

SEN9110 Simulation Masterclass

13. Simulation Languages (1)

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Brightspace: SEN9110

Agenda

- Simulation Language History

Paper: Richard E. Nance. Simulation Programming Languages: An Abridged History. In: C. Alexopoulos, K. Kang, W. R. Lilegdon, and D. Goldsman (Eds.). Proceedings of the 1995 Winter Simulation Conference. IEEE, 1995. pp. 1307-1313.

Paper: Ole-Johan Dahl and Kristen Nygaard. SIMULA - An ALGOL-based Simulation Language. Communications of the ACM, Vol 9, No 9, 1966. pp. 671-678.

- Simulation Language (Environment) demonstrations and comparison [1]
 - Arena
 - Enterprise Dynamics
 - ExtendSim
 - Plant Simulation
 - AutoMod

1.

History of Simulation Languages

Paper: Richard E. Nance. Simulation Programming Languages: An Abridged History. In: C. Alexopoulos, K. Kang, W. R. Lilegdon, and D. Goldsman (Eds.). Proceedings of the 1995 Winter Simulation Conference. IEEE, 1995. pp. 1307-1313.

Paper: Ole-Johan Dahl and Kristen Nygaard. SIMULA - An ALGOL-based Simulation Language. Communications of the ACM, Vol 9, No 9, 1966. pp. 671-678.

Requirements for discrete event simulation languages

- Generation of pseudo random numbers
- Theoretical statistical distributions
- Statistical analysis routines
- Output generation capabilities
- A time flow mechanism

Discrete Simulation Languages I

- A simulation language is based on a **worldview**. How does one see the world
- Discrete simulation language worldviews interrelate with the concept of “locality” (Weinberg 1971). How does one group behavioral logic?
- Discrete simulation language follow either the process interaction worldview, event scheduling worldview or activity scanning worldview

Discrete Simulation Languages II

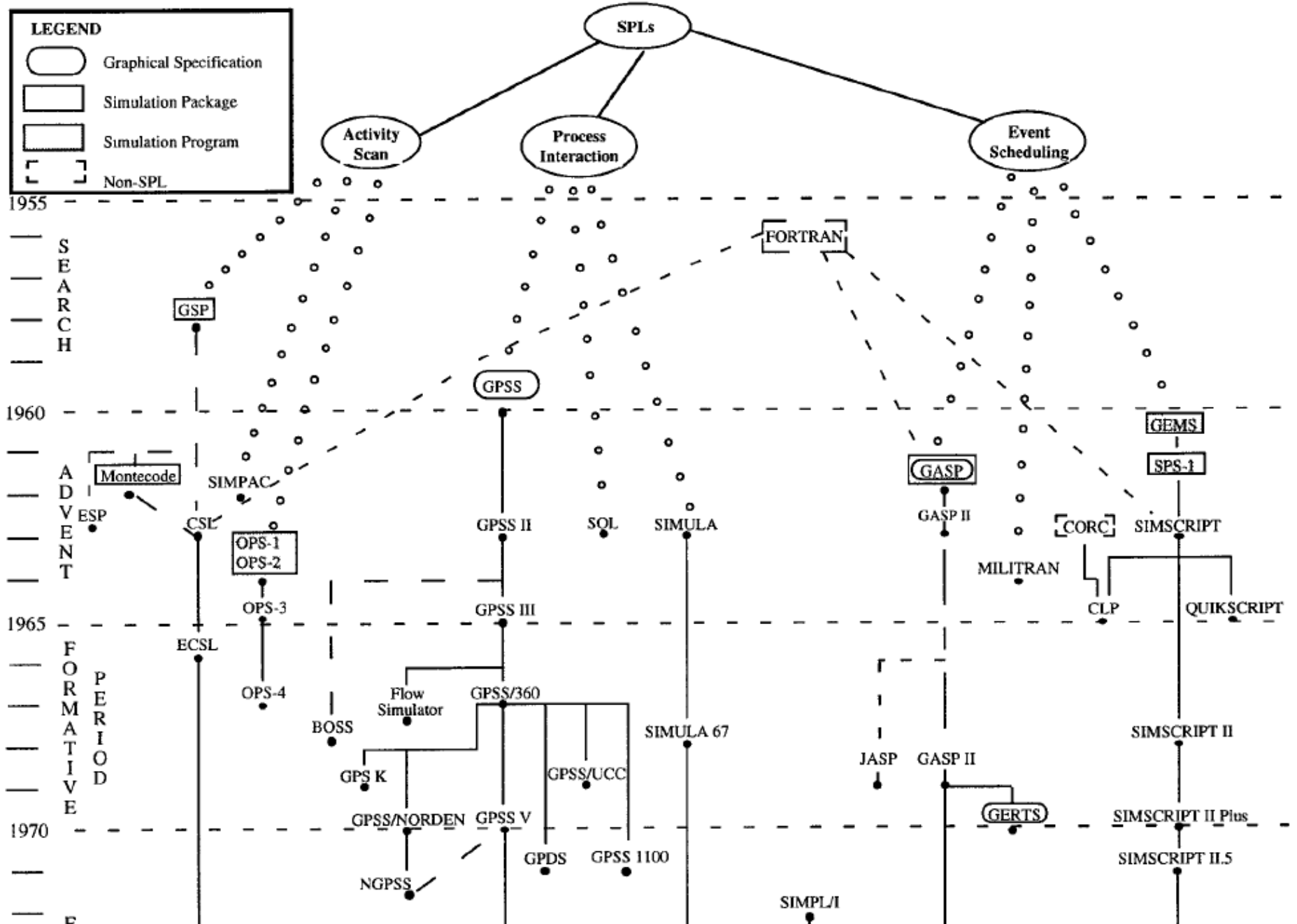
- **Event scheduling** provides locality of **time**: each event routine describes related actions that may all occur at one single instant
- **Activity scanning** provides locality of **state**: each activity routine describes all actions that occur because a particular state is reached
- **Process interaction** provides locality of **object**: each process routine describes the entire action of a particular model object

What languages are there?

- Event scheduling languages: Arena, Plant Simulation, Automod, DSOL, Enterprise Dynamics, Simio, most modern discrete-event simulation environments
- Process interaction languages: Simula, DSOL
- Activity scanning: GSP, EDSIM (time-expensive)

Early history of simulation languages

- Object-orientation is first implemented in a programming language by Ole-Johan Dahl and Kristian Nygaard in their simulation language called SIMULA'67
- SIMULA later became a general purpose programming language
- C++, Java, C#, Delphi, Oberon are all general purpose object-oriented programming languages



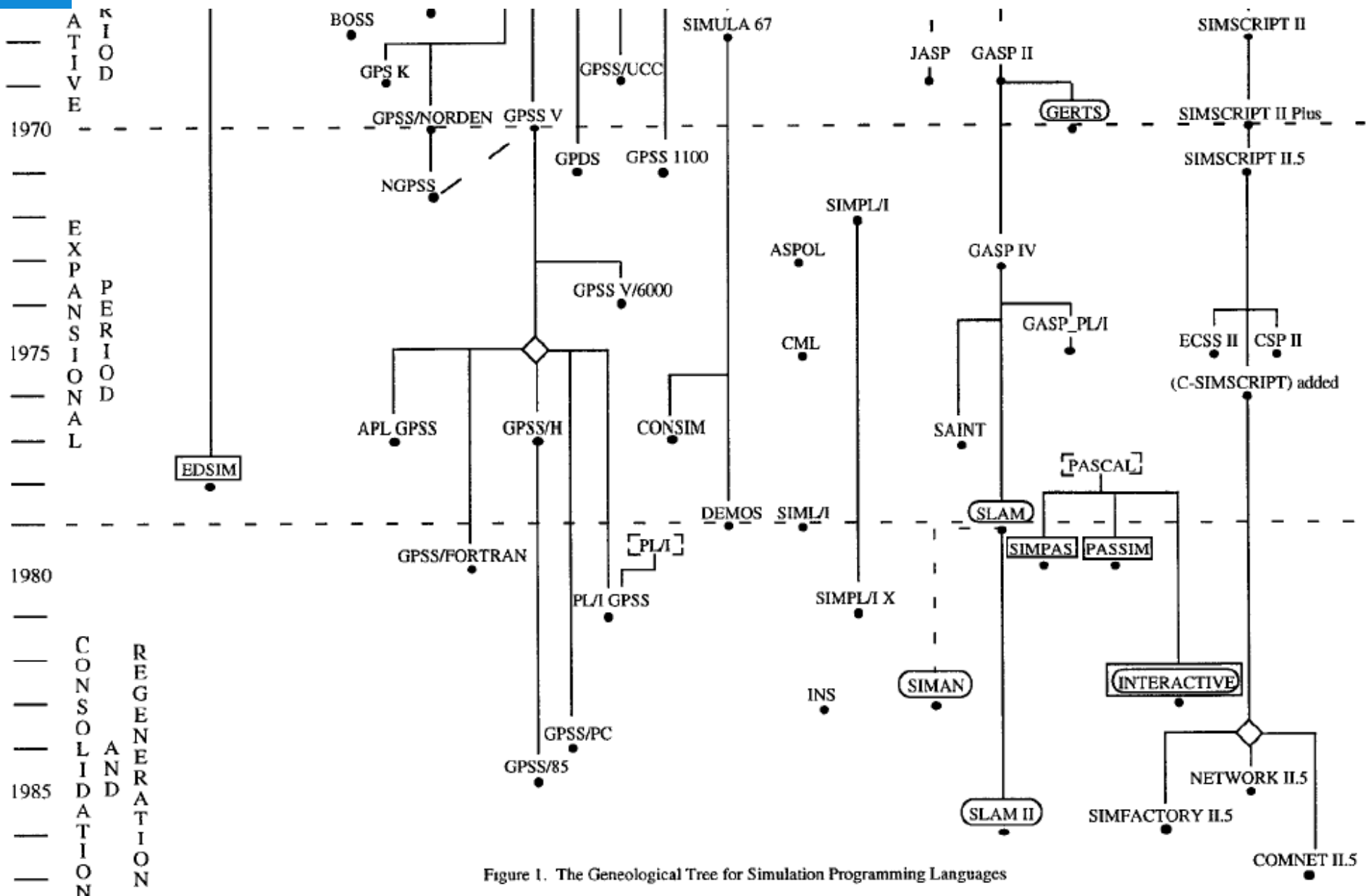
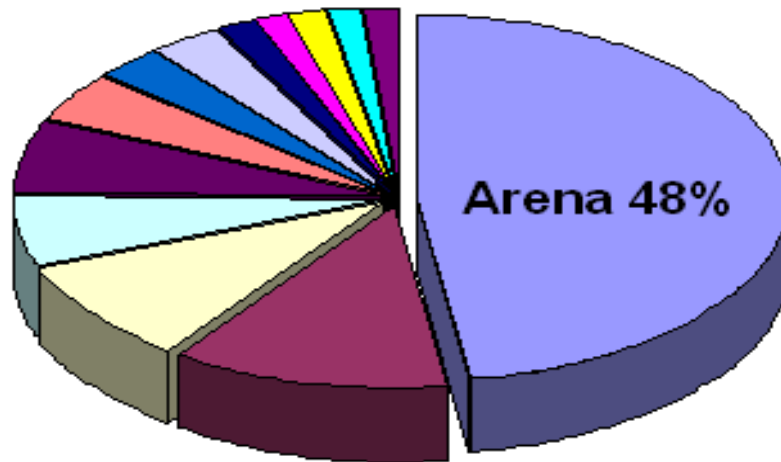


Figure 1. The Geneological Tree for Simulation Programming Languages

2006/2007 Simulation Market

Simulation Products Presented at WSC 2006

All Others Combined (31%)



AutoMod and ProModel Combined (21%)

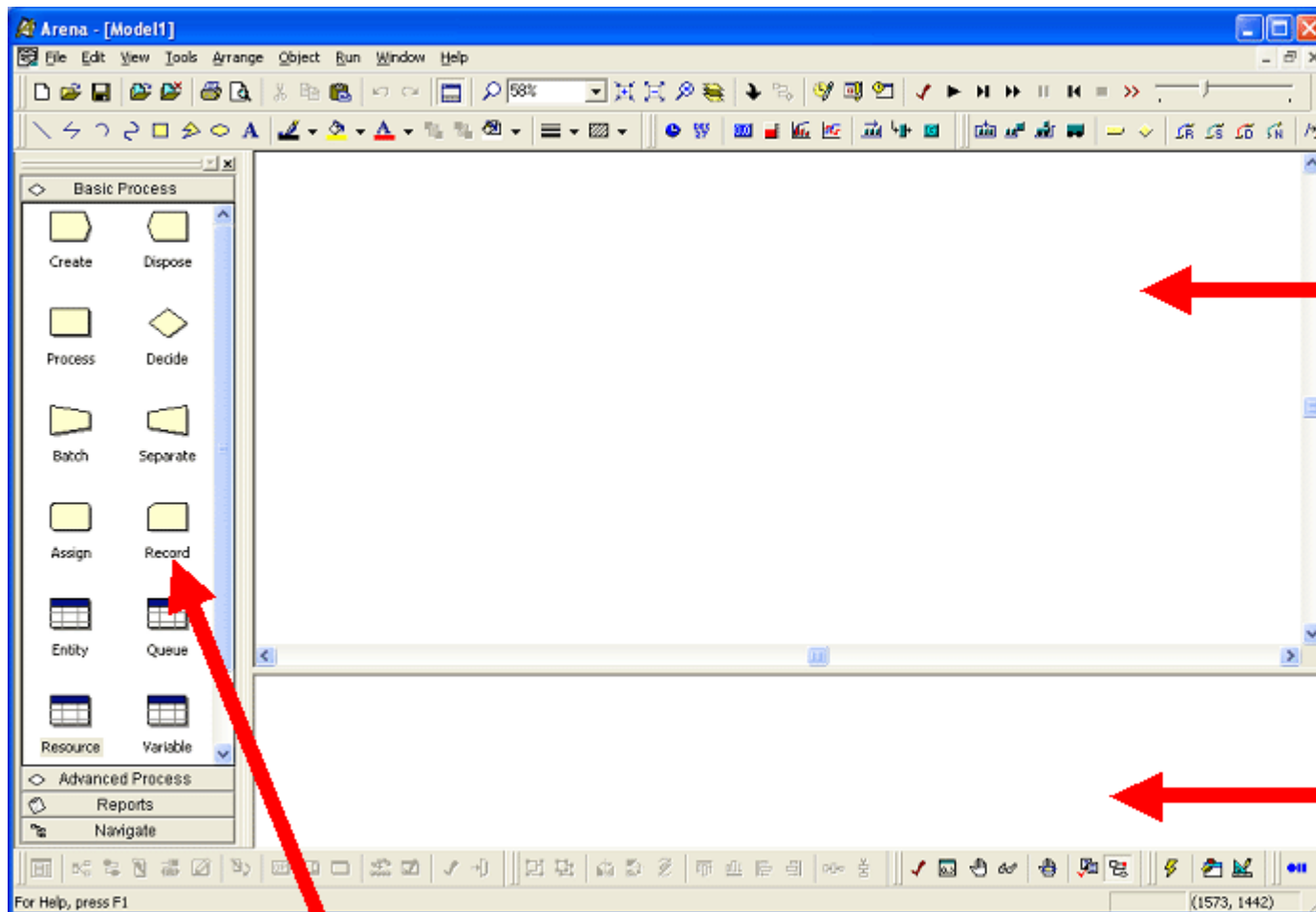
- Arena (48%)
- ProModel (12%)
- AutoMod (9%)
- Extend (6%)
- AnyLogic (6%)
- Simul8 (4%)
- eM-Plant (3%)
- SIMSCRIPT (3%)
- Enterprise Dynamics (2%)
- FlexSim (2%)
- CSIM (2%)
- Micro Saint (2%)
- iGrafx (1%)
- Witness (0%)

(<http://www.arenasimulation.com/news/default.asp>, 11 December 2007)

2.

Arena

Arena overview



Modeling area

Module data

Modules for model construction

Arena: drag - and - drop interface

Drag and drop model construction

Double click opens dialog with parameters

Selection of module shows spreadsheet with parameters

Create

Name: Create 1 Entity Type: Entity 1

Time Between Arrivals
Type: Random (Expo) Value: 1 Units: Hours

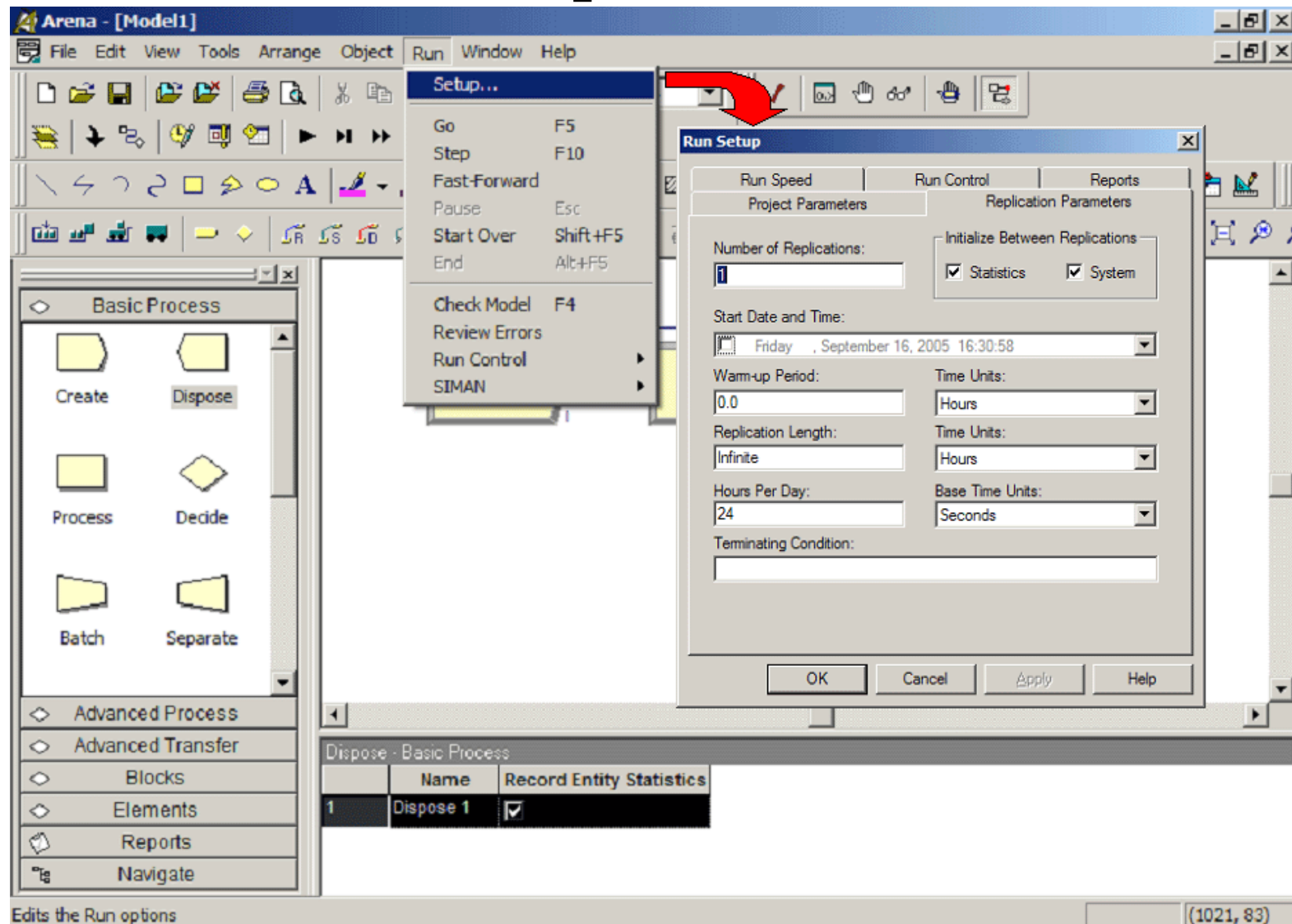
Entities per Arrival: 1 Max Arrivals: Infinite First Creation: 0.0

OK Cancel Help

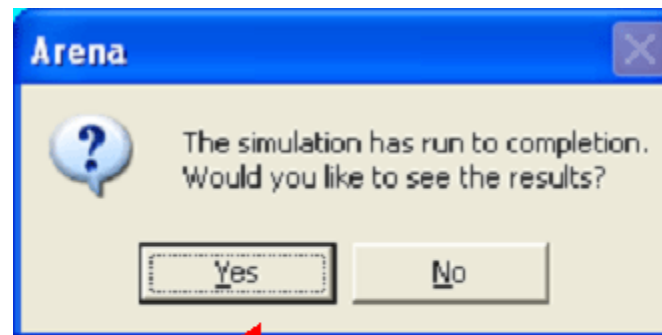
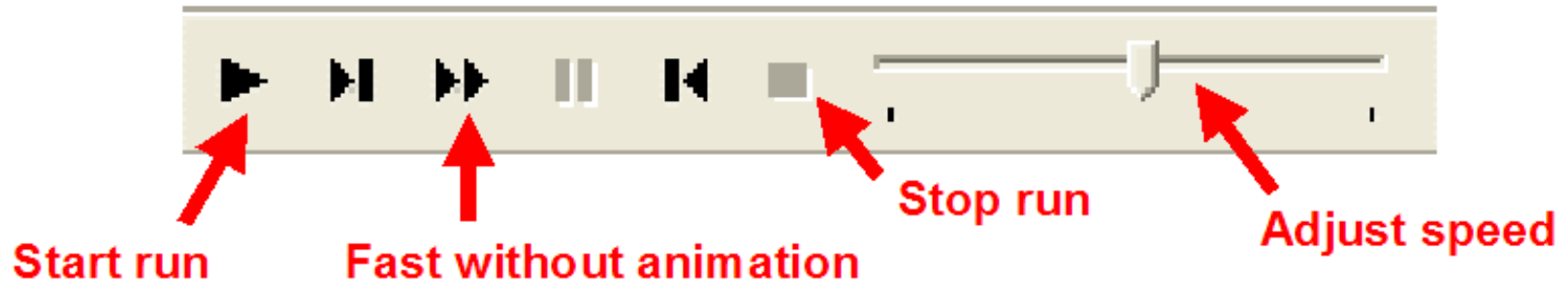
Create - Basic Process

| | Name | Entity Type | Type | Value | Units | Entities per Arrival | Max Arrivals | First Creation |
|---|----------|-------------|---------------|-------|-------|----------------------|--------------|----------------|
| 1 | Create 1 | Entity 1 | Random (Expo) | 1 | Hours | 1 | Infinite | 0.0 |

Arena: run setup



Arena: run interaction



Message end of simulation

Arena: reporting

4 of 4 60% Total:16 100%

Preview

- Category Overview.rpt
 - Unnamed Project
 - Entity
 - Queue
 - Resource
 - Usage
 - Instantaneous Utilization
 - Number Busy
 - Number Scheduled
 - Total Number Seized

Resource

Usage

| Instantaneous Utilization | Average | Half Width | Minimum Value | Maximum Value |
|---------------------------|---------|-------------|---------------|---------------|
| r_Employee | 0.8036 | 0.026041486 | 0.00 | 1.0000 |

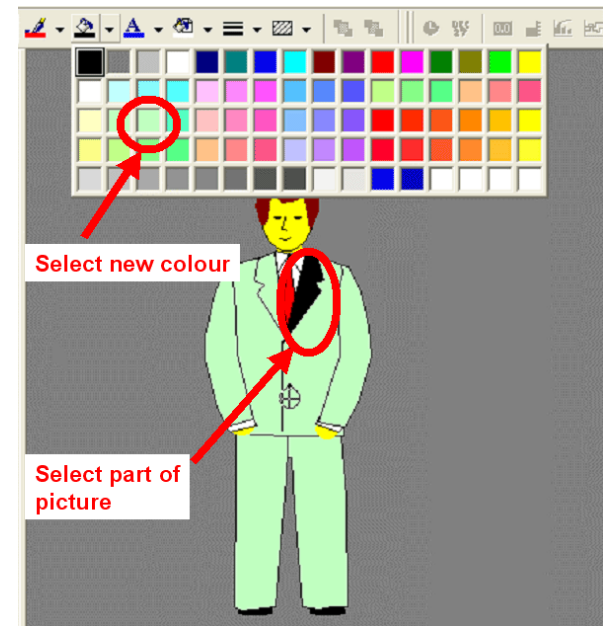
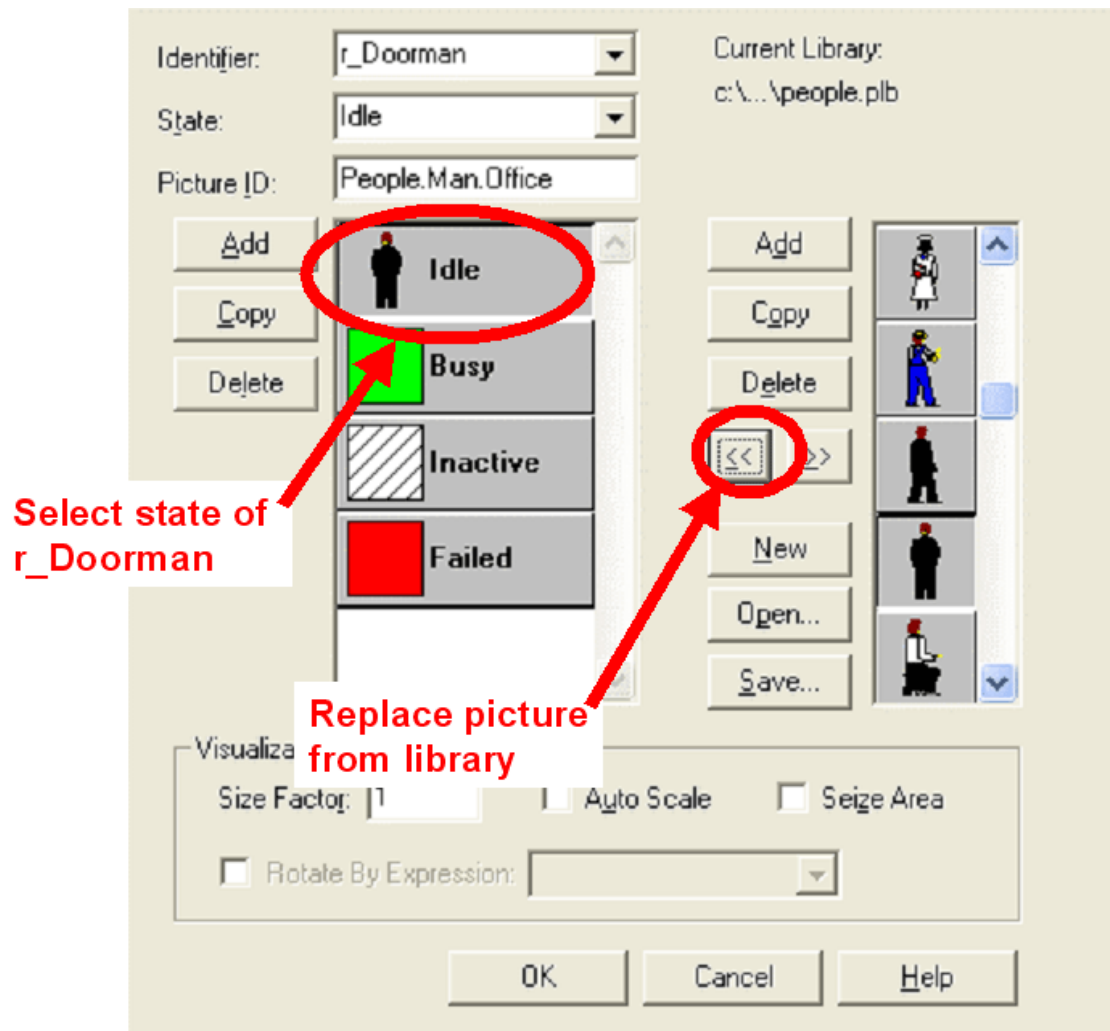
| Number Busy | Average | Half Width | Minimum Value | Maximum Value |
|-------------|---------|-------------|---------------|---------------|
| r_Employee | 0.8036 | 0.026041486 | 0.00 | 1.0000 |

| Number Scheduled | Average | Half Width | Minimum Value | Maximum Value |
|------------------|---------|----------------|---------------|---------------|
| r_Employee | 1.0000 | (Insufficient) | 1.0000 | 1.0000 |

| Scheduled Utilization | Value |
|-----------------------|--------|
| r_Employee | 0.8036 |

| Total Number Seized | Value |
|---------------------|---------|
| r_Employee | 4028.00 |

Arena: animation



Arena: Modeling concepts

Basic low level blocks

- Queue -> Seize -> Delay -> Release

Transporter

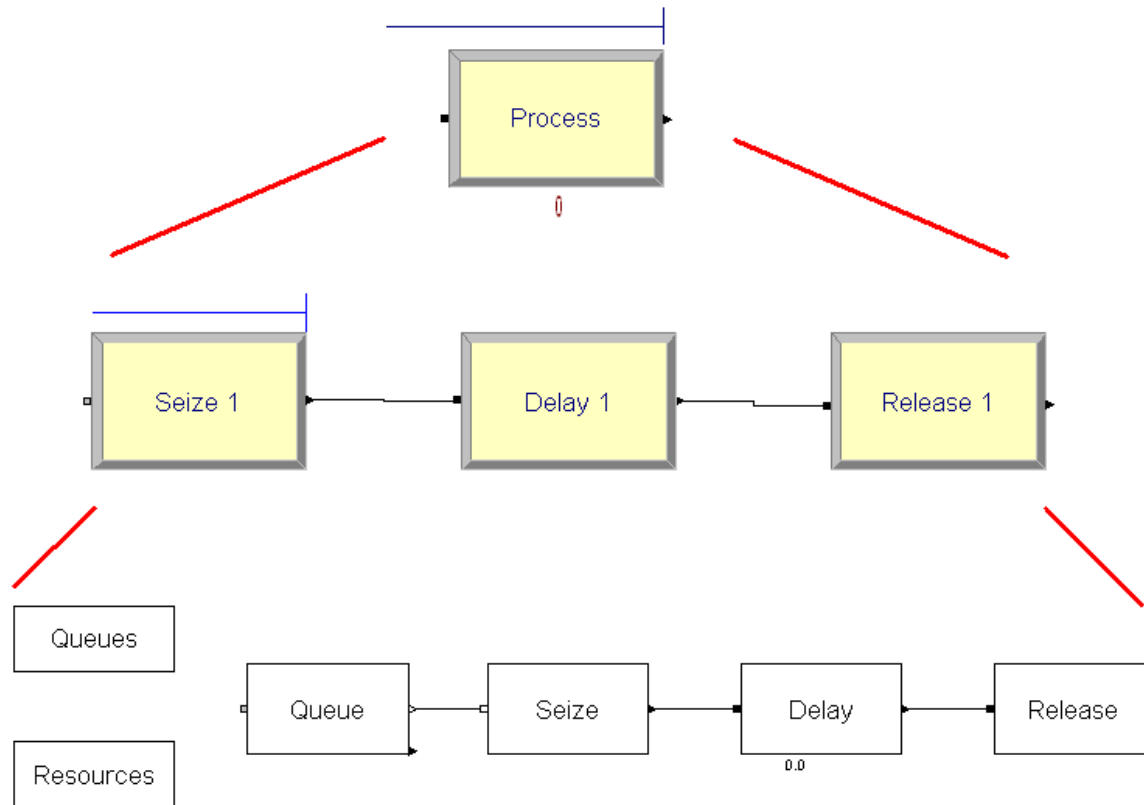
- Request
- Transport
- Free

Conveyor

- Access
- Convey
- Exit

Arena basic simulation concepts: Operation

- An operation is a step carried out by or on an entity while it moves through a system

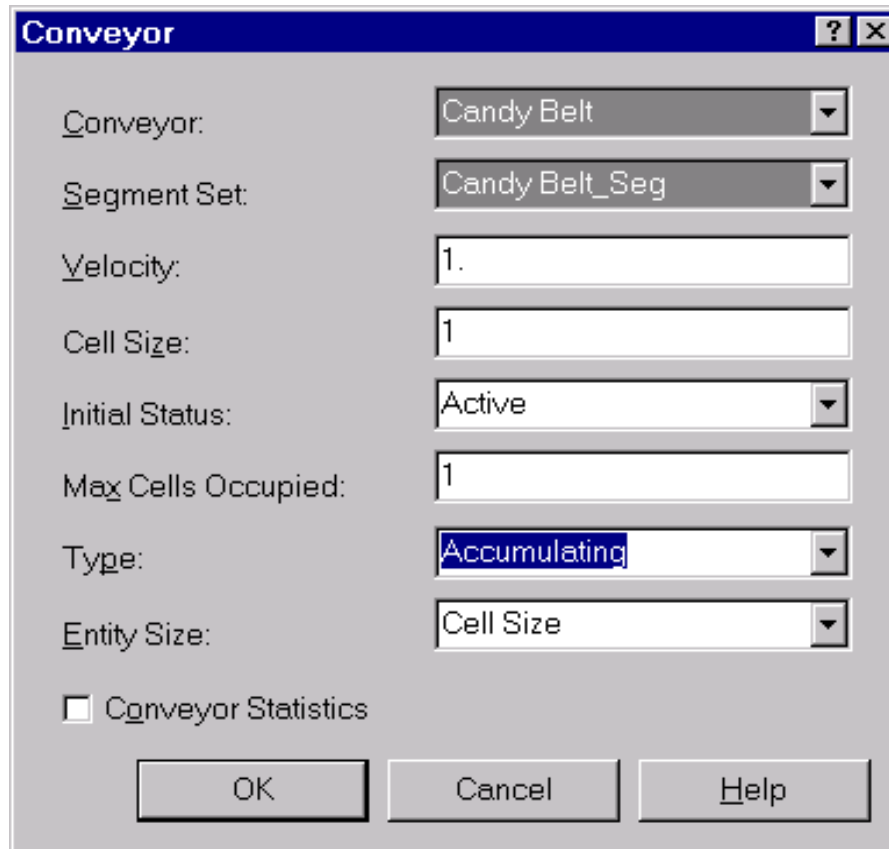


Arena: Conveyor

- Objects must wait for sufficient space on the conveyor
- Unidirectional
- Entities can not pass one another
- Two different types
 - Accumulating
 - Non-accumulating

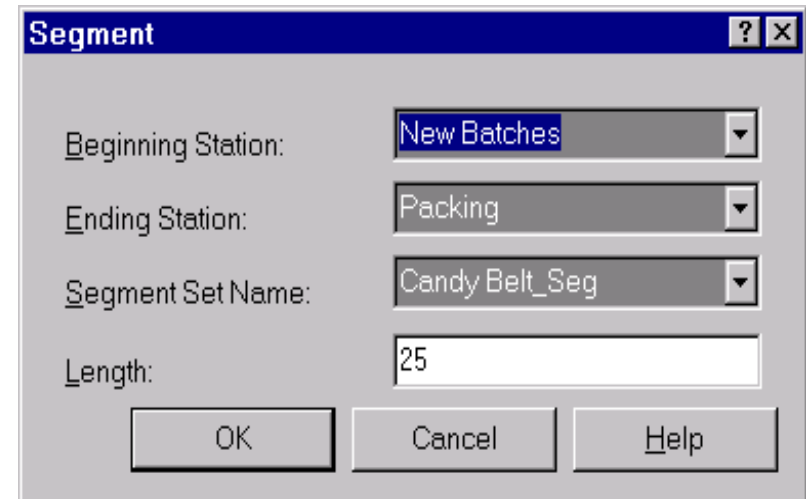
Arena: Conveyor

- High level programming



The 'Conveyor' dialog box in Arena software. It contains the following fields and controls:

- Conveyor:** A dropdown menu with 'Candy Belt' selected.
- Segment Set:** A dropdown menu with 'Candy Belt_Seg' selected.
- Velocity:** A text input field containing '1'.
- Cell Size:** A text input field containing '1'.
- Initial Status:** A dropdown menu with 'Active' selected.
- Max Cells Occupied:** A text input field containing '1'.
- Type:** A dropdown menu with 'Accumulating' selected.
- Entity Size:** A dropdown menu with 'Cell Size' selected.
- Conveyor Statistics:** An unchecked checkbox.
- Buttons:** 'OK', 'Cancel', and 'Help' buttons at the bottom.



The 'Segment' dialog box in Arena software. It contains the following fields and controls:

- Beginning Station:** A dropdown menu with 'New Batches' selected.
- Ending Station:** A dropdown menu with 'Packing' selected.
- Segment Set Name:** A dropdown menu with 'Candy Belt_Seg' selected.
- Length:** A text input field containing '25'.
- Buttons:** 'OK', 'Cancel', and 'Help' buttons at the bottom.

Arena: Conveyor

Variables: current information about the status of conveyors

- NEC number of entities being conveyed
- NEA number of accumulated entities
- LEC total length of entities being conveyed
- CLA total length of entities accumulated
- LC number of occupied cells
- MLC total conveyor length
- ICS conveyor status
- VC conveyor velocity

Arena: Free-path transporter

- Transporter can freely move about system without encountering any obstruction
- Travel time depends on the fixed distance traveled and the speed of the transporter

Arena: Guided transporter

- Movement is restricted to a pre-defined network of intersections and connecting links
- Travel time depends on:
 - vehicle's speed characteristics
 - path, congestion on paths
- Automated Guided Vehicles

3.

Enterprise Dynamics

Enterprise Dynamics: Characteristics (1)

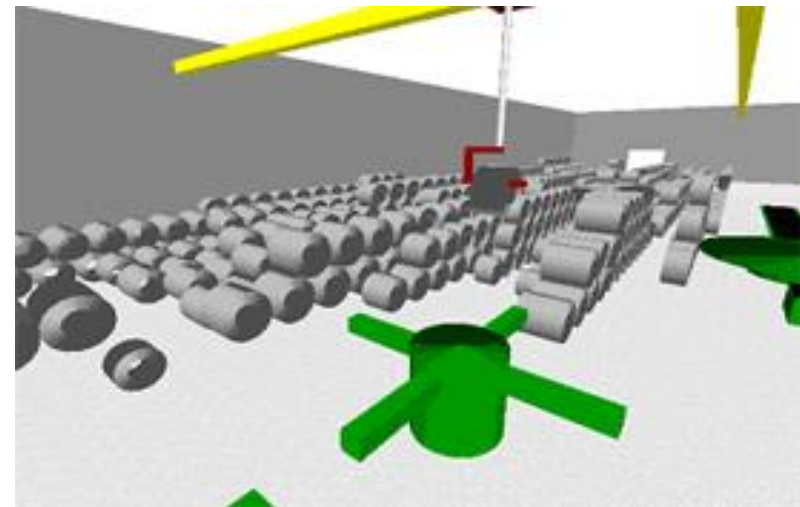
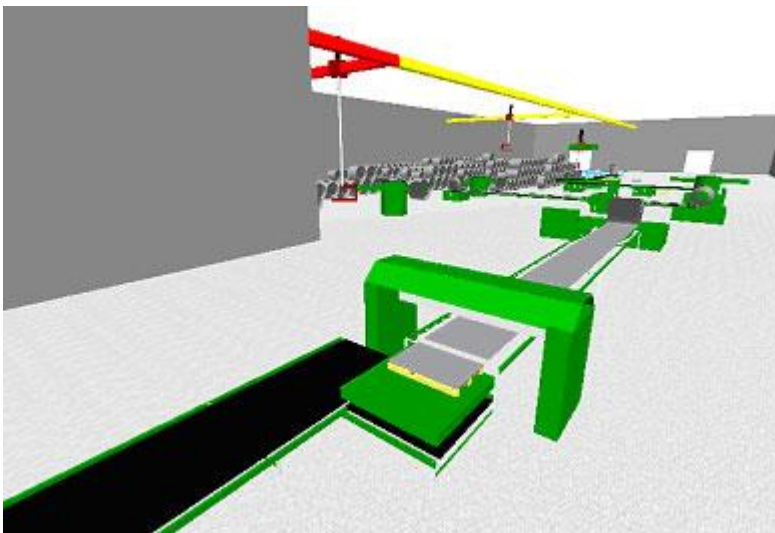
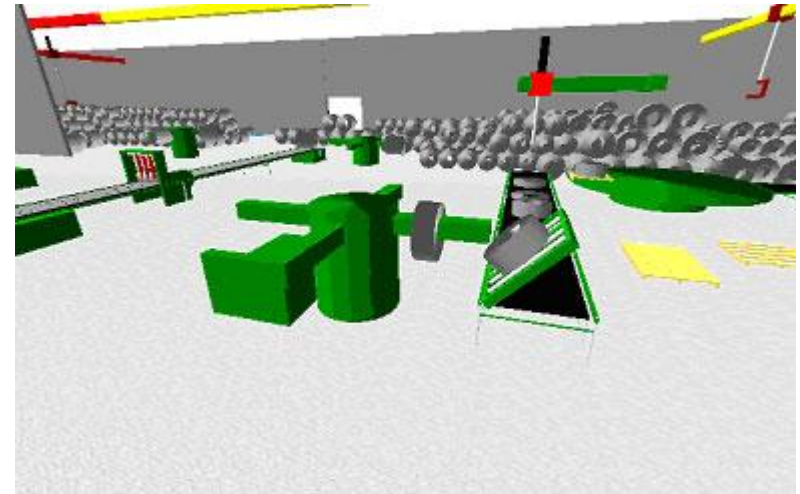
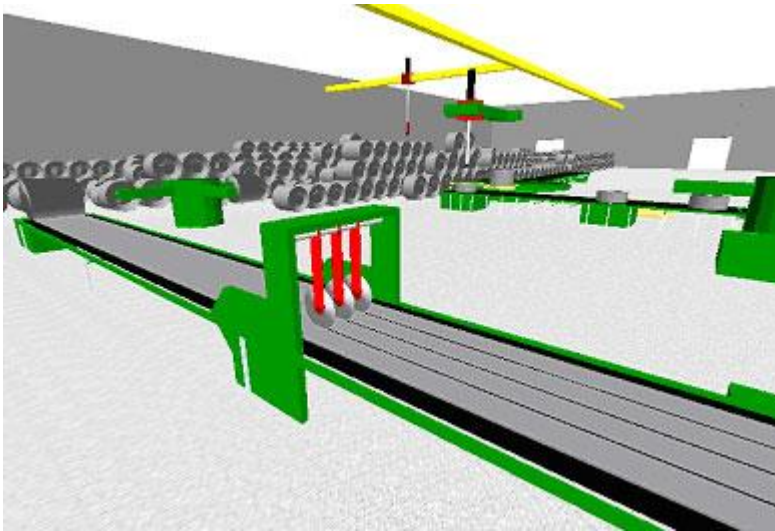
- Discrete Event Simulation package (DEVS)
- “Object Oriented” (Atoms)
 - Atom = object with 4 dimensions (x, y, z, time)
 - Each atom can have a **location**, **speed**, **rotation** and **dynamic behavior**
- Strong graphical representation
 - Immediate visualization in 3D/VR
 - Different Templates + Building Blocks
 - Logistics Suite
 - Airport Suite
 - Educational Suite

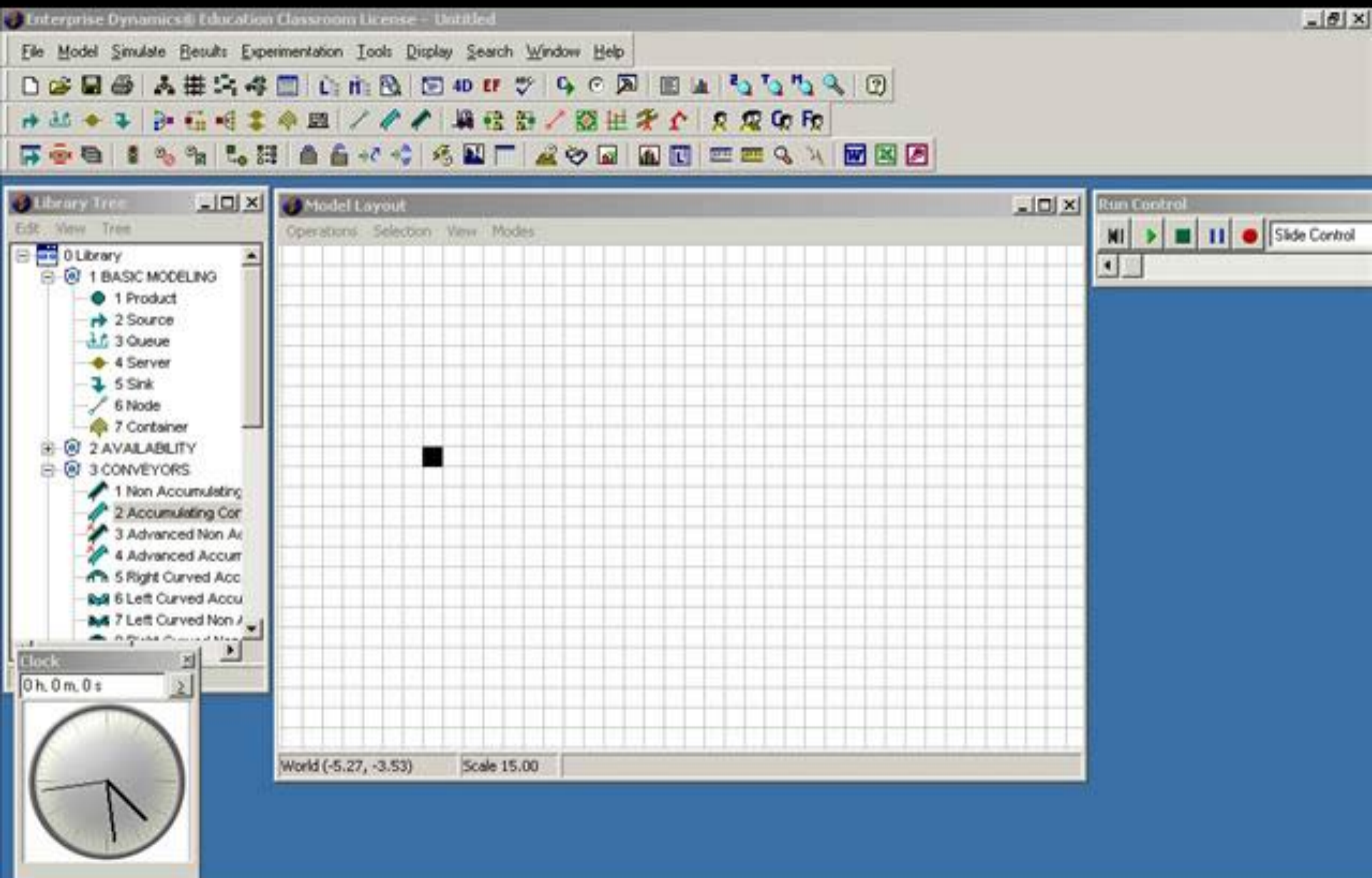


Enterprise Dynamics: Characteristics (2)

- Compatible with a lot of databases
 - MS Access, Oracle, SQL Server etc.
- Communication with external sources
 - MS Word, MS Excel, .txt-files, .xml-files etc.
 - Socket communication through TCP/IP
 - Movie creation is possible: .avi-files and .mpg-files
- HLA / IEEE 1516 implementations

Enterprise Dynamics





4.

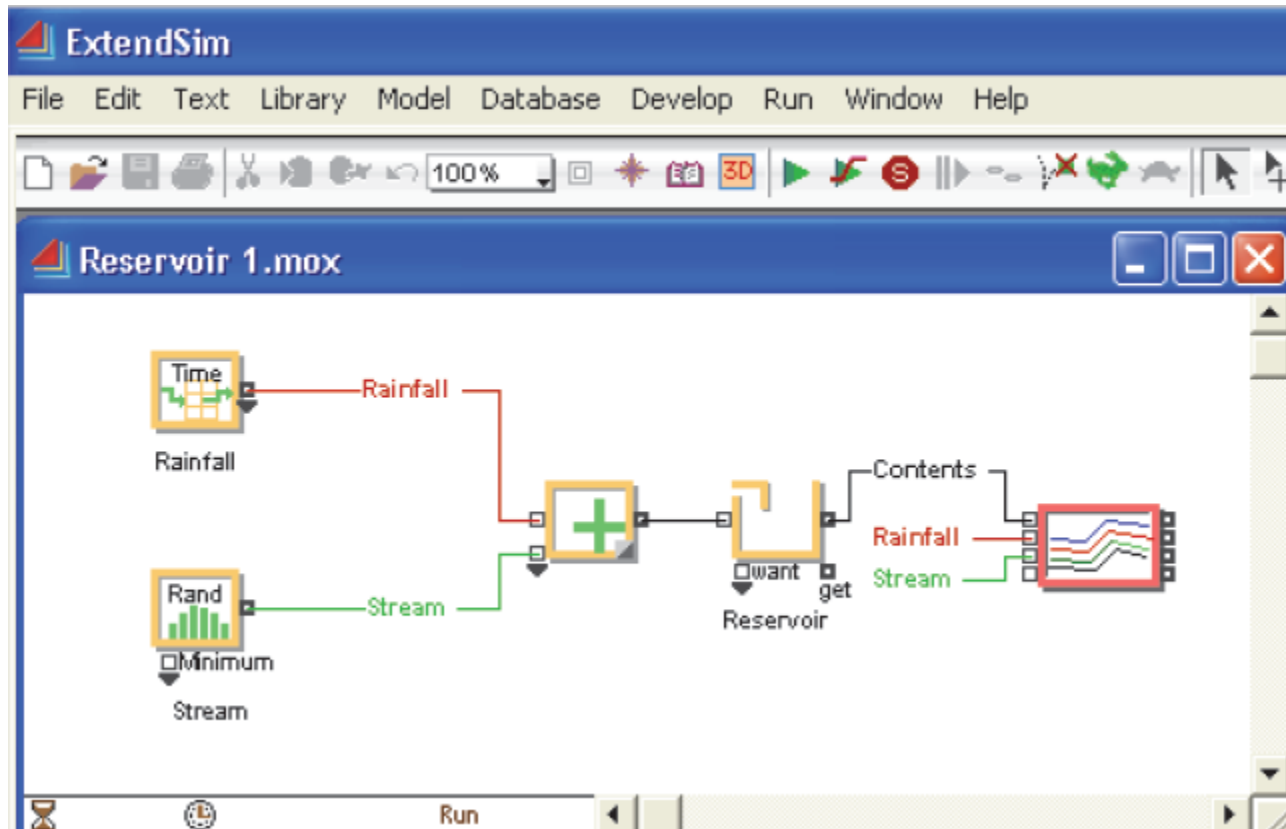
ExtendSim

ExtendSim

- Started as a continuous simulation package in 1987 for Apple hw
- 1990 Discrete-event capabilities added
- 1995 Release for Windows
- 2008 Discrete-rate capabilities added

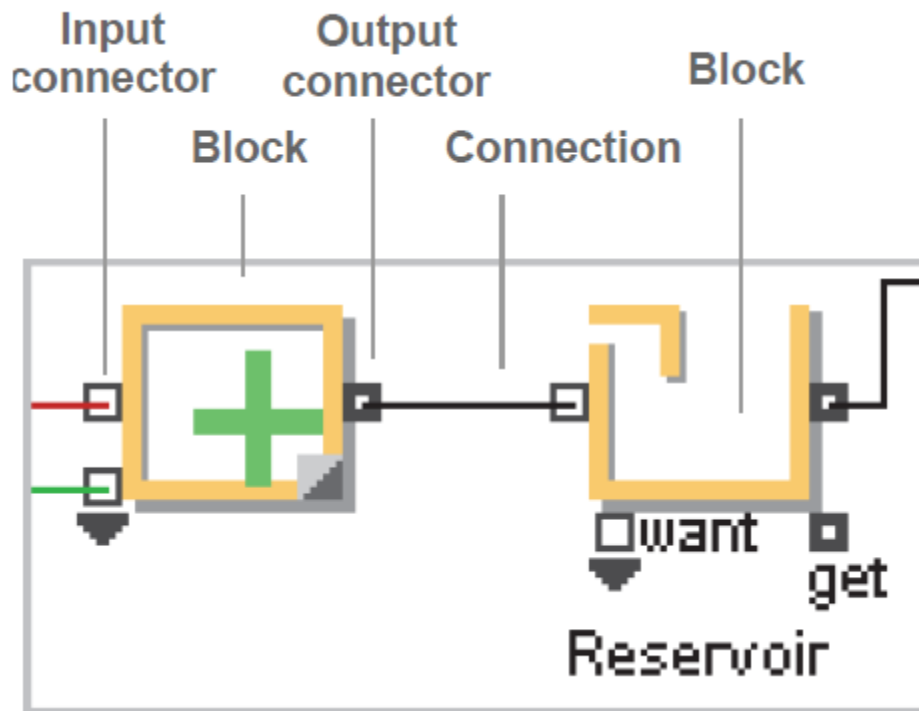
Continuous modeling basis

Example: reservoir model; reservoir is filled by rainfall and a stream.



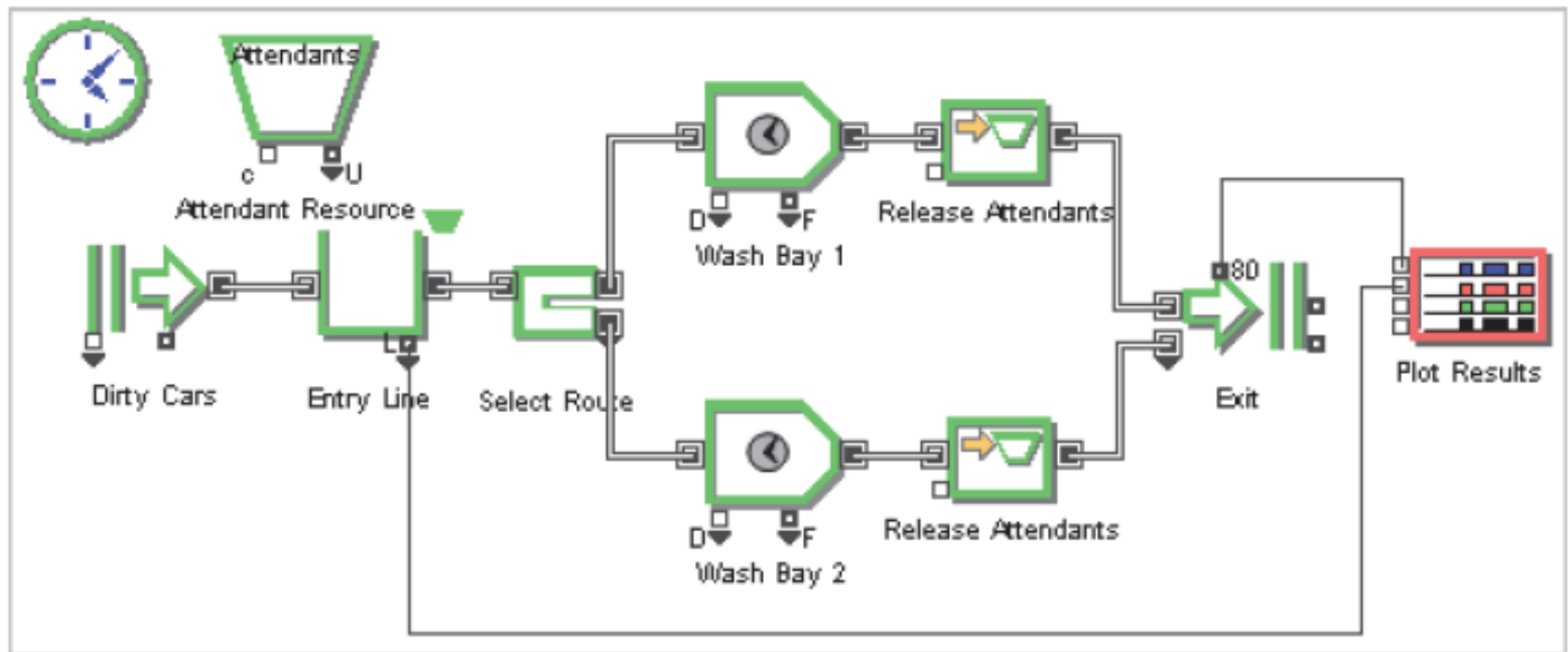
Blocks work with ports & connectors

- Library-based; many blocks available in a library
- Different ports (called connectors in ExtendSim) per block



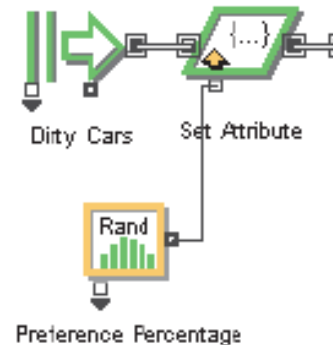
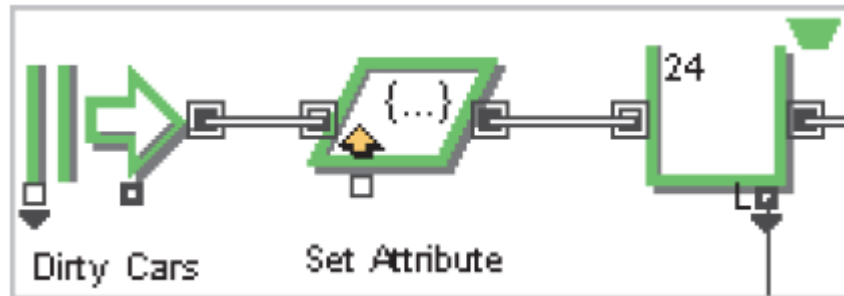
Discrete-event models

- Blocks for creating entities, queueing, selecting, resources, processes, leaving the model, graphs, etc.
- Model is purely logical – no physical space

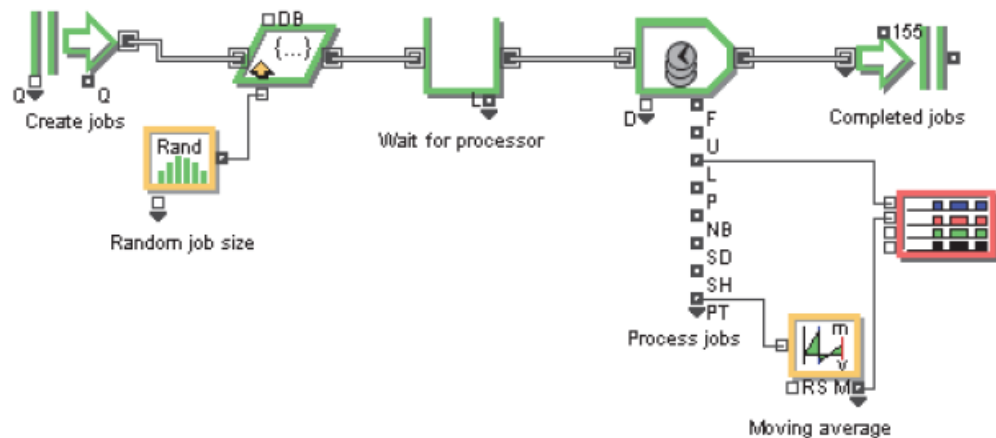


Advanced modeling

- Interacting with attributes goes with blocks between the simulation logic. Random numbers as well:

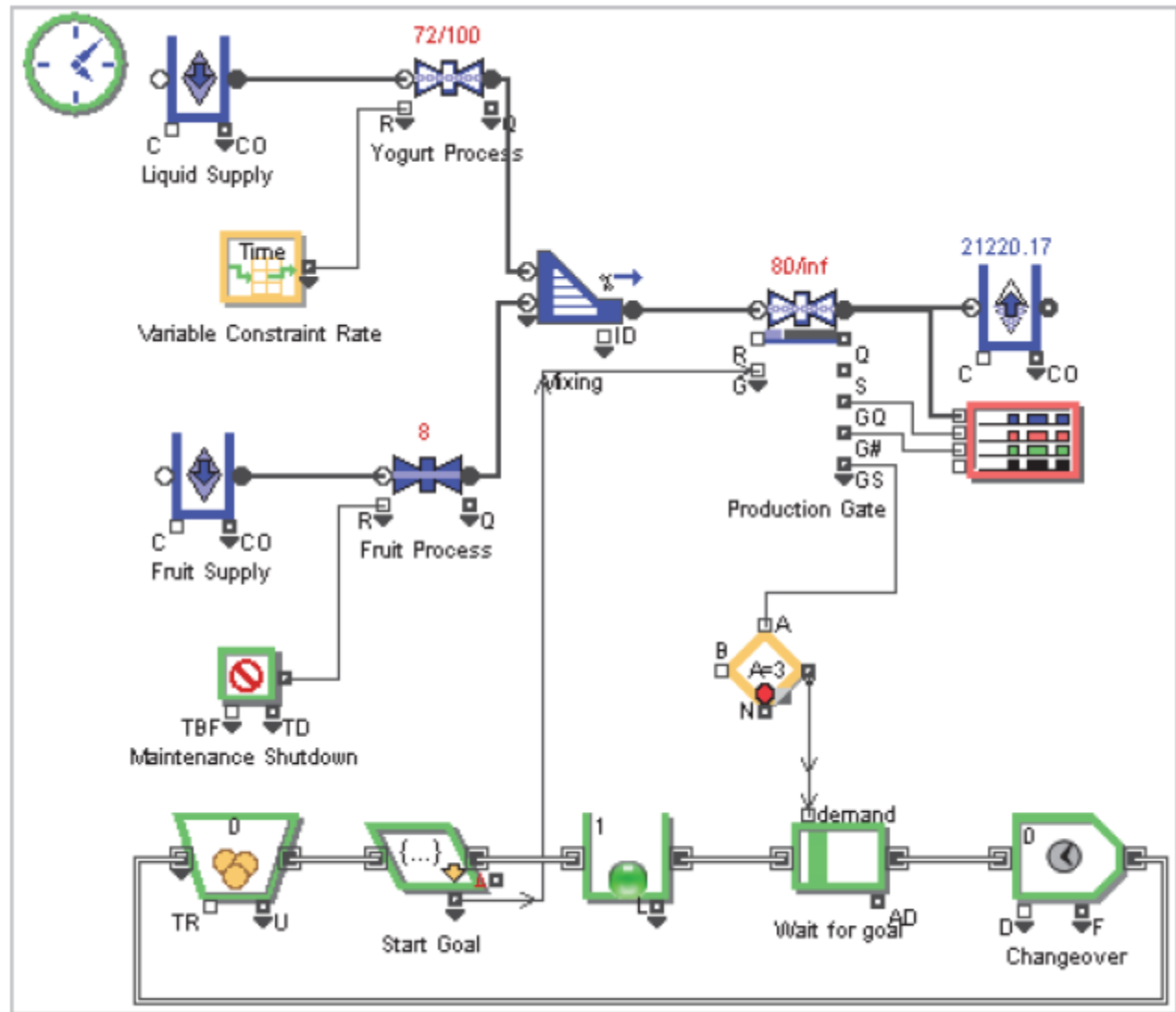


- Plotting and outputting also:



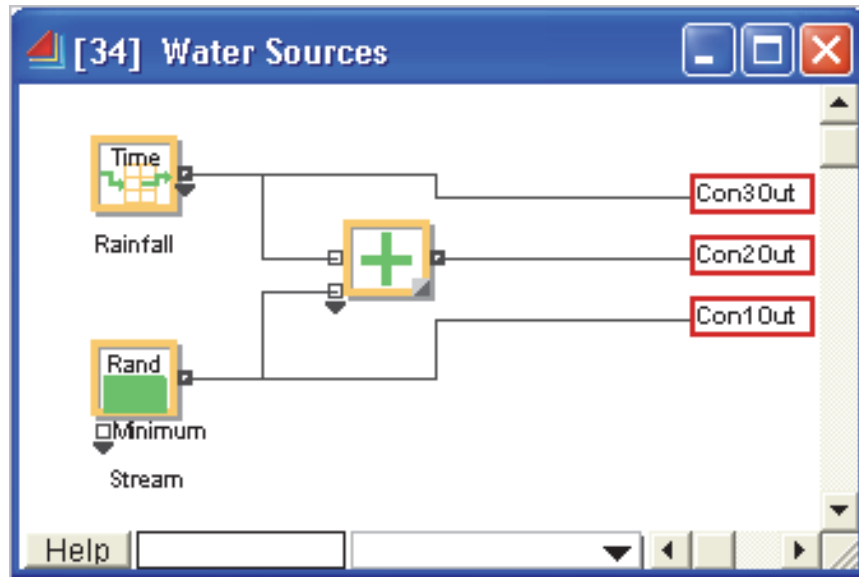
Discrete-rate models

- flow
- valves
- pipes
- tanks
- mixing
- etc.



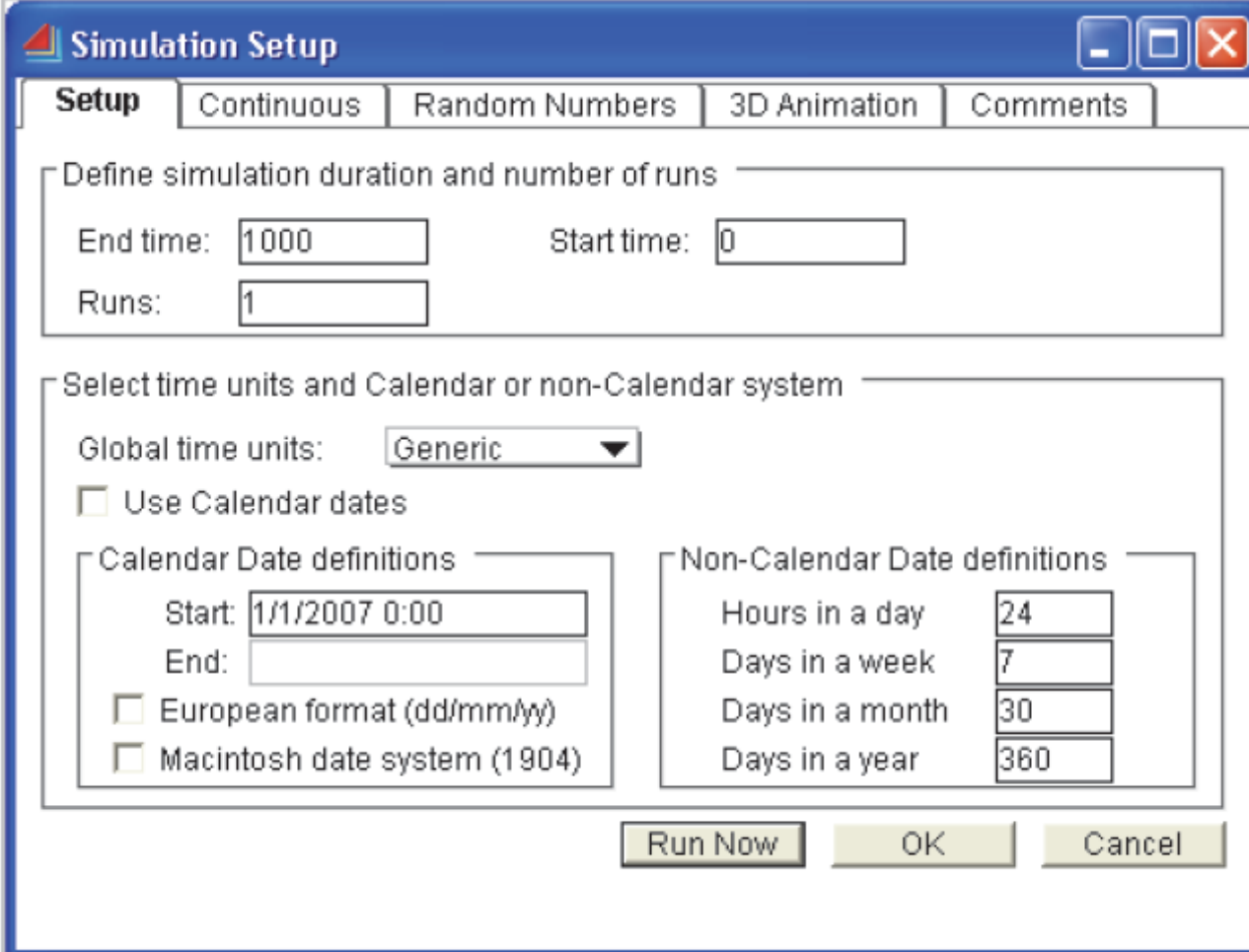
Hierarchical modeling is standard

- Grab a couple of blocks and make a submodel out of it:



- Very elegant way of making new blocks

Pretty complete run-setup



The image shows a 'Simulation Setup' dialog box with a blue title bar and standard Windows window controls. It features a tabbed interface with 'Setup' selected. The 'Setup' tab contains two main sections. The first section, 'Define simulation duration and number of runs', has input fields for 'End time' (1000), 'Start time' (0), and 'Runs' (1). The second section, 'Select time units and Calendar or non-Calendar system', includes a 'Global time units' dropdown set to 'Generic', an unchecked 'Use Calendar dates' checkbox, and two sub-sections. The 'Calendar Date definitions' sub-section has 'Start' (1/1/2007 0:00) and 'End' fields, with unchecked checkboxes for 'European format (dd/mm/yy)' and 'Macintosh date system (1904)'. The 'Non-Calendar Date definitions' sub-section has input fields for 'Hours in a day' (24), 'Days in a week' (7), 'Days in a month' (30), and 'Days in a year' (360). At the bottom are 'Run Now', 'OK', and 'Cancel' buttons.

Simulation Setup

Setup | Continuous | Random Numbers | 3D Animation | Comments

Define simulation duration and number of runs

End time: 1000 Start time: 0

Runs: 1

Select time units and Calendar or non-Calendar system

Global time units: Generic

☐ Use Calendar dates

Calendar Date definitions

Start: 1/1/2007 0:00

End:

☐ European format (dd/mm/yy)

☐ Macintosh date system (1904)

Non-Calendar Date definitions

Hours in a day: 24

Days in a week: 7

Days in a month: 30

Days in a year: 360

Run Now OK Cancel

But limited experimental design

A Scenario Manager block is available to help with running scenarios, but it is **part of the model**, instead of acting **on the model**.

| | Factor Name | Block Name | Block Number | Block Label | H-Block Name | H-Label[num] | Dialog Variable | Row, Column | Variable Value | Min Value | Max Value | Step |
|---|--------------------|------------|--------------|-------------|--------------|--------------|-----------------|-------------|----------------|-----------|-----------|--------------------------------|
| 0 | Attendants | Resource P | 21 | Attendant | | [-1] | NumServ | -1,-1 | 2 | 1 | 3 | 1 ∞ <input type="checkbox"/> |
| 1 | Wash Time | Activity | 4 | Wash Bay | | [-1] | waitDelta_prm | -1,-1 | 6 | 5 | 7 | 1 ∞ <input type="checkbox"/> |
| 2 | Wash&Wax Time | Activity | 13 | Wash/Wax | | [-1] | waitDelta_prm | -1,-1 | 8 | 6 | 8 | 1 ∞ <input type="checkbox"/> |
| 3 | Car Interarrival T | Create | 1 | Dirty Cars | | [-1] | rnd_Arg1_prm | -1,-1 | 4 | 3 | 5 | 0.5 ∞ <input type="checkbox"/> |

Run results:

| | Select | Scenario Name | Attendants | Wash Time | Wash&Wax Time | Car Interarrival Time | (M)Average queue | (M)Average wait | Details |
|---|-------------------------------------|---------------|------------|-----------|---------------|-----------------------|------------------|-----------------|---------|
| 0 | <input checked="" type="checkbox"/> | Scenario 1 | 1 | 5 | 6 | 3 | 35.417179189399 | 101.889953021 | Show |
| 1 | <input checked="" type="checkbox"/> | Scenario 2 | 1 | 5 | 6 | 3.5 | 24.054957756948 | 84.5324201843 | Show |
| 2 | <input checked="" type="checkbox"/> | Scenario 3 | 1 | 5 | 6 | 4 | 15.370510260768 | 60.8295415103 | Show |
| 3 | <input checked="" type="checkbox"/> | Scenario 4 | 1 | 5 | 6 | 4.5 | 10.941054253974 | 48.0812516130 | Show |
| 4 | <input checked="" type="checkbox"/> | Scenario 5 | 1 | 5 | 6 | 5 | 6.1907290672059 | 30.2761953476 | Show |
| 5 | <input checked="" type="checkbox"/> | Scenario 6 | 1 | 5 | 7 | 3 | 29.547632786837 | 91.7816165137 | Show |
| 6 | <input checked="" type="checkbox"/> | Scenario 7 | 1 | 5 | 7 | 3.5 | 26.613653357253 | 91.5871396797 | Show |

5.

Plant Simulation

Plant Simulation

- Developed as SiMPLE++ at the Fraunhofer Institute for Manufacturing Engineering and Automation
- Commercial release in 1992 by AESOP
- 1997 Takeover by Tecnomatix Technologies LTD
SIMPLE++ renamed to eM-Plant
- 2005 Takeover by UGS
- 2007 Takeover by Siemens

Plant Simulation

- Designed for:
 - Discrete event simulation
 - Production and logistics
 - Planning and optimization

(Heinicke & Hickman, 2000)

- Plant Simulation is used by many industries:
 - Car manufacturers
 - Baggage handling at airport
 - Shipyard
 - International Finance

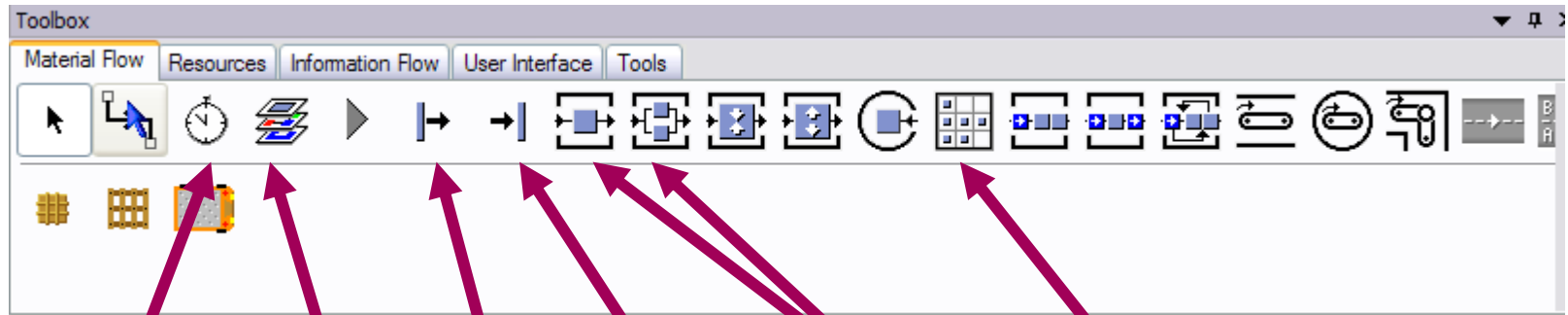
(Heinicke & Hickman, 2000)

Heinicke, M. U., & Hickman, A. (2000). Eliminate bottlenecks with integrated analysis tools in eM-Plant. Winter Simulation Conference Proceedings.

Characteristics

- Object oriented
- Discrete event simulation
- Object libraries enable hierarchical modeling
- Distributive use is possible
- Possibility to program new methods
- Visualisation: Easy 2D/3D

Plant Simulation basic library



Event
controller

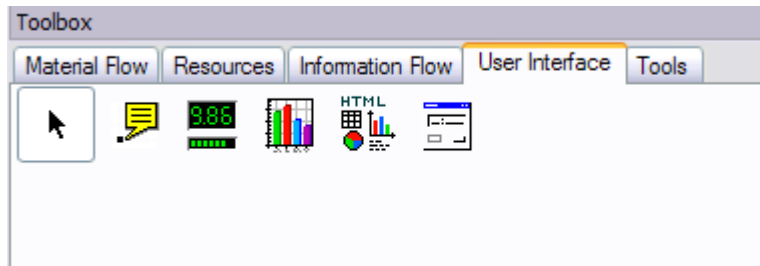
Frame

Source

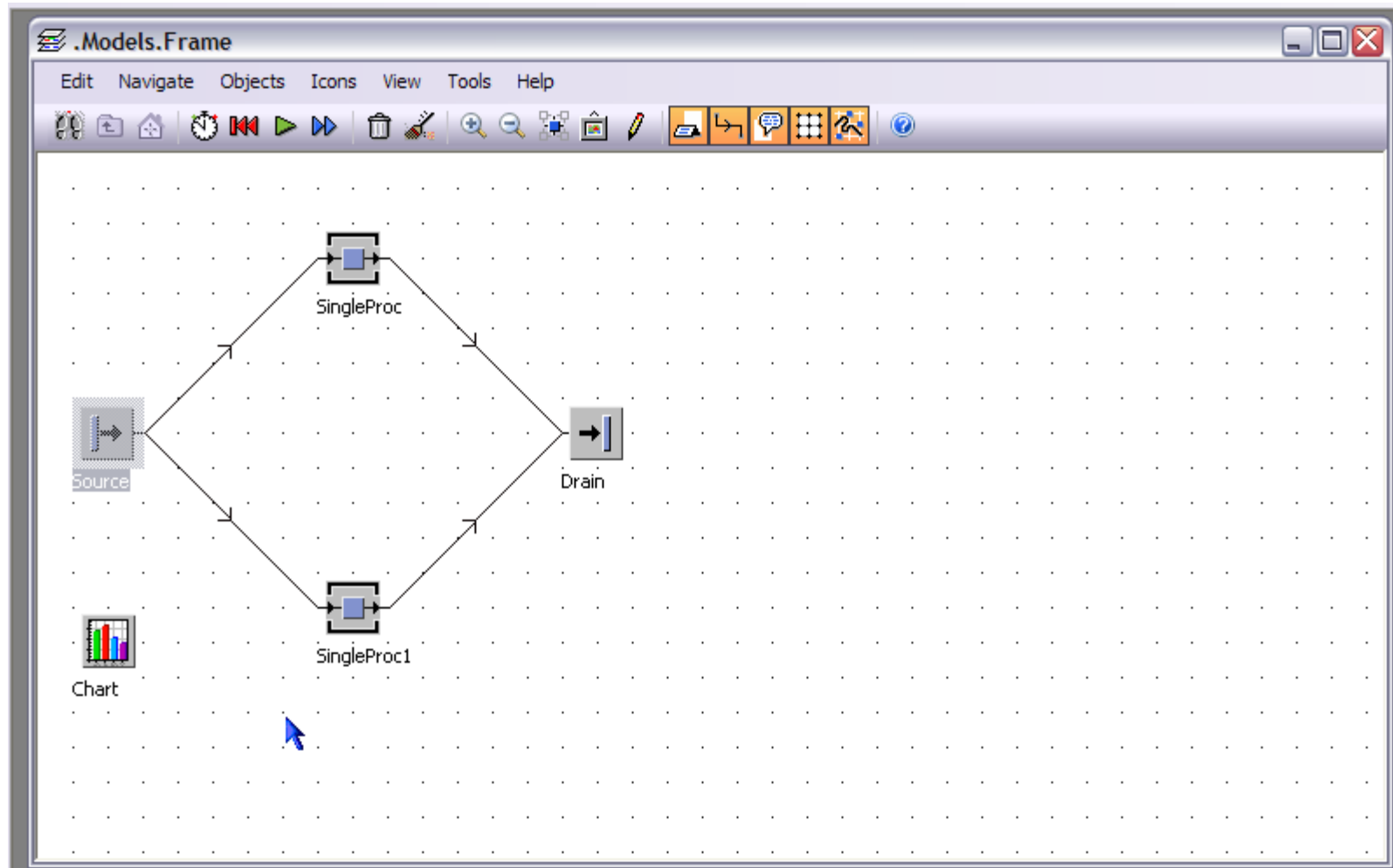
Drain

Process

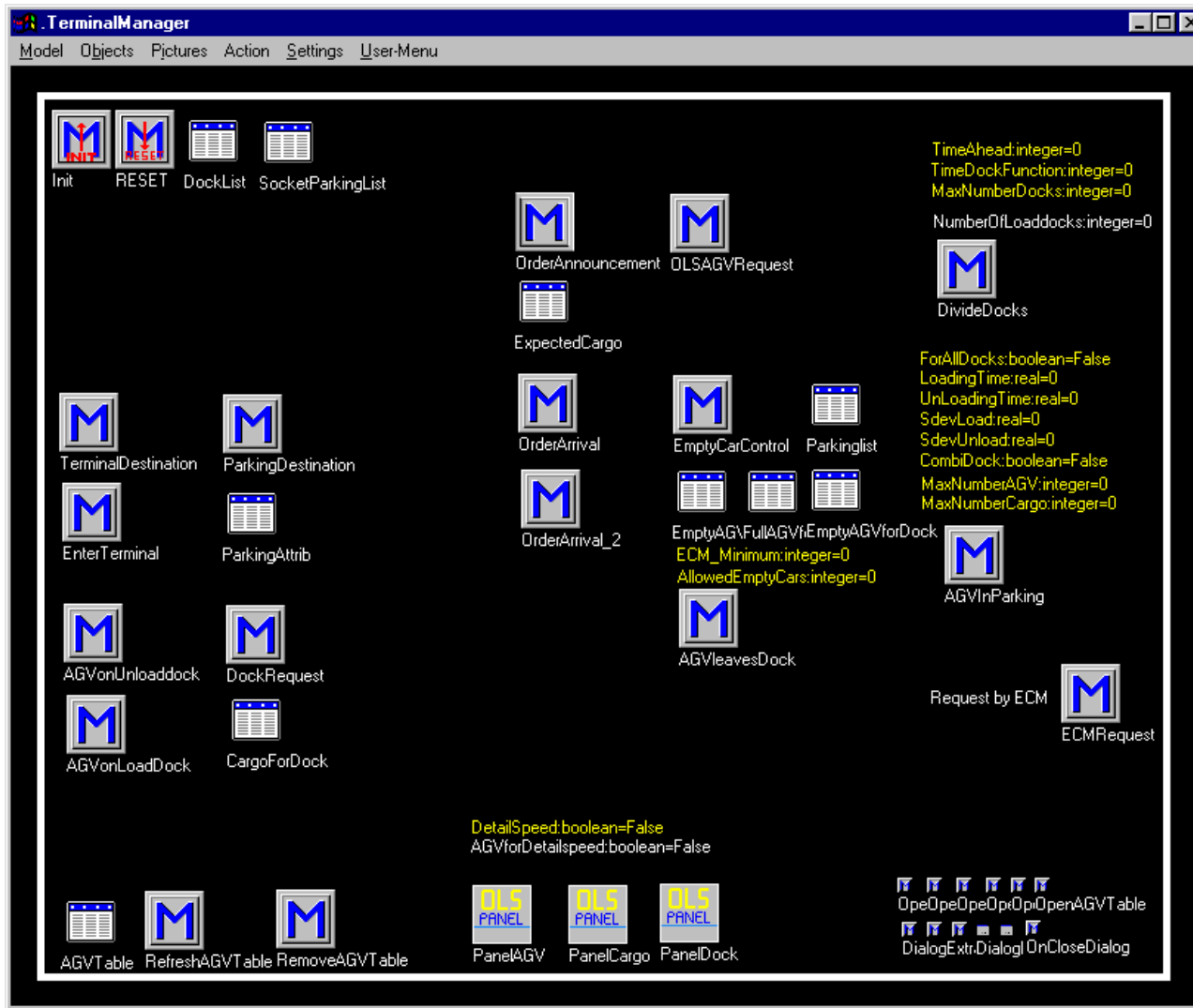
Table



Connecting processes in a frame



Methods in a frame



Source set-up

The screenshot shows a dialog box titled ".Models.EnginePlant.Receiving". It has a menu bar with "Navigate", "View", "Tools", and "Help". Below the menu bar, there are fields for "Name" (containing "Receiving") and "Label" (empty). To the right of these fields are checkboxes for "Failed" and "Exit locked", and a "Planned" dropdown menu. Below these fields are several tabs: "Attributes", "Failures", "Controls" (which is selected and highlighted with a blue arrow), "Exit Strategy", "Statistics", and "Custom Attributes". The "Controls" tab contains the following settings:

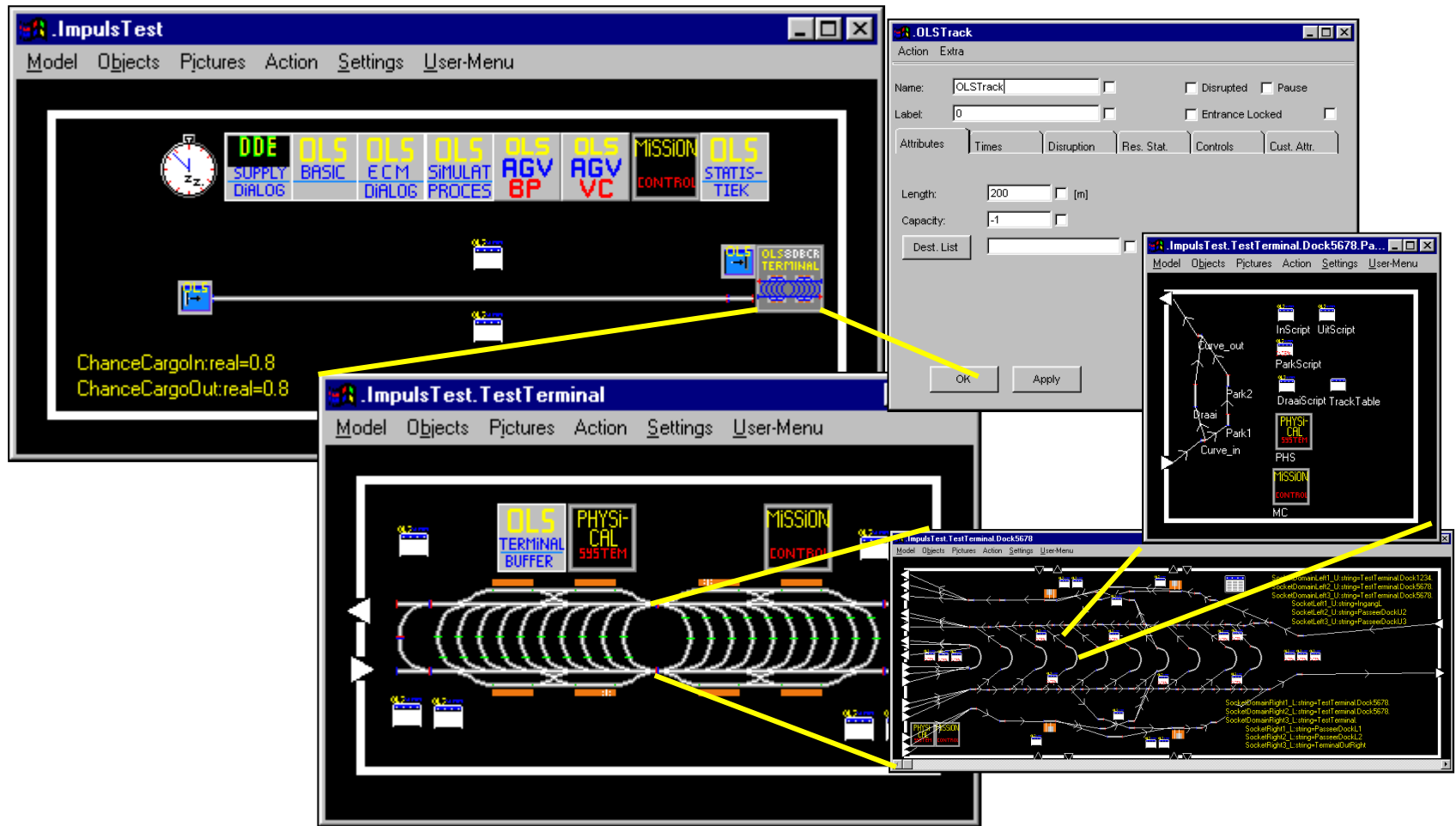
- Operating mode: ☒ Blocking
- Time of creation: Interval Adjustable
- Interval: Const, 0
- Start: Const, 0
- Stop: Const, 0
- MU selection: Constant
- MU: *.MUs.Entity

At the bottom of the dialog box are three buttons: "OK", "Cancel", and "Apply".

Several attributes for the source:

- name
- inheritance
- interarrival time
- frequencies
- object generated
- disruptions
- statistics
- controls
- attributes of the object

Complexity of hierarchies (2)



Plant Simulation: Conveyors

- Model time delay
- Library objects
 - SingleProc, ParallelProc, Track, etc.
- Application objects
 - Frame: Straight
- Sensors that can be triggered

Plant Simulation: Line

- The Line is an active material flow object.
- Use it to model conveyor systems.

The screenshot shows the configuration window for a 'Line' object in Plant Simulation. The window has a title bar with the icon and text '.Line', and standard window controls. Below the title bar is a menu bar with 'Action', 'Extras', and 'Help'. The main area contains several input fields and checkboxes. The 'Name' field is set to 'Line'. The 'Label' field is empty. There are checkboxes for 'Failed', 'Pause', 'Entr. Locked', 'Exit Locked', 'Accumulating', 'Backwards', and 'Capacity'. The 'Length' field is set to '10' with a unit '[m]'. The 'Speed' field is set to '1' with a unit '[m/s]'. The 'Time' field is set to '10.0000'. The 'Capacity' field is set to '-1'. At the bottom, there are three buttons: 'OK', 'Apply', and 'Cancel'. The 'Attributes' tab is selected, showing other tabs like 'Times', 'Failures', 'Res. Stat.', 'Controls', and 'Cust. Attr.'.

.Line

Action Extras Help

Name: Line ☐ Failed ☐ Pause

Label: ☐ Entr. Locked ☐ Exit Locked ☐

Attributes Times Failures Res. Stat. Controls Cust. Attr.

Length: 10 ☐ [m] ☐ Accumulating ☐

Speed: 1 ☐ [m/s] ☐ Backwards ☐

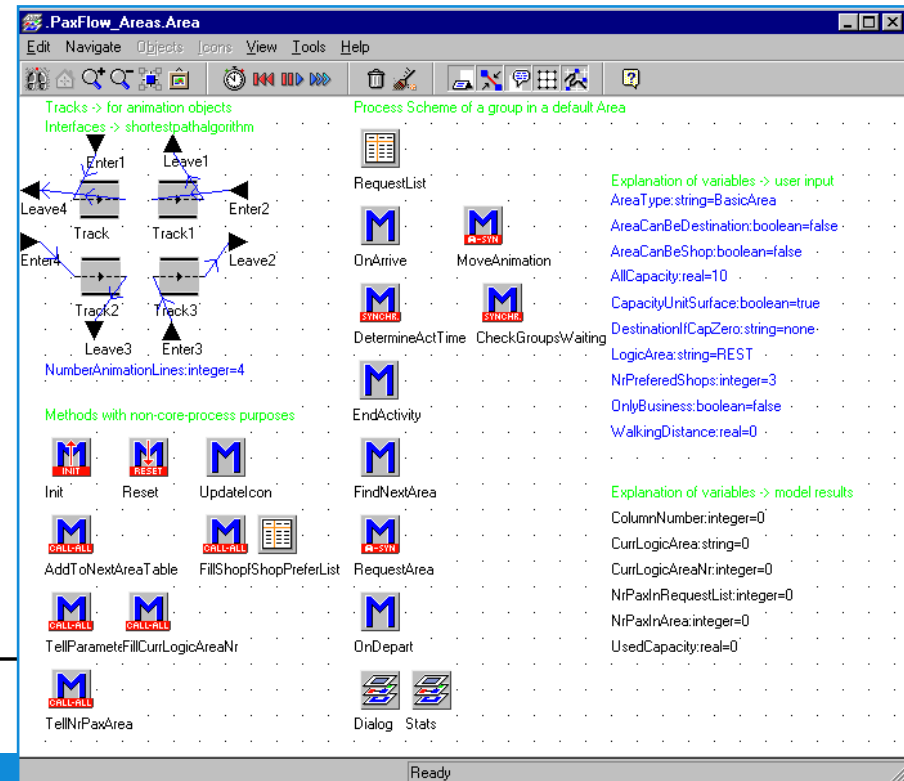
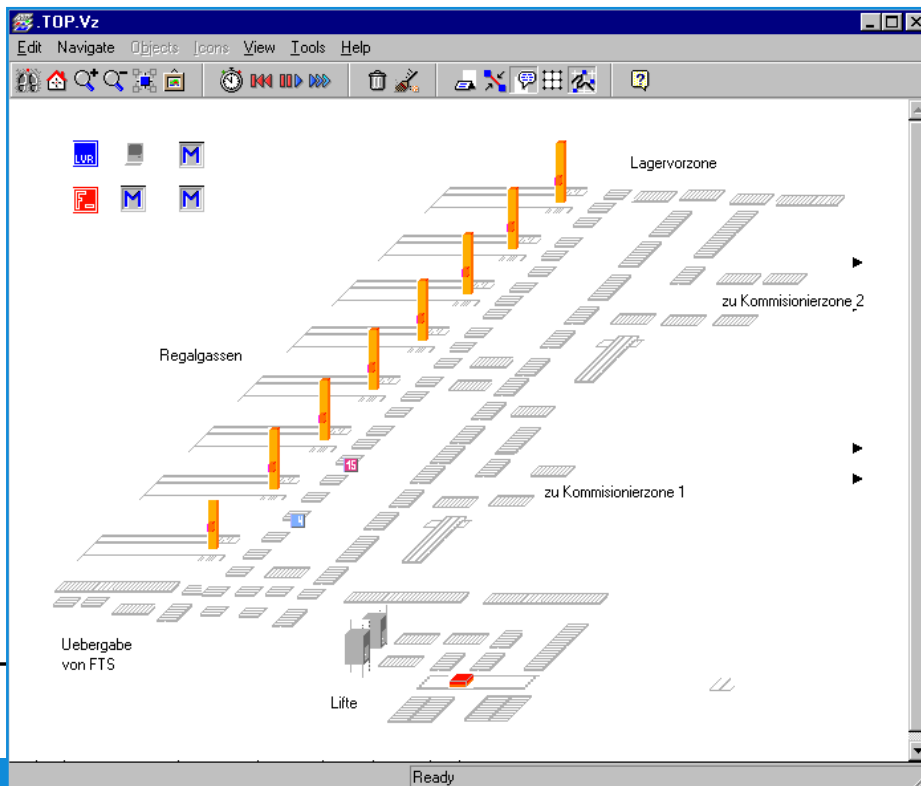
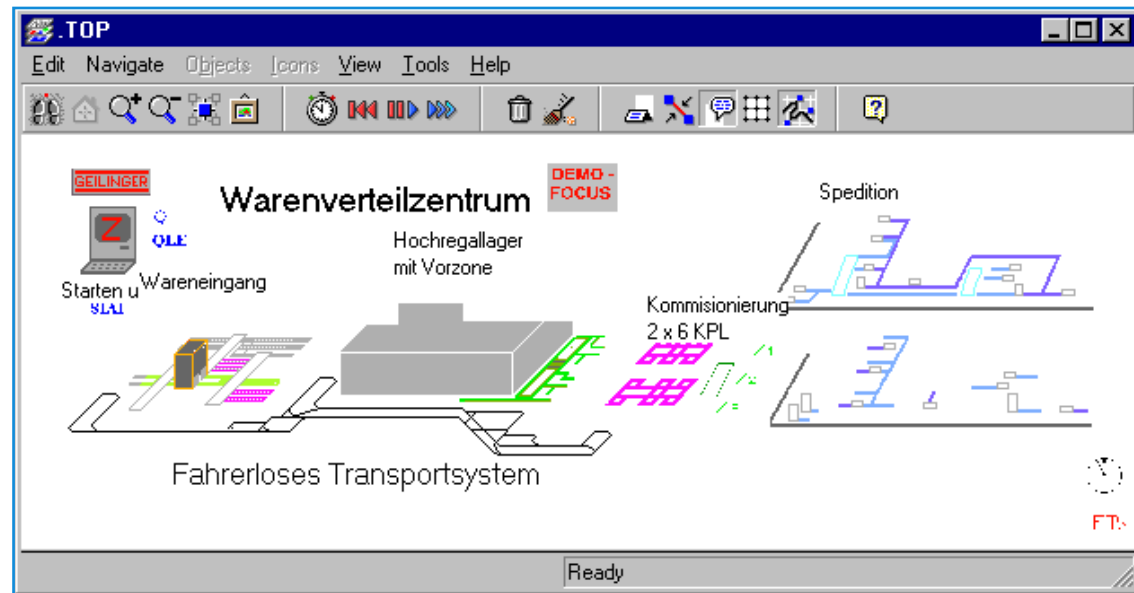
Time: 10.0000

Capacity: -1 ☐

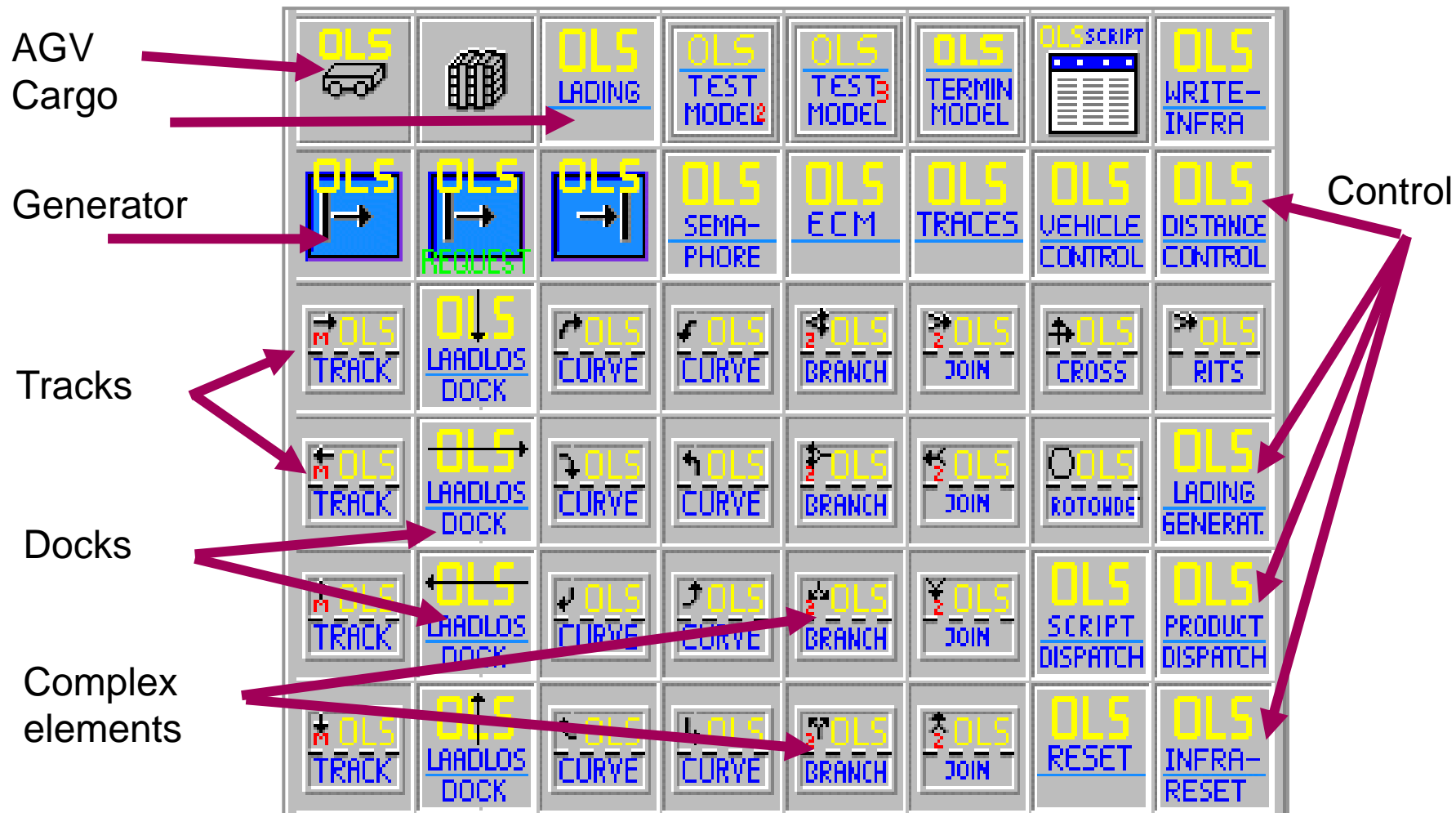
OK Apply Cancel

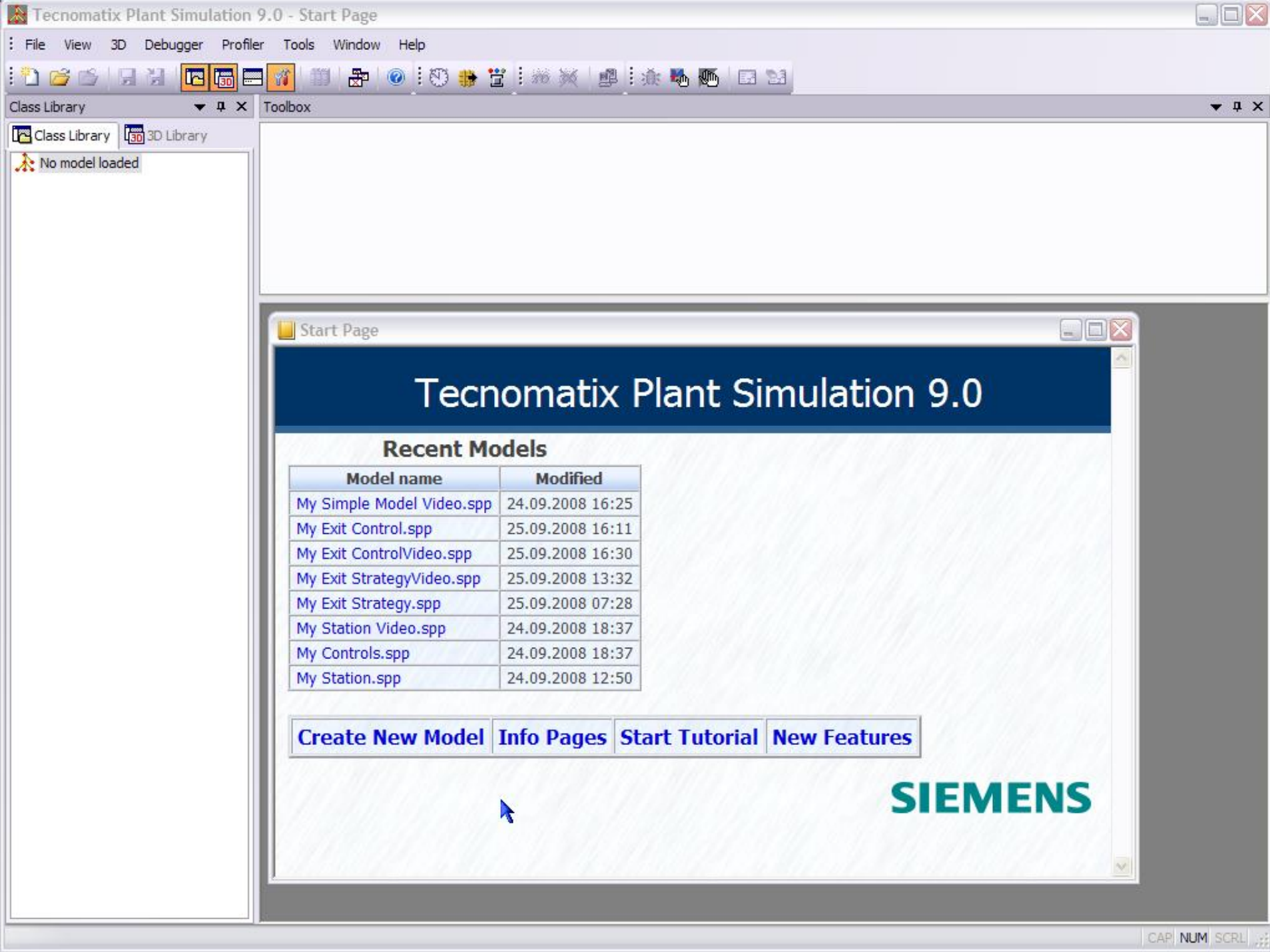
Plant Simulation

Sensors on the line ->
trigger of Methods



Own libraries can be created

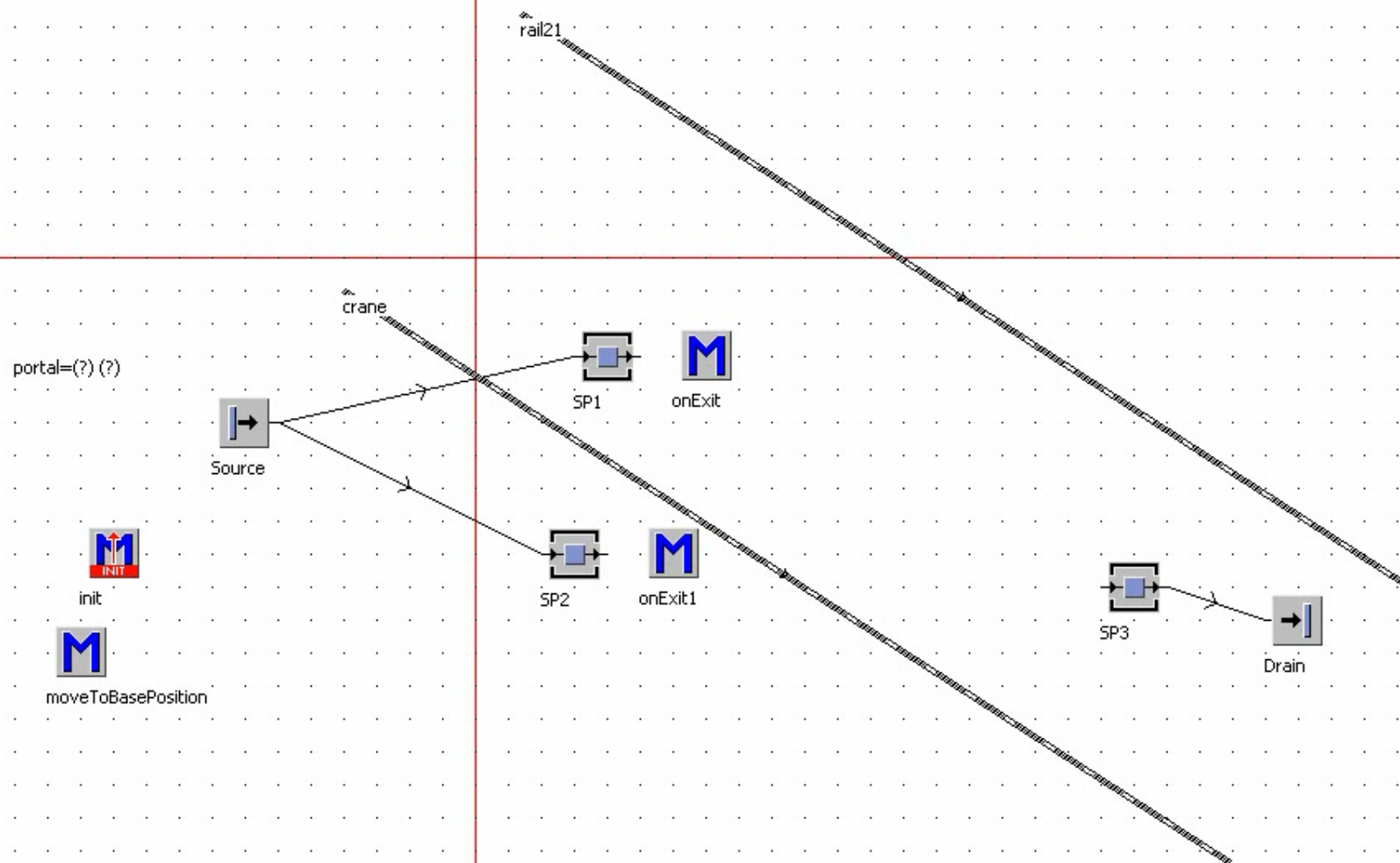






EventController

1 Portal
portal picks part at Sp1 or SP2 and moves part to SP3
test for moveToObject and moveToPosition



6.

AutoMod

AutoMod Product Suite

- AutoMod
 - Model build and simulation execution environment
- AutoStat
 - Statistical analysis including optimizations
- AutoView
 - Animation with AVI/MPEG support
- Module Communications Module (MCM)
 - Linking to third party software and control systems

AutoMod general information

- Modeling of:
 - Transportation, logistics
 - Material Handling Systems
- Development environment
 - Construction of models
 - Compile models
- Simulation environment
 - Run model, animation, gather statistics

AutoMod

- True to scale
 - conveyors
 - transporters
- No room – no move
- “A meter is a meter”

AutoMod: Systems

- Process System
 - Defines the model logic, how loads are processed in the system
 - Only one process system can be used
- Movement Systems
 - Simulation of material handling
 - Unlimited number of movement systems
- Static System
 - Background (wall, floor space)

| Process System |
|-------------------|
| Select |
| Process |
| Loads |
| Resources |
| States |
| Queues |
| Order Lists |
| Blocks |
| Variables |
| Counters |
| Functions |
| Subroutines |
| Source Files |
| Labels |
| Tables |
| Types |
| Random Streams |
| Run Control |
| Business Graphics |

AutoMod: Process System

- Process
 - Define activities that take place in model
 - Loads flow from one process to another
 - Different types of processes
- Loads
 - Loads are the physical entities that move through a system
 - Loads execute logic and cause events to happen
 - Load type, Load creation rate
 - Load attributes: specific to each load

| Process System |
|-------------------|
| Select |
| Process |
| Loads |
| Resources |
| States |
| Queues |
| Order Lists |
| Blocks |
| Variables |
| Counters |
| Functions |
| Subroutines |
| Source Files |
| Labels |
| Tables |
| Types |
| Random Streams |
| Run Control |
| Business Graphics |

AutoMod: Process System

- Resources
 - Represent machines, operators, tools
 - Limited capacity
 - Get-wait-free or use-command
 - Resource cycles (MTTF, MTTR)
- Queue
 - Space where loads can be stored
 - Use two queues: waiting and processing
- Order lists
 - A list of loads/vehicles that are delayed for a amount of time during the simulation

AutoMod: Movement systems

- Movement system
 - Template for material movements
 - Path Mover (AGVs, lift trucks, trucks)
 - Conveyor
 - Automated Storage and Retrieval Systems
 - Bridge cranes
 - Power and free chain conveyors
 - Tanks and pipes

