

New trends, technologies and tools in Modeling and Simulation

Dr. David A. Cook
Department of Computer Science
Stephen F. Austin State University
Nacogdoches, TX 75962

cookda@sfasu.edu



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What is Simulation?

- *Simulation* – very broad term – methods and applications to imitate or mimic real systems, usually via computer
- Applies in many fields, industries
- Very popular, powerful way to save time and money.
- When used effectively, speeds up “model to reality” by allowing visualization and validity testing of the model

Where is simulation used?

- Manufacturing facility
- Banks
- Airport operations (passengers, security, crews, baggage)
- Transportation/logistics/distribution operation
- Hospital facilities (ERs, operating room, admissions)
- Computer networks
- Freeways
- Medical and Surgical Training
- Fast-food restaurants, supermarkets
- Theme park
- Emergency-response system
- Shipping ports, berths
- Military combat, logistics

Why use simulation?

- Study system – measure, improve, design, control
 - Maybe just investigate changes to actual system
 - Advantage – unquestionably looking at the right thing
 - But often impossible in reality with actual system
 - System doesn't exist
 - Would be disruptive, expensive, dangerous
 - Would result in loss of lives

Using Computers to Simulate

- General-purpose languages (C, C++, C#, Java, Matlab, FORTRAN, others)
 - Tedious, low-level, error-prone
 - But, almost complete flexibility
- Support packages for general-purpose languages
 - Subroutines for list processing, bookkeeping, time advance
 - Widely distributed, widely modified
- Spreadsheets
 - Usually static models (only *very* simple dynamic models)
 - Financial scenarios, distribution sampling, SQC
 - Examples in Chapter 2 (one static, one dynamic)
 - Add-ins are available (@RISK, Crystal Ball)

Using Computers to Simulate (cont'd.)

- Simulation languages
 - GPSS, SLX,
 - Popular, some still in use
 - Learning curve for features, effective use, syntax
- High-level simulators
 - Very easy, graphical interface
 - Domain-restricted (manufacturing, communications)
 - Limited flexibility — need to make sure model is valid

When Simulations are Used

- Use of simulation has evolved with hardware, software
- Early years (1950s – 1960s)
 - Very expensive, specialized tool
 - Required big computers, special training
 - Mostly in FORTRAN (or even Assembler)
 - Processing cost as high as \$1000/hour for a sub-PC level machine

When Simulations are Used (cont'd.)

- Formative years (1970s – early 1980s)
 - Computers got faster, cheaper
 - Value of simulation more widely recognized
 - Simulation software improved, but still languages to be learned, typed, batch processed
 - Often used to clean up “disasters” in auto, aerospace industries
 - Car plant; heavy demand for certain model
 - Line underperforming
 - Simulated, problem identified
 - But demand had dried up — simulation was too late

When Simulations are Used (cont'd.)

- Recent past (late 1980s – mid 2000s)
 - Microcomputer power
 - Software expanded into GUIs, animation
 - Wider acceptance across more areas
 - Traditional manufacturing applications
 - Services
 - Health care
 - “Business processes”
 - Still mostly in large firms
 - Simulation is often part of “specs”

The Search:: 1955 - 60

- 1955 – 1960: Fortran was King, General Simulation Program was envisioned. Fortran based (with reusable functions)
- 1960s: GPSS (IBM, queueing models). Also SIMSCRIPT and SIMSCRIPT II (Rand Corp. and USAF). GASP (Algol and Fortran), and SIMULA (mostly Europe).
- 1970s – GPSS/H, GASP IV, SIMULA
 - Attempt to simplify the modeling process
 - Program generators – severe limitations

Next Leap Forward – the 1980s

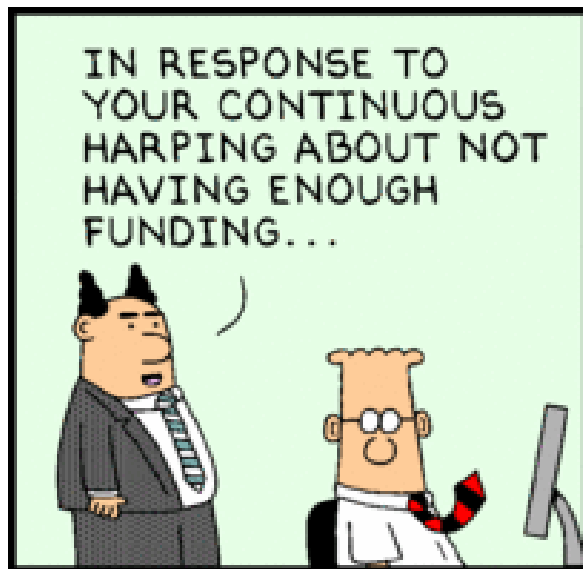
- Movement to mini and PC computers
- SLAM II (descendant of GASP)
 - 3 world views
 - Event, Network, Continuous
- SIMAN (descendant of GASP)
 - General Modeling + Block Diagrams
 - 1st first major language - PC & MS-DOS
 - Fortran functions w/ Fortran programming

1980s – Present Integrated Environments

- Growth on PC's
- Simulation Environments
 - GUI
 - Animation
 - Data analyzers

The Future (NOW)

- Virtual Reality
- Improved Interfaces
- Better Animation
- Agent-based Modeling



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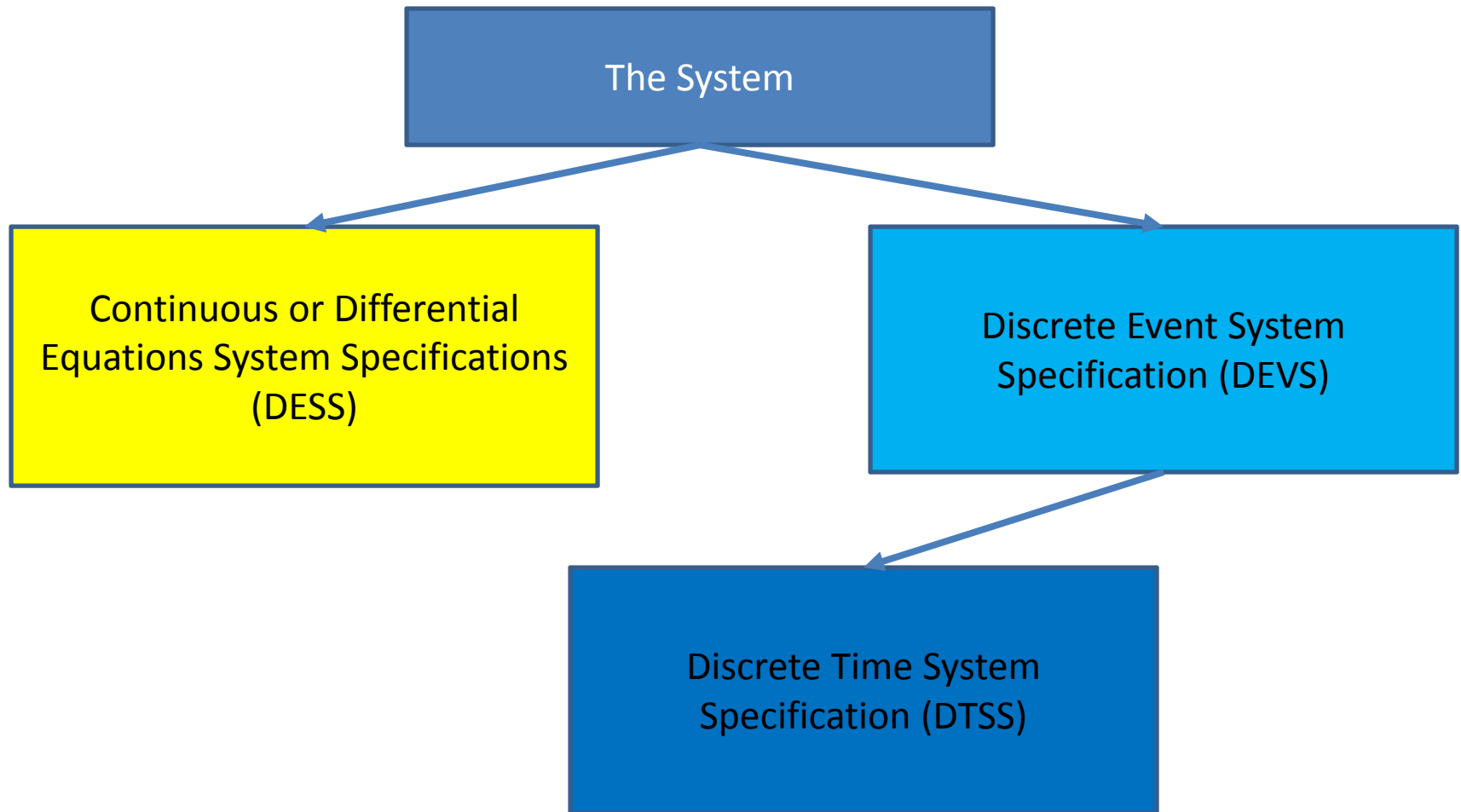
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How do you know the model is correct?

- Simulation Validity
 - Structural Simulation
 - Behavioral Simulation
 - Predictive Simulation
- Simulation Verification
 - How the simulation is built
 - What estimates are used
 - What are the unknowns
 - How accurate and of what fidelity are the results

Types of Simulation



Dynamic Simulations

- Can be
 - Continuous – changes constantly over time. For any exact time (i.e. $t = 1$ hour, 2 minutes, 13.9987665 seconds) there is a (potentially) exact value
 - Discrete – changes occur at specific and separated points in time. For example, a customer can arrive at a bank at 3:14:15, but not again until 3:14:16. It is “impossible” (i.e. a non-event) for a customer to arrive halfway between two time steps.
- Continuous and Dynamic simulations (mixed models) are possible

Discrete Event Simulations

- Discrete – changes occur at specific and separated points in time.
- For example, a customer can arrive at a bank at 3:14:15, but not again until 3:14:16. It is “impossible” (i.e. a non-event) for a customer to arrive halfway between two time steps.

Deterministic vs. Stochastic

- Deterministic – there is no element of randomness in the simulation.
- Stochastic – some part of the simulation is based on randomness. Randomness can be event-based (customer entrance time) or probability-based (the odds of an event, like a structural failure) occurring.

And the difference...

- DESS – specific time $dq/dt = a*x + b$ for all t
 - Every time t has a specific value, not necessarily dependent upon any other time t
- DTSS – $q(t + 1) = \text{some function of } q(t)$
 - Every time has value (state) based on previous time
- DEVS – there is a time t_n of the next event.
 - The state at the next event is a function of all events that have preceded the event.

All good simulations based on a model

- A simulation must be designed to either
 - Model a real system. The system can then be used for comparisons and verification and validation
 - Model an imaginary system (that might or might not be built in the future). Verification and validation much harder.

How do you know the model is correct?

- Validity
 - Structural Simulation
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 - Predictive Simulation
- Verification
 - How the simulation is built
 - What estimates are used
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What's new in Simulation today?

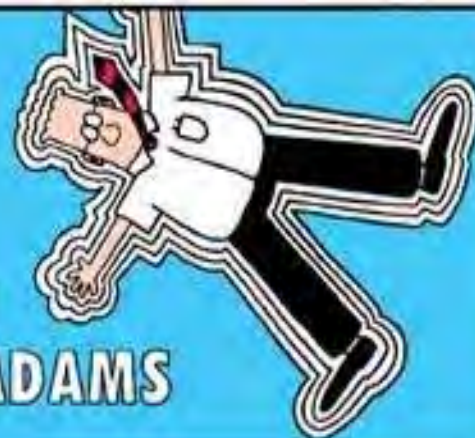
- Graphical simulation languages can be used to create the model, run the simulation, and explore the outputs.
- GUIs of varying levels of detail and specificity can be used to build complex graphical models

How to build a M&S

- Hierarchical structure
 - Multiple levels of modeling
 - Mix different modeling levels together in same model
 - Often, start high then go lower as needed
- Get ease-of-use advantage of simulators without sacrificing modeling flexibility



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I'LL NEED TO KNOW YOUR REQUIREMENTS BEFORE I START TO DESIGN THE SIMULATION.



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FIRST OF ALL, WHAT ARE YOU TRYING TO ACCOMPLISH?



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I MEAN WHAT ARE YOU TRYING TO ACCOMPLISH WITH THE SIMULATION.



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I WON'T KNOW WHAT I CAN ACCOMPLISH UNTIL YOU TELL ME WHAT THE SIMULATION CAN DO.



TRY TO GET THIS CONCEPT THROUGH YOUR THICK SKULL: THE SIMULATION CAN DO WHATEVER I DESIGN IT TO DO!



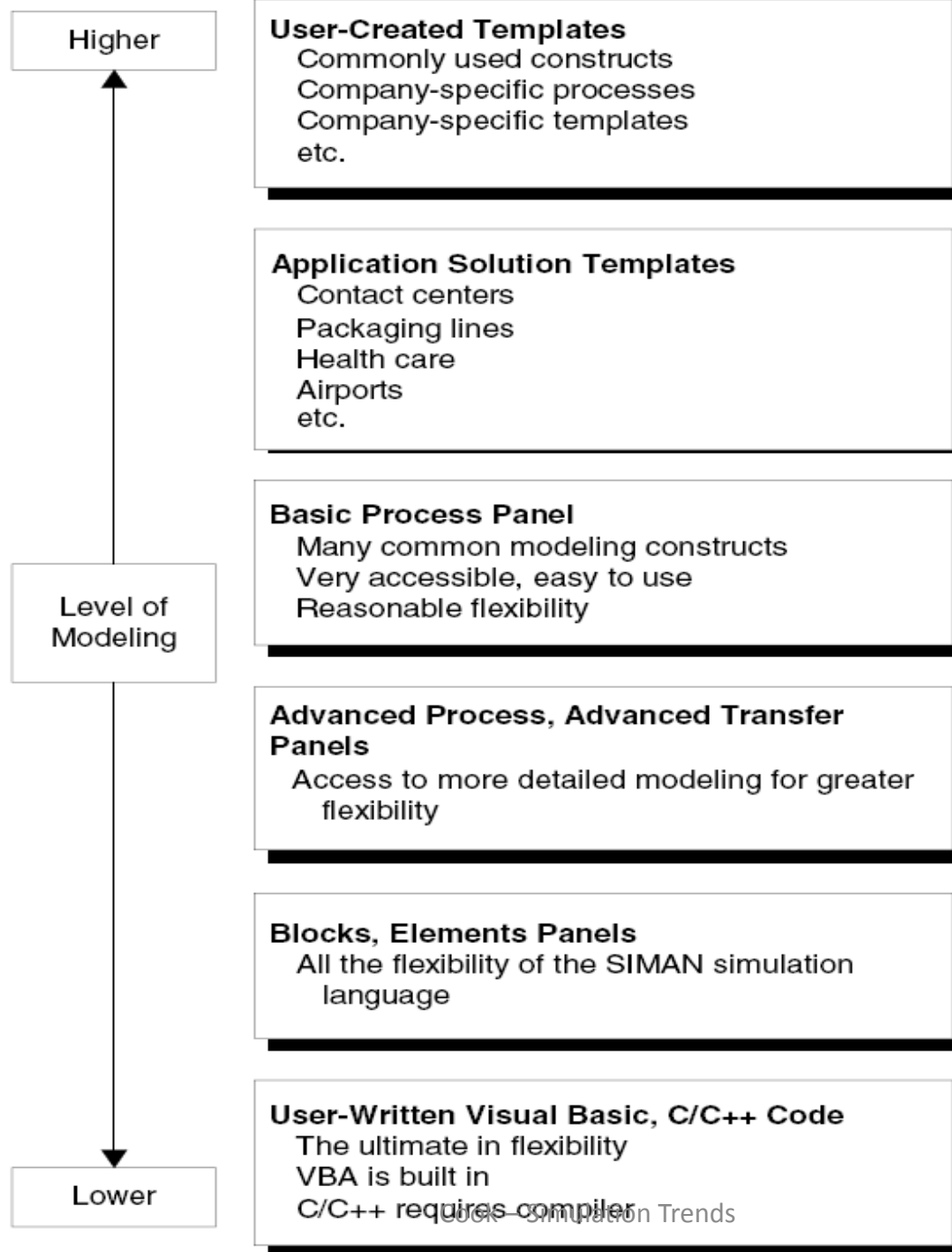
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CAN YOU DESIGN IT TO TELL YOU MY REQUIREMENTS?





A single graphical user interface consistent at any level of modeling

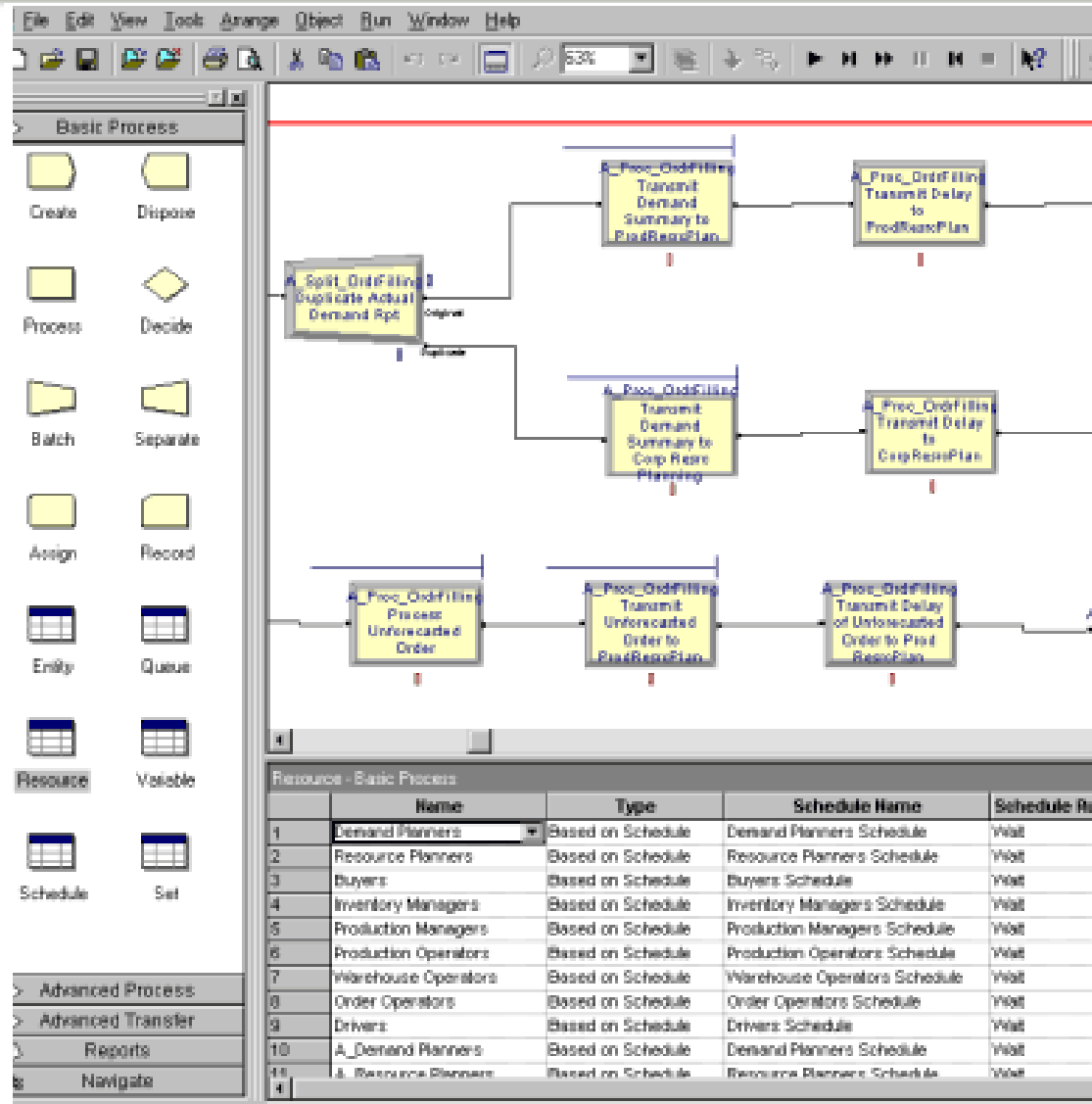
Visual and Graphical M&S Trends

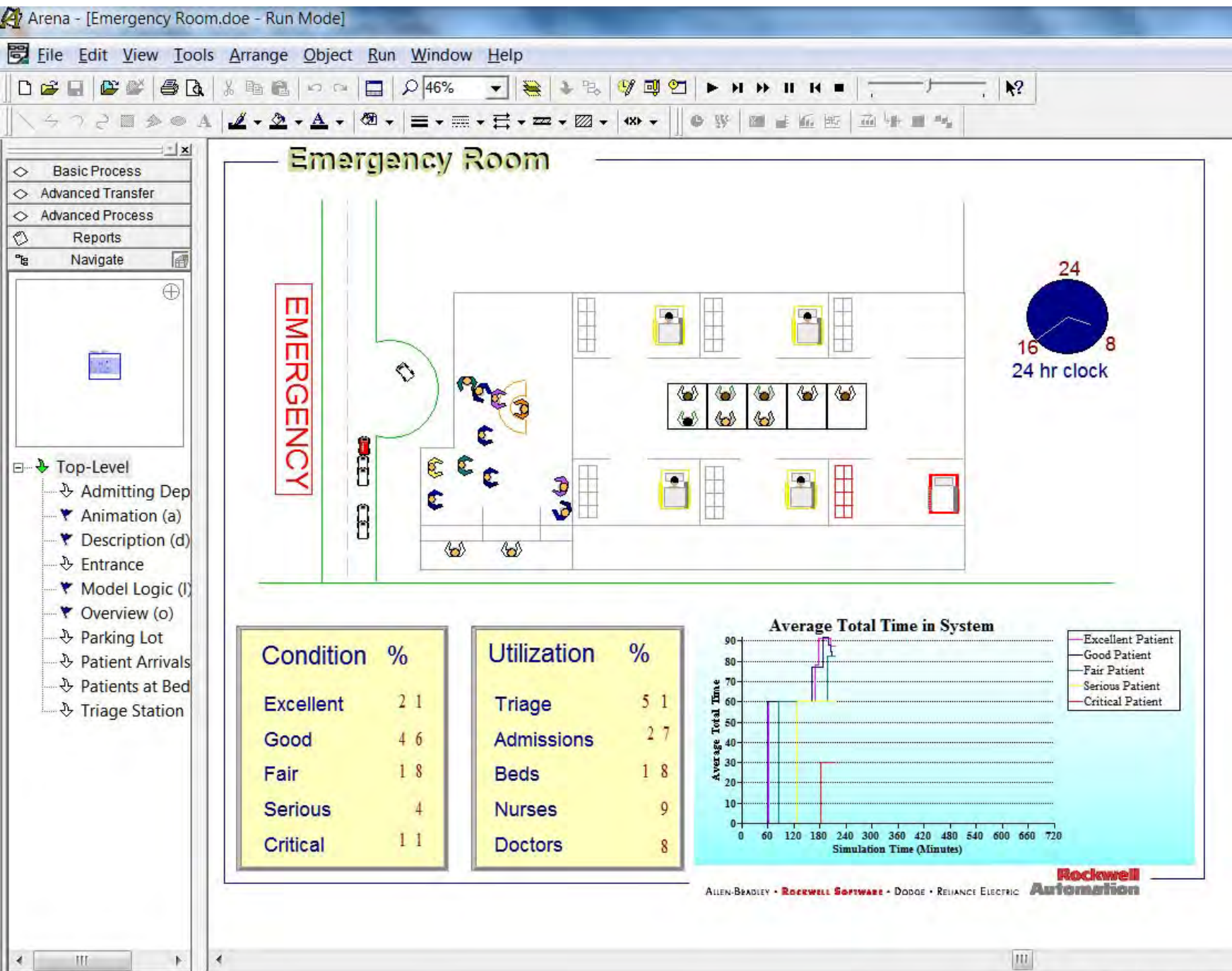
- **Highly realistic training scenarios**
- **Training realistic than games designed for entertainment**
- **Focus on end-user experience that matches real life (virtual reality)**

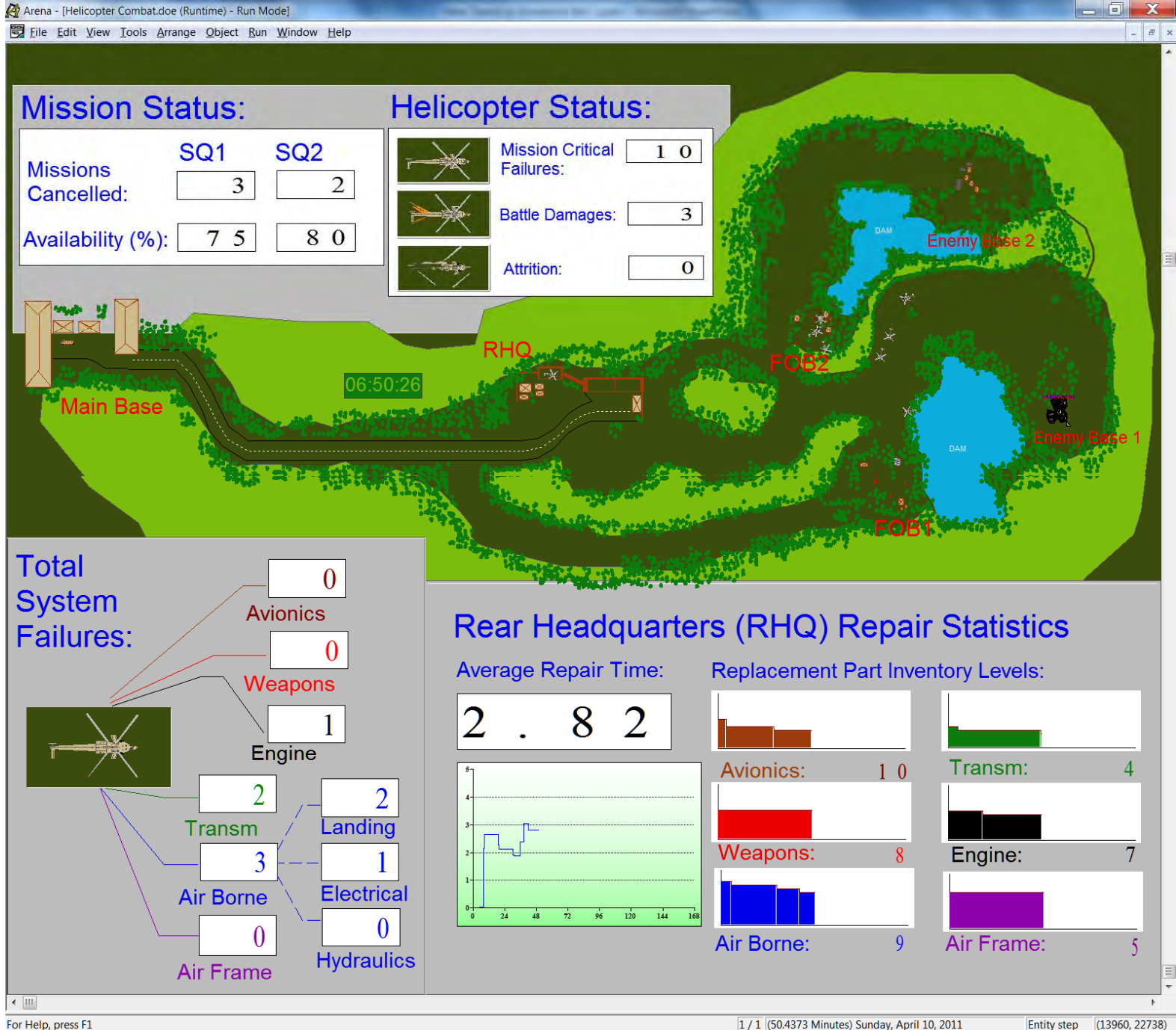
However = lots of \$\$s NOT needed!

- Simple languages and available tools let you transform models and simulations into easy to visualize products that can be used for
 - Proof of concept
 - Ease of user understanding
 - Graphical display of formerly table-driven data
- This speeds up the “model to reality” timeline

One Example - Arena







Questions or comments??

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