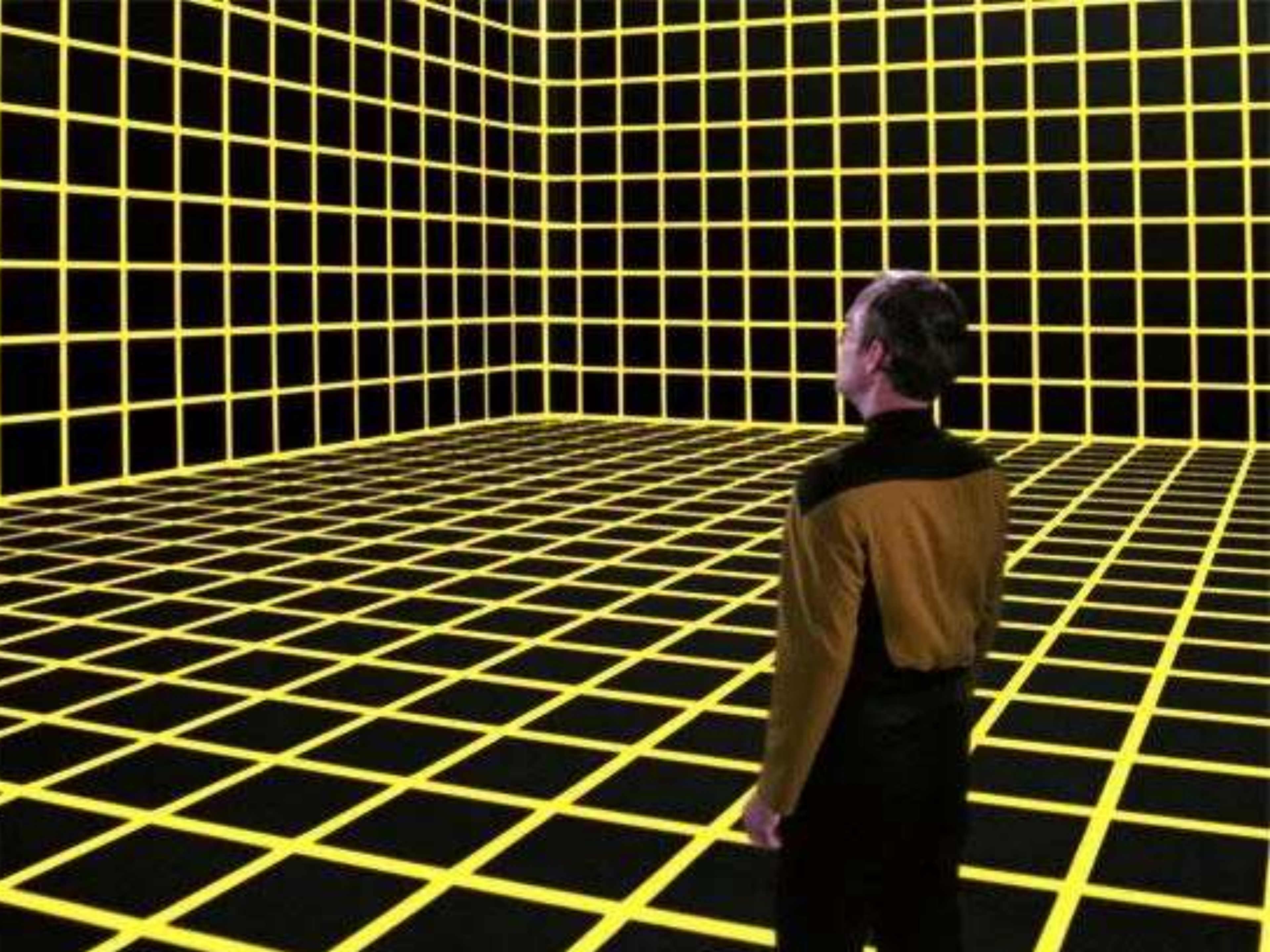
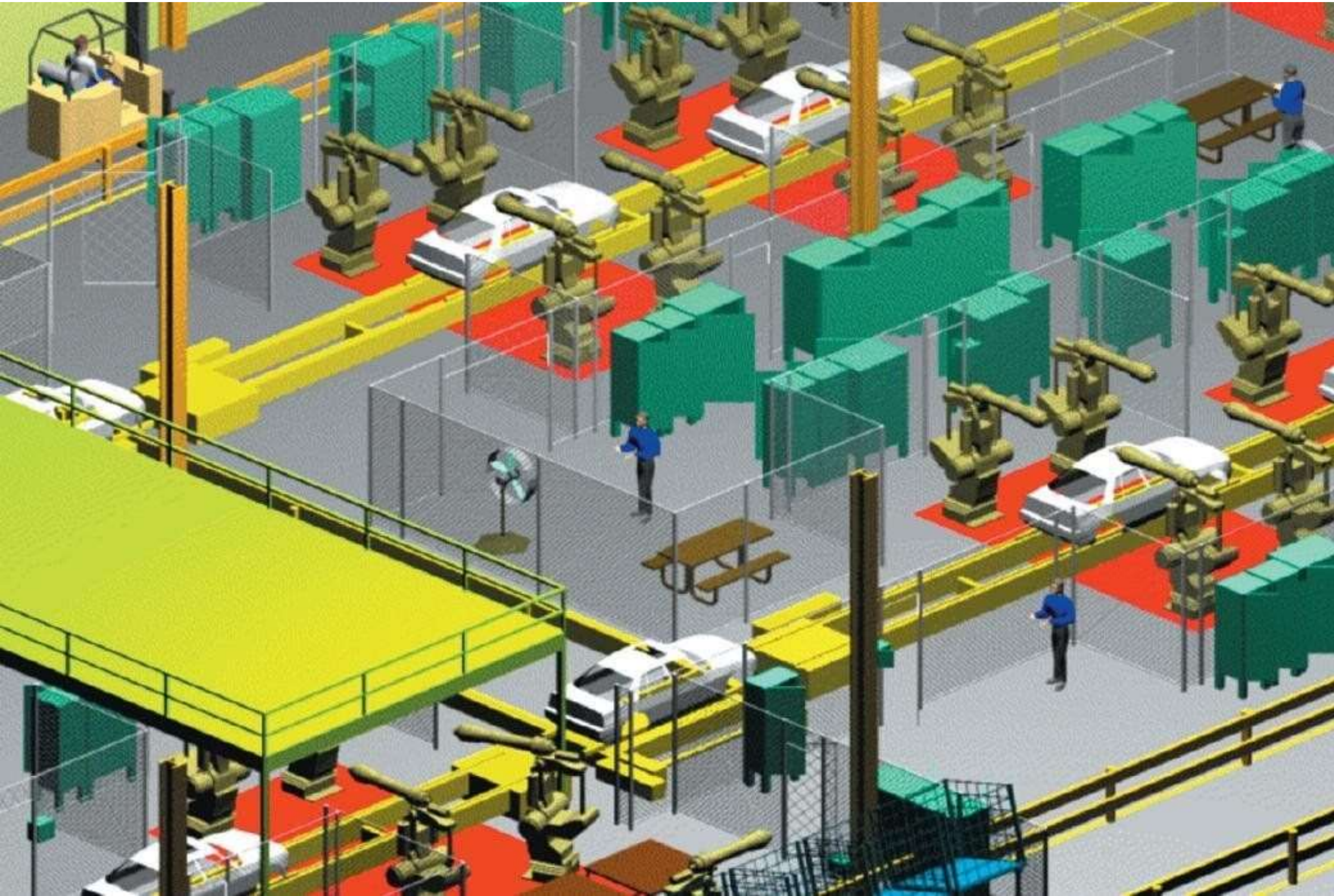


SIMULATION-AN OVERVIEW

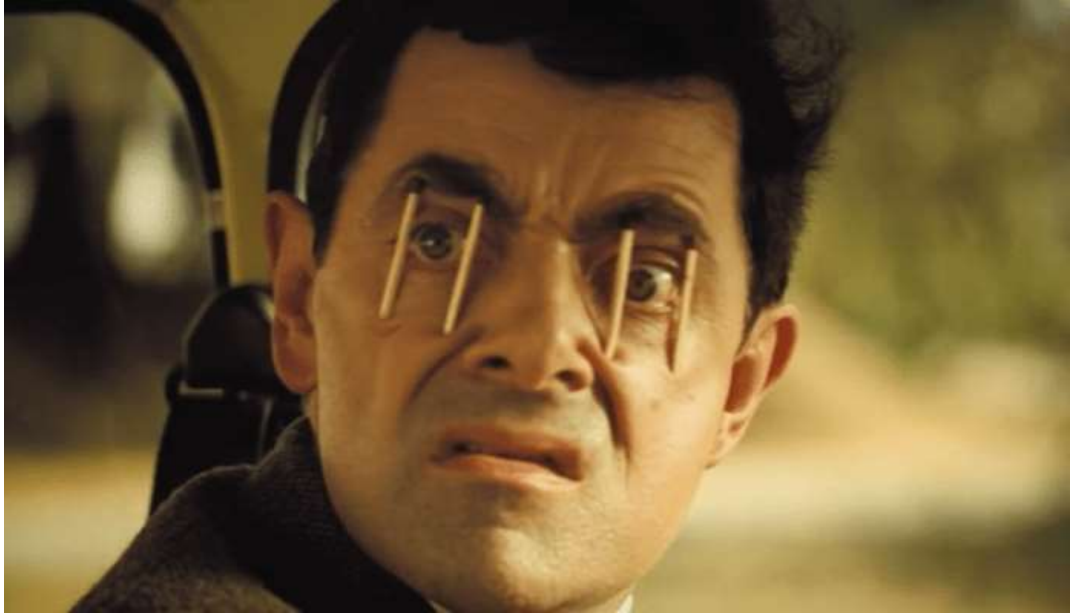
DISCRETE EVENT SIMULATION




NO, NOTHING LIKE THIS

OR THIS

BY THE WAY, YOU MUST SIMULATE

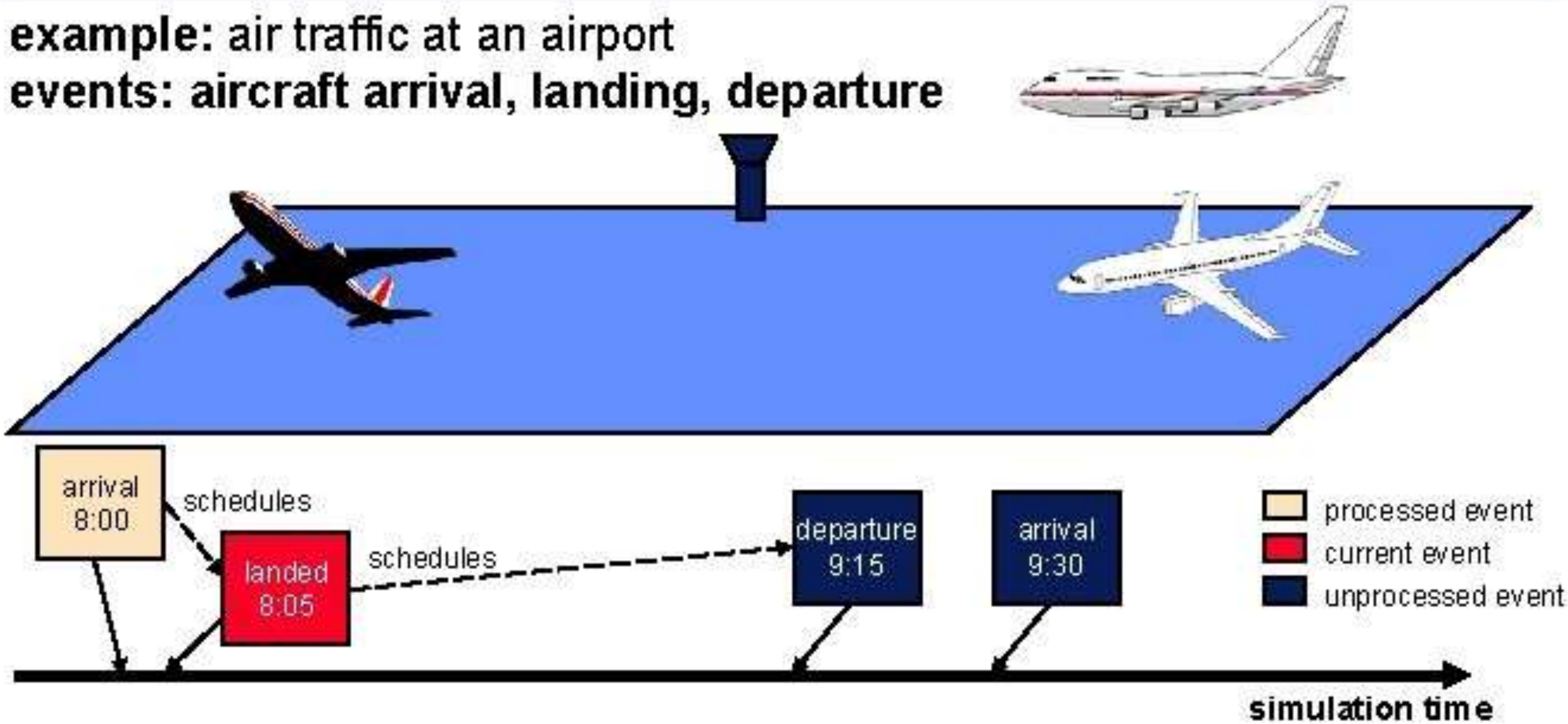


THAT YOU ARE AWAKE

DURING THIS PRESENTATION

Discrete Event Simulation (Example)

example: air traffic at an airport
events: aircraft arrival, landing, departure



- Unprocessed events are stored in a pending event list
- Events are processed in time stamp order

The importance of Modeling and Simulation

“Science used to be composed of two endeavors, theory and experiment. Now it has a third component: computer simulation, which links the other two.”

Rita R. Colwell, Ph.D.
Director, National Science Foundation
1998-2004

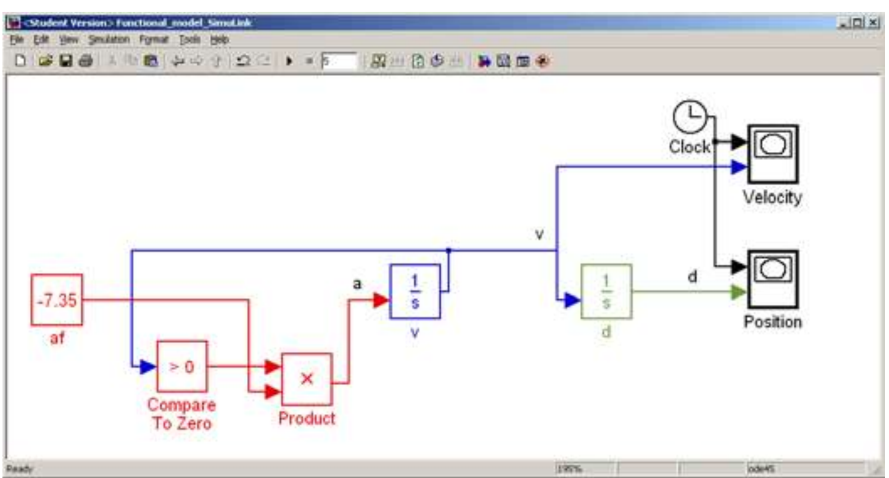
“Through computer modeling, we understand the deep implications of our very detailed observational data and formulate new theories to stimulate further observations.”

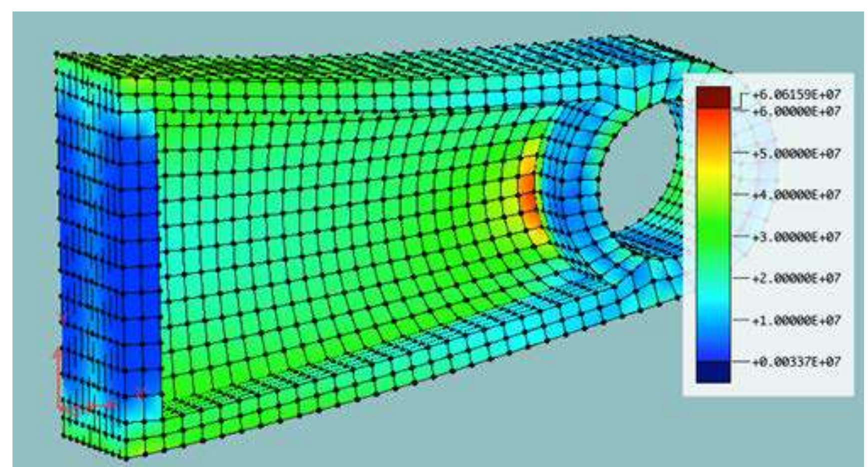
National Research Council

Modeling methods

- Physical models*
- Conceptual models
- Declarative models
- Functional models
- Constraint models
- Spatial models
- Multimodels

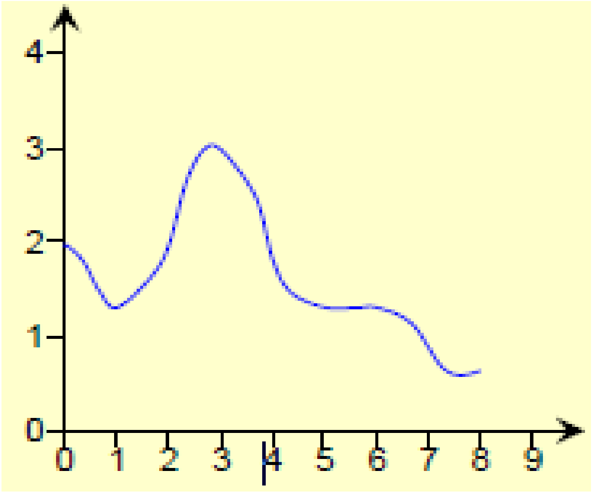
- **DES is one of many modeling methods**



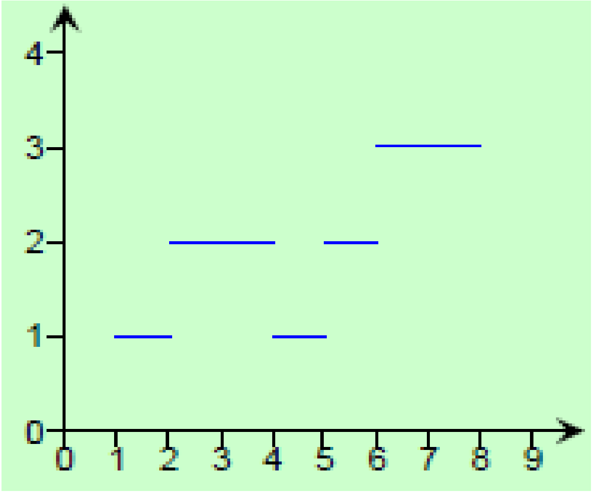


What is discrete event simulation?

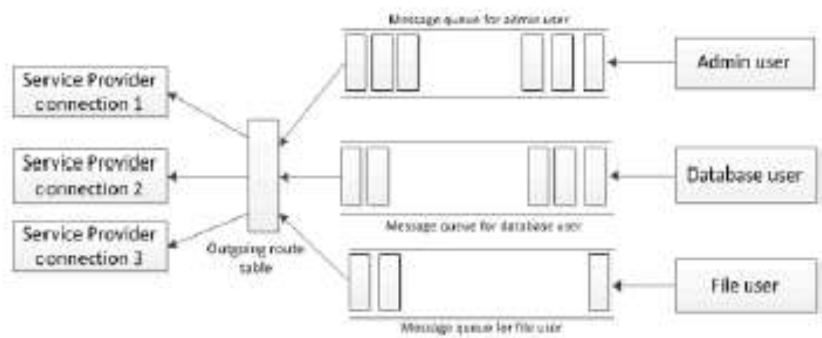
- DES is not:
  - Time-stepped
  - Continuous (or pseudo-continuous)
  - Physics-based



- DES is:
  - Event-driven
  - Discrete
  - Probability-based

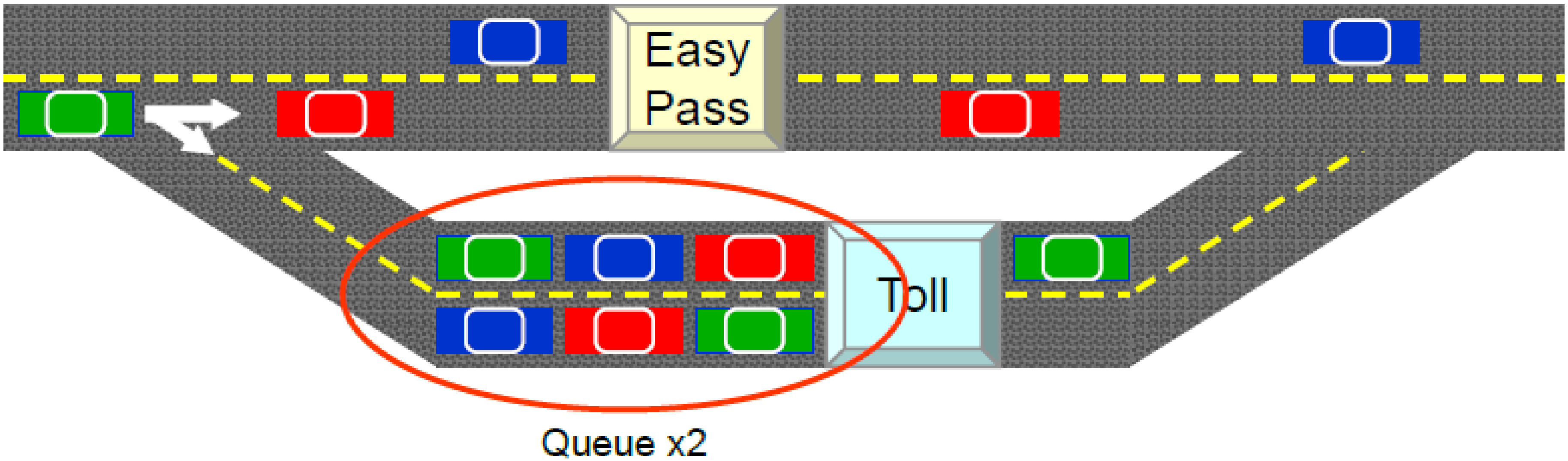


Queues and servers



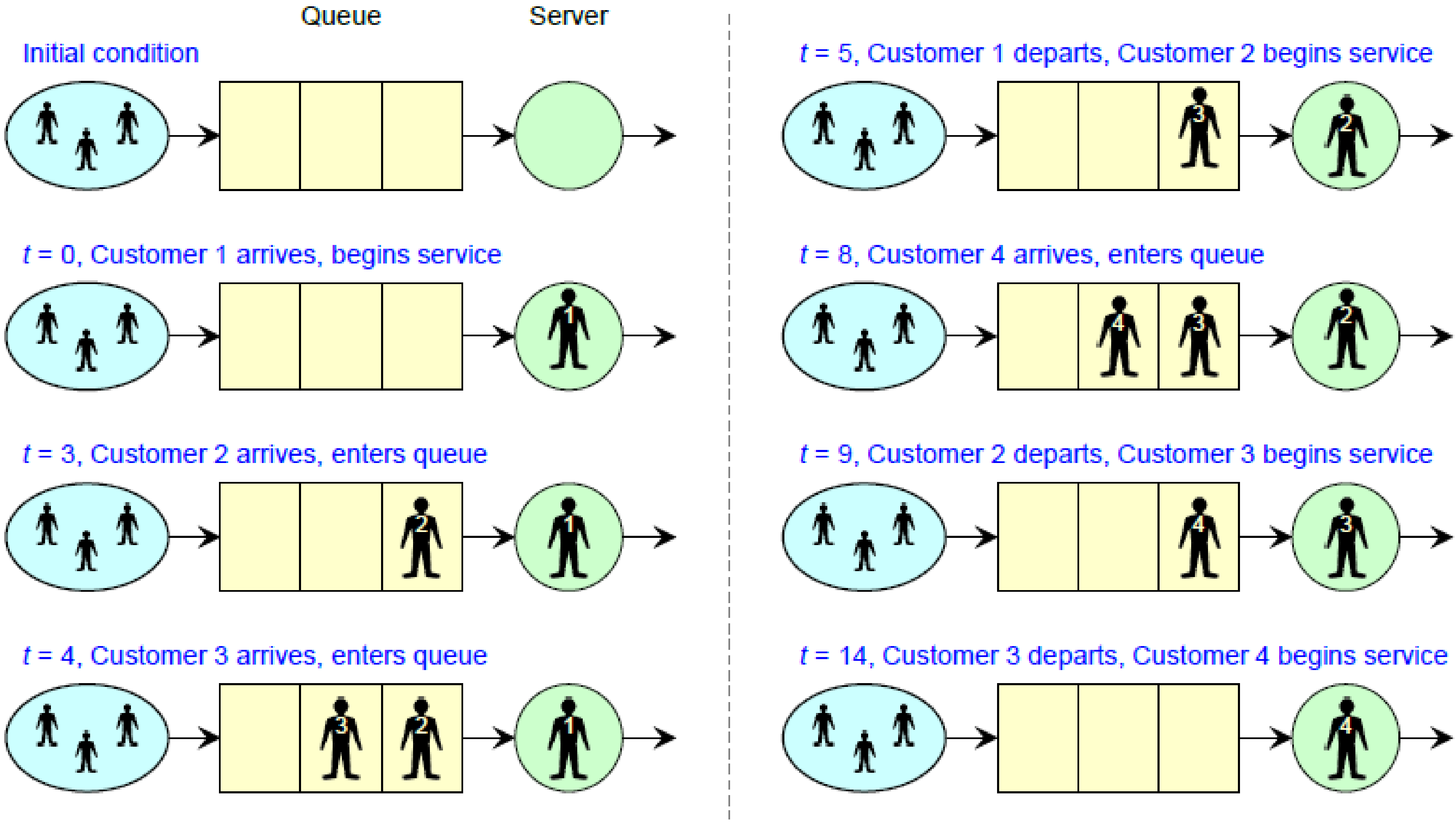
Example queueing system

Easy Pass toll station waiting lines



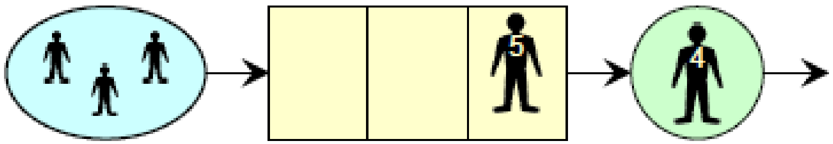
- Cars queue at toll station
- If queue length exceeds lane capacity, danger 
- Question: expected queue length?
- Question: construction expense vs. revenue loss?

A sequence of events, 1 of 2

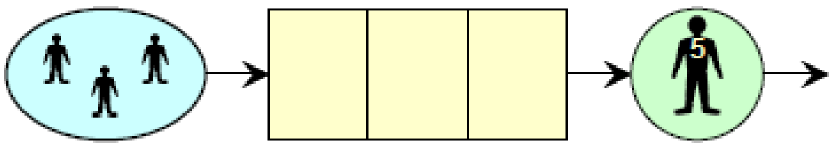


A sequence of events, 2 of 2

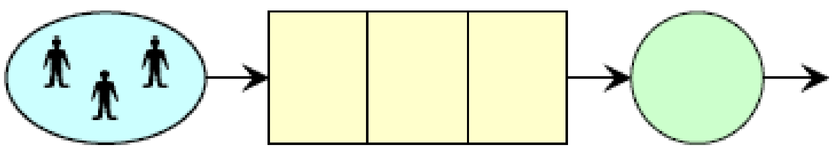
t = 16, Customer 5 arrives, enters queue



t = 17, Customer 4 departs, Customer 5 begins service



t = 22, Customer 5 departs, simulation ends



- How long did the queue get?
- What was the average queue length?
- What long did a customer wait for service, on average?
- How long did it take to service a customer, on average?

Analyzing the example simulation

Maximum queue length = 2
Mean queue length = 0.636

Mean waiting time = 2.8
Mean service time = 4.4

Time	Event	Queue length after event	Queue length * Time
0	1 arrives	0	0
3	2 arrives	1	1
4	3 arrives	2	2
5	1 departs	1	3
8	4 arrives	2	2
9	2 departs	1	5
14	3 departs	0	0
16	5 arrives	1	1
17	4 departs	0	0
22	5 departs	0	0
		Sum	14
		Mean	0.636

Customer	Arrive	Begin service	End service	Wait time	Service time
1	0	0	5	0	5
2	3	5	9	2	4
3	4	9	14	5	5
4	8	14	17	6	3
5	16	17	22	1	5
			Sum	14	22
			Mean	2.8	4.4

Concepts

- Model: representation of something else
- Simulation: executing a model over time

$$R = 2.59 \times \sqrt[4]{\sigma \times \left(\frac{\log^{-1}\left(\frac{ERP_t}{10}\right) \log^{-1}\left(\frac{G_r}{10}\right) \log^{-1}\left(\frac{MDS_r}{10}\right)}{\log^{-1}\left(\frac{FEL_r}{10}\right) F_t^2} \right)}$$

Model

Simulation

Both

Definition

Model.

A physical, mathematical, or otherwise logical representation of a system, entity, phenomenon, or process.

To an observer B, an object A^* is a model of an object A to the extent that B can use A^* to answer questions that interest him about A.

- Representation of something else, often a “real-world” system

- Some aspects of the modeled system are represented in the model, others not

Example model

Equation describing vertical height of an object moving under gravity.

$$h(t) = -4.9t^2 + vt + s$$

h = height (meters)
t = time in motion (seconds)
v = initial velocity (meters per second)
s = initial height (meters)

Note that at $t = 0$, $h = s$, as expected.

$$h(t) = -4.9t^2 + vt + s$$

Model does represent

- Height of object (output of model)
- Mass of earth (as the -4.9 coefficient)
- Initial state, as velocity v and height s

Model does not represent

- Air resistance (not included in model)
- Location (assumed to be near surface of earth)
- Mass of object (not included in model)

Example model

Program that calculates the height of an object moving under gravity.

```
/* Height of an object moving under gravity. */
/* Initial velocity v and height s constants. */
void main()
{
        float h, v = 100.0, s = 1000.0;
        int t;
        for (t = 0, h = s; h >= 0.0; t++)
        {
                h = (-4.9 * t * t) + (v * t) + s;
                cout << "Height at time " << t << " = " << h <<endl;
        }
}
```

Definition

Simulation

[Executing] a model over time.

The imitation of the operation of a real-world process or system over time.

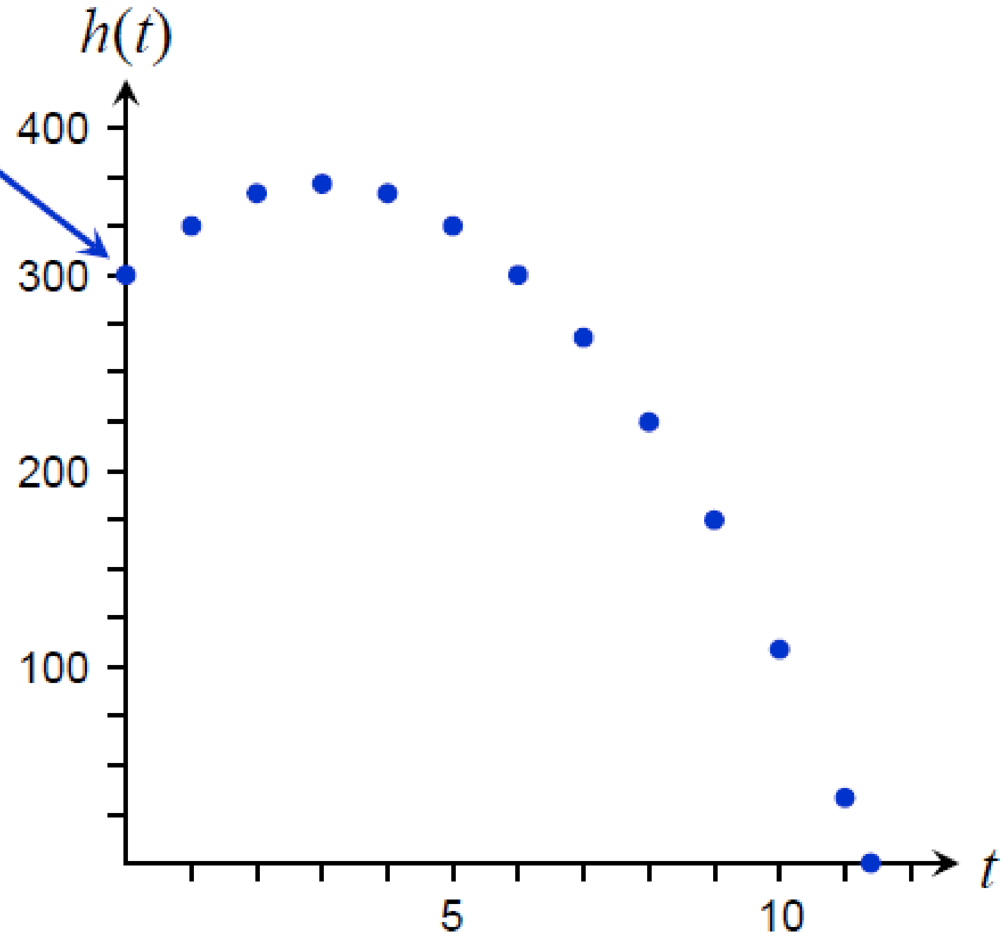
A technique for testing, analysis, or training in which real world systems are used, or where a model reproduces real world and conceptual systems.

Example simulation

Model: $h(t) = -4.9t^2 + vt + s$ Data: $v = 30$, $s = 300$

t	$h(t)$
0	300.0
1	325.1
2	340.4
3	345.9
4	341.6
5	327.5
6	303.6
7	269.9
8	226.4
9	173.1
10	110.0
11	37.1
11.46	0

Start state



Simulation vs reality

Real-world system in start state → **Time** (*Physics*) → Real-world system in end state

Modeling | Initialization | Interpretation | Validation

Model in start state → **Simulation** (*Computation*) → Model in end state

$h(t) = -4.9t^2 + vt + s$

$300 = -4.9(0)^2 + 30(0) + 300$

$h(t) = -4.9t^2 + vt + s$

$0 = -4.9(11.46)^2 + 30(11.46) + 300$

Model classification

Simuland. The subject of a model or simulation

Simuland

Experiment with the simuland

Experiment with a model of the simuland

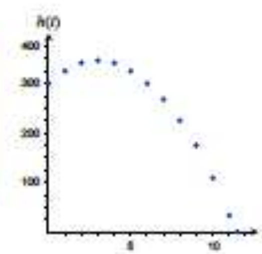
Physical model

Mathematical or logical model

$$h(t) = -4.9t^2 + vt + s$$

Analytical model

Simulation model



Simulation uses and notes

- Uses of simulation
  - Investigate “what if” questions about system
  - Study proposed changes to system to predict impact
  - Evaluate system designs before system is built

- **Notes**
  - Data about system collected during simulation
  - Measures of performance describe system
  - Some models can be “solved” without simulation

Appropriate uses of simulation

- Experimentation with complex system’s internal interactions
- Observation of effects of changes to system structure
- Learning about system through process of building model
- Studying system response to variations in input values
- Confirmation of solutions reached analytically
- Experiment with new designs or policies
- Determine new system requirements by simulating variations
- Provide training without disrupting real system
- Animate system in execution so as to provide insight

Simulation is not appropriate when …

- Problem can be solved directly
- Direct experiments are less expensive
- Cost of simulation study exceeds potential savings
- Financial resources for the study are not available
- Calendar time for the study is not available
- Data describing system and its environment are not available
- Managers or users have unreasonable expectations
- System behavior is too complex to model

Typical applications areas for DES

- Manufacturing processes
- Business processes
- Construction and project management
- Logistics, supply chain, distribution
- Health care
- Computer and communications networks
- Others

Current General Trends

Risk Analysis

- Insurance, options pricing, portfolio analysis

Call Center Analysis

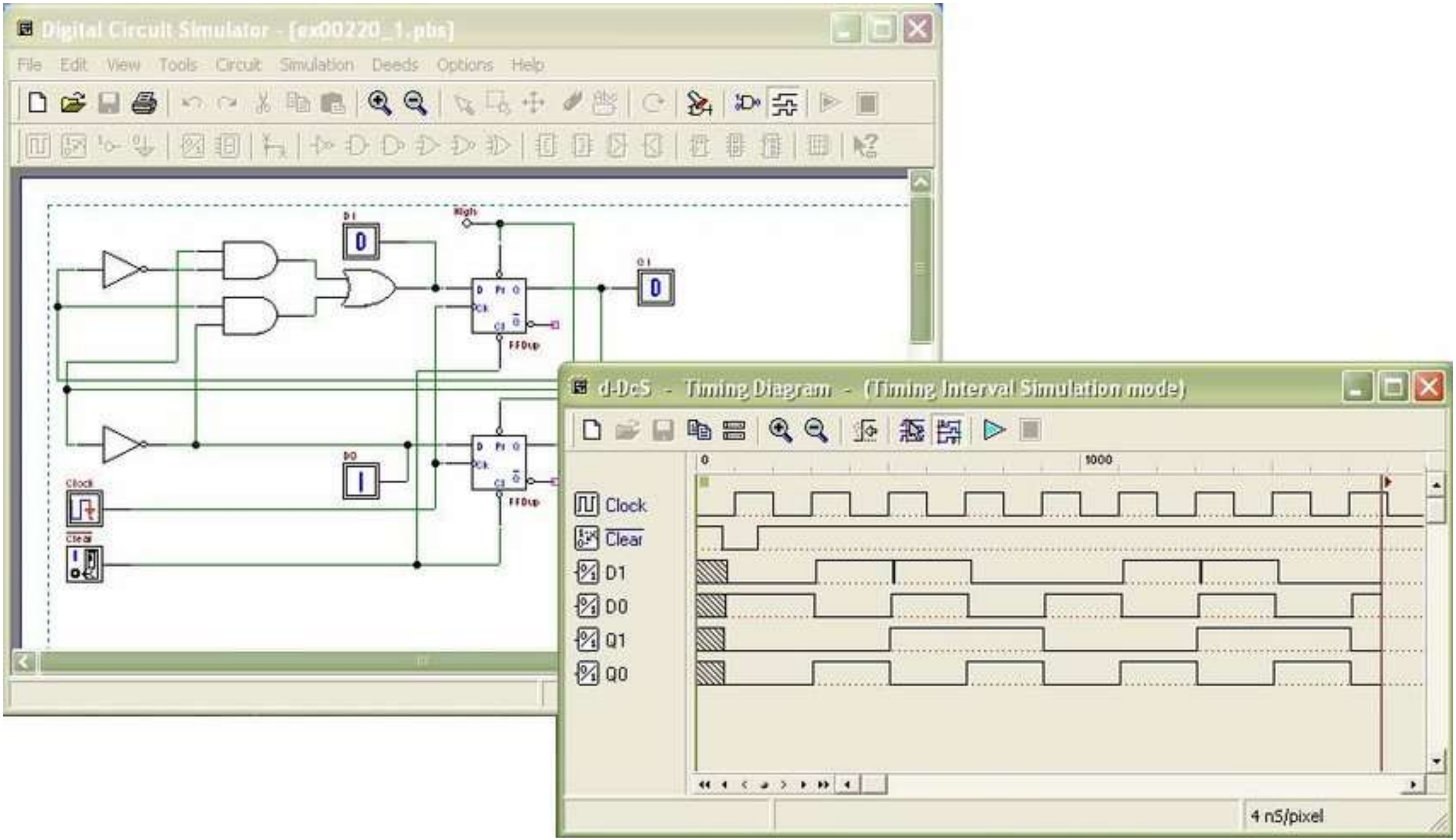
Large Scale Systems

- Internet backbones, wireless networks, supply chains

Automated Materials Handling (AMHS)

- Control system sw - emulator

Ready for Logic Design?



Digital Circuit Simulator - [ex00220_1.pbs]
File Edit View Tools Circuit Simulation Deeds Options Help
D1
High
Q1
D0
Clock
Clear
FFDup
d-DcS - Timing Diagram - (Timing Interval Simulation mode)
0
1000
Clock
Clear
D1
D0
Q1
Q0
4 nS/pixel

Just a few others

Cantera - chemical kinetics.
Celestia - a 3D astronomy program.
CP2K - molecular dynamics program.
DWSIM - chemical process simulator.
FlightGear -atmospheric and orbital flight simulator
FreeFem++ - multiphysics Finite Element Analysis software.
ns-3 - network simulator.
Simulation of Urban MObility - traffic simulation package.
SOFA - multi-physics simulation with an emphasis on medical simulation.
SU2 code - computational fluid dynamics simulation and optimal shape design.
Step - two-dimensional physics simulation engine (KDE)..
UrbanSim –land use, transportation and environmental planning

Questions?