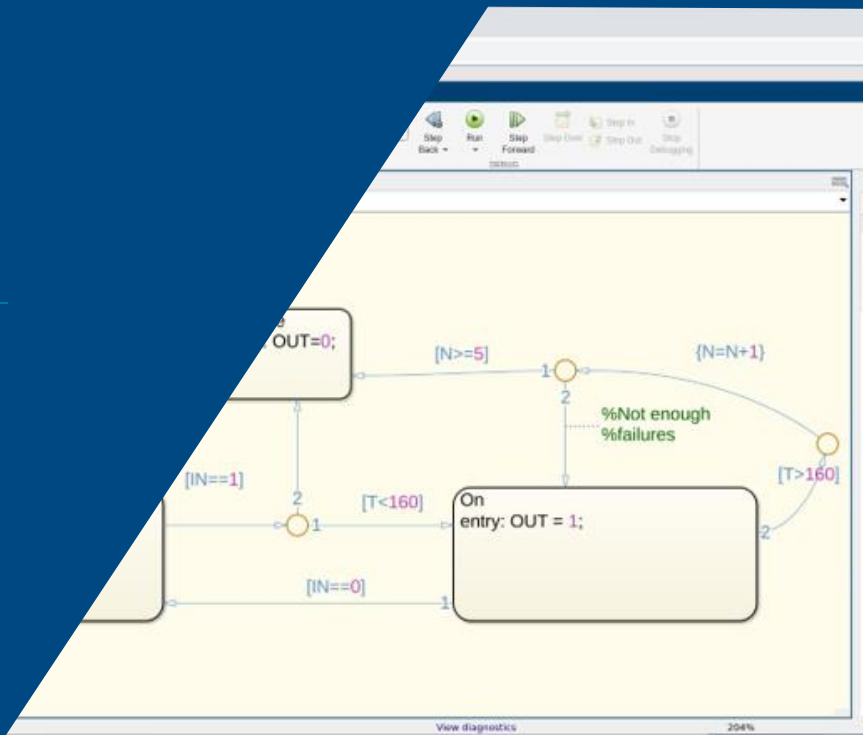
What's Your State?

Modeling State Machines with Stateflow



Teresa Hubscher-Younger

Stateflow Product Manager

Erick Saldana Sanvicente

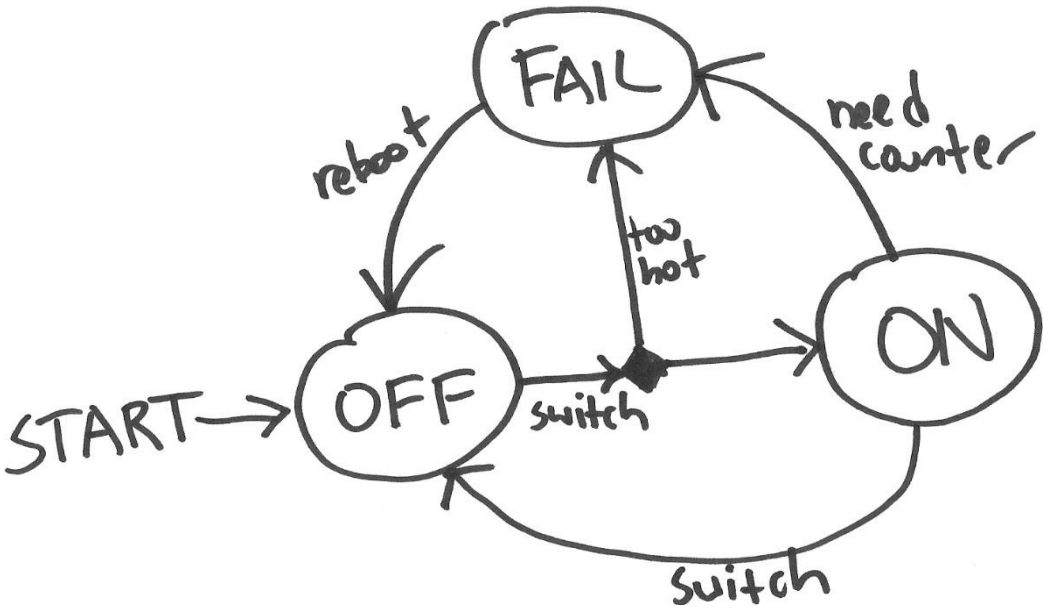
Simulink Product Marketing Manager

Q&A: William Moore

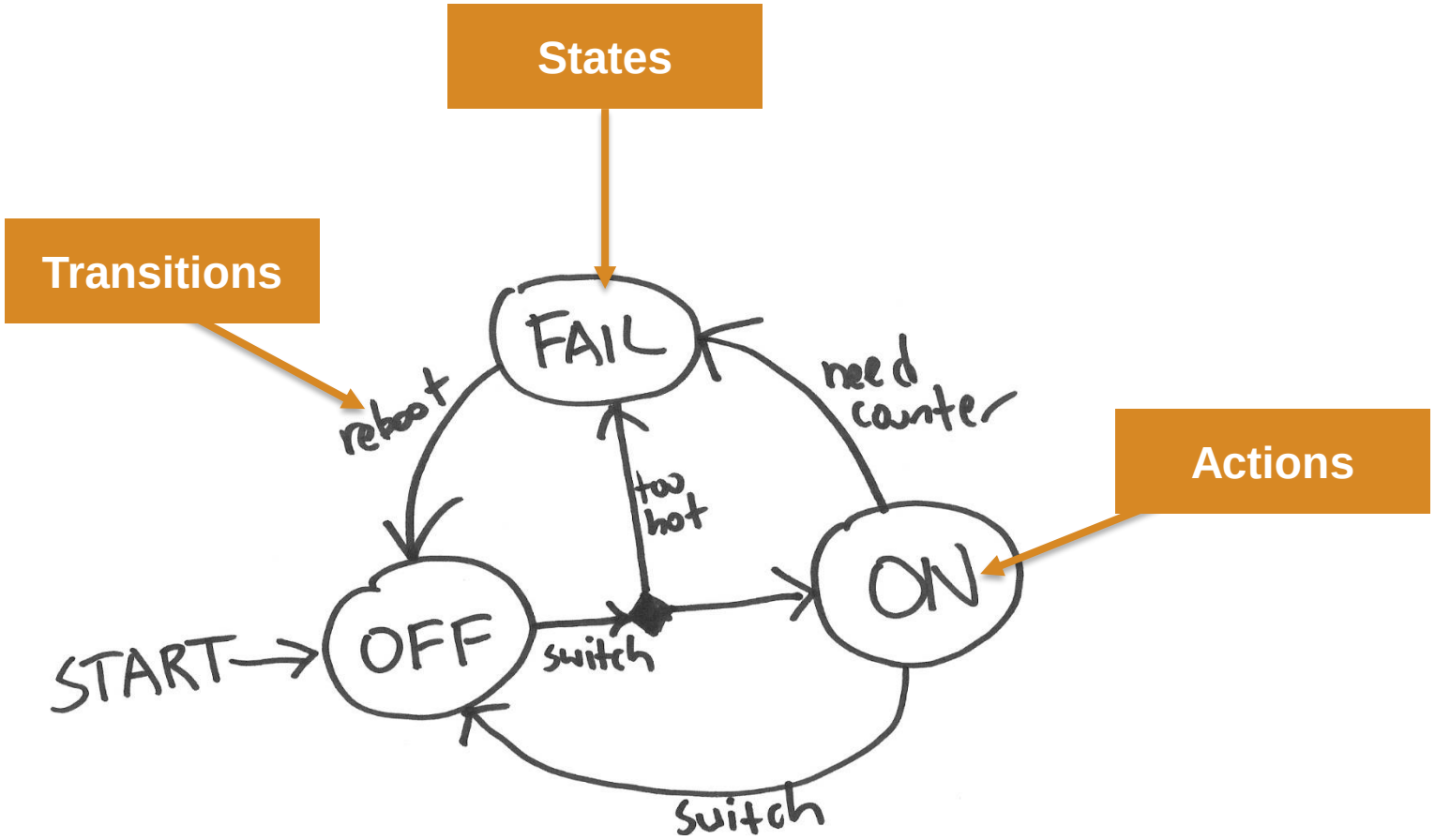
Report Generator Product Manager

What's a State Machine?

- Modeling the different **states** that a system can be in and how it transitions between those states based on inputs or events.

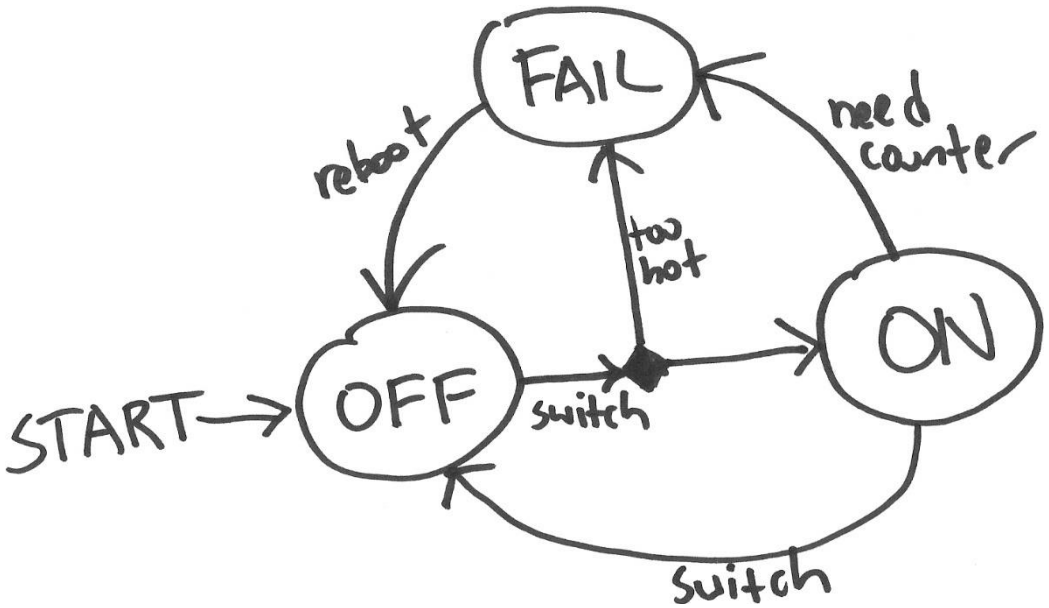


Three main components to a State Machine

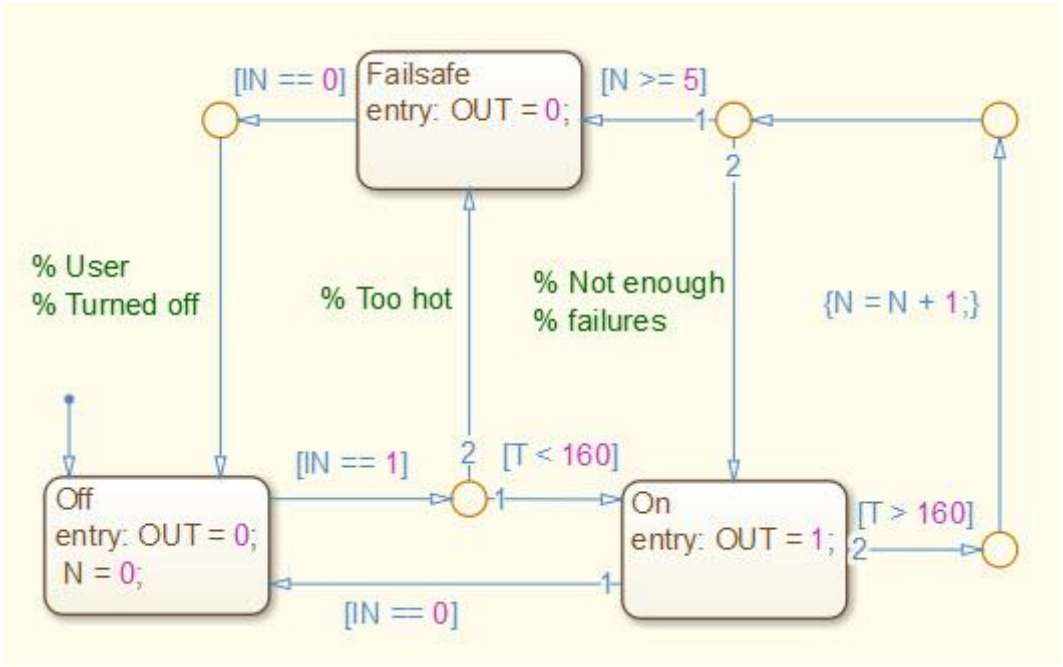


Stateflow is a State Machine Design Environment

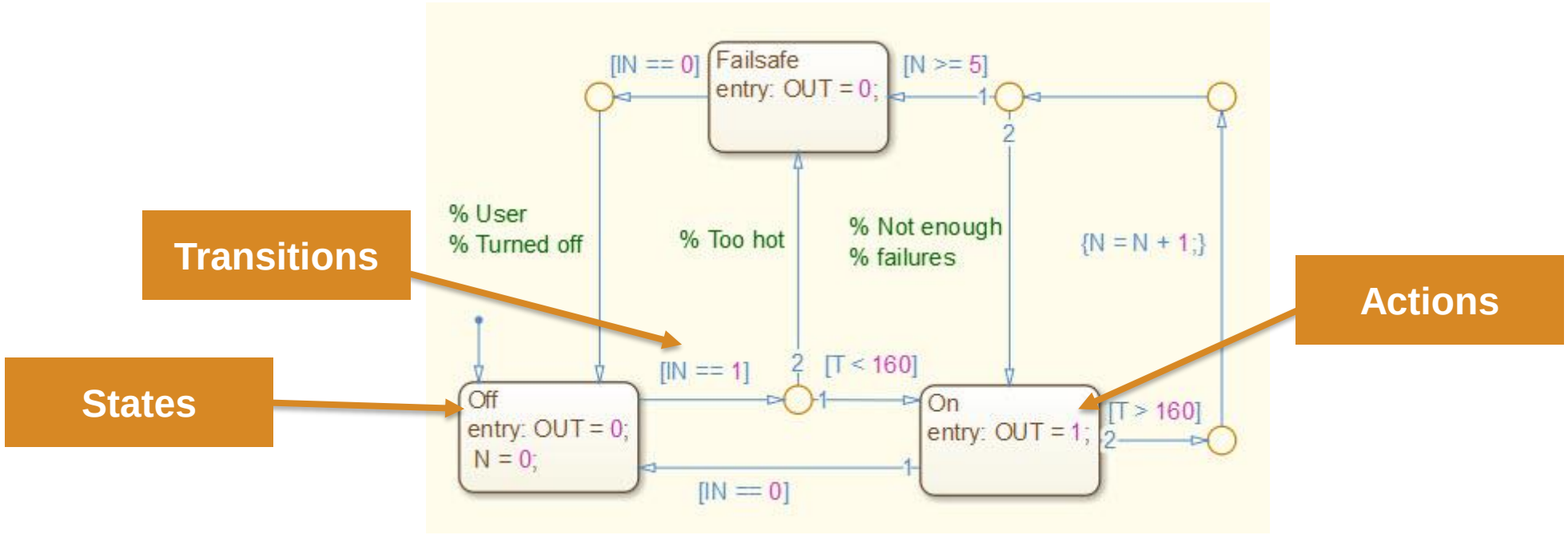
Draft



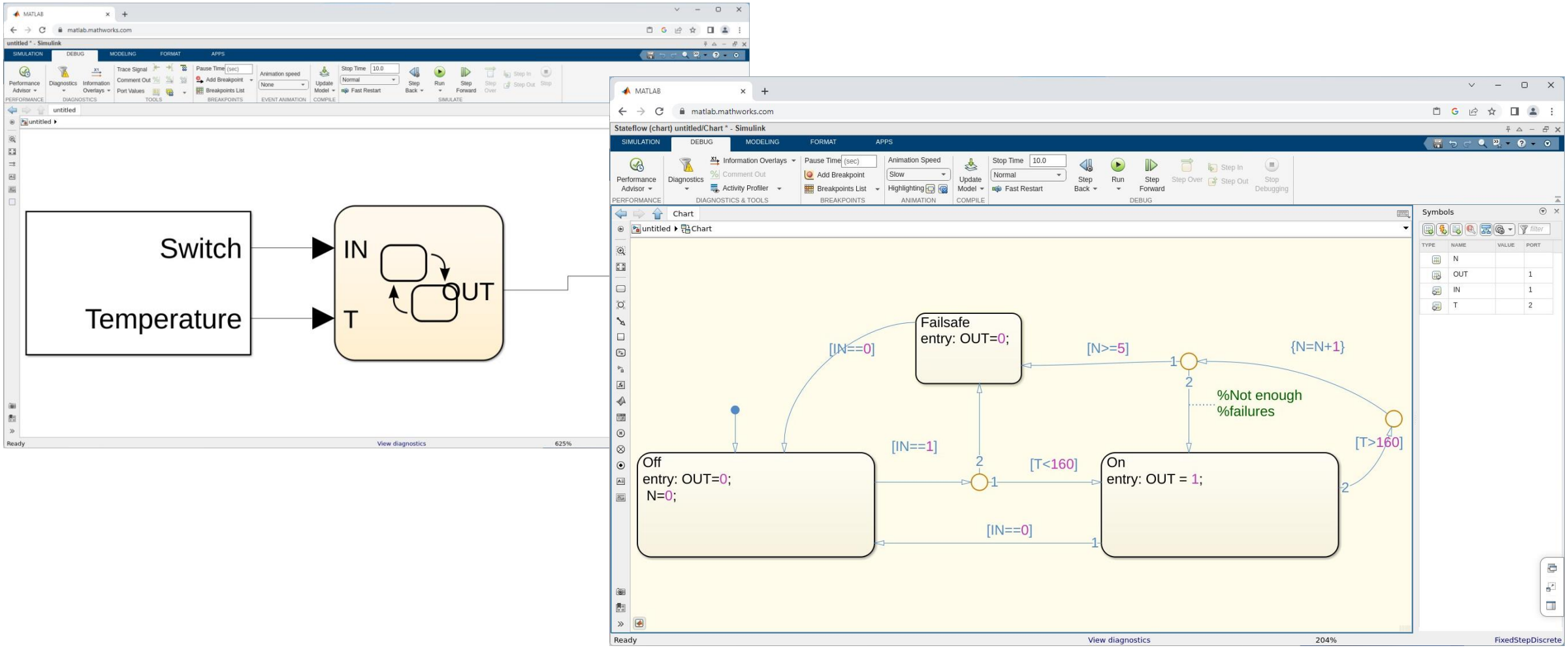
Design and Test

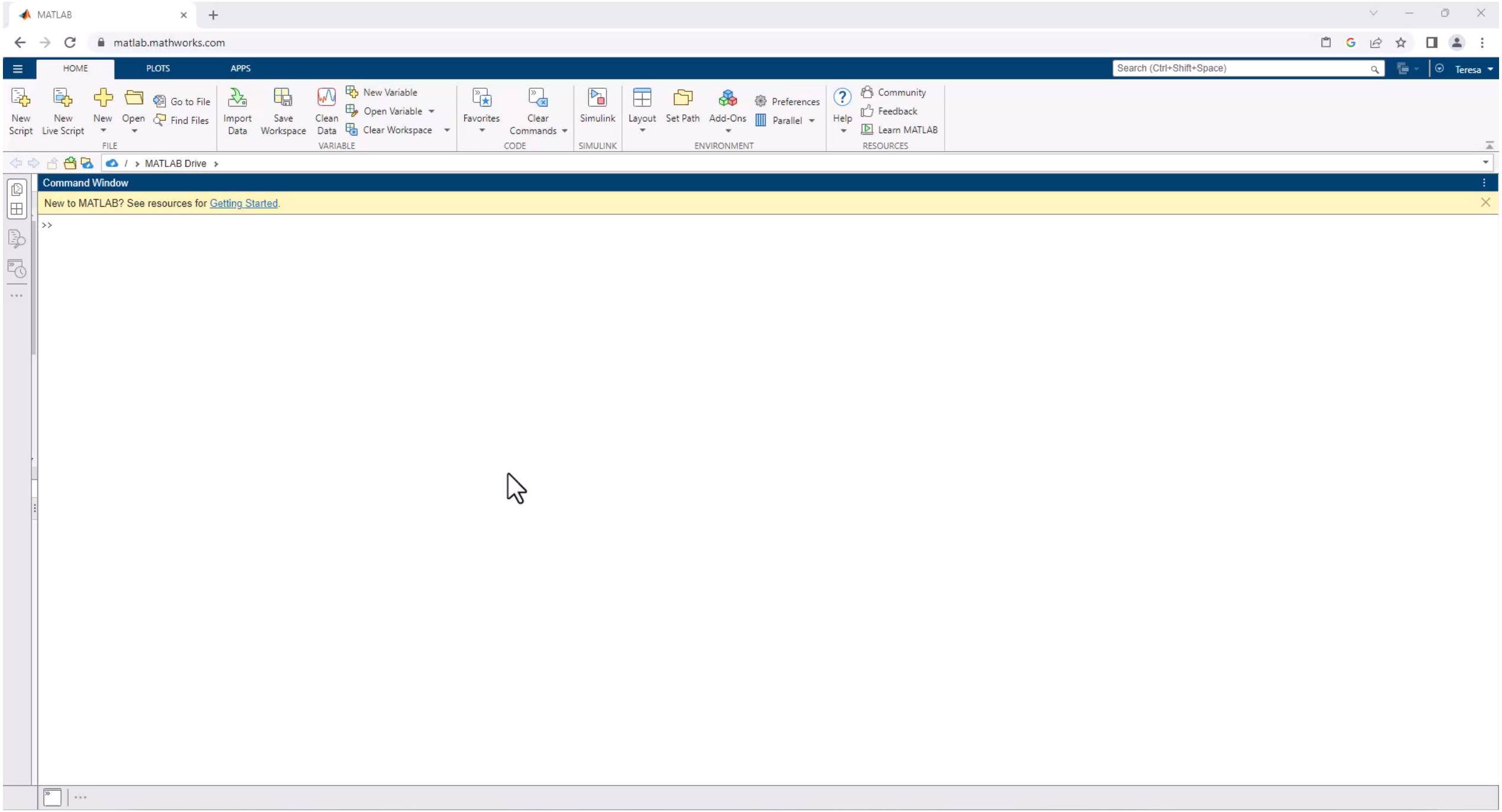


Three main components to a State Machine in Stateflow



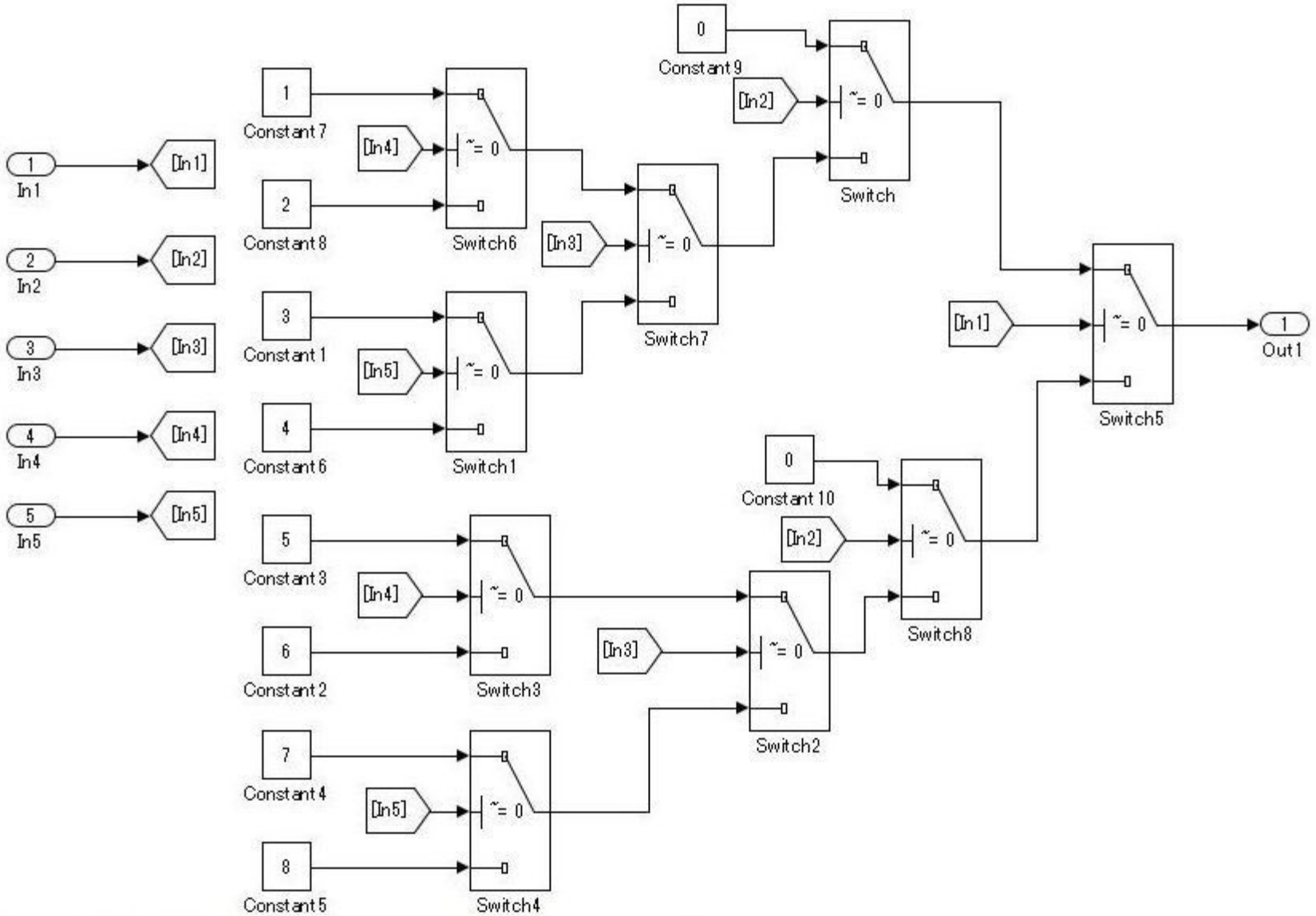
Living in Simulink



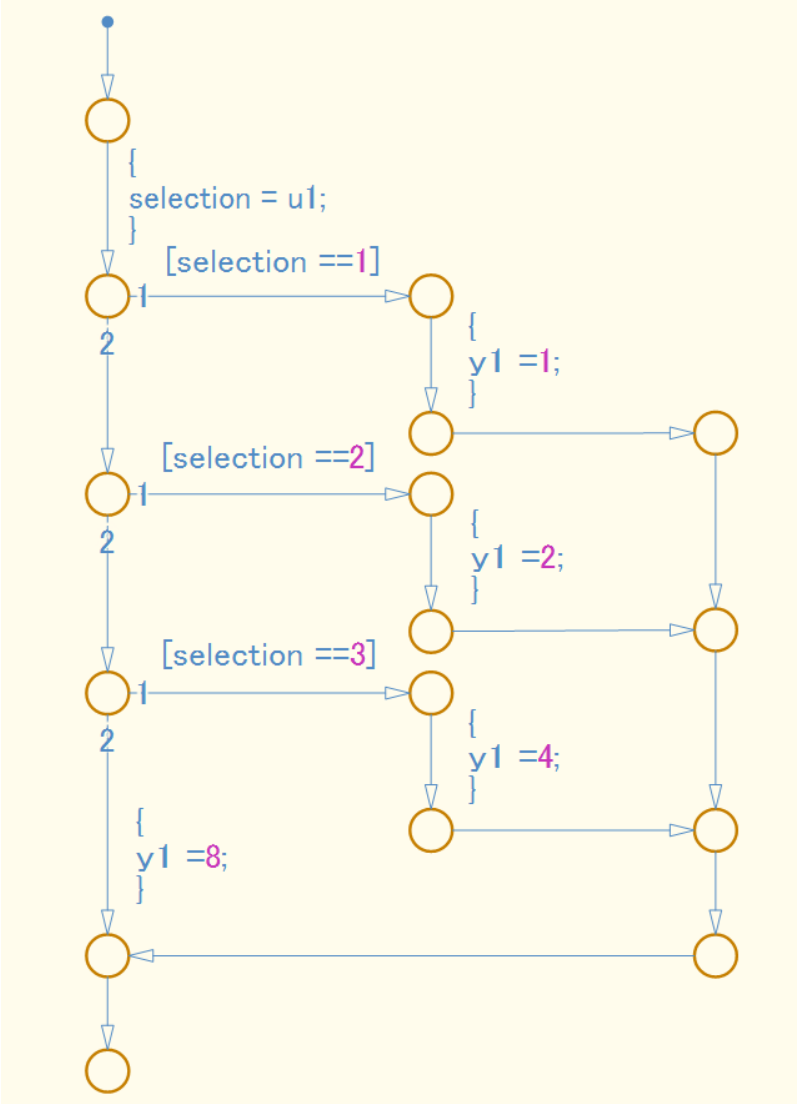

MATLAB
matlab.mathworks.com
HOME
PLOTS
APPS
Search (Ctrl+Shift+Space)
Teresa
New Script
New Live Script
New
Open
Go to File
Find Files
FILE
Import Data
Save Workspace
Clean Data
New Variable
Open Variable
Clear Workspace
VARIABLE
Favorites
Clear Commands
CODE
Simulink
SIMULINK
Layout
Set Path
Add-Ons
Preferences
Parallel
ENVIRONMENT
Help
Community
Feedback
Learn MATLAB
RESOURCES
/ > MATLAB Drive >
Command Window
New to MATLAB? See resources for Getting Started.
>>

Questions so far?

When should I switch from Simulink to Stateflow?

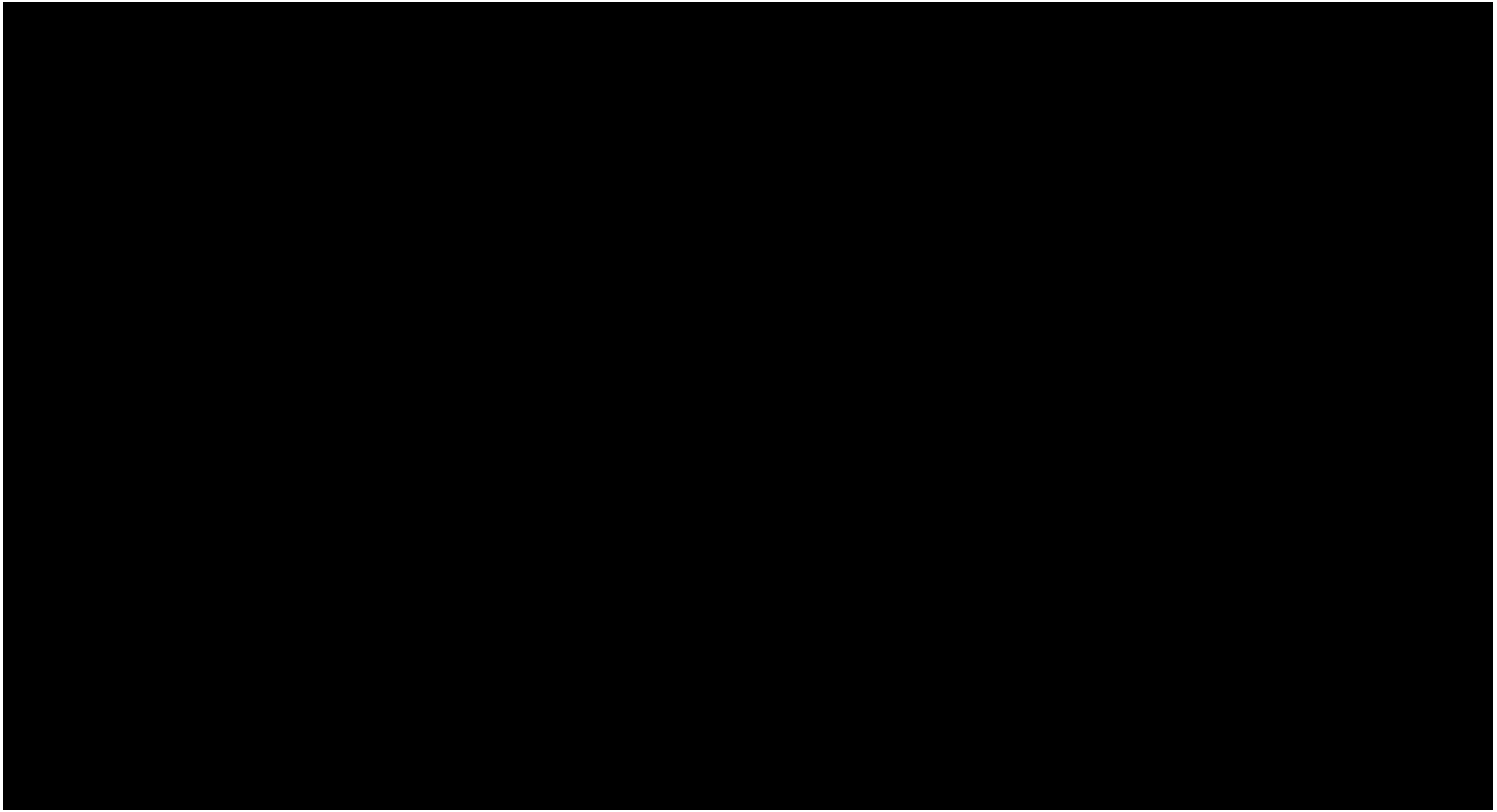


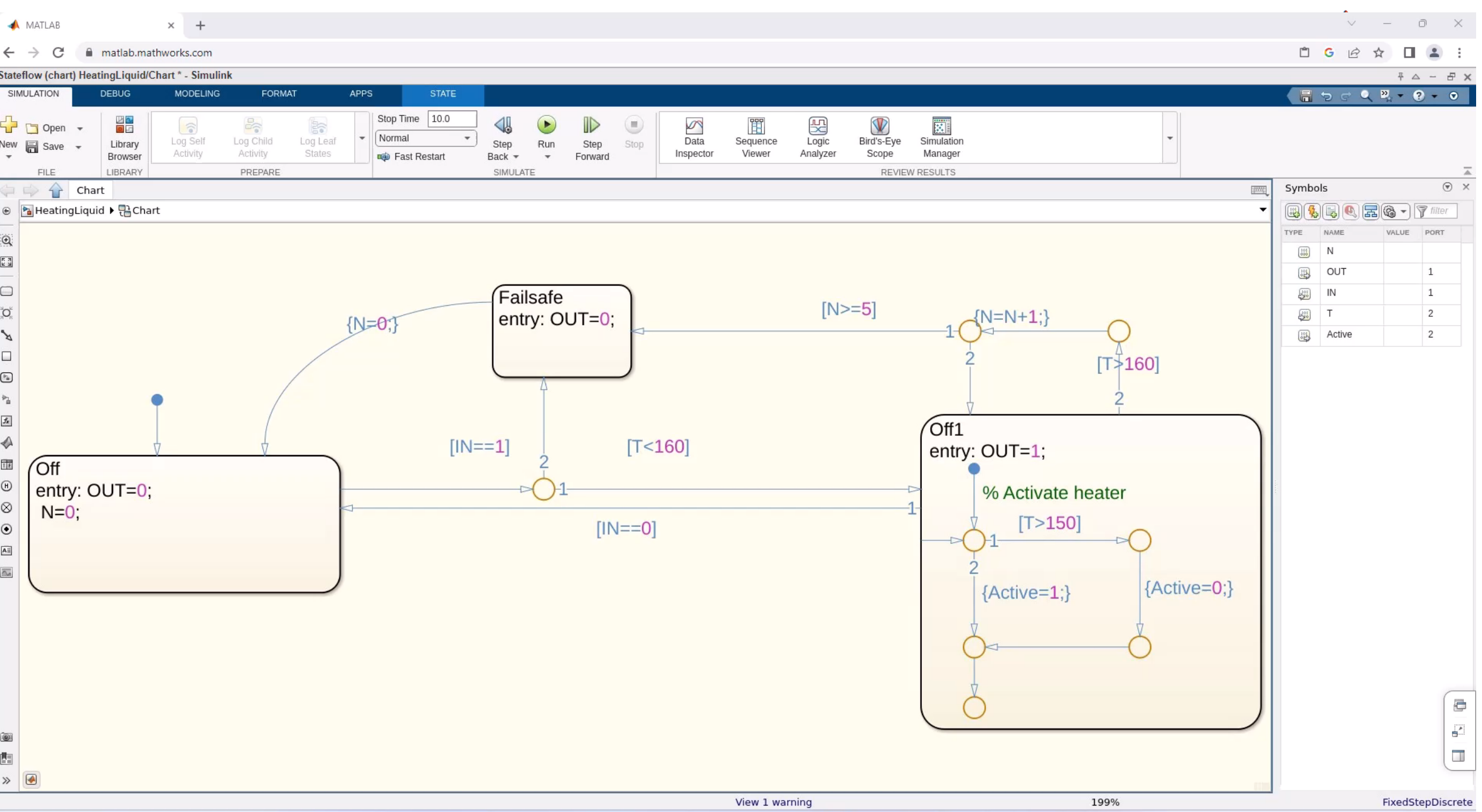
Stateflow is a flow chart design environment



Let’s add temperature maintenance to our On state

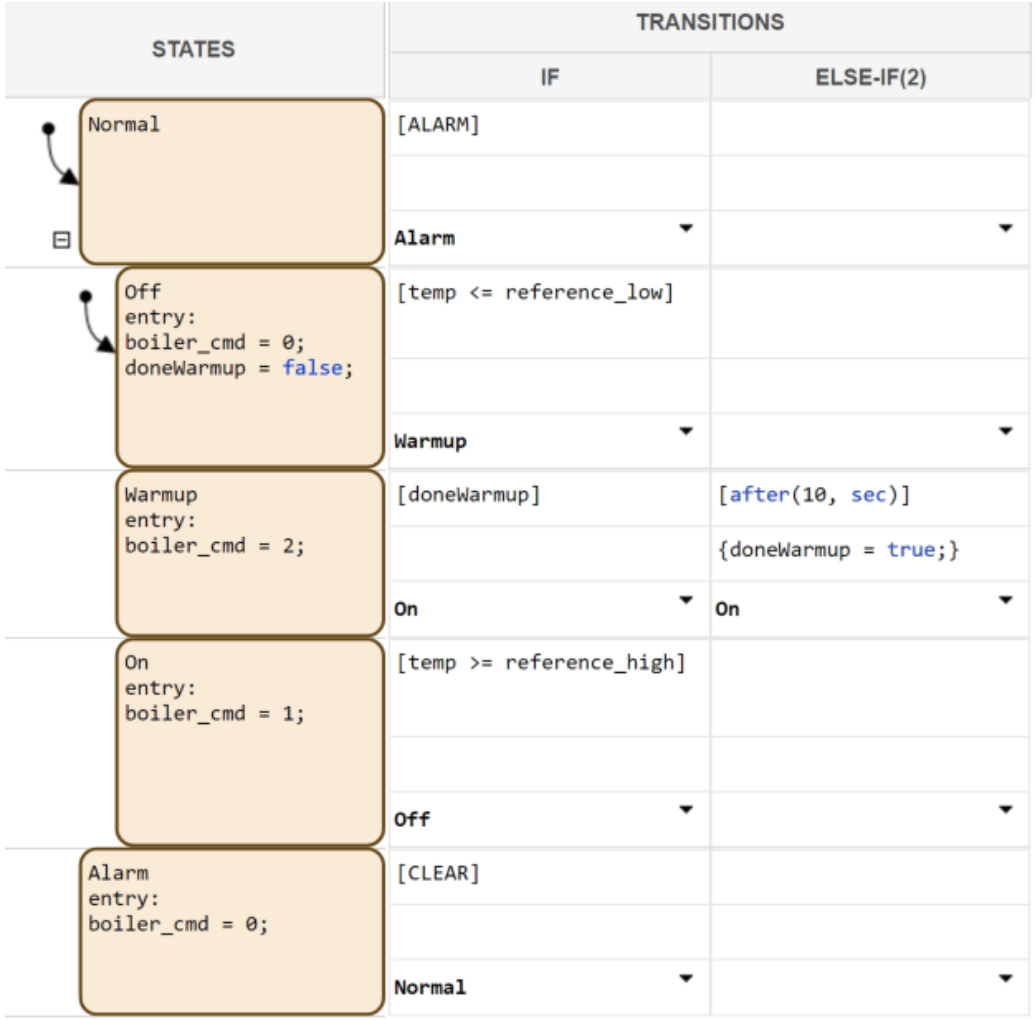
- Add the logic for activating a heater
  - If Temperature < 100, activate heater
  - Else Temperature > 150, deactivate heater




MATLAB
matlab.mathworks.com
Stateflow (chart) HeatingLiquid/Chart * - Simulink
SIMULATION
DEBUG
MODELING
FORMAT
APPS
STATE
Open
New
Save
FILE
Library Browser
LIBRARY
Log Self Activity
Log Child Activity
Log Leaf States
PREPARE
Stop Time
10.0
Normal
Fast Restart
Step Back
Run
Step Forward
Stop
SIMULATE
Data Inspector
Sequence Viewer
Logic Analyzer
Bird's-Eye Scope
Simulation Manager
REVIEW RESULTS
Chart
HeatingLiquid
Chart
Failsafe
entry: OUT=0;
{N=0;}
[N>=5]
{N=N+1;}
[T>160]
Off
entry: OUT=0;
N=0;
[IN==1]
[T<160]
[IN==0]
Off1
entry: OUT=1;
% Activate heater
[T>150]
{Active=1;}
{Active=0;}
Symbols
TYPE
NAME
VALUE
PORT
N
OUT
1
IN
1
T
2
Active
2
View 1 warning
199%
FixedStepDiscrete

Questions so far?

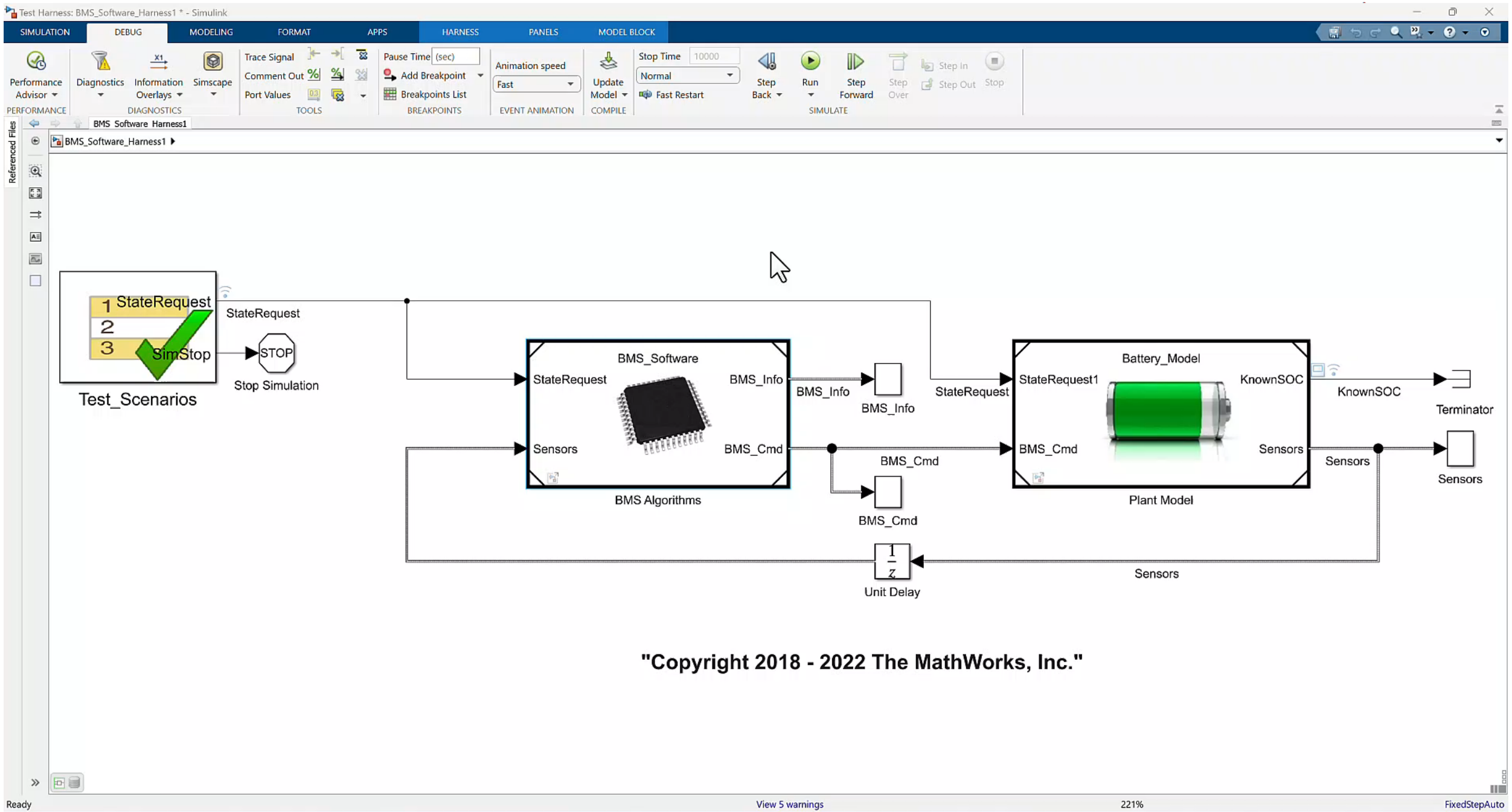
Stateflow is also a state transition table design environment

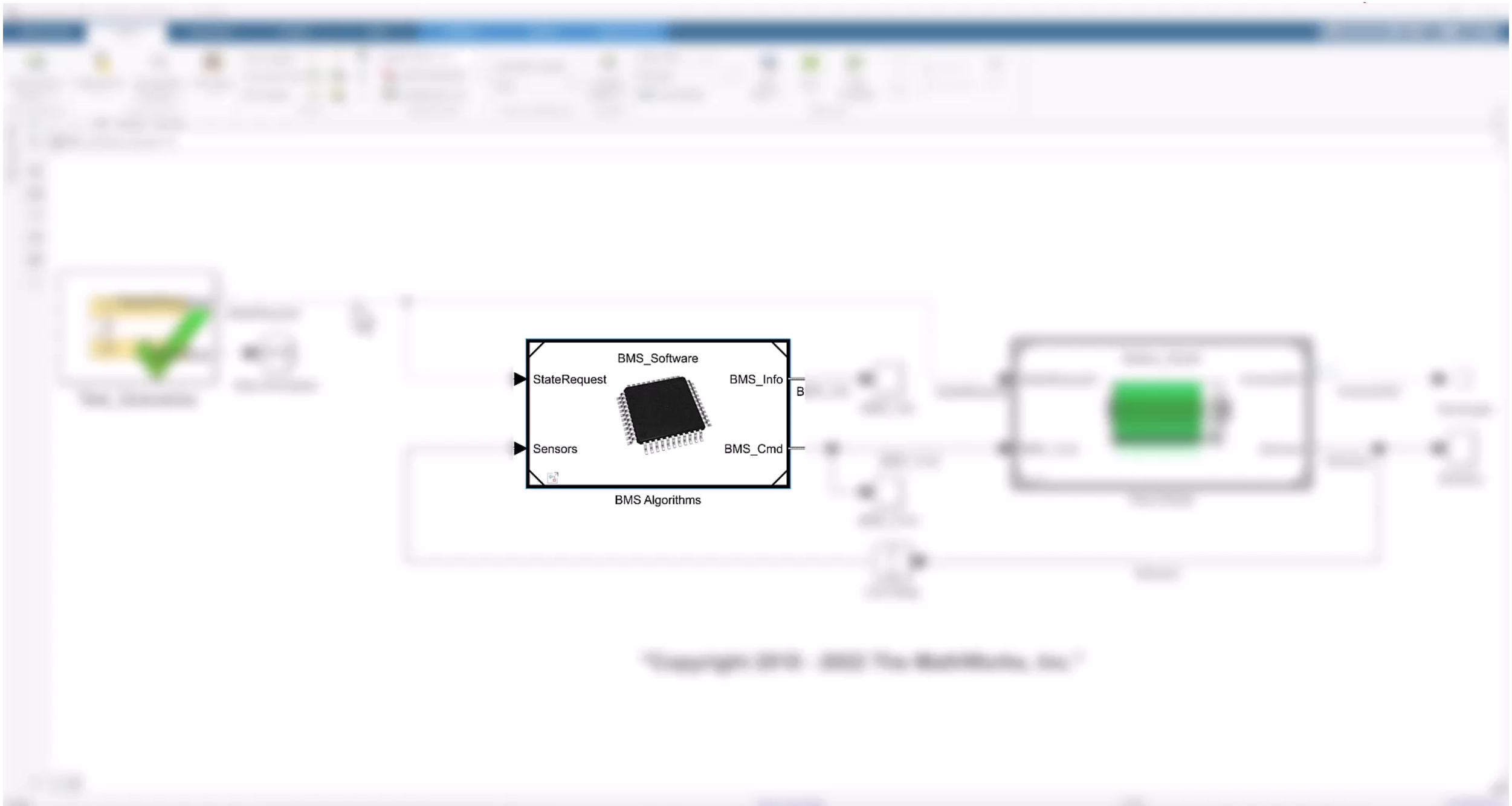


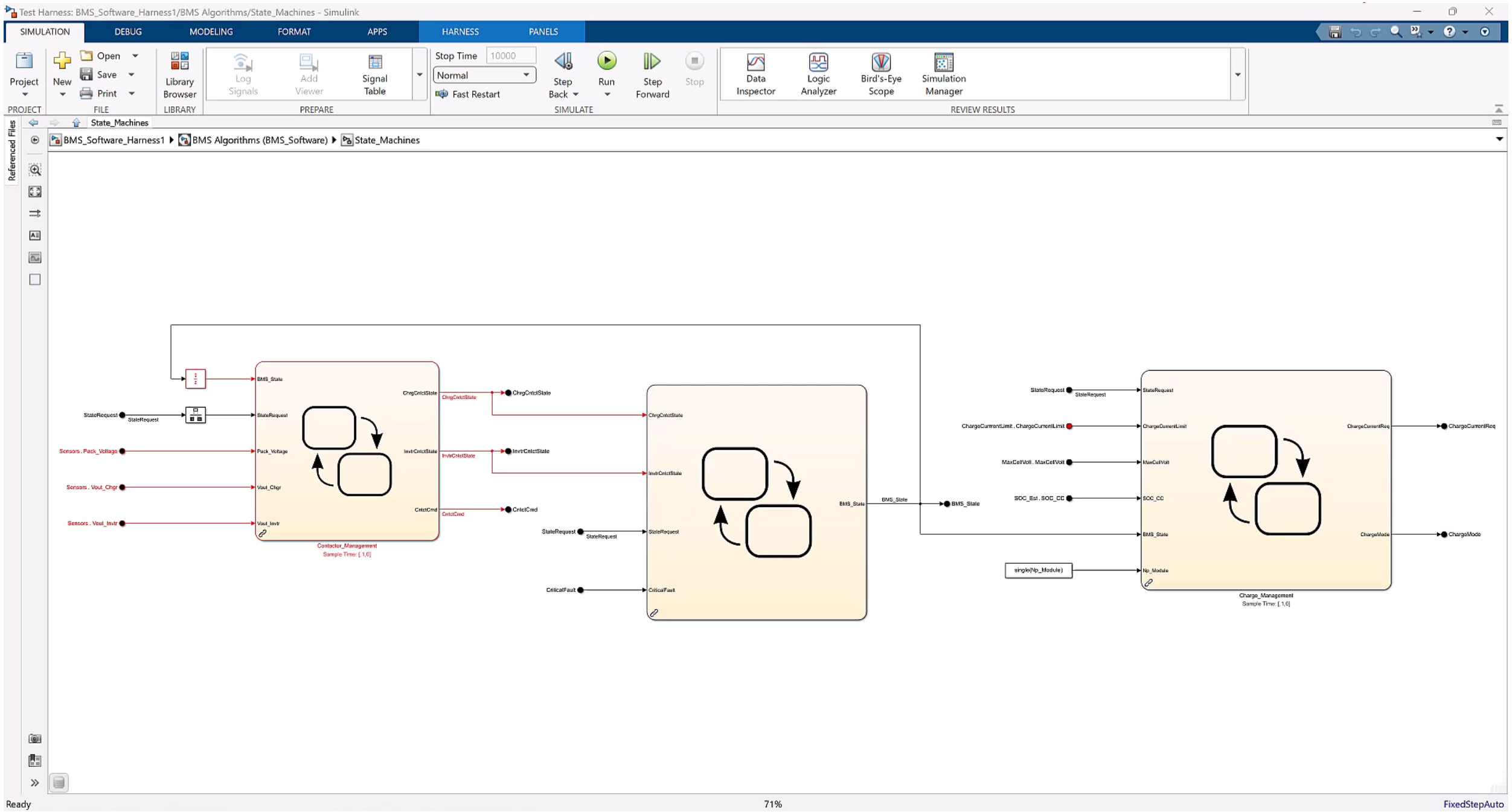
STATES	TRANSITIONS	
	IF	ELSE-IF(2)
Normal	[ALARM]	
	Alarm	

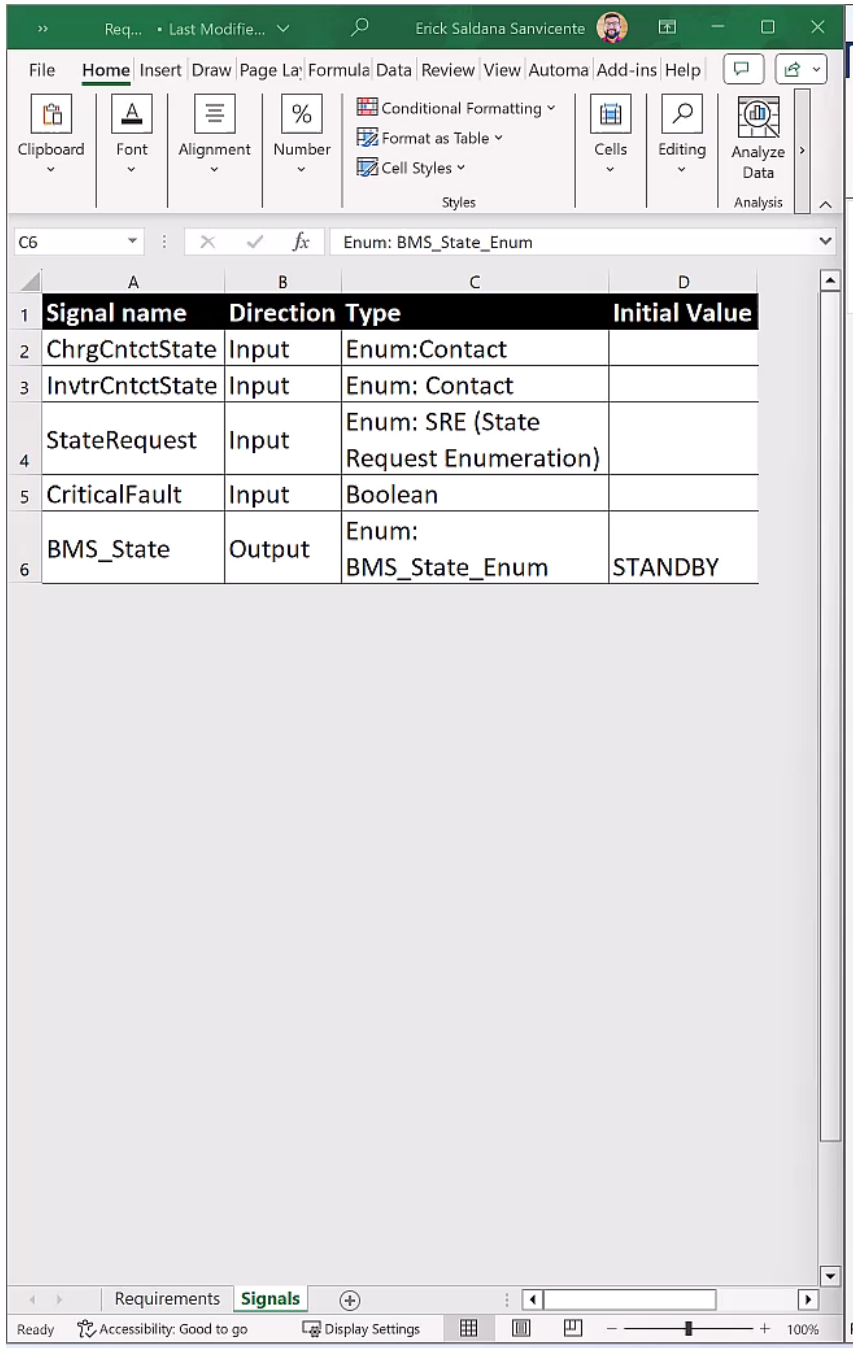
Off
entry:
boiler_cmd = 0;
doneWarmup = false;
	[temp <= reference_low]	

	Warmup	
Warmup entry: boiler_cmd = 2;	[doneWarmup]	[after(10, sec)]
		{doneWarmup = true;}
	On	**On**
On entry: boiler_cmd = 1;	[temp >= reference_high]	
	Off	
Alarm entry: boiler_cmd = 0;	[CLEAR]	
	Normal	

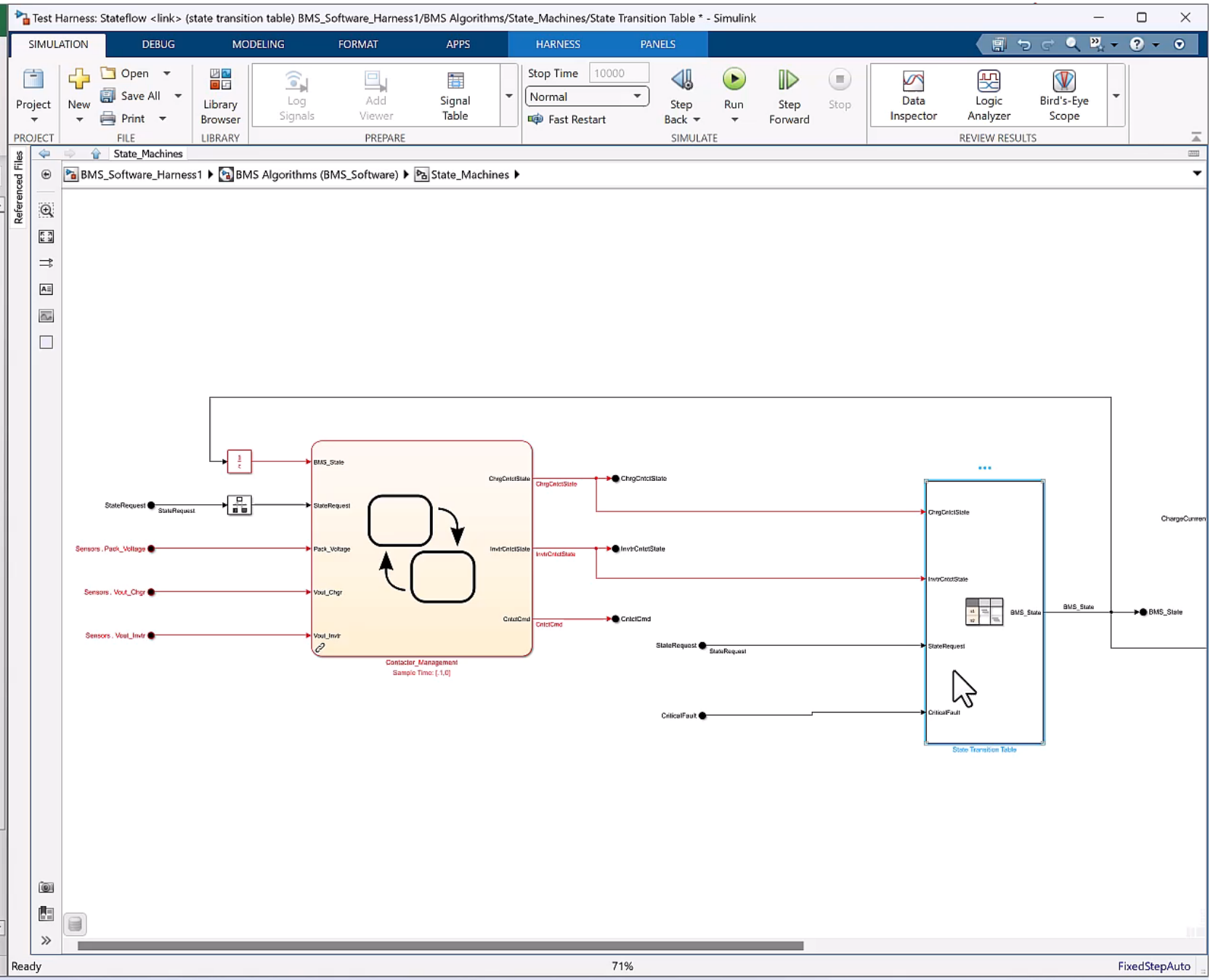

Test Harness: BMS_Software_Harness1 * - Simulink
SIMULATION
DEBUG
MODELING
FORMAT
APPS
HARNESS
PANELS
MODEL BLOCK
Performance Advisor
PERFORMANCE
Diagnostics
Information Overlays
Simscape
DIAGNOSTICS
Trace Signal
Comment Out
Port Values
TOOLS
Pause Time (sec)
Add Breakpoint
Breakpoints List
BREAKPOINTS
Animation speed
Fast
EVENT ANIMATION
Update Model
COMPILE
Stop Time 10000
Normal
Fast Restart
Step Back
Run
Step Forward
Step Over
Step In
Step Out
Stop
SIMULATE
Referenced Files
BMS_Software_Harness1
1 StateRequest
2
3 SimStop
Test_Scenarios
StateRequest
STOP
Stop Simulation
BMS_Software
StateRequest
Sensors
BMS_Info
BMS_Cmd
BMS Algorithms
BMS_Info
BMS_Info
StateRequest
BMS_Cmd
BMS_Cmd
Battery_Model
StateRequest1
BMS_Cmd
KnownSOC
Sensors
Plant Model
KnownSOC
Terminator
Sensors
Sensors
1/z
Unit Delay
Sensors
"Copyright 2018 - 2022 The MathWorks, Inc."
Ready
View 5 warnings
221%
FixedStepAuto

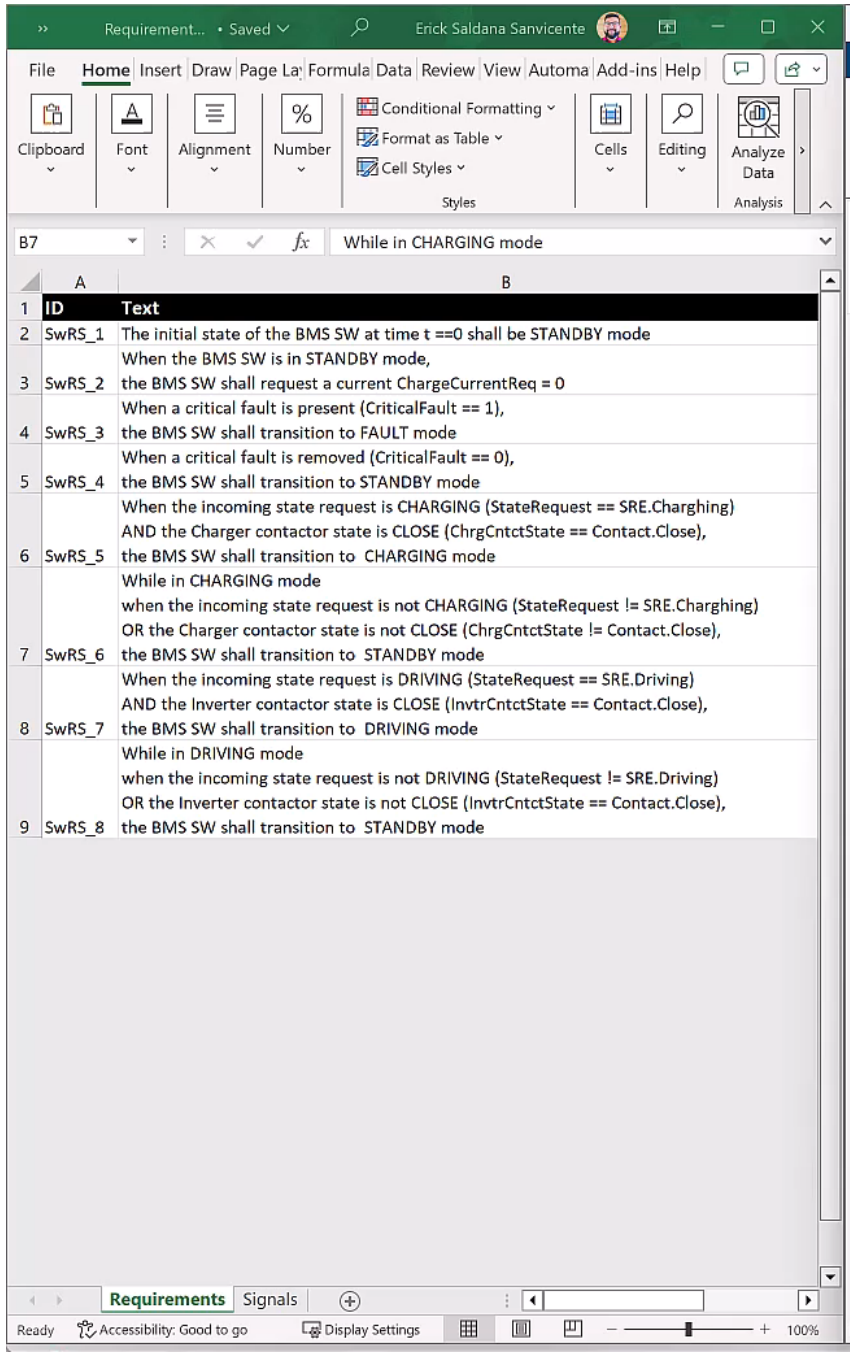



Test Harness: BMS_Software_Harness1/BMS Algorithms/State_Machines - Simulink
SIMULATION
DEBUG
MODELING
FORMAT
APPS
HARNESS
PANELS
Project
New
Open
Save
Print
Library Browser
Log Signals
Add Viewer
Signal Table
Stop Time
10000
Normal
Fast Restart
Step Back
Run
Step Forward
Stop
Data Inspector
Logic Analyzer
Bird's-Eye Scope
Simulation Manager
PROJECT
FILE
LIBRARY
PREPARE
SIMULATE
REVIEW RESULTS
State_Machines
BMS_Software_Harness1
BMS Algorithms (BMS_Software)
State_Machines
Referenced Files
BMS_State
StateRequest
Pack_Voltage
Vout_Chgr
Vout_Invtr
ChrgCntctState
InvtrCntctState
CntctCmd
Contactor_Management
Sample Time: [-1,0]
CriticalFault
ChargeCurrentLimit
MaxCellVolt
SOC_CC
No_Module
ChargeCurrentReq
ChargeMode
single(No_Module)
Charge_Management
Sample Time: [-1,0]
Ready
71%
FixedStepAuto

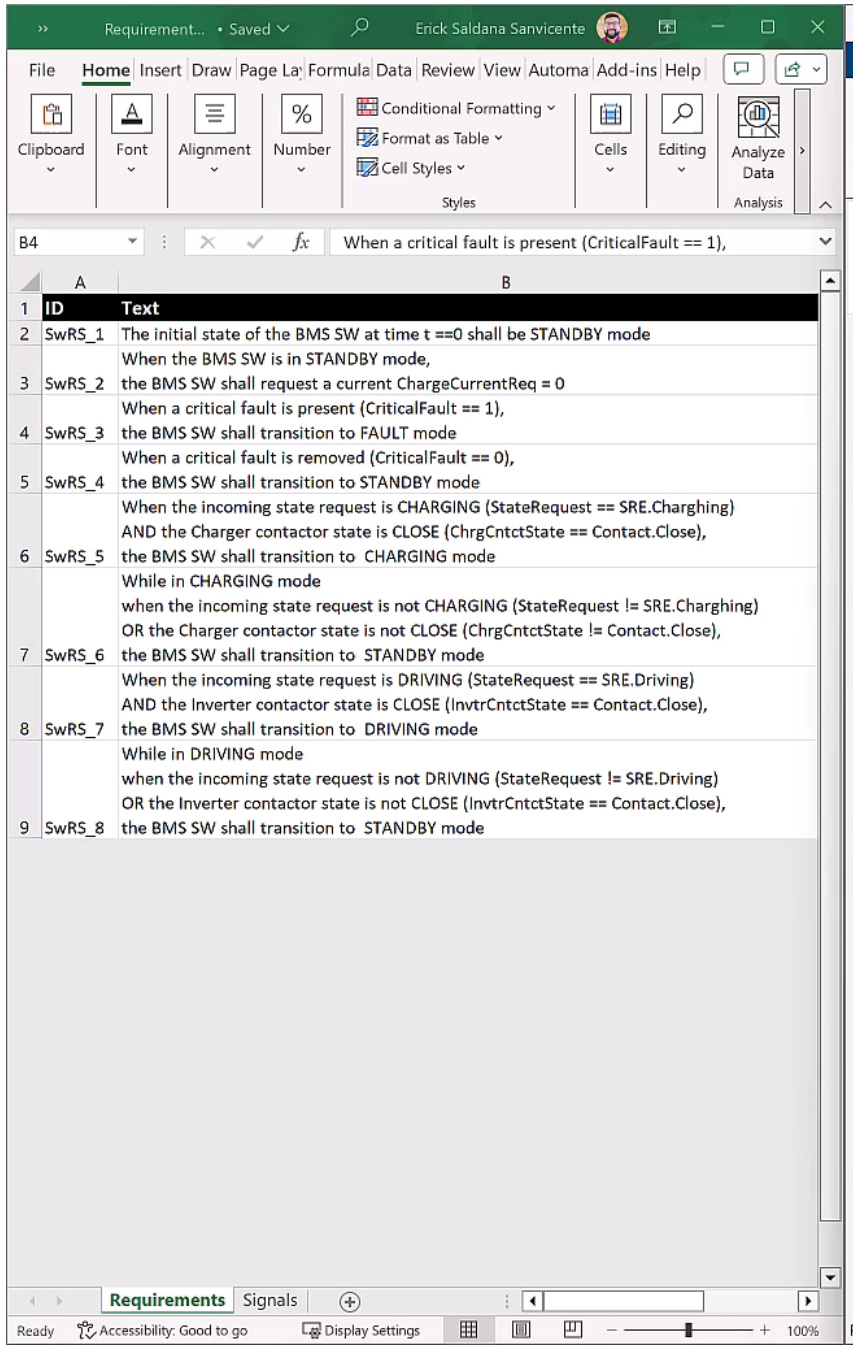


	A	B	C	D
1	**Signal name**	**Direction**	**Type**	**Initial Value**
2	ChrgCntctState	Input	Enum:Contact	
3	InvtrCntctState	Input	Enum: Contact	
4	StateRequest	Input	Enum: SRE (State Request Enumeration)	
5	CriticalFault	Input	Boolean	
6	BMS_State	Output	Enum: BMS_State_Enum	STANDBY





ID	Text
SwRS_1	The initial state of the BMS SW at time t ==0 shall be STANDBY mode
SwRS_2	When the BMS SW is in STANDBY mode, the BMS SW shall request a current ChargeCurrentReq = 0
SwRS_3	When a critical fault is present (CriticalFault == 1), the BMS SW shall transition to FAULT mode
SwRS_4	When a critical fault is removed (CriticalFault == 0), the BMS SW shall transition to STANDBY mode
SwRS_5	When the incoming state request is CHARGING (StateRequest == SRE.Charghing) AND the Charger contactor state is CLOSE (ChrgCntctState == Contact.Close), the BMS SW shall transition to CHARGING mode
SwRS_6	While in CHARGING mode when the incoming state request is not CHARGING (StateRequest != SRE.Charghing) OR the Charger contactor state is not CLOSE (ChrgCntctState != Contact.Close), the BMS SW shall transition to STANDBY mode
SwRS_7	When the incoming state request is DRIVING (StateRequest == SRE.Driving) AND the Inverter contactor state is CLOSE (InvtrCntctState == Contact.Close), the BMS SW shall transition to DRIVING mode
SwRS_8	While in DRIVING mode when the incoming state request is not DRIVING (StateRequest != SRE.Driving) OR the Inverter contactor state is not CLOSE (InvtrCntctState == Contact.Close), the BMS SW shall transition to STANDBY mode



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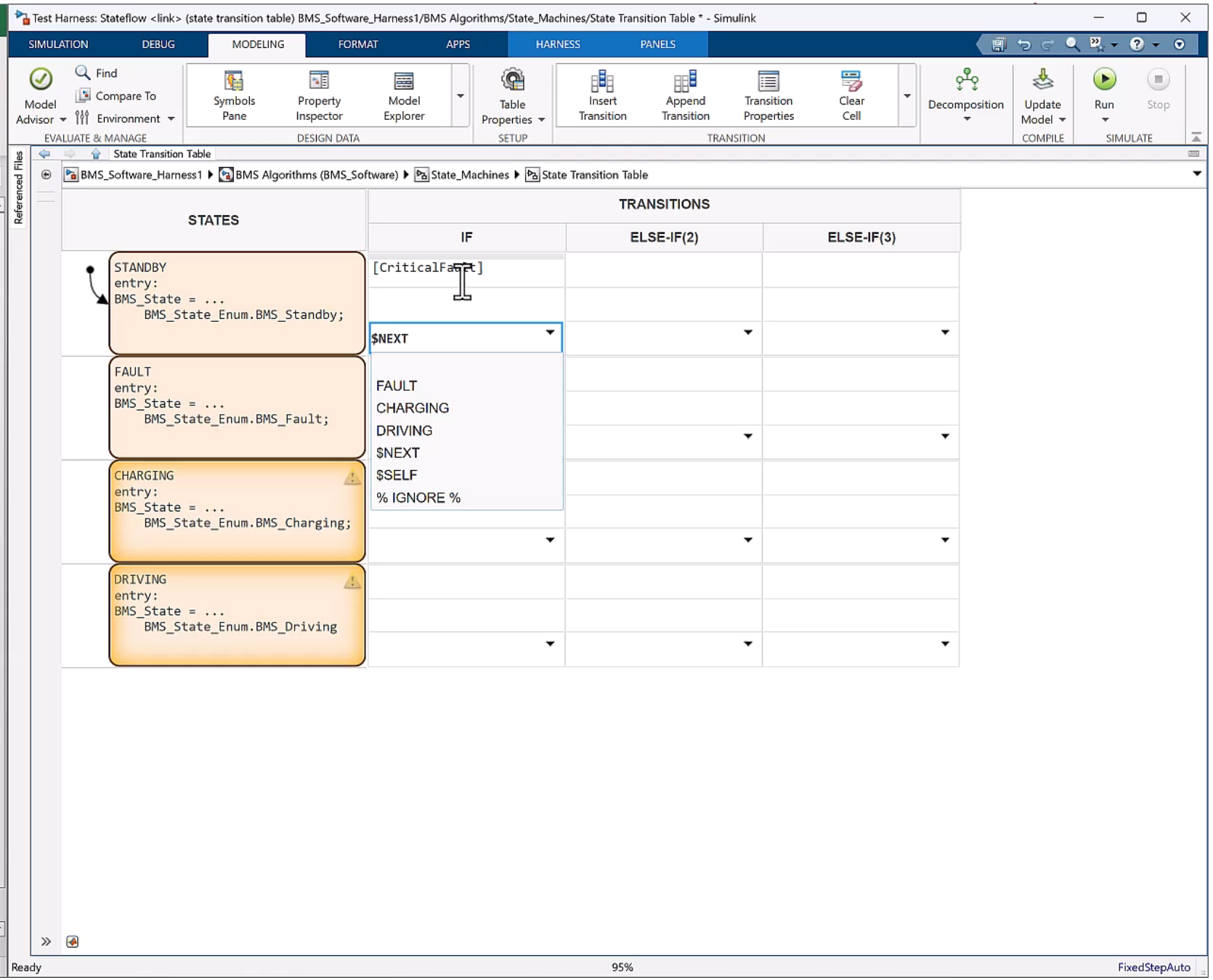

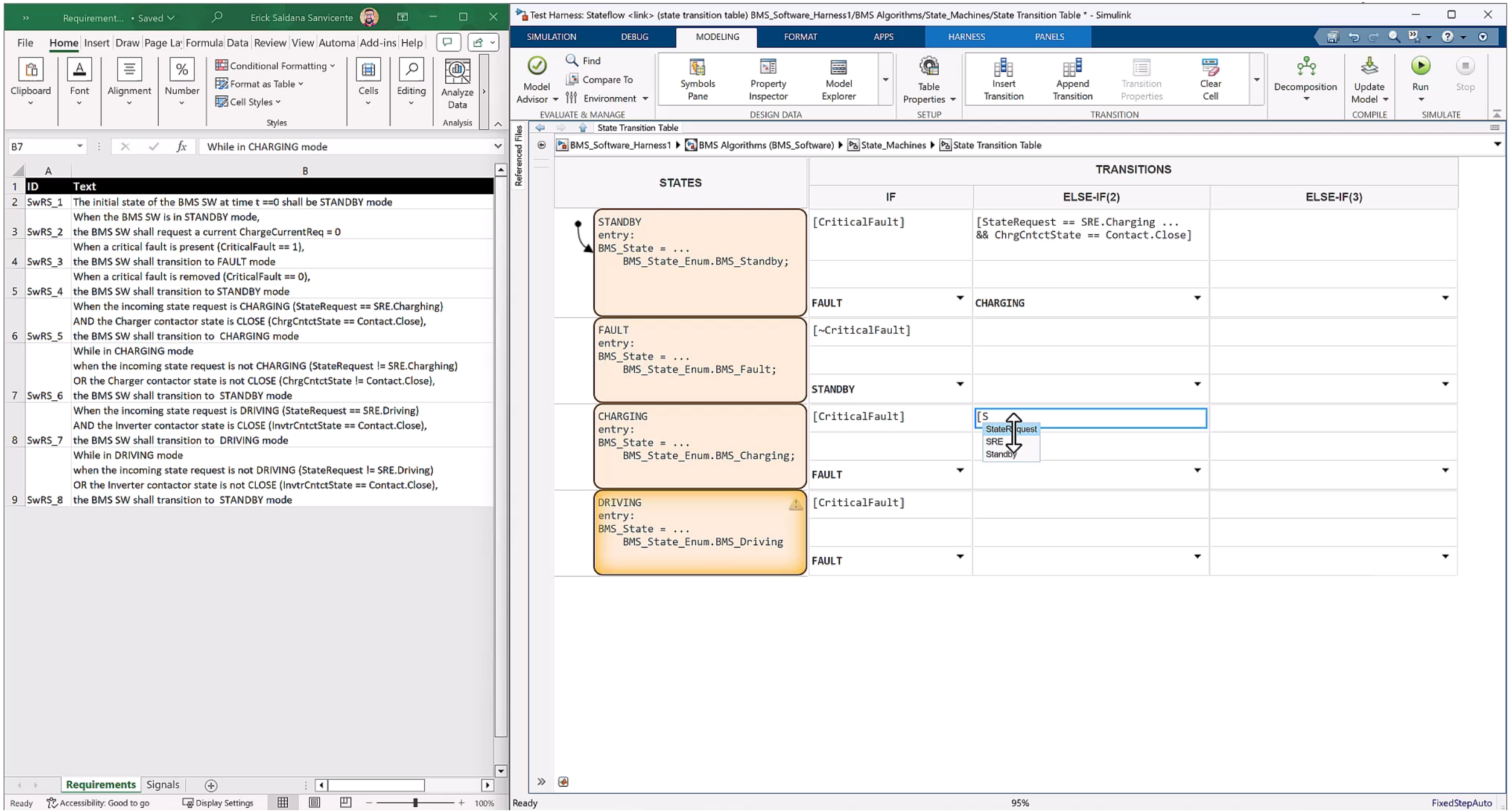
Requirement... • Saved
Erick Saldana Sanvicente
File Home Insert Draw Page La Formula Data Review View Automa Add-ins Help
Clipboard Font Alignment Number Conditional Formatting Format as Table Cell Styles Styles Cells Editing Analyze Data Analysis
B7
While in CHARGING mode
A B
1 ID Text
2 SwRS_1 The initial state of the BMS SW at time t ==0 shall be STANDBY mode
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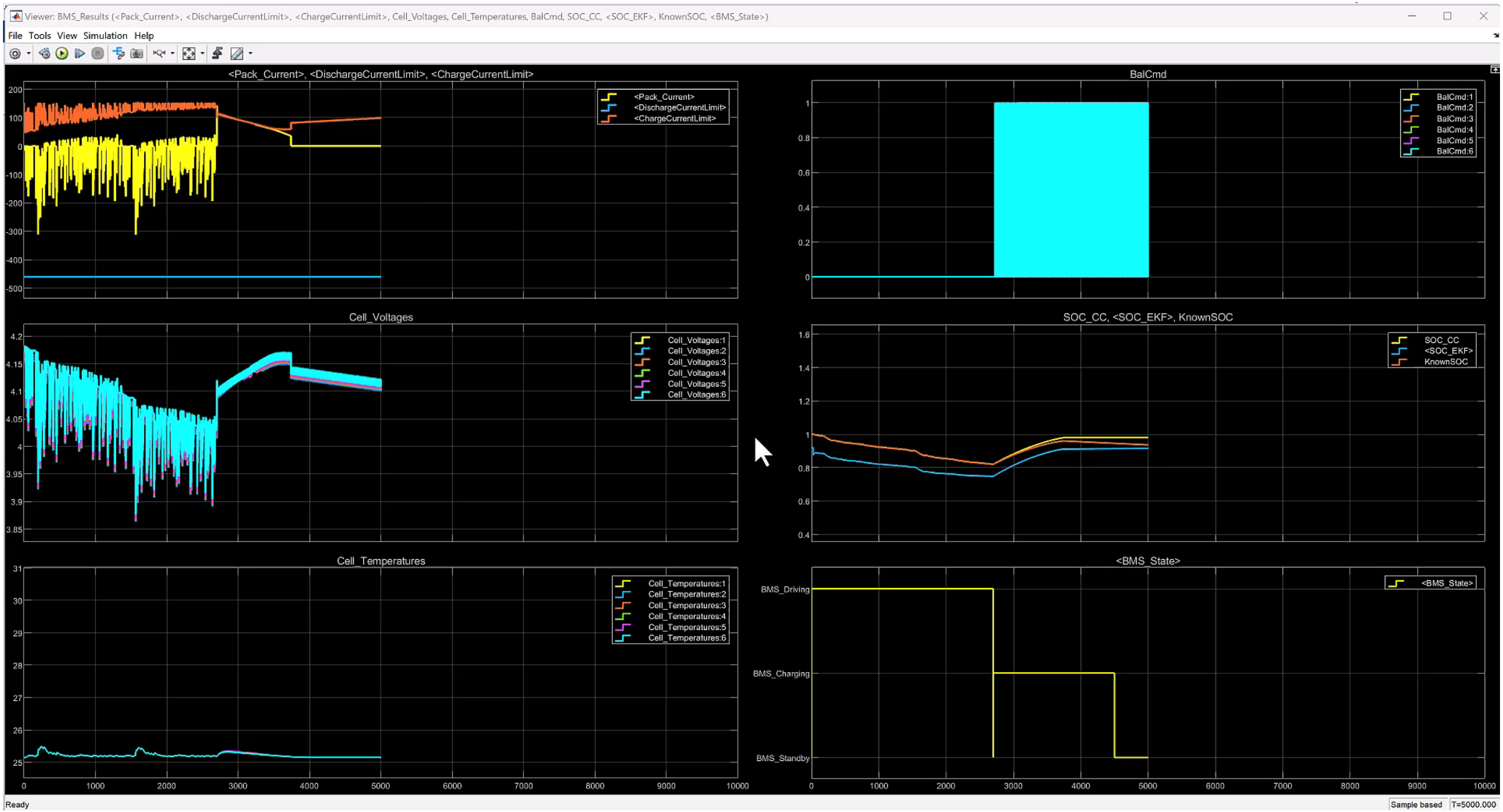
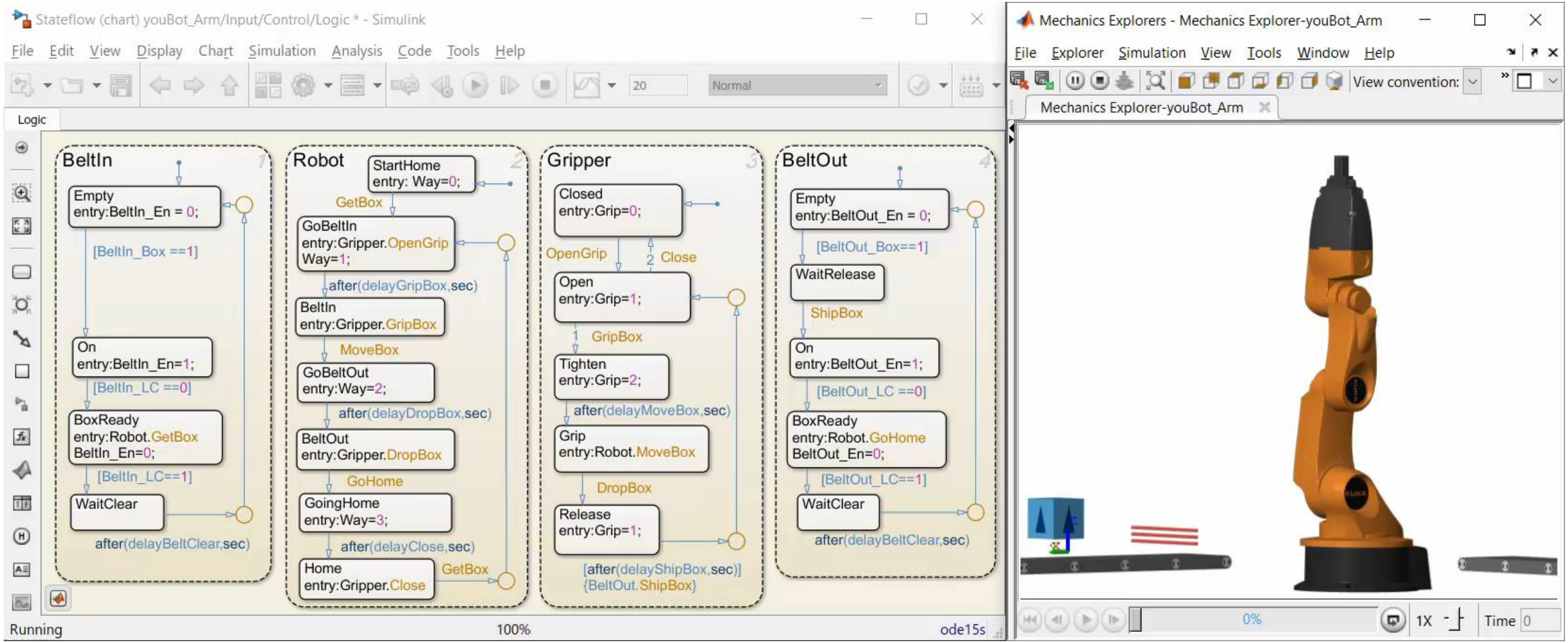
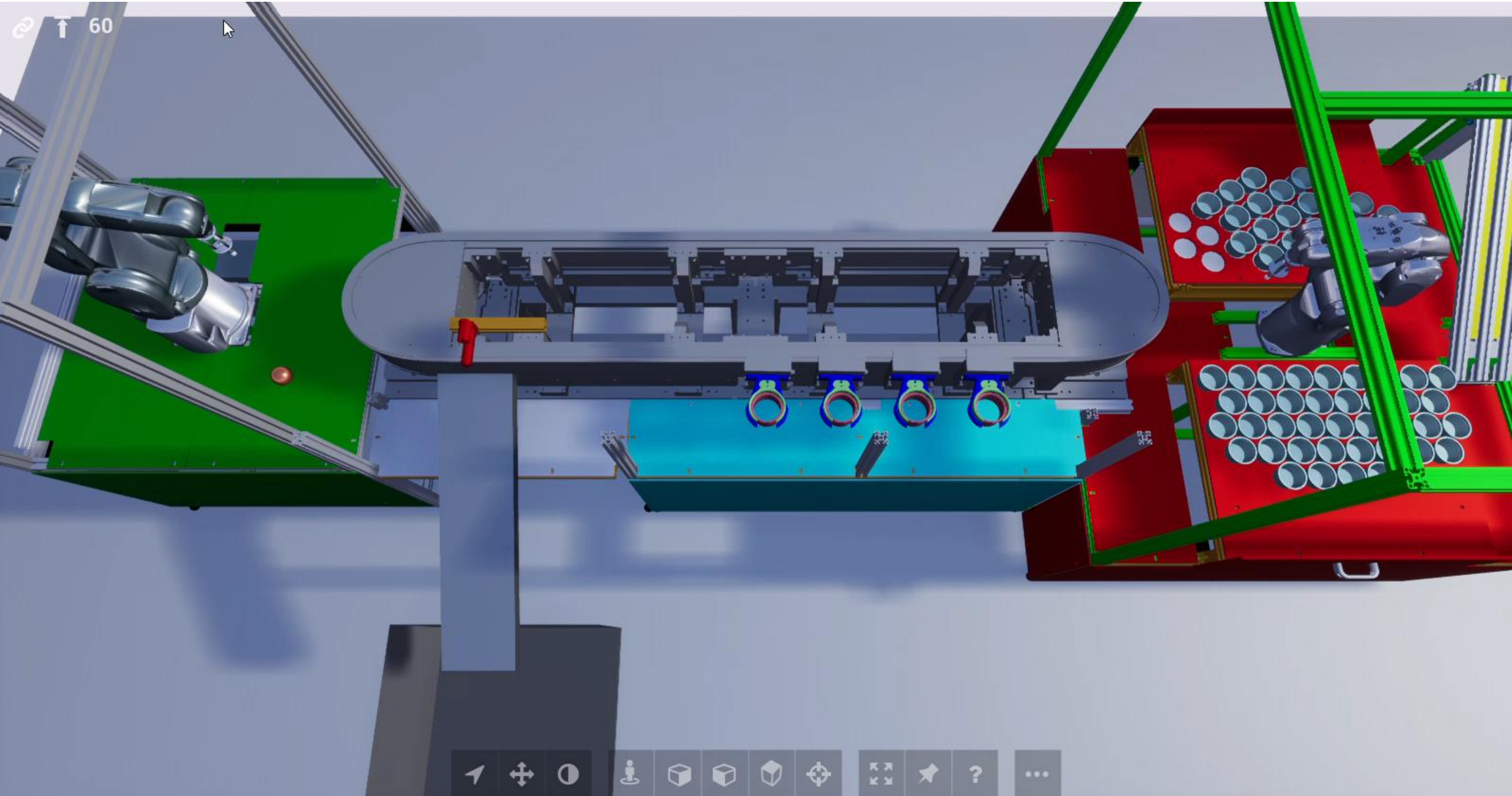
Requirements Signals
Ready Accessibility: Good to go Display Settings 100%
Test Harness: Stateflow <link> (state transition table) BMS_Software_Harness1/BMS Algorithms/State_Machines/State Transition Table * - Simulink
SIMULATION DEBUG MODELING FORMAT APPS HARNESS PANELS
Model Advisor Find Compare To Environment EVALUATE & MANAGE
Symbols Pane Property Inspector Model Explorer DESIGN DATA
Table Properties SETUP
Insert Transition Append Transition Transition Properties Clear Cell TRANSITION
Decomposition
Update Model COMPILE
Run Stop SIMULATE
State Transition Table
BMS_Software_Harness1 BMS Algorithms (BMS_Software) State_Machines State Transition Table
Referenced Files
STATES
TRANSITIONS
IF
ELSE-IF(2)
ELSE-IF(3)
STANDBY
entry:
BMS_State = ...
BMS_State_Enum.BMS_Standby;
[CriticalFault]
[StateRequest == SRE.Charging ...
&& ChrgCntctState == Contact.Close]
FAULT
CHARGING
FAULT
entry:
BMS_State = ...
BMS_State_Enum.BMS_Fault;
[~CriticalFault]
STANDBY
CHARGING
entry:
BMS_State = ...
BMS_State_Enum.BMS_Charging;
[CriticalFault]
[S
StateRequest
SRE
Standby
FAULT
DRIVING
entry:
BMS_State = ...
BMS_State_Enum.BMS_Driving
[CriticalFault]
FAULT
Ready
95%
FixedStepAuto


Viewer: BMS_Results (<Pack_Current>, <DischargeCurrentLimit>, <ChargeCurrentLimit>, Cell_Voltages, Cell_Temperatures, BalCmd, SOC_CC, <SOC_EKF>, KnownSOC, <BMS_State>)
File Tools View Simulation Help
<Pack_Current>, <DischargeCurrentLimit>, <ChargeCurrentLimit>
<Pack_Current>
<DischargeCurrentLimit>
<ChargeCurrentLimit>
BalCmd
BalCmd:1
BalCmd:2
BalCmd:3
BalCmd:4
BalCmd:5
BalCmd:6
Cell_Voltages
Cell_Voltages:1
Cell_Voltages:2
Cell_Voltages:3
Cell_Voltages:4
Cell_Voltages:5
Cell_Voltages:6
SOC_CC, <SOC_EKF>, KnownSOC
SOC_CC
<SOC_EKF>
KnownSOC
Cell_Temperatures
Cell_Temperatures:1
Cell_Temperatures:2
Cell_Temperatures:3
Cell_Temperatures:4
Cell_Temperatures:5
Cell_Temperatures:6
<BMS_State>
BMS_Driving
BMS_Charging
BMS_Standby
Ready
Sample based
T=5000.000

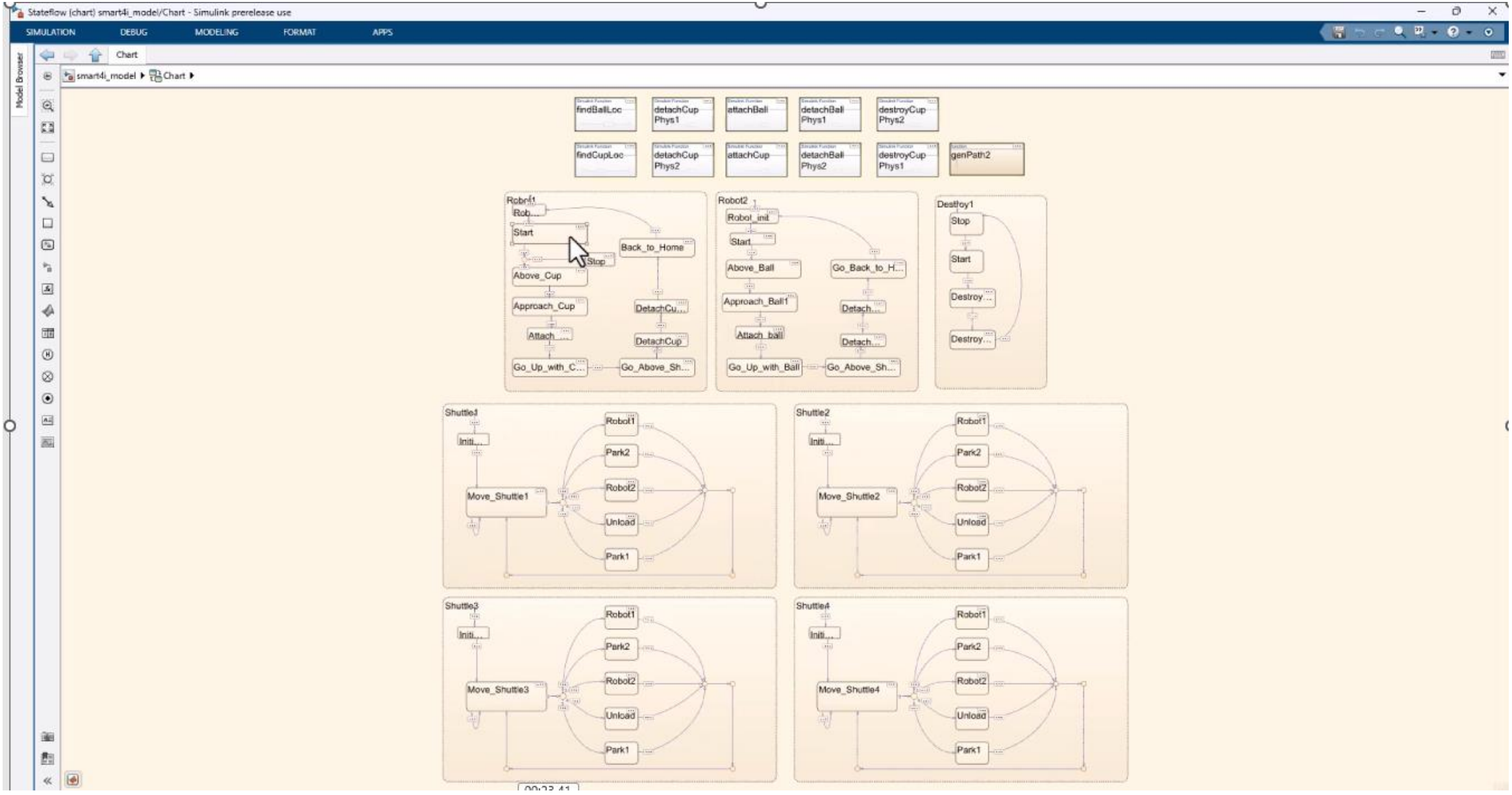
Questions so far?

System-level control strategies are often represented by state machines



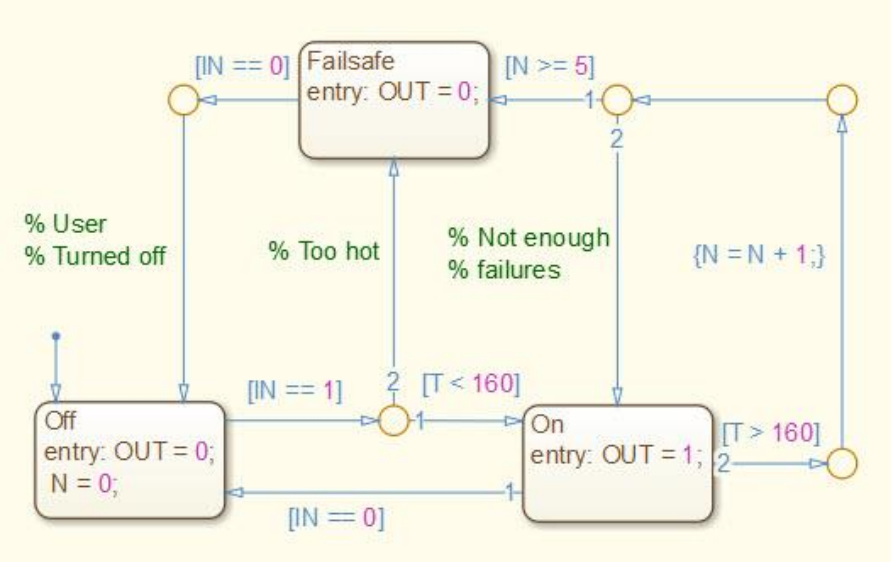

60

Supervisory Control Logic



Stateflow, like Simulink, is also a deployment tool

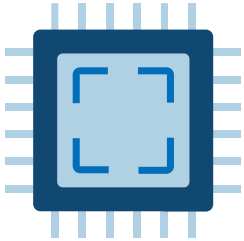
Design



Code

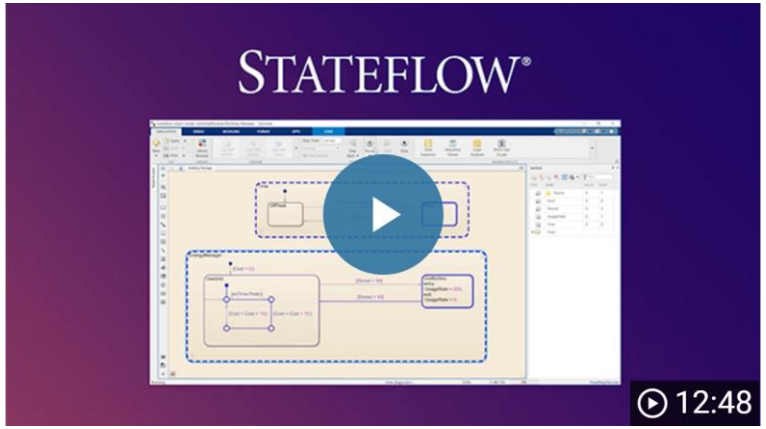
```
/* Model step function */
void Chart_step(void)
{
  /* Chart: '<Root>/Chart' incorporates:
   *  Inport: '<Root>/IN'
   *  Inport: '<Root>/T'
   */
  /* Gateway: Chart */
  /* During: Chart */
  if (Chart_DWork.is_active_c3_Chart == 0U) {
    /* Entry: Chart */
    Chart_DWork.is_active_c3_Chart = 1U;

    /* Entry Internal: Chart */
    /* Transition: '<S1>:137' */
    Chart_DWork.is_c3_Chart = Chart_IN_Off;

    /* Outport: '<Root>/OUT' */
    /* Entry 'Off': '<S1>:125' */
    Chart_Y.OUT = 0.0;
    Chart_DWork.N = 0.0;
  } else {
    switch (Chart_DWork.is_c3_Chart) {
     case Chart_IN_Failsafe:
      /* During 'Failsafe': '<S1>:138' */
      if (Chart_U.switch_on == 0.0) {
        /* Transition: '<S1>:129' */
        /* Transition: '<S1>:123' */
        /*  User */
        /*  Turned off */
        Chart_DWork.is_c3_Chart = Chart_IN_Off;
```

Deploy

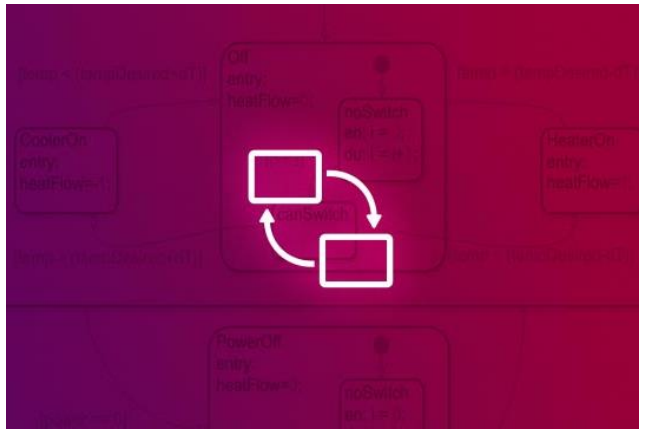


Resources for Getting Started with Stateflow (links in chat)

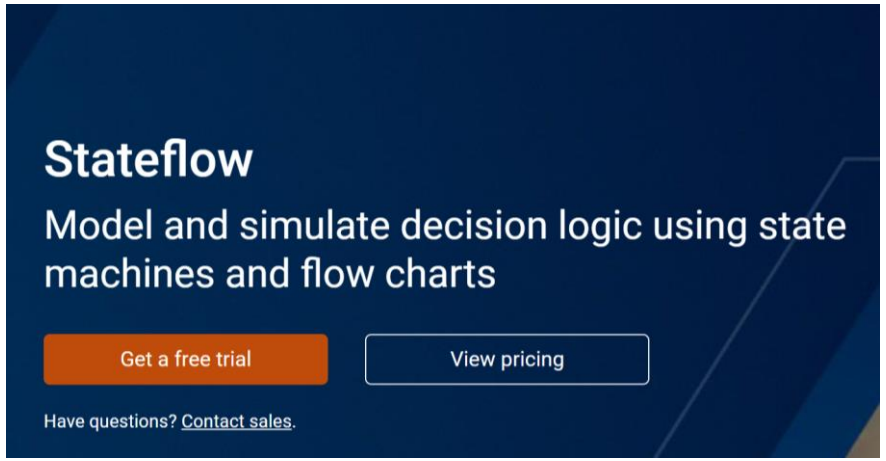
"Getting Started with Stateflow" Video



Stateflow Onramp



Stateflow Product Page



Stateflow Documentation