Graphical Programming Languages in Model-Based Design

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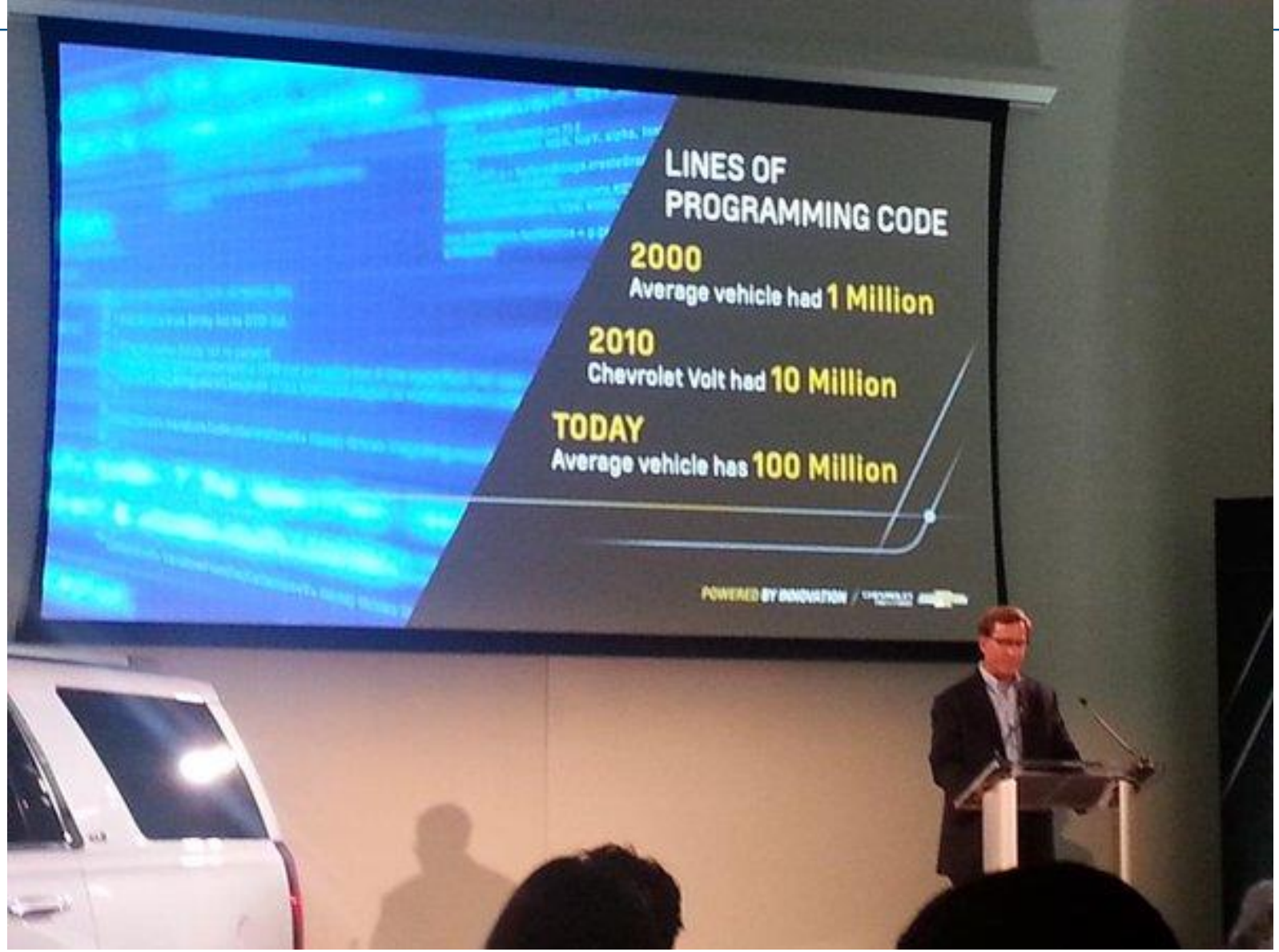
Design Automation

"When I step into a new car these days,
I don't smell leather anymore,
I smell software"

MATLAB Automotive Conference, Stuttgart, 2015



John Lauckner, CTO at General Motors

***Autonomous* systems**

***Industry* standards**

Software

Everywhere and in everything

And growing exponentially!

Scaling up doesn’t just mean raising your game

Scaling up means playing a different game

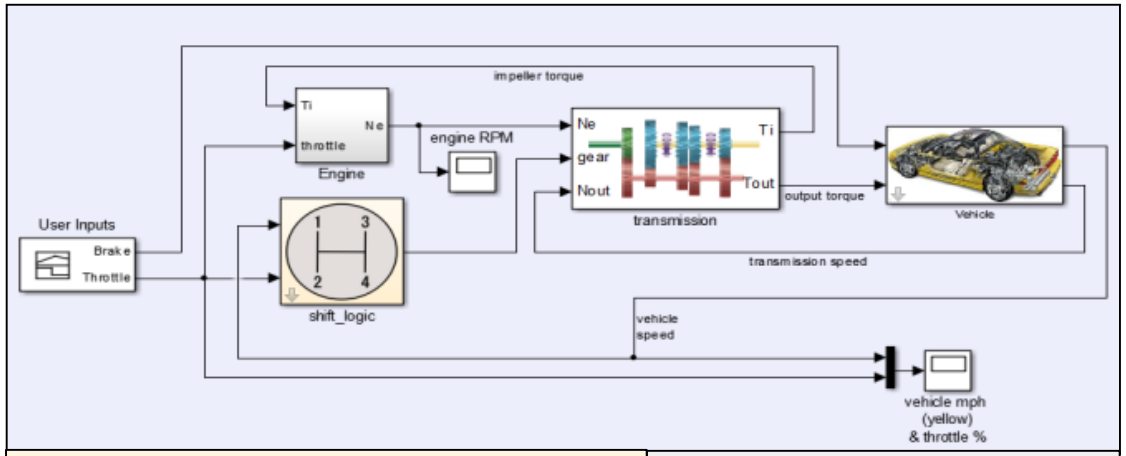
Abstraction

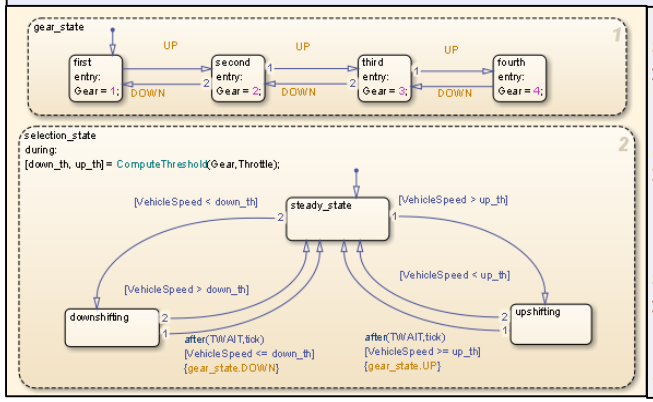
Transform a hard problem to an easier problem

High-level languages

High-level languages at MathWorks

Simulink






```
% Predicted state and covariance
x_prd = A * x_est;
p_prd = A * p_est * A' + Q;

% Estimation
S = H * p_prd' * H' + R;
B = H * p_prd';
klm_gain = (S \ B)';

% Estimated state and covariance
x_est = x_prd + klm_gain * (z - H * x_prd);
p_est = p_prd - klm_gain * H * p_prd;

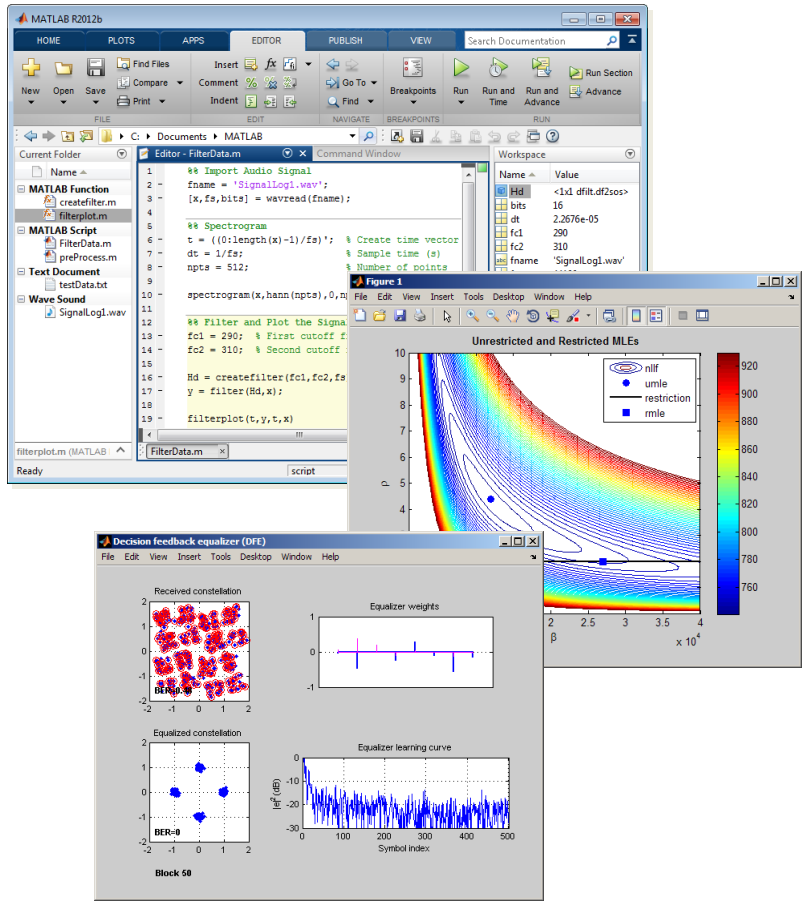
% Compute the estimated measurements
y = H * x_est;
```

Stateflow **MATLAB**

MATLAB

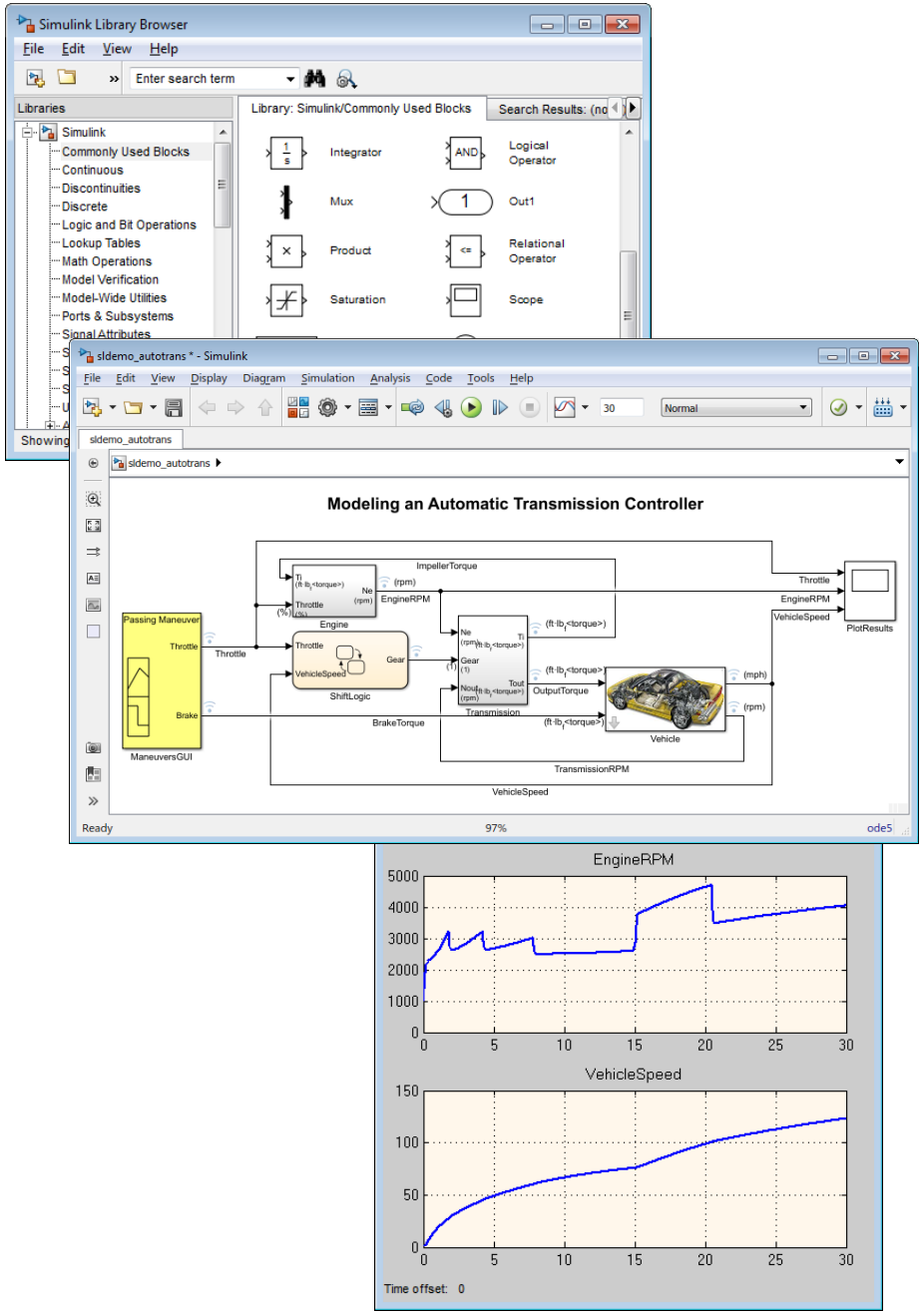
The leading environment for technical computing

- The industry-standard, high-level programming language for algorithm development
- Numeric computation
- Parallel computing, with multicore and multiprocessor support
- Data analysis and visualization
- Toolboxes for signal and image processing, statistics, optimization, symbolic math, and other areas
- Tools for application development and deployment
- Foundation of MathWorks products



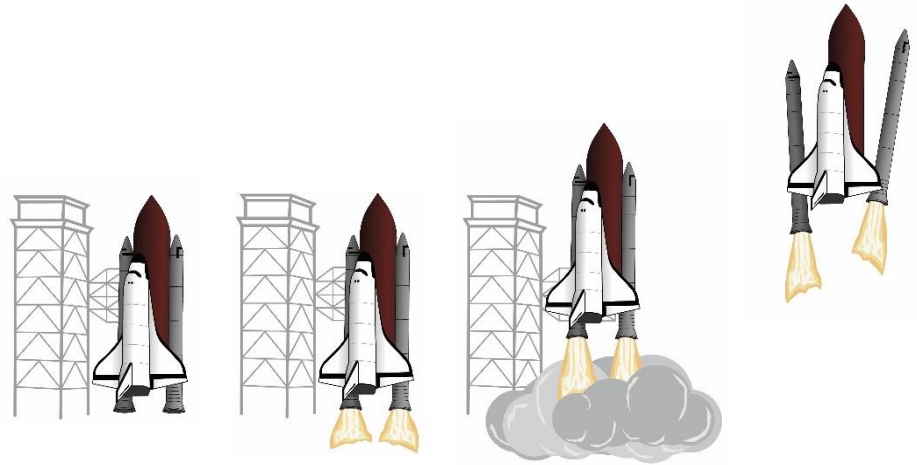
Simulink

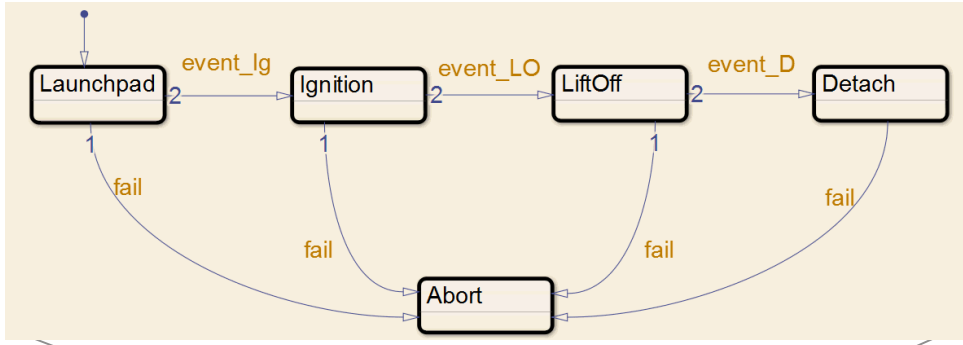
- Block-diagram environment
- Model, simulate, and analyze multidomain systems
- Design, implement, and test:
  - Control systems
  - Signal processing systems
  - Communications systems
  - Other dynamic systems
- Platform for Model-Based Design

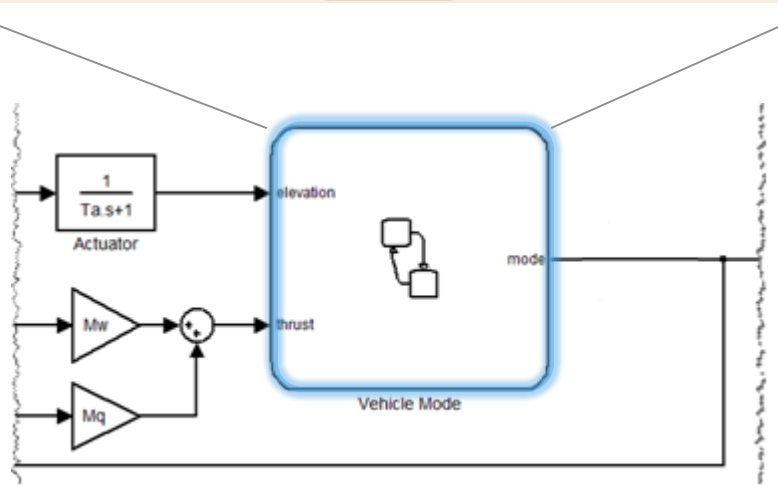


Stateflow

- Model and simulate decision logic for reactive systems:
  - supervisory control
  - task scheduling
  - fault management
- Develop mode-logic using state machines and flow charts
- See how the logic behaves with diagram animation and integrated debugger

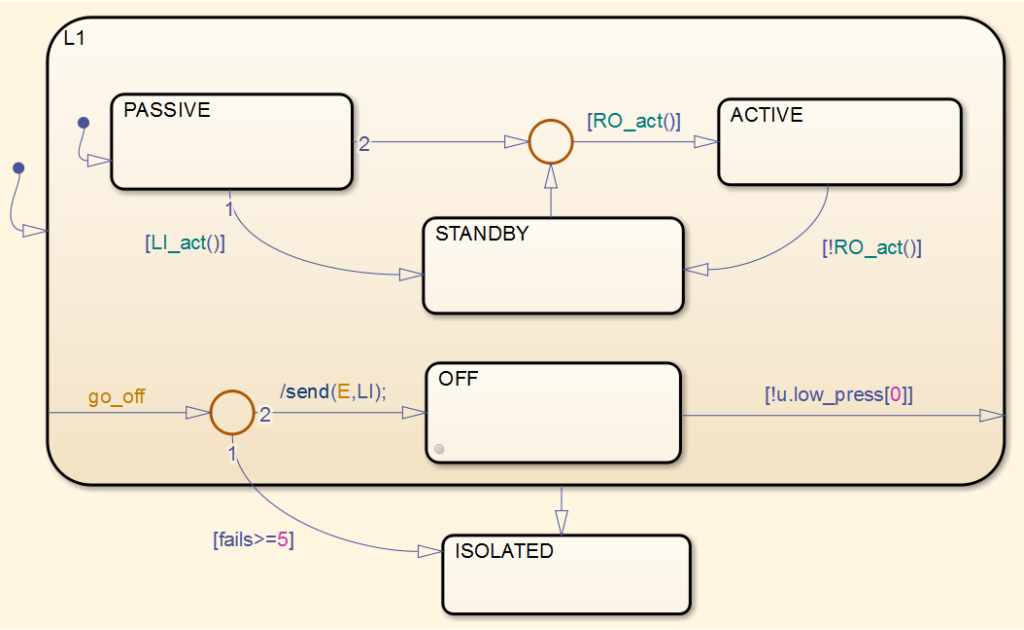






What are State Machines?

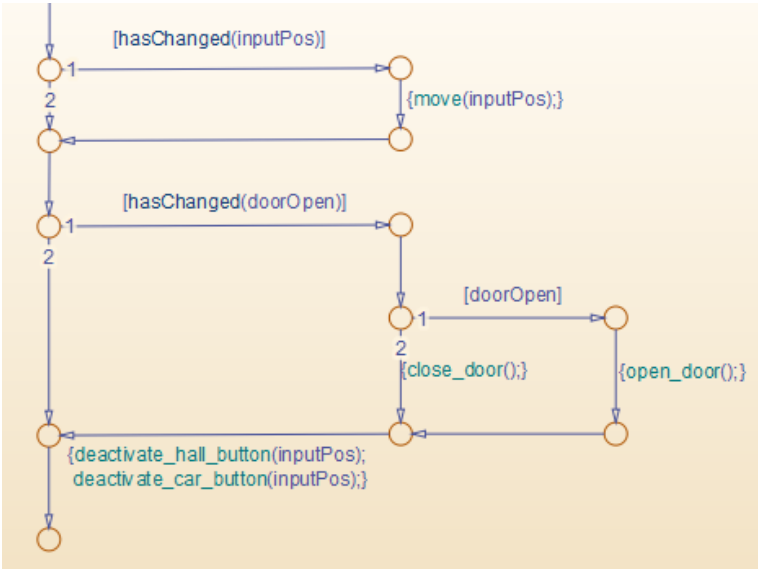
- Represent reactive systems that have states or modes
- States change based on defined conditions and events



Fault Management

What are Flow Charts?

- Represent an algorithm or process



Why state machines ?

Abnormal region identification: hysteresis

I want to identify large contiguous regions in my data vector that satisfy a certain property (say a threshold)

- my abnormal region starts when my sequence falls below “t1”
- my normal region starts again when my sequence rises above “t2”

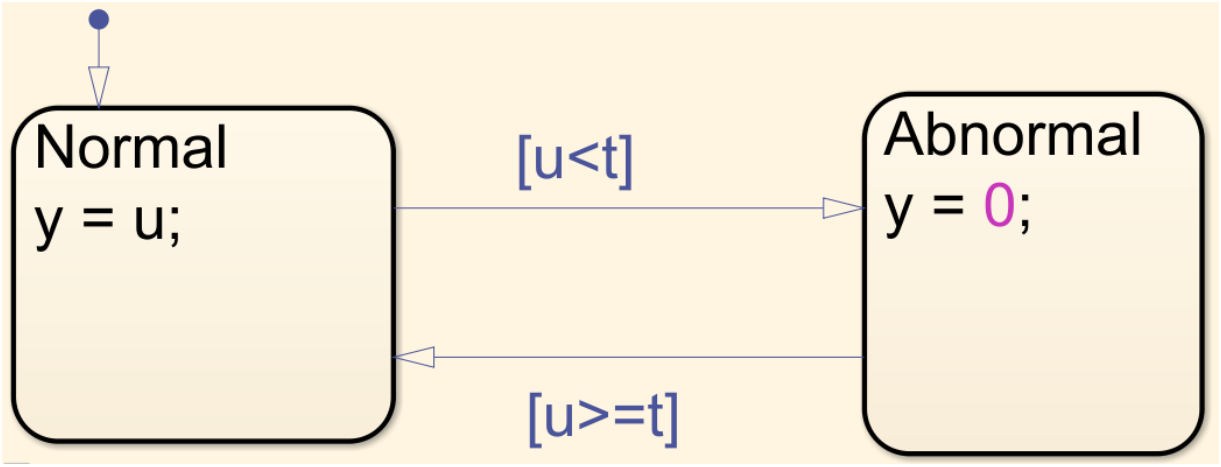
Abnormal region identification

I want to identify large contiguous regions in my data vector that satisfy a certain property (say a threshold)

- Can be done in a few lines of MATLAB code and a simple state machine

```
for i=1:length(inData)
    if(inData(i)>=t)
        outData(i) = inData(i);
    else
        outData(i) = 0;
    end
end

%outData = inData.*(inData<t);
```



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```
inNormalRegion = true;
for i=1:length(inData)
    if(inNormalRegion && (inData(i)<t1))
        inNormalRegion = false;
    elseif(~inNormalRegion && (inData(i)>=t2))
        inNormalRegion = true;
    end
    if(inNormalRegion)
        outData(i) = inData(i);
    else
        outData(i) = 0;
    end
end
```

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    end
    if(inNormalRegion)
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    else
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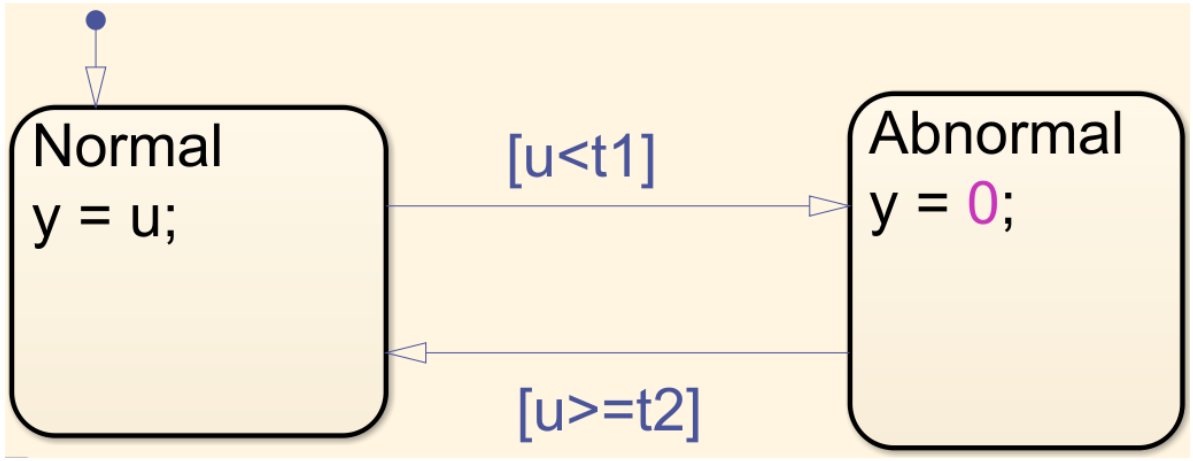
end
```



Abnormal region identification: hysteresis + debouncing

I want to identify large contiguous regions in my data vector that satisfy a certain property (say a threshold)

- my abnormal region starts when my sequence falls below “t1” for at least N1 samples

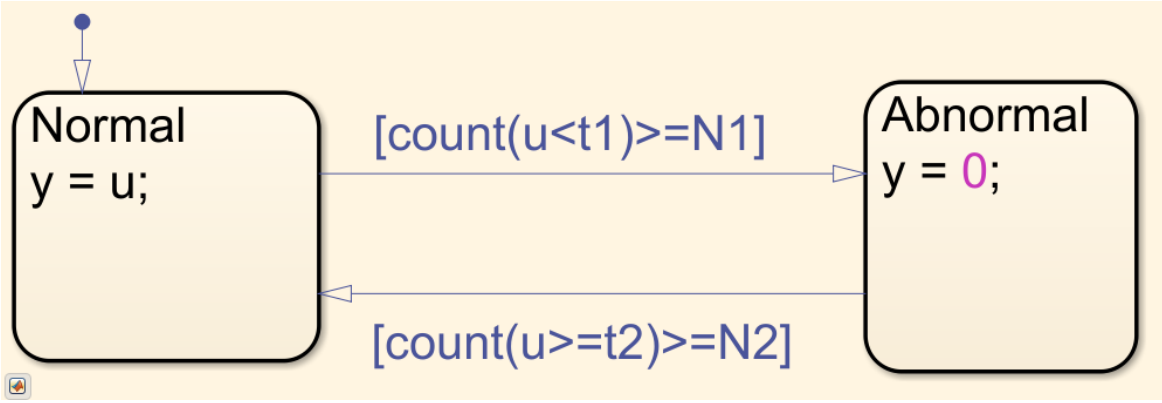
- my normal region starts again when my sequence rises above “t2” for at least N2 samples

Abnormal region identification: hysteresis + debouncing

```
inNormalRegion = true;
counter = 0;
for i=1:length(inData)
    if(inNormalRegion)
        if(inData(i)<t1)
            counter = counter+1;
            if(counter>=N1)
                inNormalRegion = false;
            end
        else
            counter = 0;
        end
     else
        if(inData(i)>=t2)
            counter = counter+1;
            if(counter>=N2)
                inNormalRegion = true;
            end
        else
            counter = 0;
        end
     end
     if(inNormalRegion)
         outData(i) = inData(i);
    else
         outData(i) = 0;
    end
end
```

Abnormal region identification: hysteresis + debouncing

```
inNormalRegion = true;
counter = 0;
for i=1:length(inData)
    if(inNormalRegion)
        if(inData(i)<t1)
            counter = counter+1;
            if(counter>=N1)
                inNormalRegion = false;
            end
        else
            counter = 0;
        end
     else
        if(inData(i)>=t2)
            counter = counter+1;
            if(counter>=N2)
                inNormalRegion = true;
            end
        else
            counter = 0;
        end
     end
     if(inNormalRegion)
         outData(i) = inData(i);
    else
         outData(i) = 0;
    end
end
```



As the problem gets more complex, the code gets complex

```
for i=1:length(inData)
    if(inData(i)>=t)
        outData(i) = inData(i);
    else
        outData(i) = 0;
    end
end
```

```
inNormalRegion = true;
for i=1:length(inData)
    if(inNormalRegion && (inData(i)<t1))
        inNormalRegion = false;
    elseif(~inNormalRegion && (inData(i)>=t2))
        inNormalRegion = true;
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        outData(i) = 0;
    end
end
```

```
inNormalRegion = true;
counter = 0;
for i=1:length(inData)
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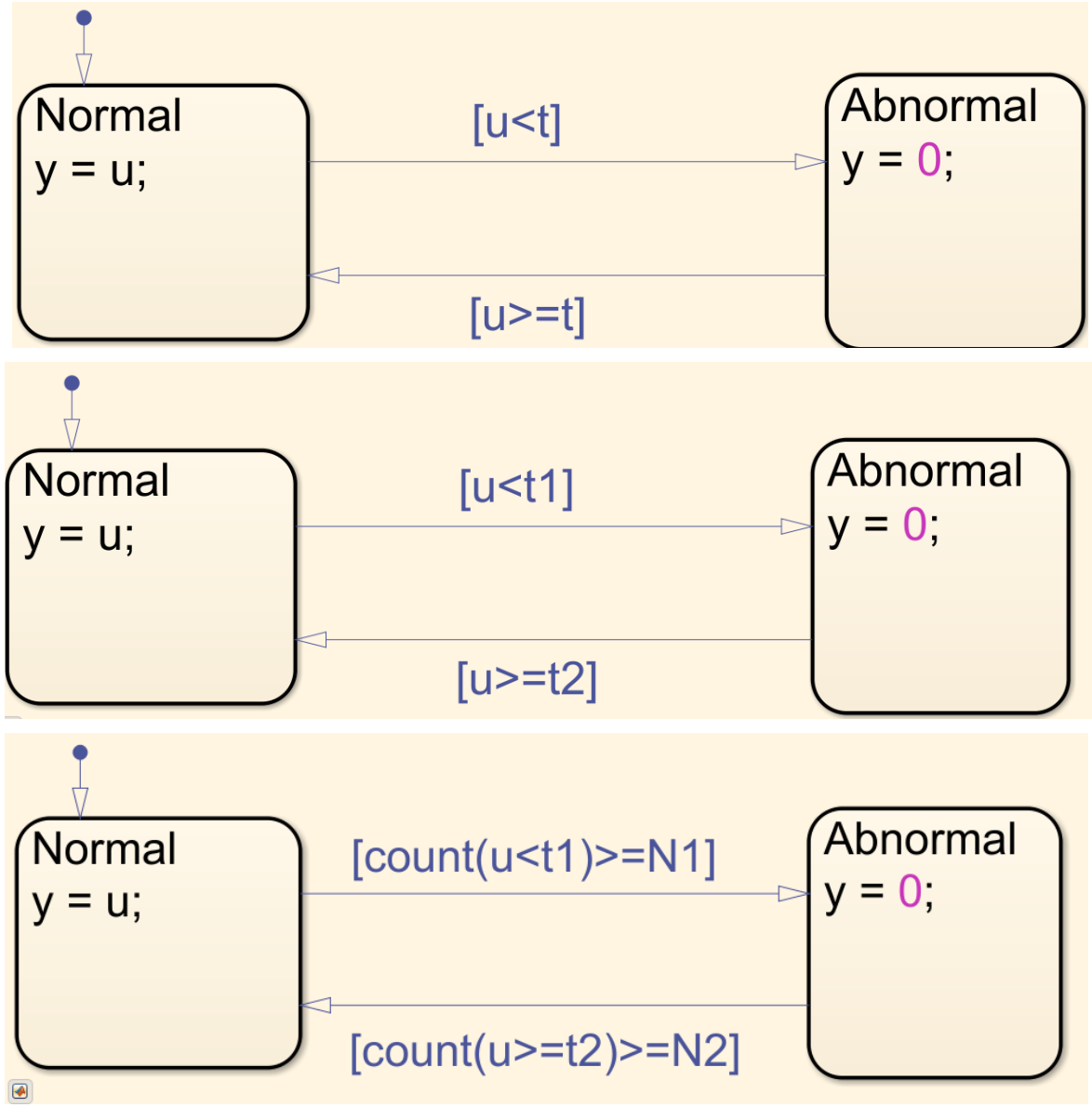
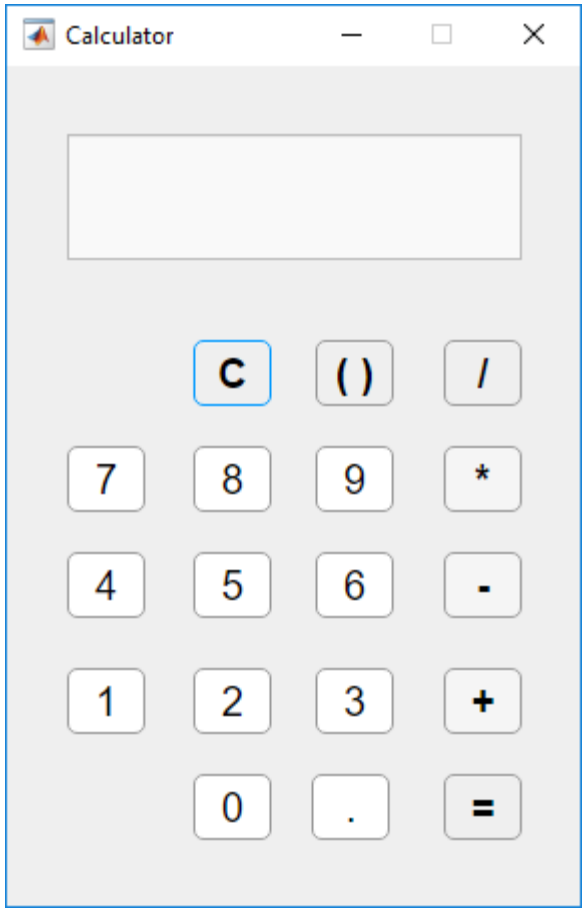
        if(inData(i)<t1)
            counter = counter+1;
            if(counter>=N1)
                inNormalRegion = false;
            end
        else
            counter = 0;
        end
     else
        if(inData(i)>=t2)
            counter = counter+1;
            if(counter>=N2)
                inNormalRegion = true;
            end
        else
            counter = 0;
        end
     end
     if(inNormalRegion)
         outData(i) = inData(i);
    else
         outData(i) = 0;
    end
end
```

While the chart remains concise

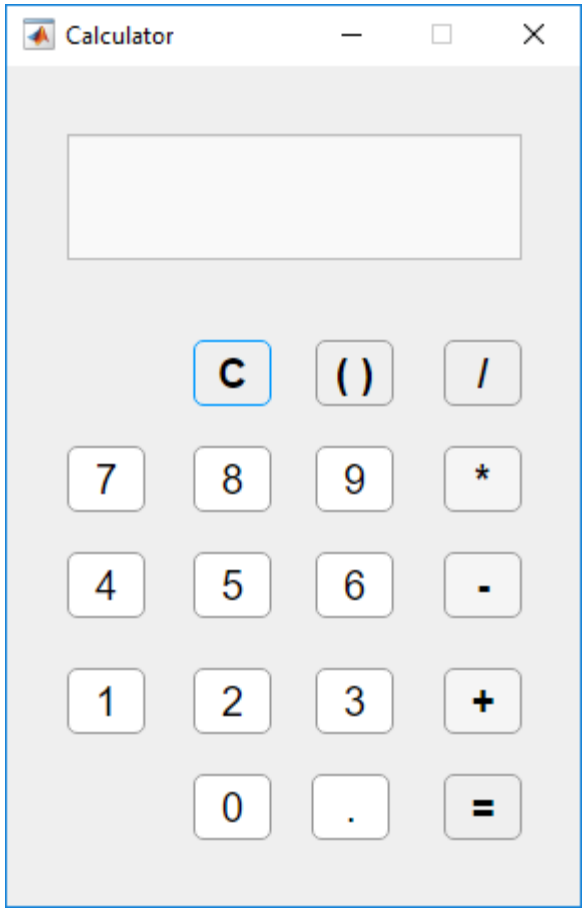


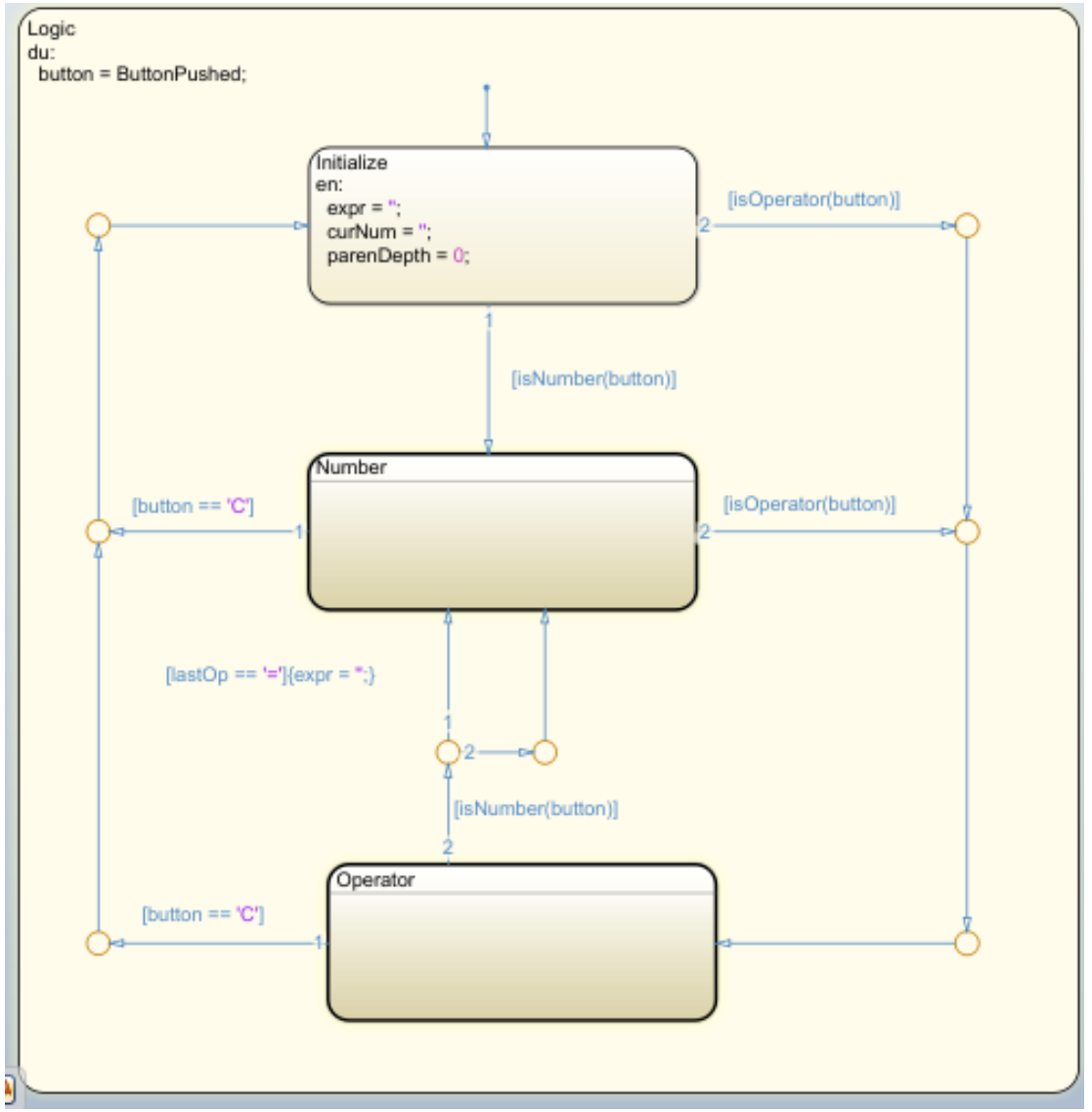
State Machines are everywhere

Is there a state machine in here ?

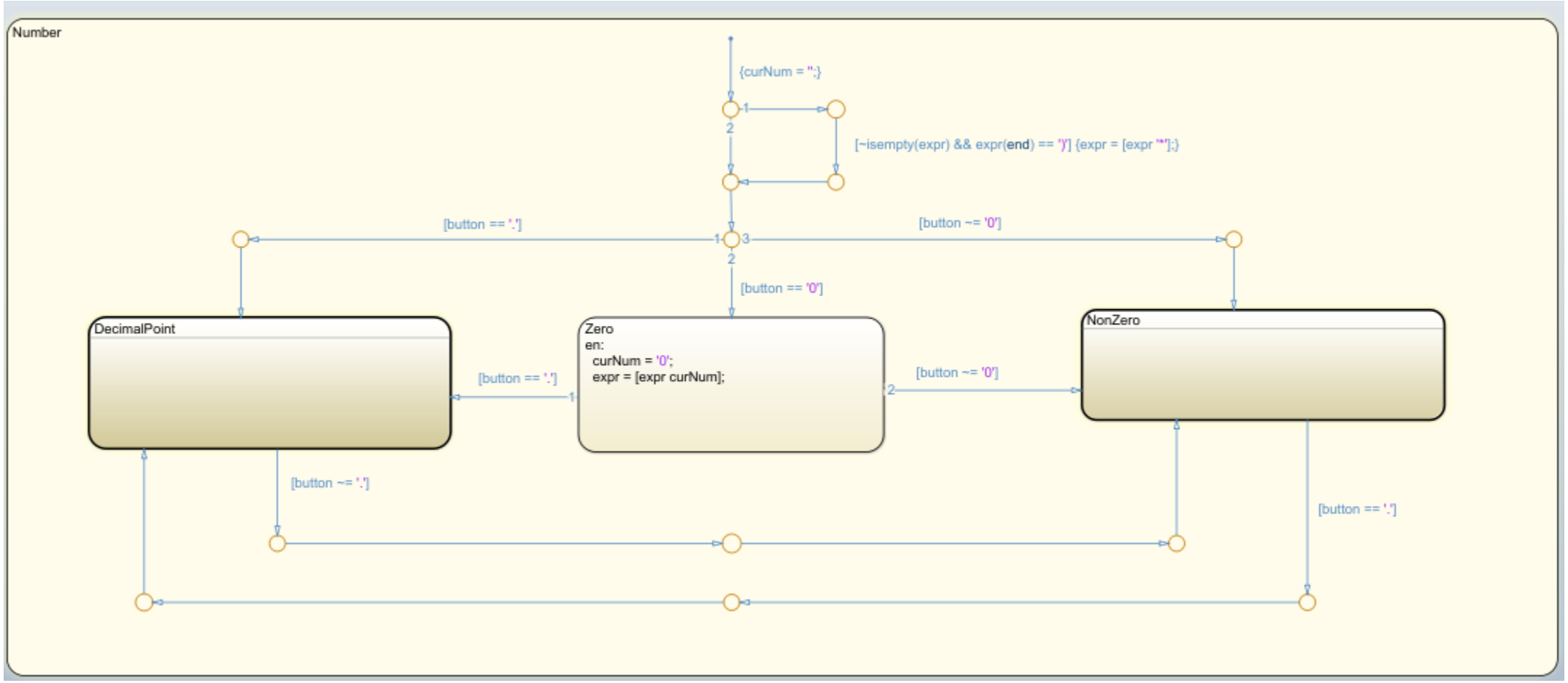


Calculator state machine





Logic for handling number entry



State Machines are everywhere

Symbol/Frame Detection in Communication Systems

We receive either a pulse (1) or not a pulse (0) every 10ms

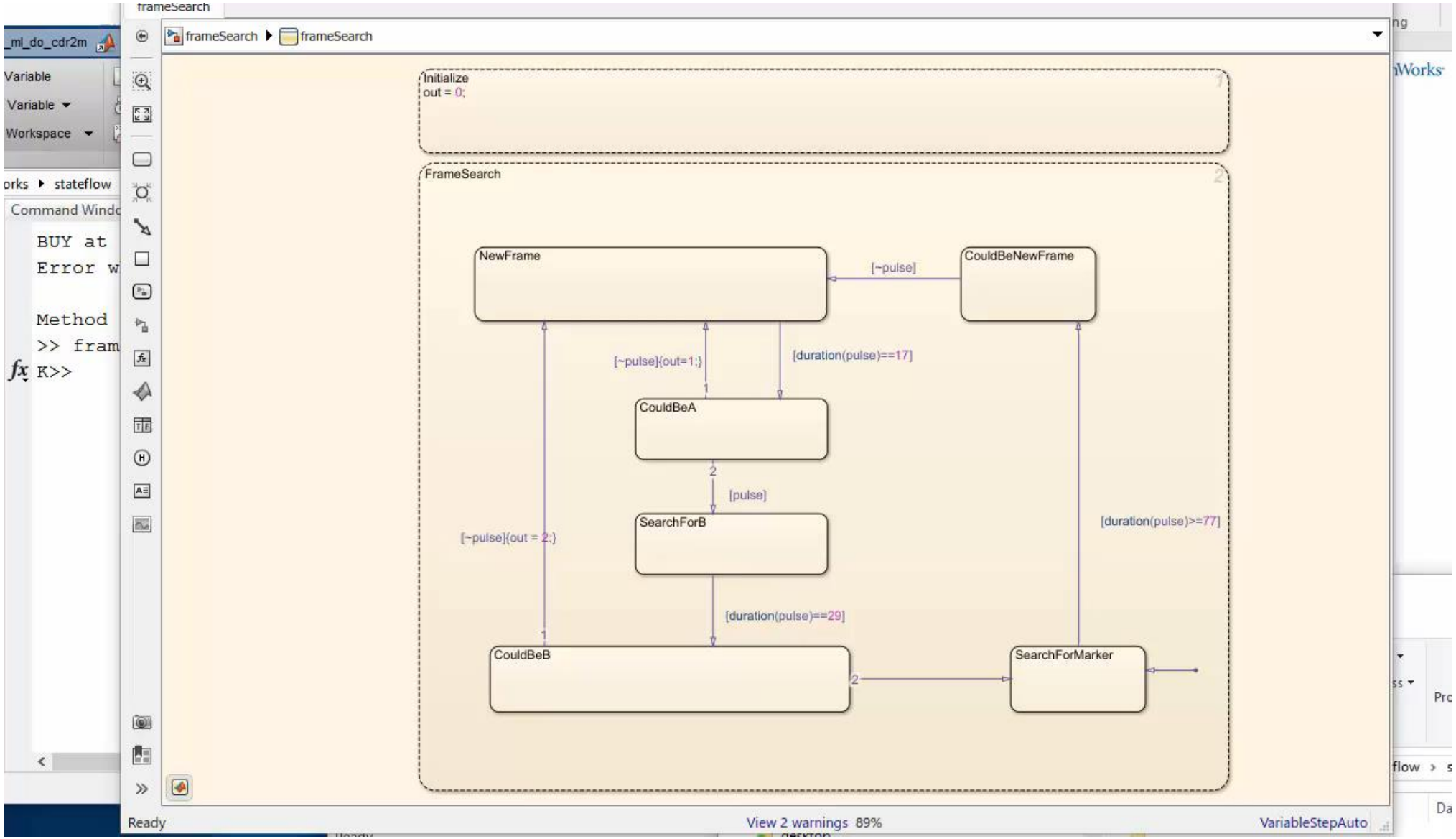
MARKER - A 770-ms pulse (sequence of 77 pulses) is sent every 10 seconds for synchronization

MISS - No pulse (0) is sent at the beginning of each frame, to indicate the start of a new frame

A - A 170-ms pulse (sequence of 17 pulses) indicates symbol A

B - A 470-ms pulse (sequence of 47 pulses) indicates symbol B

Stateflow Diagram for Frame and Symbol Detection



State machines are in space

"Until Deep Space 1, state charts and automatic code generation technology had not been used on large systems for spacecraft avionics software. MathWorks tools made this approach possible."

Dr. Wesley Huntress, NASA

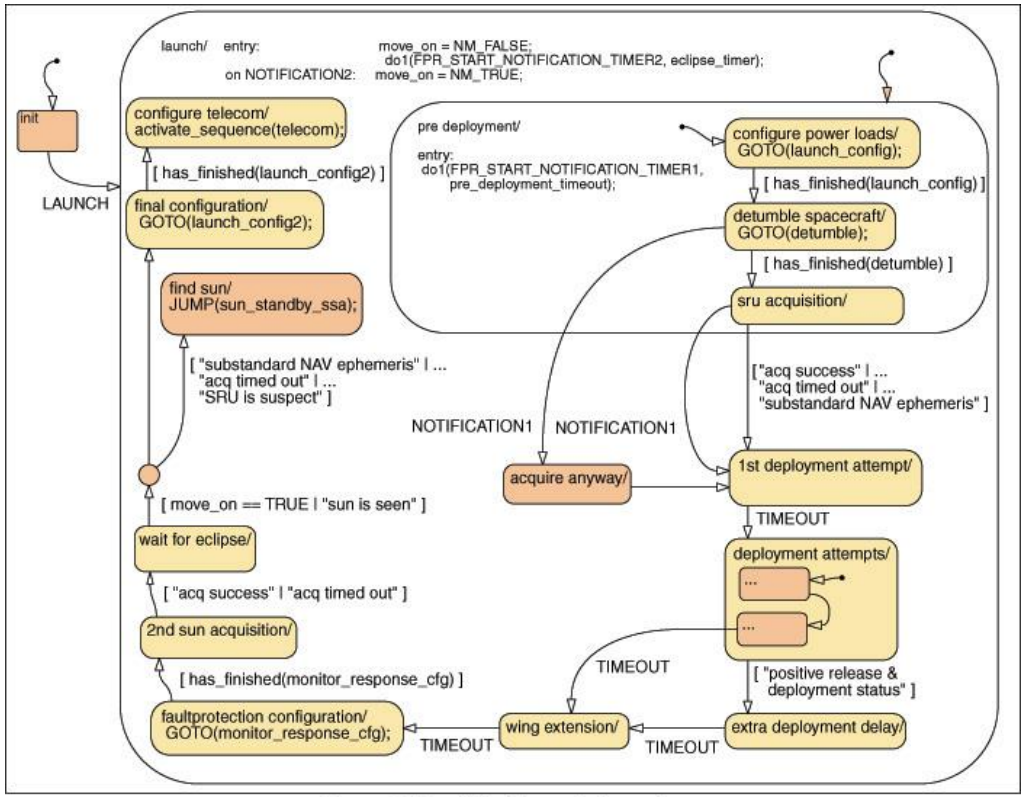
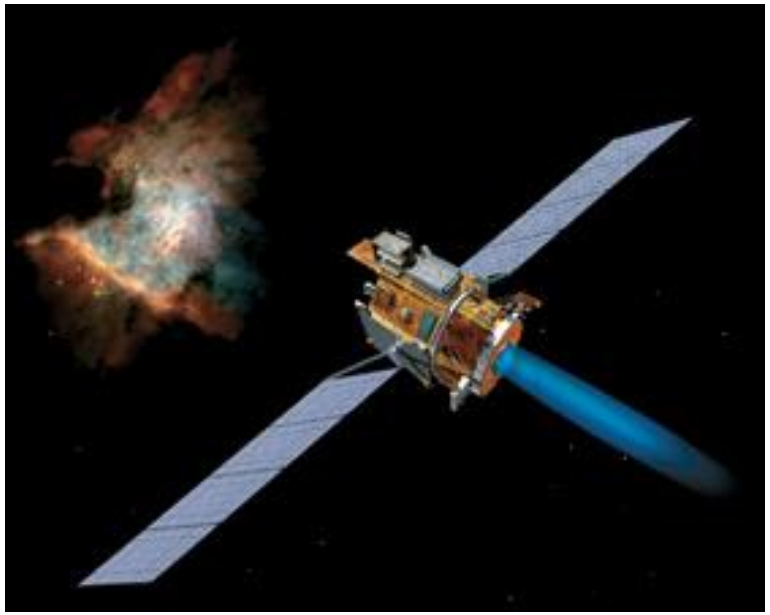
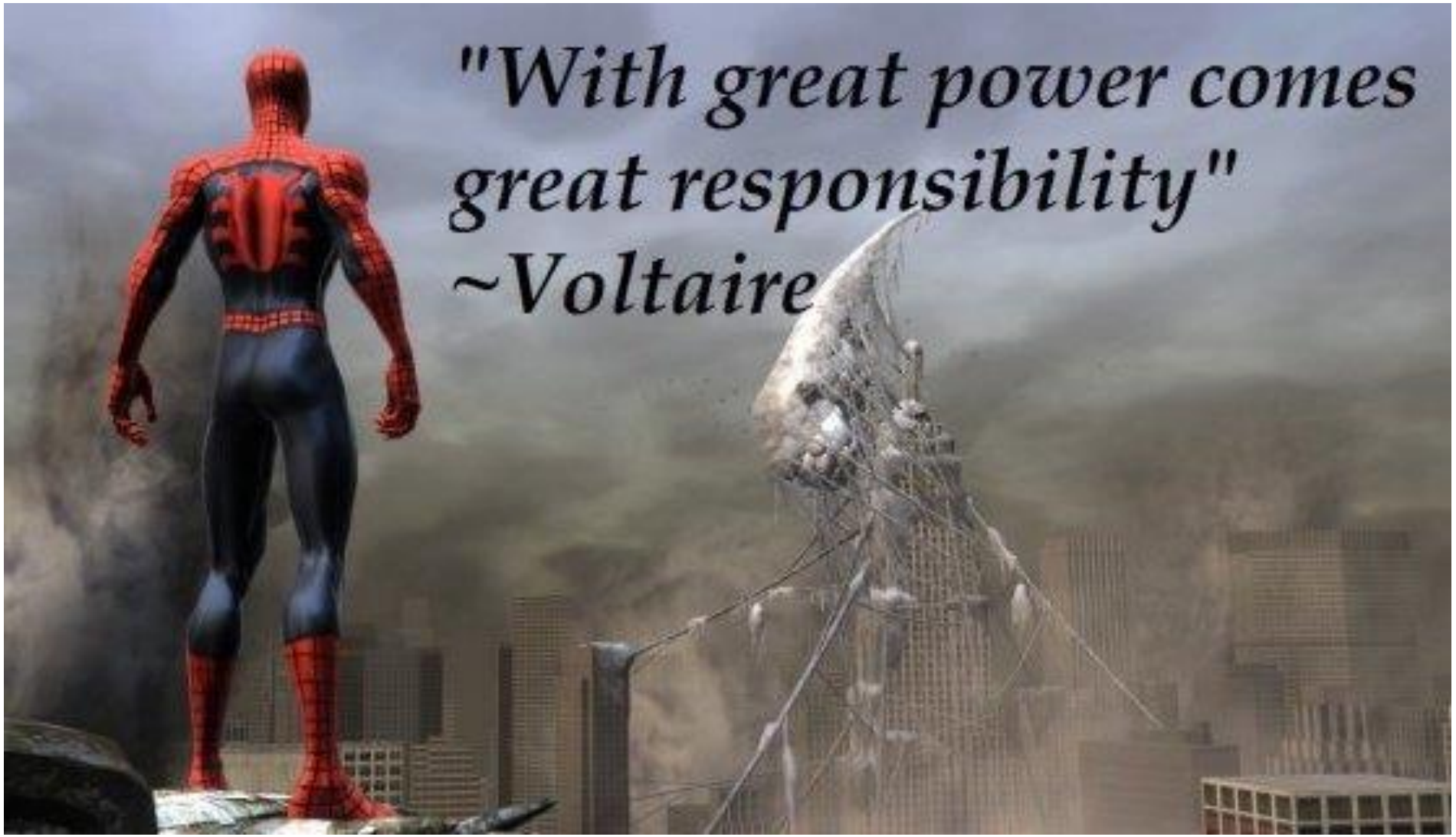


Figure 2 Simplified Launch Statechart



Deep Space 1 spacecraft
Launch date: October 24, 1998


"With great power comes
great responsibility"
~Voltaire

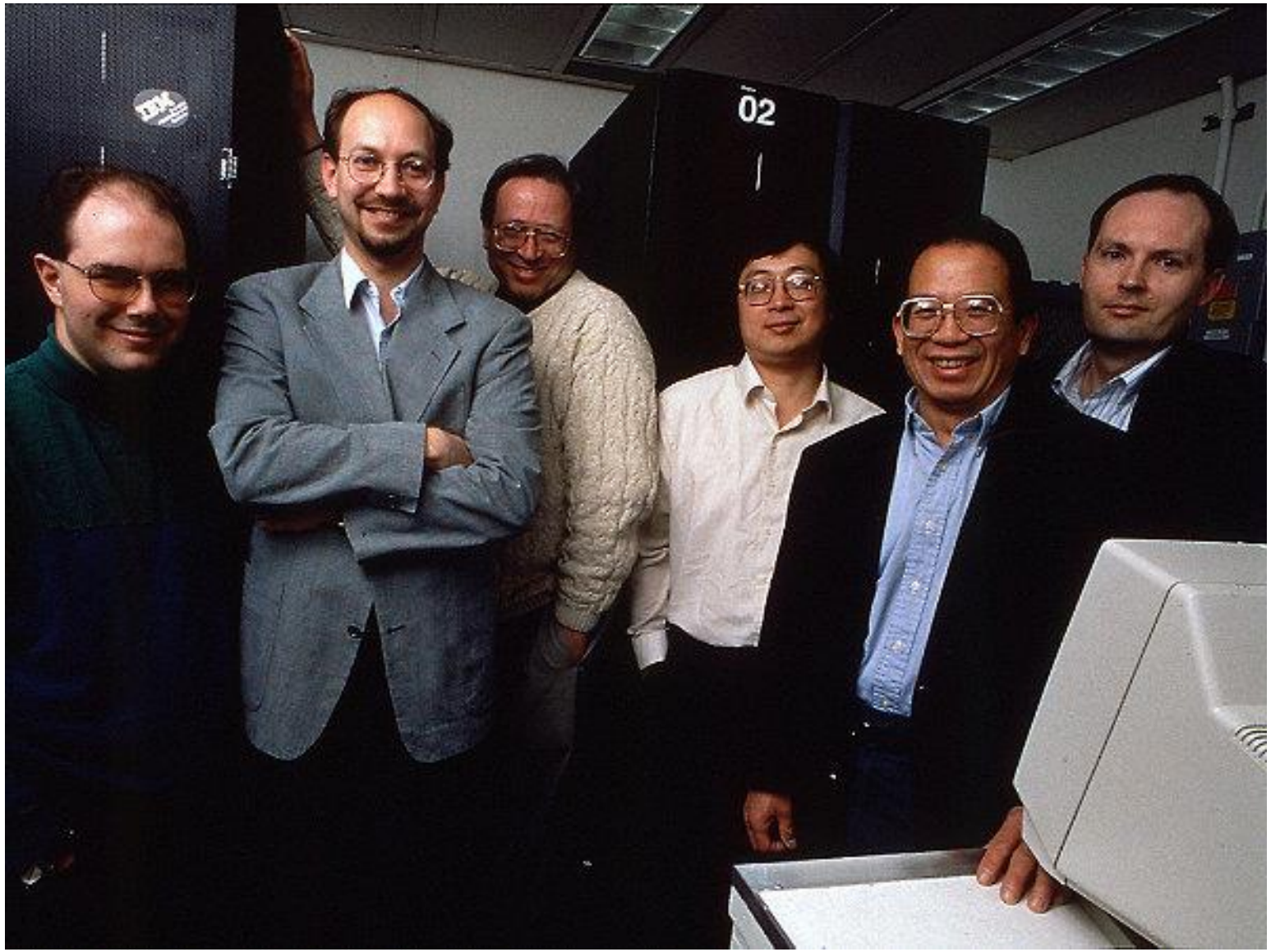
Challenges for Graphical Programming Languages

- Simulation and Debugging
- Design Error Detection
- Automatic Code Generation

Demo

1997: Deep Blue defeats Gary Kasparov

Joel Benjamin: the chess grandmaster behind Deep Blue



Automation needs your help

- Computers are stupid
  - It is the human expertise that makes them smart
- World class automation tools needs world class researchers
  - Your expertise in creating efficient systems is critical to build automated tools
- Automation is the wave of the future
  - If we do not do this, someone else will

Model Based Design has many interesting problem areas

- Language Design
  - Efficient ways to denote graphical variants
  - Combining state charts and physical domains
- Automatic Code Generation
  - Balancing optimization with traceability
  - Targeting heterogenous hardware (CPU, GPU, FPGA etc.)
- Verification and Validation
  - Deadlock detection in the presence of messages
  - Quality of Service estimates
  - Security and safety properties

Enabling Success in Academia with MATLAB

CURRICULUM DEVELOPMENT

AUTOGRADING ASSIGNMENTS

PROJECT-BASED LEARNING

RESEARCH COMPUTING

• • •

We are here to help.

Balaji Sharma , Customer Success Team, MathWorks

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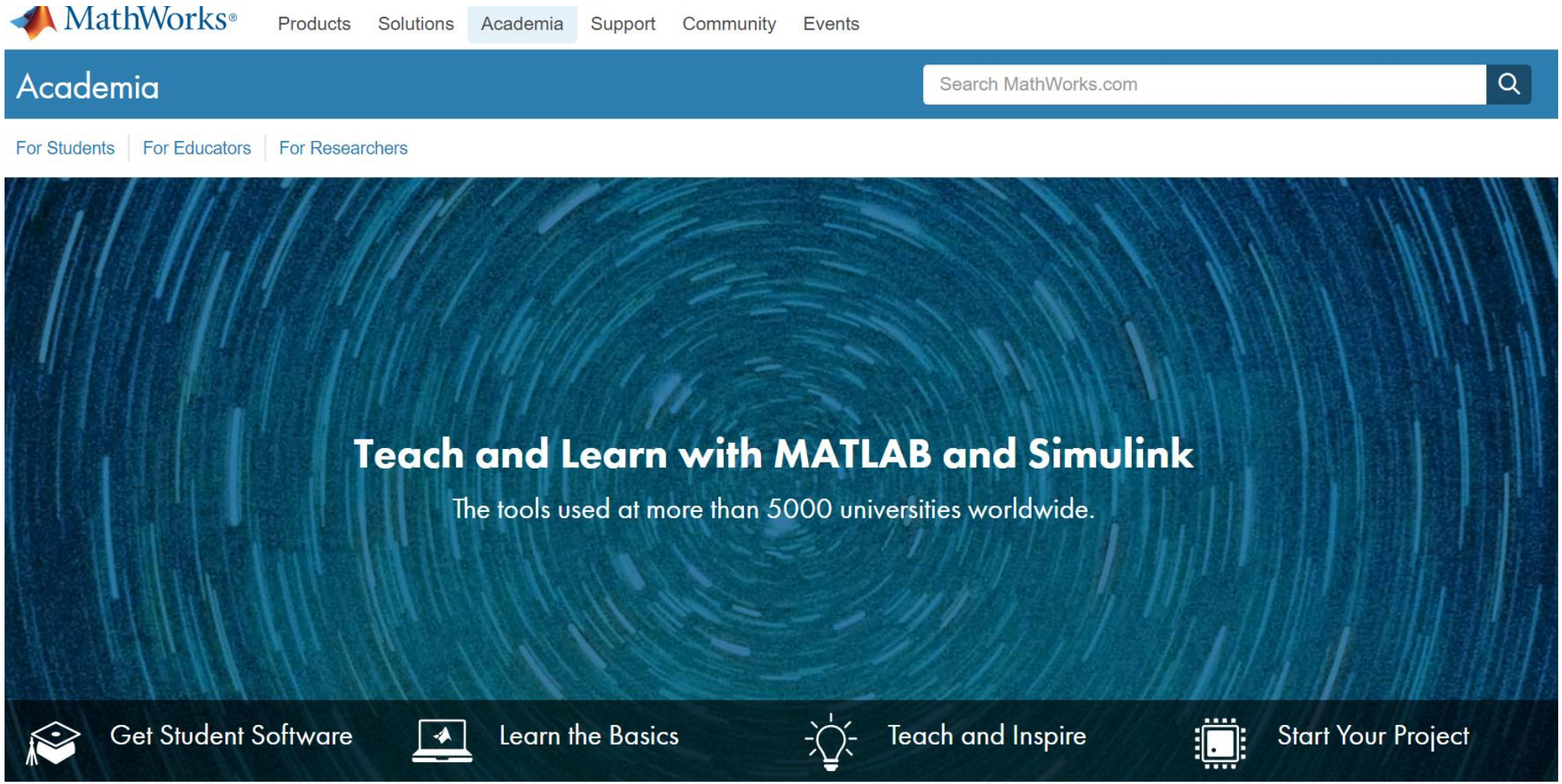

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