Model-Based Design and Virtual Commissioning of Production Machinery

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Principal Application Engineering
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Agenda

Model-Based Design

1. Modelling Mechanical Systems at different Levels of Detail
2. Controls Design and automated Code Generation

Virtual Commissioning

1. Co-Simulation with Unreal Engine for large scale 3D modelling
2. Accelerate Modelling by using CAD Import
3. Hardware in the Loop (HiL) Simulation

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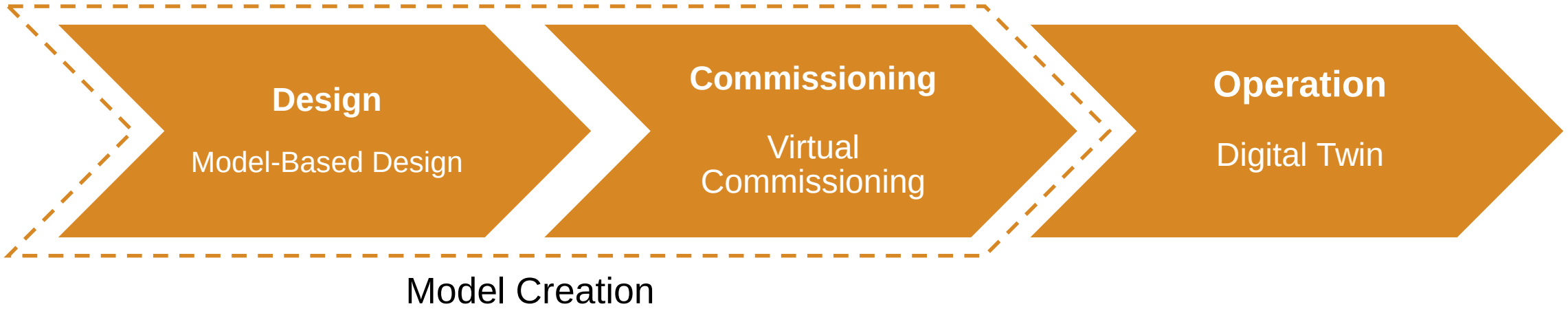
Life Cycle of Production Equipment



Life Cycle of production Equipment

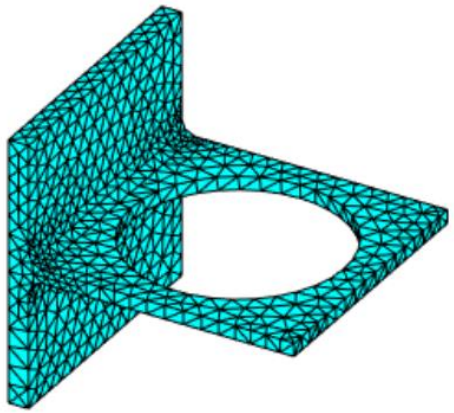
#1 Physical Plant

Simulation of Mechanics – Levels of Detail

PDE Toolbox

FEM-Simulation

Inside of mechanical Part



Simscape Multibody

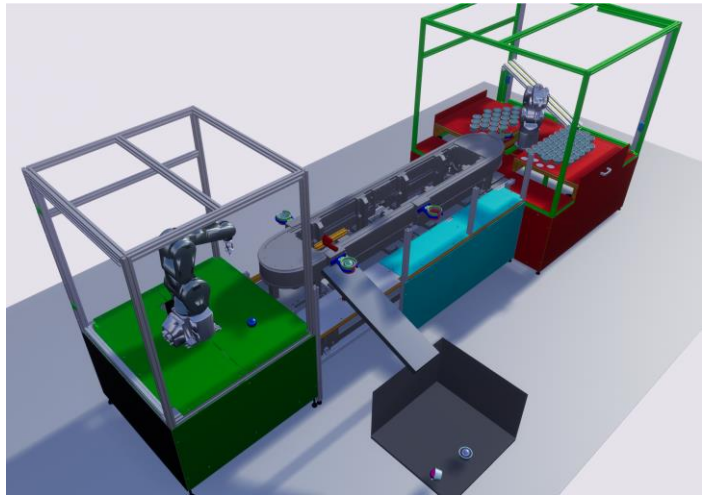
Multibody-Simulation

Between a limited # mechanical Part

Simulink 3D Animation

Large-Scale 3D Simulation

Large System with several machine units

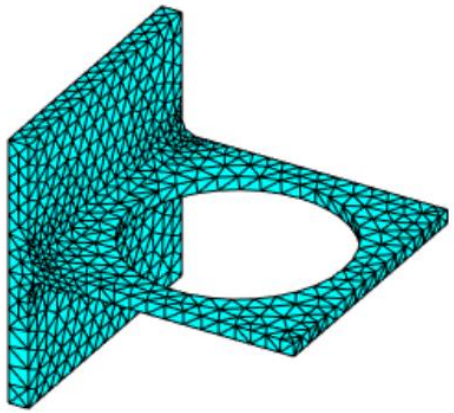


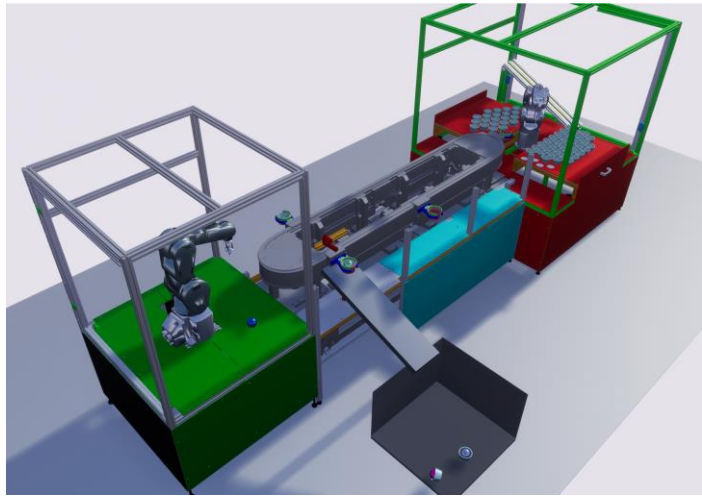
Performance

Physical Detail

Simulation of Mechanics – Levels of Detail

PDE Toolbox	Simscape Multibody	Simulink 3D Animation
FEM-Simulation	**Multibody-Simulation**	**Large-Scale 3D Simulation**
Inside of mechanical Part	**Between a limited # mechanical Part**	**Large System with several machine units**



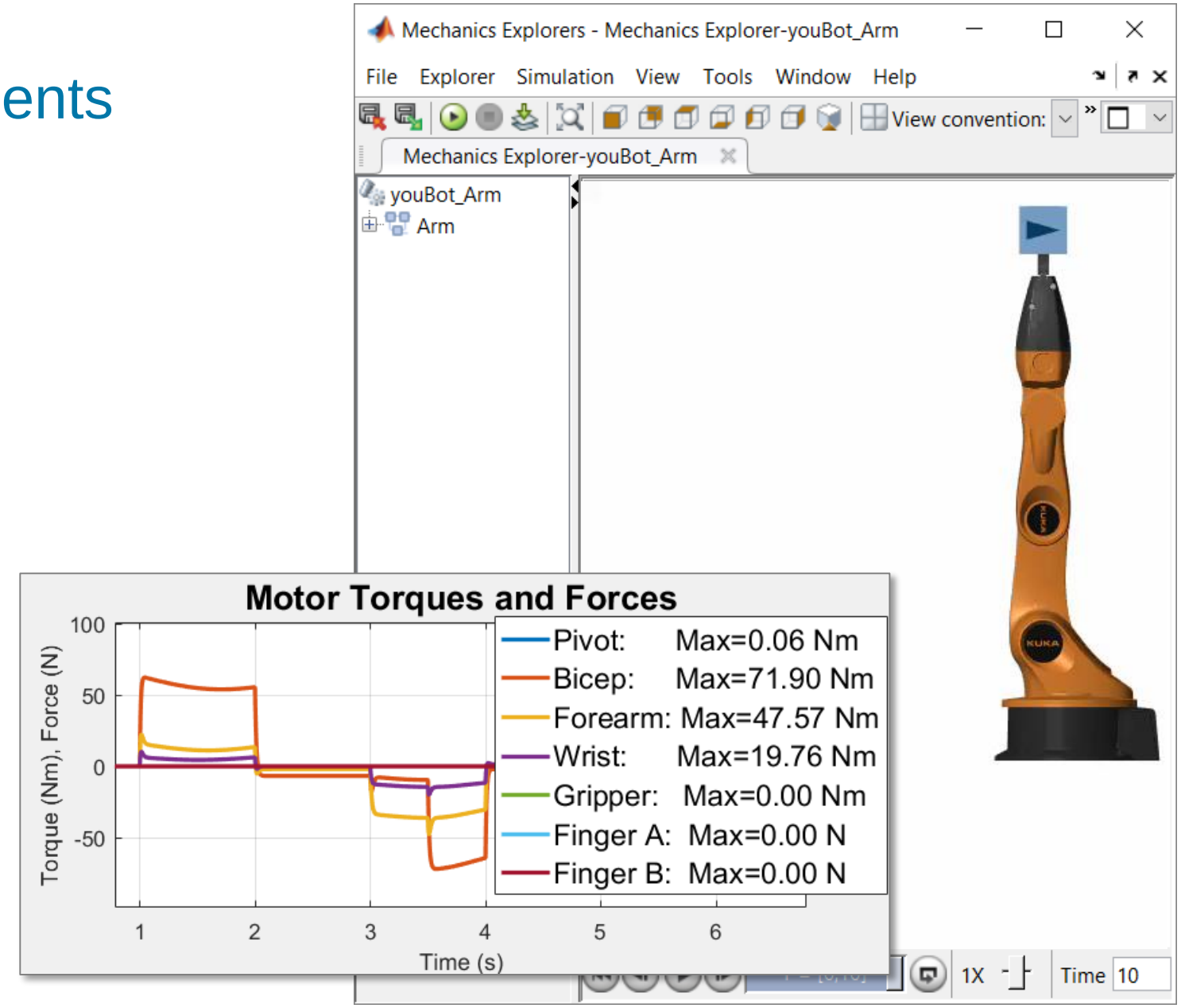


Physical Detail

Performance

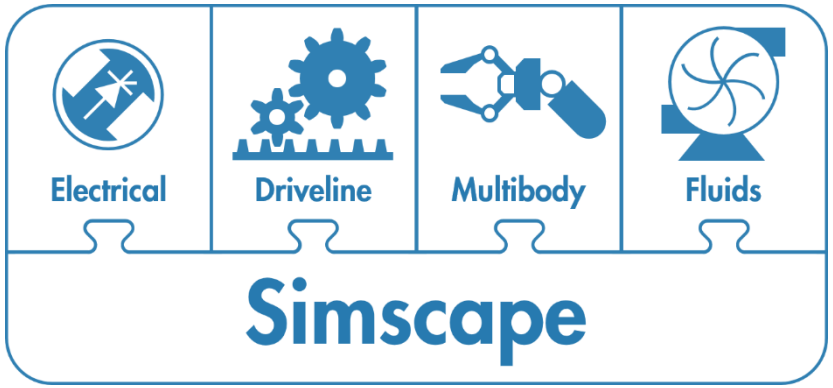
Example:
Determine Motor Requirements

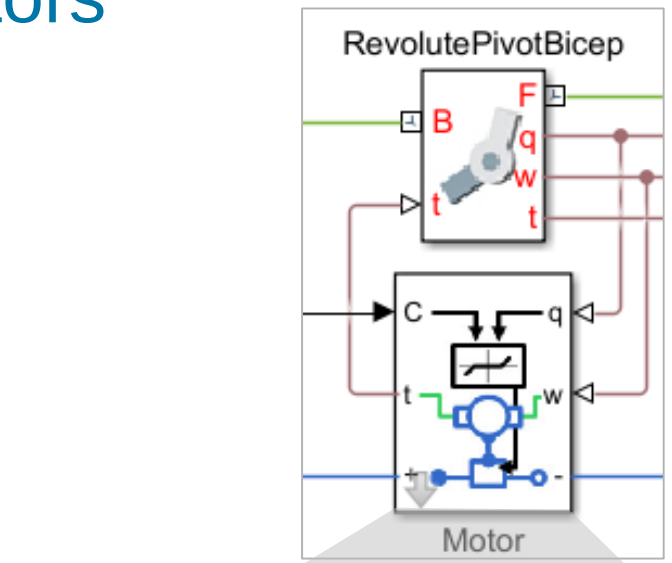
- Define and run a set of tests
  - Maximum payload, speed
  - Worst case friction levels
  - Full range of movement
- Use dynamic simulations to calculate required torque and bearing forces
- If design changes, automatically rerun tests and re-evaluate results

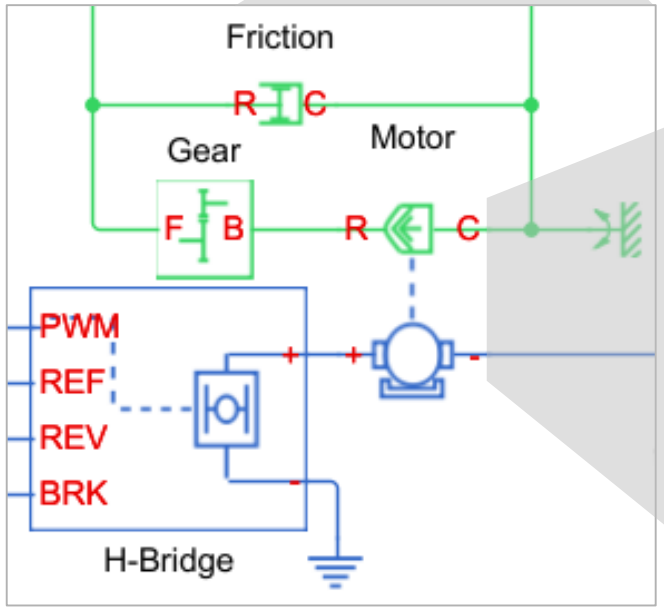


Integrate Electrical Actuators

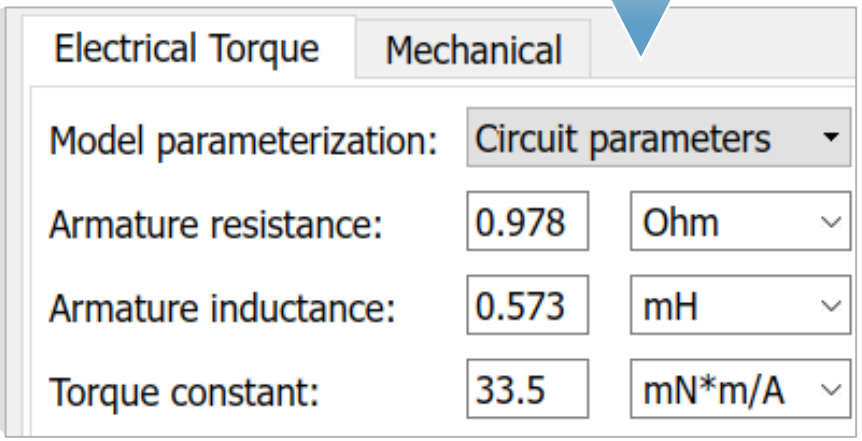
- Add motors, drive circuitry, gears, and friction
- Choose motors based on torque requirements
- Assign parameters directly from data sheets







251601		
Motor Data		
Characteristics		
Terminal resistance	Ω	0.978
Terminal inductance	mH	0.573
Torque constant	mNm / A	33.5
Speed constant	rpm / V	285
Speed / torque gradient	rpm / mNm	8.32
Mechanical time constant	ms	11.8
Rotor inertia	gcm²	135

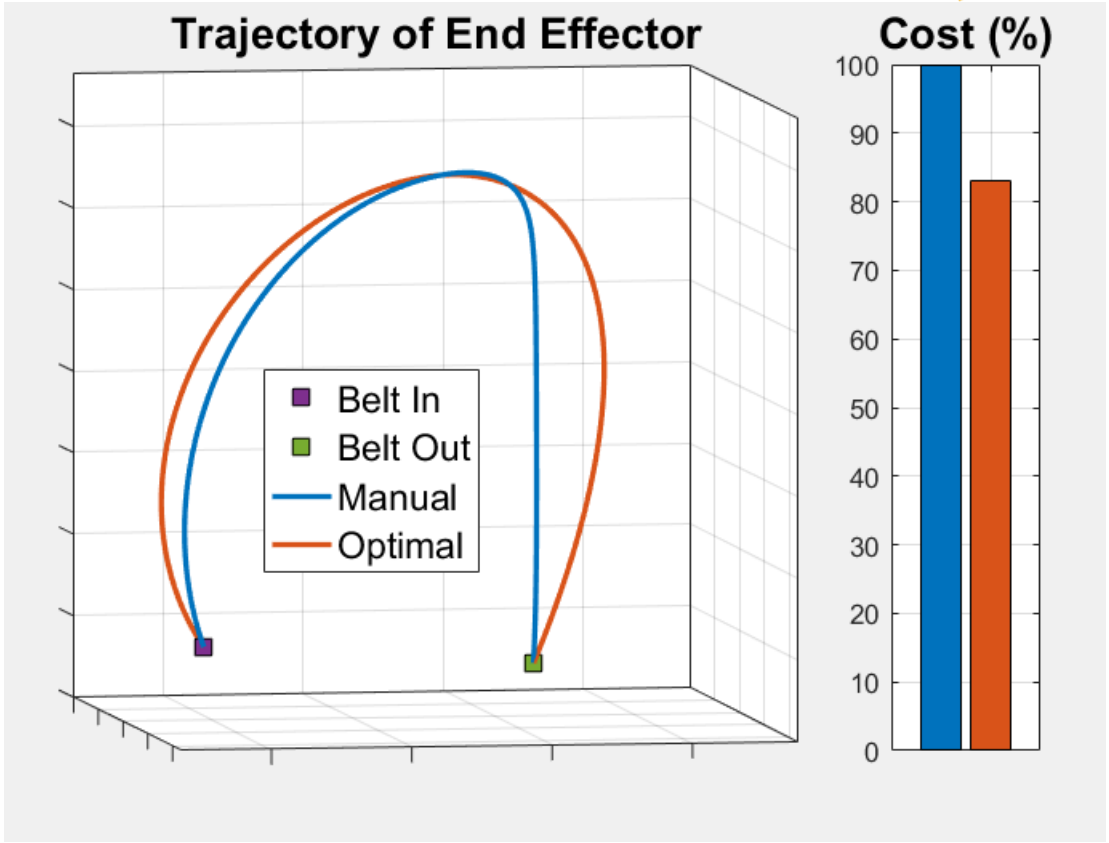


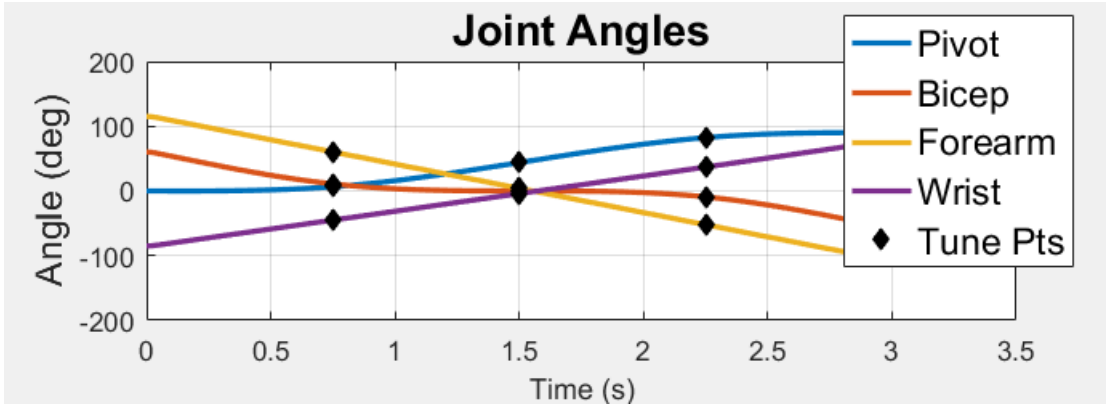
Optimize Power Consumption

Model:

Challenge: Identify arm trajectory that minimizes power consumption.

Solution: Use dynamic simulation to calculate power consumption, and use optimization algorithms to tune trajectory.





Krones develops Digital Twin

Challenge

Increase the performance of an automated beverage-packaging system by incorporating a dynamic tripod robot into the design

Solution

Use Simulink and Simscape Multibody to create an accurate digital twin that supports design optimization, fault testing, and predictive maintenance

What

Results

- Robot performance increased
- Product development time shortened
- Testing time significantly reduced

The Krones Robobox T-GM package-handling robot.

Why

"Simulations of the digital twin in Simulink enabled us to obtain data and insights that would be either impossible to get via hardware tests or simply too costly and time-consuming. Visualizing forces and moments helped us to understand the effects of individual components on a highly dynamic robot."

- Benedikt Böttcher, Krones

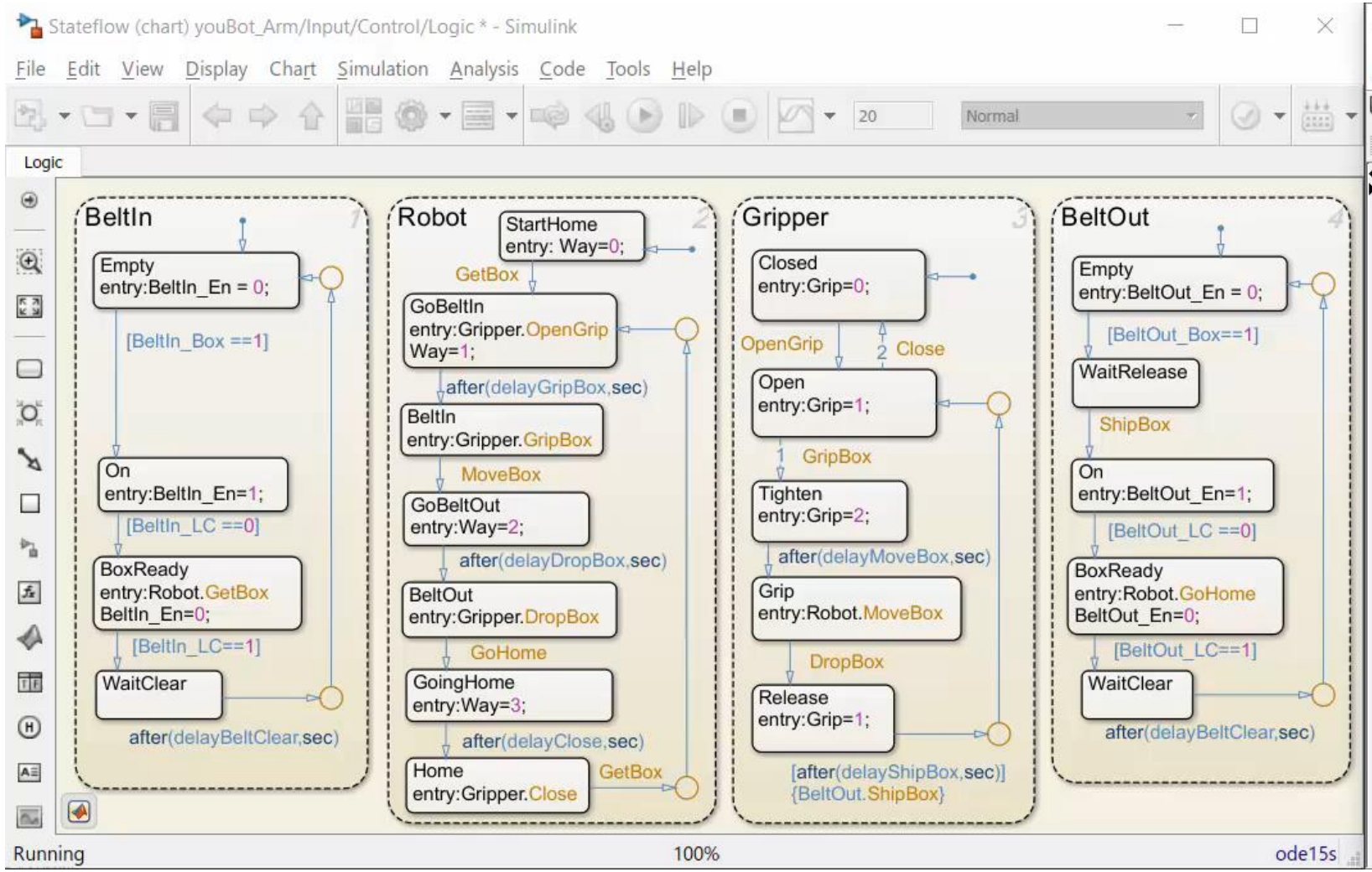
Link to user story

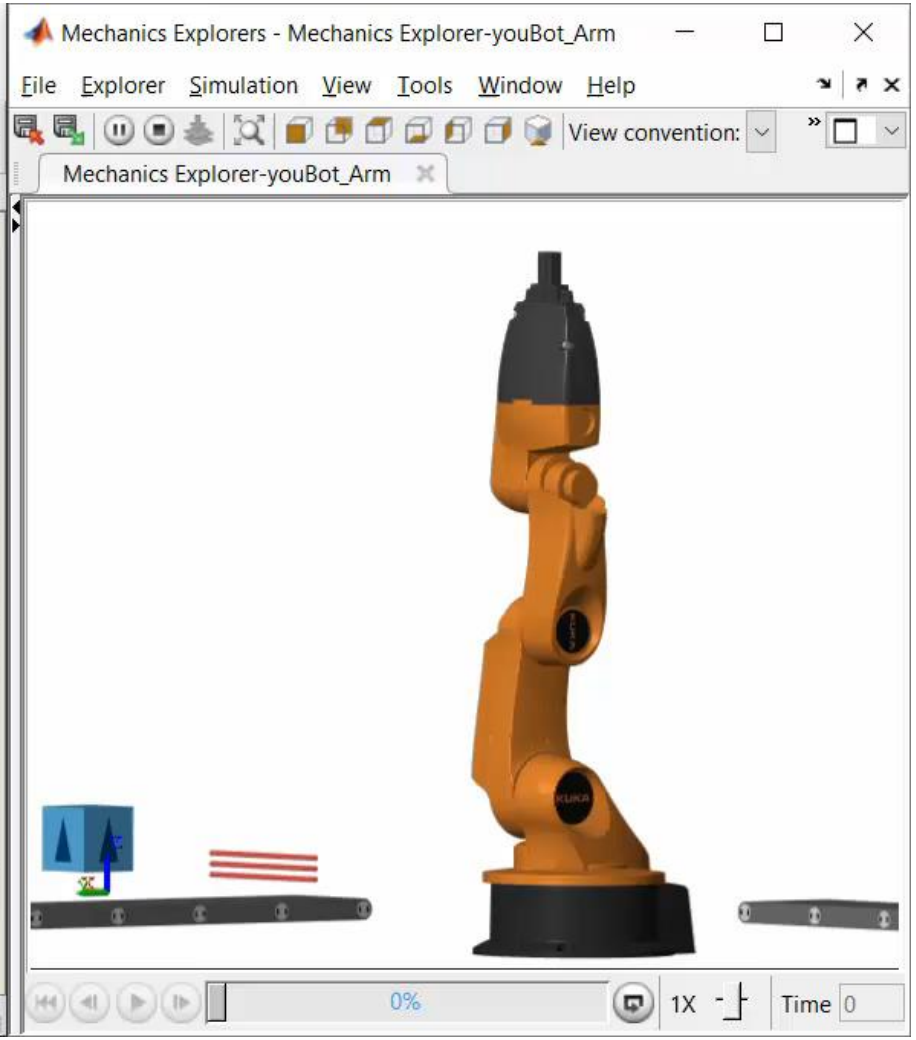
Quelle: YouTube

Life Cycle of production Equipment

#2 Controls

Design Control Logic

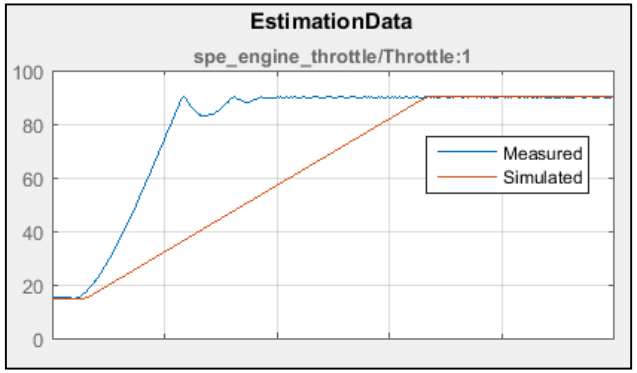




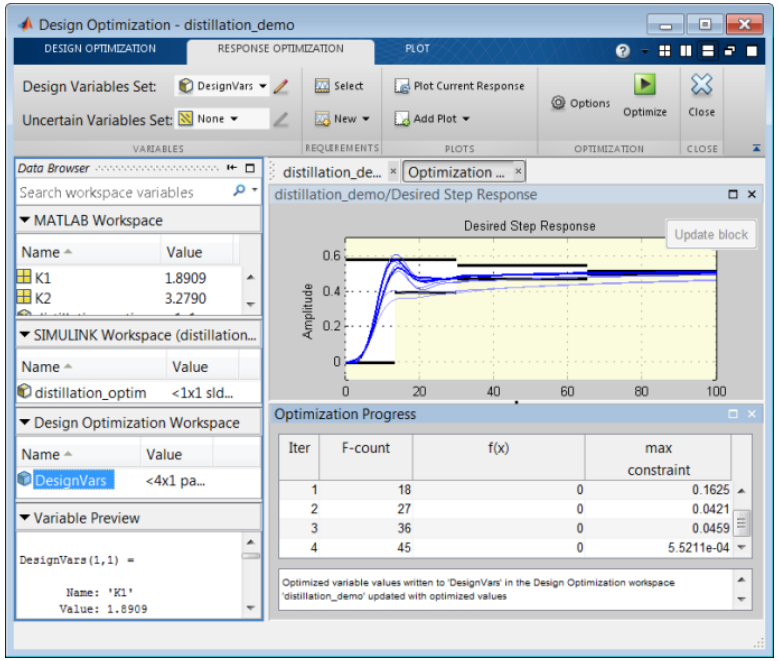
Design Optimization

- Estimate and tune system parameters using numerical optimization
- Analyze system sensitivity to parameter variations
- Perform modeling and control design tasks:
  - Increase model accuracy by calibrating model parameters with test data
  - Automatically find system parameter values to meet design requirements
- Used by system engineers and control engineers to optimize physical system, controller, and overall design

Before

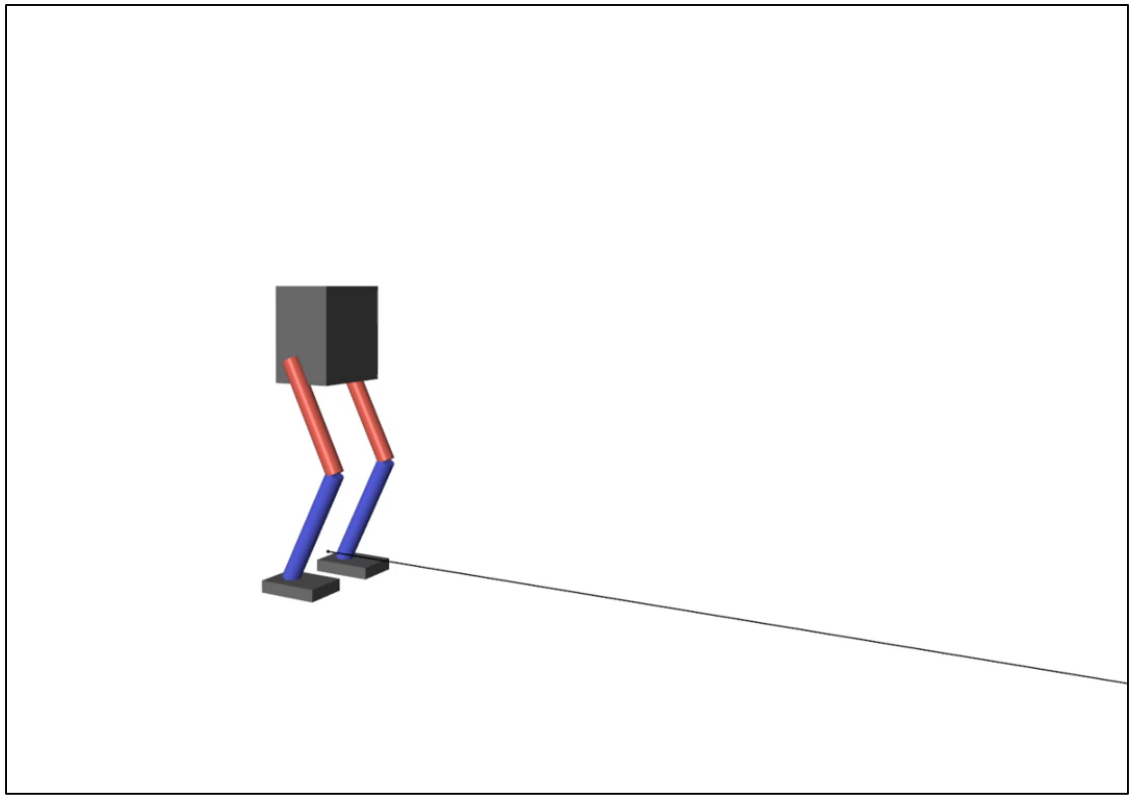


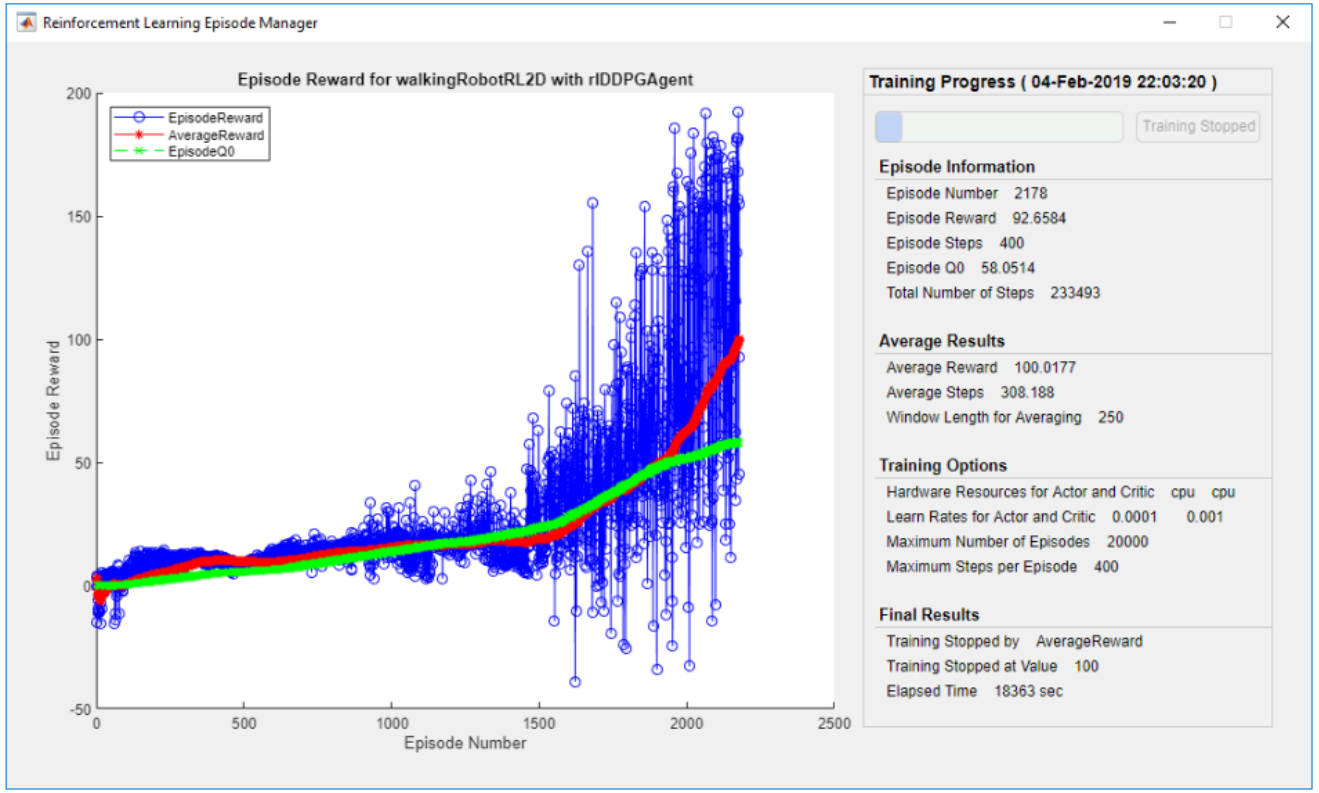
After



Training an AI Agent via Reinforcement Learning


```
trainOpts.UseParallel = true;
trainOpts.ParallelizationOptions.Mode = 'async';
```



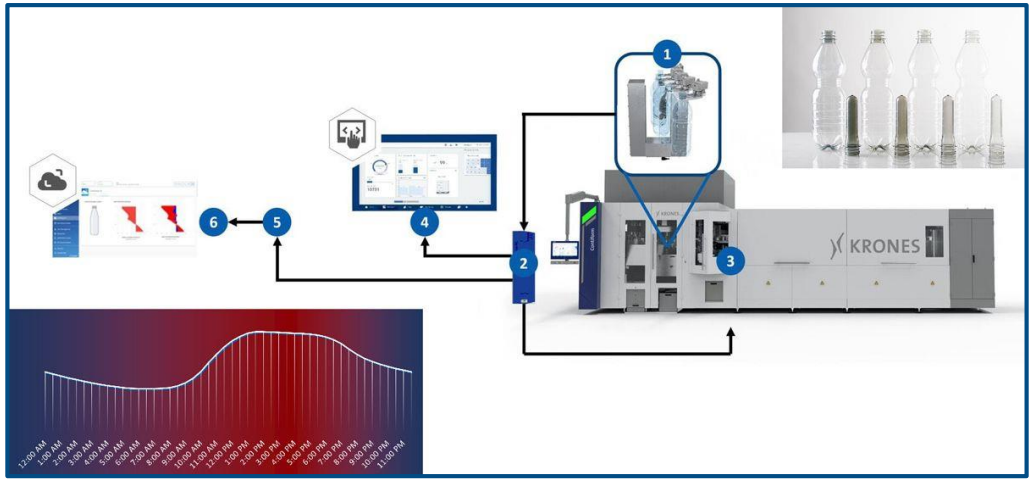


Krones AG Builds Reinforcement Learning–Based Process Control in the Blow Molder Contiloop AI for PET and rPET Bottles

Using **Simulink** and **Reinforcement Learning** Toolbox, Krones AG designed the Contiloop AI blow molder **controller agent**, which uses parameters such as air temperature and humidity, light transmission, and material temperature to continuously adjust process parameters. The AI is trained for new material and conditions using the Krones IIoT platform

Key Outcomes/Advantages:

- Improved bottle quality with less scrap through use of AI algorithms and monitoring
- Reduced number of operator interventions and manual errors
- Achieved continuous measurement of bottle quality and drift detection at an early stage
- Developed comprehensive workflow—from data analysis over embedding the plant model to deployment of trained agent—using Simulink and Reinforcement Learning Toolbox



Contiloop AI with information flow for the blow process.

"Our initial experience came from several use cases implemented with MATLAB and Simulink, and the exchange with MathWorks was very valuable to overcome the difficulties in development, generalization, and deployment of the closed-loop AI application."

- Benedikt Böttcher, Krones AG

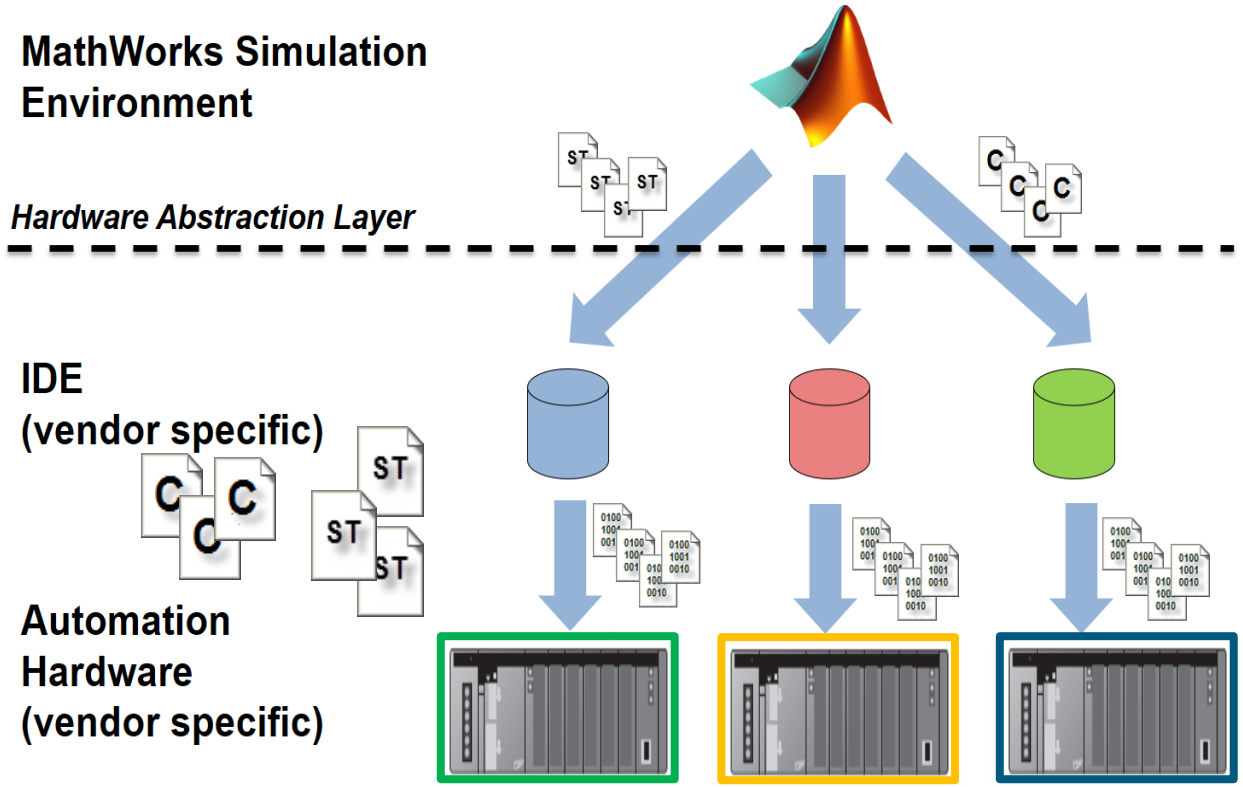
Link to user story

Life Cycle of production Equipment

#3 Code Generation

Generate code automatically and integrate into your PLC IDE

- Design and test hardware independent functionality (C/C++, IEC 61131-3, HDL)
- Reduce errors introduced with manual coding



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Event-Based Modeling – Control Logic Deployment

- Generate IEC 61131-3 or C/C++ code
- Use Target Library interface for IDE integration

Vendor	IDE	IEC 61131-3	C/C++	Connections Partner
3S - Smart Software Solutions	CODESYS	✓		✓
B&R Industrial Automation	Automation Studio	✓	✓	✓
Bachmann Electronic	SolutionCenter	✓	✓	✓
Beckhoff Automation	TwinCAT	✓	✓	✓
Bosch Rexroth	IndraWorks	✓	✓	✓
Mitsubishi Electric	CW Workbench		✓	✓
Ingeteam	Ingesys IC3		✓	✓
Omron	Sysmac Studio	✓		✓
Phoenix Contact	PC WORX	✓	✓	✓
Rockwell Automation	RSLogix / Studio 5000	✓		✓
Schneider Electric	Unity Pro	✓		
Siemens	TIA Portal / STEP 7	✓	✓	✓

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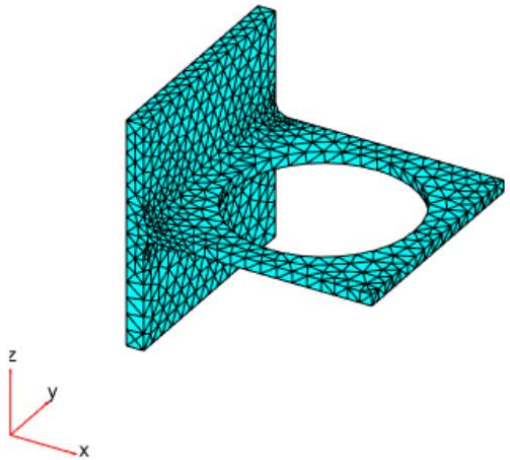

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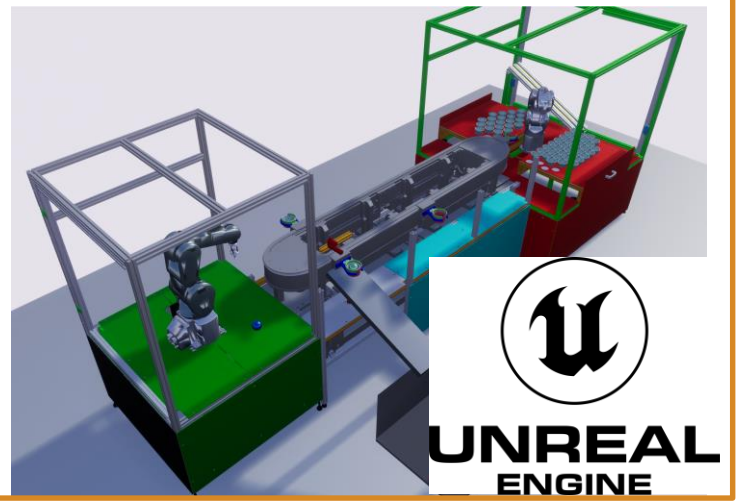
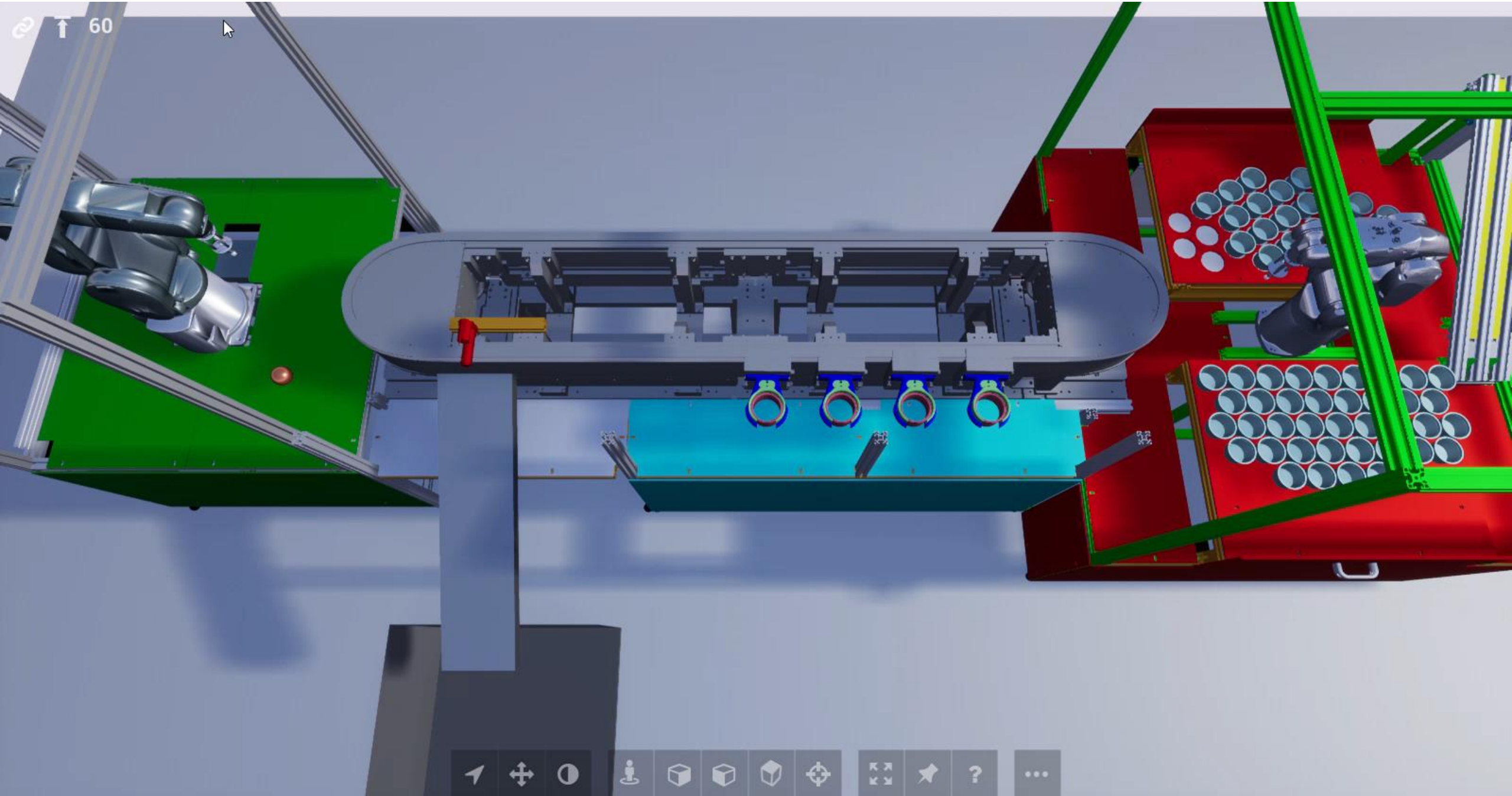


Physical Detail

Performance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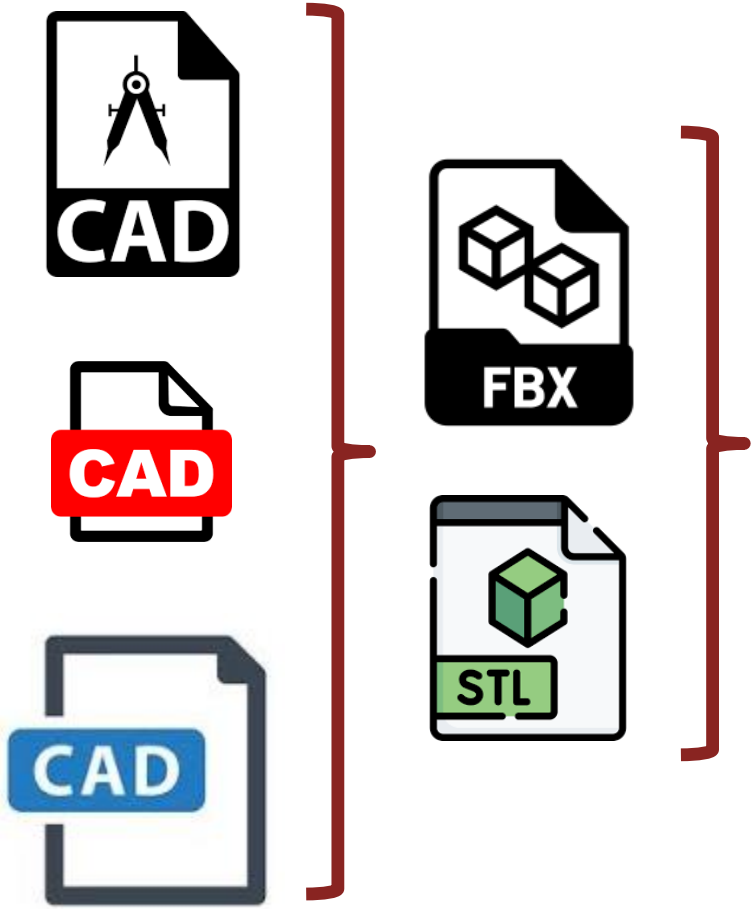
Model Creation using CAD Files

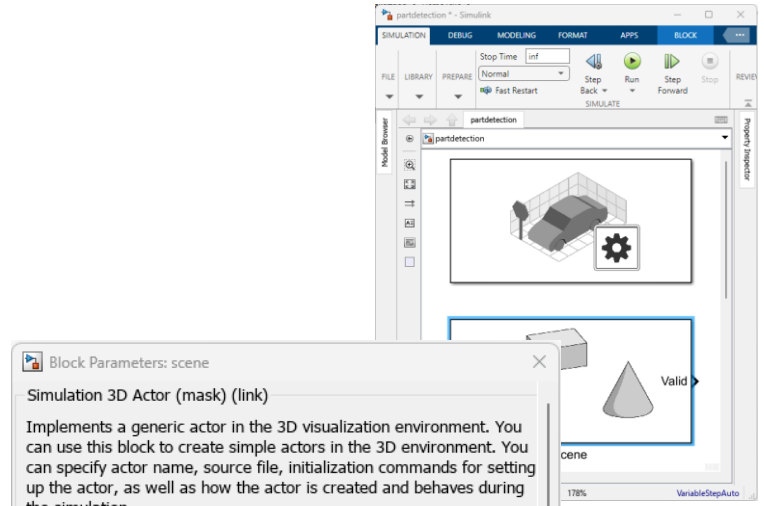
CAD Tool | **3D Format**

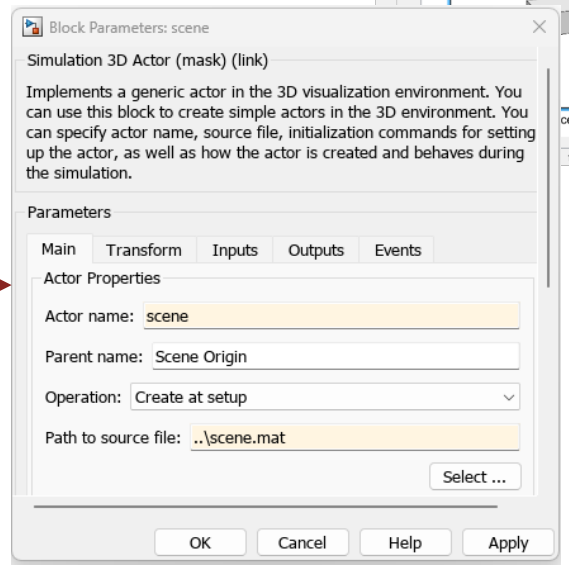


scene_creation.m

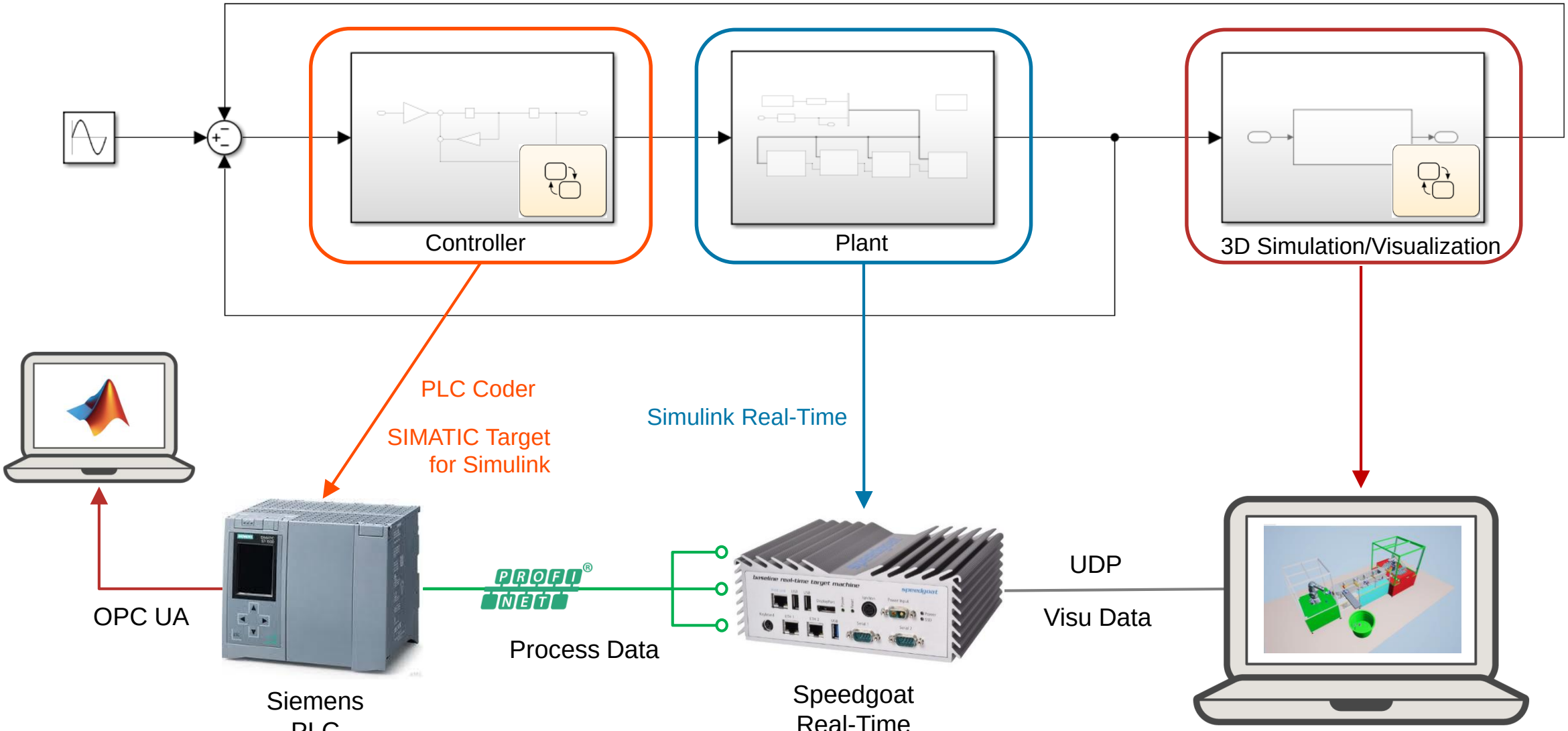
```
world = sim3d.World();
load(part1.fbx);
load(part2.stl);
create.Shape(box);
…
world.add(parts);
save(parts,‘scene.mat‘);
```

scene.mat

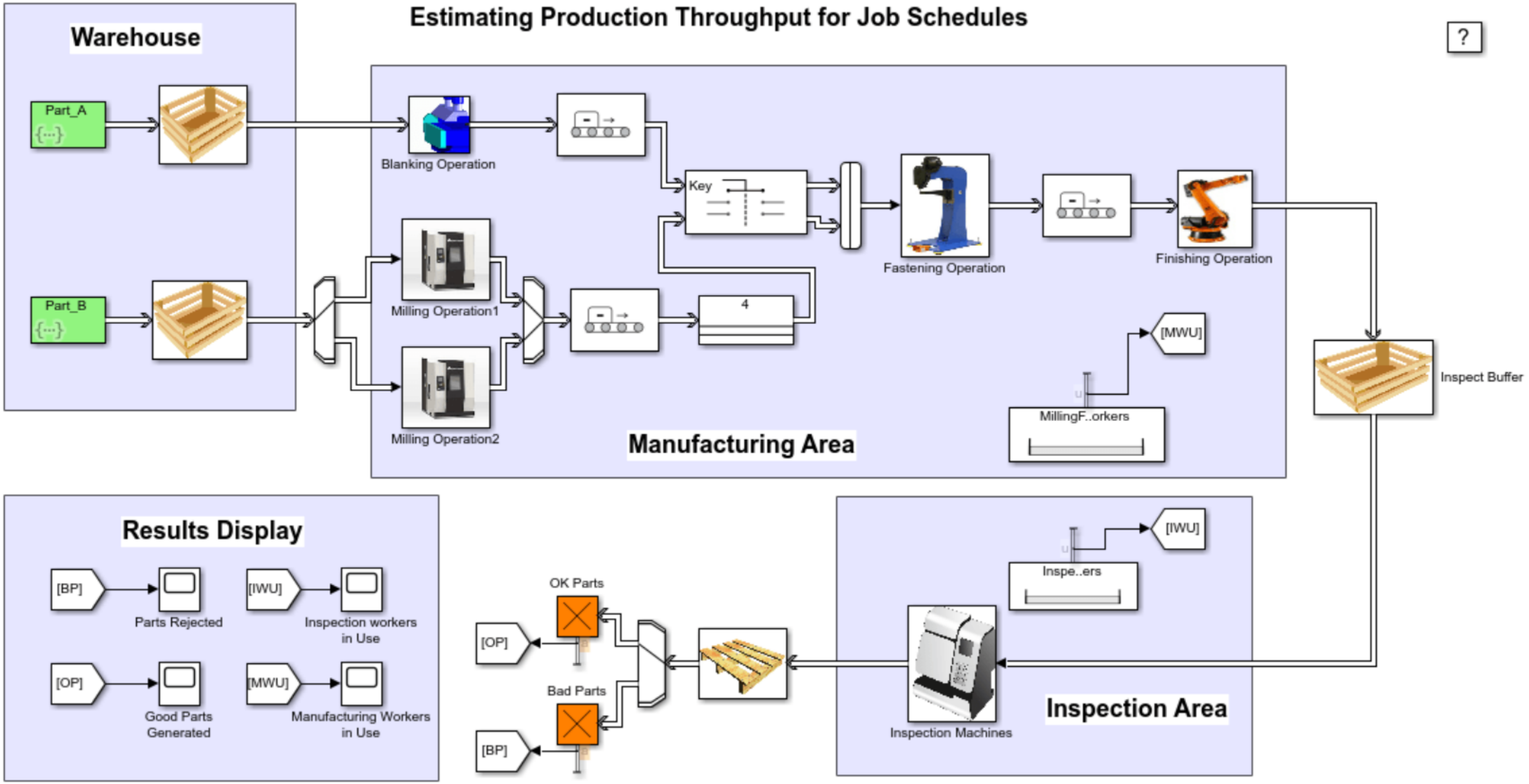




Virtual Commissioning - Real-Time setup (example Siemens)



Model a Job Shop using Throughput Analysis



https://www.mathworks.com/help/releases/R2024a/simevents/ug/job-scheduling-and-resource-estimation-for-a-manufacturing-plant.html

Summary

1. Models can help in each of these steps
2. Define the requirements for your model upfront
3. To get a high ROI start early using models