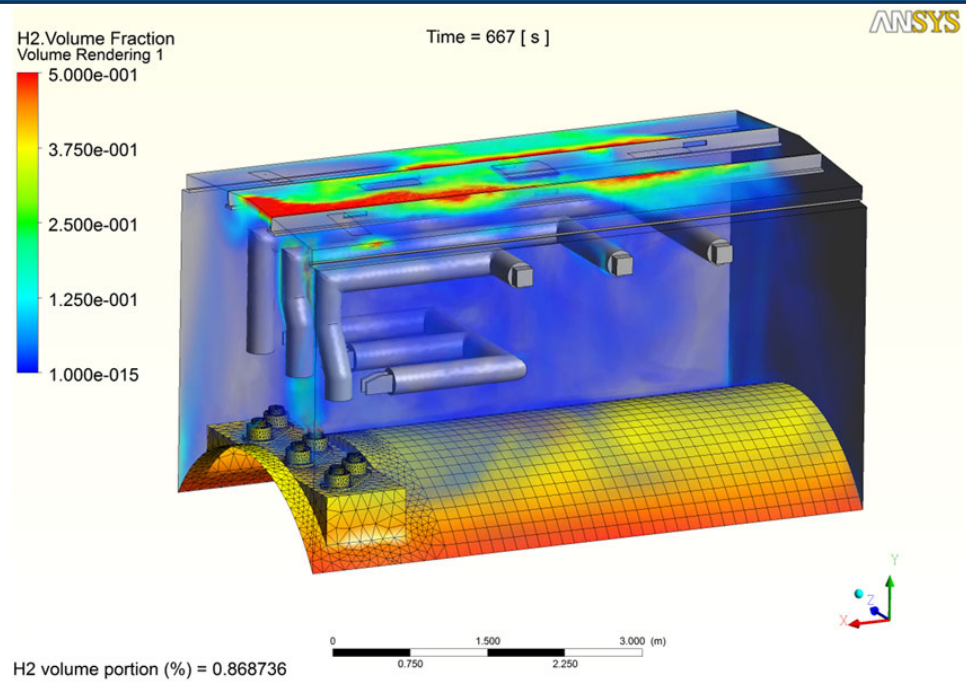
Engineering Simulation

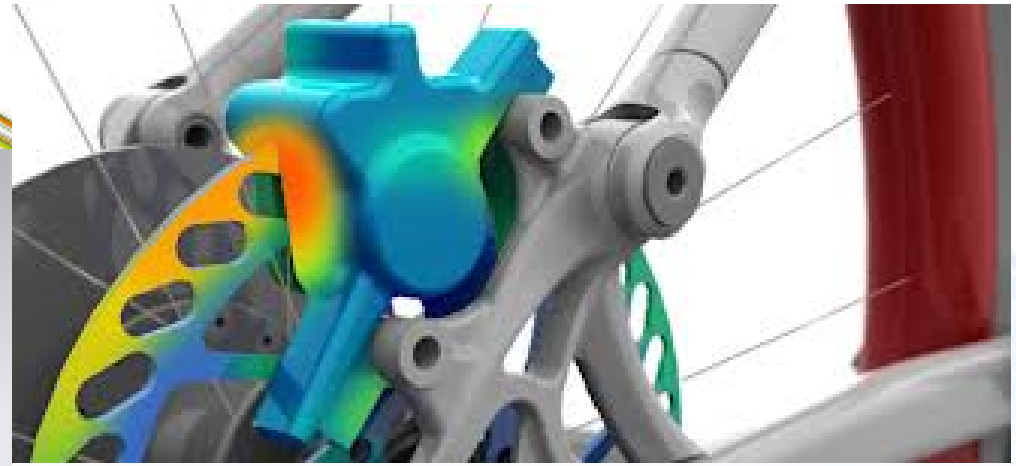
- Thermal Diffusion Analysis
- Stress and stiffness Analysis of mechanical systems
- Air resistance analysis
- Design optimization of complex engineering systems
- Computational Fluid Dynamics (CFD)





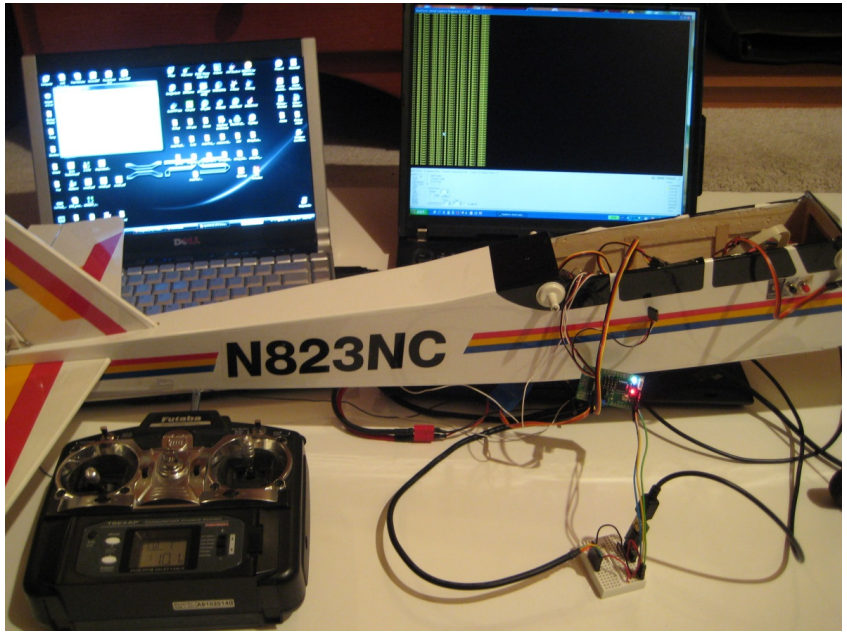






HITL Simulation

- Testing real systems in simulated environments
- Reverse engineering existing systems
- Testing real system interaction with a simulated system
- System characterization

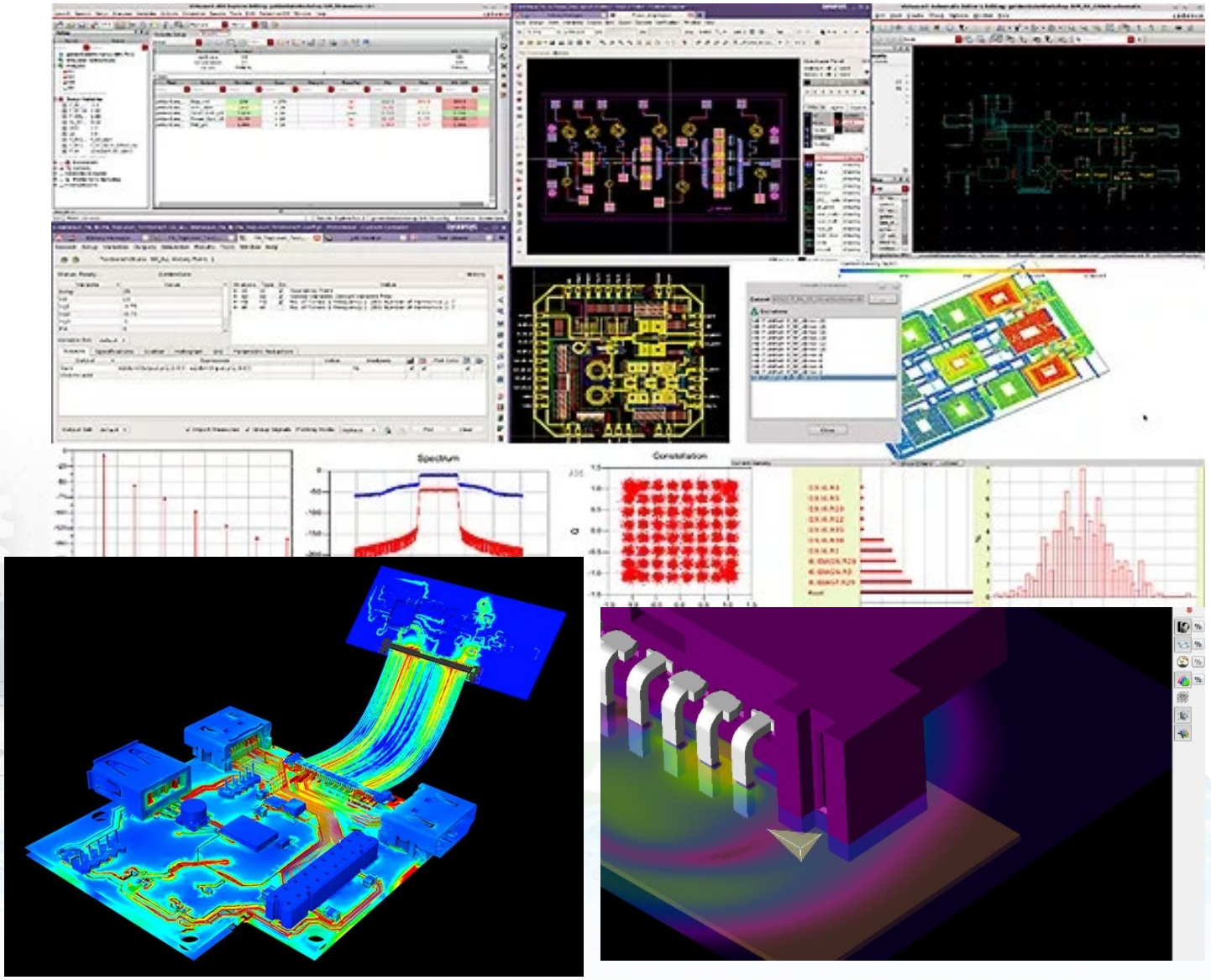


Platform Operator and Combat Training

- Live training of personel in simulated combat scenarios
- Civilian / military Land/Sea/Airborn e platform simulators
- Air Traffic Controller training

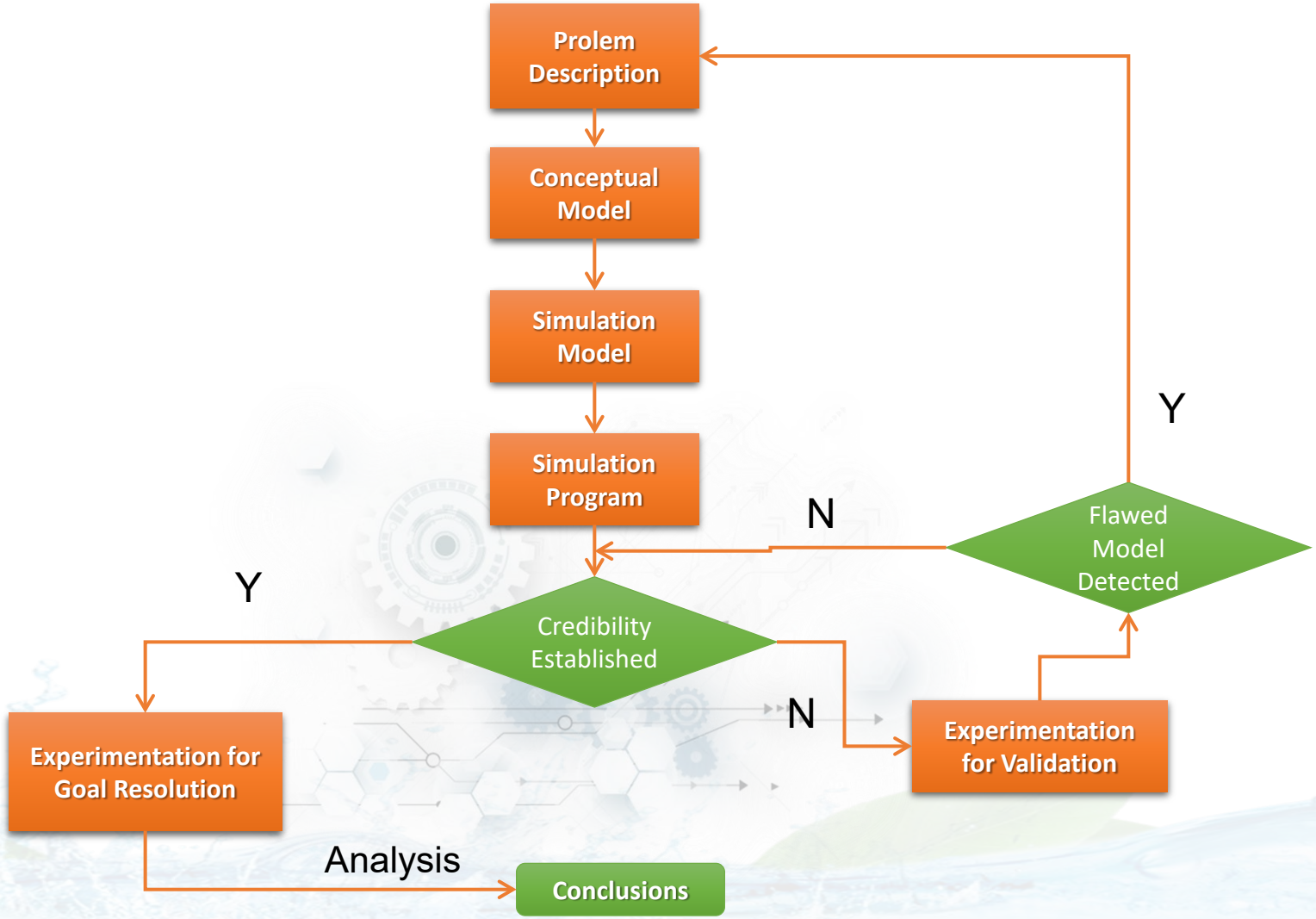
RF/Digital Electronic Circuit Simulations

- Simulating effects of layout parasitics, complex modulated signals, and digital control circuitry
- Functional analysis of circuits
- Finite Difference Time Domain (FDTD) simulation of EM propagation
- Finite Element Method (FEM) 3D EM simulation



Basic Simulation Modeling

Modeling and Simulation Process



1.2 SYSTEMS, MODELS, AND SIMULATION

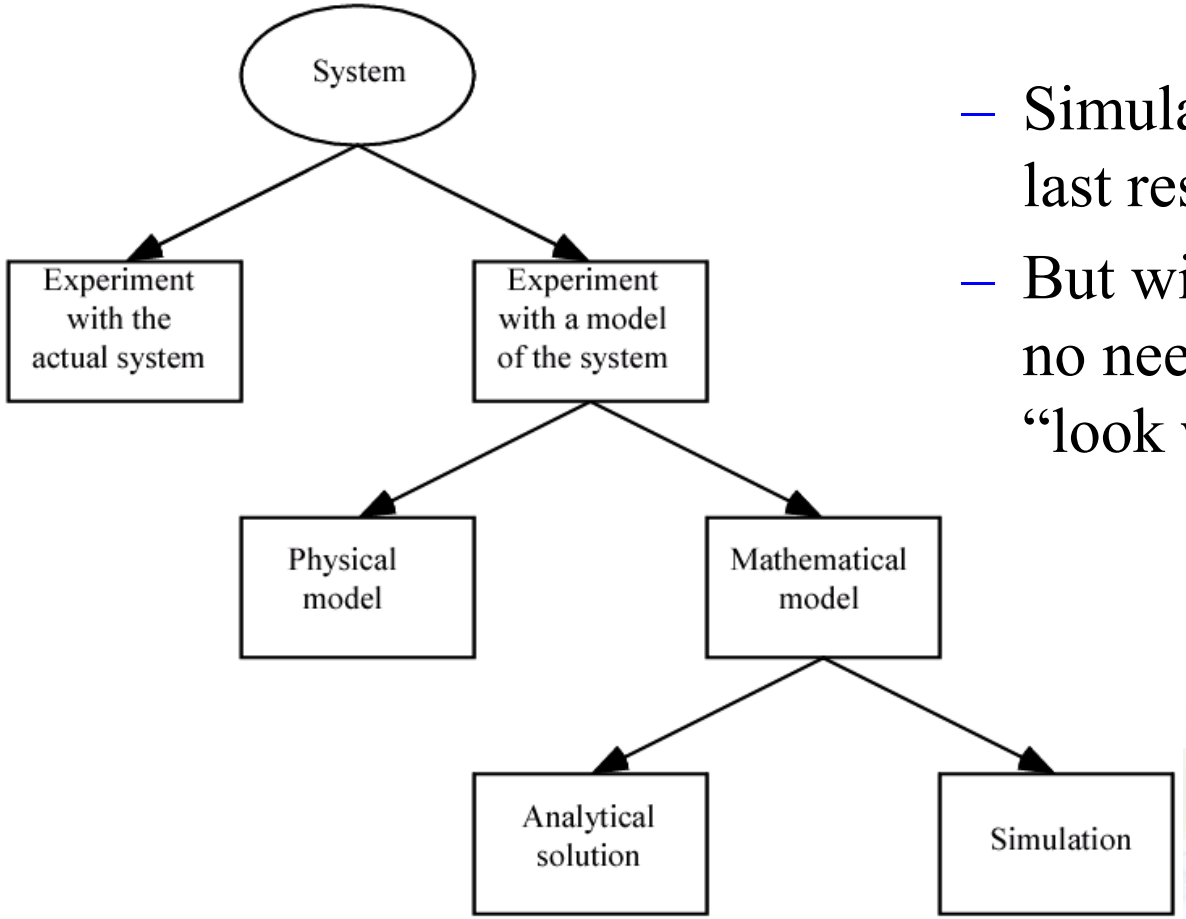
- ***System:*** A collection of entities (people, parts, messages, machines, servers, …) that act and interact together toward some end (Schmidt and Taylor, 1970)
  - In practice, depends on objectives of study
  - Might limit the boundaries (physical and logical) of the system
  - level of detail (e.g., what is an entity?)
  - Usually assume a time element – *dynamic* system
- ***State of a system:*** Collection of variables and their values necessary to describe the system at that time
  - Might depend on desired objectives, output performance measures
  - Example: A Bank model could include number of busy tellers, time of arrival of each customer, etc.

1.2 Systems, Models, and Simulation (cont'd.)

- Types of systems
  - *Discrete*
    - State variables change instantaneously at separated points in time
    - Bank model: State changes occur only when a customer arrives or departs
  - *Continuous*
    - State variables change continuously as a function of time
    - Airplane flight: State variables like position, velocity change continuously
- Many systems are partly discrete, partly continuous

1.2 Systems, Models, and Simulation (cont'd.)

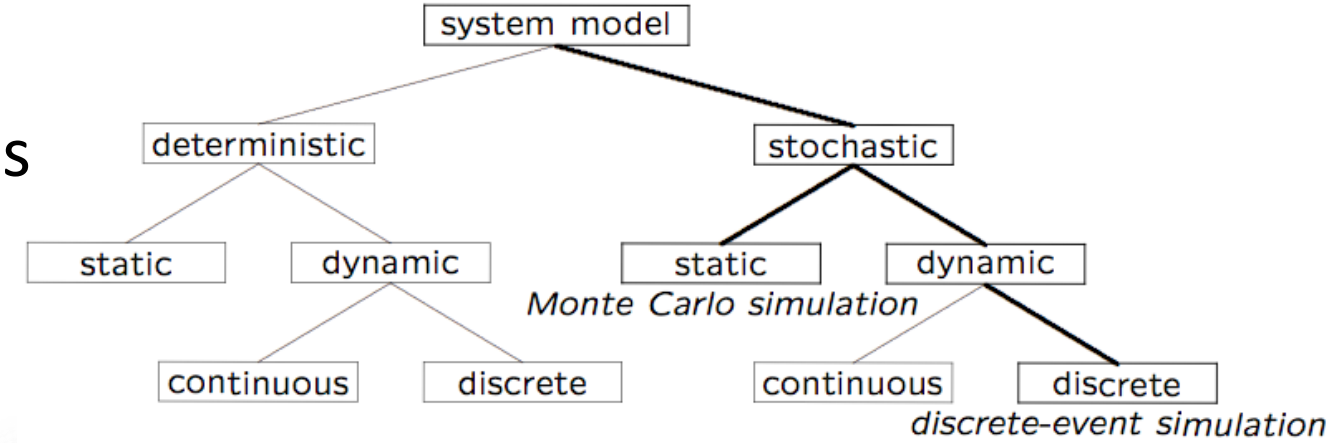
- Ways to study a system



- Simulation is "method of last resort?" Maybe …
- But with simulation there's no need (or less need) to "look where the light is"

1.2 Systems, Models, and Simulation (cont'd.)

- Classification of simulation models
  - *Static* vs. *dynamic*
  - *Deterministic* vs. *stochastic*
  - *Continuous* vs. *discrete*



- Most operational models are **dynamic, stochastic**, and **discrete** – will be called ***Discrete-Event Simulation (DES)*** *models*

We will be focusing on DES models in this course