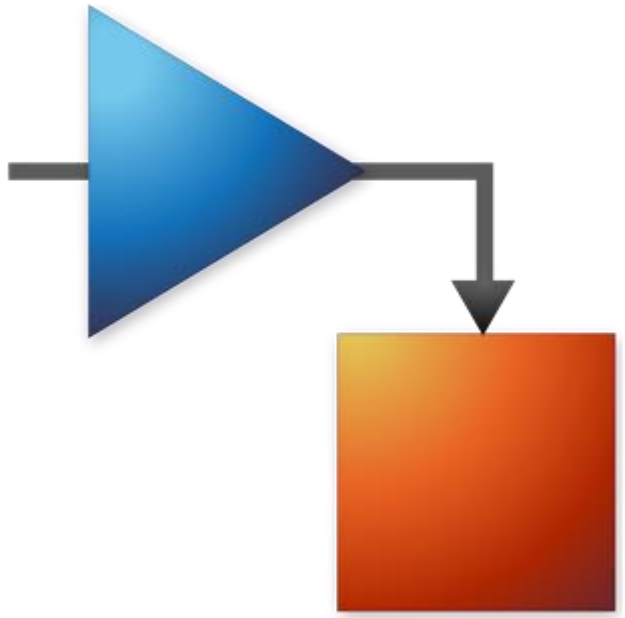
Introduction to Simulink

Mughees Asif
3rd Year Aerospace Engineering
QMUL MathWorks Student Ambassador



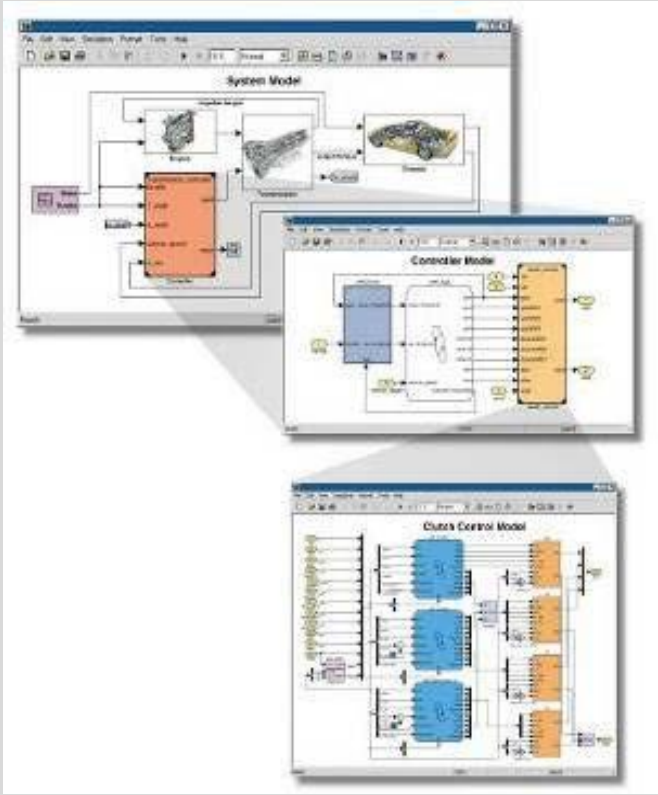
Outline

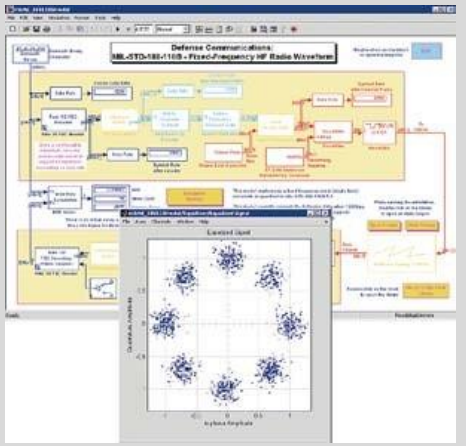
- **What is Simulink?**
- Working with Simulink
- How Simulink works
- Componentizing models
- Continuous and discrete models

Simulink

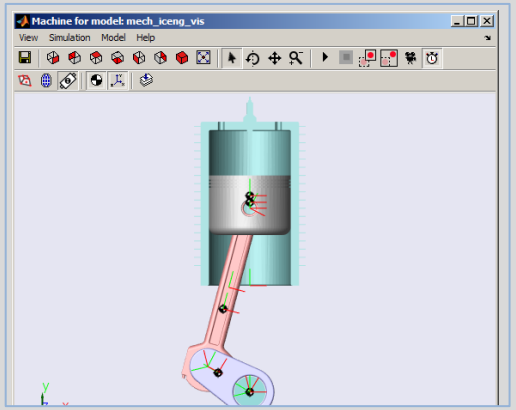
Simulink is a software package for modeling, simulating, and analyzing dynamic systems

- Block diagram editing
- Non-linear simulation
- Hybrid (continuous and discrete) models
- Asynchronous (non-uniform sampling) simulation
- Fully integrated with MATLAB, MATLAB toolboxes and blocksets.

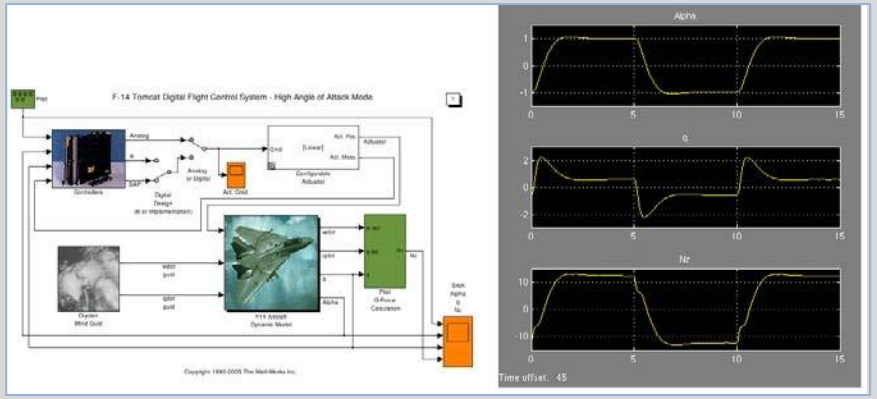


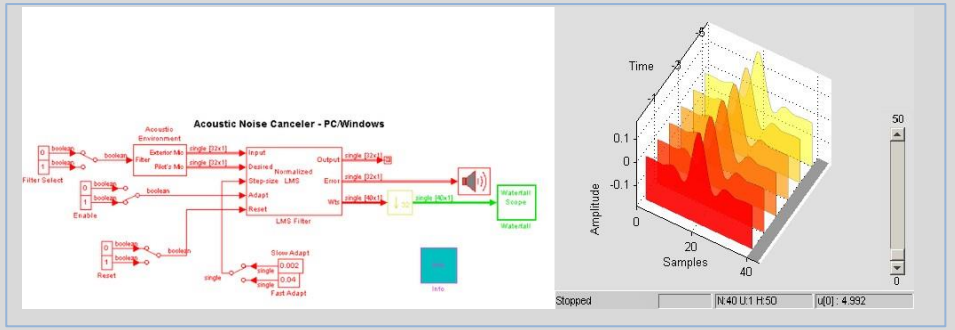


Simulink



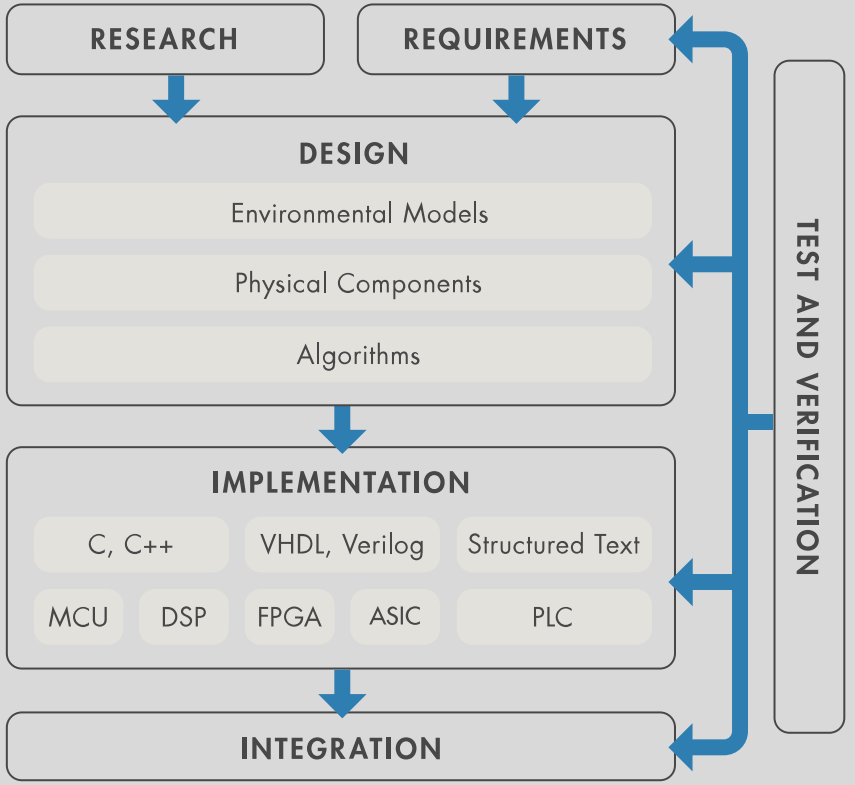
- Accurately design, implement, and test:
  - Control systems
  - Signal Processing systems
  - Communications systems
  - Embedded systems
  - Physical systems
  - other Dynamical systems



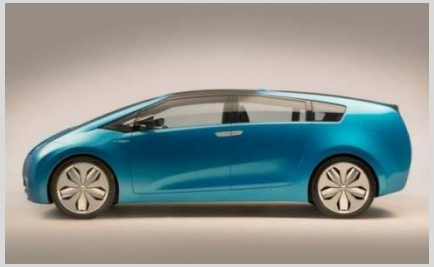


Model Based Design with Simulink

- Definition
  - A *model* is defined as a representation of a system for the purpose of studying the system.
- Types
  - Static vs. dynamic.
  - Deterministic vs. stochastic
  - Discrete vs. continuous
- Implementation
  - Automatic code generation
  - Rapid prototyping for HIL, SIL
  - Verification and validation



Simulink Applications



Bell Helicopter Develops the First Civilian Tiltrotor, Using Model-Based Design

The BA609, flying in airplane mode.

Challenge

To design and build the BA609, the first and fastest commercially available tiltrotor aircraft in the world

Solution

Use Model-Based Design with MATLAB, Simulink, and Real-Time Workshop software to model, simulate, test, and verify designs

Results

- Full collaboration with suppliers via Simulink models
- Flight control system code generated automatically from models
- 40% improvement in design and development time
- Flawless first flight, which went exactly like the simulation

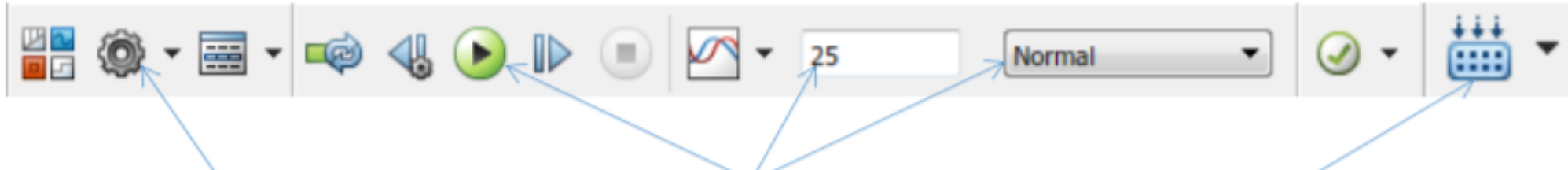
"Simulations and a rapid, iterative approach enabled us to minimize the unknowns and ensure that we had established enough margin that when we ran into a surprise we could continue to have a safe flight test program—and run it with unprecedented efficiency."

David King
Bell Helicopter

Outline

- Why Simulink?
- **Working with Simulink**
- How Simulink works
- Componentizing models
- Continuous and discrete models

Simulink Toolbar



Model Settings

All of the settings related to how to numerically solve the equations of the model are found in "Model Configuration Parameters" Cog.

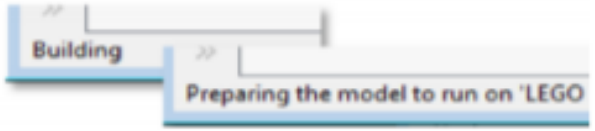
Run Model

To run the simulation, press the green arrow. Be aware there are different modes e.g. 'Normal'. If you are working with hardware the mode will be 'External'.

The textbox is how many seconds you want the simulation to run for.

Build Model

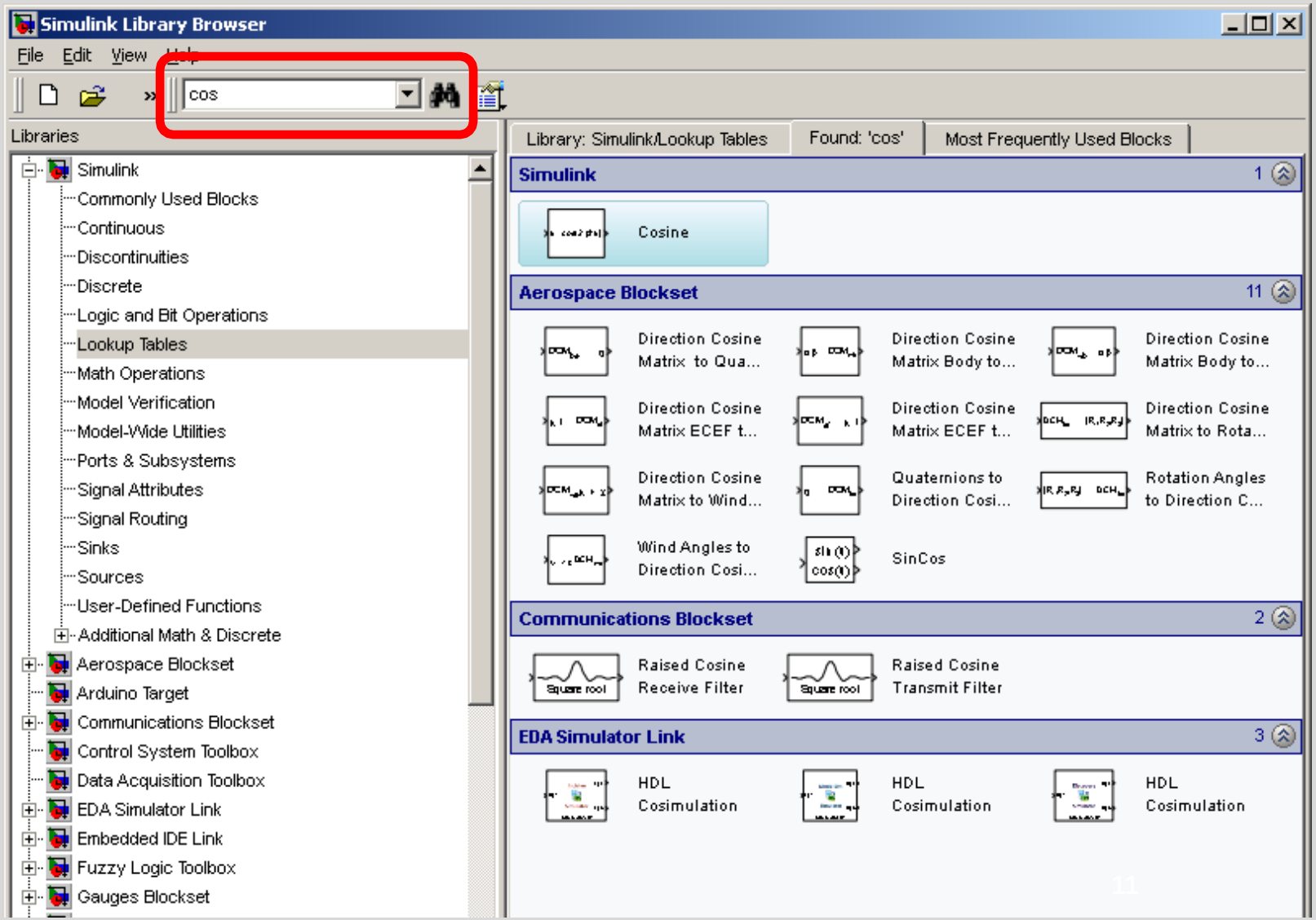
If your model is interacting with hardware, you will need to *build* the model before it can run. The current status is shown in the lower left of the Simulink window.



Overview of the library

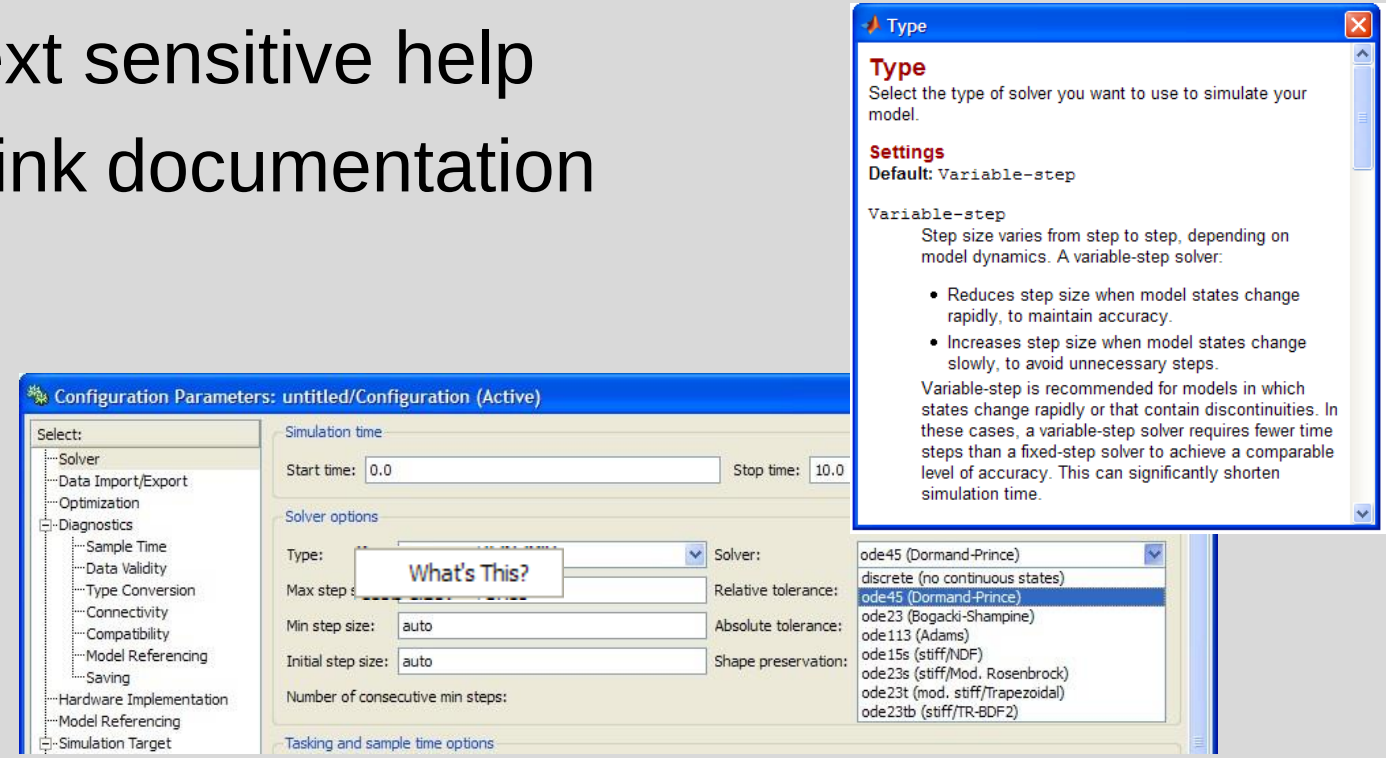
Library Name	Examples
Sources	Constant, Sine Wave, Steps
Sinks	Scope, XY Graphs
Math operations	Add, divide, absolute
Ports & subsystems	Subsystem, Enable port, Inputs and Outputs: In1 and Out1
User defined functions	Fcn, MATLAB Fcn
Lookup tables	1D Lookup table
Signal Routing	Mux, BusCreator, Goto, Switch
Continouse	Integrator, Derivative
Discrete	Unit delay, Discrete Derivative
Logical and Bit operations	Compare to Zero, Logical operators

Finding Blocks



Getting Help

- Context sensitive help
- Simulink documentation

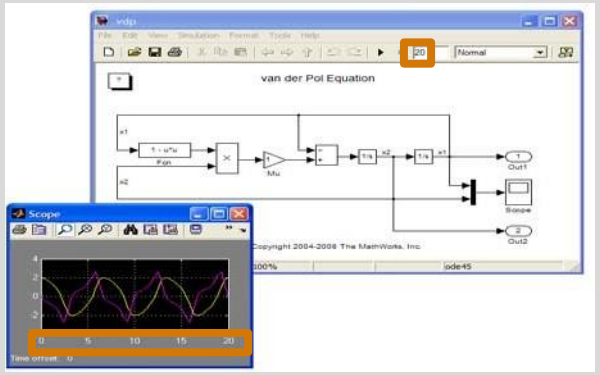


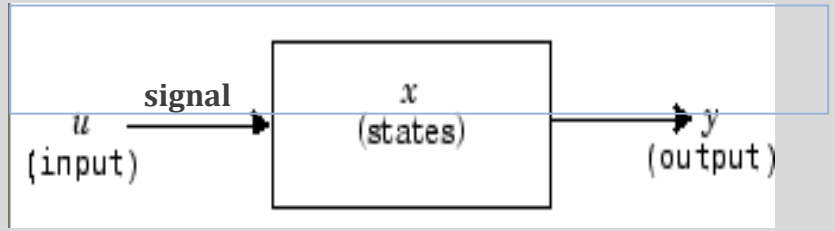
Outline

- Why Simulink?
- Working with Simulink
- **How Simulink works**
- Componentizing models
- Continuous and discrete models

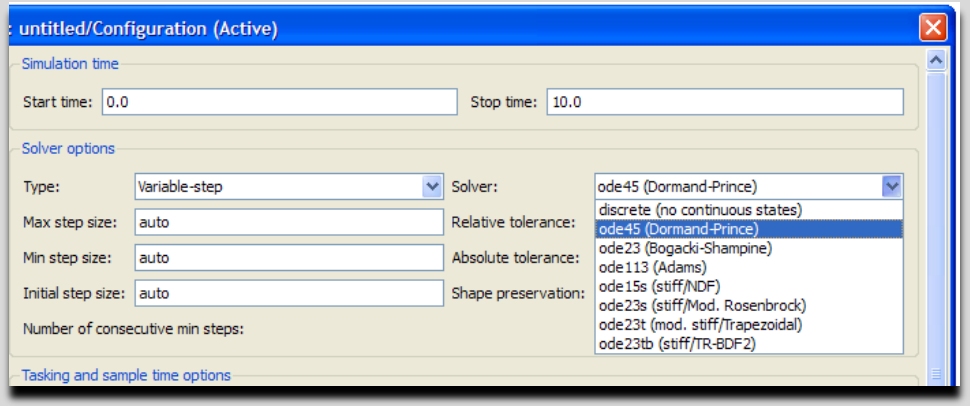
How Simulink Works

- Engine provides variable-step and fixed- step ODE solvers
- Block Diagram representation of dynamic systems
- Blocks define governing equations
- Signals are propagated between blocks over time





Simulink Solvers



- Solver?
  - Determines solution at current time step
  - Determines the next simulation time step
- Solver options:

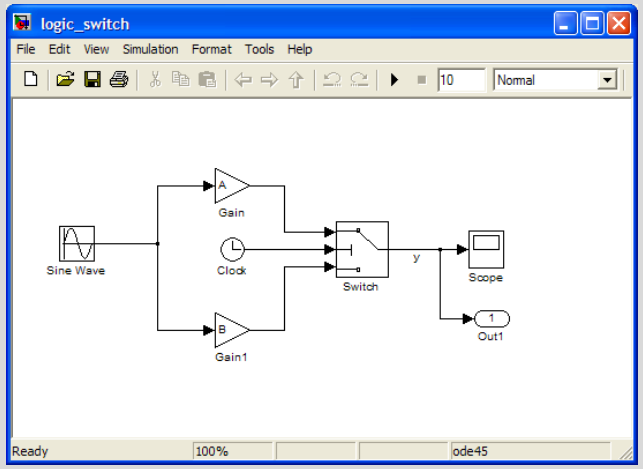
Fixed-Step	Variable-Step
✓Ode1	✓Ode45
✓Ode2	✓Ode23
✓Ode3	✓Ode113
✓Ode4	✓Ode15s
✓Ode5	✓Ode23s
✓Ode8	✓Ode23t
	✓Ode23tb

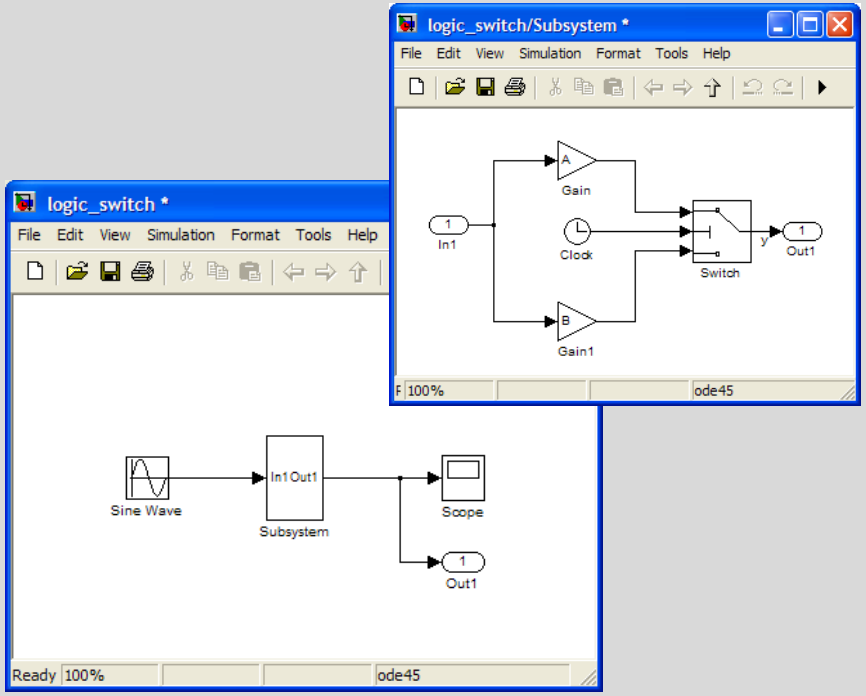
Outline

- Why Simulink?
- Working with Simulink
- How Simulink works
- **Componentizing models**
- Continuous and discrete models

Creating Subsystems

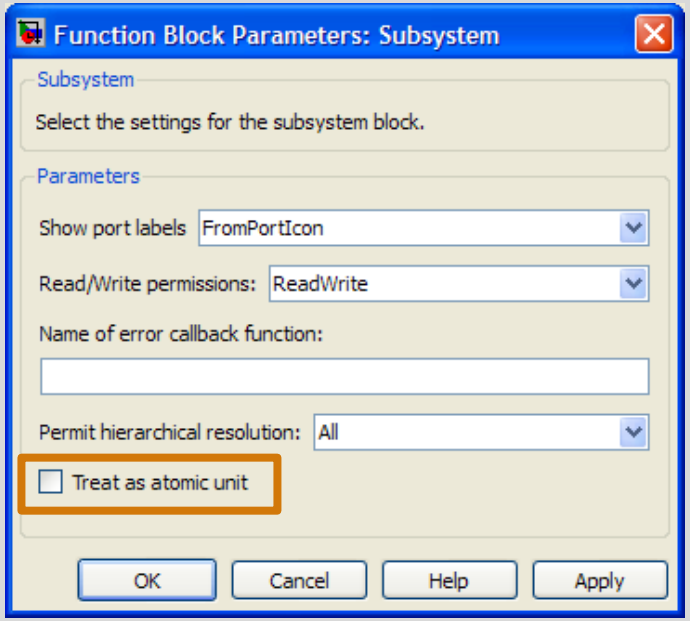
- Context menu → Create Subsystem
- Subsystem ports
- Inside a subsystem





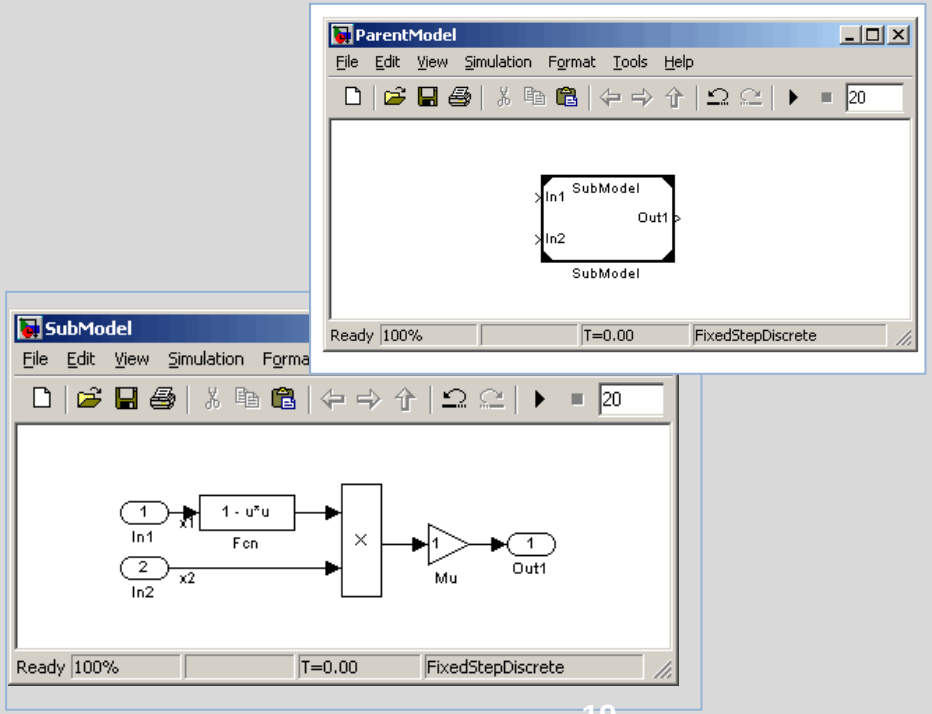
Subsystems

- Why?
  - Reduce blocks displayed in a model window
  - Keep functionally related block together
  - Establish hierarchical block diagram



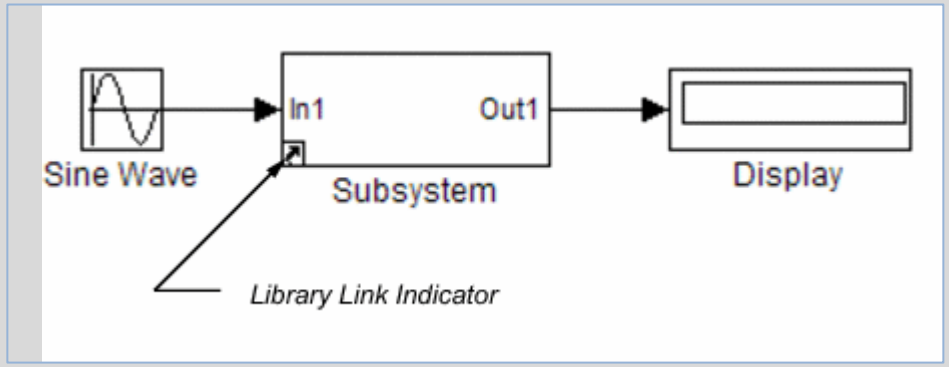
Model Referencing

- One model in another- *parent and referenced model*
- Advantages:
  - Componentization/Modularization
  - IP protection
  - Multiple referencing
  - Acceleration



Block Library

- Collection of blocks
- Prototype block vs Reference block
- Library Links
  - Disable link
  - Restore link
  - Break link

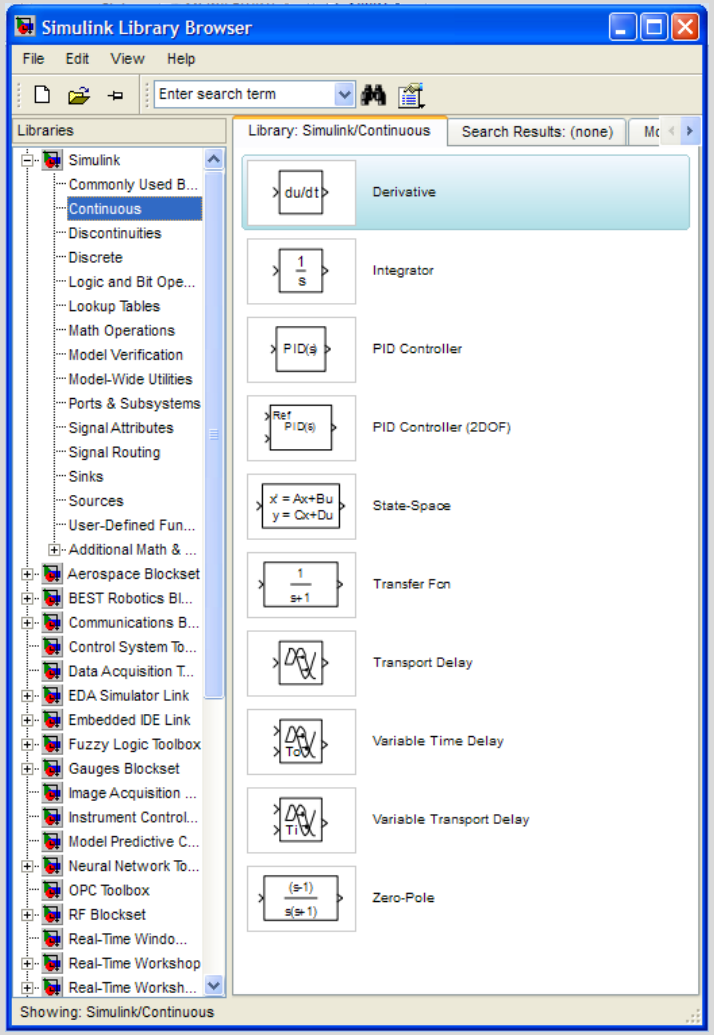


- Other features
  - Display in Simulink Library Browser
  - Add documentation

Outline

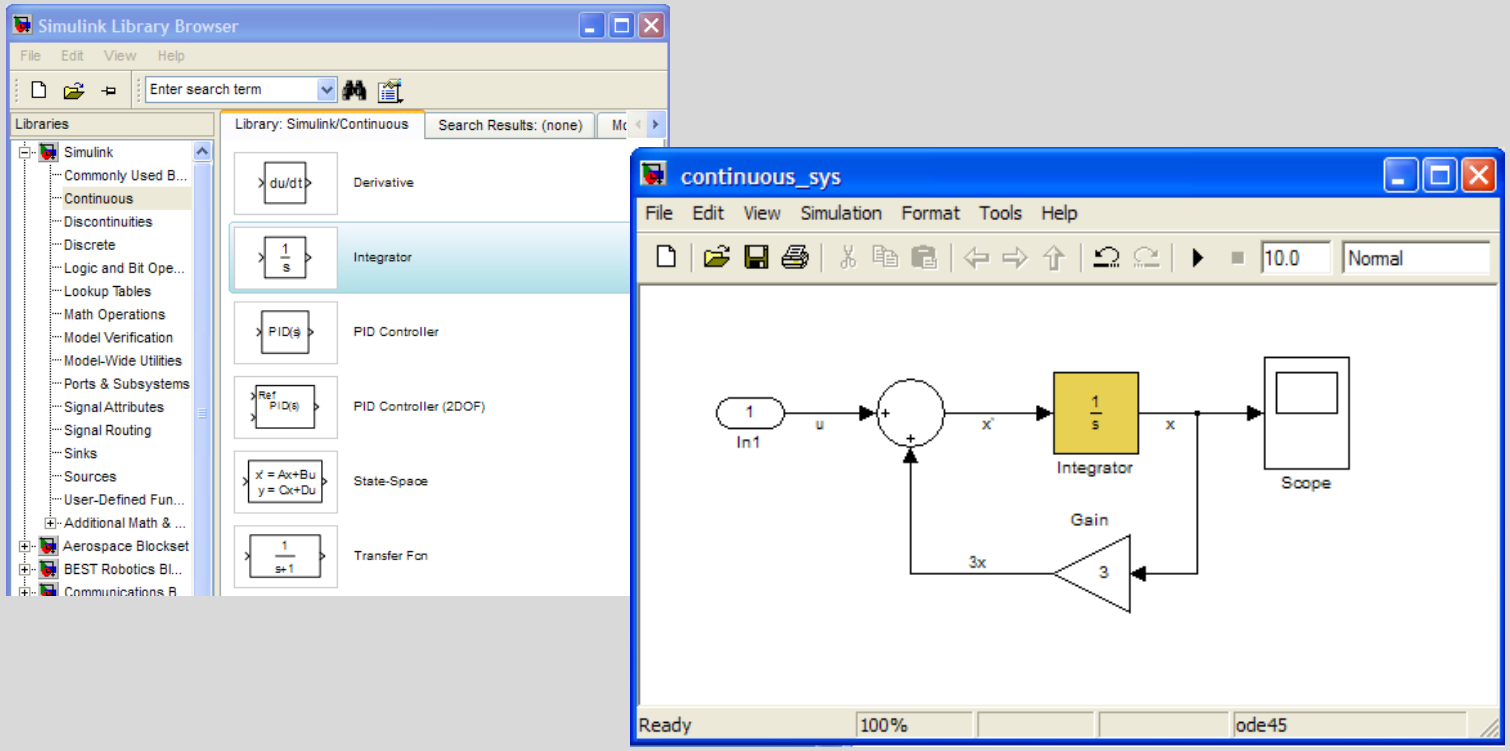
- Why Simulink?
- Working with Simulink
- How Simulink works
- Componentizing models
- **Continuous and discrete models**

‘Continuous’ Library



Continuous systems: Time-Domain Representation using Integrator Block

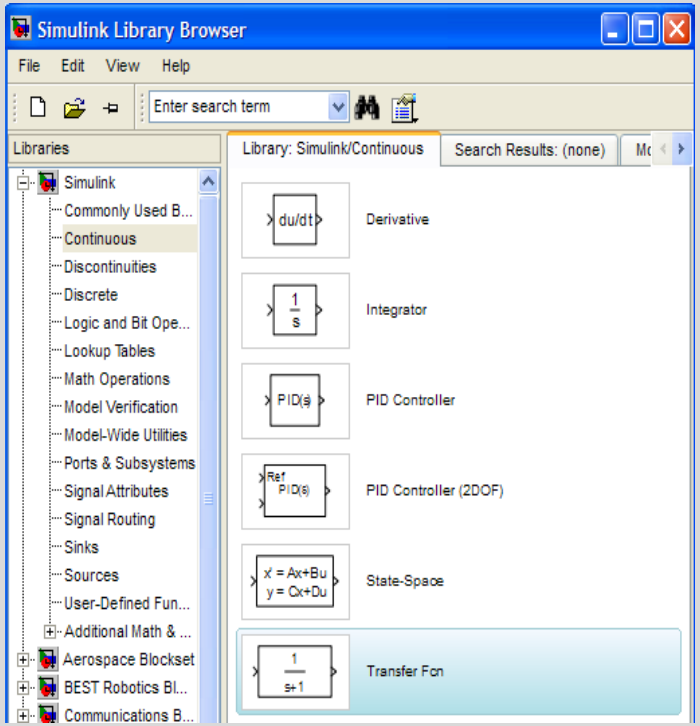
$$x'(t) = 3x(t) + u(t)$$

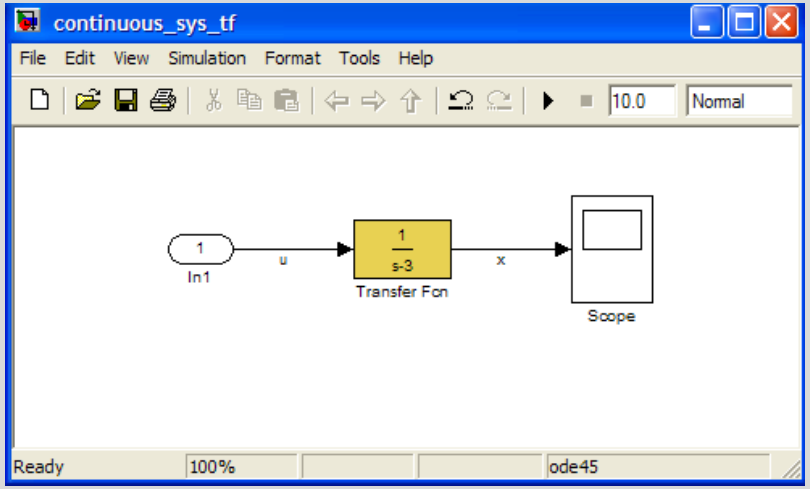


Continuous systems: Frequency-Domain Representation using Transfer Function Block

$$x'(t) = 3x(t) + u(t) \Leftrightarrow \frac{X(s)}{U(s)} = \frac{1}{s-3}$$

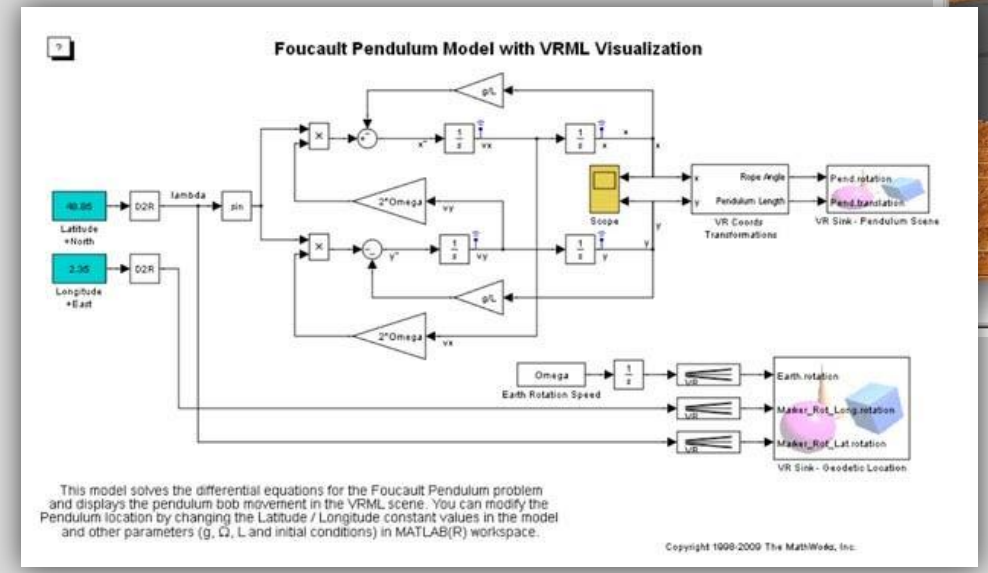
```
Transfer function:
sx = 3x + u
x = u/(s-3)
x/u = 1/(s-3)
```



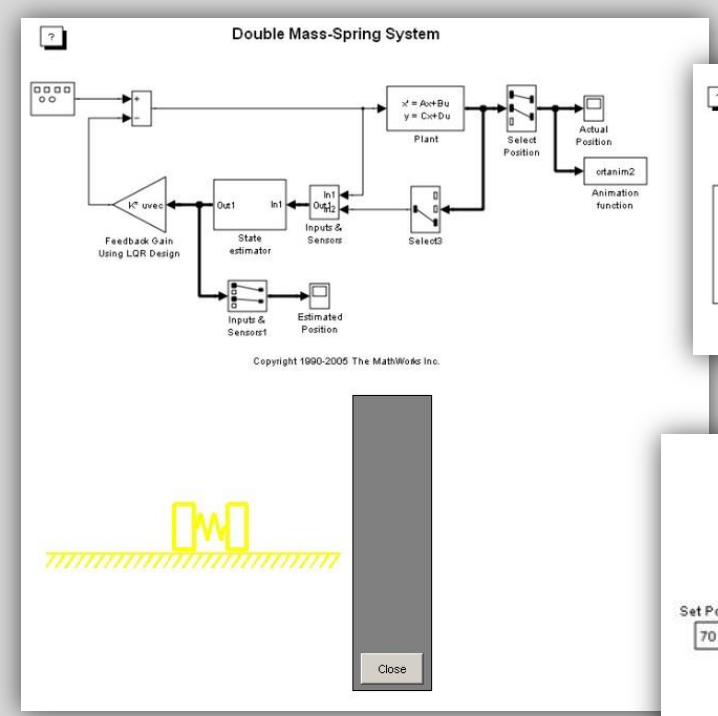


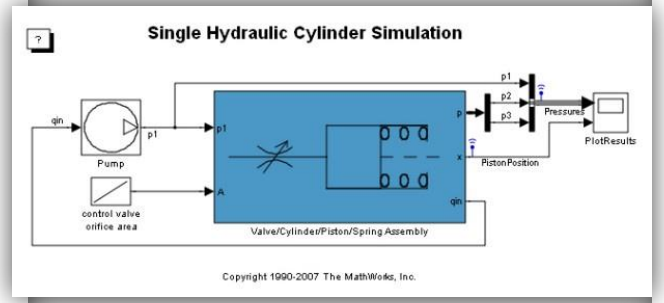
Simulink Demo: Foucault Pendulum Model with VRML Visualization

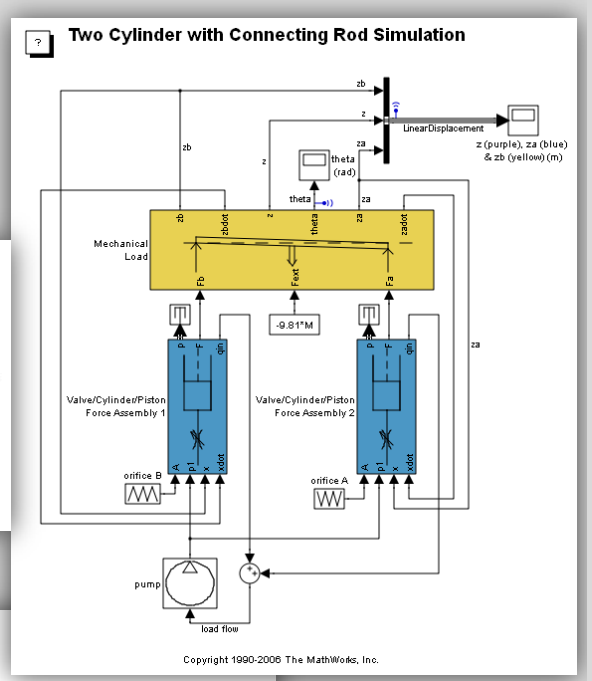
`sldemo_foucault_vr.mdl`

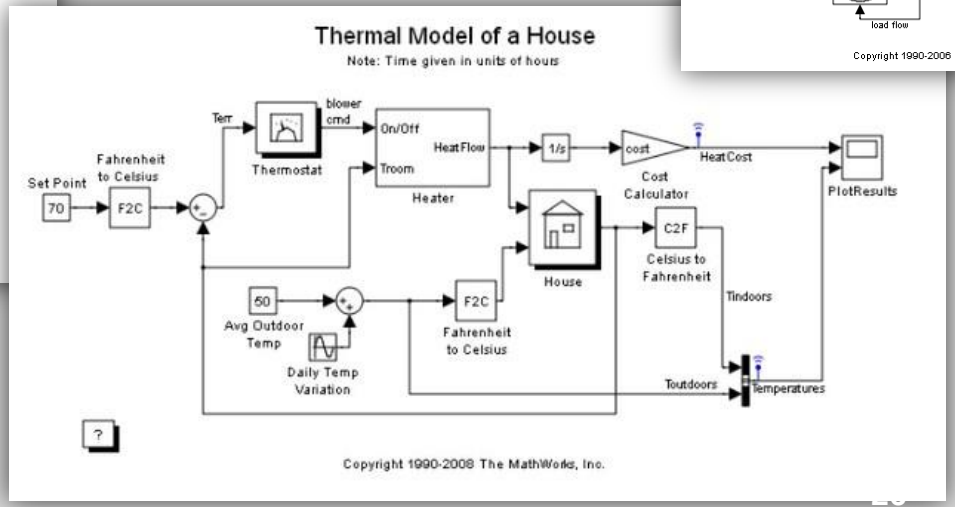


Other Demos for Continuous Systems





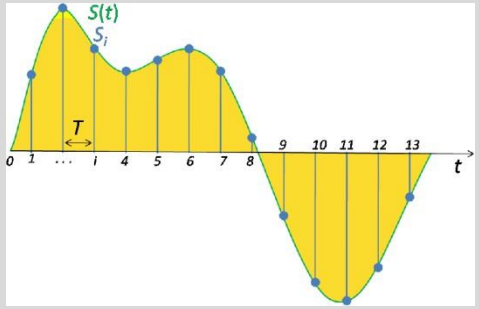


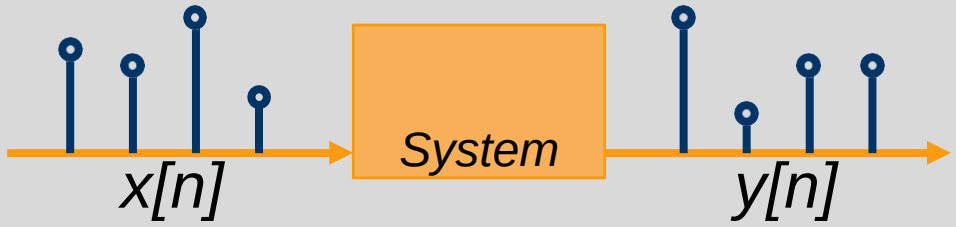


Discrete Systems

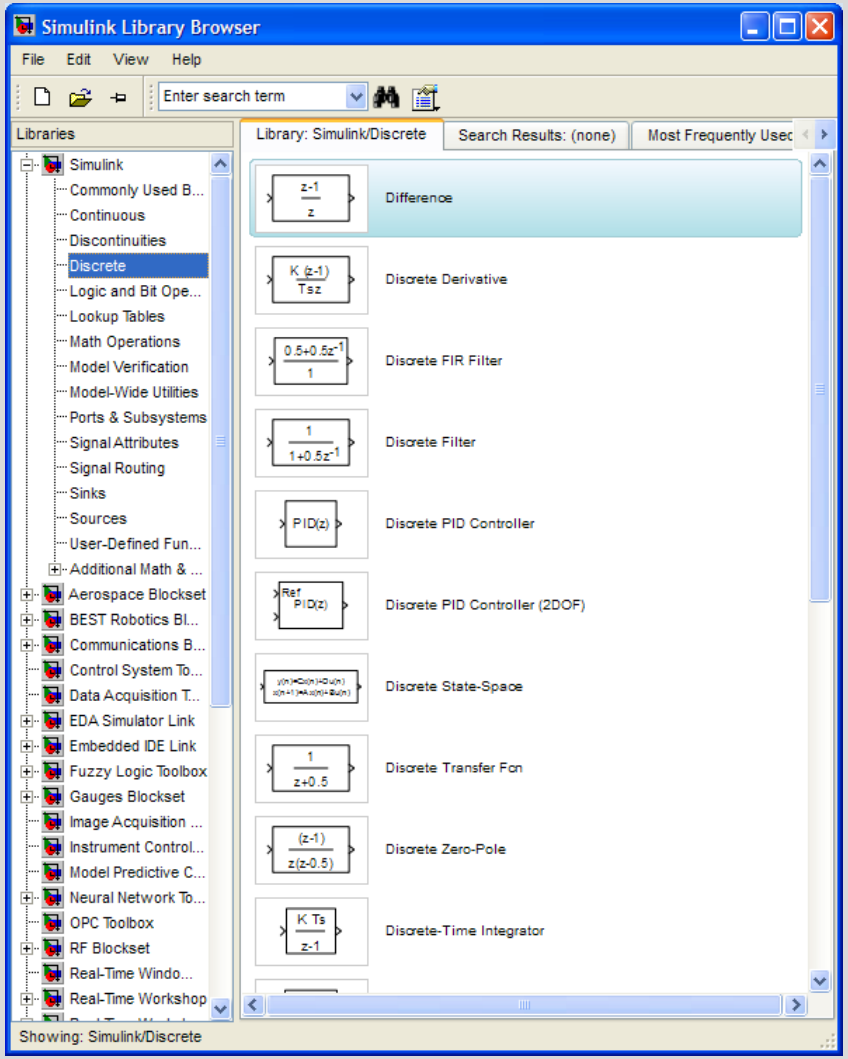
- System that takes an input sequence of samples and outputs a sequence of samples
- Sampling

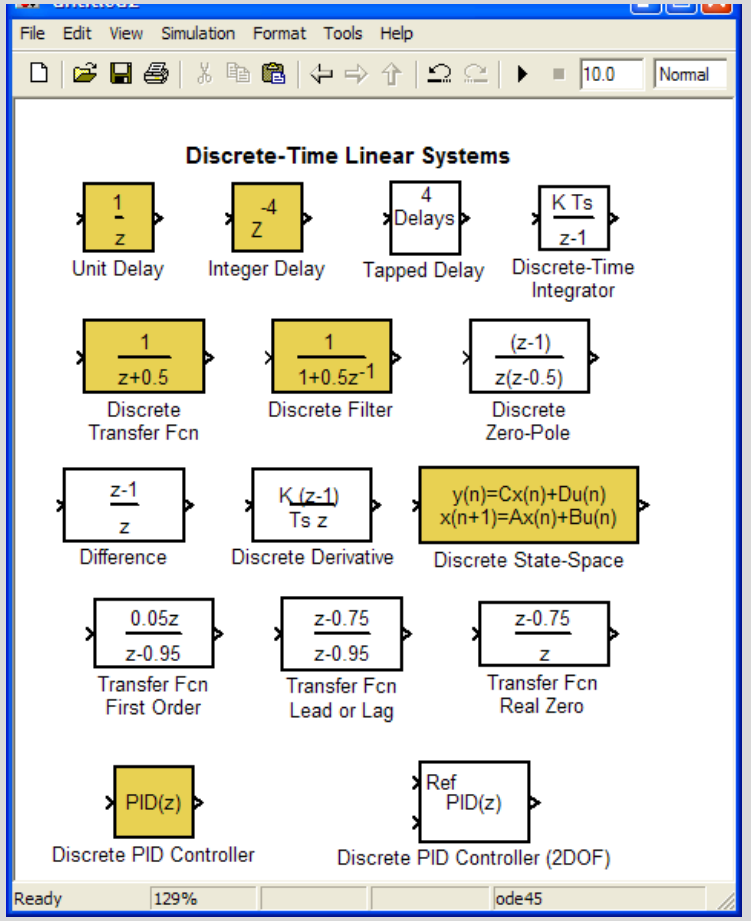
$$y[k] = 0.1x[k] + x[k-1]$$
$$x[k+1] = -0.5x[k] + u[k]$$





‘Discrete’ Library

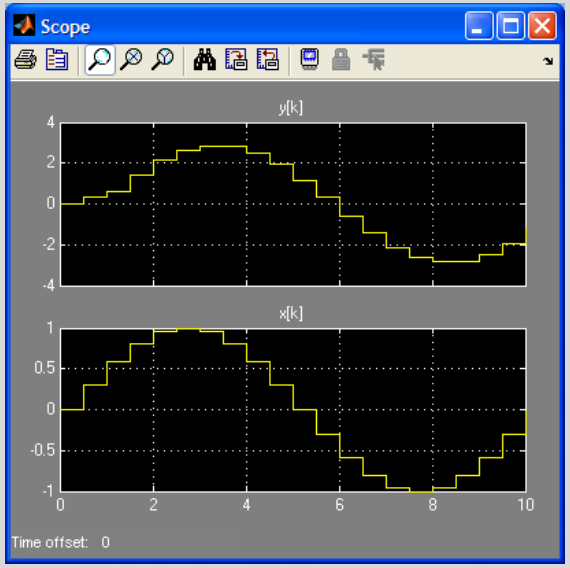




Discrete system example

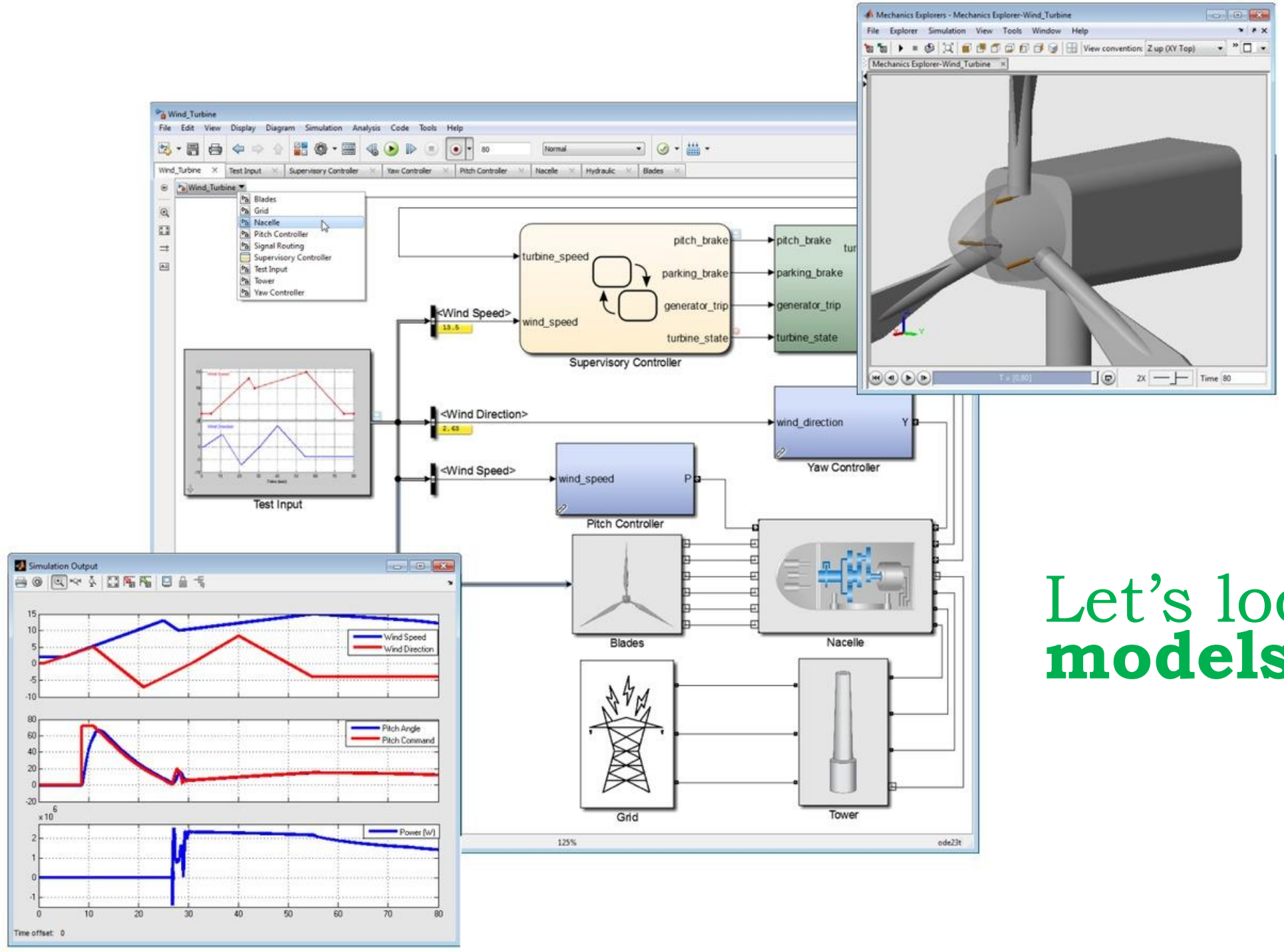
- Second order FIR filter

$$y[k] = \frac{x[k] + ax[k-2]}{2}$$



Summary

- Why Simulink?
- Working with Simulink
- How Simulink works
- Componentizing models
- Continuous and discrete models



Let's look at some **models** now!

Cisco

- **Campus Ambassador**
- Do join the **LinkedIn page** for graduate/internship opportunities: https://www.linkedin.com/groups/12470630/
- Join the **email newsletter** to stay up-to-date: https://forms.gle/QZamk91qoJm3pt4s6
- To **access** the job opportunities, use the link: https://rb.gy/y8u16a

Developer Student Clubs

Queen Mary, University of London

- Work in a team of 17 students, in collaboration with Google
- Leveraging Google products to solve local community challenges
- Do join the **LinkedIn page** to get involved: https://www.linkedin.com/groups/12467711/
- Check out the team and for future updates, do **join the chapter**: https://dsc.community.dev/queen-mary-university-of-london/

KAHOOT! Challenge

Will post all prizes by next day

All sizes available

First	1 x ***t-shirt*** 1 x ***baseball cap*** 1 x ***sunglasses*** 10 x ***pens***
Second	1 x ***drawstring bag*** 1 x ***baseball cap*** 10 x ***pens*** 20 x ***stickers***
Third	10 x ***pens*** 10 x ***stickers***

Thank you!

MATLAB® & SIMULINK®

Join the FB group to stay up to date with future events:

https://www.facebook.com/groups/196042678284982

The code and presentation can be downloaded from:

https://github.com/mughees-asif/matlab-qmul#queen-mary-matlab-tutorials