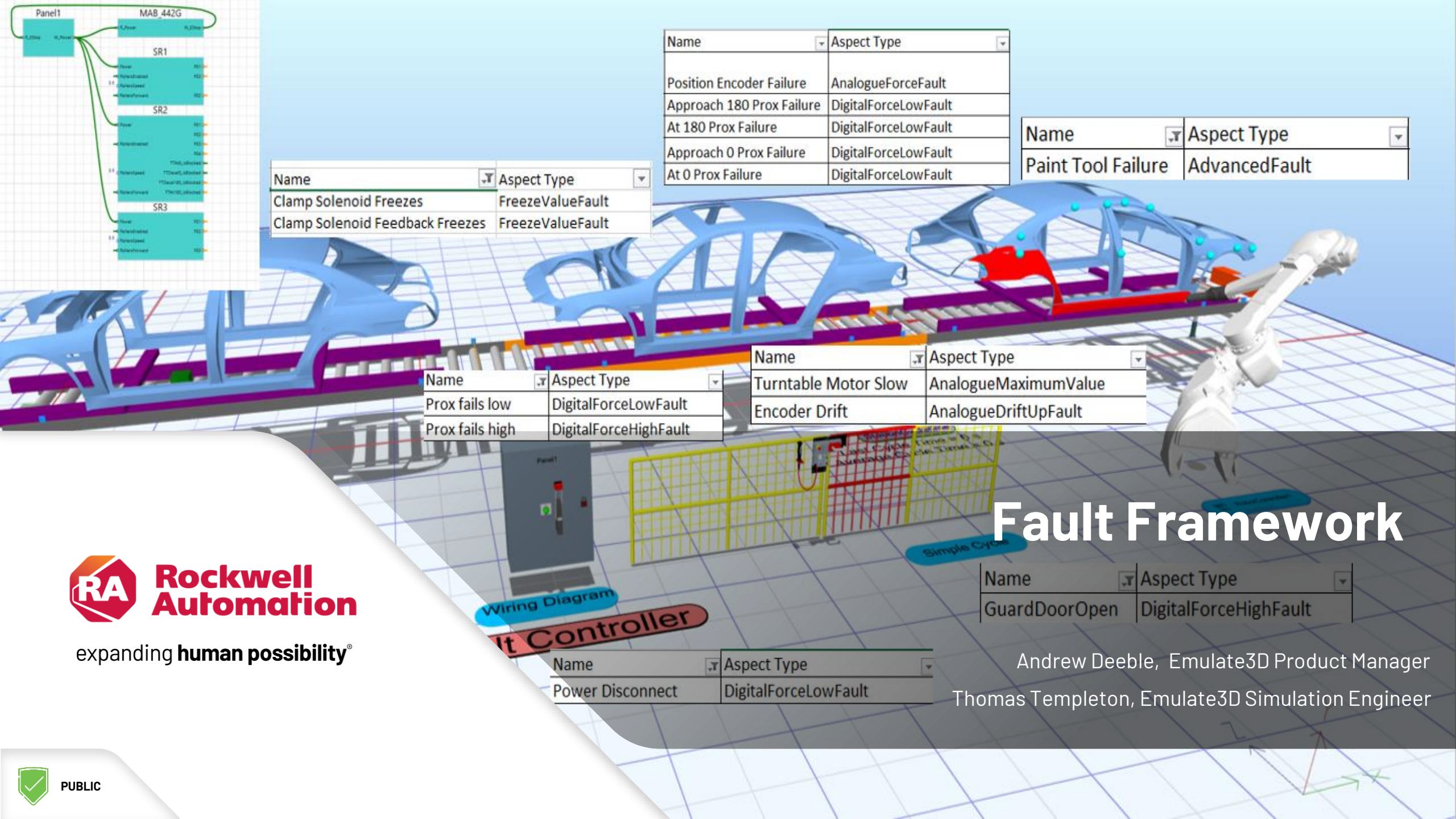


Fault Framework

Andrew Deeble, Emulate3D Product Manager

Thomas Templeton, Emulate3D Simulation Engineer

Rockwell Automation

expanding **human possibility**®

PUBLIC

Stages of Virtual Commissioning

Can we connect?

Simply connecting to the model finds issues:

- Map IO to virtual equipment
- Connect the HMIs
- Initialize and reset alarms
- Check safety feedback

Can we run in manual?

Begin testing system by forcing values:

- Verify sensor feedback
- Dry run motors
- Test manual functions
- Step through the sequence

Can we run in auto?

Create product and see how our system responds:

- Run idealized cycle on auto
- Reposition field sensors
- Verify predicted throughput
- Test safety, stops, restarts

Ready to go on site?

Wait there is more!

...Maximising Value from Virtual Commissioning

Can we connect?

Can we run in manual?

Can we run in auto?

Advanced testing

Testing in the virtual world is easier than in the real:

Inject device faults

Check alarms & diagnostics

Run varied load schedules

Stress test the system

Operator Training

Familiarize and train on an accurate model:

Familiarize with HMIs

Run training scenarios

Train on device failures

Grade operator responses

System Upgrades

Reuse the model to test potential changes:

Regression test code changes

Optimize performance

Test hypothetical scenarios

Reproduce issues virtually

Fault Framework Discrete Example with Stop* - Emulate3D 2024 (Beta)

File | Home | Arrange | Visualization | •Package Tools | •Fault Framework | •CAD Is The Model

Quick Search

Select | Navigate | Text | Find | Find Next | Select All | Edit Custom Properties | Edit Script | Visual Studio | Enable Debug | Reset | Settings | Editing

Animate | Message Log | Tools | Layers | Default View | Plan View | Zoom Extents | Default View | Add View | Remove View | View

Volumetric Physics | Physics | IO Browser | Lag | Emulation

Experiments | Event List | Analysis | Simulation

FaultsCatalog

Search...

Catalogs | FaultsCatalog

Advanced Faults | Advanced Assertions | Snappable Assertions

Fault Controller

Not | Not | Explc | Hieran | FaultsCat

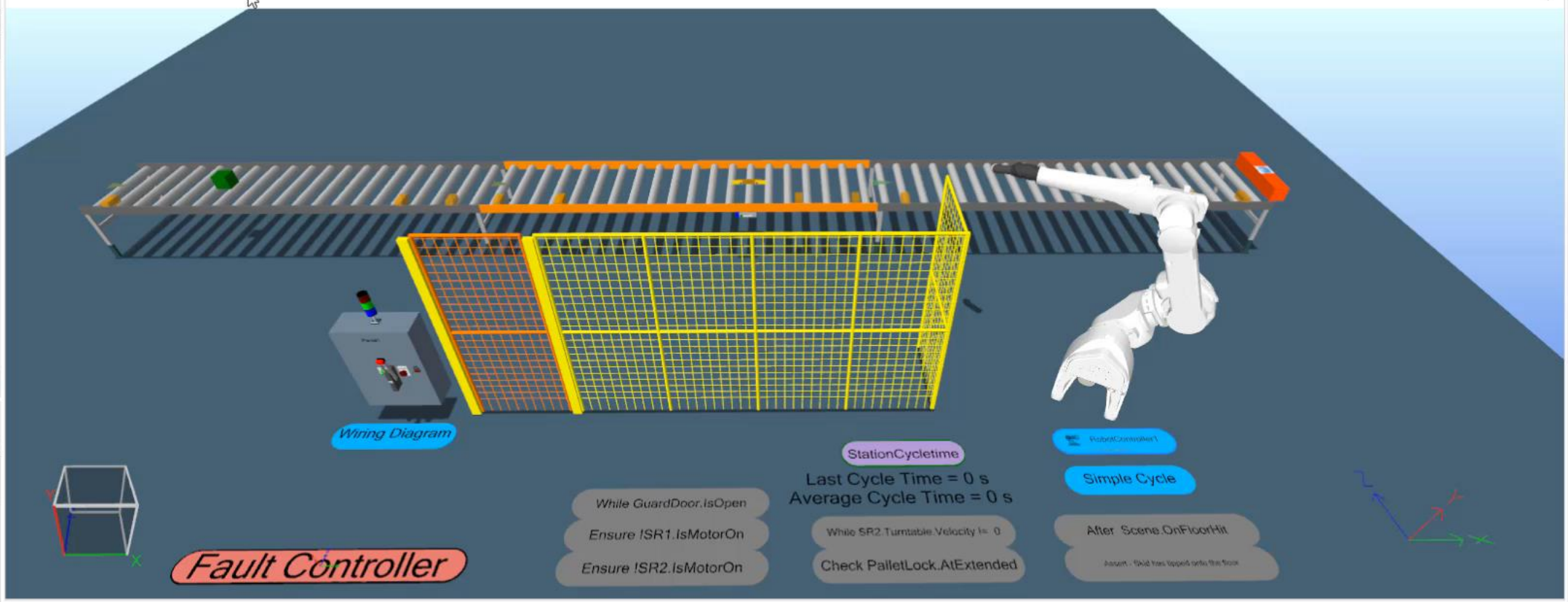
Properties: FaultController

Search

Control	
AddMessageToTable	False
DisableAllAssertions	False
DisableAllFaults	False
EnableAllAssertions	False
EnabledFaultsCount	0
LogMessage	
Fault Schedules	
AllFaults	AllFaults (8 rows)
ExampleFaults	ExampleFaults (2 rows)
No Faults	No Faults (0 rows)
General	
Name	**FaultController**
Position	
World Location	**5.3001 m, 0.005 m, -5.4**

ExampleFaults

Properti | Properti | Connect | Events:



MessageLog

Model	Category	Message

Table - ExampleFaults | MessageLog

FPS: 23.03 | Speed: 1.00 / 1.00 | Size: 1610x609 | Default Display | World Location | X 5.3 m | Y 0.005 m | Z -5.44 m | Reset Layout | Connections: 0 | Loads: 0 | Time: 0:00:00:00.00

Fault Framework

Add fault aspects to any visual

Force and unforce any property

Prebuilt or custom QL / C# faults

Add assertions to monitor any visual

Identify incorrect model behaviour

Simple pass/fail, and detailed log

Manually inject faults to test controls

Save your test in one click for reuse

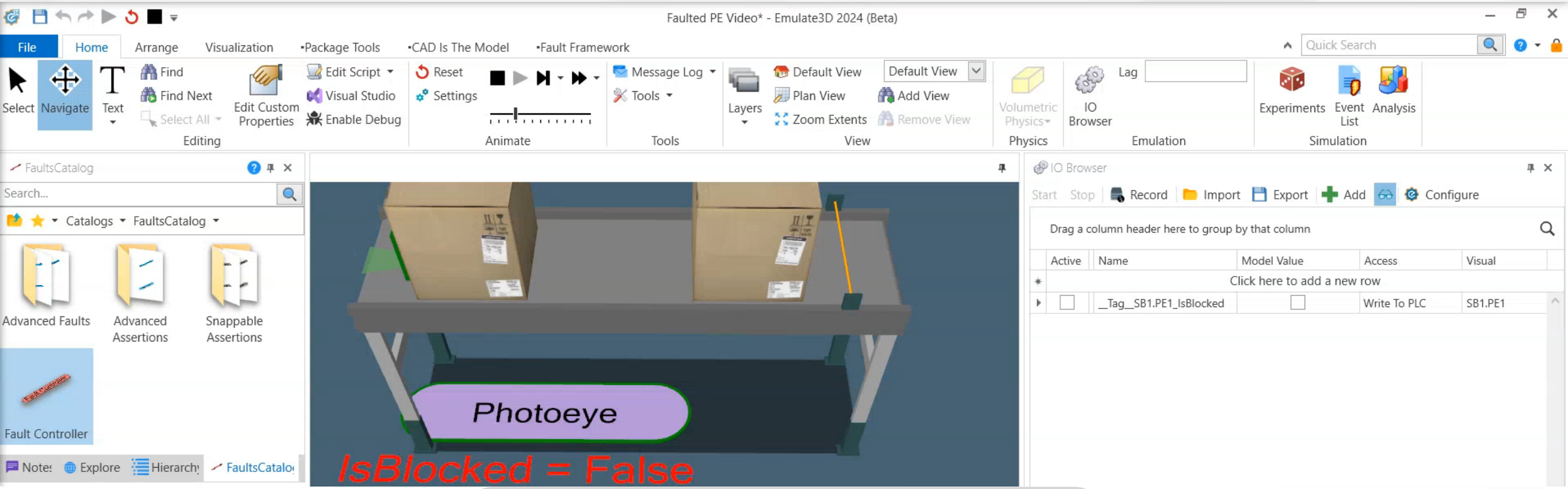
Create your own regression tests

Forcing Values with Fault Aspects

Forcing no longer affects the binding between property and tag

Now properties themselves can be forced

Add aspects to components to represent faults and force values



Adding Faults

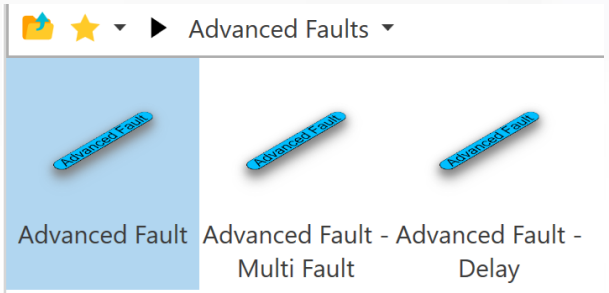
Force or freeze values

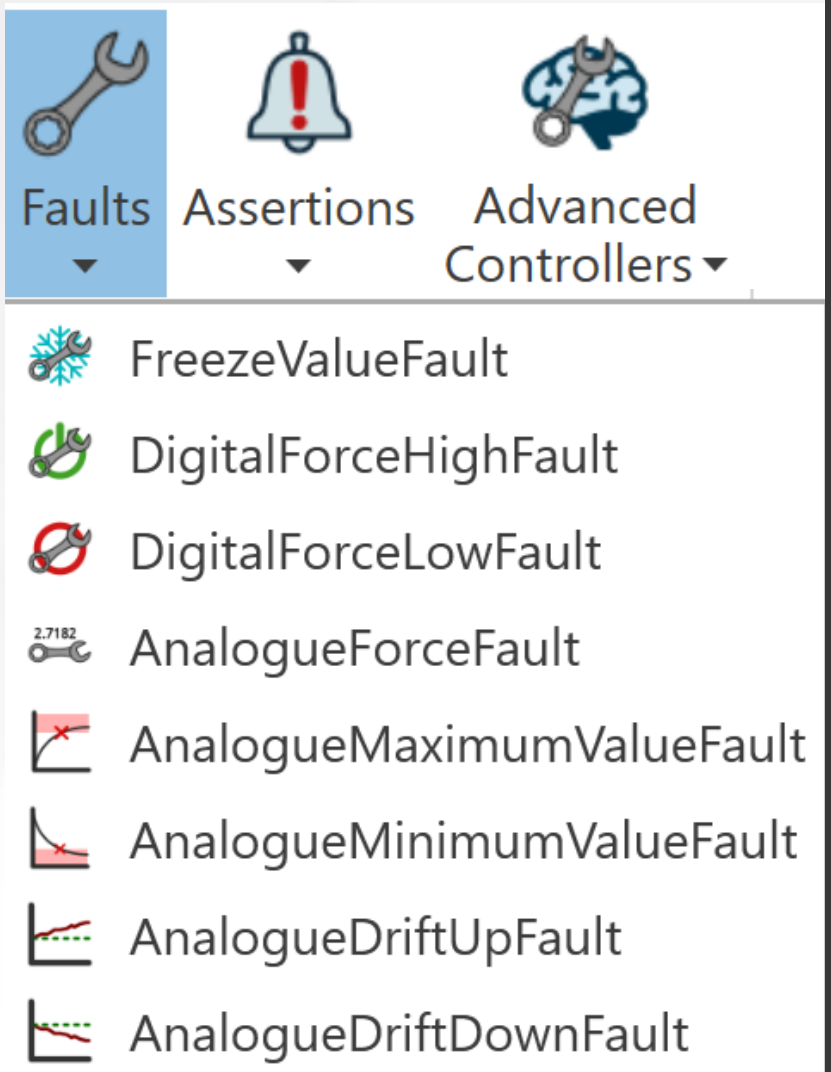
Drift or limit values

Delay the updating of signals

Custom QuickLogic faults

Full API and IFault interface





Fault Framework

`add [message] to FullLog table`
Add a custom message to the FullLog table in the Analysis Window.

`disable assertion [visual] . [assertionName]`
Disable an assertion. No name needed for an Advanced Assertion.

`disable fault [visual] . [faultName]`
Disable a fault. No name needed for an Advanced Fault.

`enable assertion [visual] . [assertionName]`
Enable an assertion. No name needed for an Advanced Assertion.

`enable fault [visual] . [faultName]`
Enable a fault. No name needed for an Advanced Fault.

`evaluate [condition]`
Get the current value of a boolean expression property.

`force [visual] . [propertyName] to [value]`
Force a property to a certain value.

`is assertion [visual] . [assertionName] enabled`
Is an assertion enabled. No name needed for an Advanced Assertion.

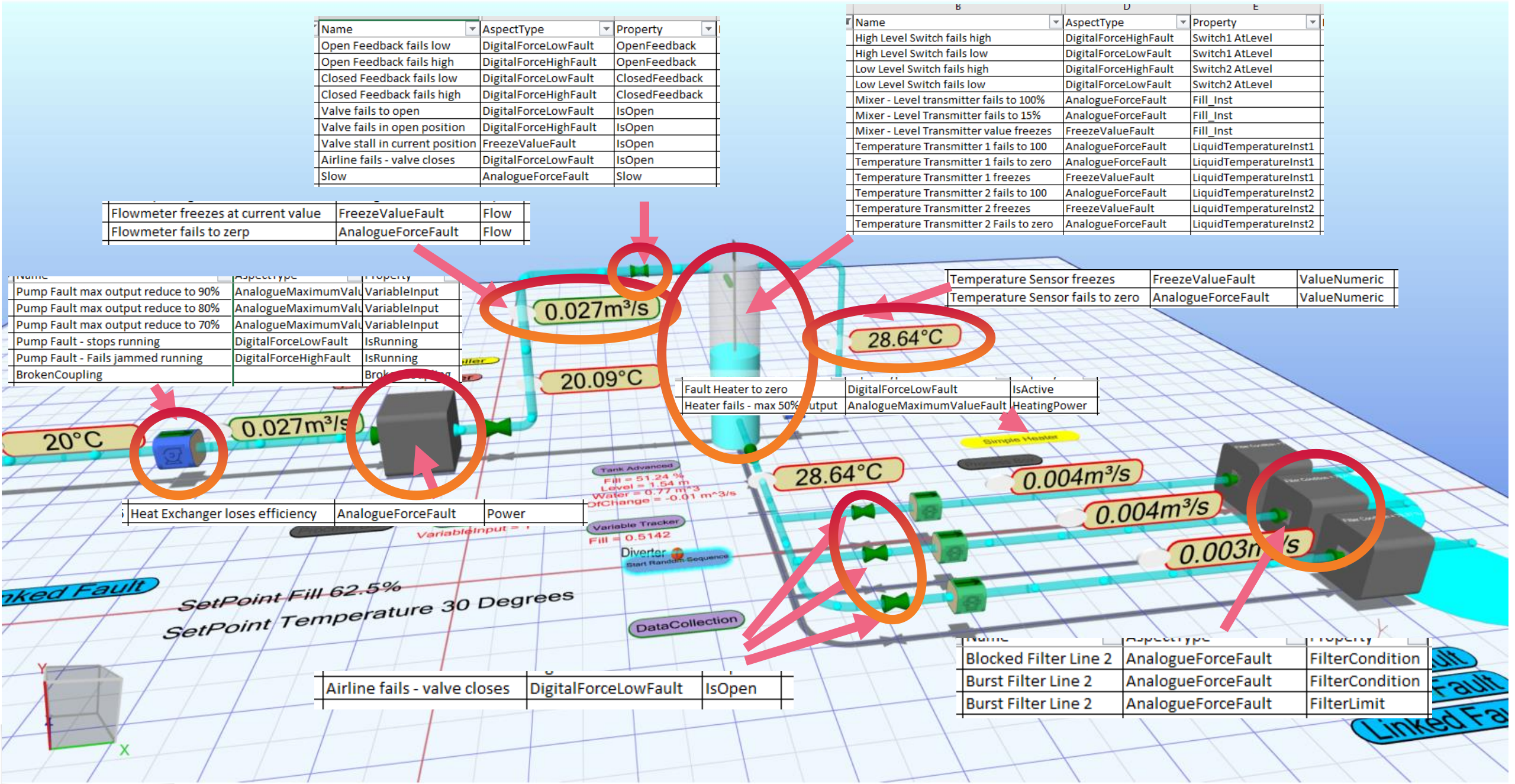
`is fault [visual] . [faultName] enabled`
Is a fault enabled. No name needed for an Advanced Fault.

`unforce [visual] . [propertyName]`
Unforce a property.

`unforced value of [visual] . [propertyName]`
Get the unforced value of a forced property.

`wait until boolean [condition] is true`
Wait until a boolean expression property is True.

`wait until unforced value of [visual] . [propertyName] changes`
Wait until the unforced value of a forced property changes.

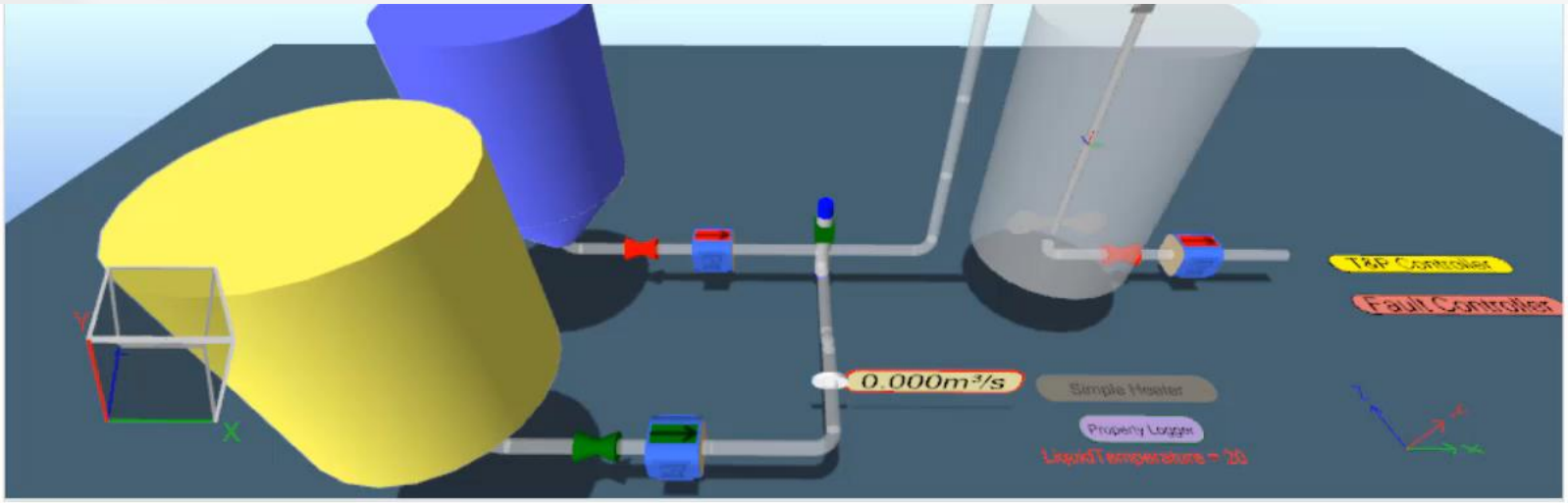

Name | AspectType | Property
Open Feedback fails low | DigitalForceLowFault | OpenFeedback
Open Feedback fails high | DigitalForceHighFault | OpenFeedback
Closed Feedback fails low | DigitalForceLowFault | ClosedFeedback
Closed Feedback fails high | DigitalForceHighFault | ClosedFeedback
Valve fails to open | DigitalForceLowFault | IsOpen
Valve fails in open position | DigitalForceHighFault | IsOpen
Valve stall in current position | FreezeValueFault | IsOpen
Airline fails - valve closes | DigitalForceLowFault | IsOpen
Slow | AnalogueForceFault | Slow
Name | AspectType | Property
High Level Switch fails high | DigitalForceHighFault | Switch1 AtLevel
High Level Switch fails low | DigitalForceLowFault | Switch1 AtLevel
Low Level Switch fails high | DigitalForceHighFault | Switch2 AtLevel
Low Level Switch fails low | DigitalForceLowFault | Switch2 AtLevel
Mixer - Level transmitter fails to 100% | AnalogueForceFault | Fill_Inst
Mixer - Level Transmitter fails to 15% | AnalogueForceFault | Fill_Inst
Mixer - Level Transmitter value freezes | FreezeValueFault | Fill_Inst
Temperature Transmitter 1 fails to 100 | AnalogueForceFault | LiquidTemperatureInst1
Temperature Transmitter 1 fails to zero | AnalogueForceFault | LiquidTemperatureInst1
Temperature Transmitter 1 freezes | FreezeValueFault | LiquidTemperatureInst1
Temperature Transmitter 2 fails to 100 | AnalogueForceFault | LiquidTemperatureInst2
Temperature Transmitter 2 freezes | FreezeValueFault | LiquidTemperatureInst2
Temperature Transmitter 2 Fails to zero | AnalogueForceFault | LiquidTemperatureInst2
Flowmeter freezes at current value | FreezeValueFault | Flow
Flowmeter fails to zerp | AnalogueForceFault | Flow
Temperature Sensor freezes | FreezeValueFault | ValueNumeric
Temperature Sensor fails to zero | AnalogueForceFault | ValueNumeric
Pump Fault max output reduce to 90% | AnalogueMaximumValu | VariableInput
Pump Fault max output reduce to 80% | AnalogueMaximumValu | VariableInput
Pump Fault max output reduce to 70% | AnalogueMaximumValu | VariableInput
Pump Fault - stops running | DigitalForceLowFault | IsRunning
Pump Fault - Fails jammed running | DigitalForceHighFault | IsRunning
BrokenCoupling
Fault Heater to zero | DigitalForceLowFault | IsActive
Heater fails - max 50% utput | AnalogueMaximumValueFault | HeatingPower
Heat Exchanger loses efficiency | AnalogueForceFault | Power
Airline fails - valve closes | DigitalForceLowFault | IsOpen
Blocked Filter Line 2 | AnalogueForceFault | FilterCondition
Burst Filter Line 2 | AnalogueForceFault | FilterCondition
Burst Filter Line 2 | AnalogueForceFault | FilterLimit
0.027m³/s
20.09°C
28.64°C
20°C
0.027m³/s
28.64°C
0.004m³/s
0.004m³/s
0.003m³/s
Tank Advanced
Fill = 51.24 %
Level = 1.54 m
Water = 0.77 m^3
OfChange = -0.01 m^3/s
Variable Tracker
Fill = 0.5142
Diverter
Start Random Sequence
SetPoint Fill 62.5%
SetPoint Temperature 30 Degrees
DataCollection
Linked Fault

Adding Basic Assertions

Monitor values to see if they go out of range

Assign severity levels, None – Low – Medium - High

Log test results in the Analysis window and CSV output



MessageLog

Model	Category	Message
0.00	Console	Faults: 7, Assertions: 2

Filter...

Add Aspect...

Analogue Too High Assertion

Analogue Too High Assertion Unsafe Temperature

Limit	85
Aspect Name	Unsafe Temperature
Enabled	☑
Active	☐
Property Name	LiquidTemperature

Extra Features

Exclusive Limit	☐
Occurred	☐
Severity	High

Plant P Ax_Liquid Property Sensor Temperature Sensor

Liquid Property Sensor

Property	Temperature
Sensor Level	0 m
Value	20

Rockwell Automation

Adding Assertions

Assertion Aspects, same as Fault Aspects

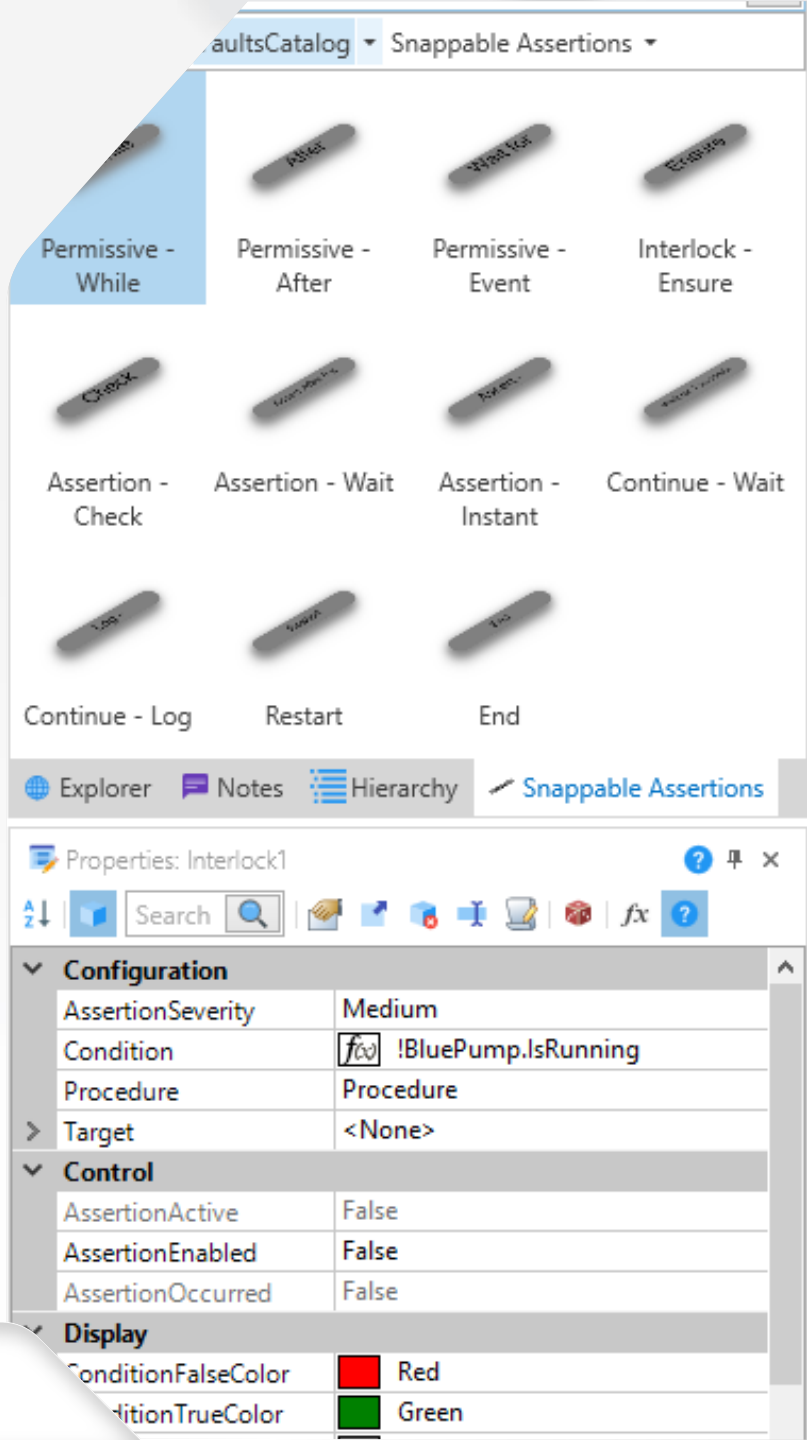
Advanced Assertions with QuickLogic Widgets

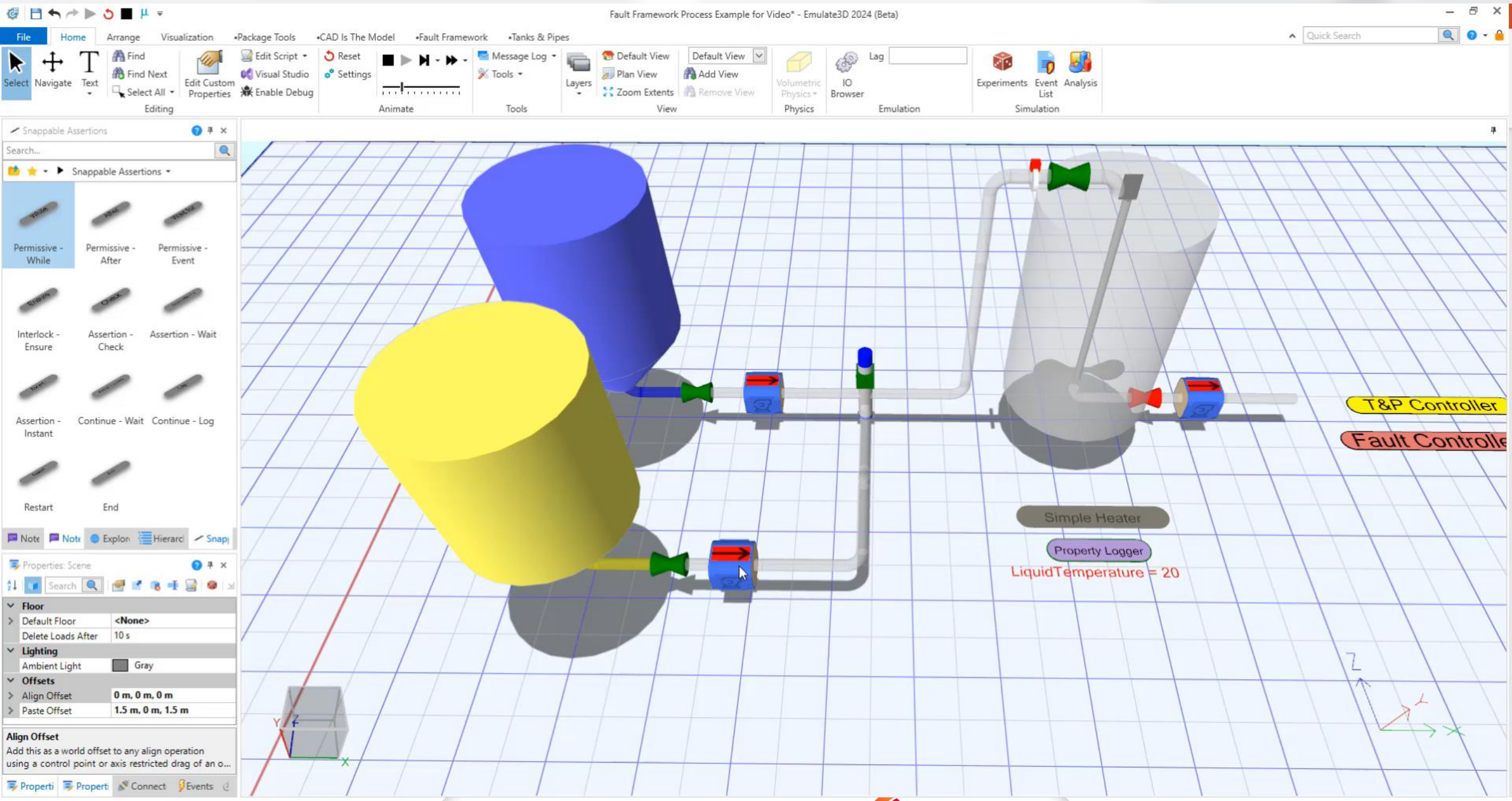
Snappable Assertions can be chained together

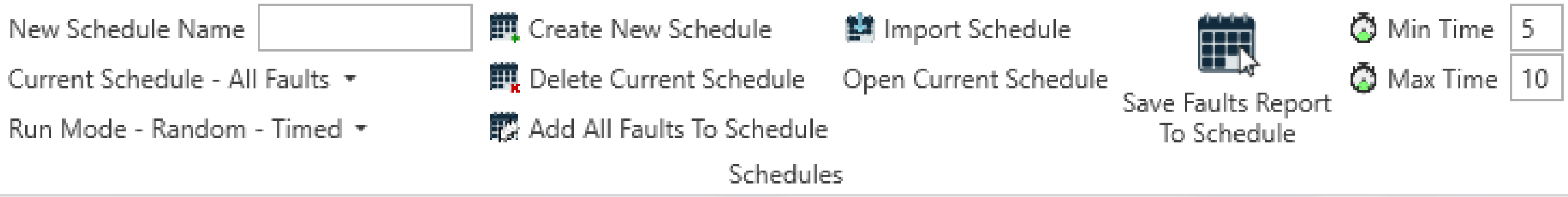
Permissives, waits, and restarts enable other assertions

Interlocks and Assertions monitor values

Choose colours and severity levels




Fault Framework Process Example for Video* - Emulate3D 2024 (Beta)
File
Home
Arrange
Visualization
•Package Tools
•CAD Is The Model
•Fault Framework
•Tanks & Pipes
Quick Search
Select
Navigate
Text
Find
Find Next
Select All
Editing
Edit Custom Properties
Edit Script
Visual Studio
Enable Debug
Reset
Settings
Animate
Message Log
Tools
Layers
Default View
Plan View
Zoom Extents
Add View
Remove View
View
Volumetric Physics
Physics
IO Browser
Lag
Emulation
Experiments
Event List
Analysis
Simulation
Snappable Assertions
Search...
Permissive - While
Permissive - After
Permissive - Event
Interlock - Ensure
Assertion - Check
Assertion - Wait
Assertion - Instant
Continue - Wait
Continue - Log
Restart
End
Properties: Scene
Floor
Default Floor
<None>
Delete Loads After
10 s
Lighting
Ambient Light
Gray
Offsets
Align Offset
0 m, 0 m, 0 m
Paste Offset
1.5 m, 0 m, 1.5 m
Align Offset
Add this as a world offset to any align operation using a control point or axis restricted drag of an o...
T&P Controller
Fault Controlle
Simple Heater
Property Logger
LiquidTemperature = 20



Schedules

Create test schedules which enable and disable faults

Manually run a test and then save it out in one click

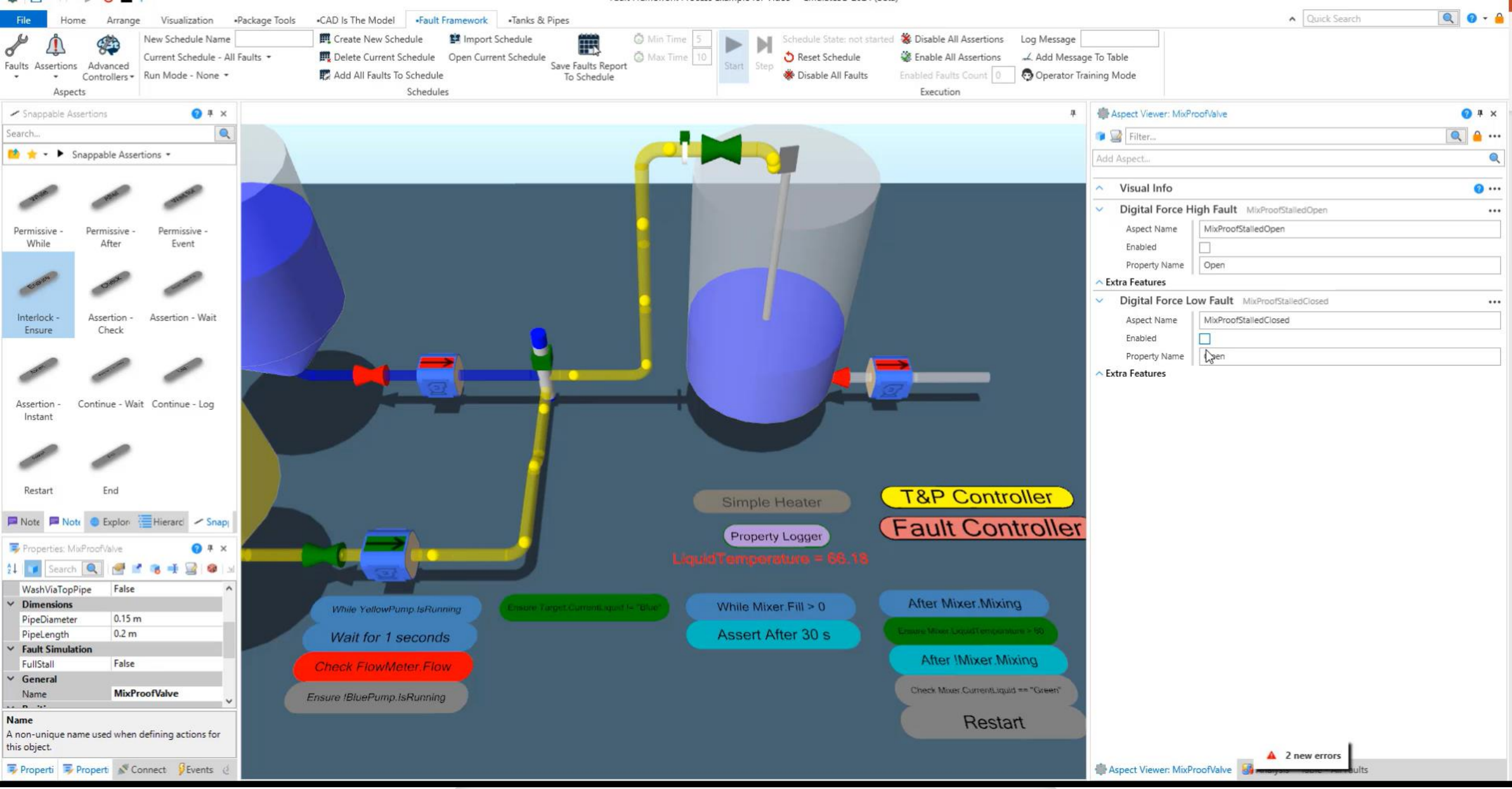
Run the test to a schedule, step through manually, or run randomly

Table - Test1

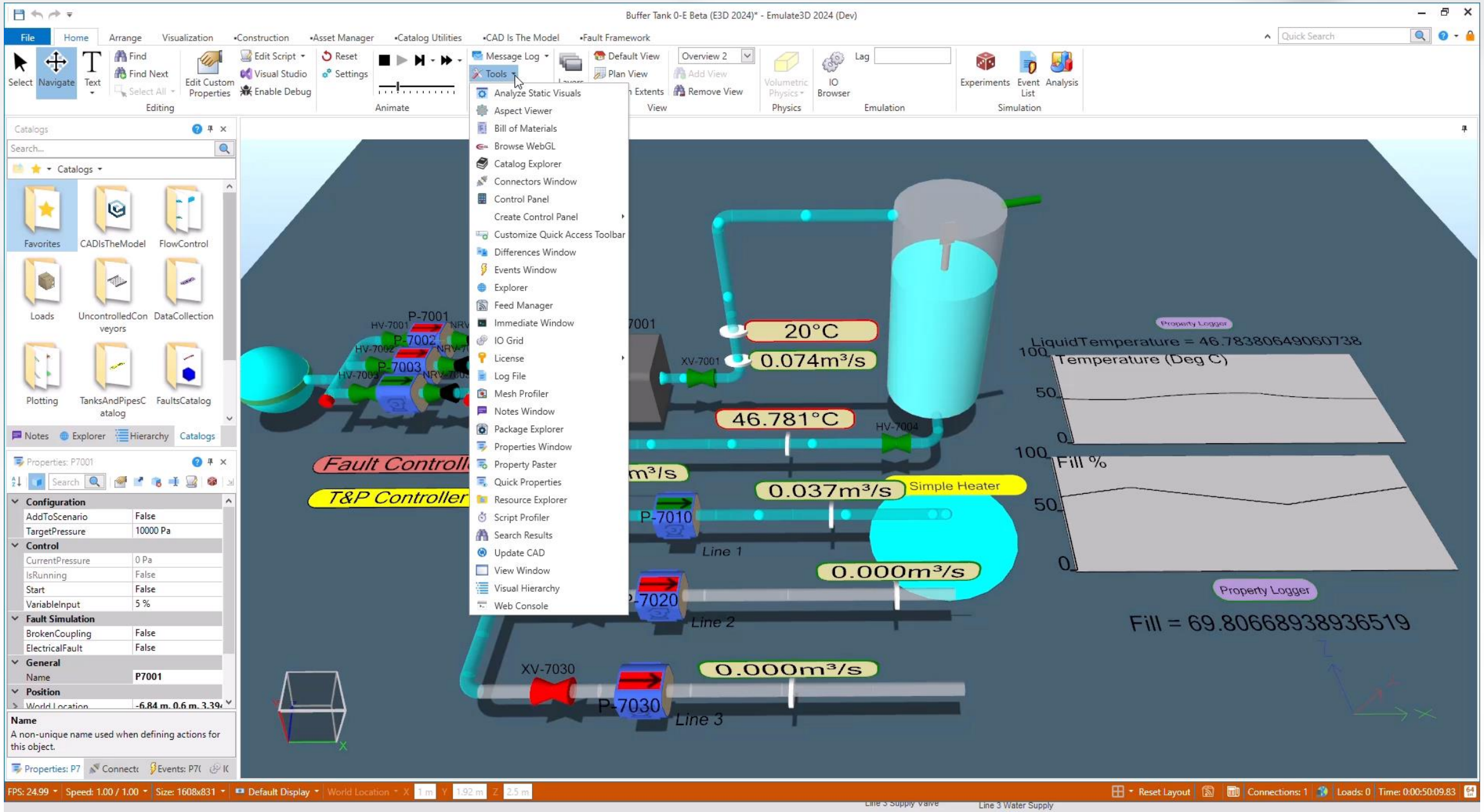
Edit Schema | Edit In Analysis

Drag a column header here to group by that column

	VisualType	FaultType	VisualName	FaultName	PropertyName	ForceValue	EnableTime	DisableTime
1	MixProofValve	DigitalForceHigh	MixProofValve	MixProofStalledOpen	Open	True	1.2520338	5.4112612
2	MixProofValve	DigitalForceLow	MixProofValve	MixProofStalledClosed	Open	False	6.7814875	16.6707762


File
Home
Arrange
Visualization
•Package Tools
•CAD Is The Model
•Fault Framework
•Tanks & Pipes
Quick Search
Faults
Assertions
Advanced Controllers
Aspects
New Schedule Name
Current Schedule - All Faults
Run Mode - None
Create New Schedule
Delete Current Schedule
Add All Faults To Schedule
Import Schedule
Open Current Schedule
Save Faults Report To Schedule
Schedules
Min Time
Max Time
Start
Step
Schedule State: not started
Reset Schedule
Disable All Faults
Disable All Assertions
Enable All Assertions
Enabled Faults Count
Log Message
Add Message To Table
Operator Training Mode
Execution
Snappable Assertions
Search...
Permissive - While
Permissive - After
Permissive - Event
Interlock - Ensure
Assertion - Check
Assertion - Wait
Assertion - Instant
Continue - Wait
Continue - Log
Restart
End
Properties: MixProofValve
WashViaTopPipe
False
Dimensions
PipeDiameter
0.15 m
PipeLength
0.2 m
Fault Simulation
FullStall
False
General
Name
MixProofValve
Name
A non-unique name used when defining actions for this object.
Simple Heater
Property Logger
LiquidTemperature = 66.18
T&P Controller
Fault Controller
While YellowPump.IsRunning
Wait for 1 seconds
Check FlowMeter.Flow
Ensure !BluePump.IsRunning
Ensure Target.CurrentLiquid != "Blue"
While Mixer.Fill > 0
Assert After 30 s
After Mixer.Mixing
Ensure Mixer.LiquidTemperature > 90
After !Mixer.Mixing
Check Mixer.CurrentLiquid == "Green"
Restart
Aspect Viewer: MixProofValve
Filter...
Add Aspect...
Visual Info
Digital Force High Fault
MixProofStalledOpen
Aspect Name
MixProofStalledOpen
Enabled
Property Name
Open
Extra Features
Digital Force Low Fault
MixProofStalledClosed
Aspect Name
MixProofStalledClosed
Enabled
Property Name
Extra Features
2 new errors

Operator Training Examples



Sawtooth Example* - Emulate3D 2024 (Beta)

File | Home | Arrange | Visualization | •Package Tools | •CAD Is The Model | •Tanks & Pipes | •Fault Framework

Quick Search

Select | Navigate | Text | Find | Find Next | Select All | Edit Custom Properties | Edit Script | Visual Studio | Enable Debug | Reset | Settings | Message Log | Tools | Layers | Default View | Plan View | Zoom Extents | Default View | Add View | Remove View | Volumetric Physics | IO Browser | Lag | Experiments | Event List | Analysis

Editing | Animate | Tools | View | Physics | Emulation | Simulation

Snappable Assertions*

Search...

Snappable Assertions

Permissive - While | Permissive - After | Permissive - Event

Interlock - Ensure | Assertion - Check | Assertion - Wait

Assertion - Instant | Continue - Wait | Continue - Log

Nc | Nc | Expl | Hiera | Snappable As

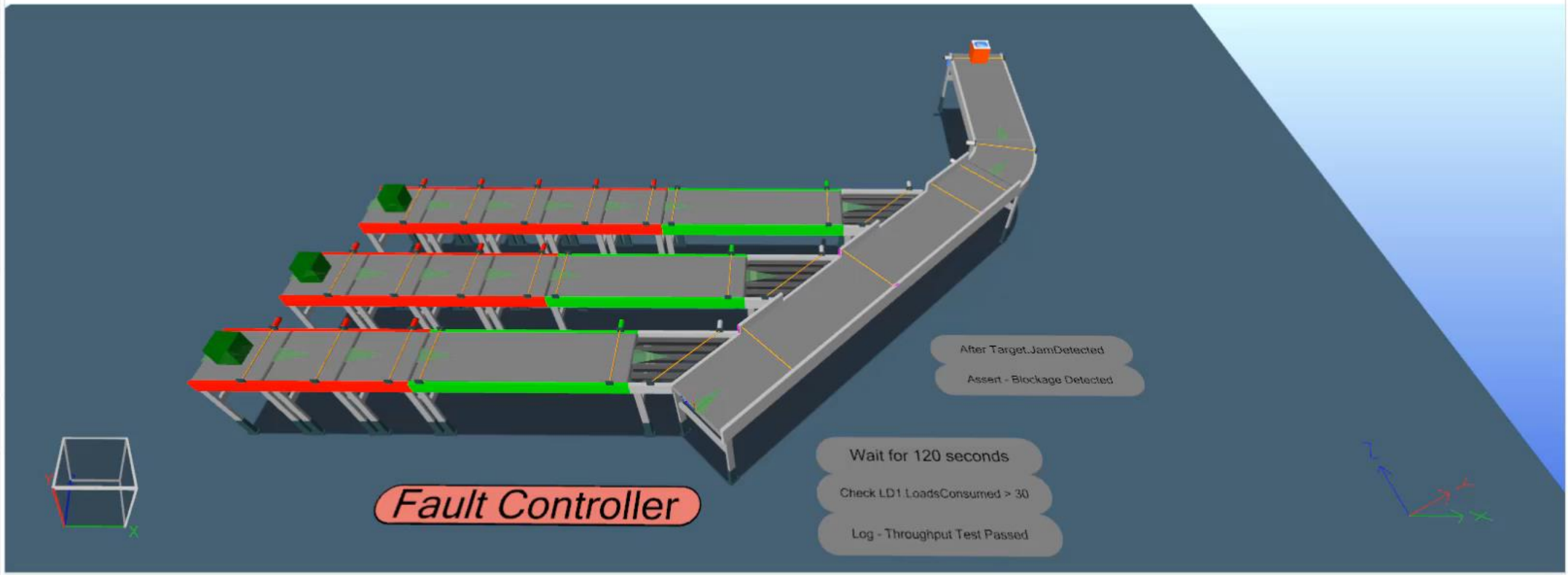
Properties: SB6

Search

Config: Appearance	
ColorCodeSideProfile	True
Dimensions	Custom
IsNarrowBelt	False
Config: Control	
ControlMode	None
DisableProtocol	False
Dimensions	
ConveyorHeight	0.83 m
Length	4.0869 m
Width	0.616 m
General	
Name	SB6
Type	Transport Belt Conveyor
Motor	

Name
A non-unique name used when defining actions for this object.

Properti | Properti | Connect | Events



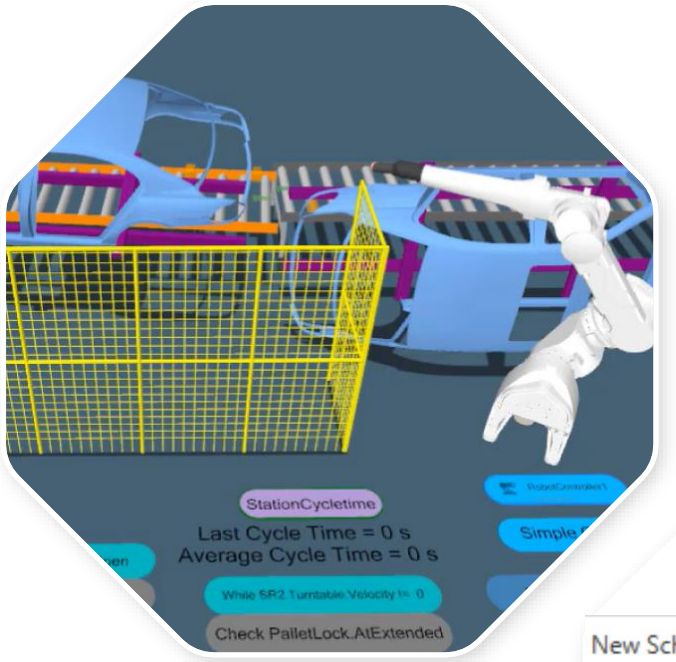
Experiments

Run Selected | Run Selected In Parallel | New | Add Experiment Property | Delete | Options | Cancel

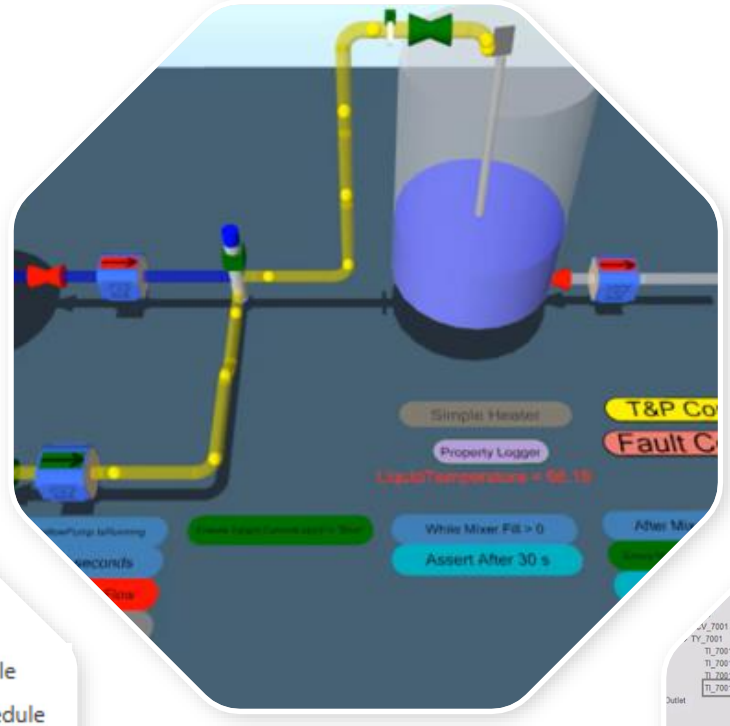
	Run	Experiment	Fixed Time	Start Time	Run Duration	Reset	Status	FaultController.C
	☑	1	☑	00:00:00	00:02:10	☑	Complete	Test1
	☑	2	☑	00:00:00	00:02:10	☑	Complete	Test2
	☑	3	☑	00:00:00	00:02:10	☑	Complete	Test3
	☑	4	☑	00:00:00	00:02:10	☑	Complete	Test4
▶	☑	5	☑	00:00:00	00:02:10	☑	Complete	Test5

FPS: 25.01 | Speed: 1.00 / 1.00 | Size: 1610x586 | Default Display | World Location | X 2.822 m | Y 0.83 m | Z -2.351 m | Reset Layout | Loads: 0 | Time: 0:00:00:00.00

Fault Framework

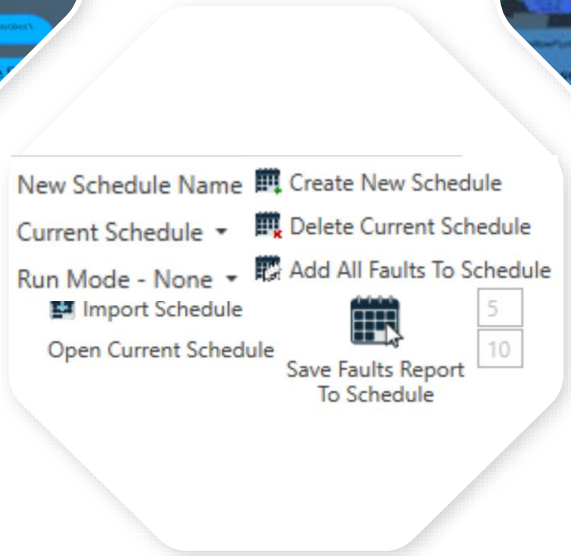


Add Faults to Any Model

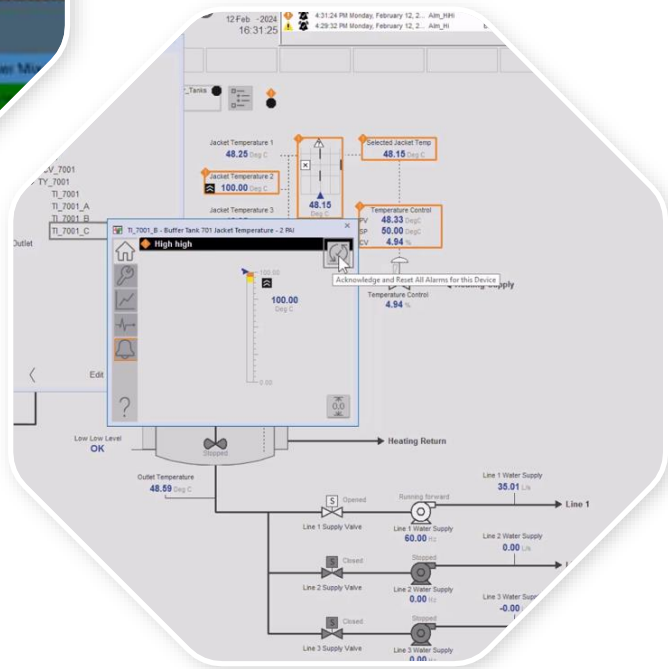


Create Operator Training Scenarios

Record Regression Tests



Verify Model Behaviour



THANK YOU!
Any Question?

Rockwell Automation

expanding human possibility®

www.rockwellautomation.com