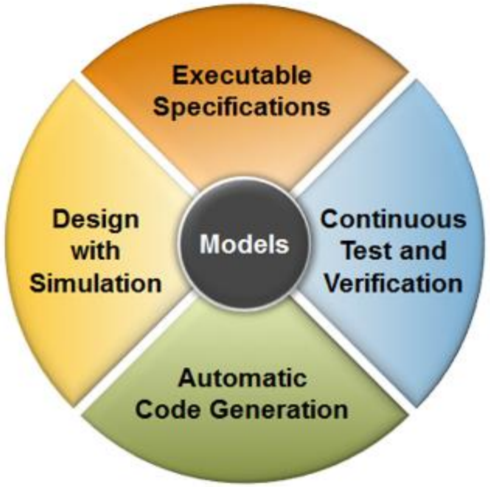
Physical Modeling as Enabler for Simulation-Based Design

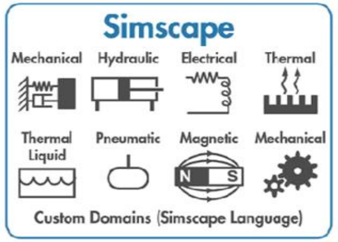
NORDIC
MATLAB EXPO 2016
21 April | Stockholm

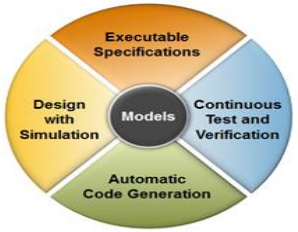


April 21st 2016 – Waterfront Congress Center (Stockholm)

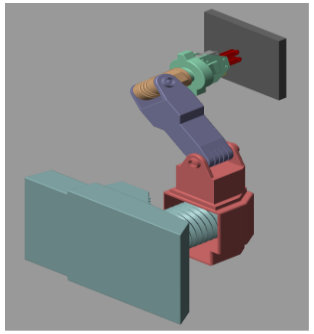
Agenda

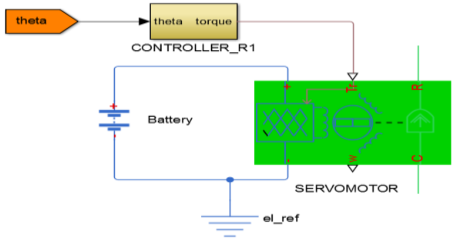
1. Physical modeling (simulation-based design)



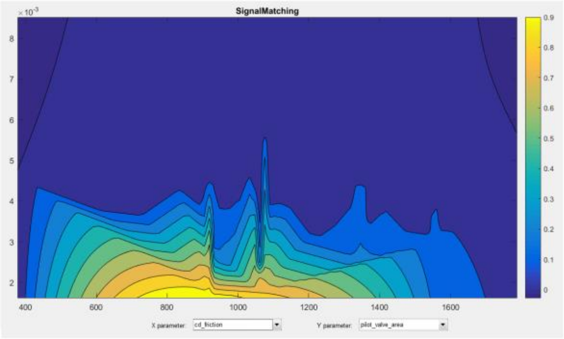


2. Mechatronic design workflow



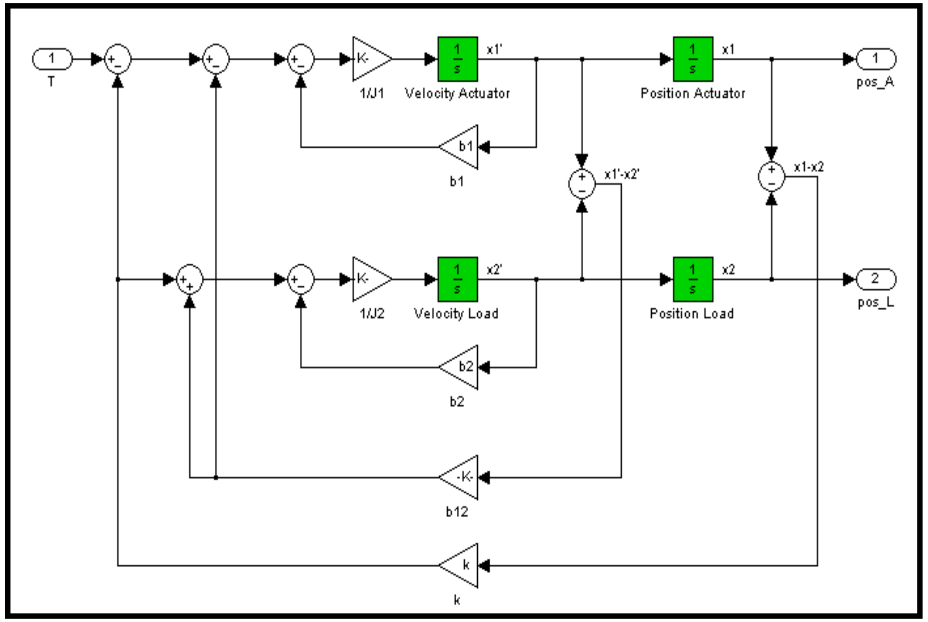


3. Design optimization



4. Conclusions

First Principles Modeling

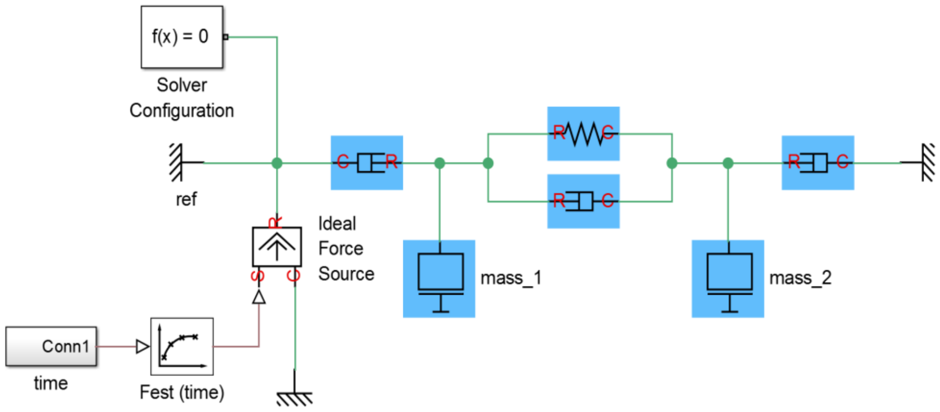


First principles (Simulink)

- ❑ suitable for simple systems
- ❑ common during 90s

Differential algebraic equations created manually (blocks)

Physical Modeling



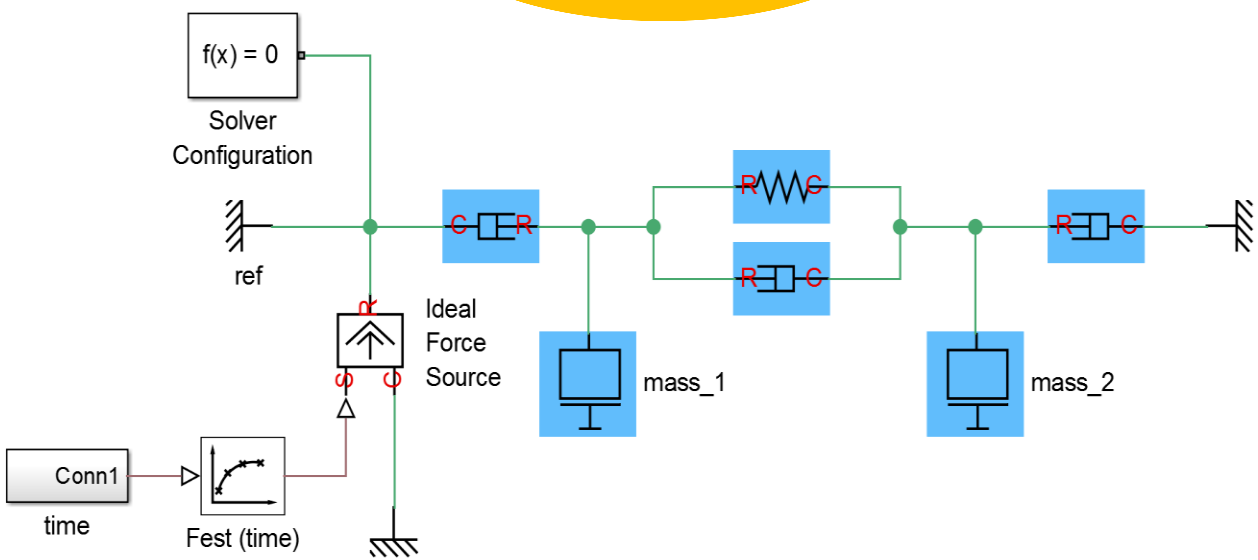
Physical Networks (Simscape)

- ❑ complexity & multi-domain
- ❑ solver flexibility (testing)
- ❑ proven (automotive, aerospace)
- ❑ high priority development

Differential algebraic equations automatically created (topology)

Physical Networks (Simscape)

scalability
re-usability



Physical Modeling (requirements)

system design
(integration, optimization)

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system design
(integration, optimization)

development of
control algorithms

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system design
(integration, optimization)

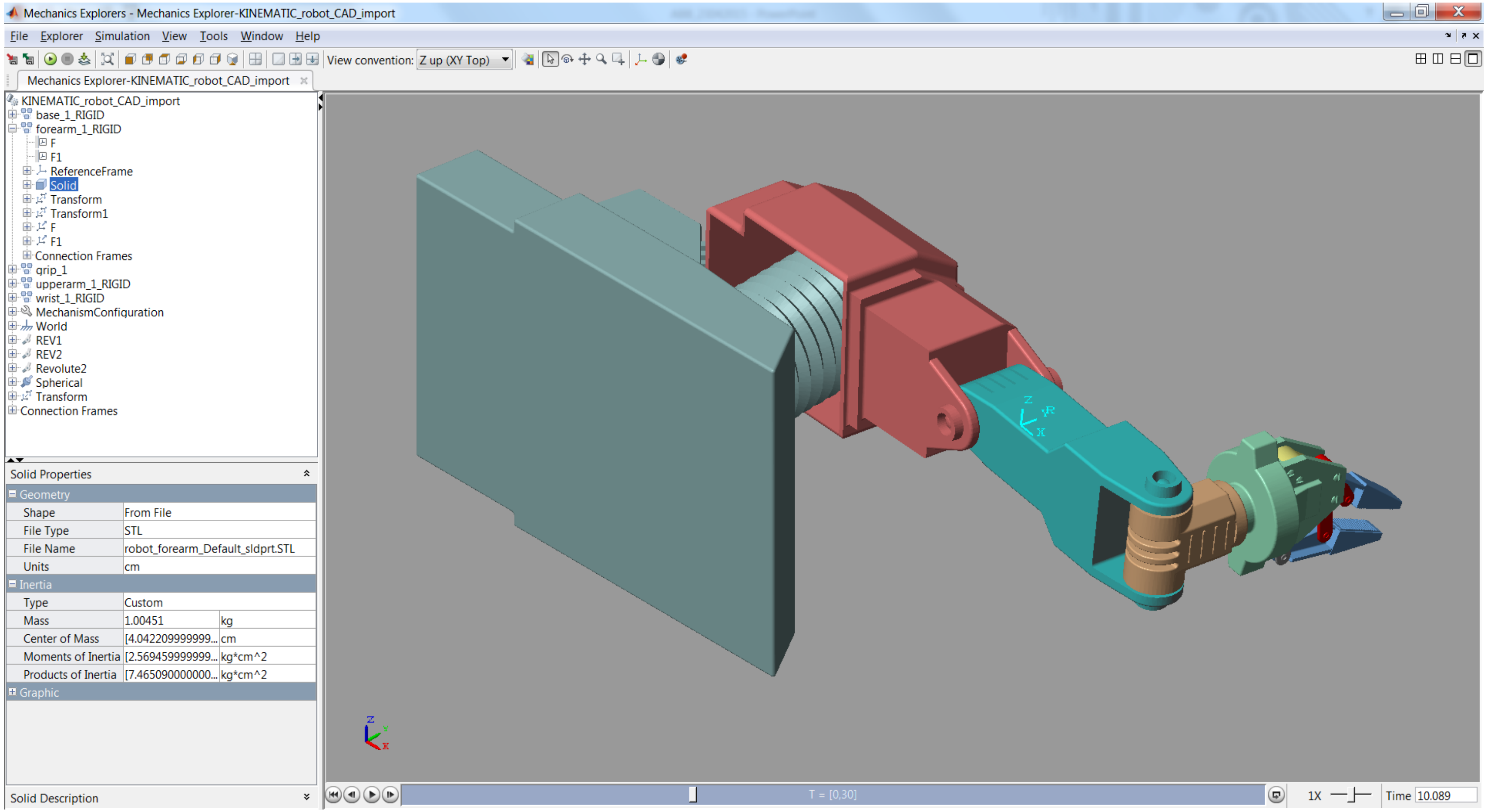
development of
control algorithms

hardware-based
physical emulation
(real-time testing)

Mechatronic Design (recommended workflow)

Mechatronic design – step 1

1. CAD import => 3D mechanical systems in Simulink



Mechatronic design – step 2

2. Kinematic Analysis

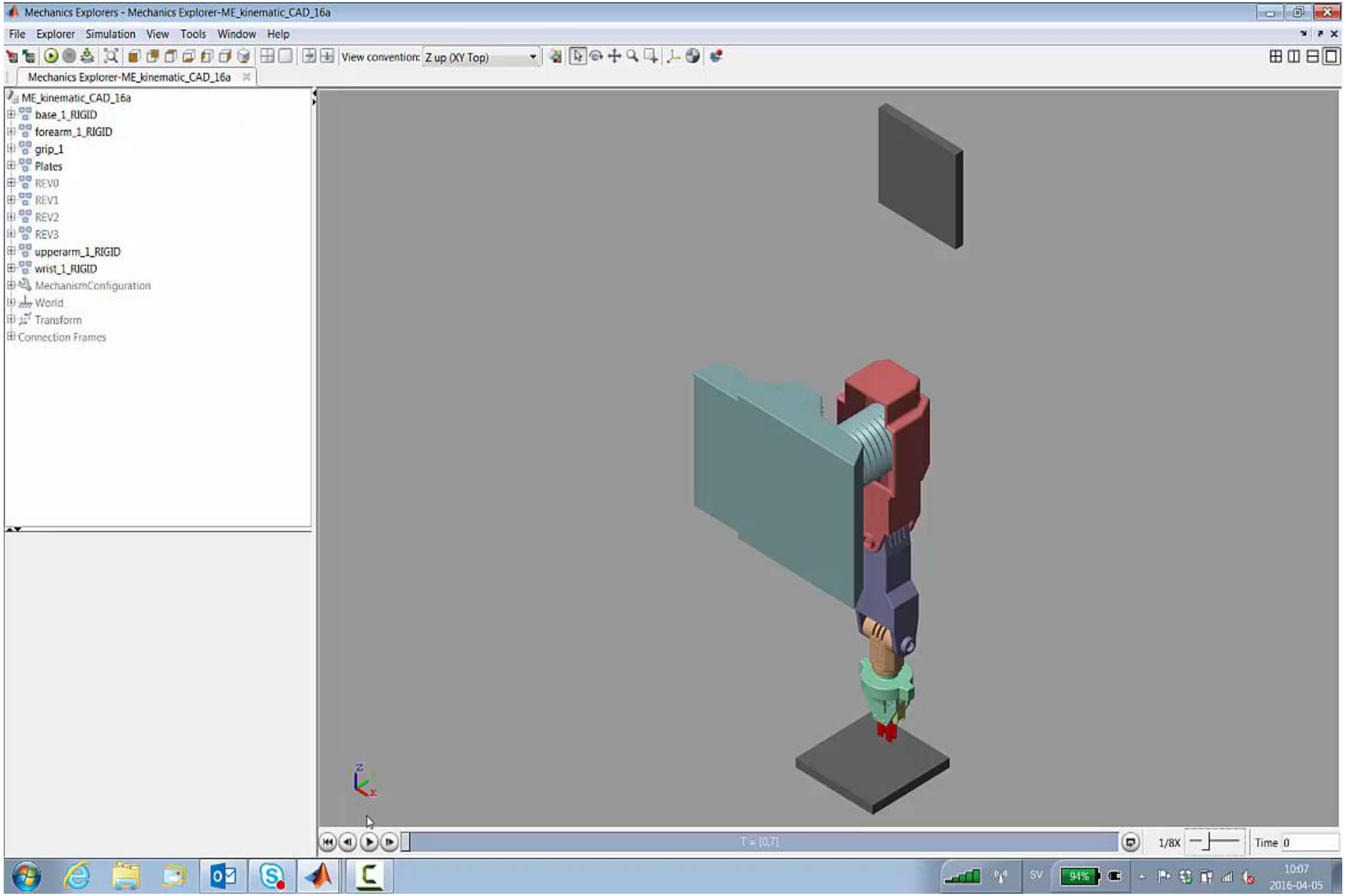
- imposition of a given kinematic movement (duty cycle)
- evaluation of required torque/forces

Mechatronic design – step 3

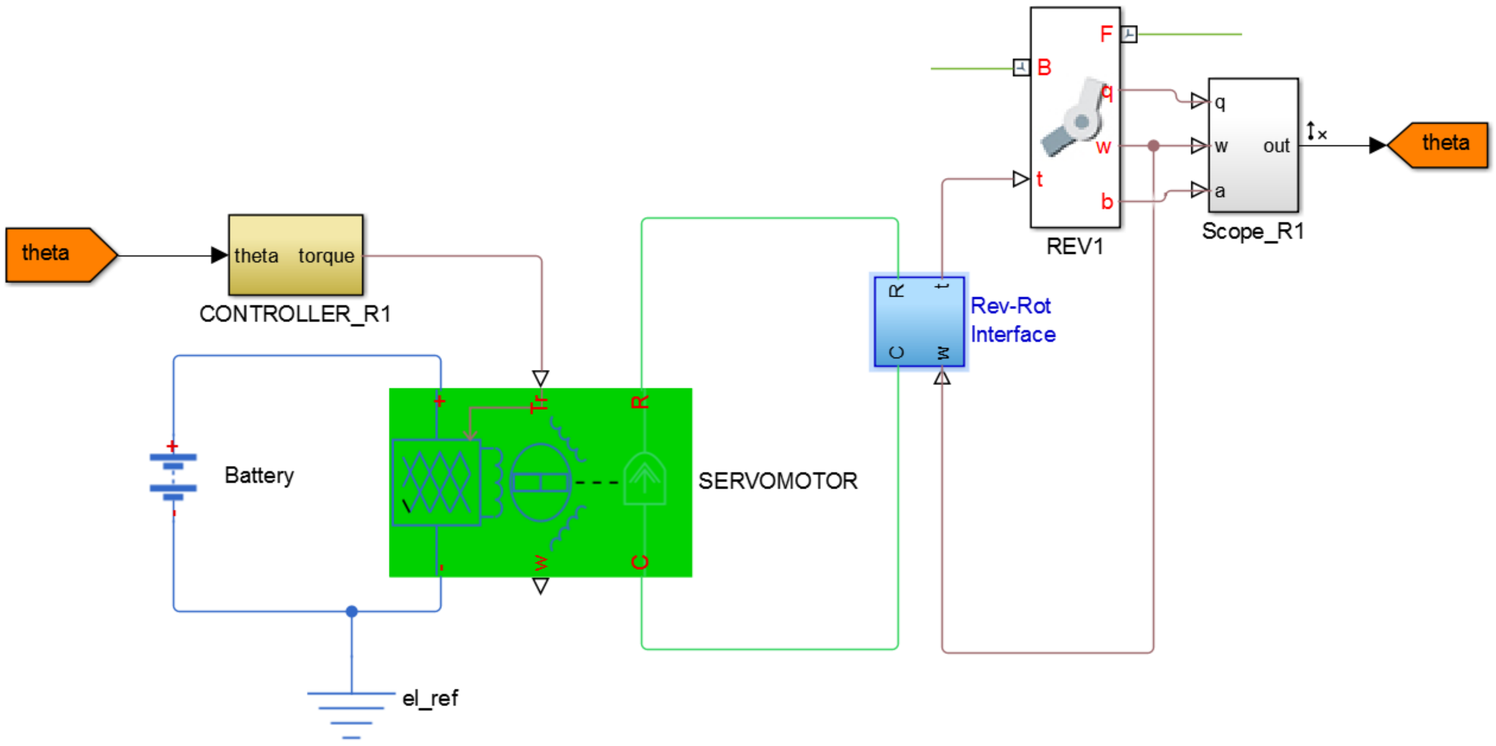
demo

3. Dynamic Analysis

- ❑ closed-loop motion control
- ❑ application of torque and/or force
- ❑ control design (tuning, stability ….)


Mechanics Explorers - Mechanics Explorer-ME_kinematic_CAD_16a
File Explorer Simulation View Tools Window Help
View convention: Z up (XY Top)
Mechanics Explorer-ME_kinematic_CAD_16a
ME_kinematic_CAD_16a
base_1_RIGID
forearm_1_RIGID
grip_1
Plates
REV0
REV1
REV2
REV3
upperarm_1_RIGID
wrist_1_RIGID
MechanismConfiguration
World
Transform
Connection Frames
T = [0,7]
1/8X
Time 0

Mechatronic design – step 4

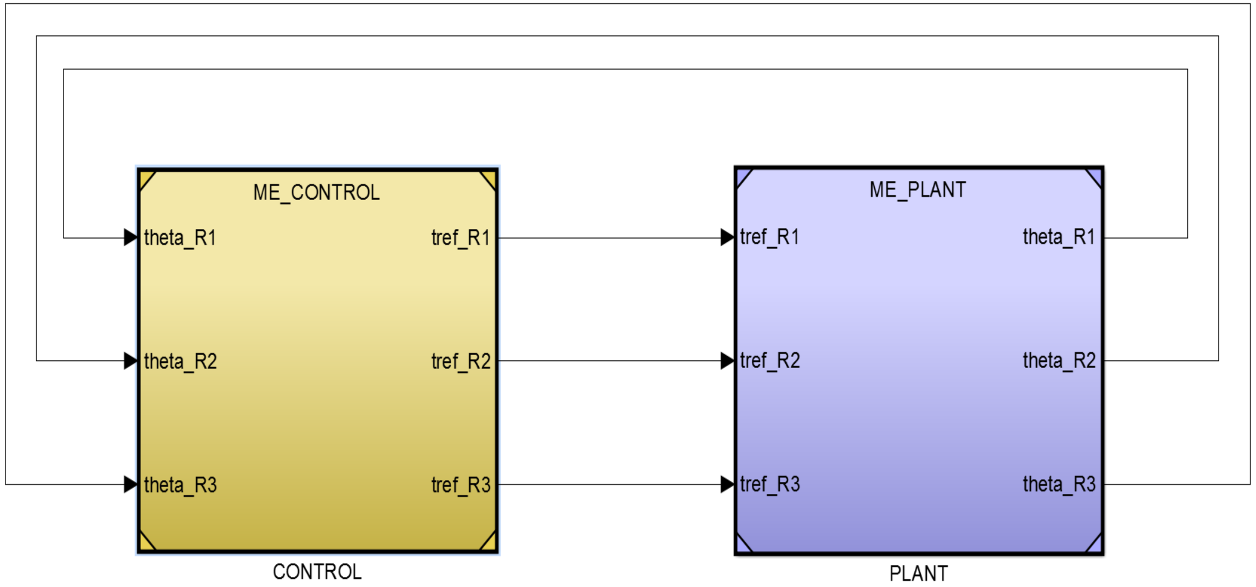


4. Actuator Design

- ❑ selection of actuator (PMSM, brushless…)
- ❑ optimal sizing (avoid overdimensioning)
- ❑ electric effects (network, battery, energy consumption…)

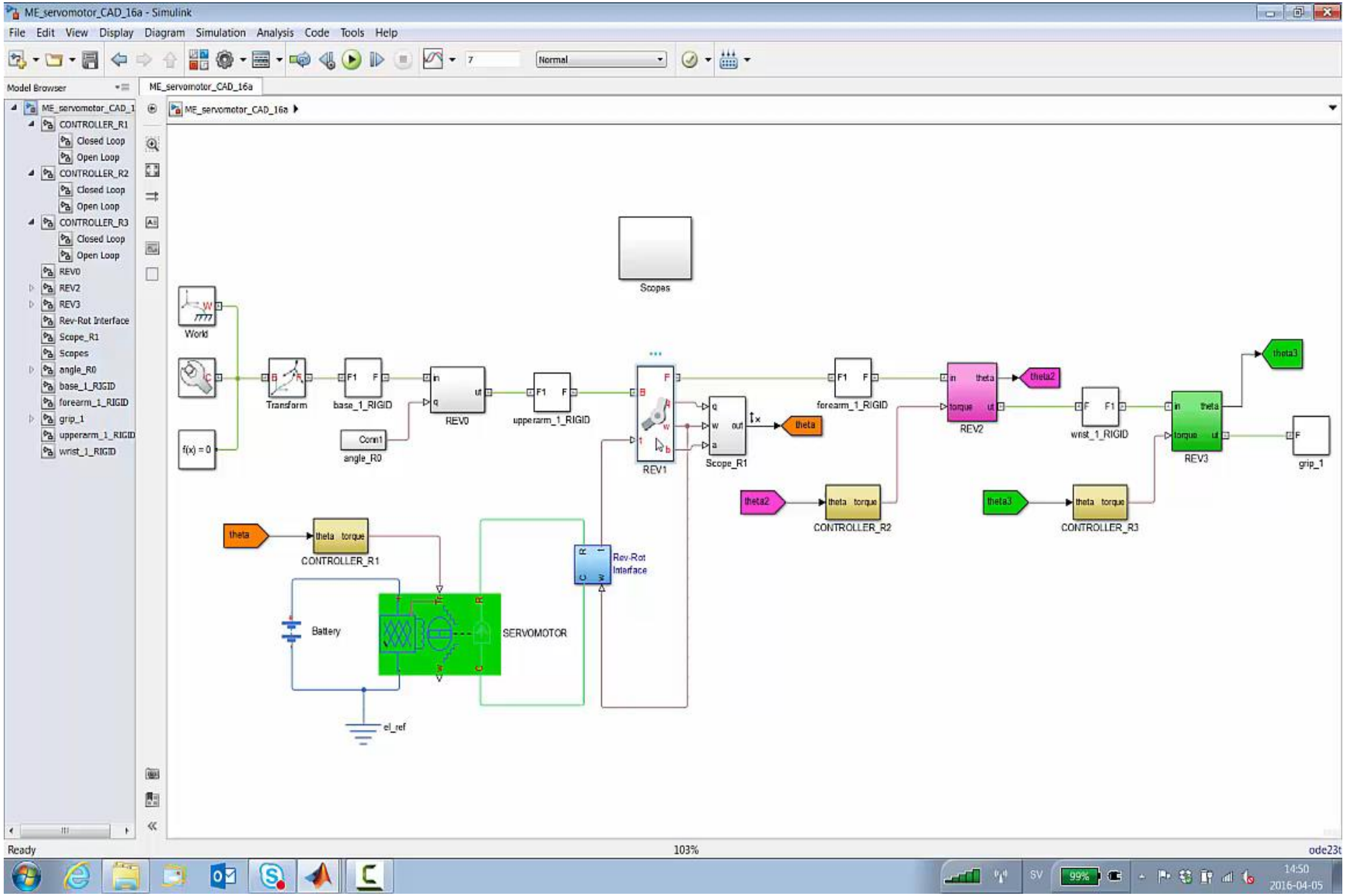
Mechatronic design – step 5

demo



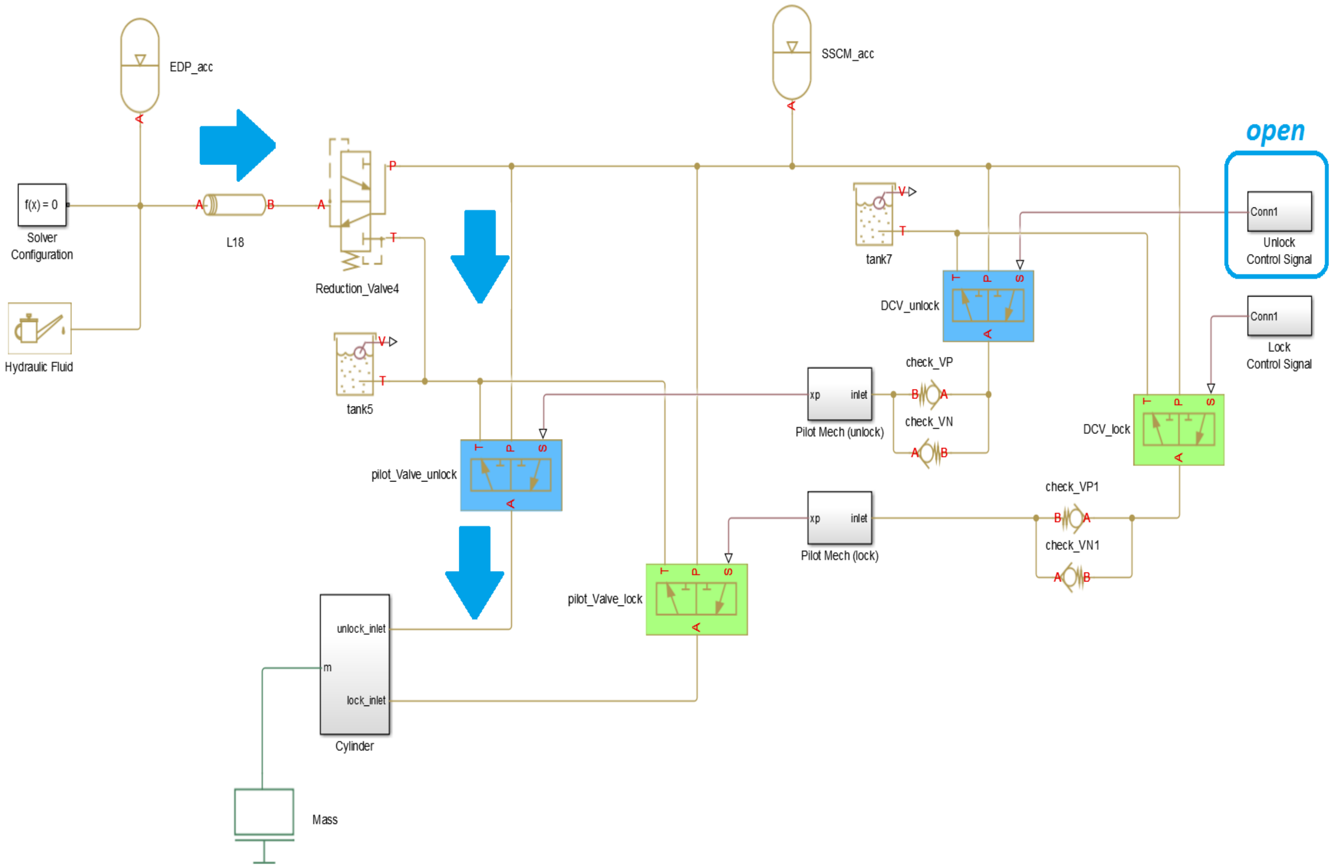
5. Model re-use for real-time testing

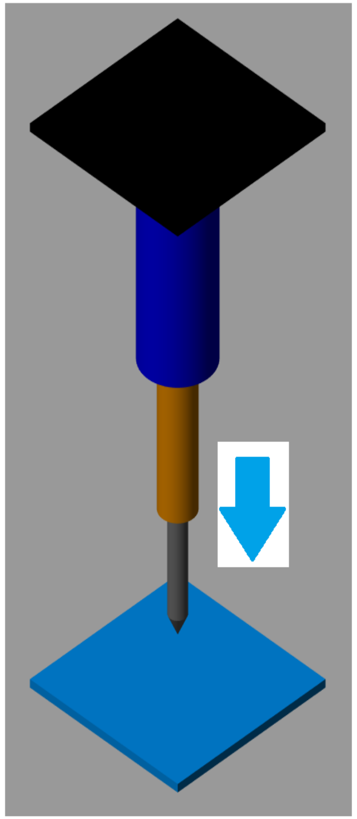
- ❑ discretization [solver, sample time]
- ❑ benchmark [fidelity vs. speed]
- ❑ code generation


ME_servomotor_CAD_16a - Simulink
File Edit View Display Diagram Simulation Analysis Code Tools Help
Model Browser
ME_servomotor_CAD_16a
CONTROLLER_R1
Closed Loop
Open Loop
CONTROLLER_R2
Closed Loop
Open Loop
CONTROLLER_R3
Closed Loop
Open Loop
REV0
REV2
REV3
Rev-Rot Interface
Scope_R1
Scopes
angle_R0
base_1_RIGID
forearm_1_RIGID
grip_1
upperarm_1_RIGID
wrist_1_RIGID
Scopes
World
Transform
base_1_RIGID
REV0
upperarm_1_RIGID
angle_R0
REV1
Scope_R1
theta
forearm_1_RIGID
REV2
theta2
wrist_1_RIGID
REV3
theta3
grip_1
CONTROLLER_R1
CONTROLLER_R2
CONTROLLER_R3
Battery
SERVOMOTOR
Rev-Rot Interface
el_ref
Ready
103%
ode23t

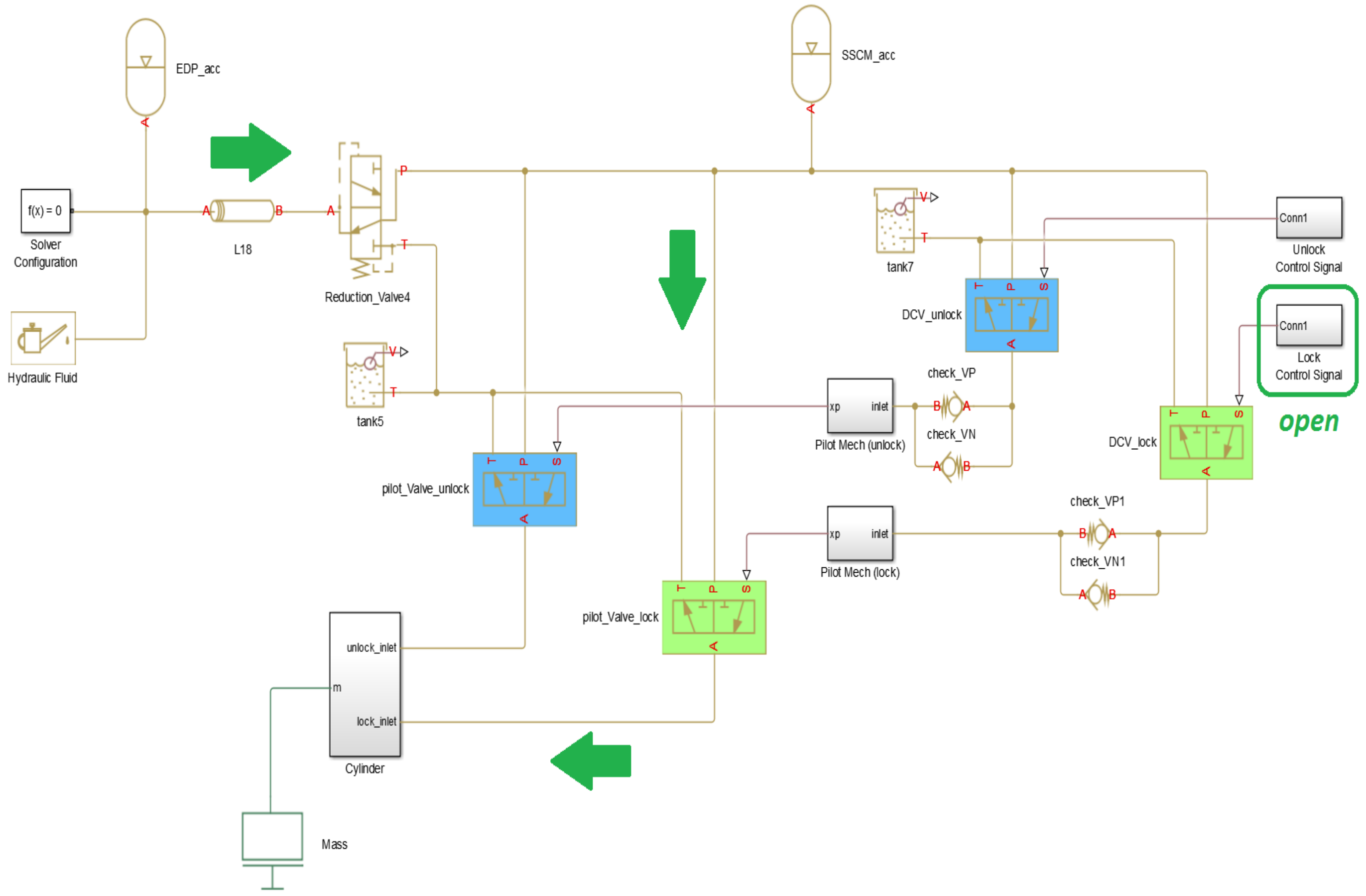
Design Optimization (based on physical model)

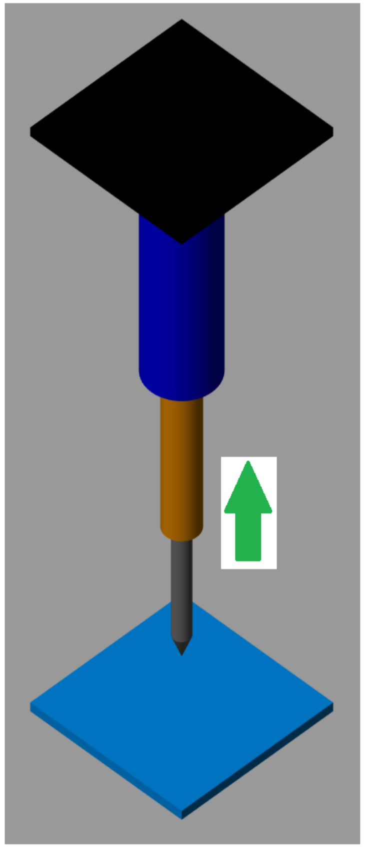
Hydro-mechanic drill mechanism (unlock)





Hydro-mechanic drill mechanism (lock)

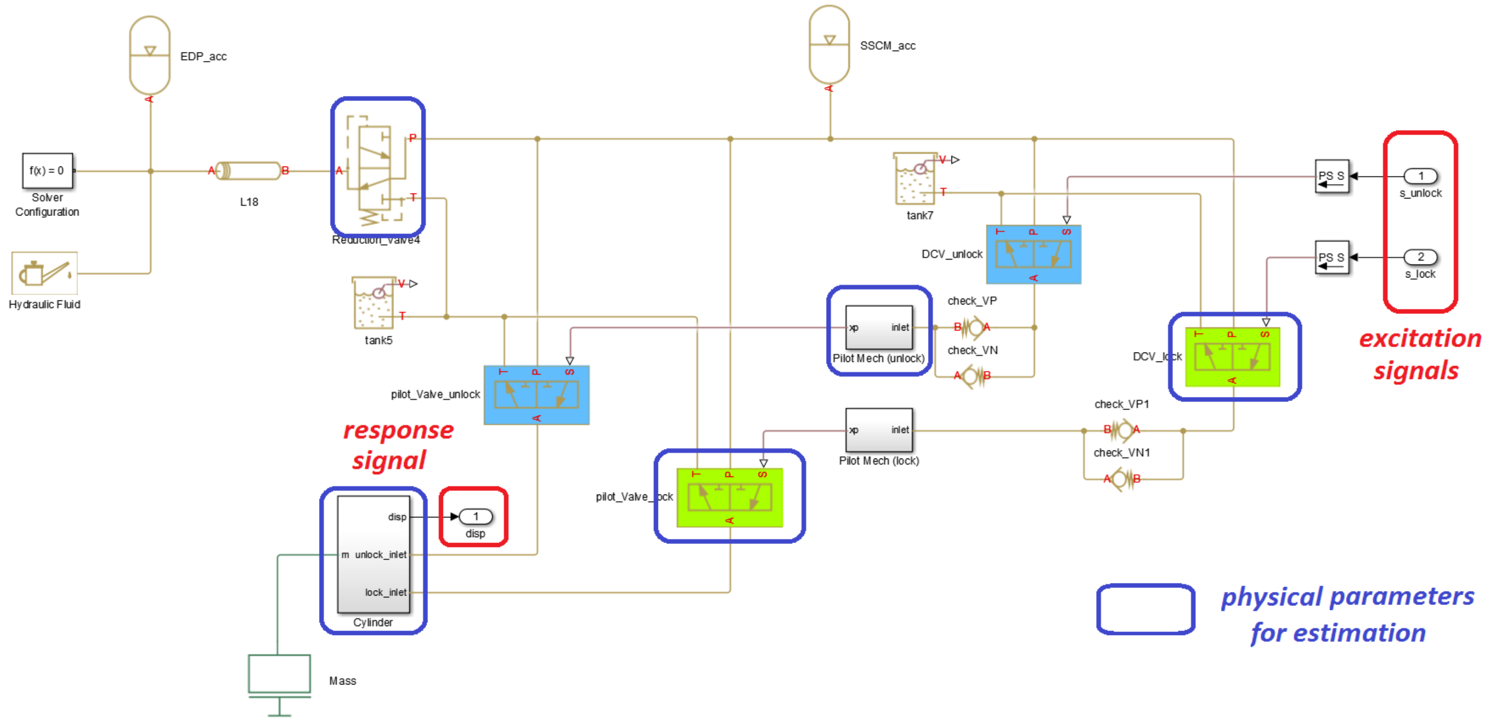




Design Optimization – task 1

1. Parameter Estimation (calibration)

- ❑ measurement signals to MATLAB workspace
- ❑ optimization-based method (iterative execution)

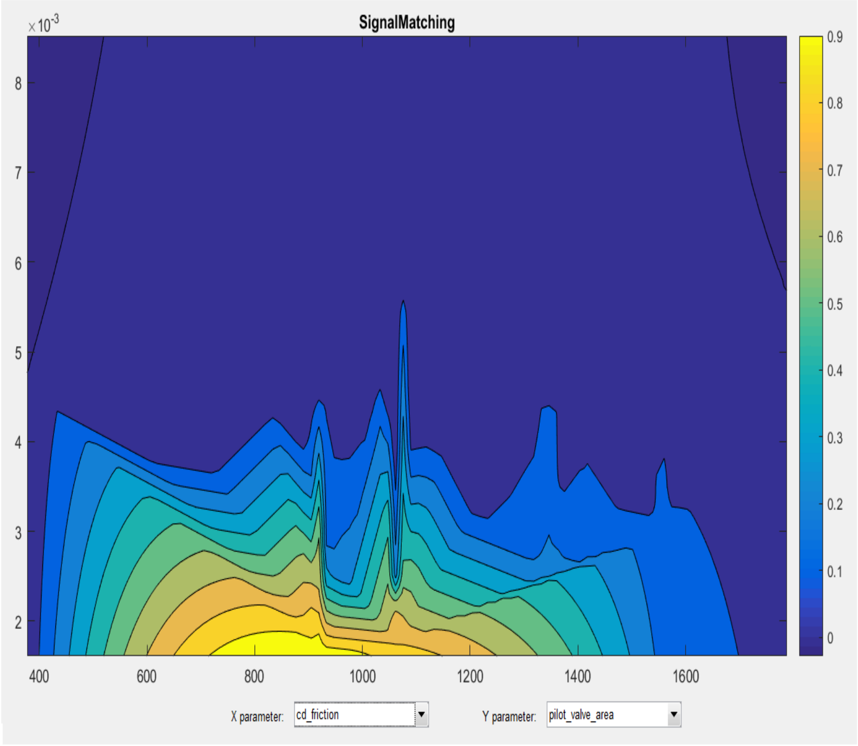


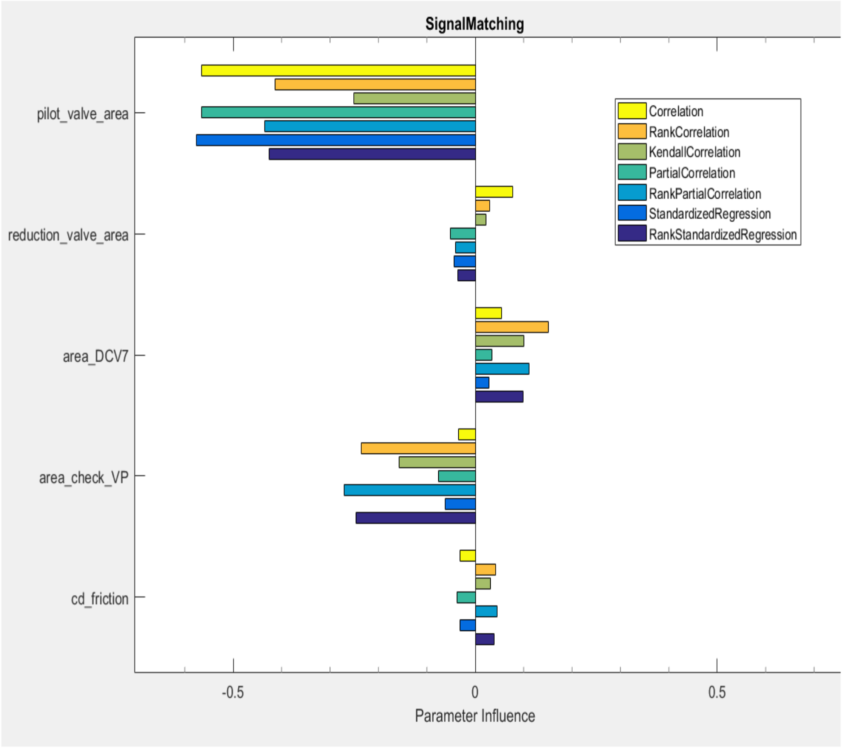
Design Optimization – task 2

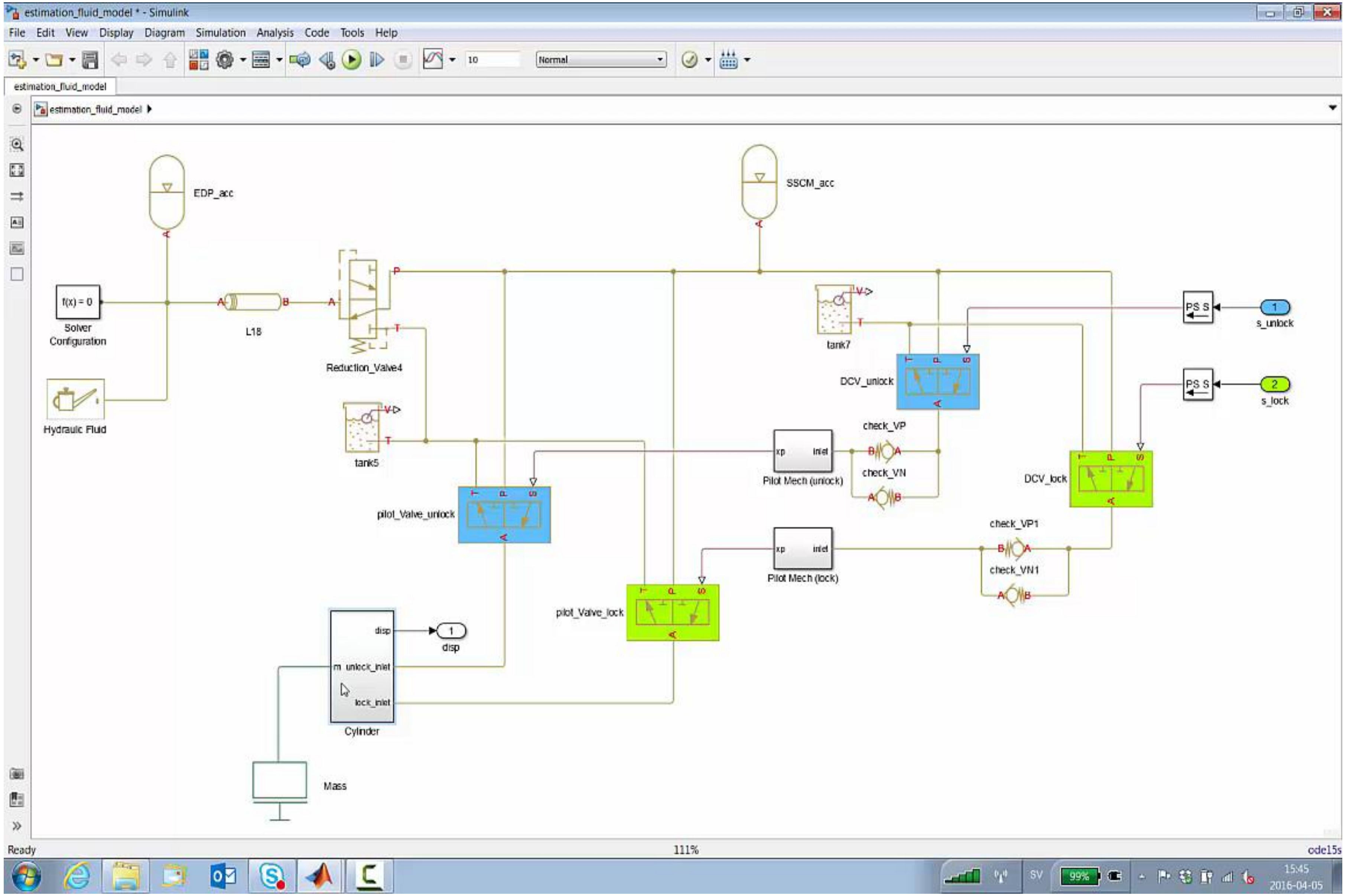
2. Sensitivity Analysis (system insight)

- ❑ parameter sweep [MATLAB scripting]
- ❑ statistic methods [formal & systematic]

demo



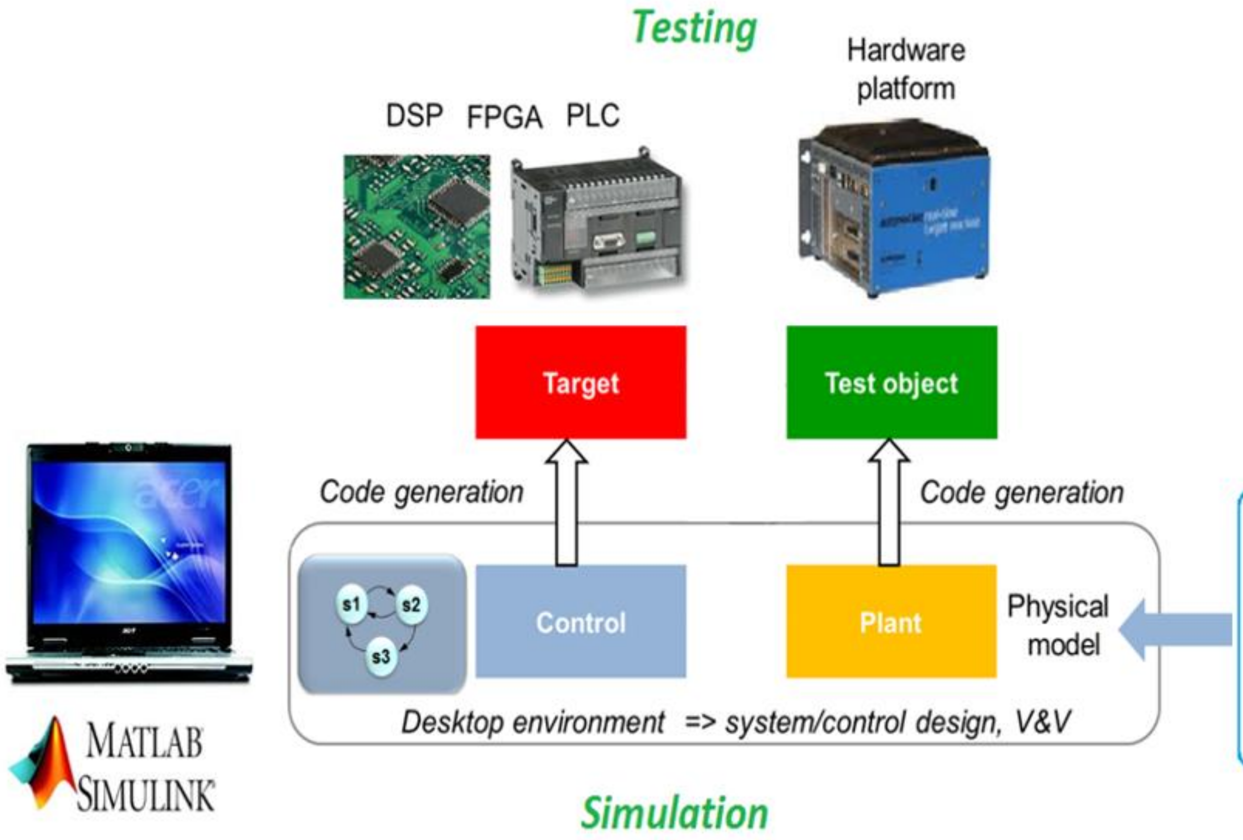




estimation_fluid_model * - Simulink
File Edit View Display Diagram Simulation Analysis Code Tools Help
EDP_acc
SSCM_acc
f(x) = 0
Solver Configuration
L18
Reduction_Valve4
Hydraulic Fluid
tank5
tank7
DCV_unlock
DCV_lock
check_VP
check_VN
check_VP1
check_VN1
Pilot Mech (unlock)
Pilot Mech (lock)
pilot_Valve_unlock
pilot_Valve_lock
s_unlock
s_lock
disp
Cylinder
Mass
Ready
111%
ode15s

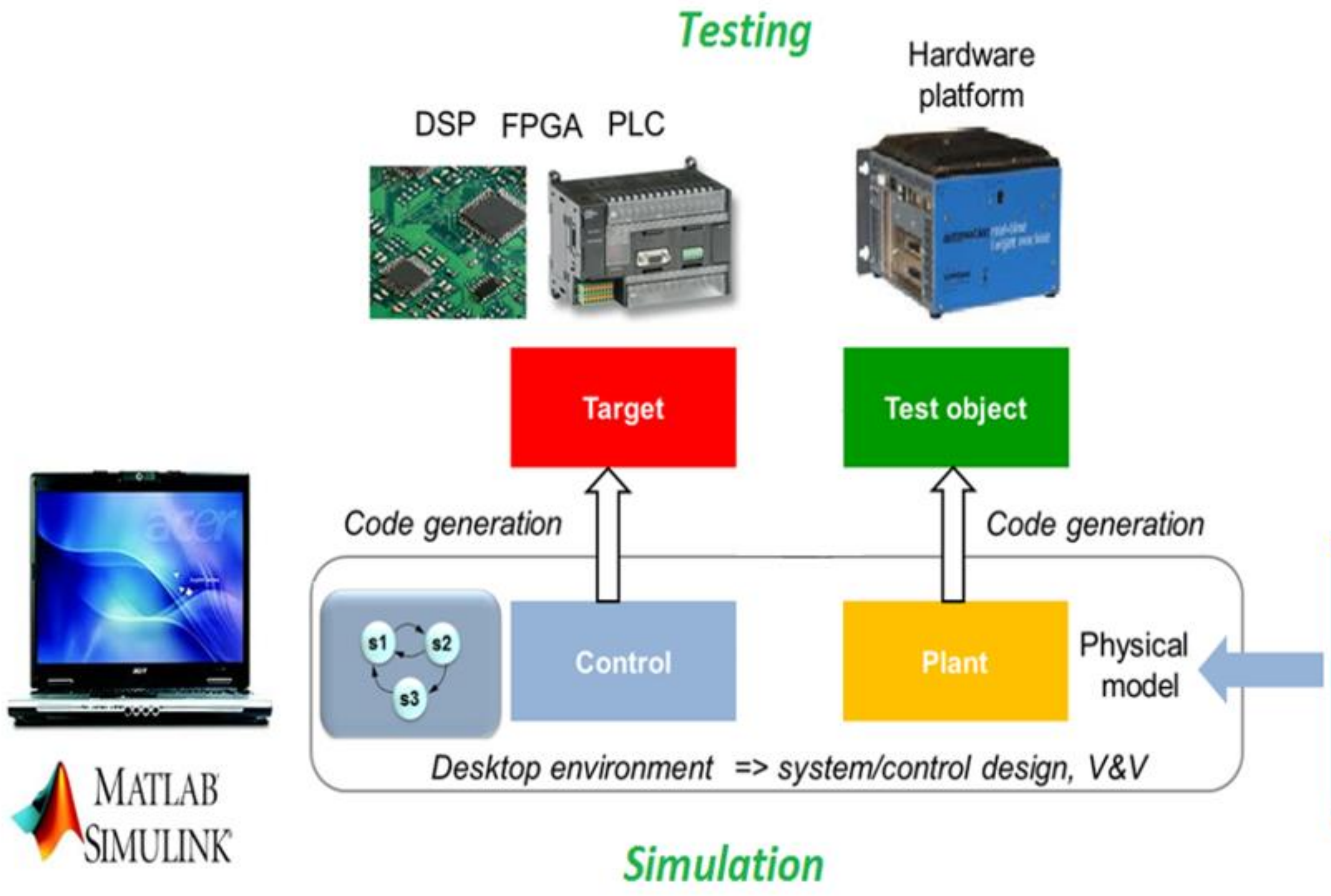
Conclusions

Simulation-based Design = System



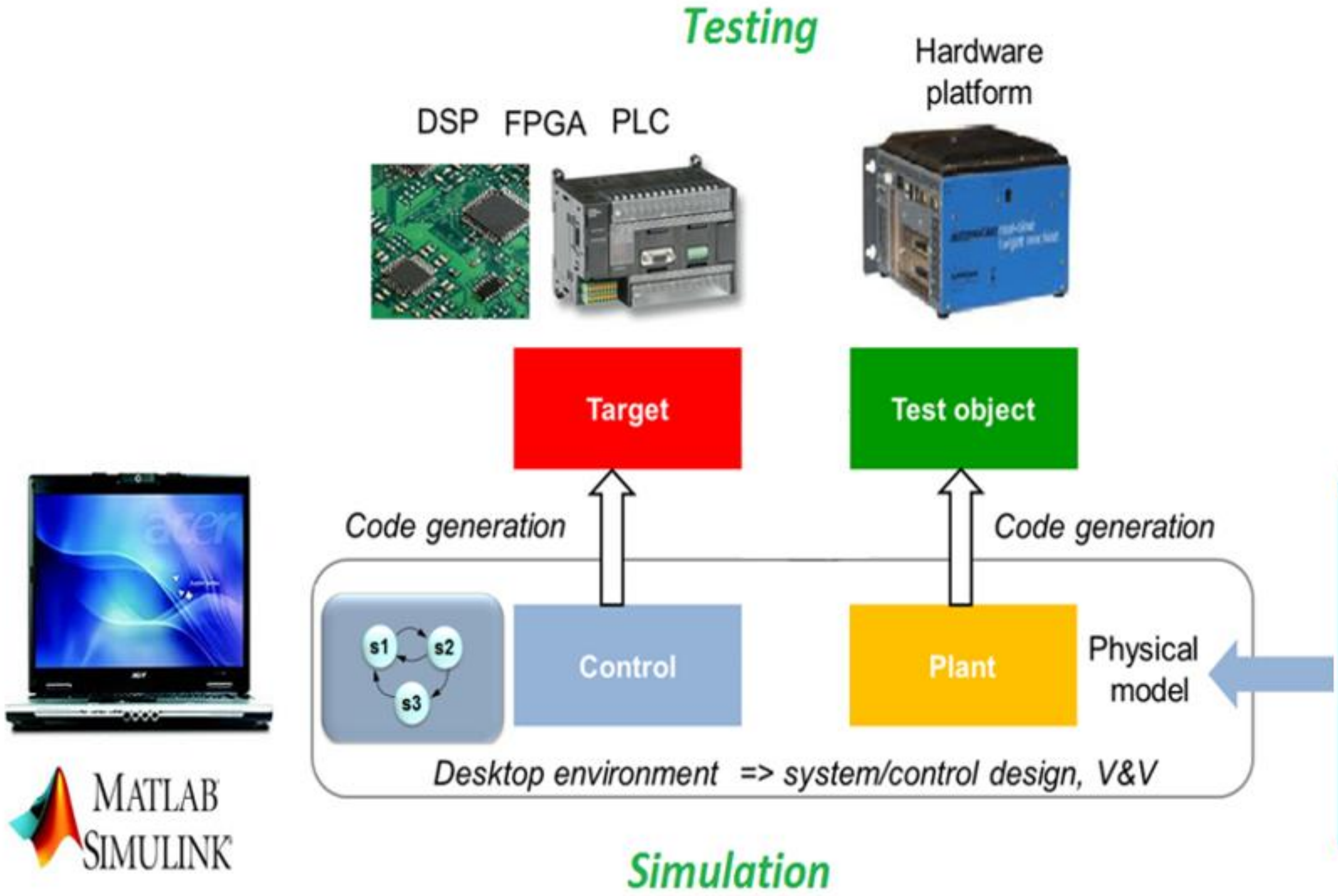
system design
(integration, optimization)

Simulation-based Design = Controls



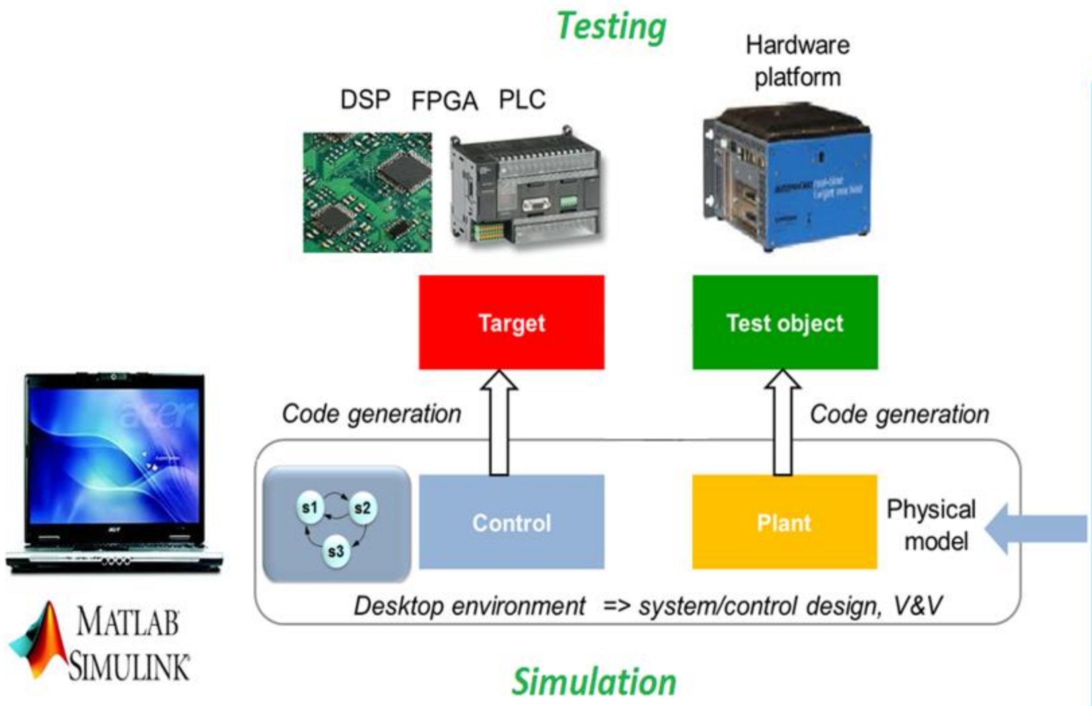
development of control algorithms

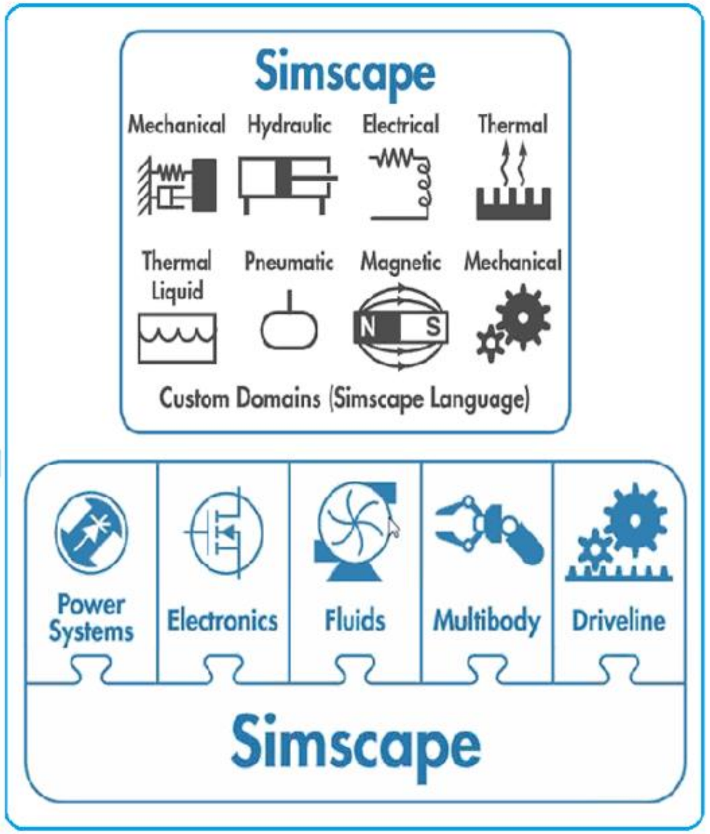
Simulation-based Design = Testing



hardware-based physical emulation (real-time testing)

MATLAB/Simulink offers a unique environment for data analytics & embedded development





Partnership with MathWorks reduces risk and accelerates the adoption process

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