



Demonstration of INTO-CPS Capabilities

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THE UNIVERSITY of York



AGROINTELLI





Tutorial Schedule

- 09:00 – 10:00: Introduction to INTO-CPS (PGL)
- 10:00 – 10:30: Coffee break
- 10:30 – 11:30: Introduction to VDM (JF)
- 11:30 – 12:30: Introduction to 20-sim (KP)
- 12:30 – 13:30: Lunch
- 13:30 – 14:30: Industrial results using INTO-CPS (PGL)
- 14:30 – 15:30: Demonstration of INTO-CPS Capabilities (KL+KP)
- 15:30 – 16:00: Coffee break (demo of 3D capabilities)
- 16:00 – 17:00: Demonstration of Hands-on Practicals



Overview

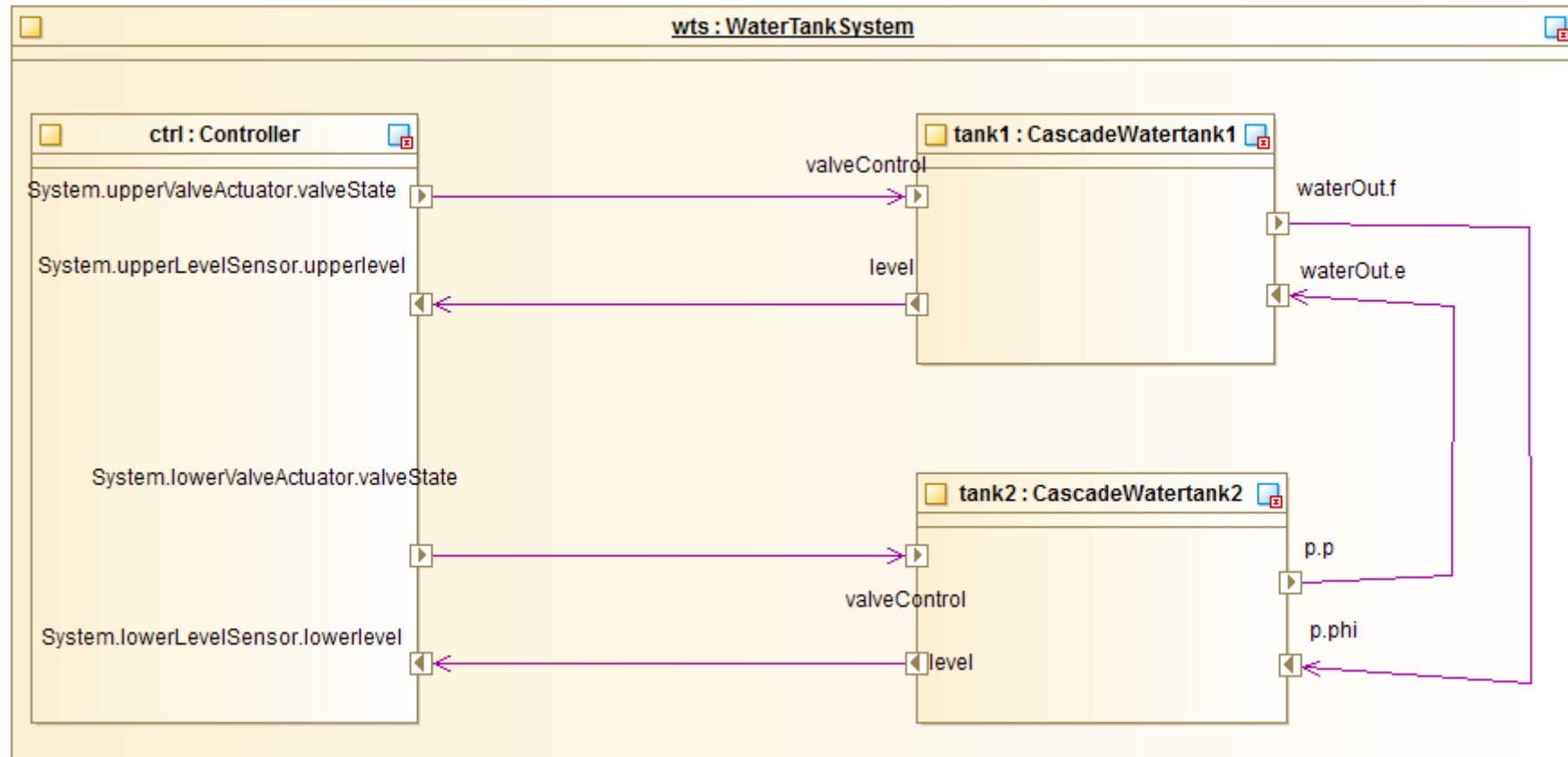
- System Modelling using SysML
- INTO-CPS Application basics
- FMU Generation
 - 20-sim
 - Overture
- Simulation
 - Simulator: COE
 - Graphical Simulations Interface
 - 3D Animation – using Unity
- Design Space Exploration
- Test Automation
- Model Checking

System Modelling using SysML

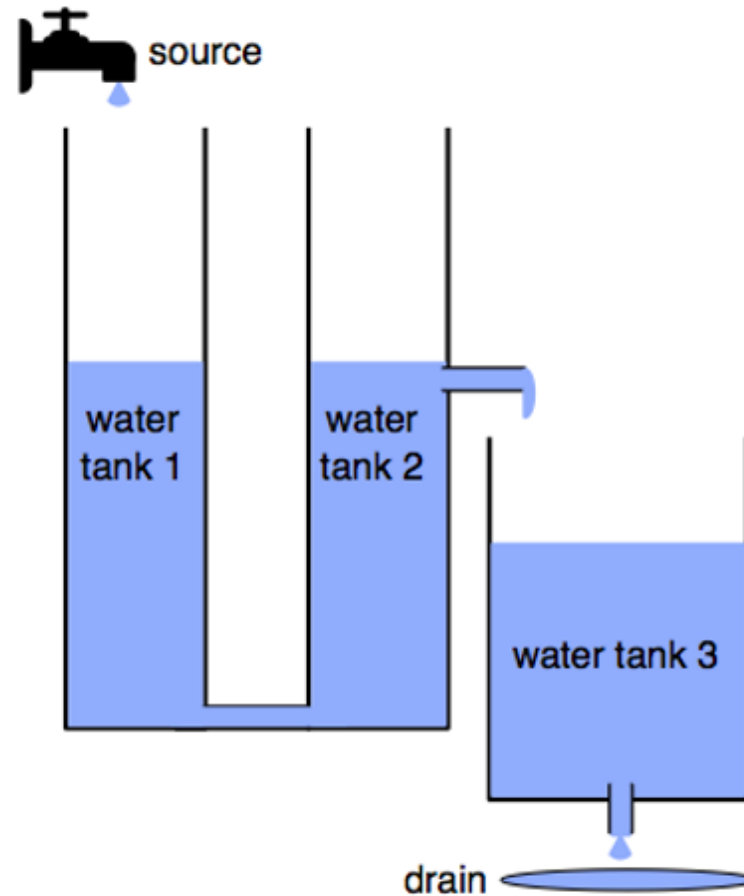


- Custom SysML FMI Profile
- Modelio

SysML: Cascading Watertank

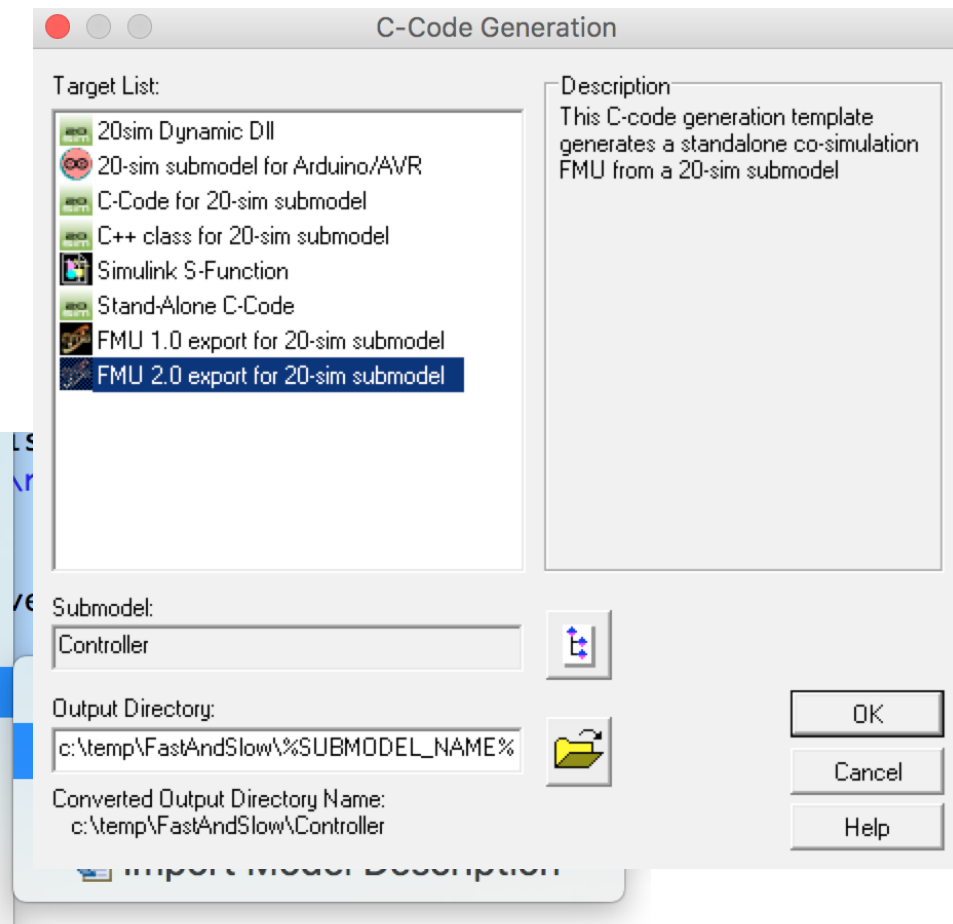
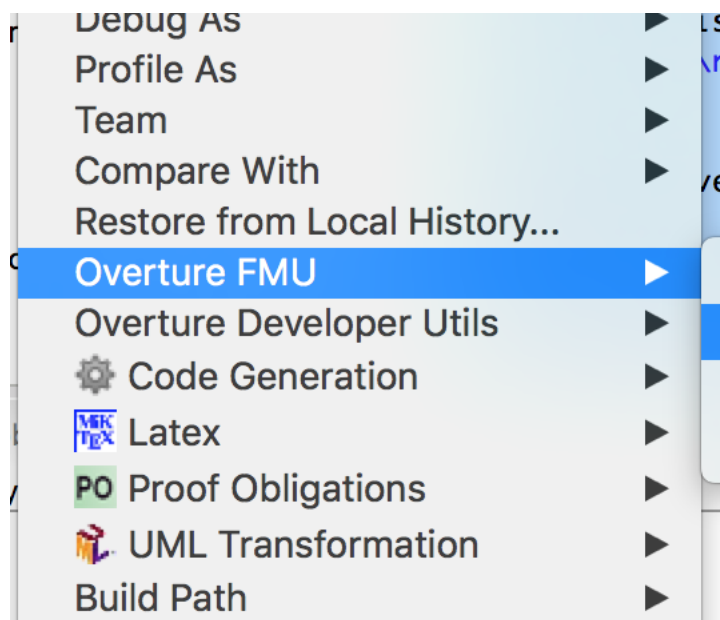


SysML: Cascading Watertank



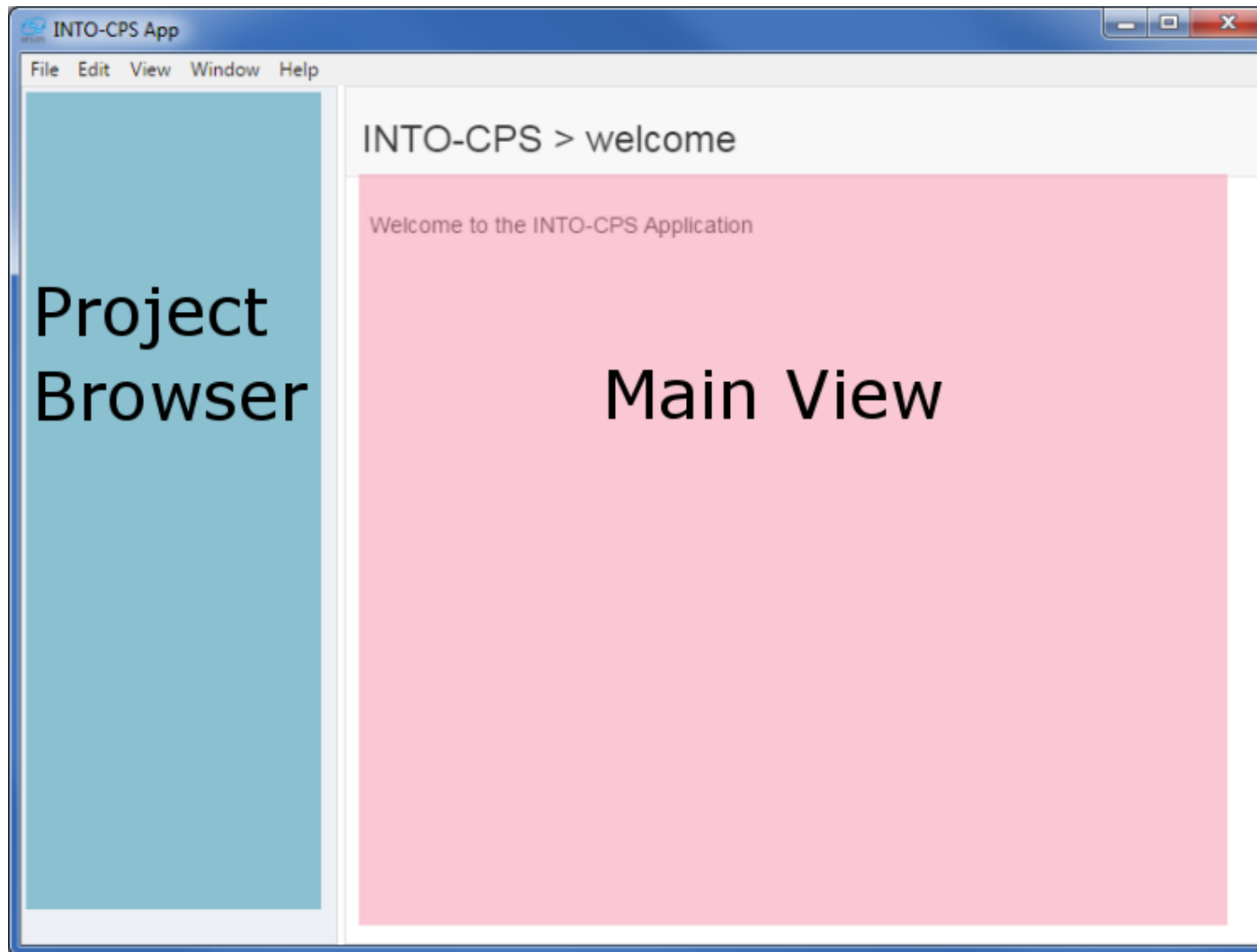
FMU Generation

- Overture
- 20-sim
- Open Modelica



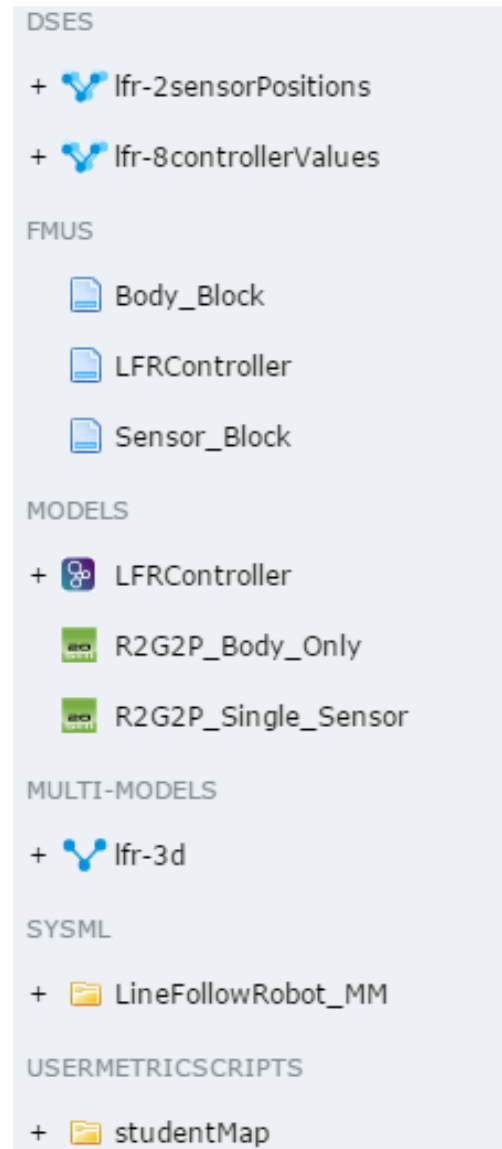


The INTO-CPS Application





The Project Browser





FMUs in Multi-Models

bodyFMU

Body_Block.fmu

Supported

FMU instances

FMU

{controllerFMU}
{sensor1FMU}
{sensor2FMU}
{bodyFMU}

Instances

controller

Connections

Output instance

{bodyFMU}.body
{sensor1FMU}.sensor1
{sensor2FMU}.sensor2
{controllerFMU}.controller

Output variable

lf_1_sensor_position_x
lf_1_sensor_position_y
lf_1_sensor_reading

Input instance

{bodyFMU}.body
{sensor1FMU}.sensor1
{sensor2FMU}.sensor2
{controllerFMU}.controller

Input variable

<input checked="" type="checkbox"/> lfLeftVal
<input type="checkbox"/> lfRightVal
<input type="checkbox"/> total_energy_used



Co-simulation Engine

- FMI 2.0 Compliant



CATIA	FMI_1.0	Available (36) ▾	Available (220) ▾	Available (36) ▾	Available (199) ▾	'Environment for Product Design and Innovation, including systems engineering tools based on Modelica, by Dassault Systèmes'
	FMI_2.0	Available (22) ▾	Available (116) ▾	Available (27) ▾	Available (147) ▾	
INTO-CPS Co-simulation Orchestration Engine (COE)	FMI_2.0	<div>✓ Available (323) Darwin64 (19) Linux32 (21) Linux64 (31) Win32 (130) Win64 (122)</div>				'A free standalone FMI co-simulation master implemented in Java with a JSON API. It is developed as part of the INTO-CPS project .'
ControlBuild	FMI_1.0	Available (18) ▾	Available (21) ▾	Available (32)		'Environment for IEC 61131-3 control applications from Dassault Systèmes'
	FMI_2.0	Planned	Available	Available (14)		
Coral	FMI_1.0				Available	'Free and open-source software for distributed co-simulation.'
	FMI_2.0					

- Distribution Support across:
 - Platforms: Darwin, Linux and Windows
 - Architectures: x86 and x64
- Performance:
 - Execute FMUs in parallel
 - Multicore utilization



COE: Master Algorithm

- Fixed Step
- Variable Step
 - Constraints on step size
 - Zero Crossing
 - Bounded Difference
 - Sample Time
 - Get Max Step Size
- Has recovery for Discard
 - `getRealStatus(LastSuccessfulTime)` and rollback
- Simple Stability Algorithm
 - successive substitution

Basic Configuration

Start time	0
End time	30
Algorithm	Variable Step

Initial step size	0.1
Minimum step size	1e-17
Maximum step size	1

Constraints

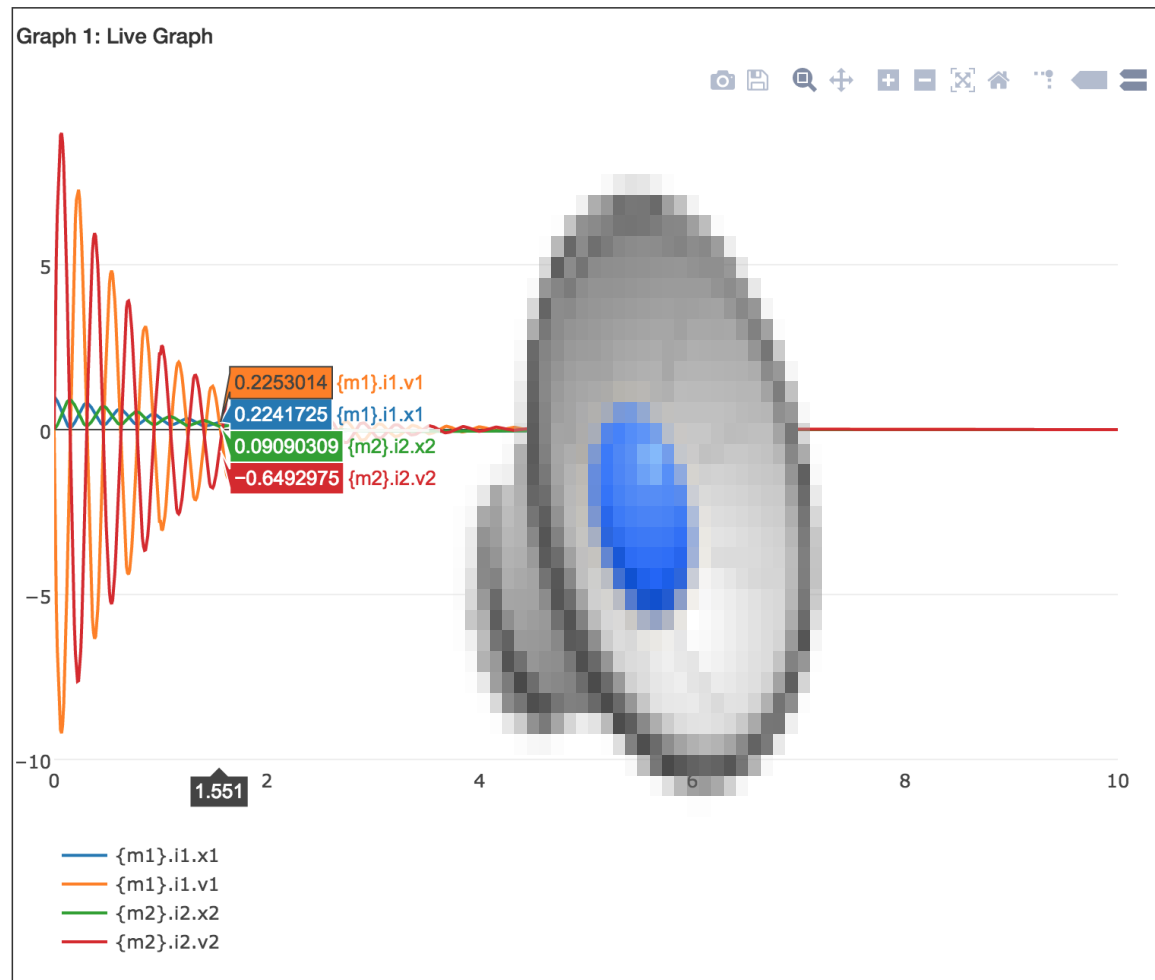
Zero Crossing

ID	max
Ports	{tank}.t.level {control}.c.maxlevel
Order	1
Absolute Tolerance	0.01
Safety	

Zero Crossing

ID	min
Ports	{tank}.t.level {control}.c.minlevel
Order	1
Absolute Tolerance	0.01
Safety	1

COE: Stabilization





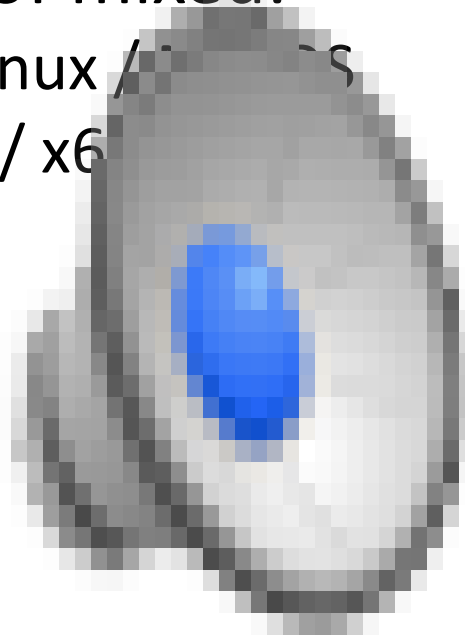
COE: Performance

- Parallel Execution of e.g. FMI setX/getX/doStep
 - Appx. Speed up by 65 %
- One shot mode for cluster deployment
- Distribution across computer architectures
- Hierarchical Simulation



COE: Distribution

- Enable simulation of mixed:
 - Platforms: Win / Linux / ...
 - Architectures: x32 / x64

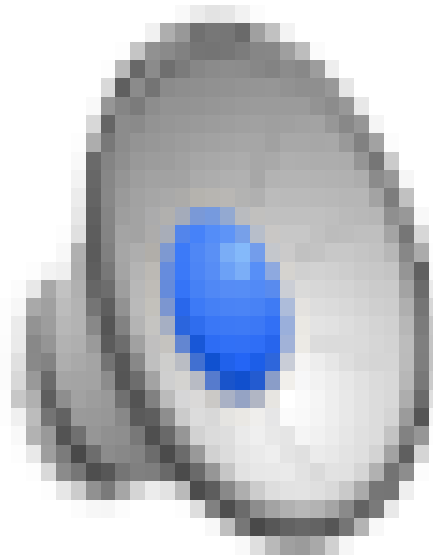




COE: Hierarchical Simulation

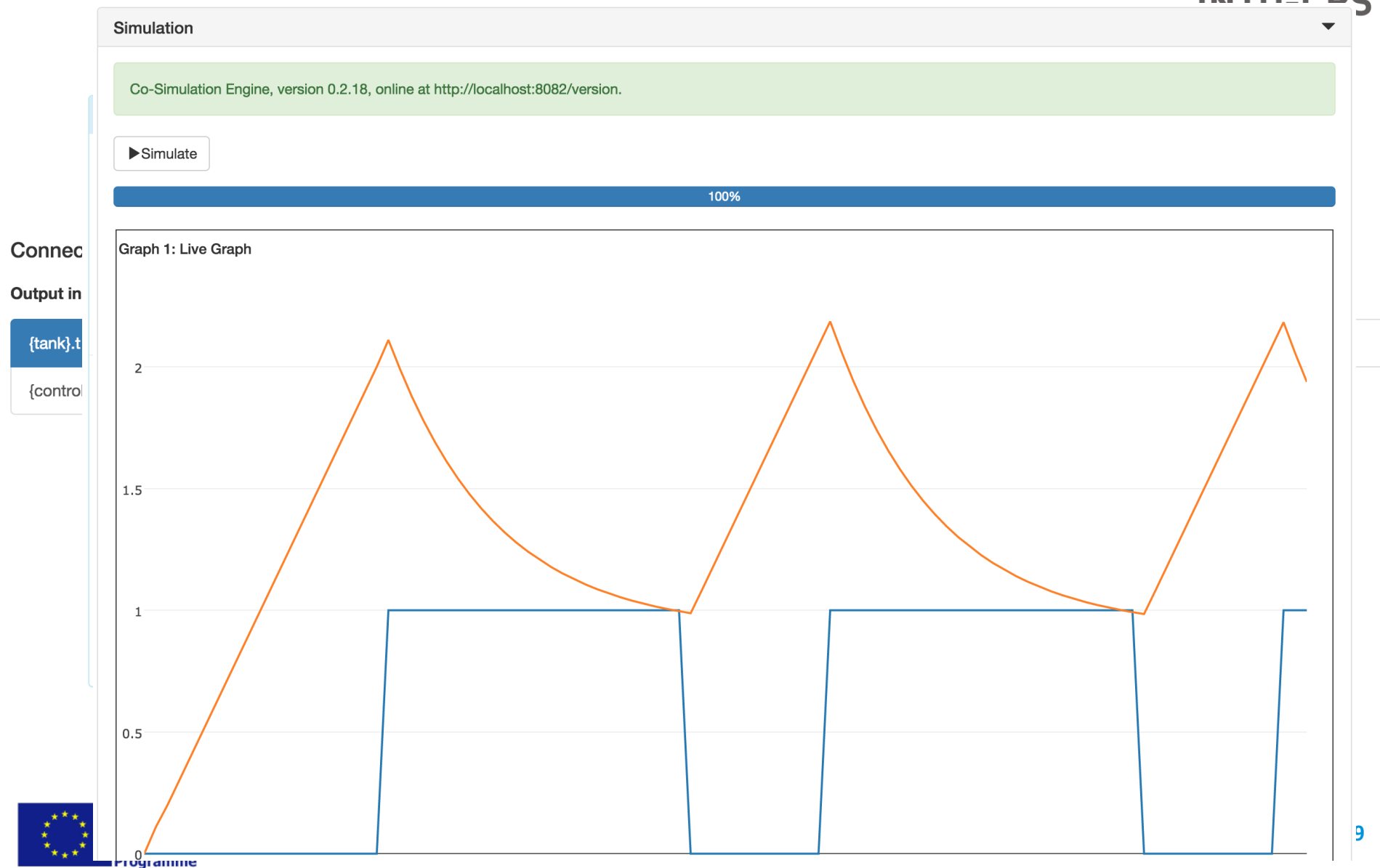
- Enable encapsulation of sub system as an FMU
- Improve performance with multi rate simulations
 - One part of the system requires a smaller step size then the rest of the system

COE: Hierarchical Simulation

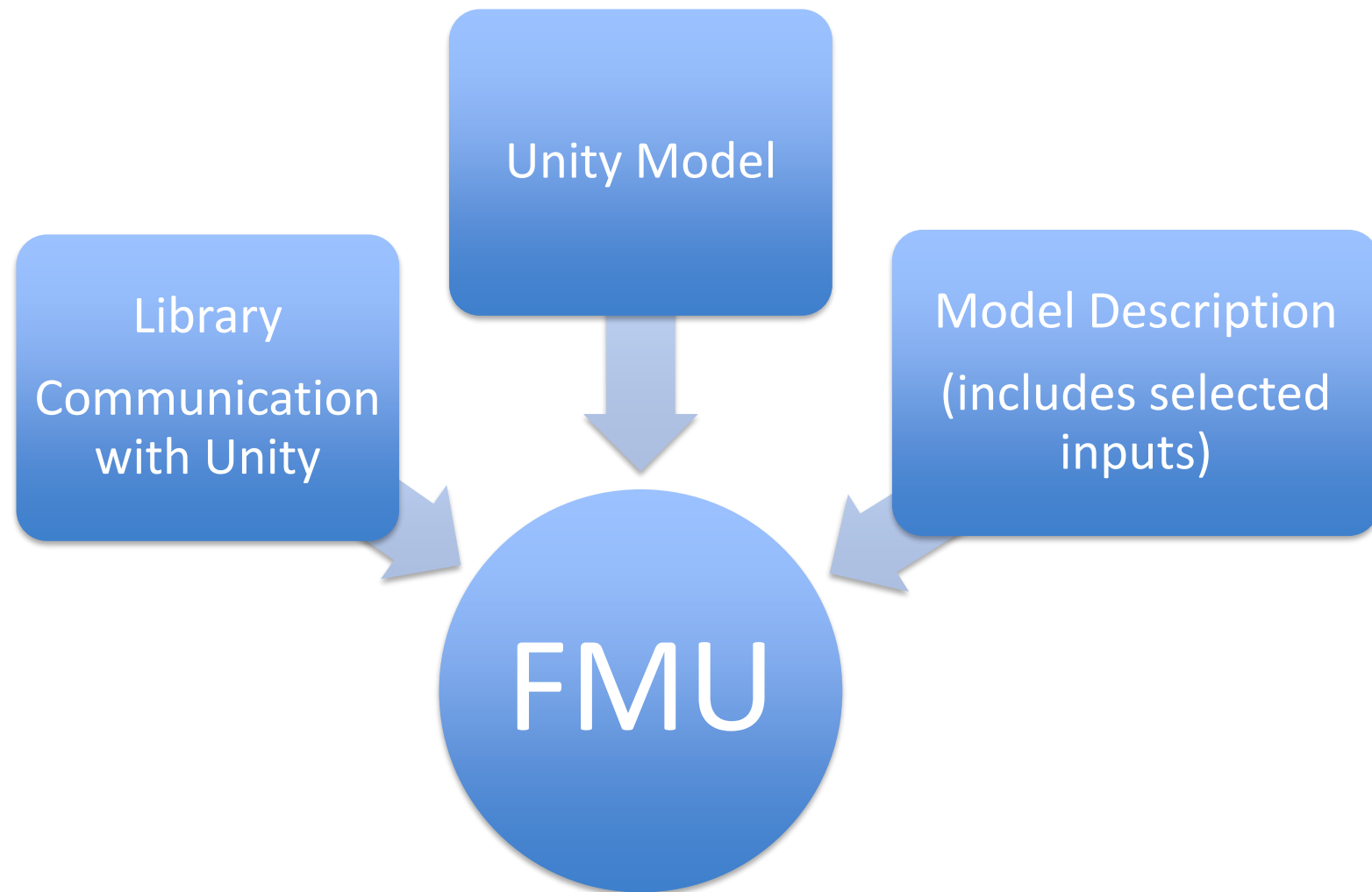




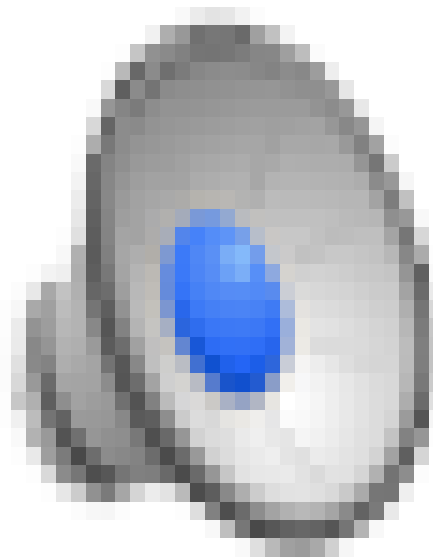
COE: Configurations



COE: 3D Animation – using Unity

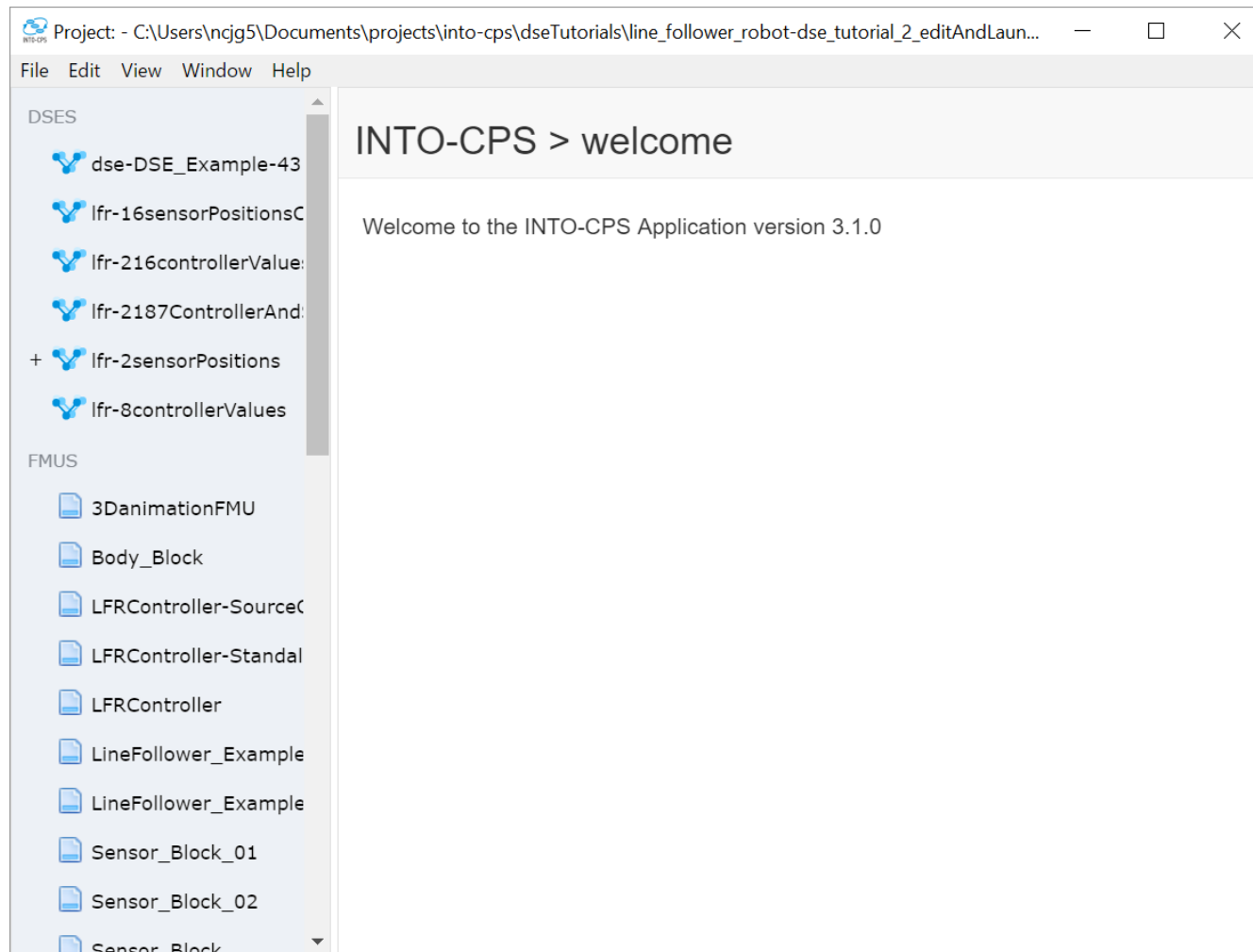


COE: 3D Animation – using Unity

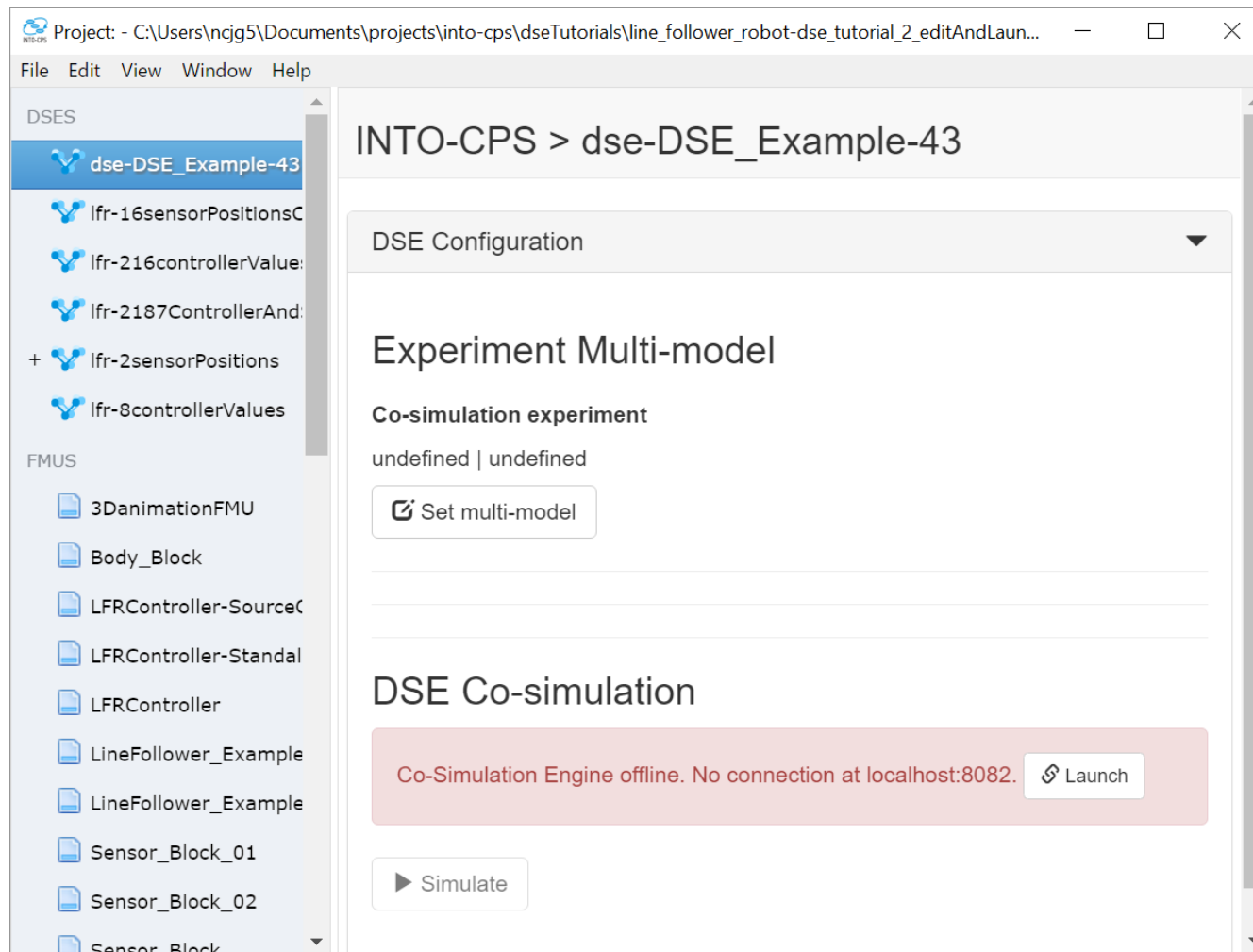




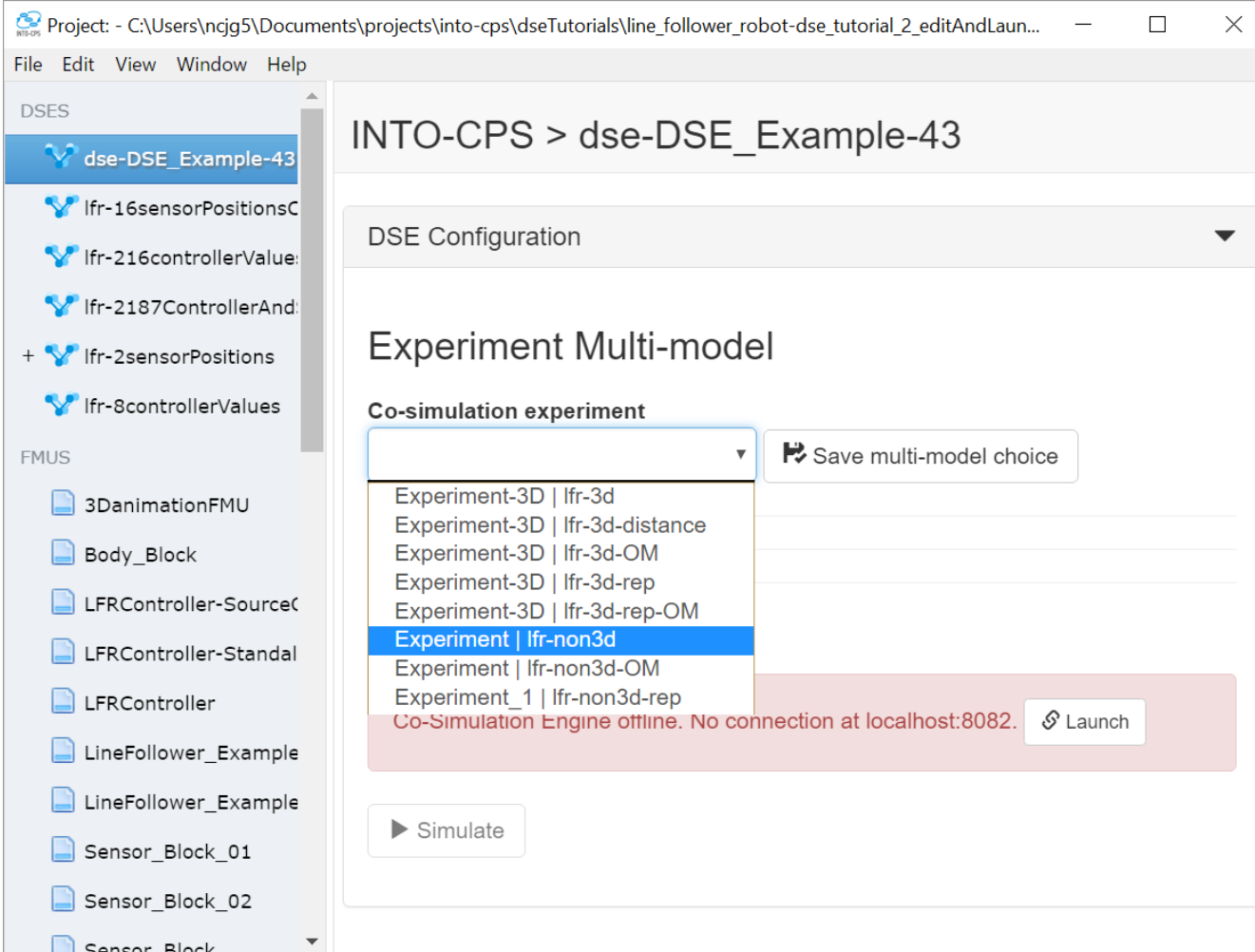
Design Space Exploration



Design Space Exploration



Design Space Exploration



The screenshot displays the INTO-CPS software interface for Design Space Exploration (DSE). The window title is "Project: - C:\Users\ncjg5\Documents\projects\into-cps\dseTutorials\line_follower_robot-dse_tutorial_2_editAndLaun...". The menu bar includes File, Edit, View, Window, and Help.

The left sidebar shows a tree view of the project structure:

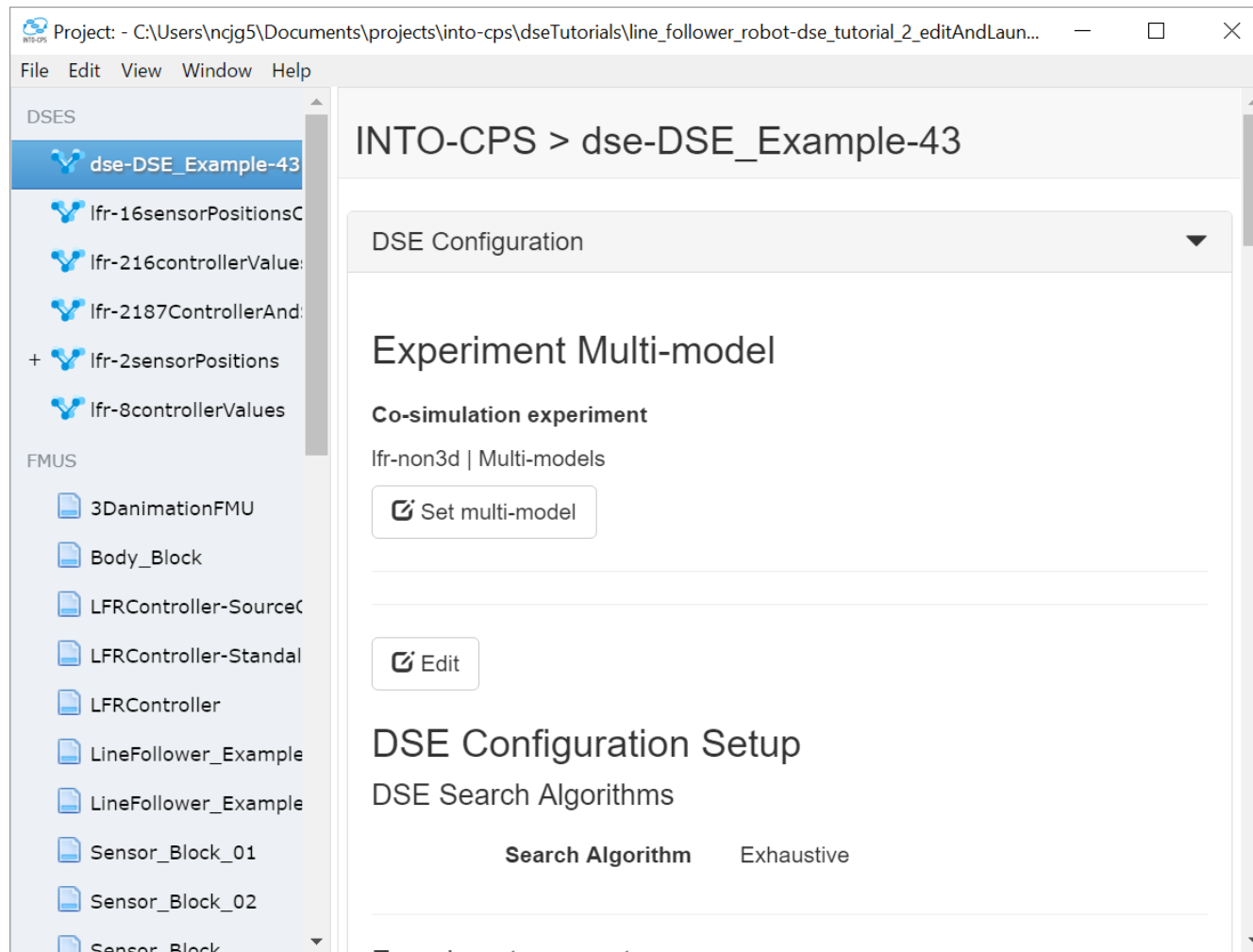
- DSES
 - dse-DSE_Example-43
 - lfr-16sensorPositionsC
 - lfr-216controllerValue
 - lfr-2187ControllerAnd
 - + lfr-2sensorPositions
 - lfr-8controllerValues
- FMUS
 - 3DanimationFMU
 - Body_Block
 - LFRController-SourceC
 - LFRController-Standal
 - LFRController
 - LineFollower_Example
 - LineFollower_Example
 - Sensor_Block_01
 - Sensor_Block_02
 - Sensor_Block

The main area displays the "INTO-CPS > dse-DSE_Example-43" configuration. The "DSE Configuration" section is expanded, showing the "Experiment Multi-model" configuration. Under "Co-simulation experiment", a dropdown menu is open, listing several experiment options:

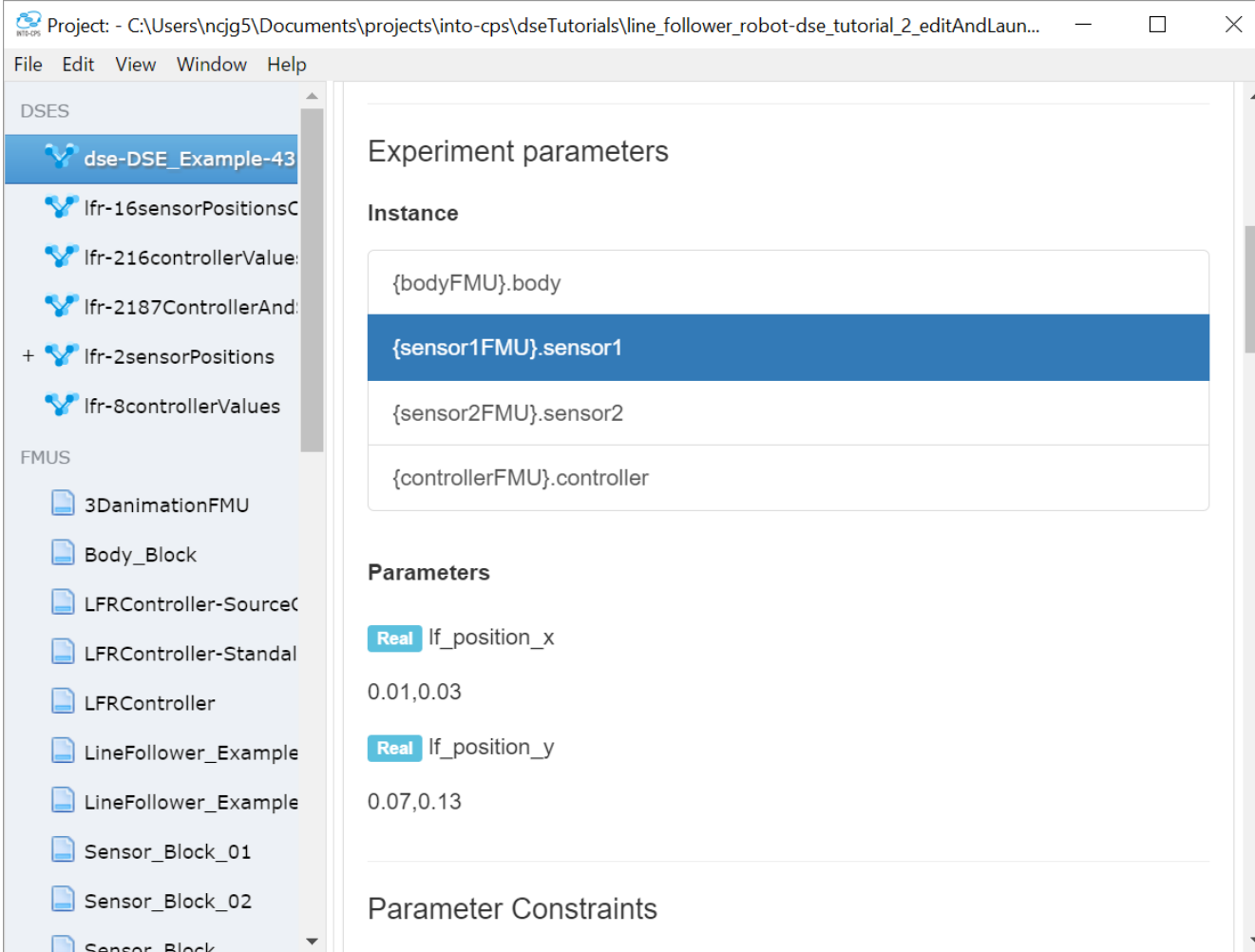
- Experiment-3D | lfr-3d
- Experiment-3D | lfr-3d-distance
- Experiment-3D | lfr-3d-OM
- Experiment-3D | lfr-3d-rep
- Experiment-3D | lfr-3d-rep-OM
- Experiment | lfr-non3d (highlighted)
- Experiment | lfr-non3d-OM
- Experiment_1 | lfr-non3d-rep

Below the dropdown, a red message bar states: "Co-Simulation Engine offline. No connection at localhost:8082." A "Launch" button is visible next to the message. A "Save multi-model choice" button is also present. At the bottom, a "Simulate" button is available.

Design Space Exploration



Design Space Exploration



The screenshot displays the INTO-CPS Design Space Explorer (DSE) interface. The window title is "Project: - C:\Users\ncjg5\Documents\projects\into-cps\dseTutorials\line_follower_robot-dse_tutorial_2_editAndLaun...". The menu bar includes File, Edit, View, Window, and Help.

The left sidebar shows a tree view of the design space:

- DSES**
 - dse-DSE_Example-43 (selected)
 - lfr-16sensorPositionsC
 - lfr-216controllerValue
 - lfr-2187ControllerAnd
 - + lfr-2sensorPositions
 - lfr-8controllerValues
- FMUS**
 - 3DanimationFMU
 - Body_Block
 - LFRController-SourceC
 - LFRController-Standal
 - LFRController
 - LineFollower_Example
 - LineFollower_Example
 - Sensor_Block_01
 - Sensor_Block_02
 - Sensor_Block

The main panel displays the configuration for the selected DSE:

Experiment parameters

Instance

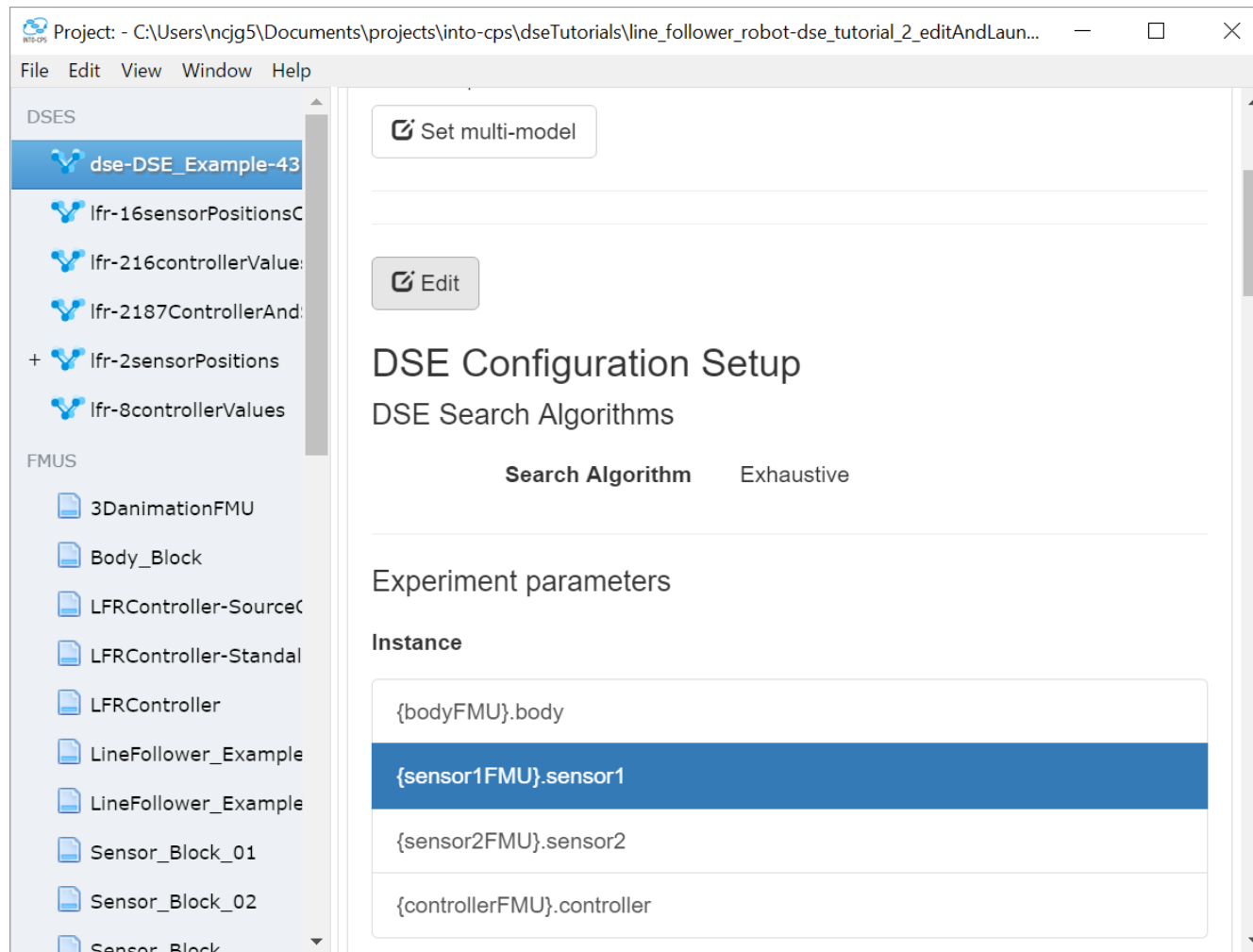
{bodyFMU}.body
{sensor1FMU}.sensor1
{sensor2FMU}.sensor2
{controllerFMU}.controller

Parameters

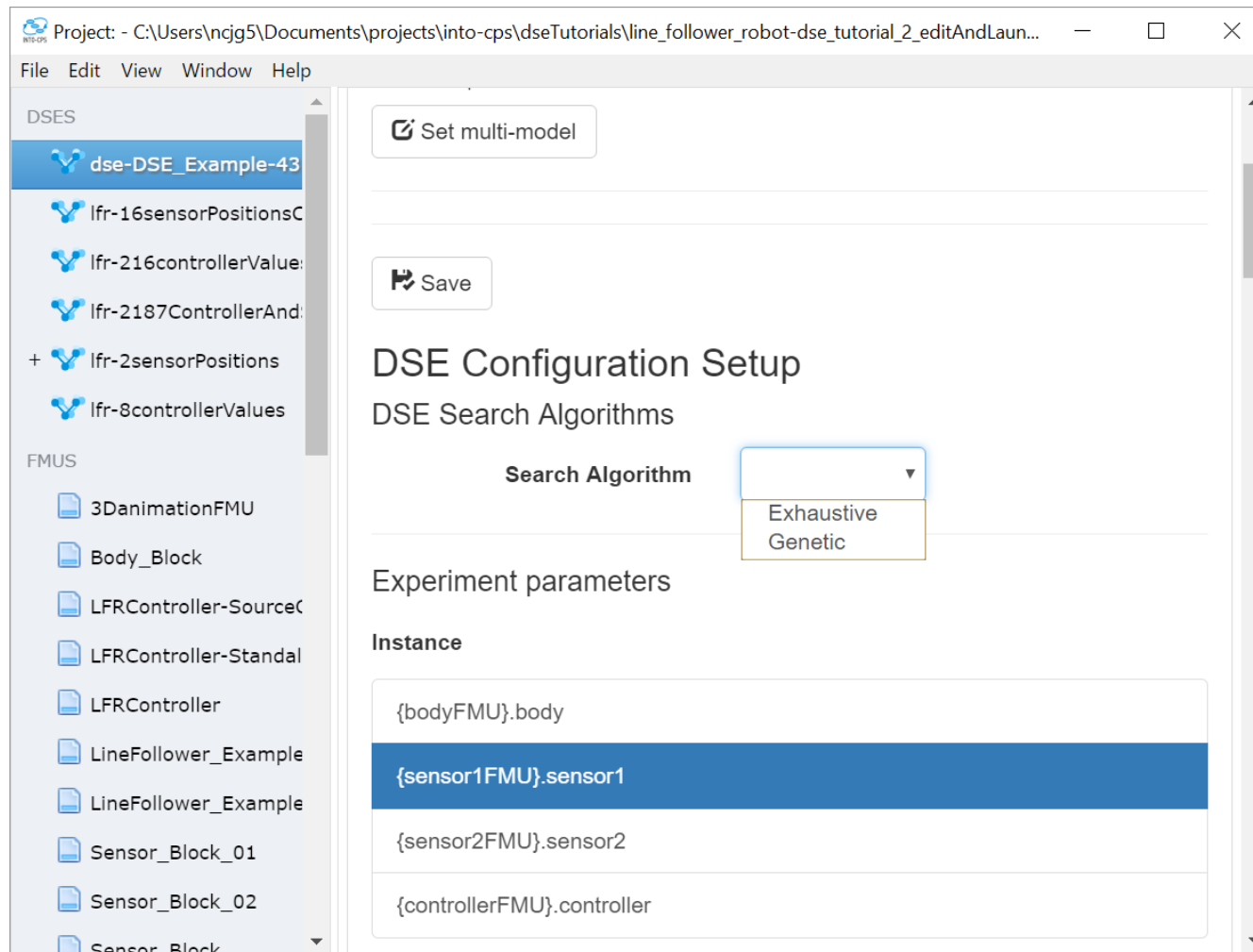
Real If_position_x
0.01,0.03
Real If_position_y
0.07,0.13

Parameter Constraints

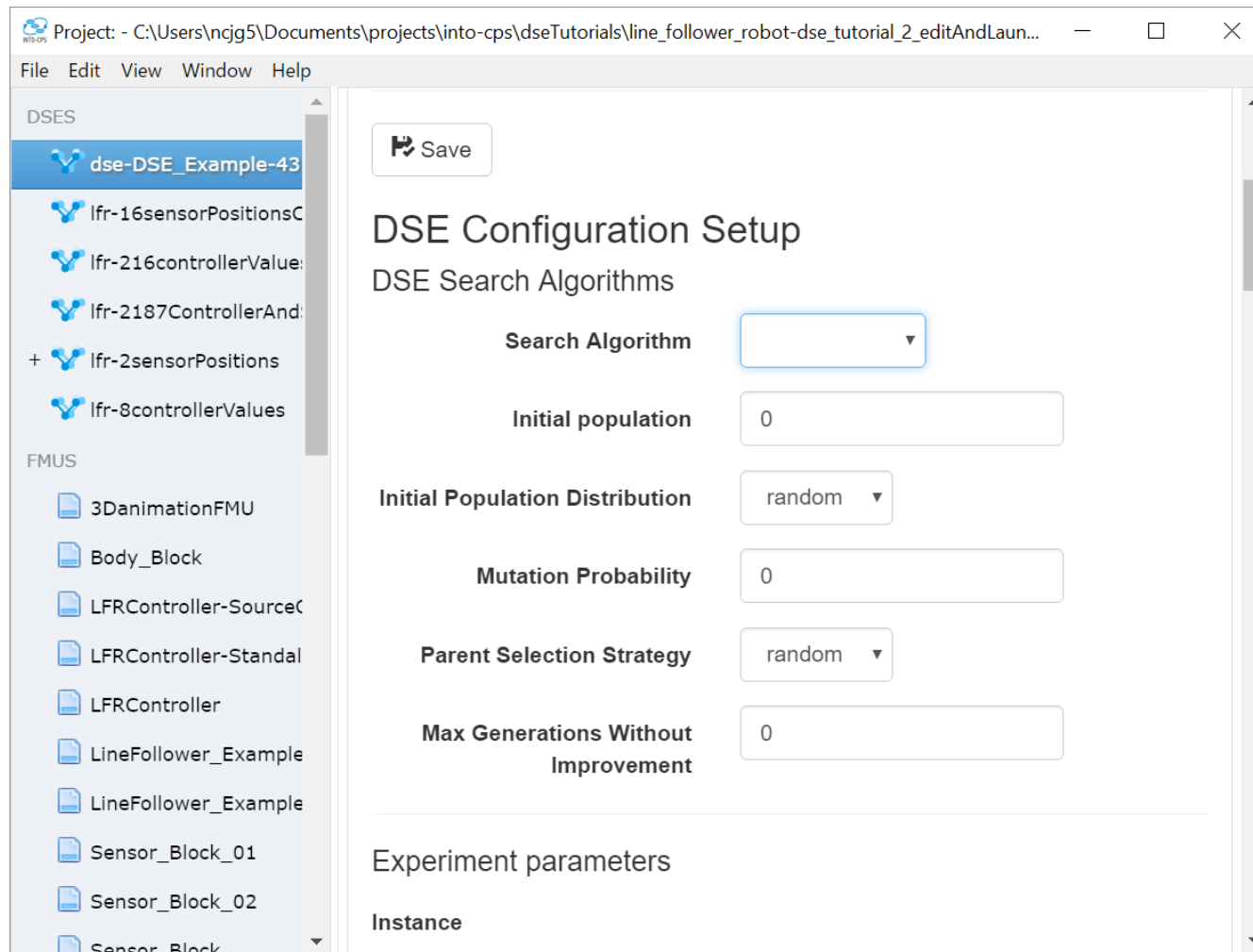
Design Space Exploration



Design Space Exploration

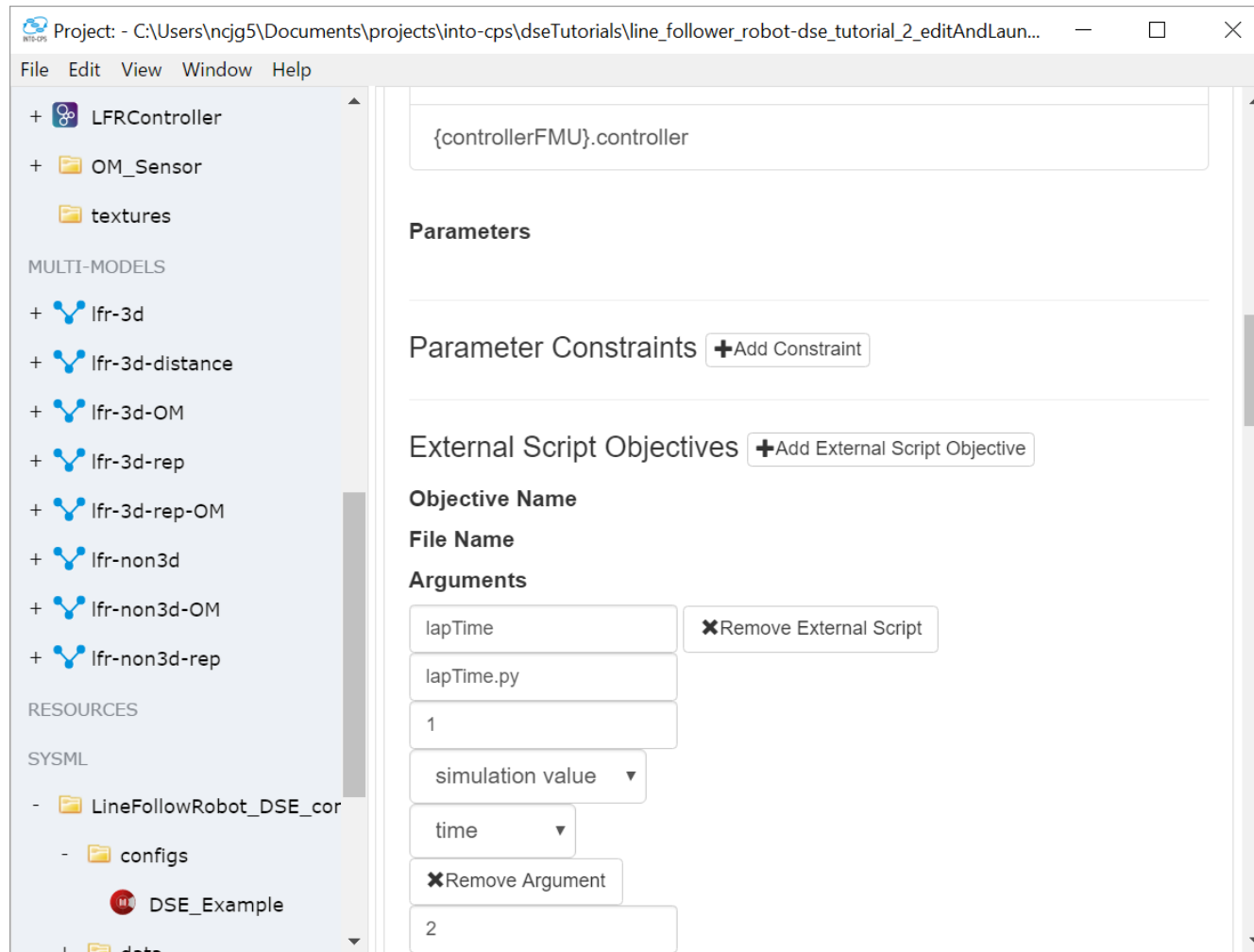


Design Space Exploration

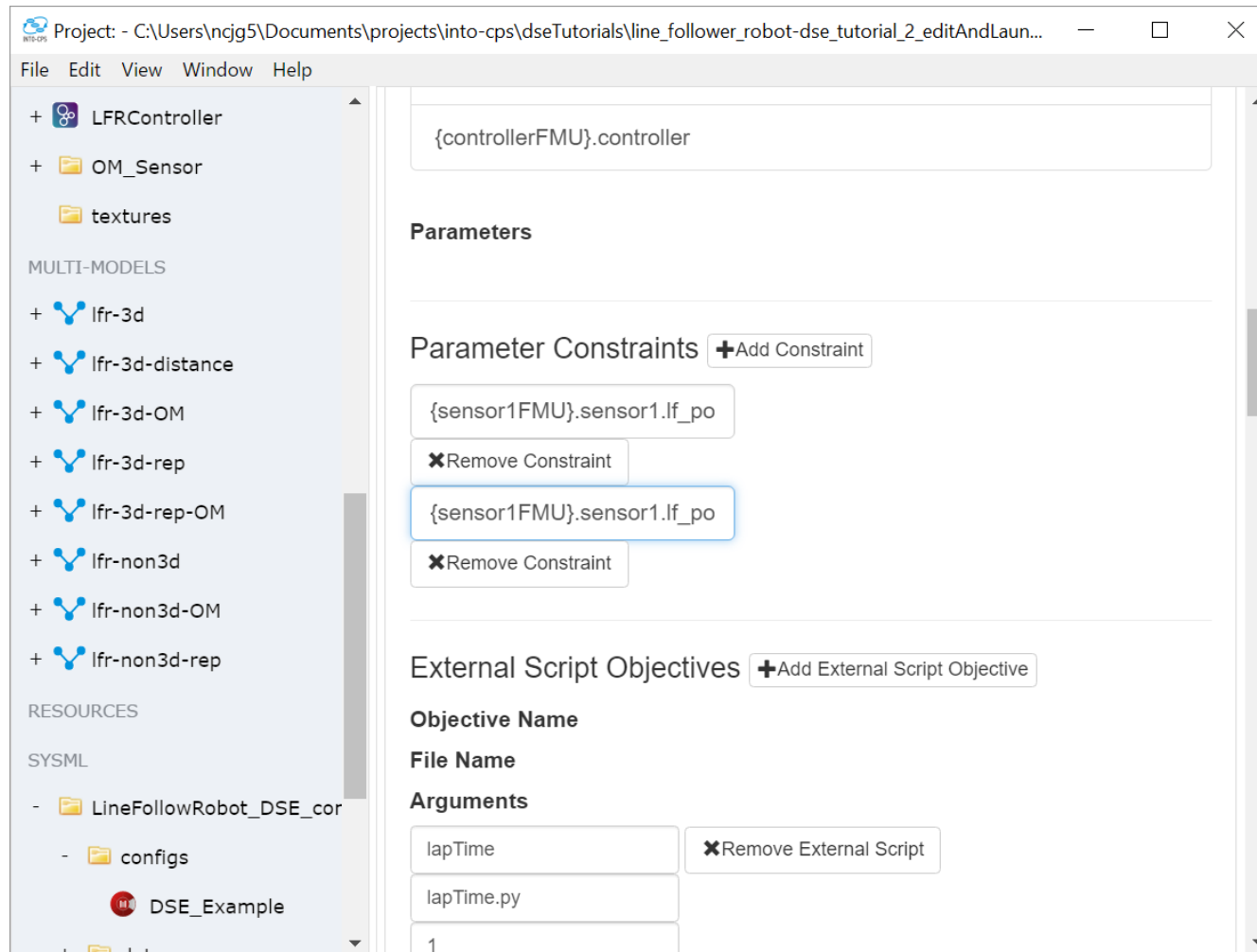




Design Space Exploration

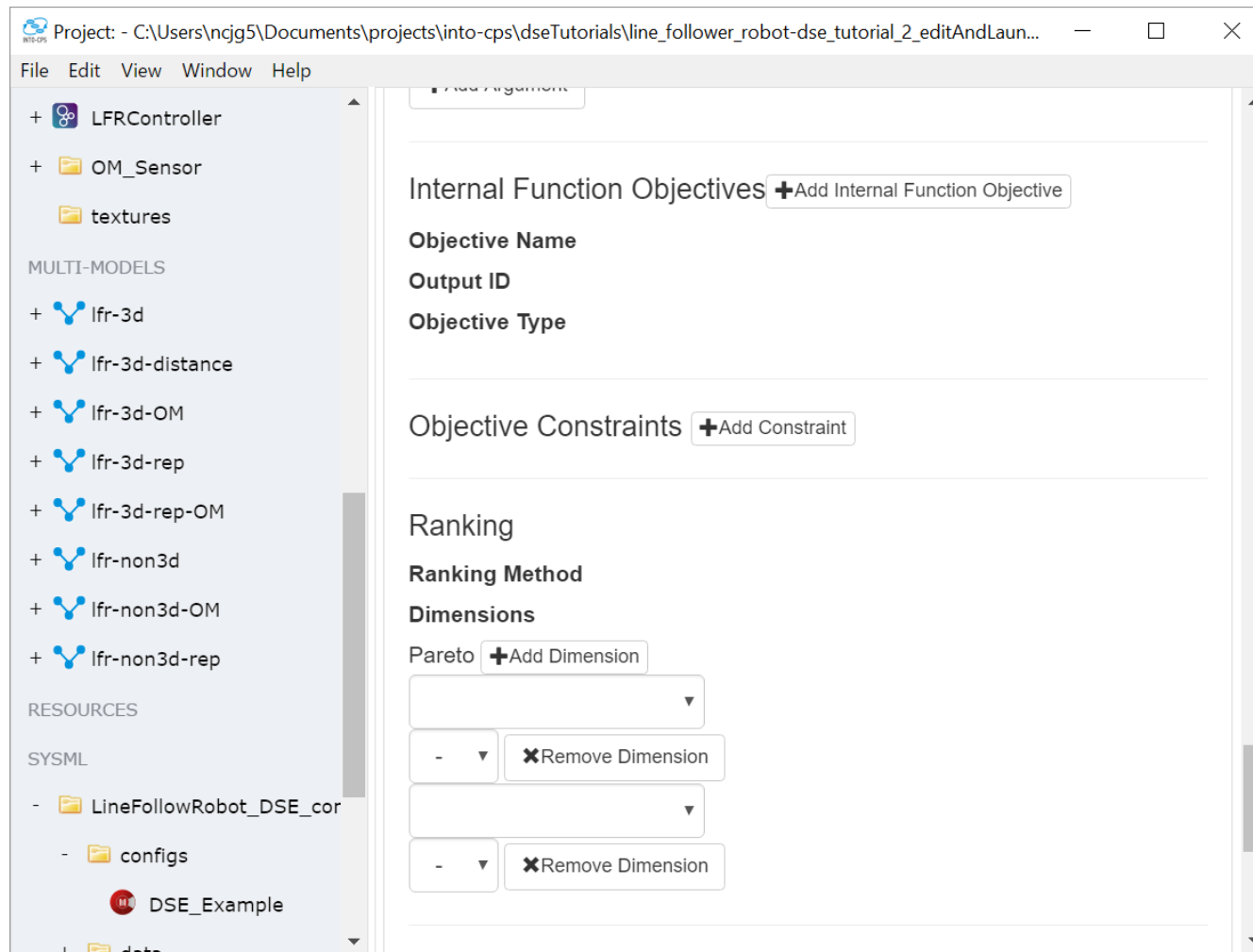


Design Space Exploration

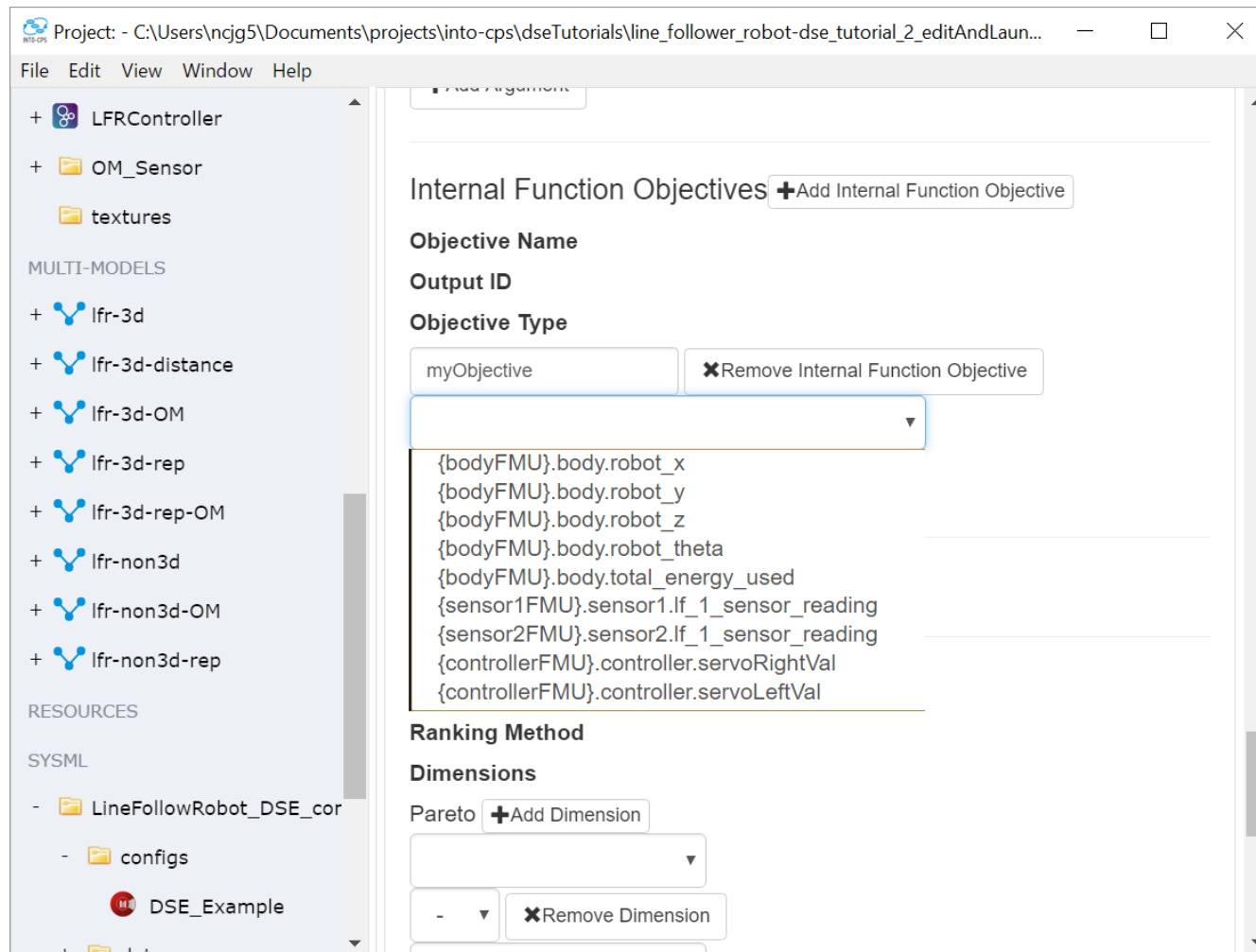




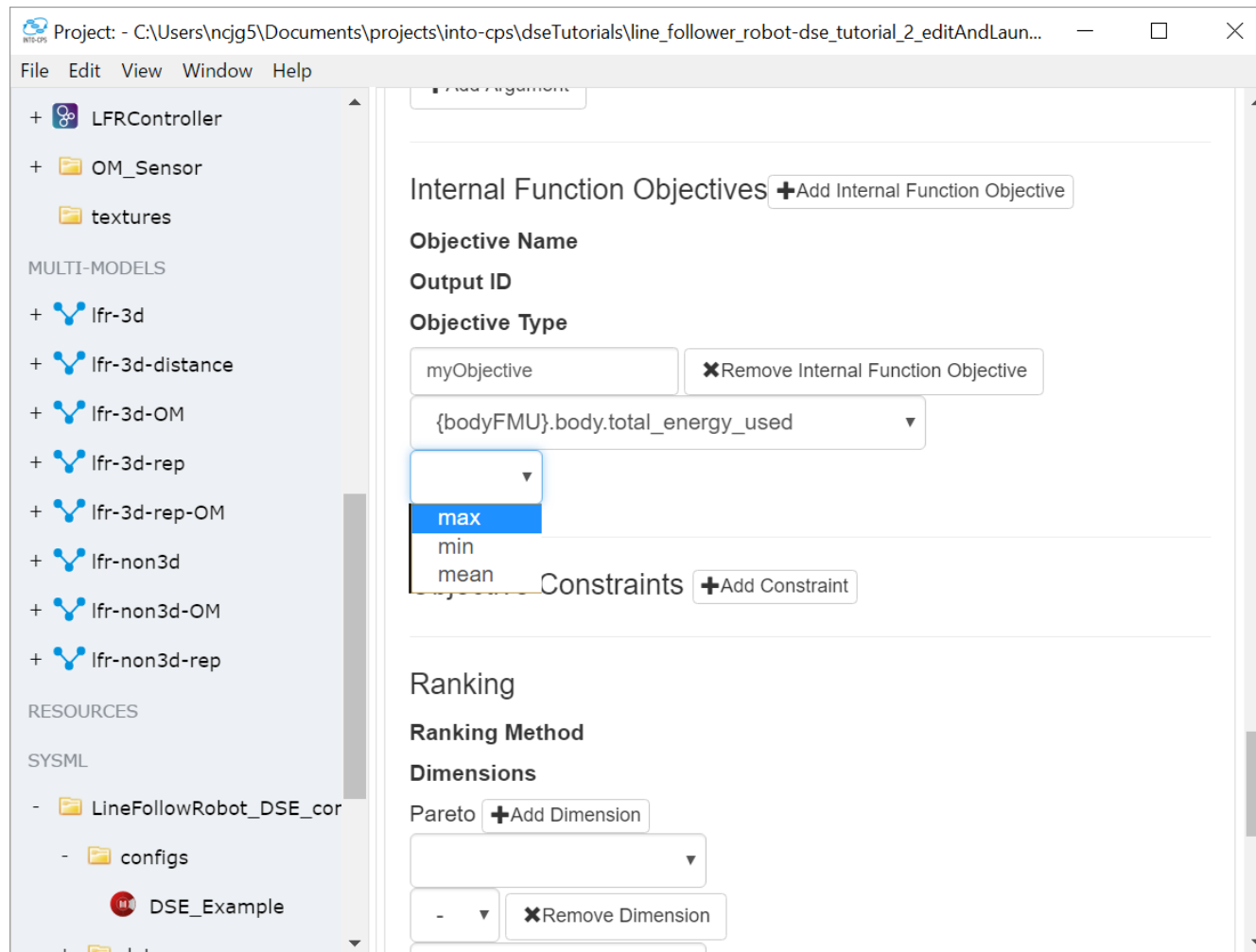
Design Space Exploration



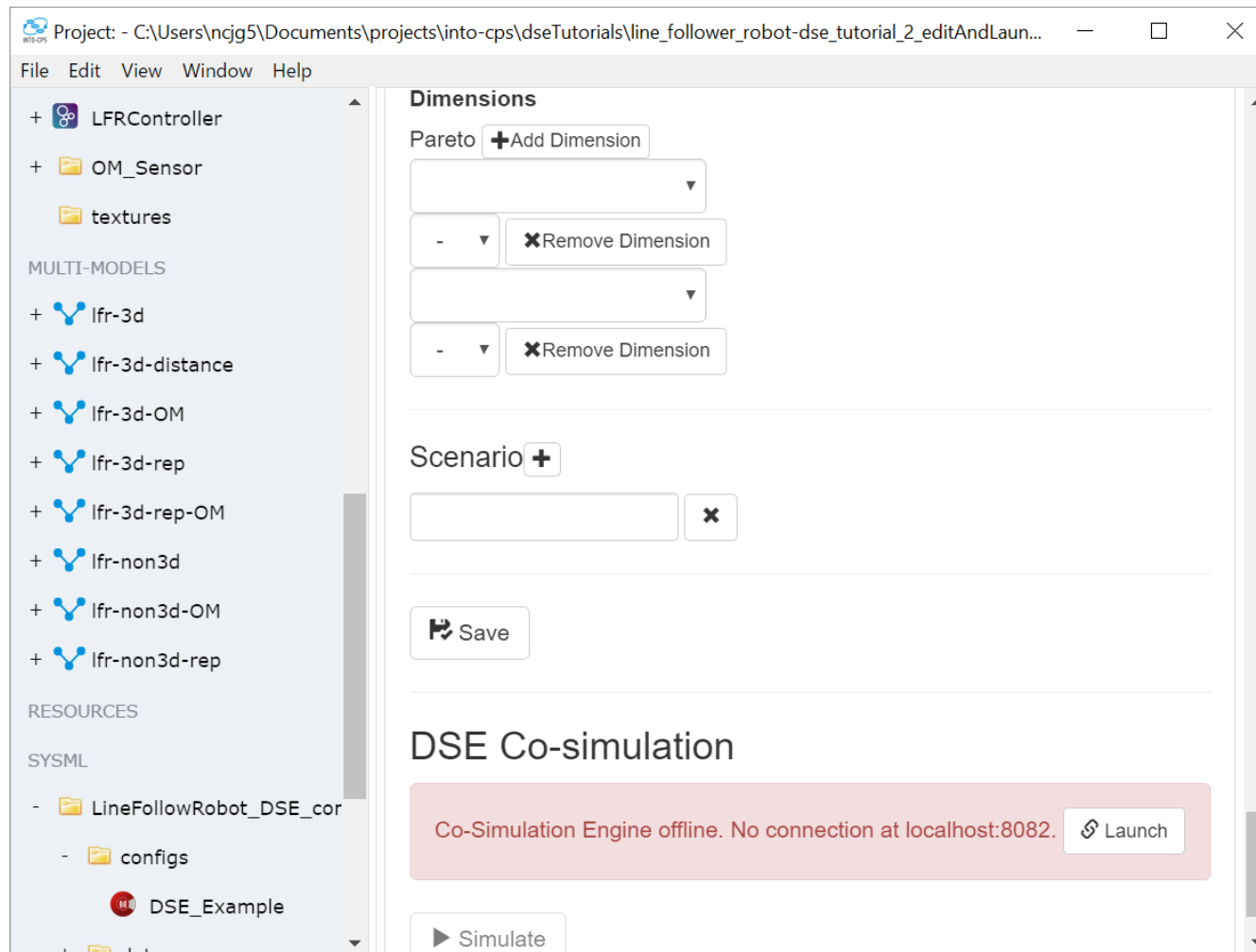
Design Space Exploration



Design Space Exploration

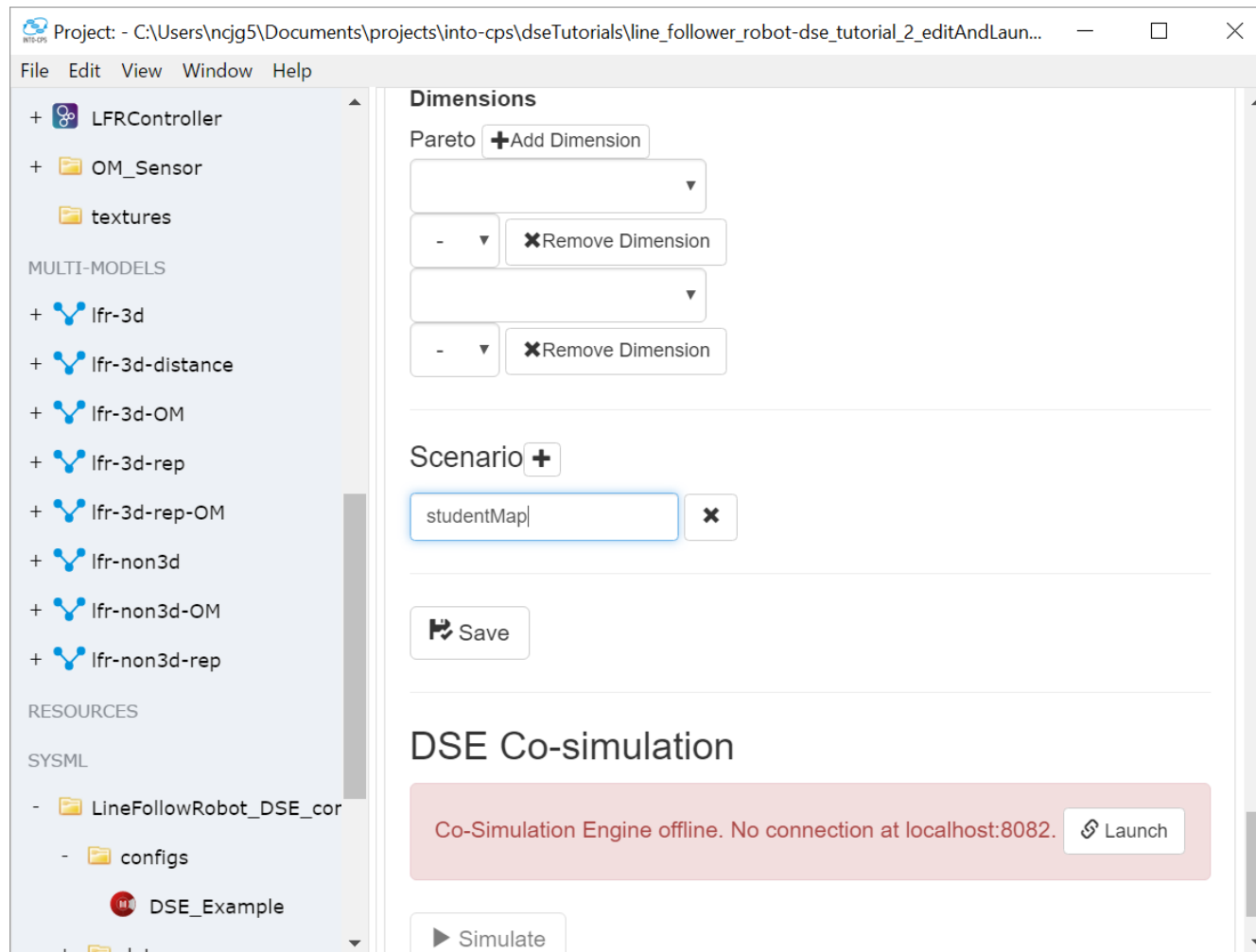


Design Space Exploration



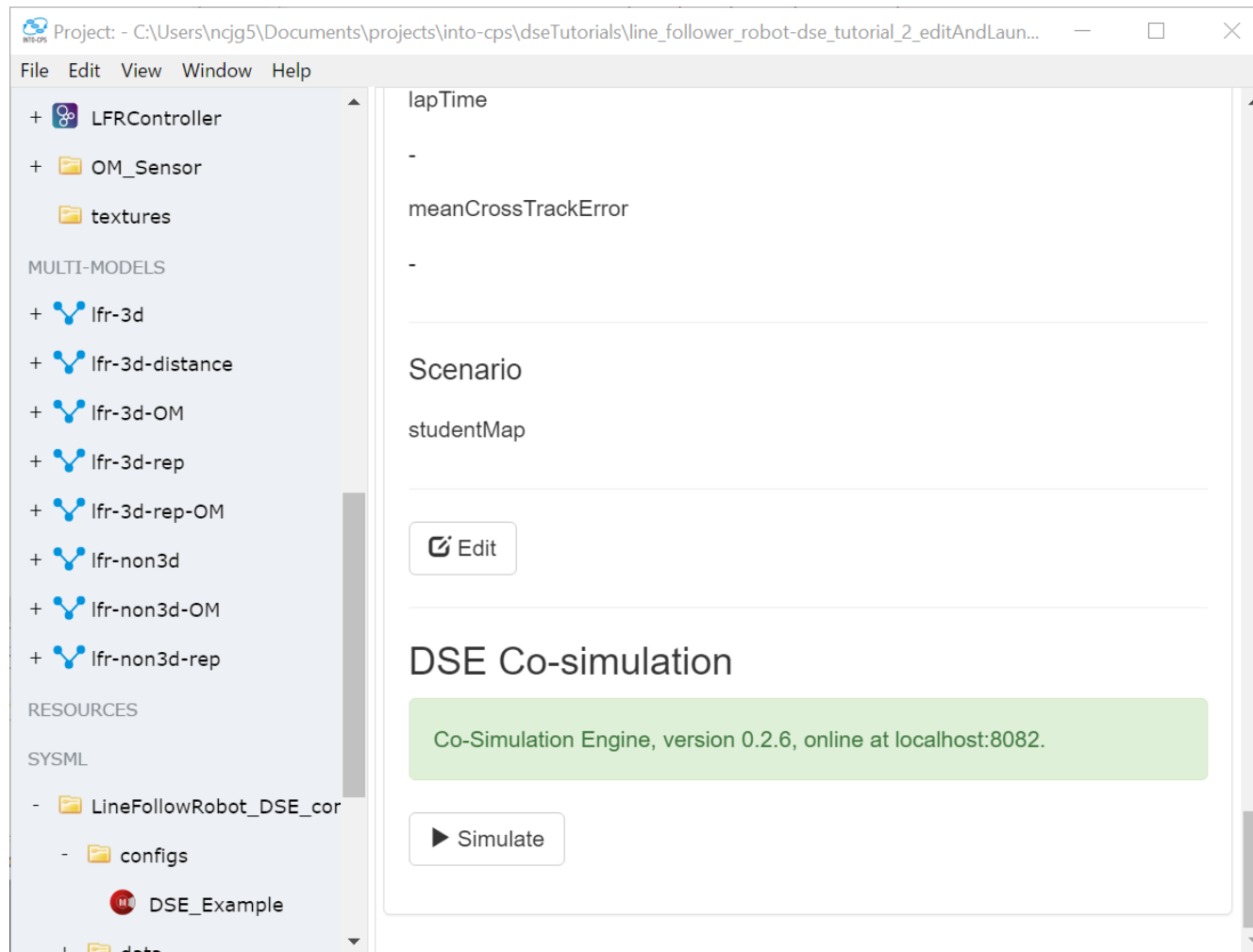


Design Space Exploration





Design Space Exploration

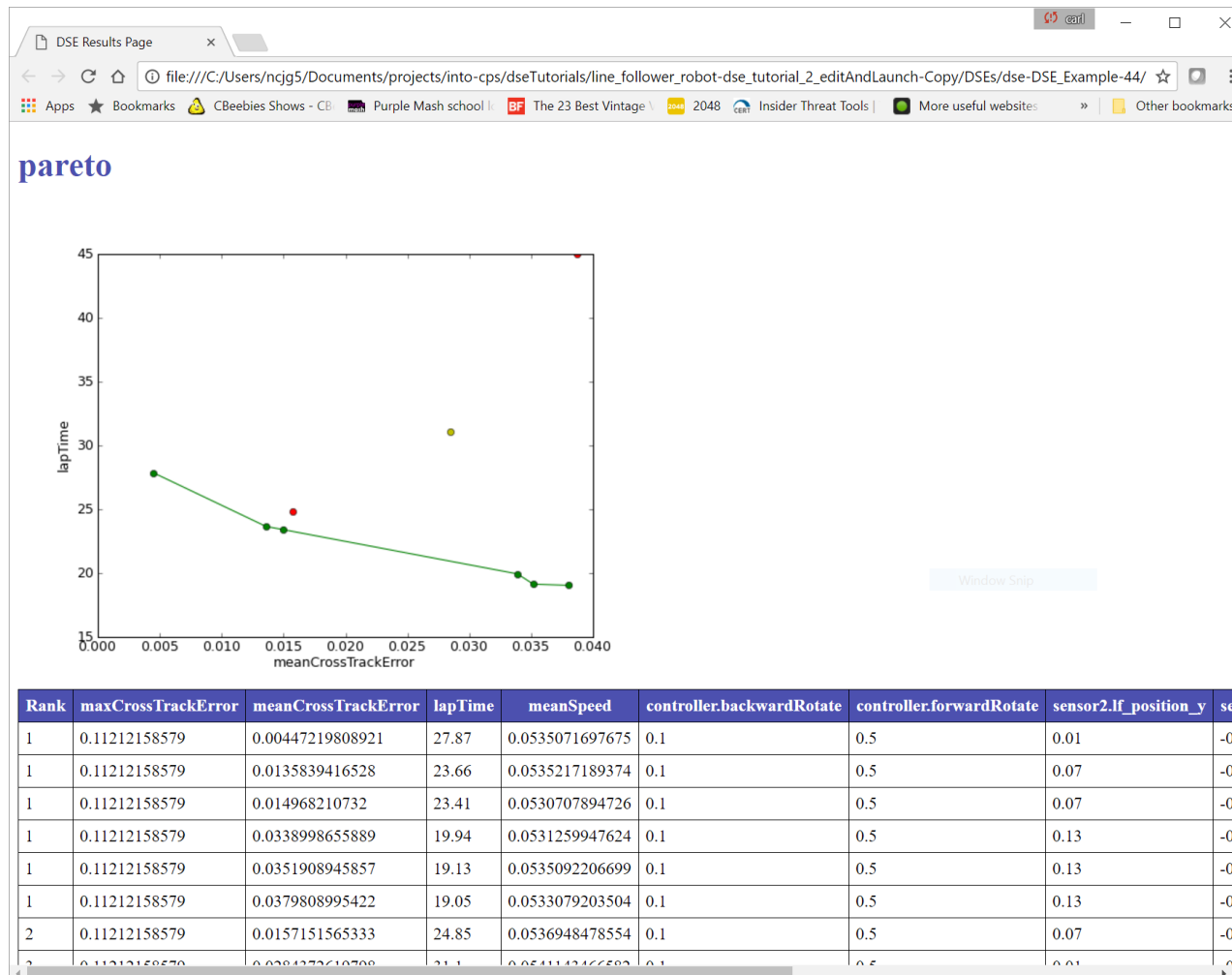




Design Space Exploration

The screenshot displays the INTO-CPS Design Space Exploration (DSE) interface. On the left, a 'Co-Simulation Orchestration Engine Server Status' window shows the process launch details for 'org.crescendo.fmi.ShmServer'. Below it, a Java console window displays the execution log, including 'DoStep' calls and 'Collecting inputs from cache' messages. On the right, the 'DSE Co-simulation' configuration window is shown, listing various components like 'dse-DSE_Example-43', 'lfr-16sensorPositionsC', and 'lfr-216controllerValue'. The 'Scenario' section includes a 'studentMap' and an 'Edit' button. The 'DSE Co-simulation' section indicates the 'Co-Simulation Engine, version 0.2.6, online at localhost:8082.' and features a 'Simulate' button.

Design Space Exploration



Test Automation / Model Checking

