Building the Future.
System by System.

Use of Capella as Digital Twin to Perform Complex Systems Simulation

Prepared by Prof. Dr. **Christopher** Shneider Cerqueira

chris@ita.br

Summary

Context

Who we are....

Concepts

What you are going to find (more or less) in the literature

Our assumptions and characteristics

CapellaSim Add-on

It is on github but the final final real final version release will be made available with the student master thesis.

Quick Example

Connecting Capella to Physical Things

It is not HIL (could be), the idea is to have a twin representation of the physical vehicle into the systemic view and track its behavior changes validating it.

Final Considerations

Context

Who we are….

INSTITUTO
TECNOLÓGICO
DE AERONÁUTICA
1950

http://www.ita.br

Some info context

- We are a group of 2 professor (myself -> MBSE and prof. Jonas Fulindi -> STPA)
- We use Capella since 2018 and have the T4C / RAT.
  - Since 2019 we have a graduate course that has around of 30 students (OPM/Capella) per year.
  - Use in 3 undergraduate courses to teach: Verification & Validation, Space Mission Architecture and Space Ground Segment Architecture. Around 30 students per course.
  - Over 15 final works (undergrad/msc) using MBSE.
- Our lab is requested to do some help into strategic projects so we already applied Capella into 6 government acquisition processes.
- We have a funded project to interconnect MBSE with Modelling & Simulation as well as architecture optimization to create a Model based Mission Engineering Framework

Our group

PhD students

Jeanne Samara Lima (UTM Business Plans / Systems Eng.)

Priscila Renata Cardoso (Operational Research and Systems Engineering)

Emerson Oliveira (Verification and Validation)

Maj. Daniel Pleffken (Certification)

Maj Leonan Falqueto (Mission Optimization)

Lt. Col. Guilherme Moreira (Scenarios and Formal Methods)

Master's Students

Matheus Cogo (Architecture Consistency Check)

Ariane Novais (Interaction with Digital Twins)

Cap Bruno Avelino (Route Optimization)

Ângelo Florentino (Interaction with simulation)

Maj Thiago Melo (Cyber Simulation Sandbox)

Rebeca Suede Cap (Requirements)

Collaborators

Ariele Ferraz (Sensor Fusion)

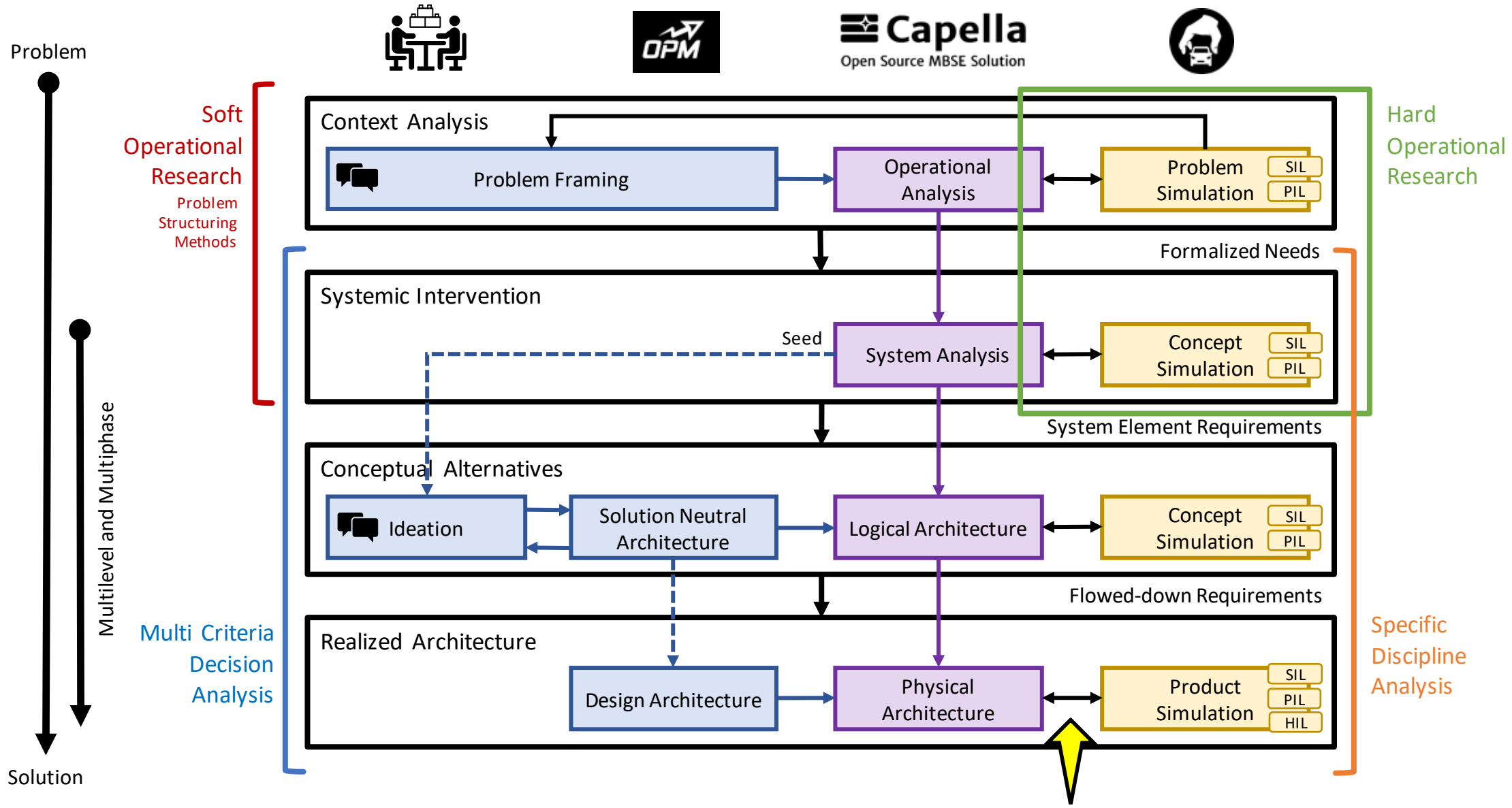
Guilherme Matos (FullStack – VR)

João Cioffi (Machine Learning)

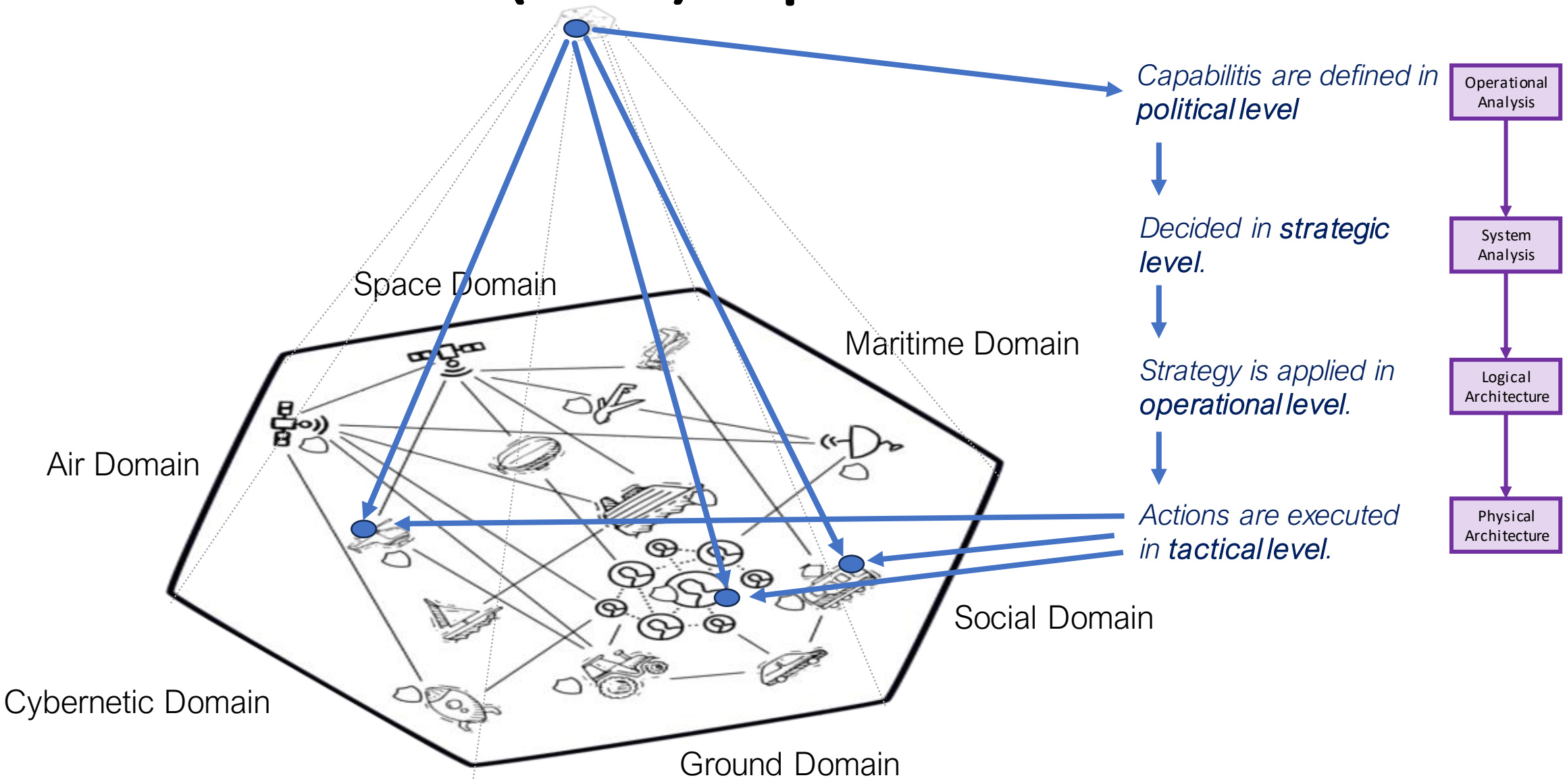
Moara Oliveira (Embedded Design)

Arthur Assis Alves (Simulated UTM Dev)

Our Multi Methodology MBSE Framework



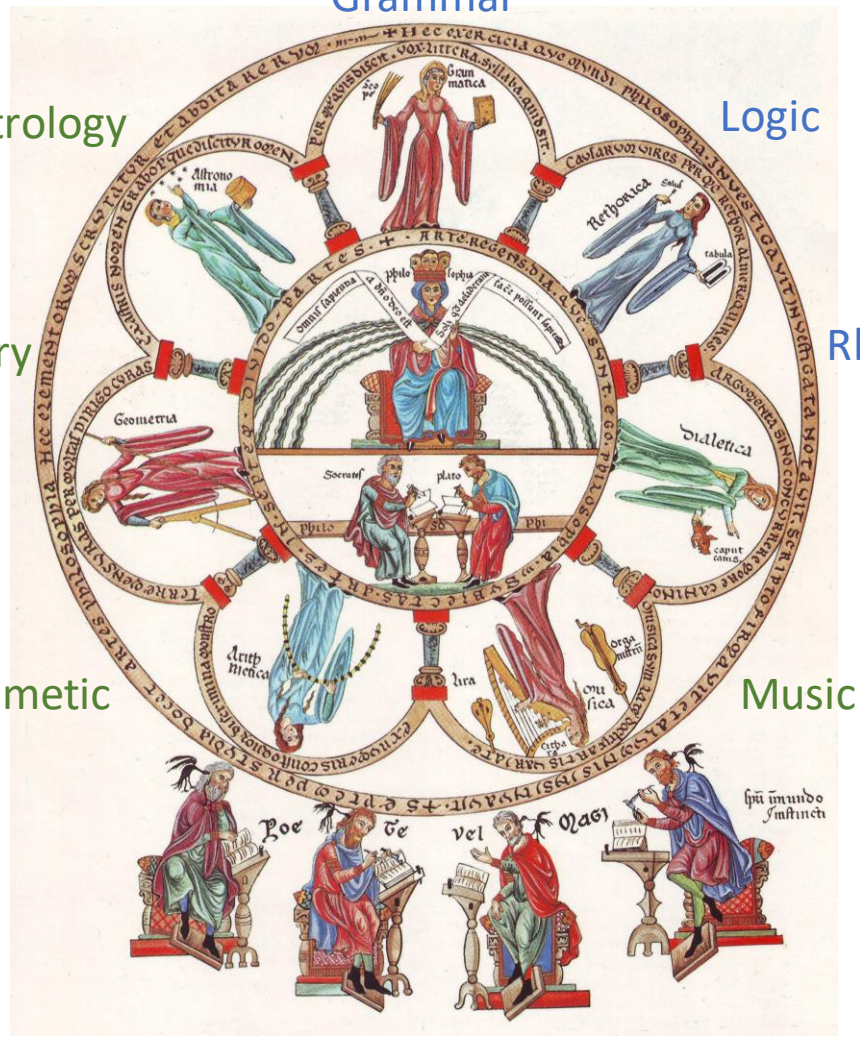
Multidomain (SoS) Operations



Concepts

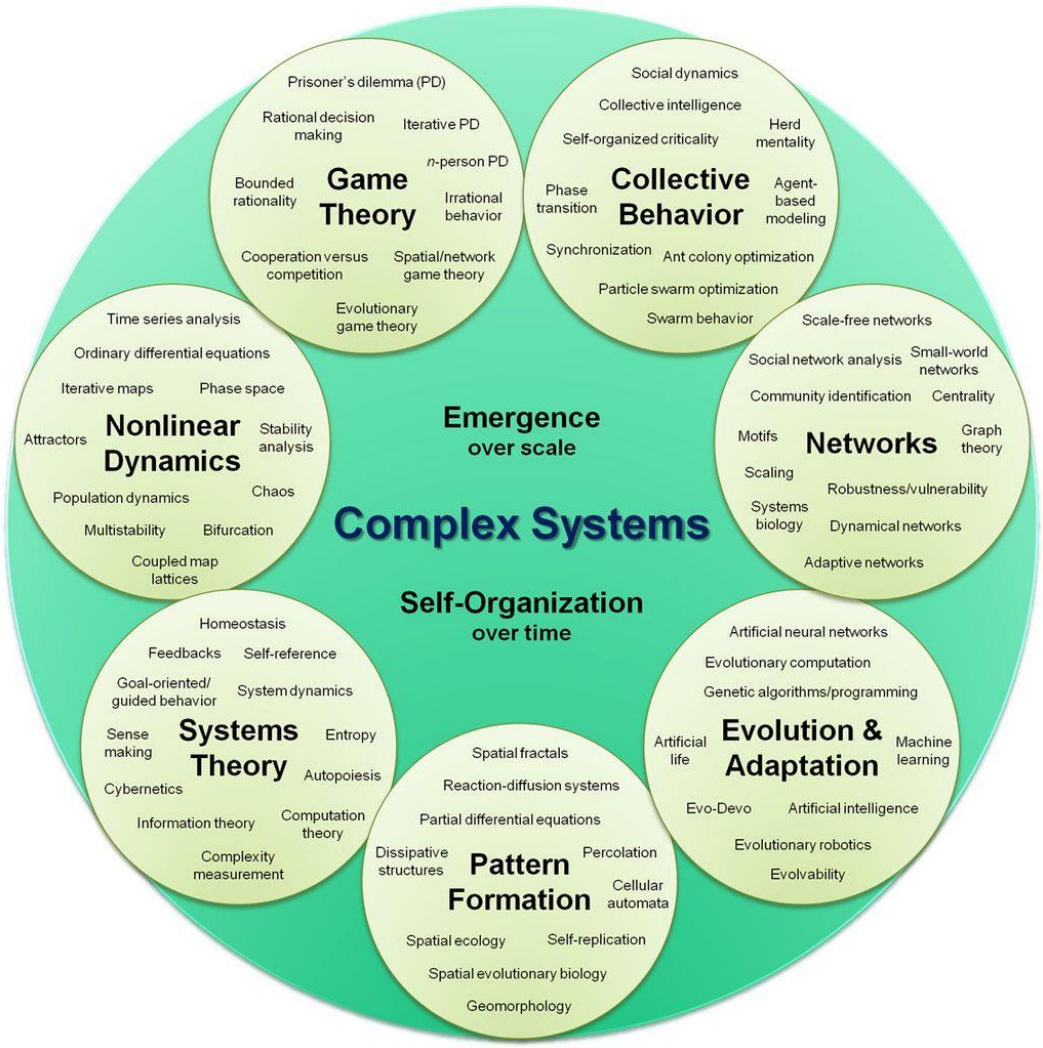
What you are going to find (more or less) in the literature

Complex Systems



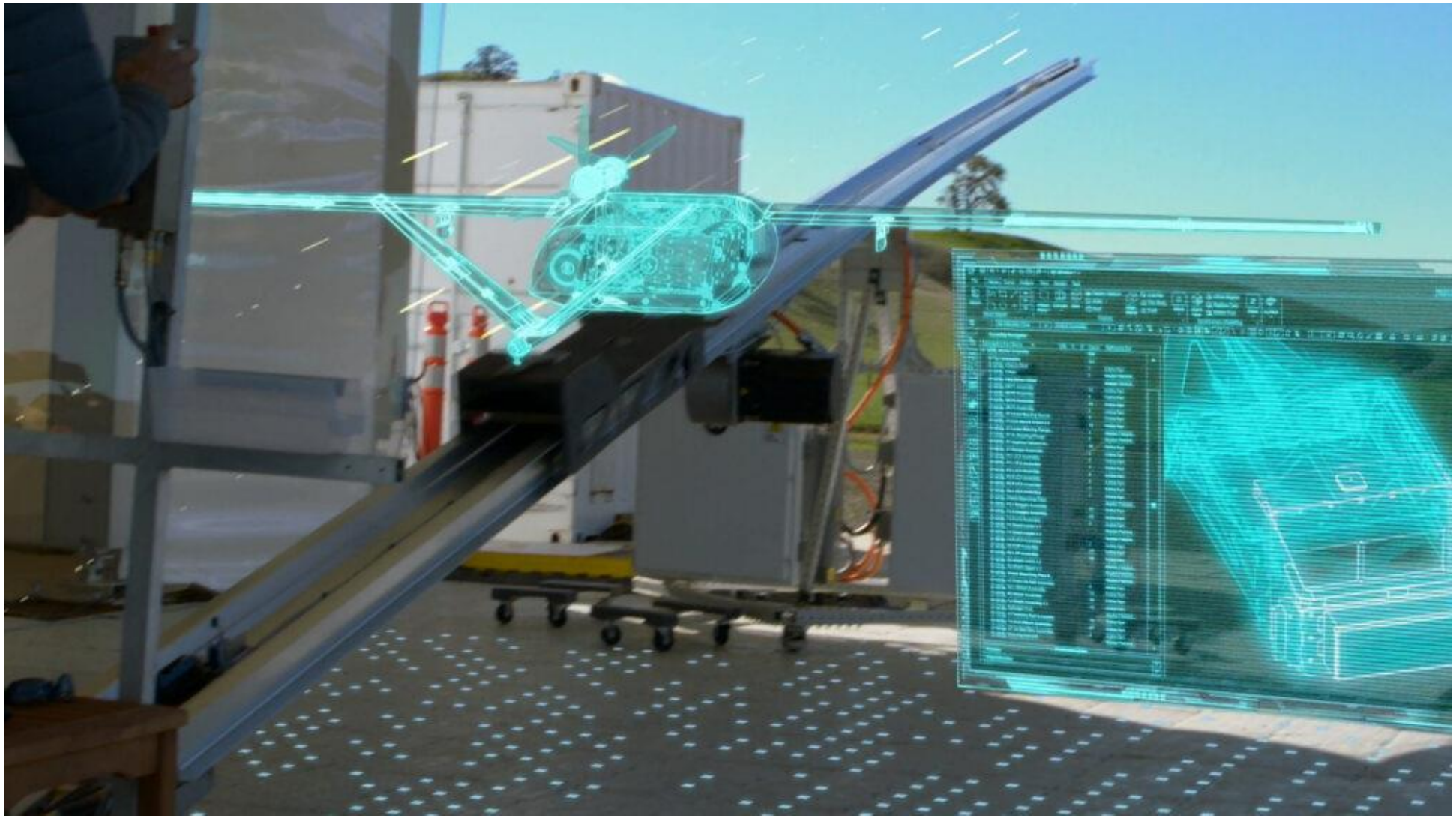
The Hortus Deliciarum of Herrad of Hohenbourg (Landsberg, 1176-96)

https://liberalarts.online/trivium-and-quadrivium/



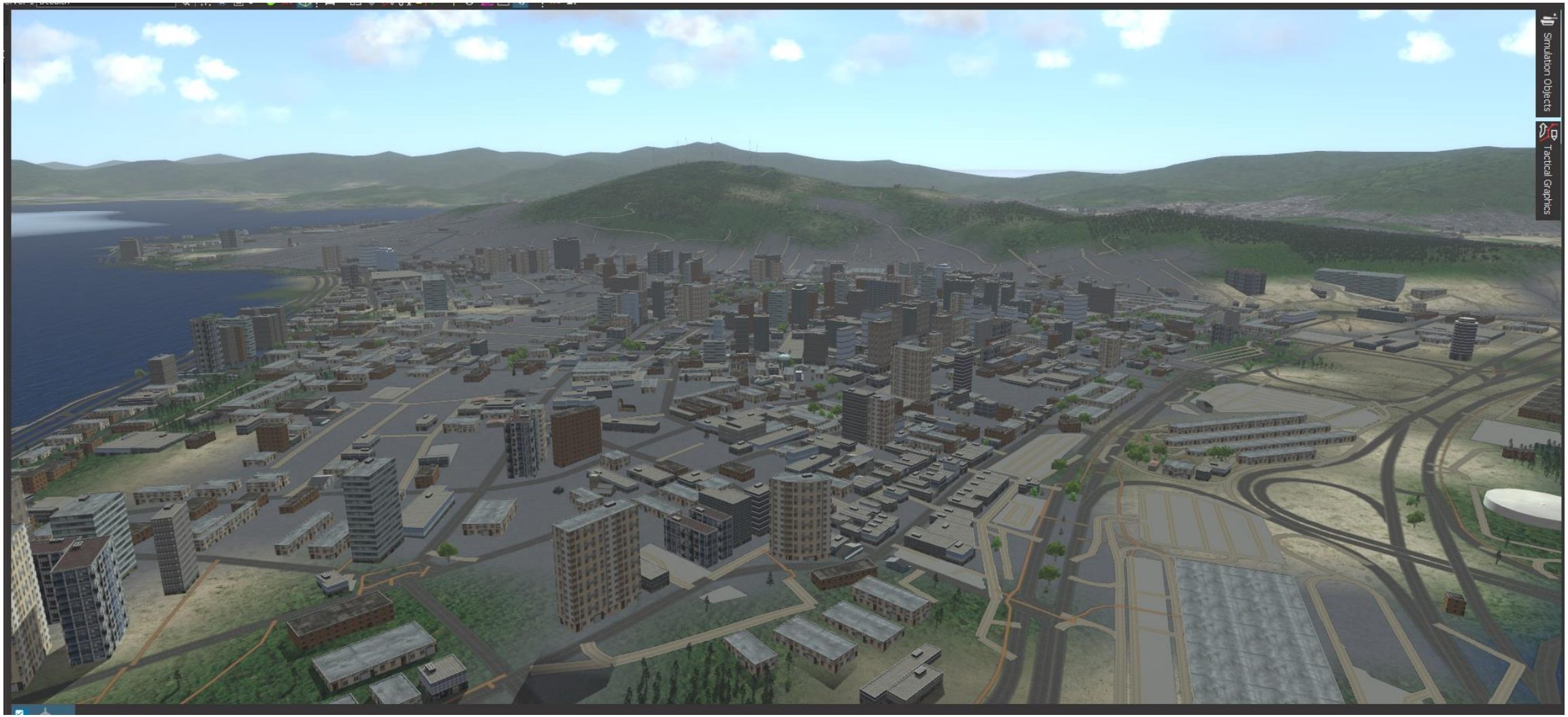
Introduction to the Modeling and Analysis of Complex Systems - Milne Open Textbooks (opensuny.org)

Digital Twin



https://blogs.sw.siemens.com/xcelerator/2020/07/07/drones-deliver-critical-supplies-to-communities-in-need/

Simulation

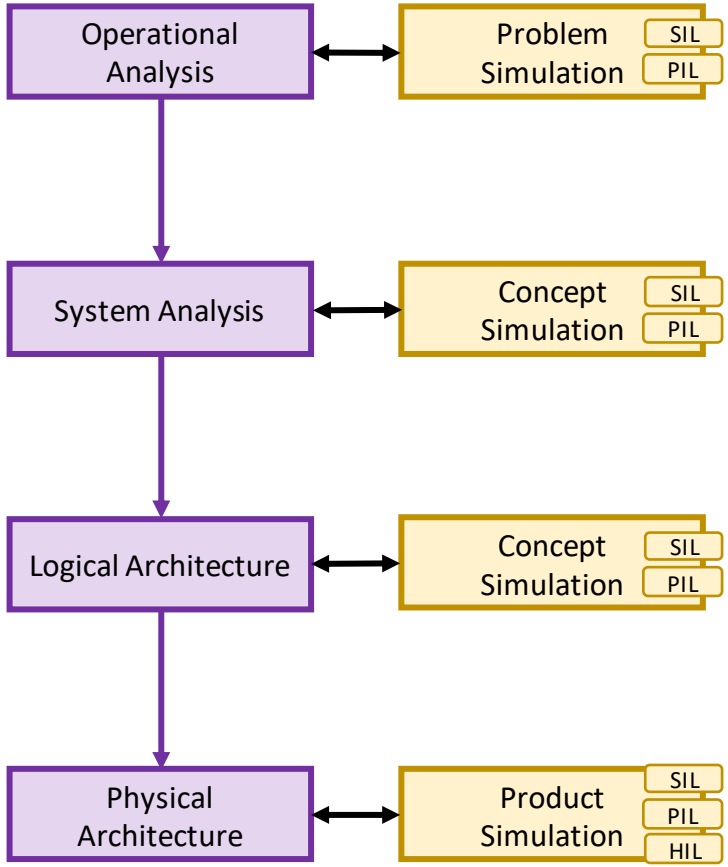


Scenery from Florianópolis City at Brazil, from OpenStreetMap seen at MAK's VR-Forces

Our assumptions and characteristics

On how could we add simulation into Capella? And if we should do that…

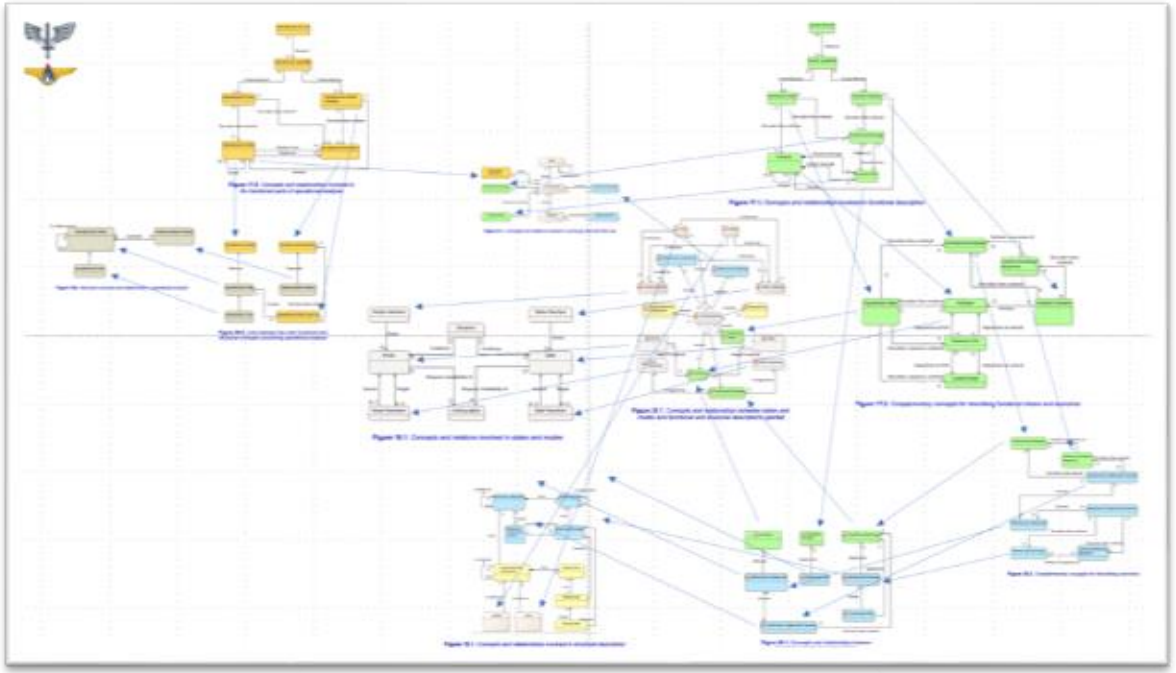
- Decide on the approach:
  - **Read the model** and **moves** the parameters: RCE
  - The simulation tool **imports and parse the model**: Python / OpenModellica / Scilab
  - Create a addon that **exports the model** and maintain it sync: Python / OpenModellica / Scilab
  - **Embed into Capella.**



- Why do we simulate?
  - Verify/Validate… the architecture (behavior or structure) / the model / concepts / CONOPs

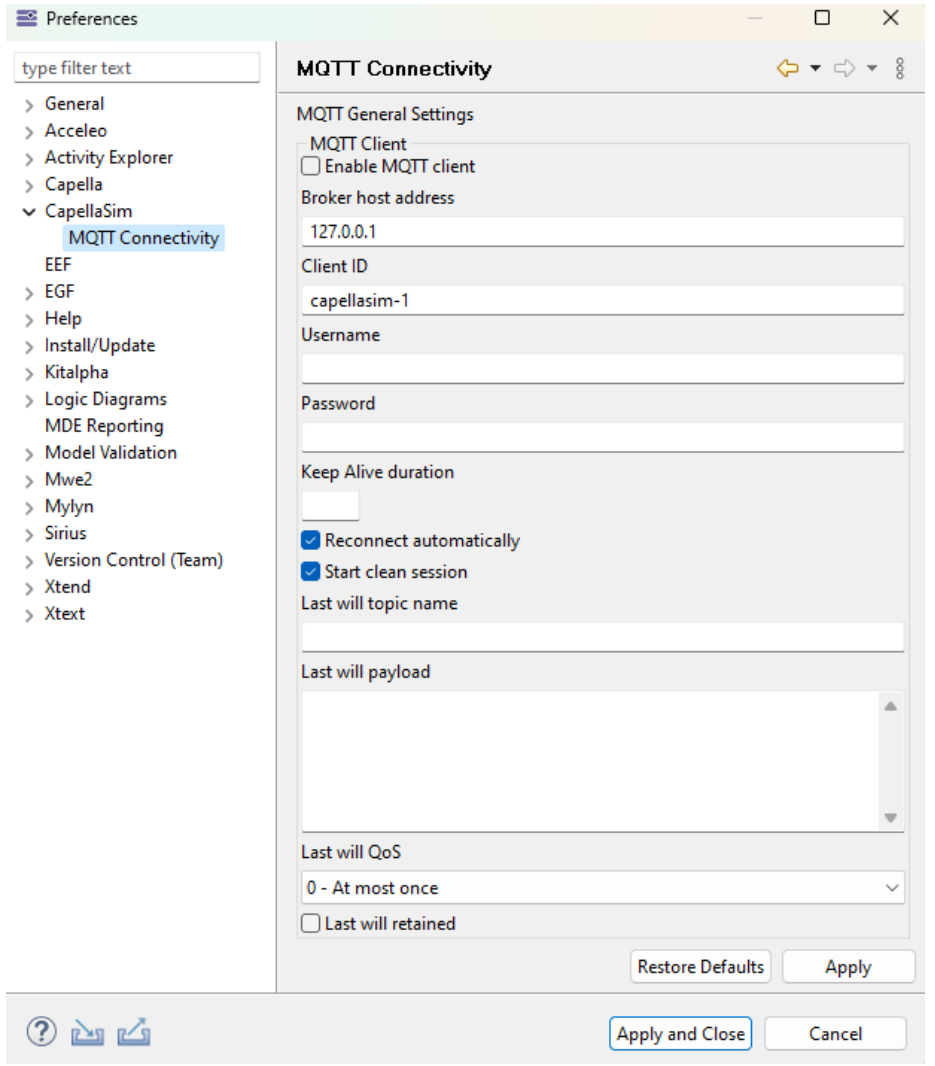
On how does the Capella Model needs to be? And the amount of changes…

- Regarding the metamodel:
  - There has to be about **zero changes**. *I would not like to change it into our T4C server*.
  - Capella has **behavioral diagrams** (static / reactive).
- To the users?
  - There has to be no change unless it **eases the use**.
  - As new things will appear/be controlled, the **UI design has to follow to the same type of navigation**.



On how to open a running Capella to the rest of world? And interface with it...

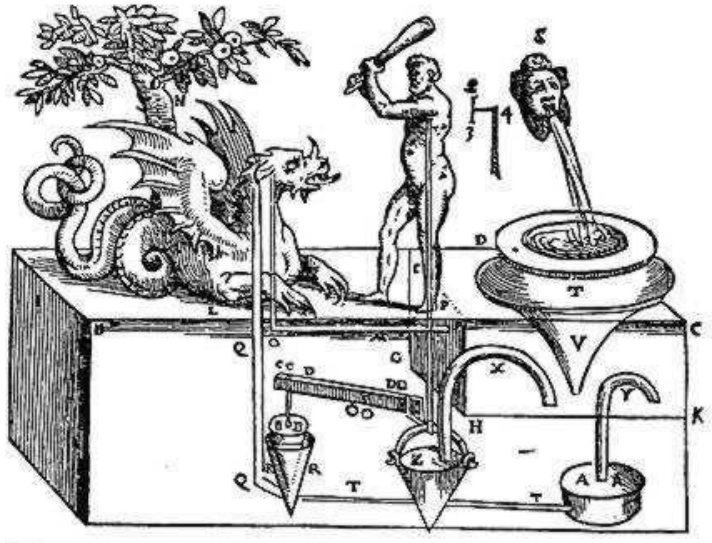
- Well... Capella is simulating, executing the reactive model.
- Can we interconnect **simulating Capellas** and integrate it, without actually sharing the model.
  - (the use of S2SS or the T4C are more to the model integration / sharing).
- Distributed Simulation:
  - Hard runtimes: HLA / DIS
  - “Soft” runtime: **ROS**
  - “Even softier” runtime: **MQTT**

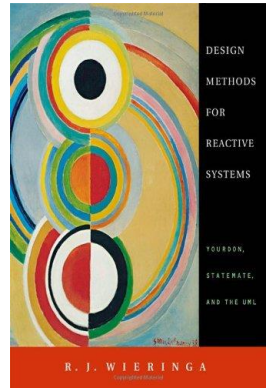


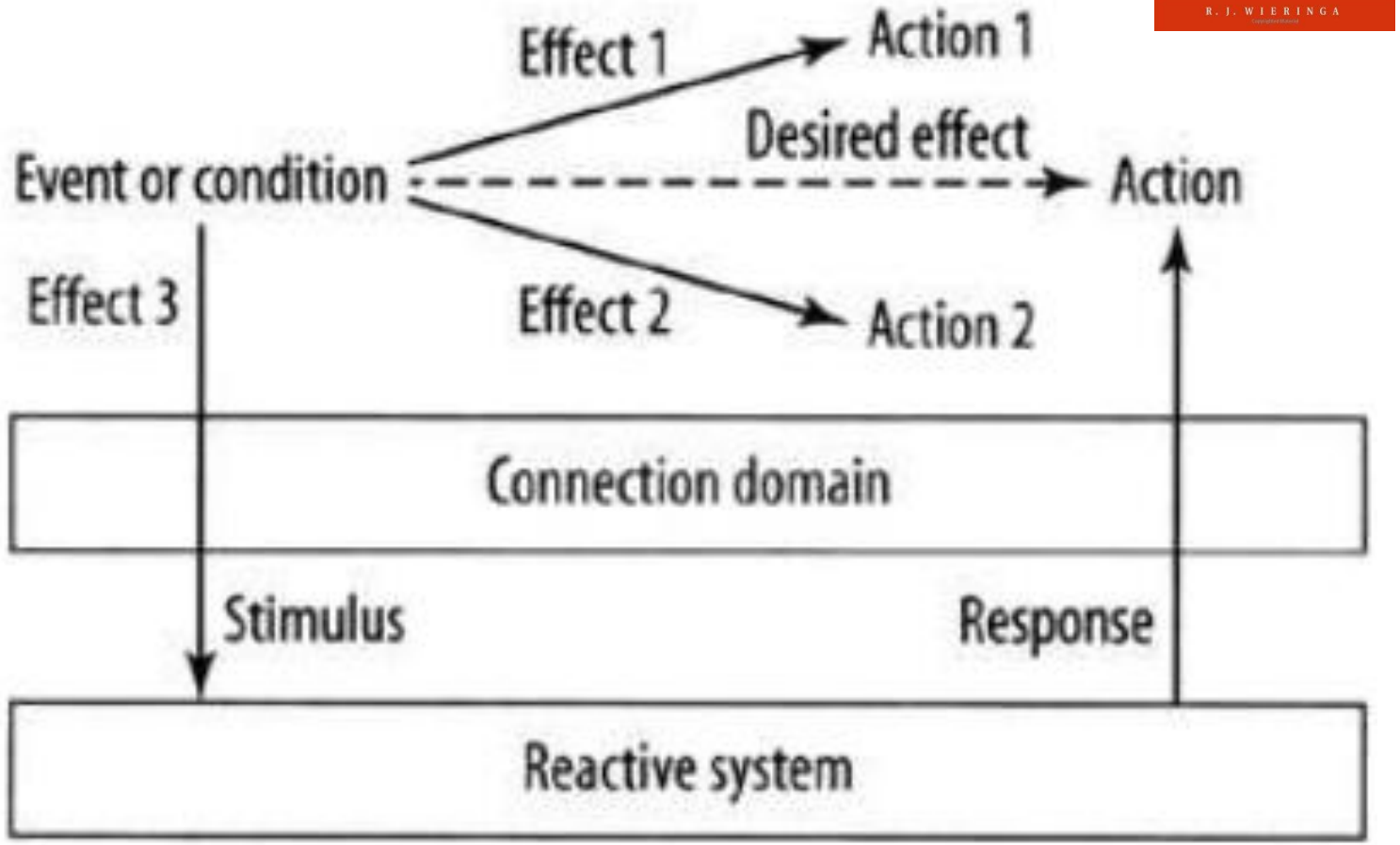
CapellaSim Add-on

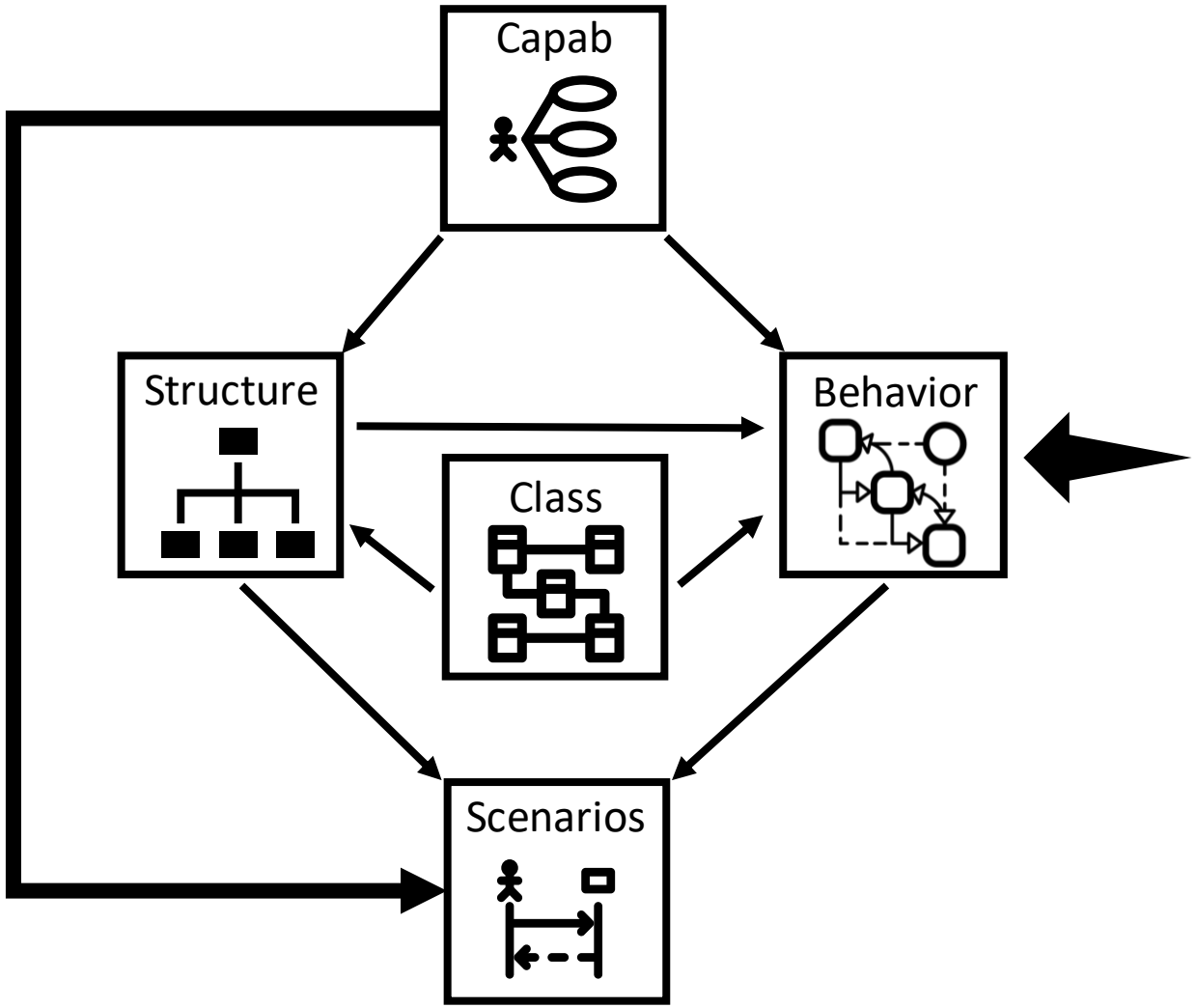
It is on github but the final final real final version release will be made available with the student master thesis.

Statechart - Reactive Simulation

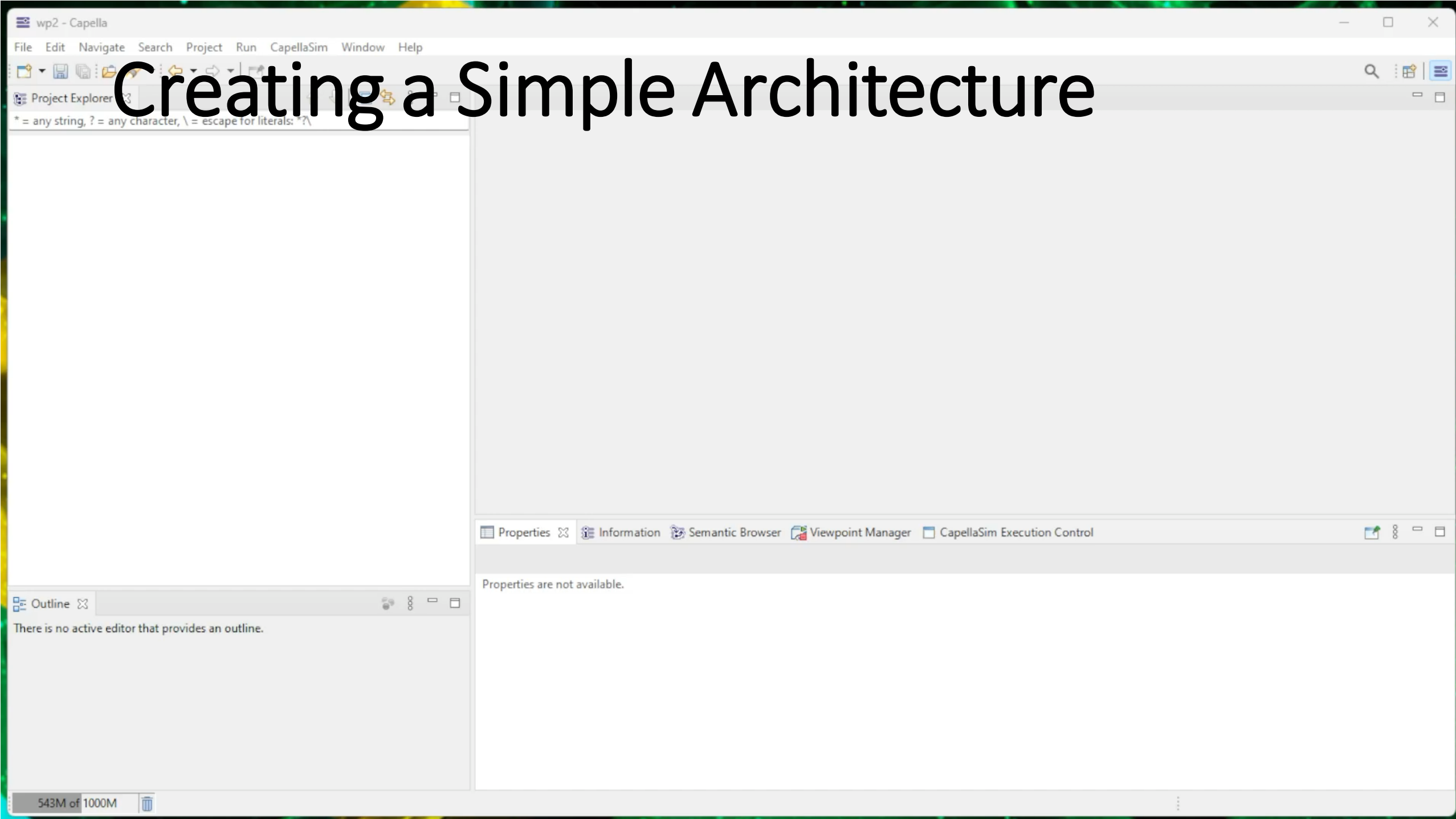




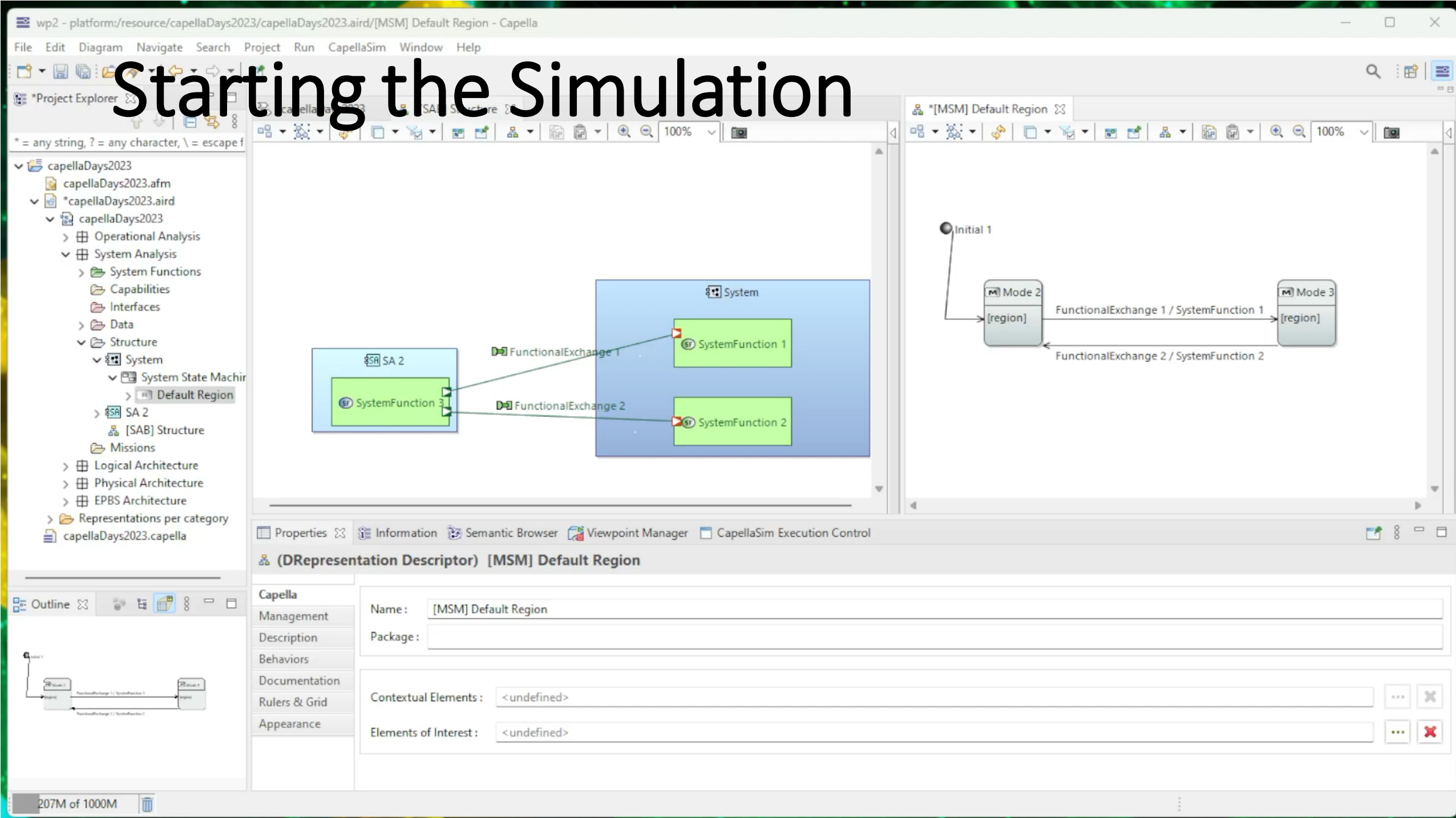



Capab
Structure
Behavior
Class
Scenarios

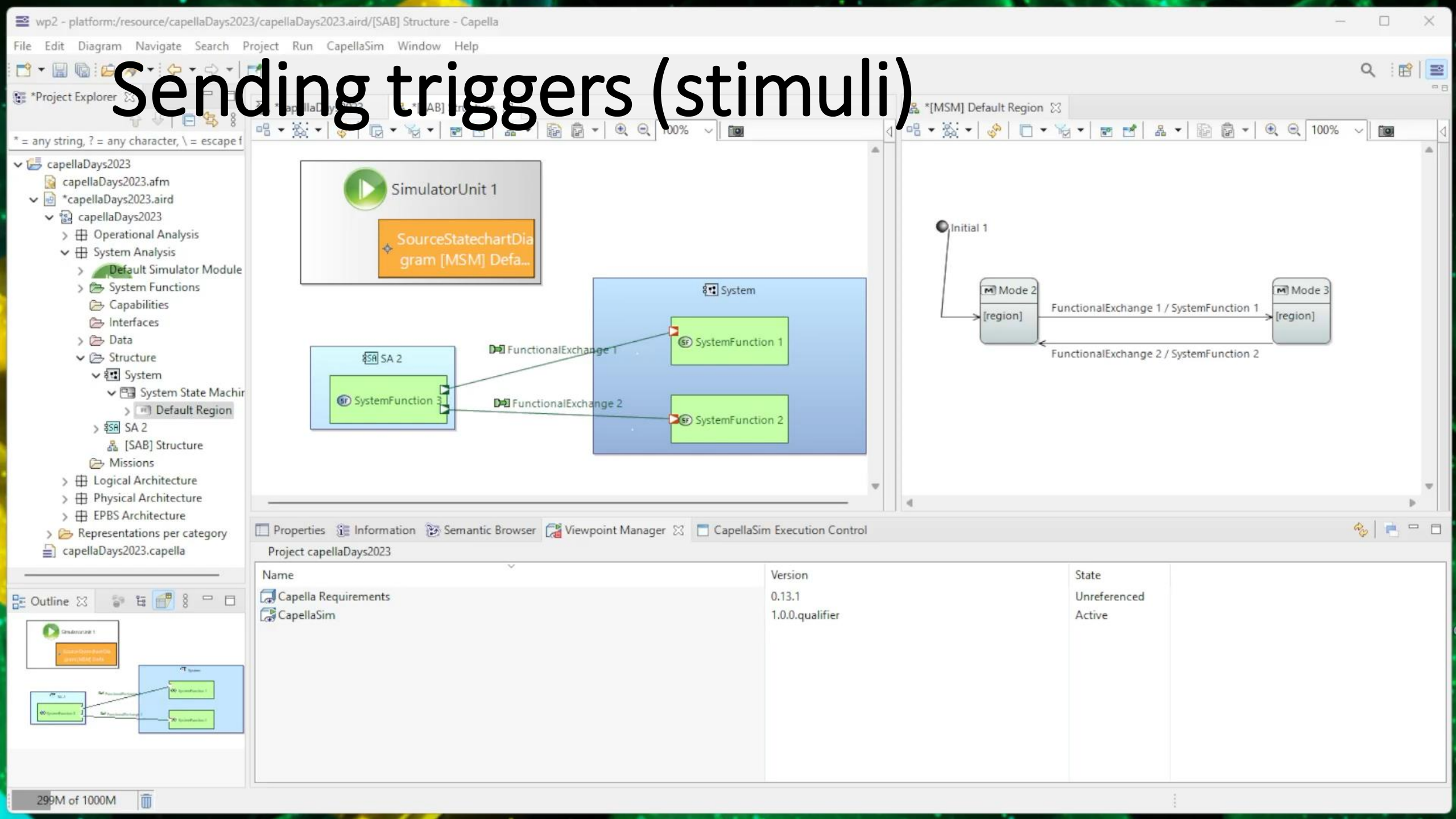
Creating a Simple Architecture



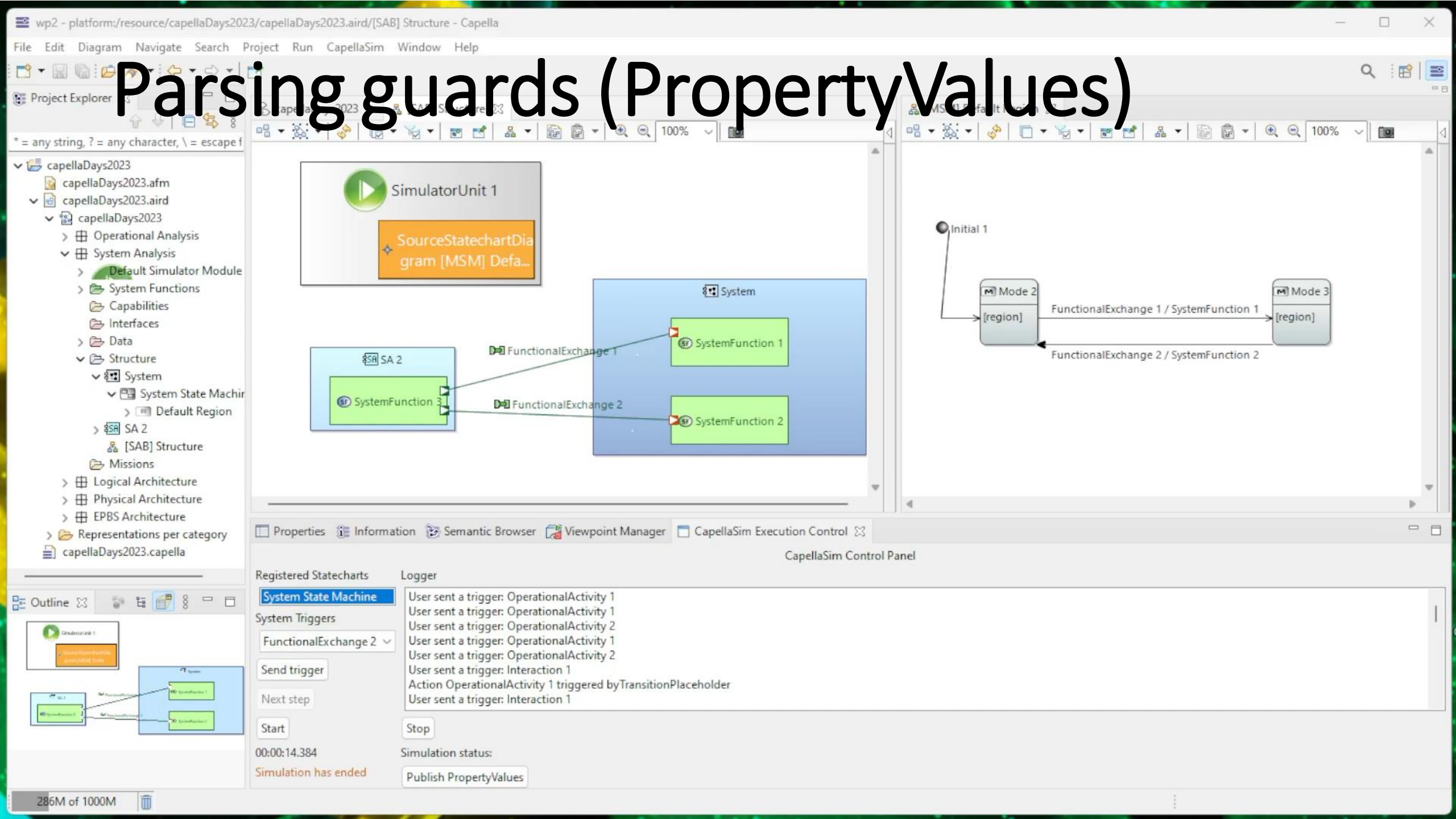
Starting the Simulation



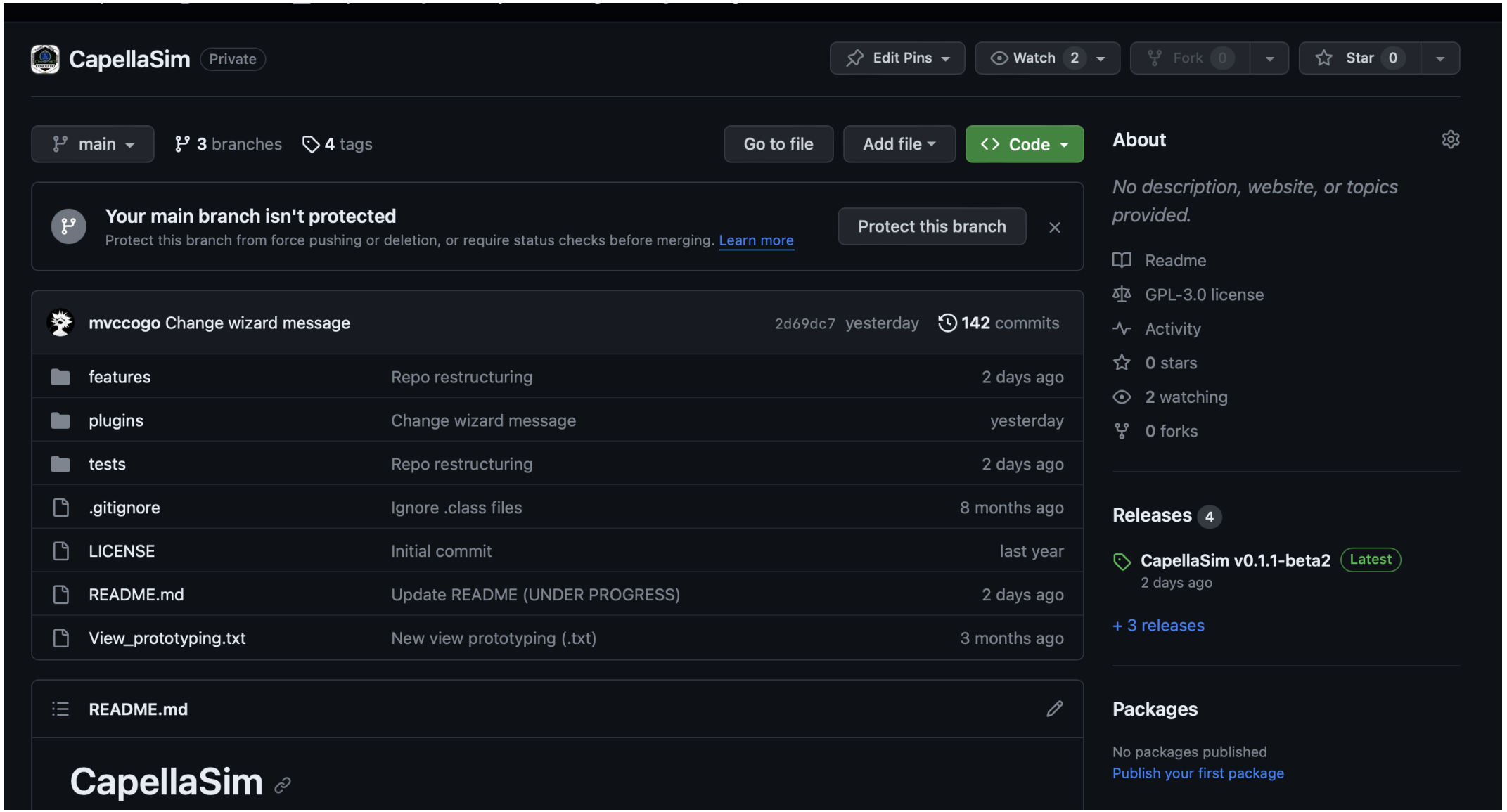
Sending triggers (stimuli)



Parsing guards (PropertyValues)



Soon will be public at Github

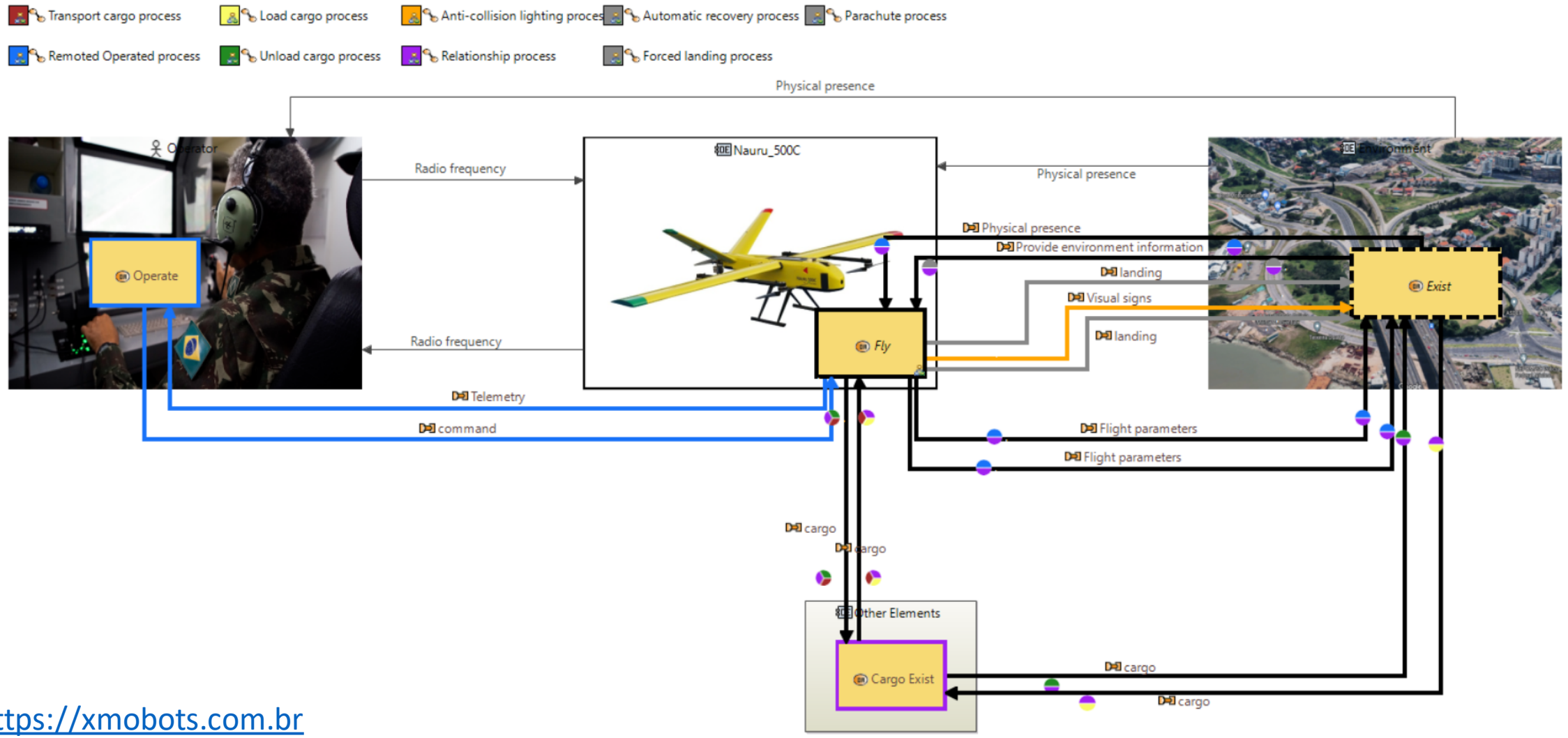


Quick Example

Appling into a UAV context

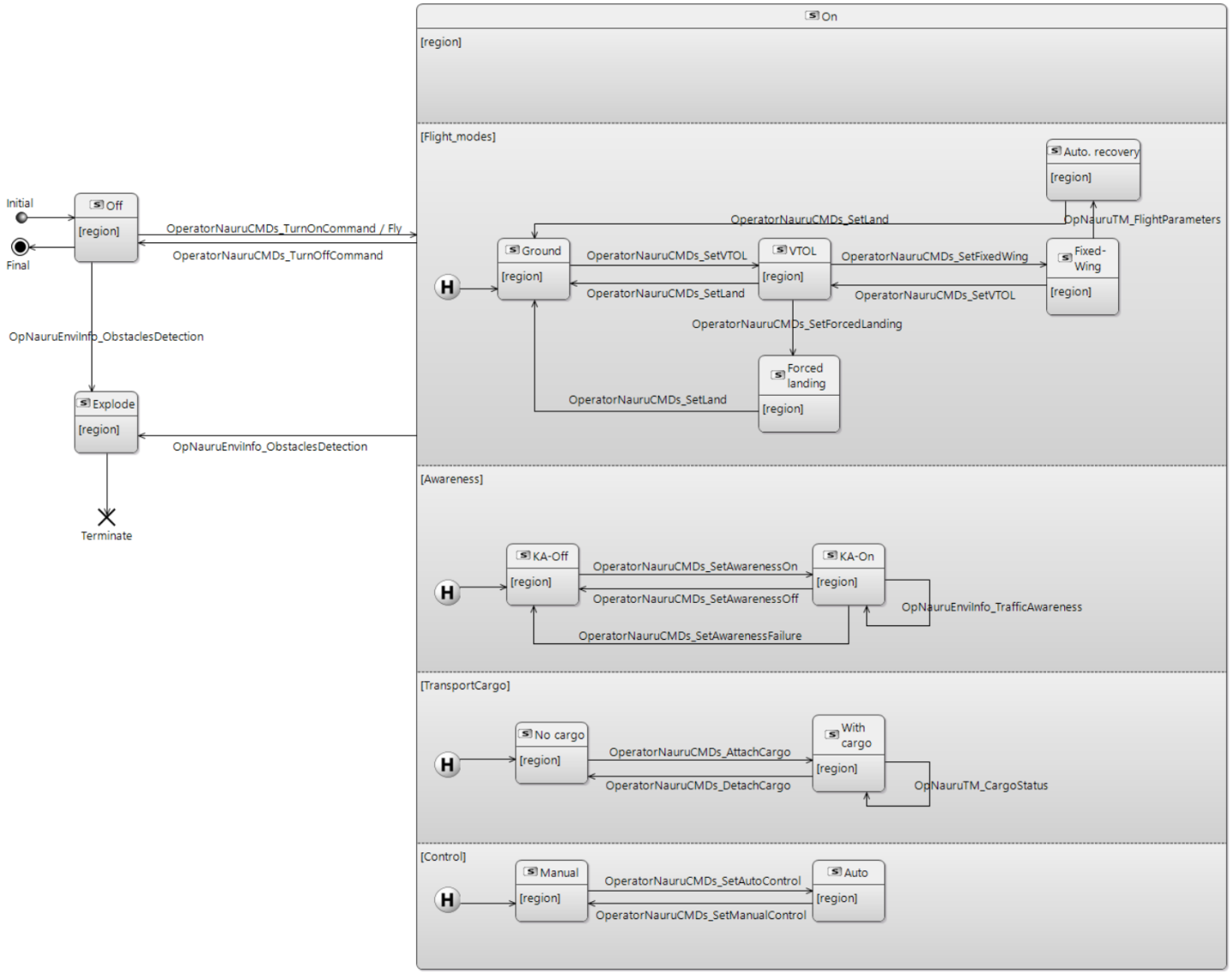
Modelling the Aircraft functions

(same approach to all layers)

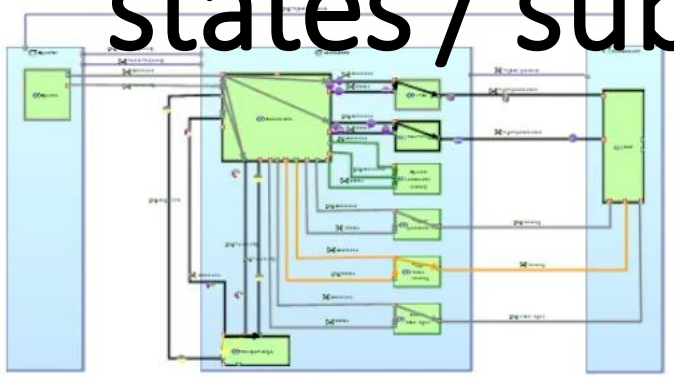


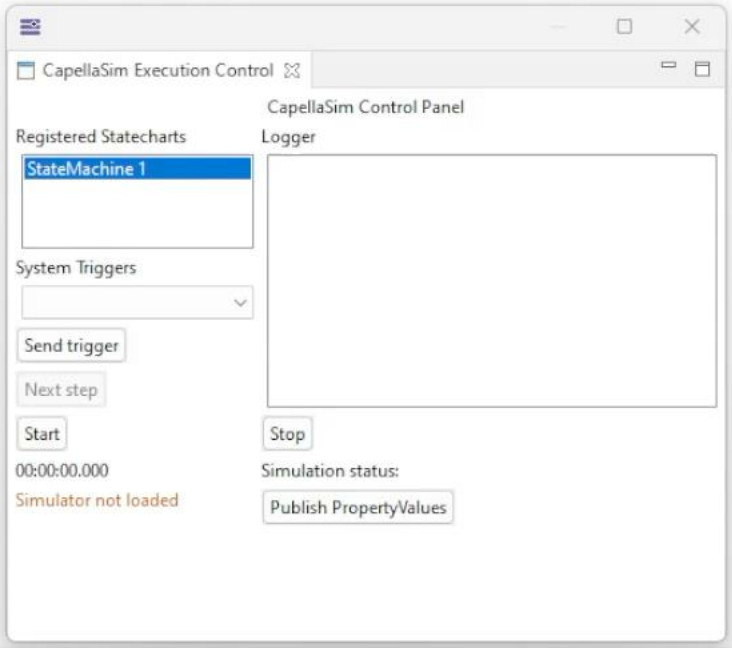
https://xmobots.com.br

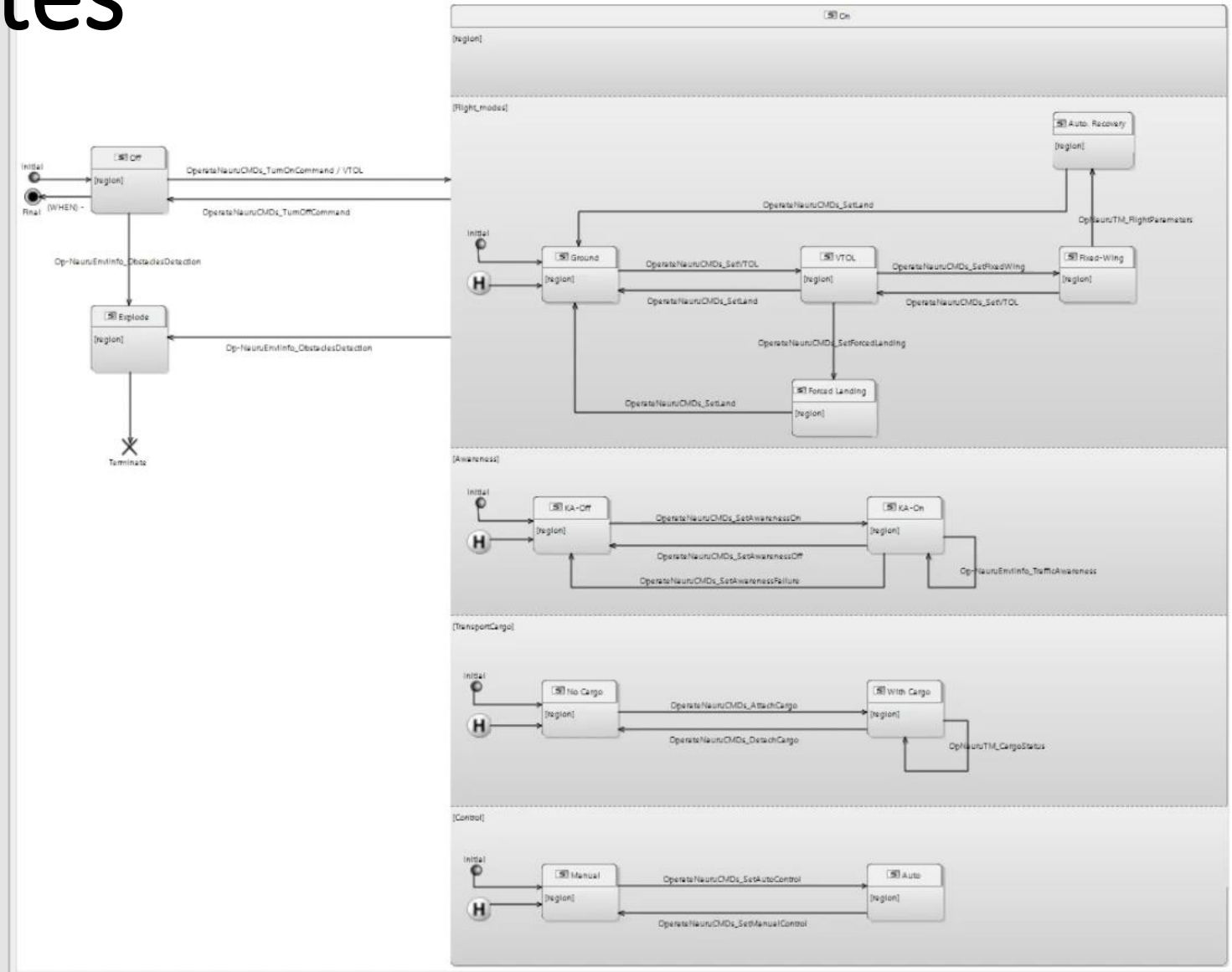
Modelling the State Machine



Simulating the commands and changing the states / substates





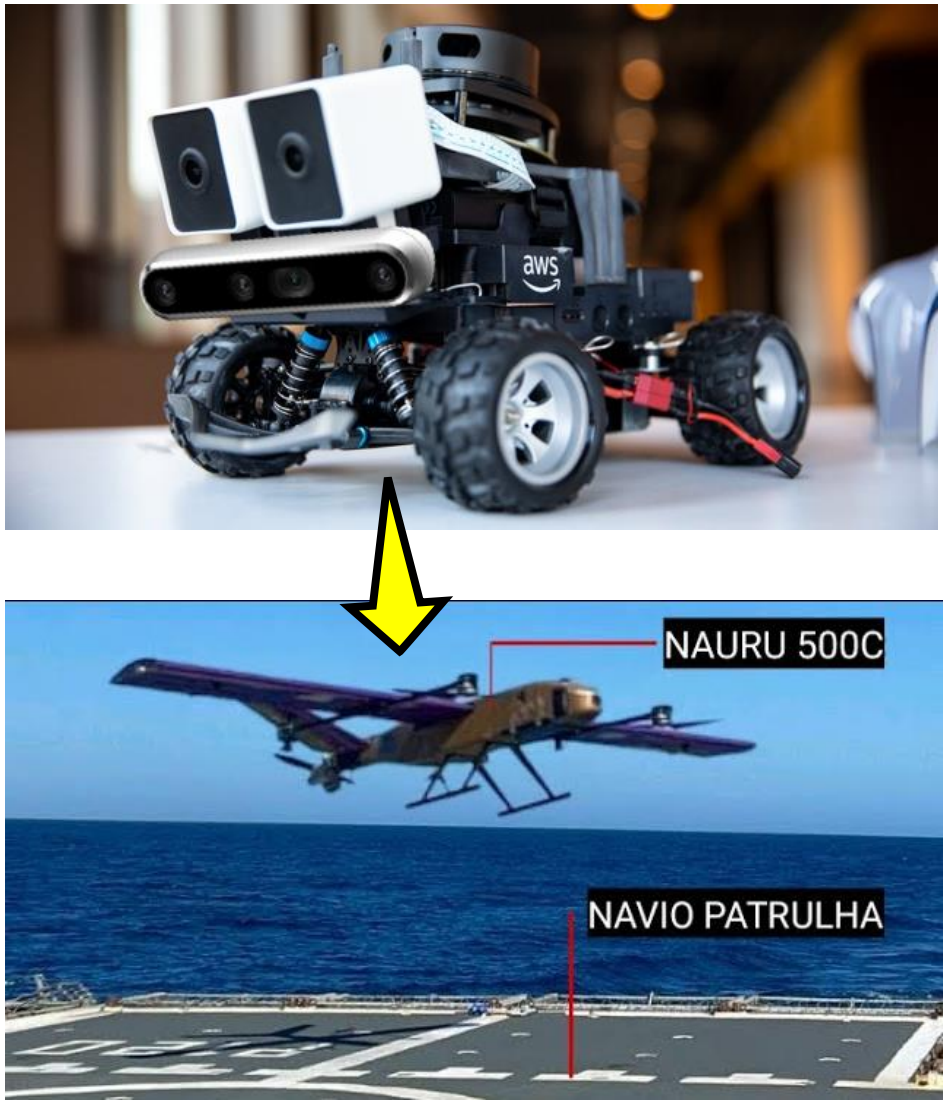


Connecting Capella to Physical Things

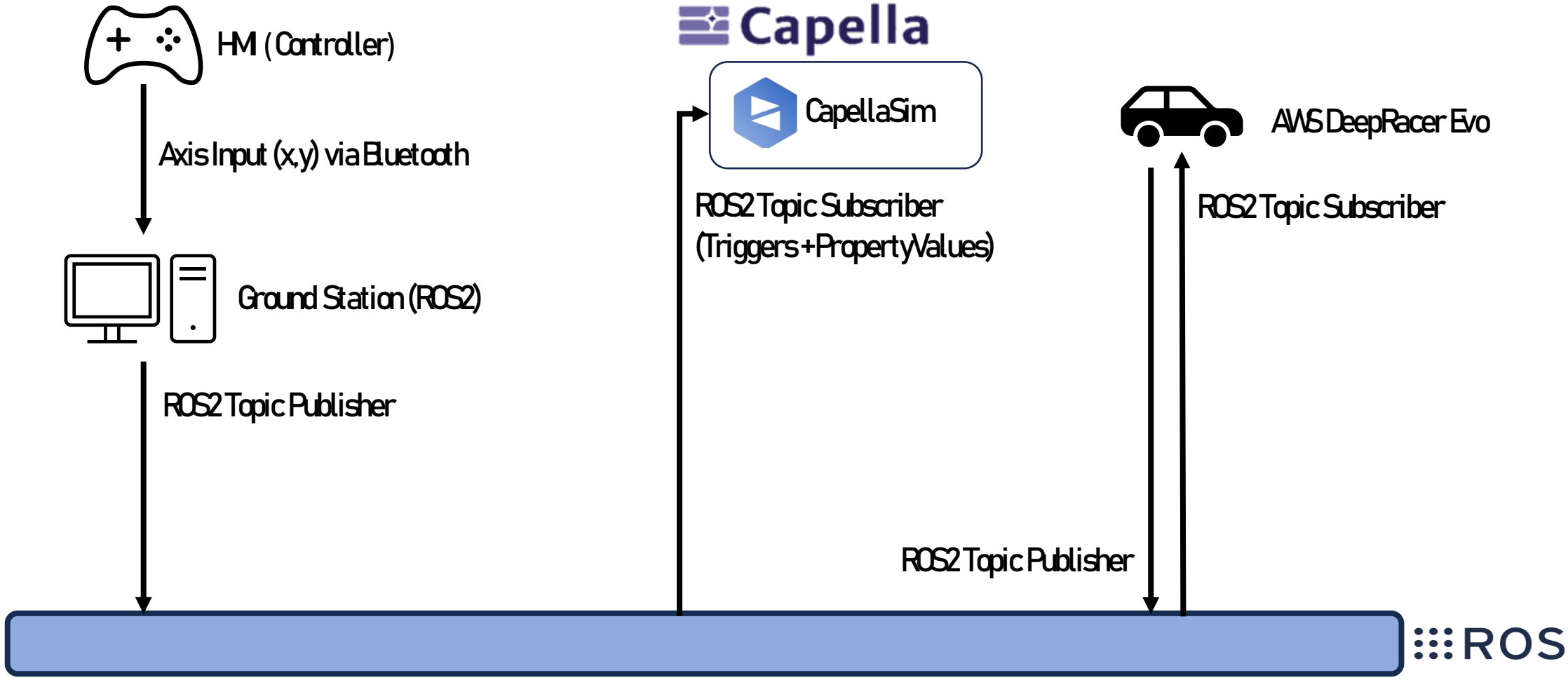
It is not HIL (could be), the idea ia to have a twin representation of the physical vehicle into the systemic view and track its behavior changes validating it.

Design of Experiments

- Use a representative of the vehicle to run 2D detect and avoid experiments. Flying crashes are more expensive ☺.
- Use of Capella to track the changes during the simulation.
  - Live Simulation: Commands sent to the vehicle by a HMI should be sent to the Capella, sending triggers to the state-machine should also be sent to the vehicle.

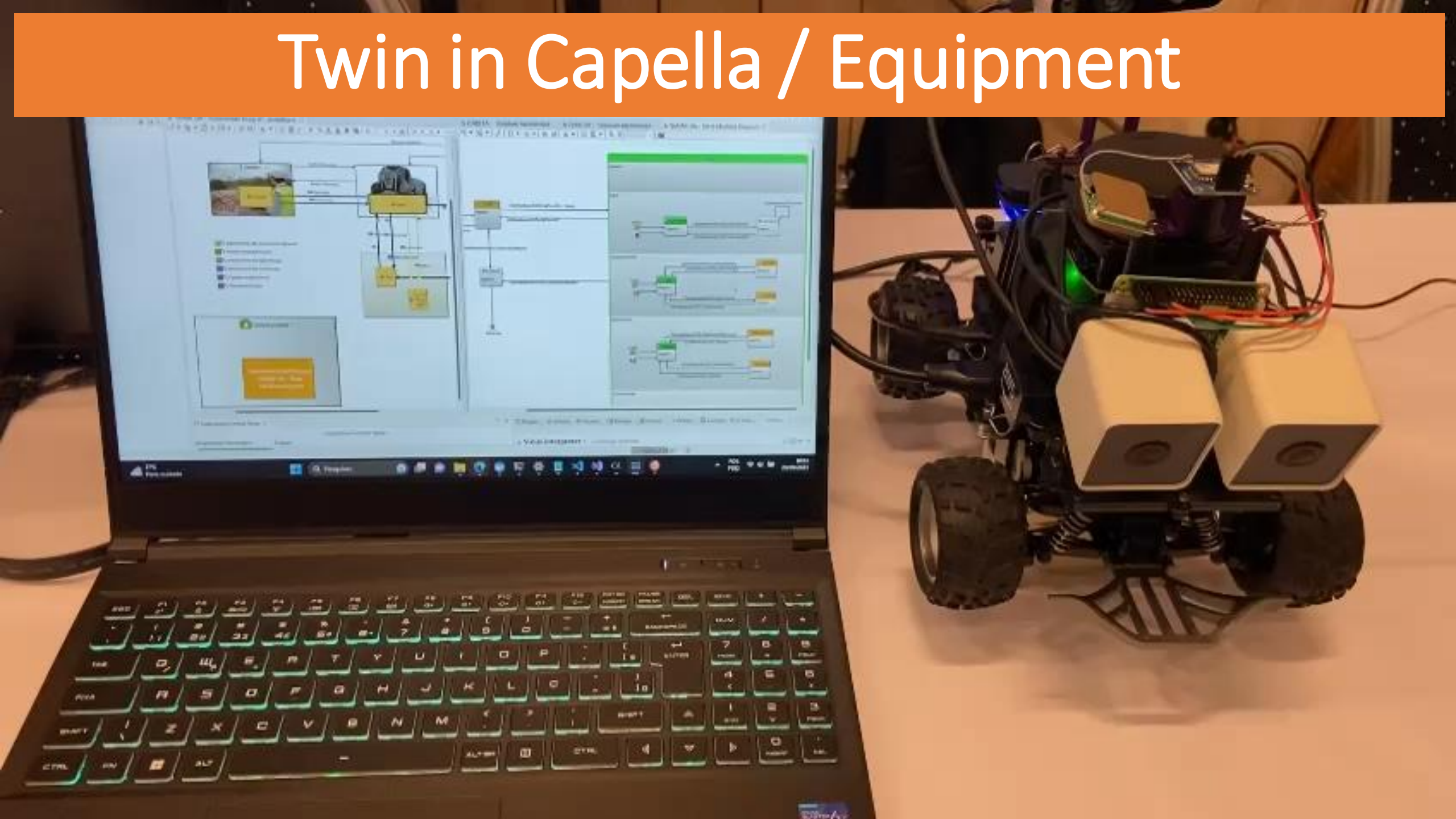


ROS


HMI (Controller)
Axis Input (x,y) via Bluetooth
Ground Station (ROS2)
ROS2 Topic Publisher
Capella
CapellaSim
ROS2 Topic Subscriber
(Triggers+PropertyValues)
AWS DeepRacer Evo
ROS2 Topic Subscriber
ROS2 Topic Publisher
ROS

https://portal.waraps.org
WASP
WALLENBERG AI, AUTONOMOUS SYSTEMS AND SOFTWARE PROGRAM
WASP RESEARCH ARENAS
Public Safety
WATCH
Opened Streams
drone1
Available Streams

Twin in Capella / Equipment



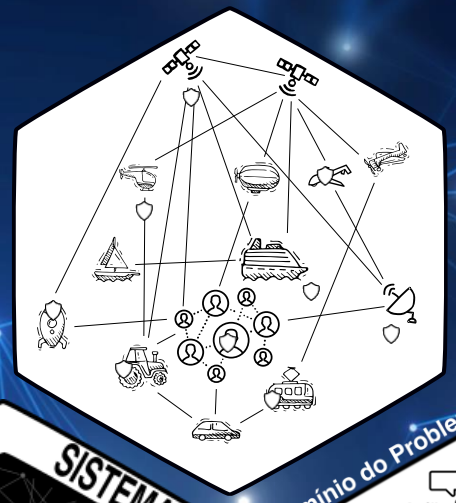
Final Considerations

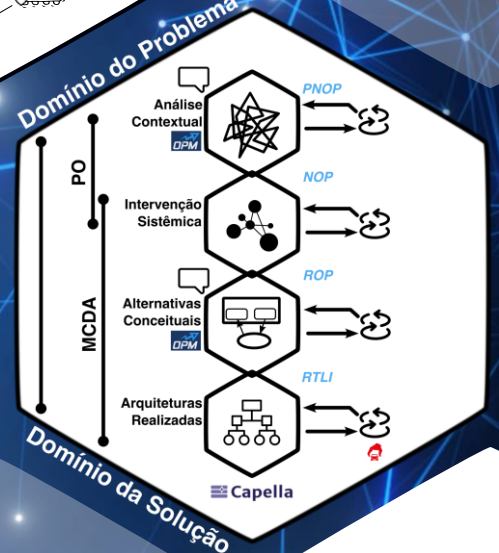
Some on-going developments

- Our lab is working into **multidomain problems** and **Brazilian Air Force Life Cycle Framework**.
- We have a question: "**Is the current Systems Engineering UI Metaphor natural?**"
- In terms of development:
  - Library Management Add-On (ways to better filter elements of the library)
  - Architecture Optimization Add-On (ways to check interfaces and simulation results)
  - Distributed Simulation Add-On (what was presented)
  - Operational Research Add-On (we started with Soft Systems Methodology)
  - simple_OPM Add-On (changes on the block-diagram to be able to show structure/behavior simultaneously)

conceptiolab.dev.br

Thank you!





Capella
Open Source MBSE Solution