MATLAB EXPO 2019

Optimizing Robotic Systems with Simscape

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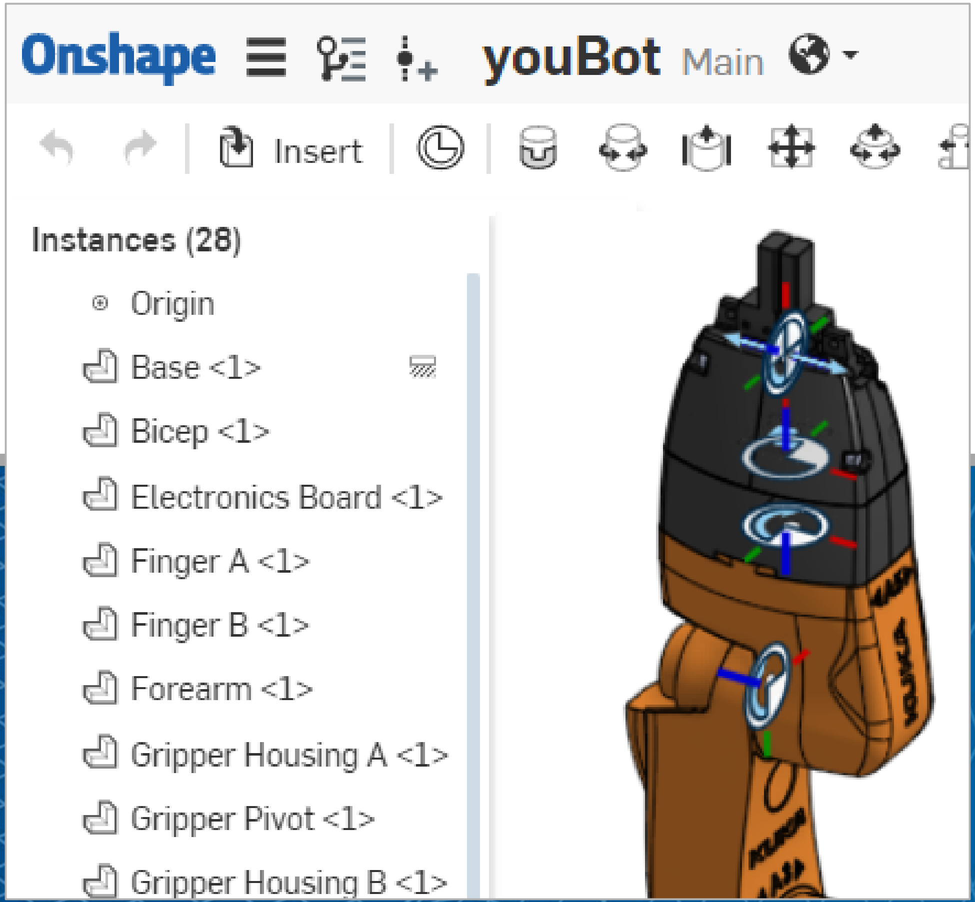
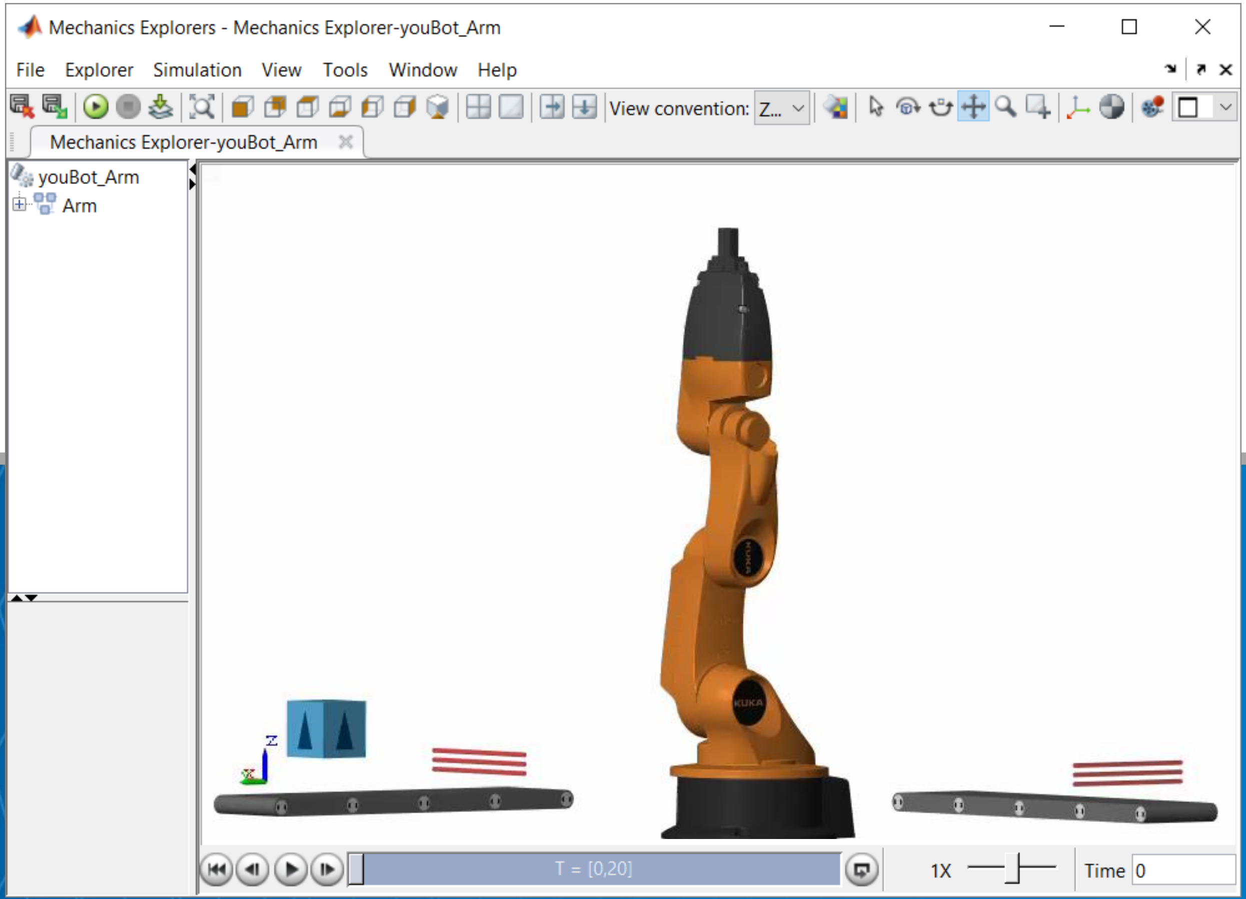
Optimizing Robotic Systems with Simscape





In this session

- Simscape and MATLAB enable engineers to combine CAD models with multidomain, dynamic simulation

MATLAB

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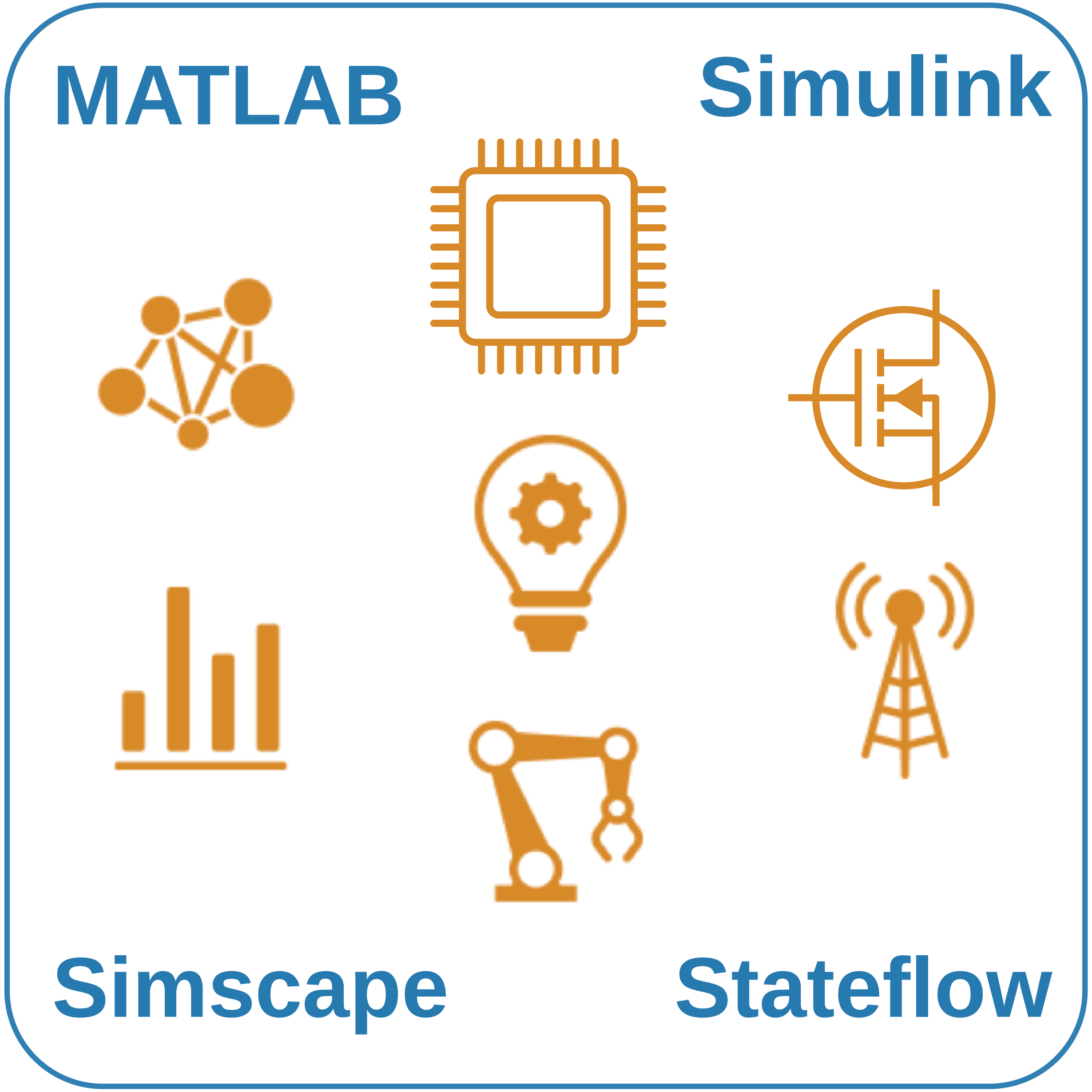
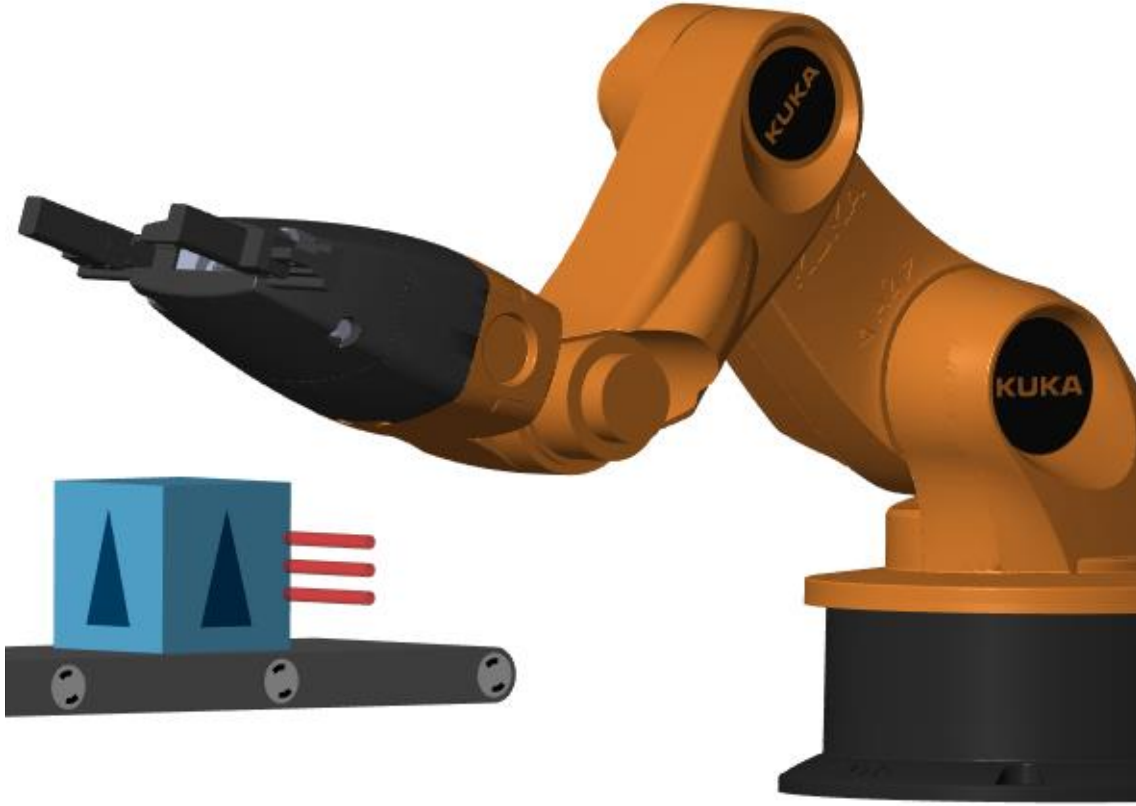


In this session:

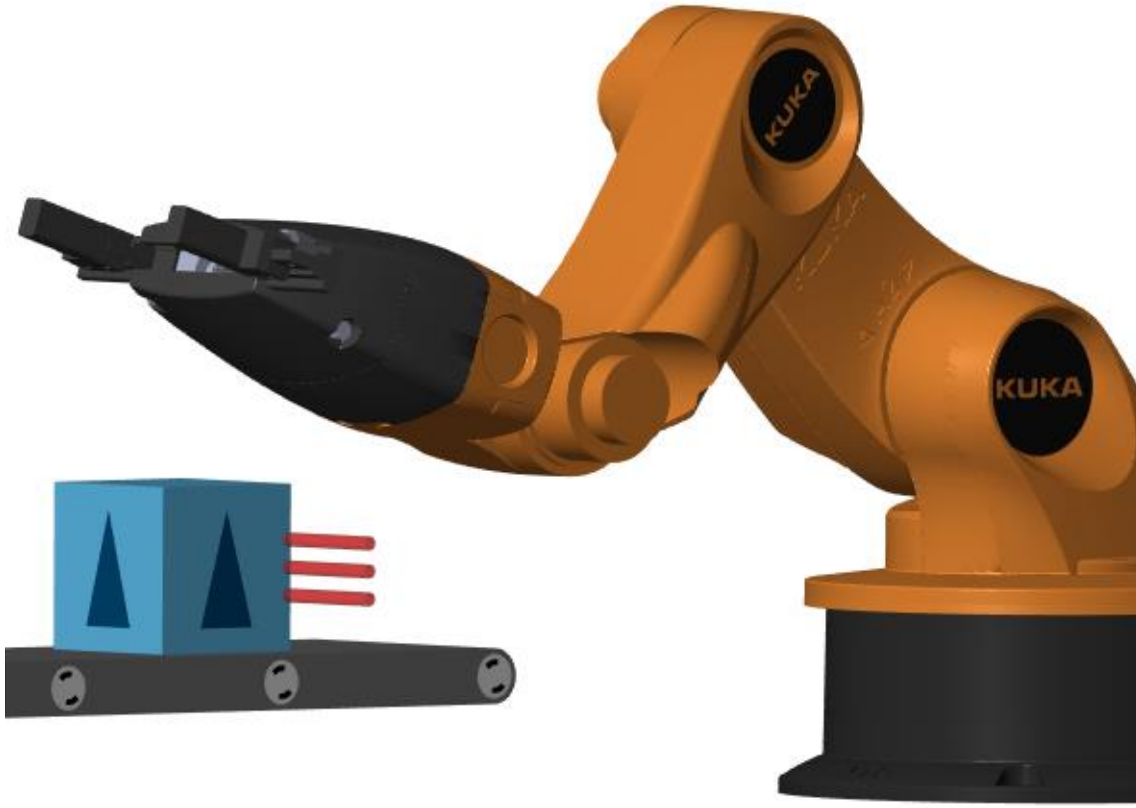
- Simscape and MATLAB enable engineers to combine CAD models with multidomain, dynamic simulation

- Results you can achieve:
  1. Optimized mechatronic systems
  2. Improved quality of overall system
  3. Shortened development cycle



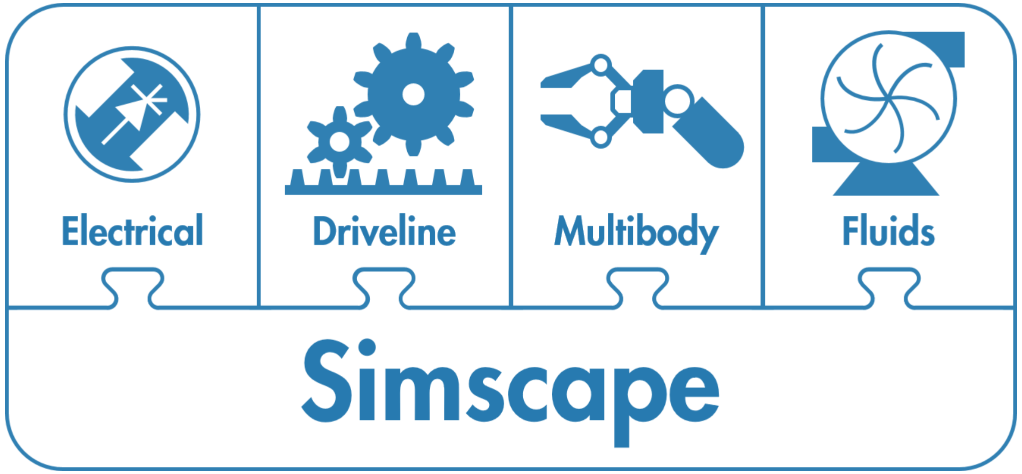
Why Combine CAD and Multidomain Dynamic Simulation?

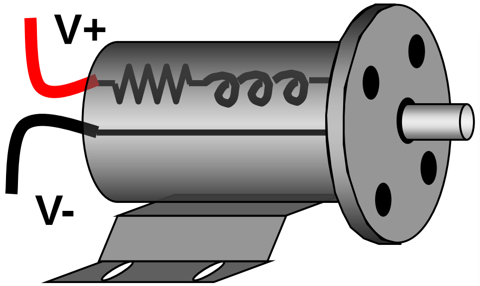
- **Fewer iterations** on mechanical design because **requirements are refined**
- **Fewer mechanical prototypes** because **mistakes are caught earlier**
- **Reduced system cost** because **components are not oversized**
- **Less system downtime** because system is **debugged using virtual commissioning**

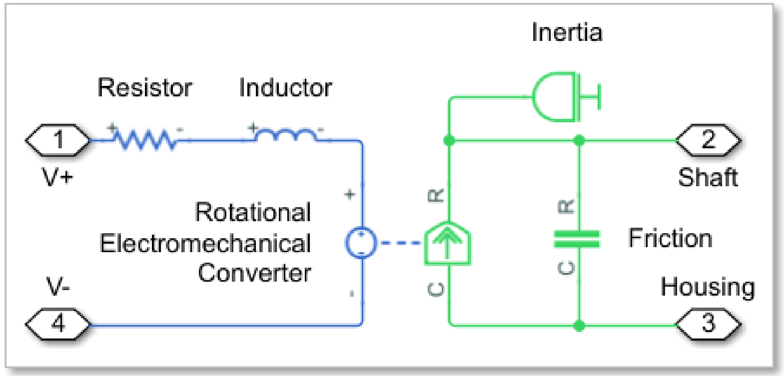


Simscape
Overview

- Enables physical modeling (acausal) of multidomain physical systems
  - Assemble a schematic
  - Equations derived automatically
  - Leverage MATLAB and Simulink







$$i = (C_0 + C_v v)\frac{dv}{dt} + \frac{v}{r_d}$$

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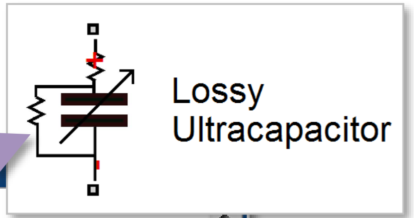
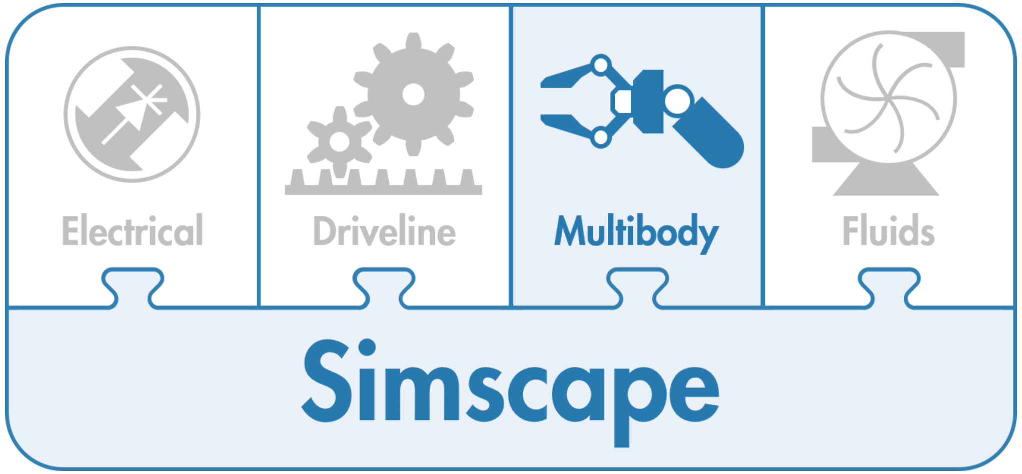
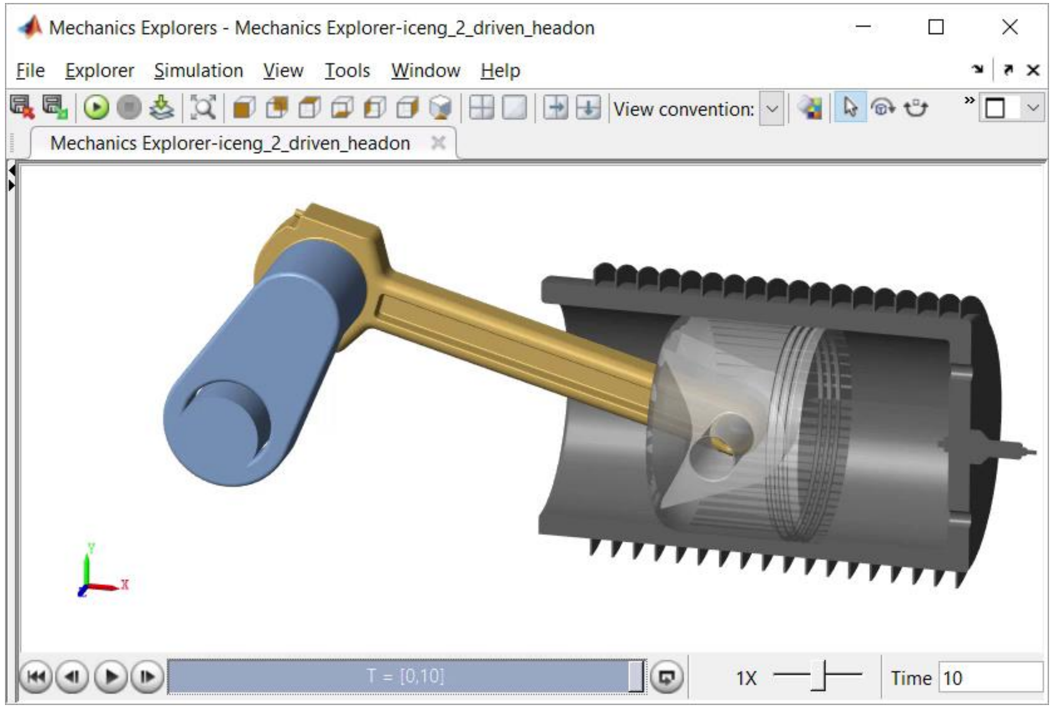
equations
   i == (C0 + Cv*vc)*vc.der + vc/Rd;
   v == vc + i*R;
end
```



Simscape Multibody
Overview

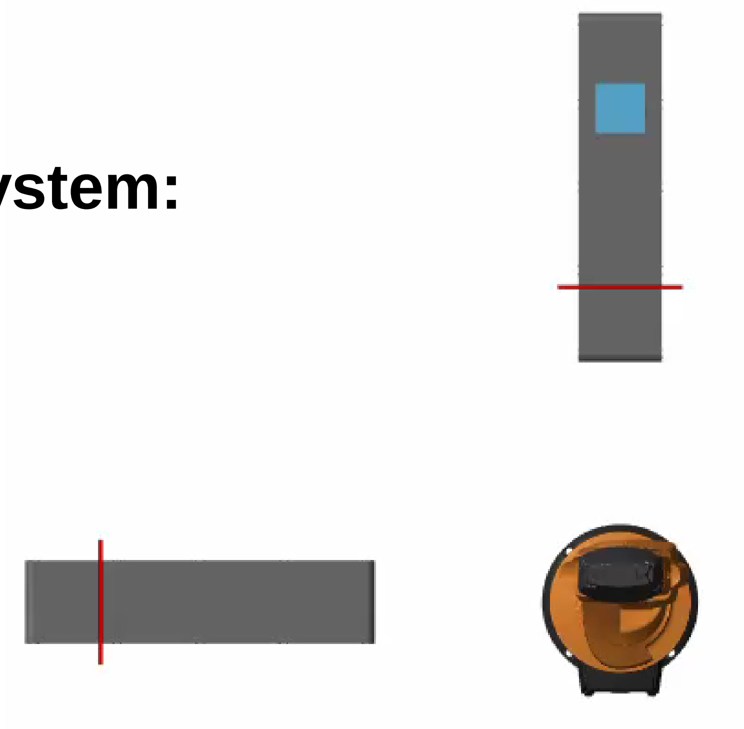
- Enables multibody simulation of 3D mechanical systems
  – Assemble bodies and joints including import from CAD
  – No need to derive and program equations





Design Challenge

System:

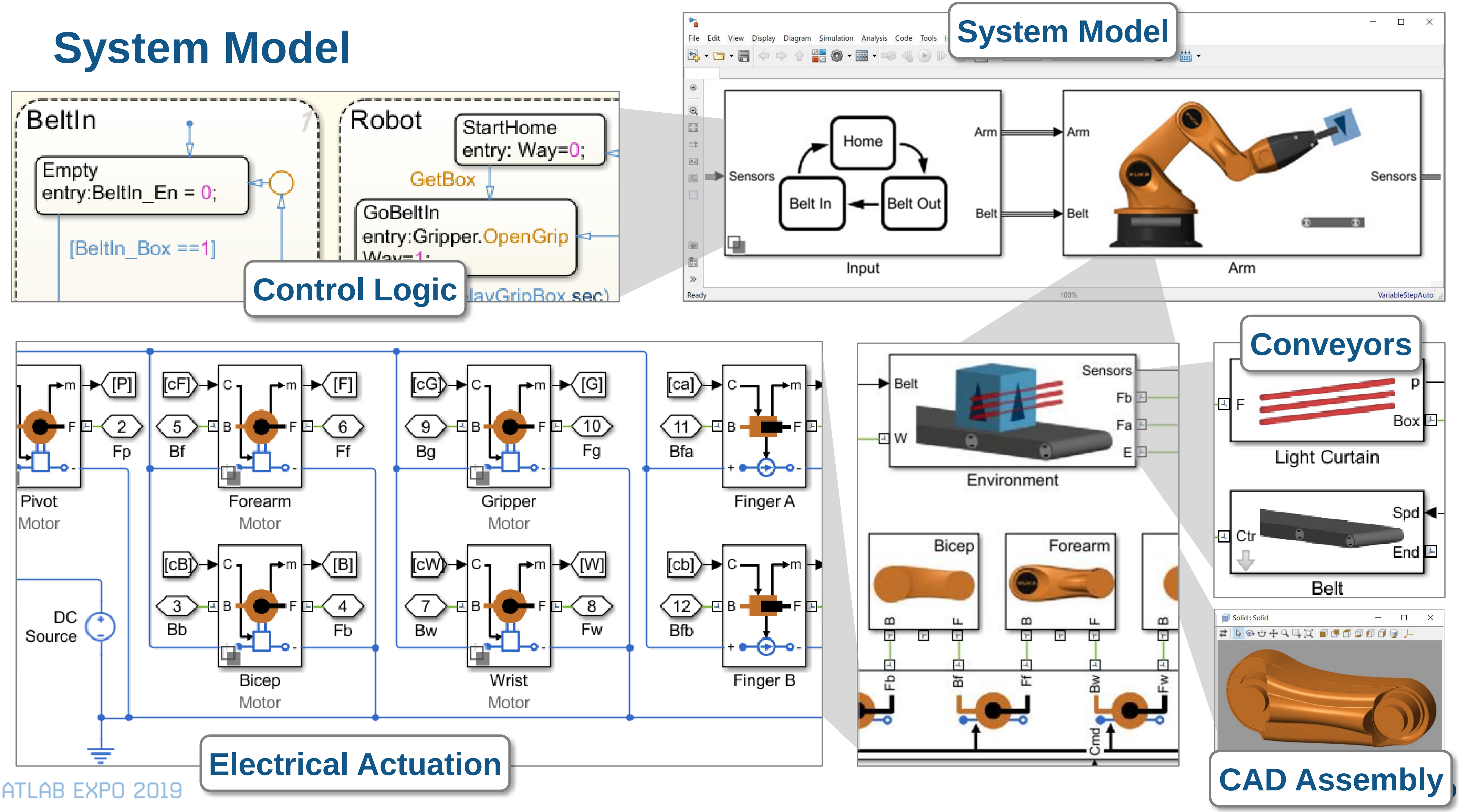


Challenge: Select motors and define controls for robot and conveyor belts.

Solution: Import CAD model into Simscape; use simulation to define actuator requirements and control logic

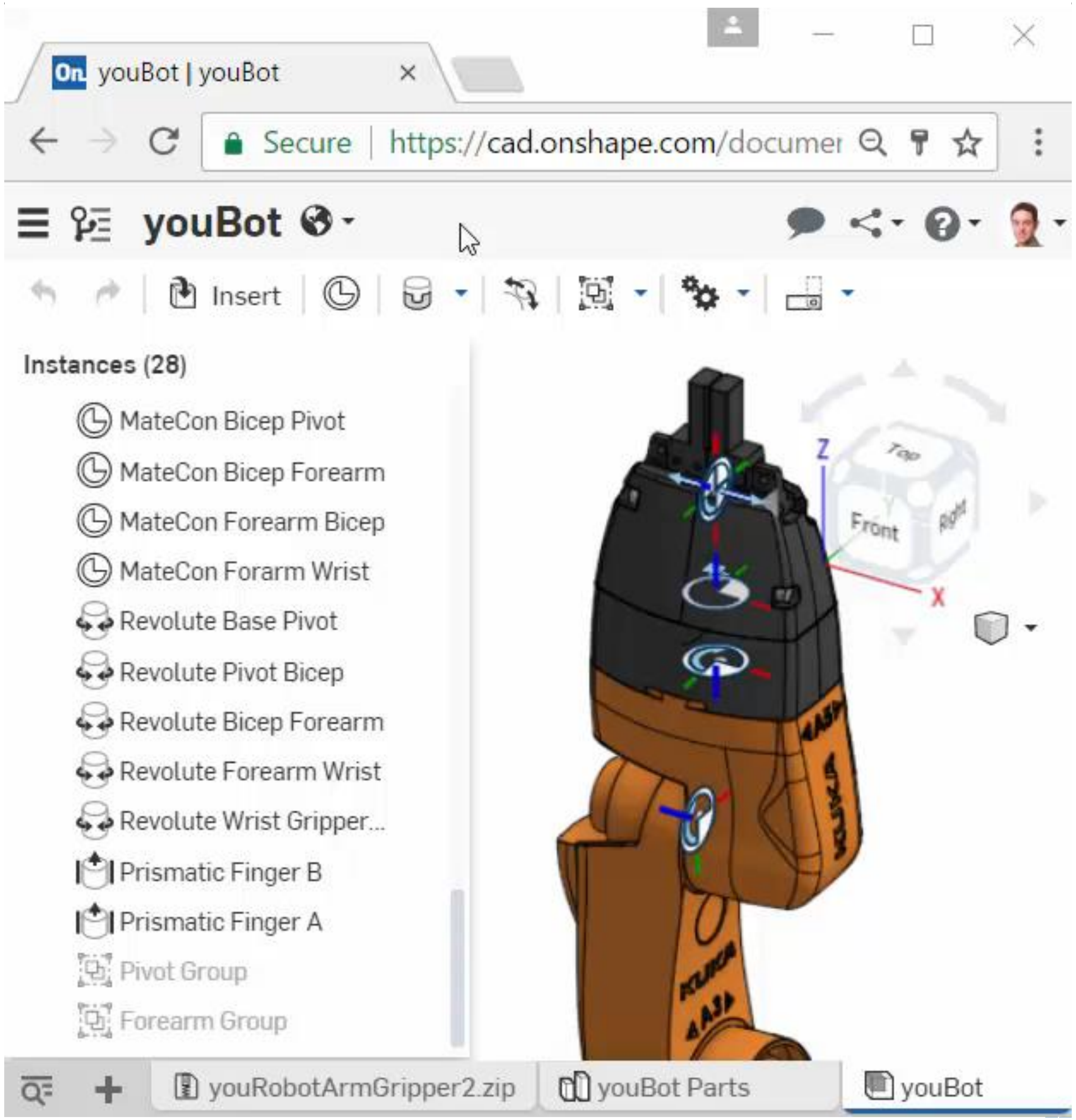
1. Import CAD Model
2. Determine Motor Requirements
3. Integrate Electrical Actuators
4. Minimize Power Consumption
5. Develop Control Logic

System Model



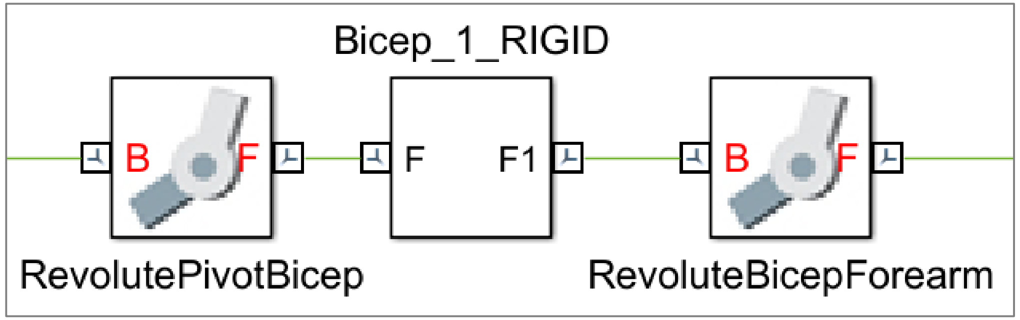
Kuka Robot

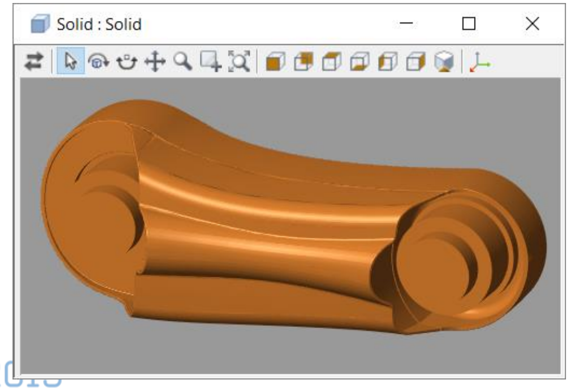
- 5 degrees of freedom, and a gripper
- Key advantage of Onshape: Ability to directly define joints
  - Exact mapping to constraints used in multibody simulation
- System engineer reuses mechanical design in dynamic simulation

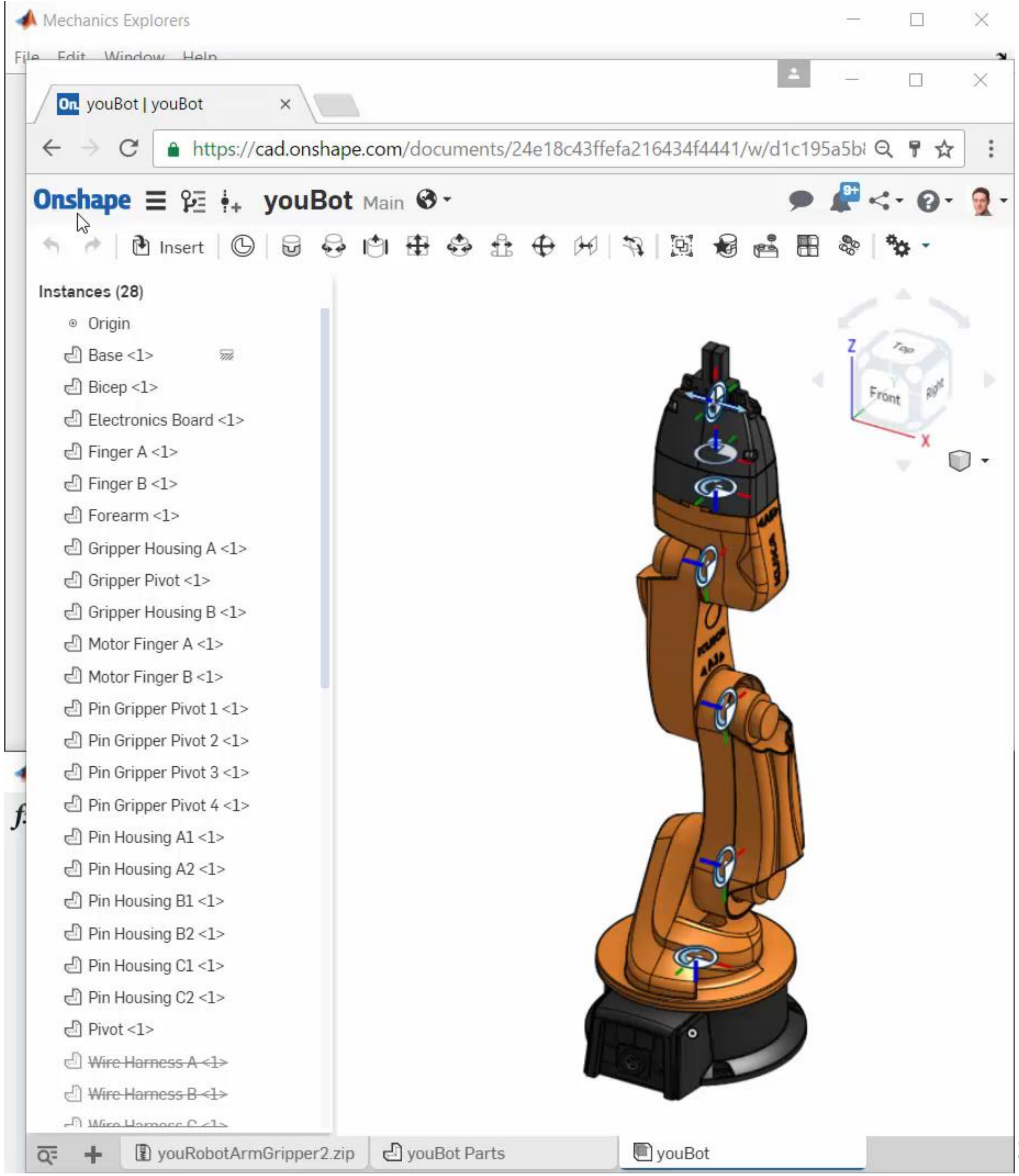


1. Import Model from CAD

- Convert CAD assembly to dynamic simulation model for use within Simulink
  - Mass, inertia, geometry, and joints



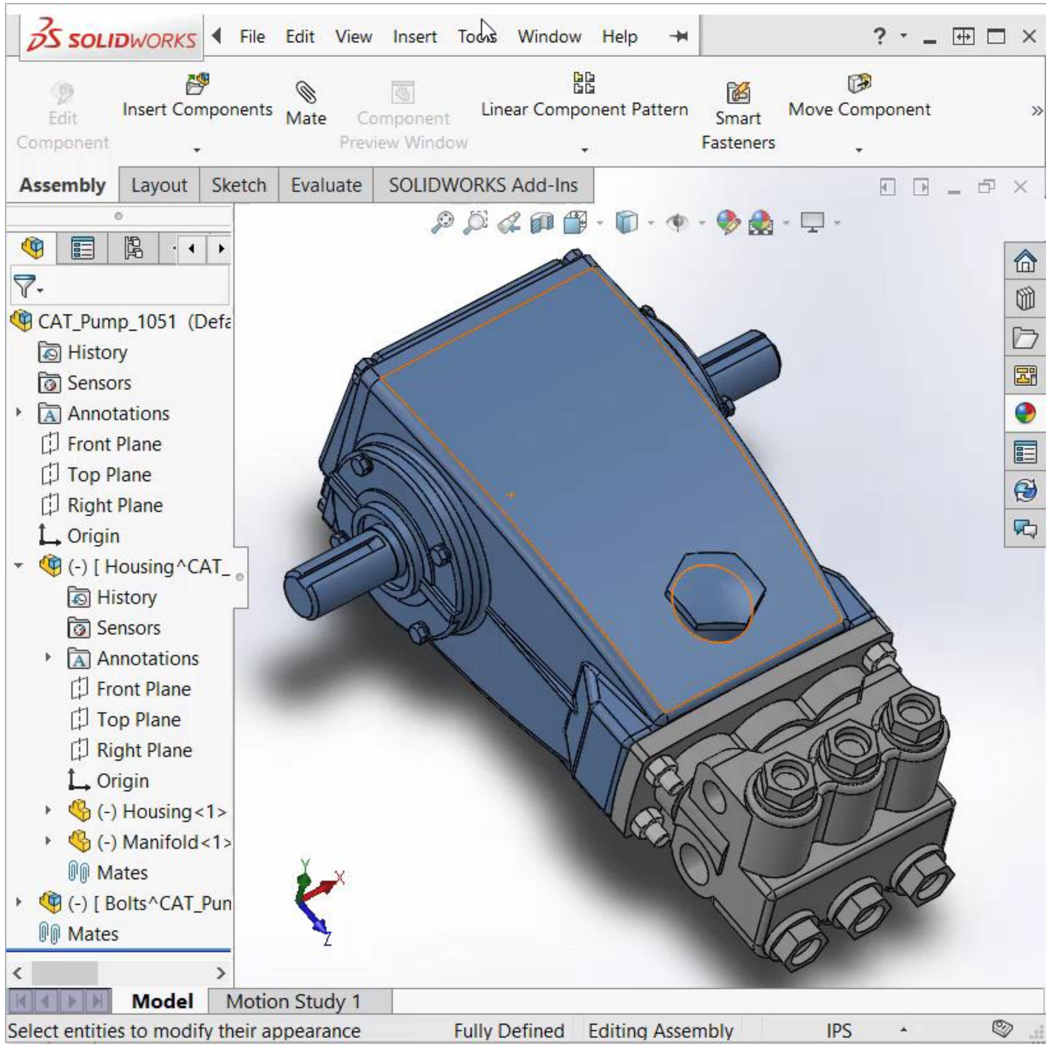




Simscape Multibody CAD Import

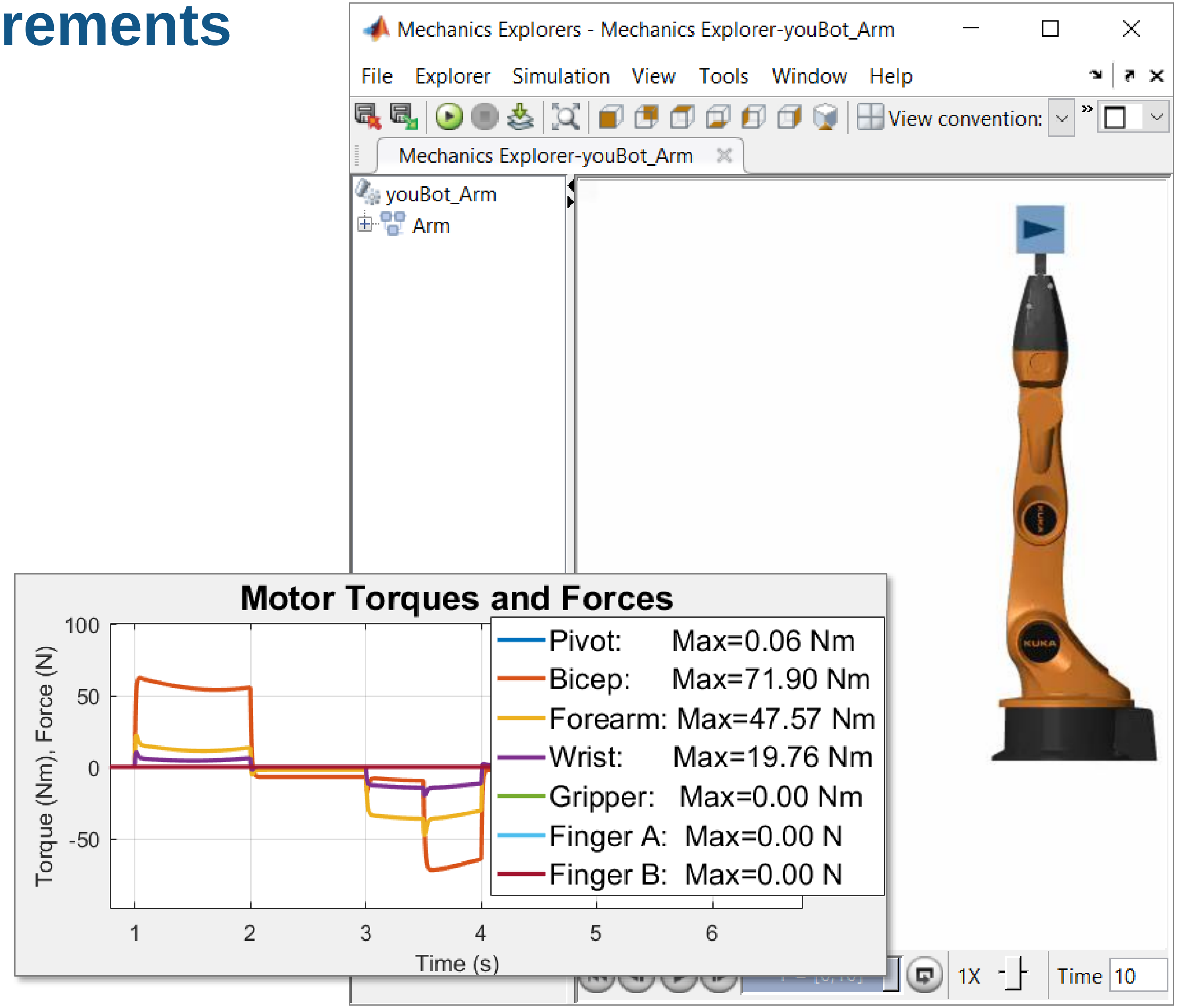
- Import CAD assemblies
  - Part definitions
  - Converts mate definitions to joints
  - SOLIDWORKS, Inventor, Onshape, and PTC Creo® (Pro/ENGINEER®)

- Import CAD Parts
  - CATIA, NX, SolidEdge, and others
  - STEP files



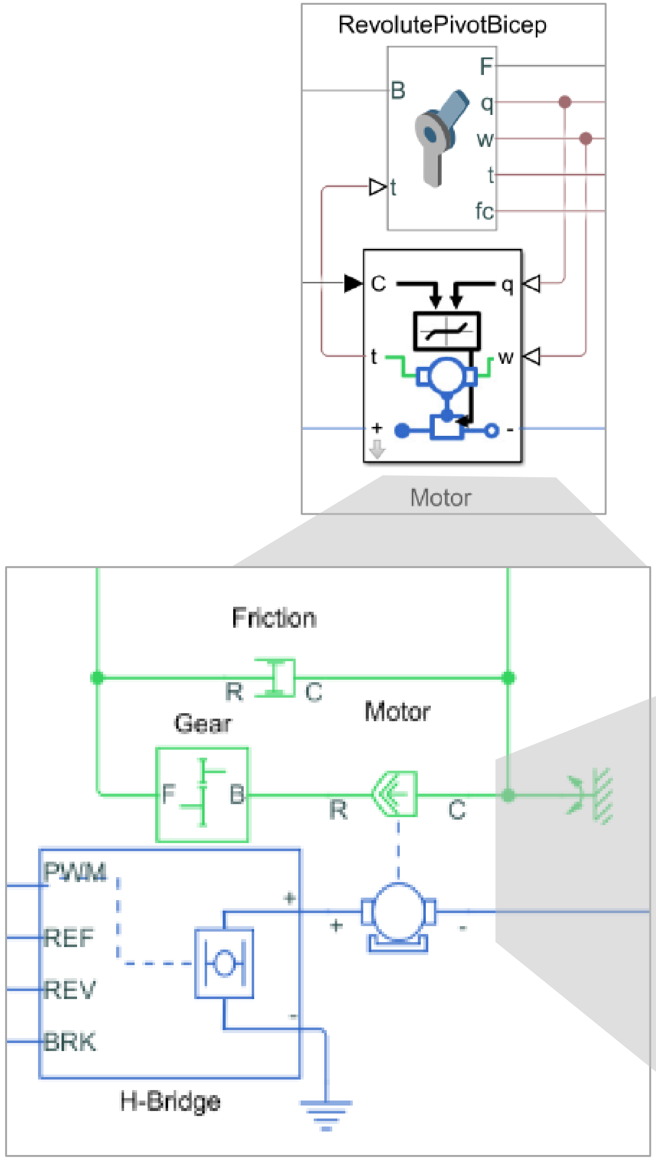
2. Determine Motor Requirements

- 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



3. Integrate Electrical Actuators

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



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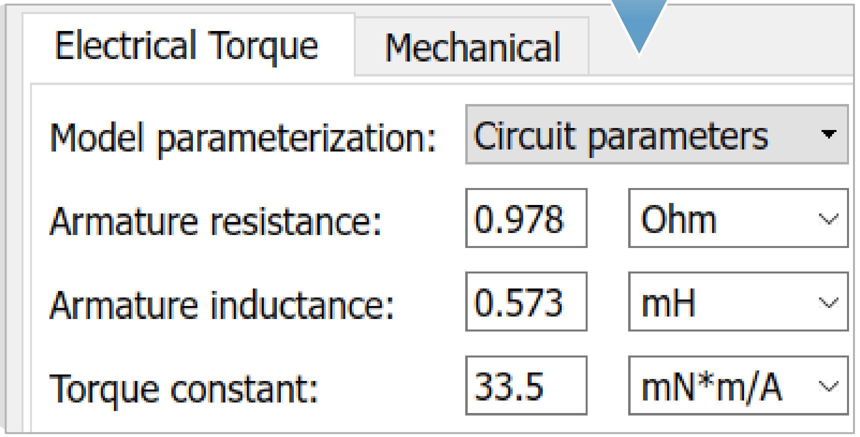
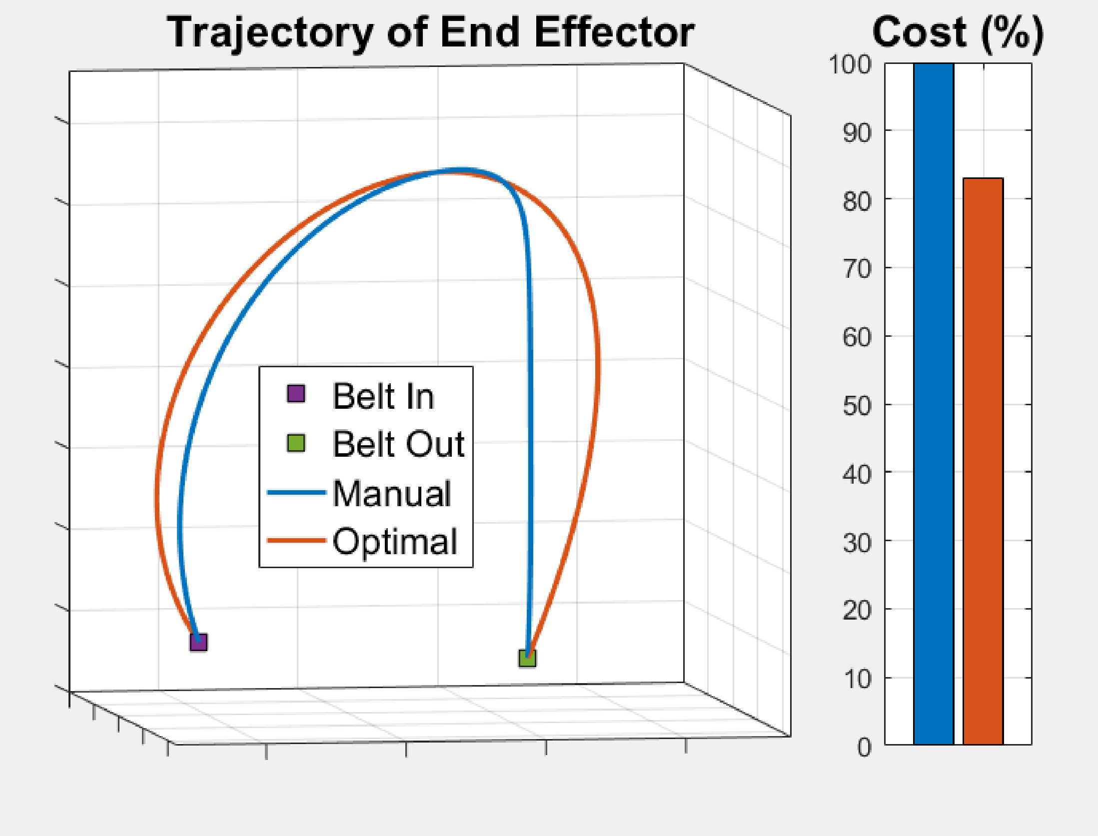
Motor Data		
Characteristics		
Terminal resistance	Ω	0.978
Terminal inductance	mH	0.573
Torque constant	mNm / A	33.5
Speed constant	rpm / V	285
Speed / torque gradient	rpm / mNm	8.32
Mechanical time constant	ms	11.8
Rotor inertia	gcm²	135



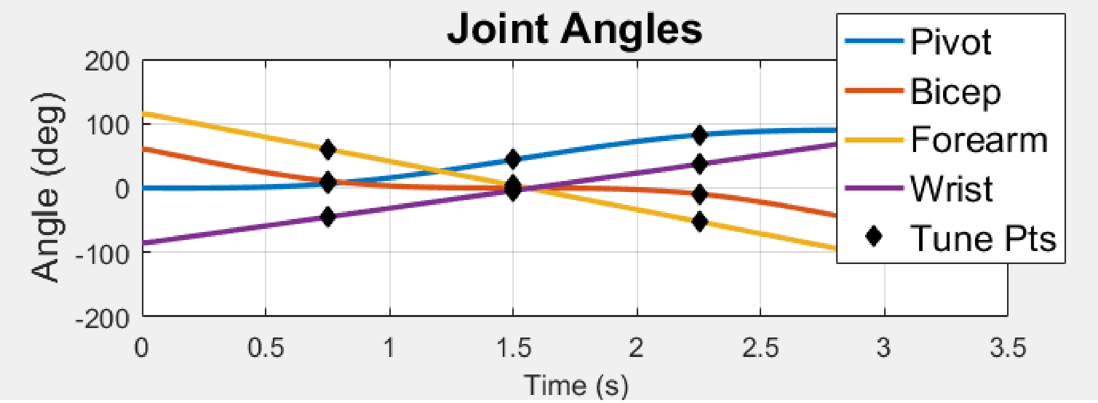
4. Minimize Power Consumption

Model:

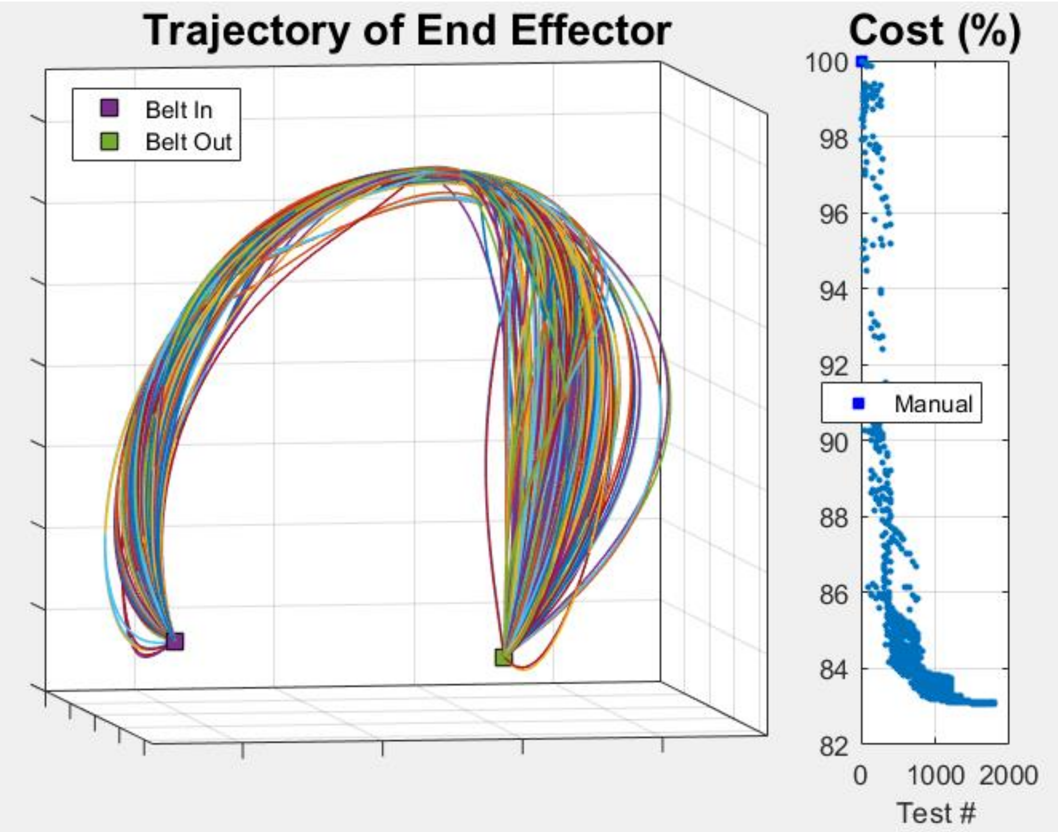


Challenge: Identify arm trajectory that minimizes power consumption.

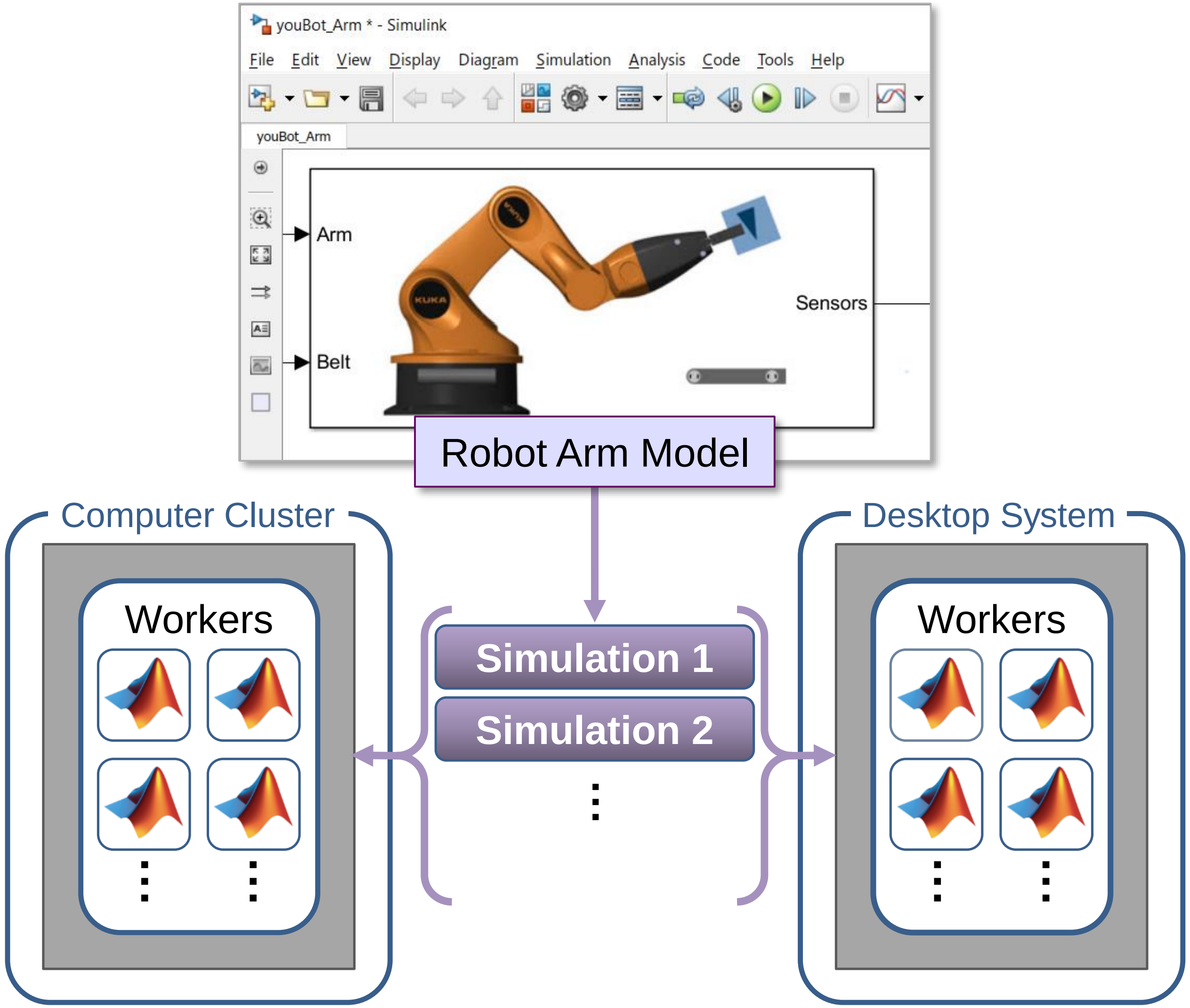
Solution: Use dynamic simulation to calculate power consumption, and use optimization algorithms to tune trajectory.



Accelerate Design Iterations Using Parallel Computing



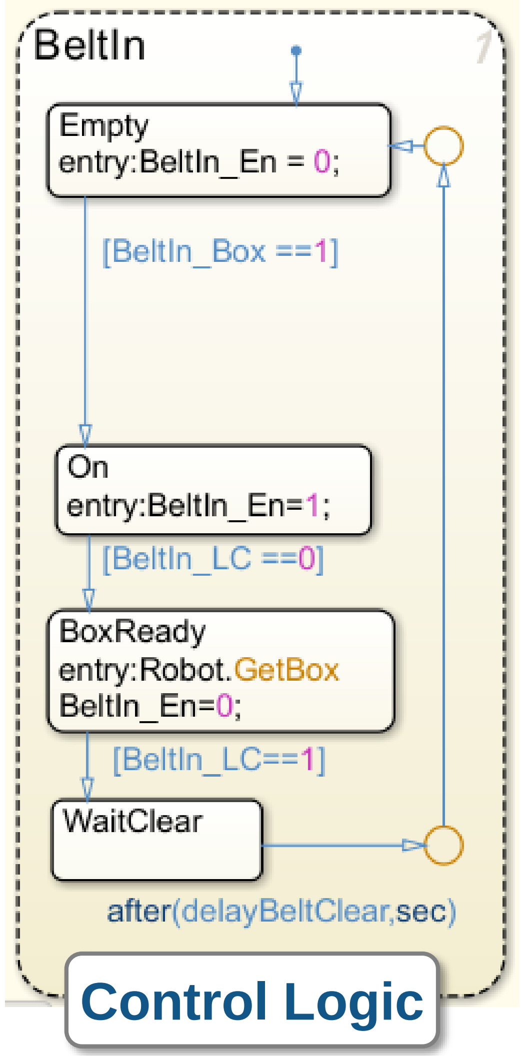
This optimization task required nearly 2000 simulations.

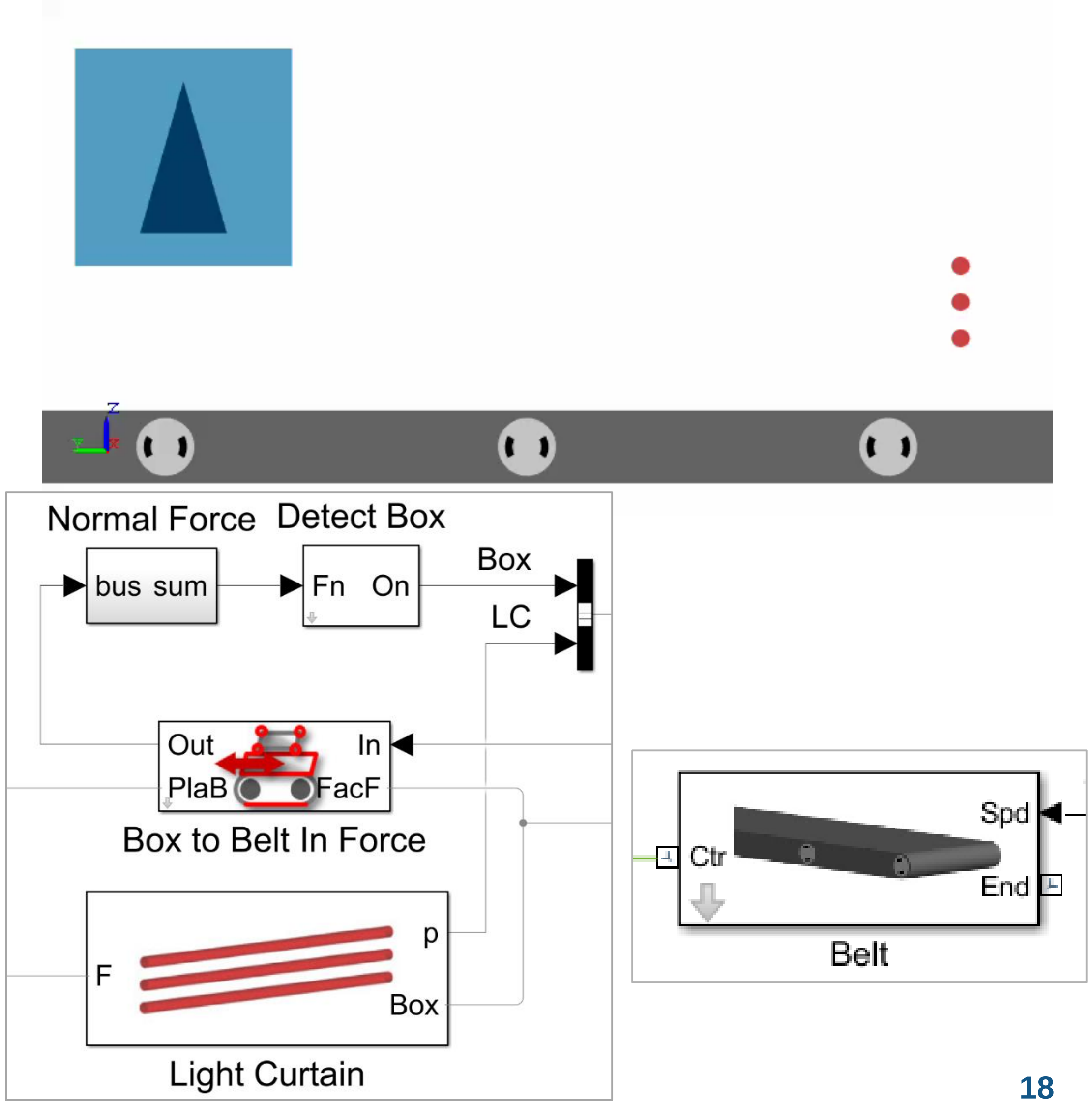


Running simulations in parallel speeds up your testing process.

5. Design Control Logic for Arm and Conveyor Belts

- Sense quantities within model that govern system events
- Design logic using a state chart
- Use outputs of logic to control models of system components





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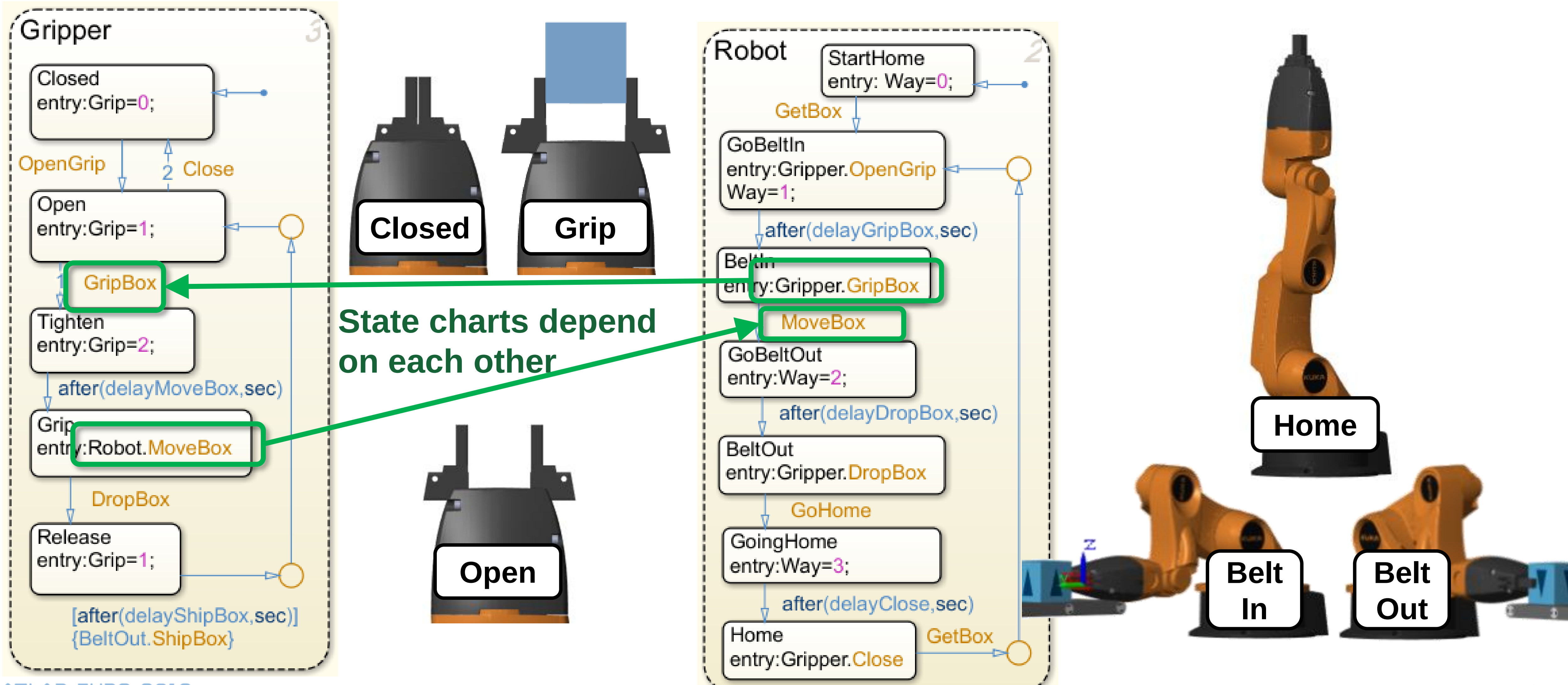

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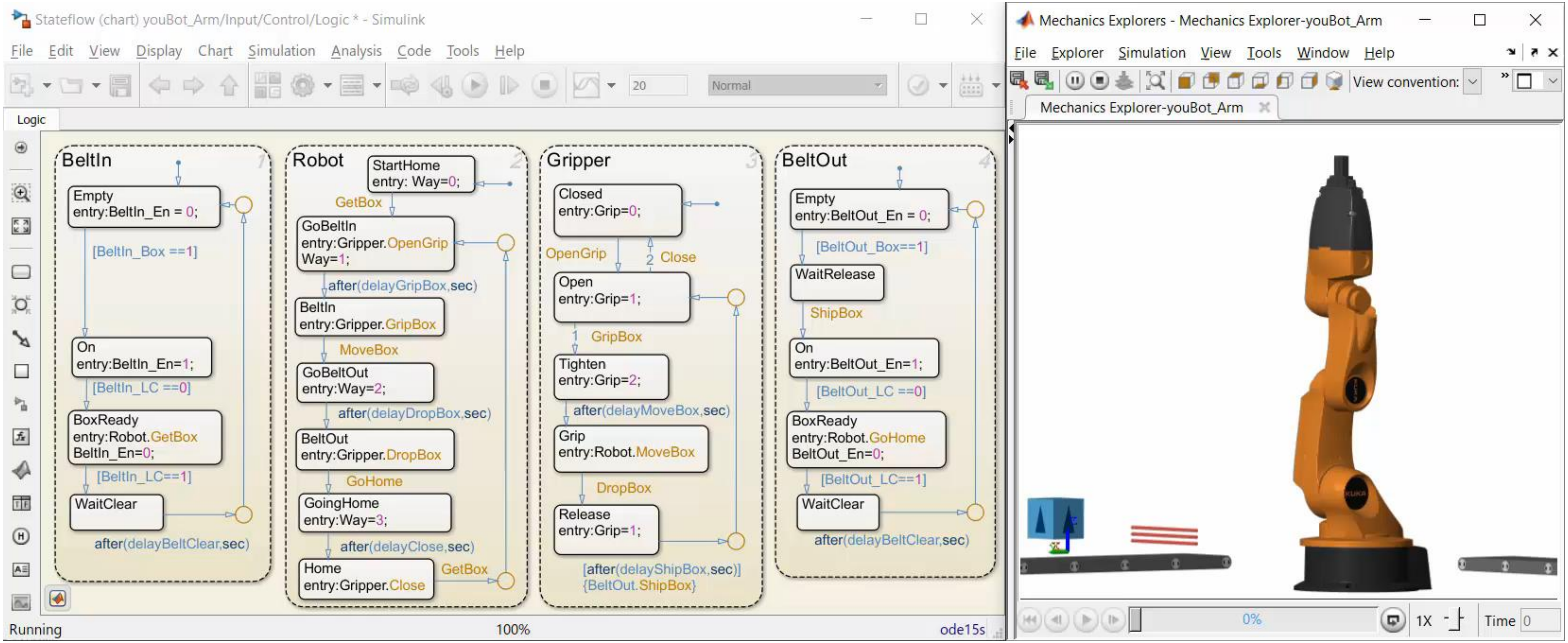


Test Production Control Software

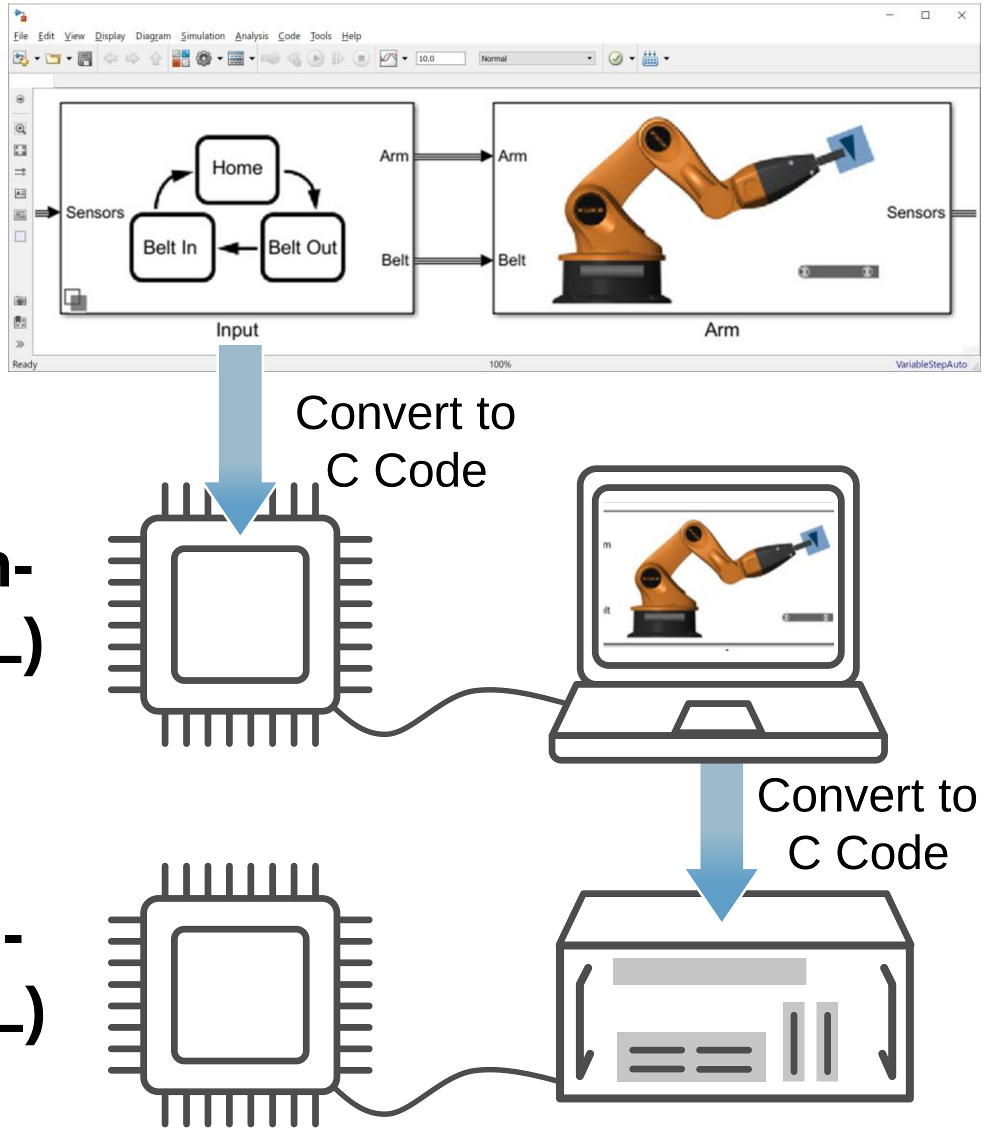
- Automatically convert algorithms to production code
  - C Code, IEC 61131-3 Code

- Incrementally test the effect of each conversion step
  - Fixed-point math
  - Latency on production controller

- Use the same plant model
  - Test without expensive hardware prototypes

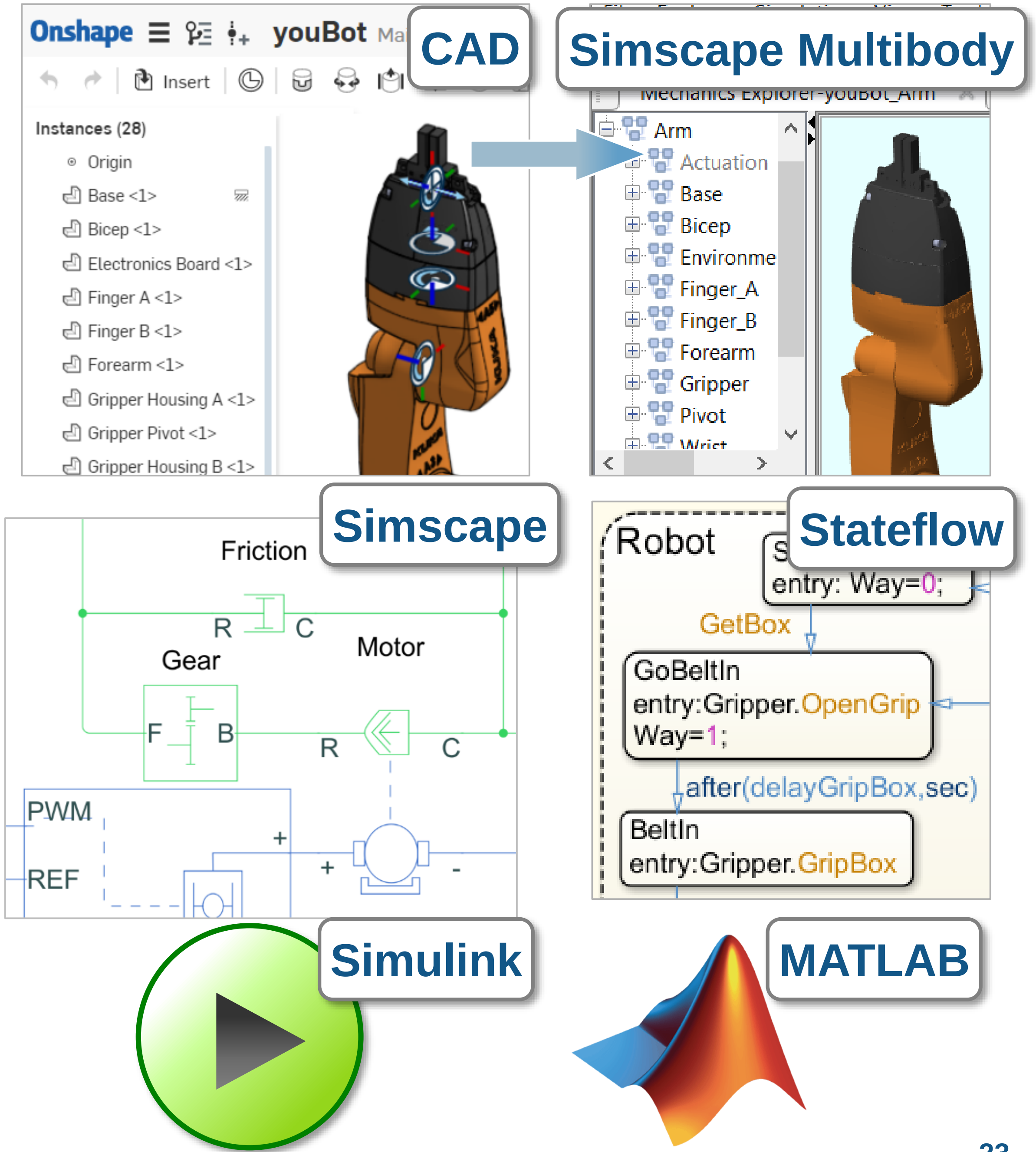
Processor-in-the-Loop (PIL)

Hardware-in-the-Loop (HIL)



How we did it

- Convert CAD assemblies into dynamic simulation models with **Simscape Multibody**
- Add electric actuators with **Simscape** and control logic using **Stateflow**
- Optimize system using **MATLAB**
- Perform dynamic simulation in **Simulink**



Summary

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- Results:
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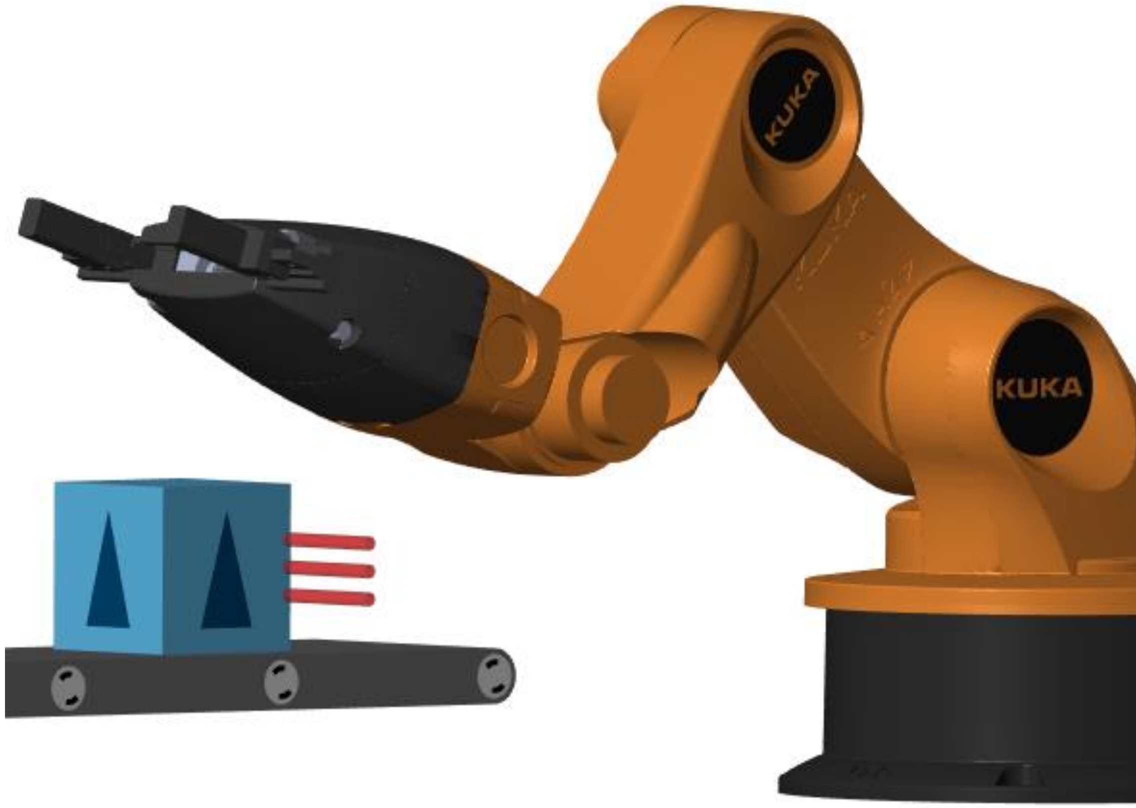

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Modeling Physical Systems with Simscape

- Create models in various physical domains
- Combine Simulink and Simscape models
- Model energy transfer between different physical domains
- Create user-defined Simscape components

Thank You

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