Model Driven Engineering Approach to Design Sensing and Actuation Subsystems

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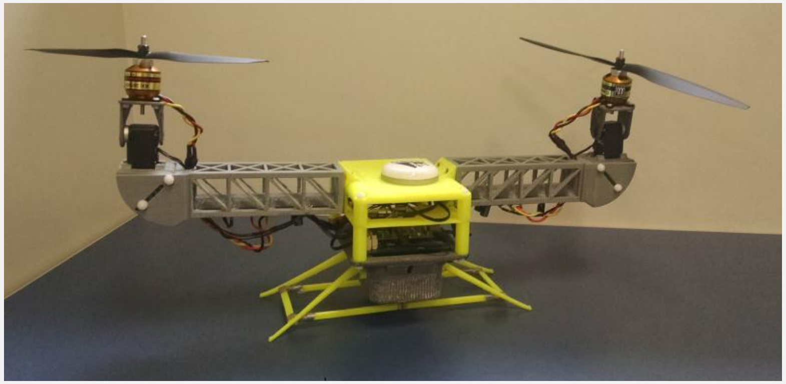
Outline

- Motivation
- Proposed Approach
- Conclusions

PROVant Project

- Focus on design autonomous bi-rotor UAVs;
- Integrate different design teams (Control, Aeronautic, Software);
- Composed by at least 18 people (PhD, Master, and Undergrad students).



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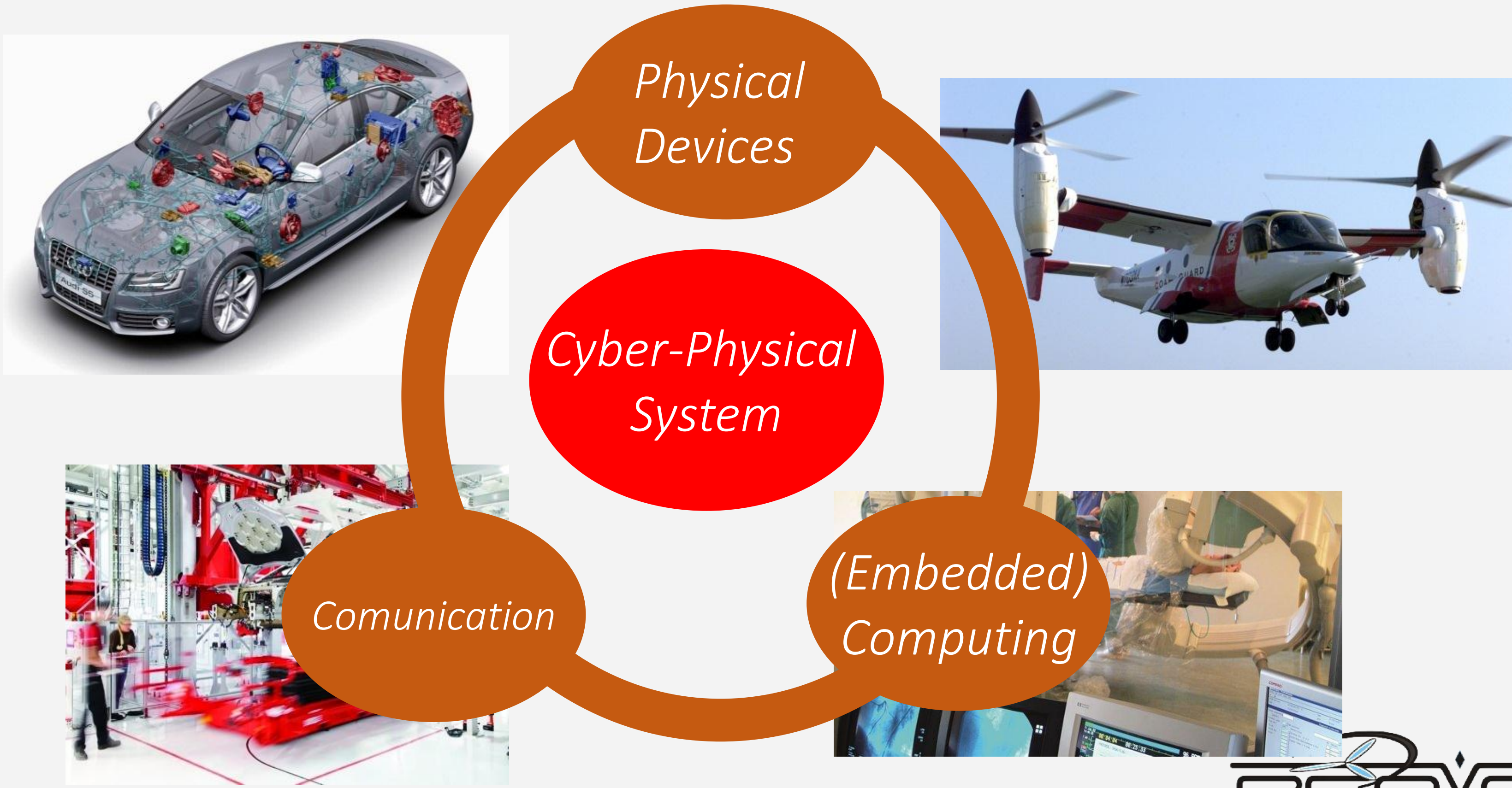
Cyber-Physical Systems (CPS)

CPS combines computation and physical systems, providing proper control

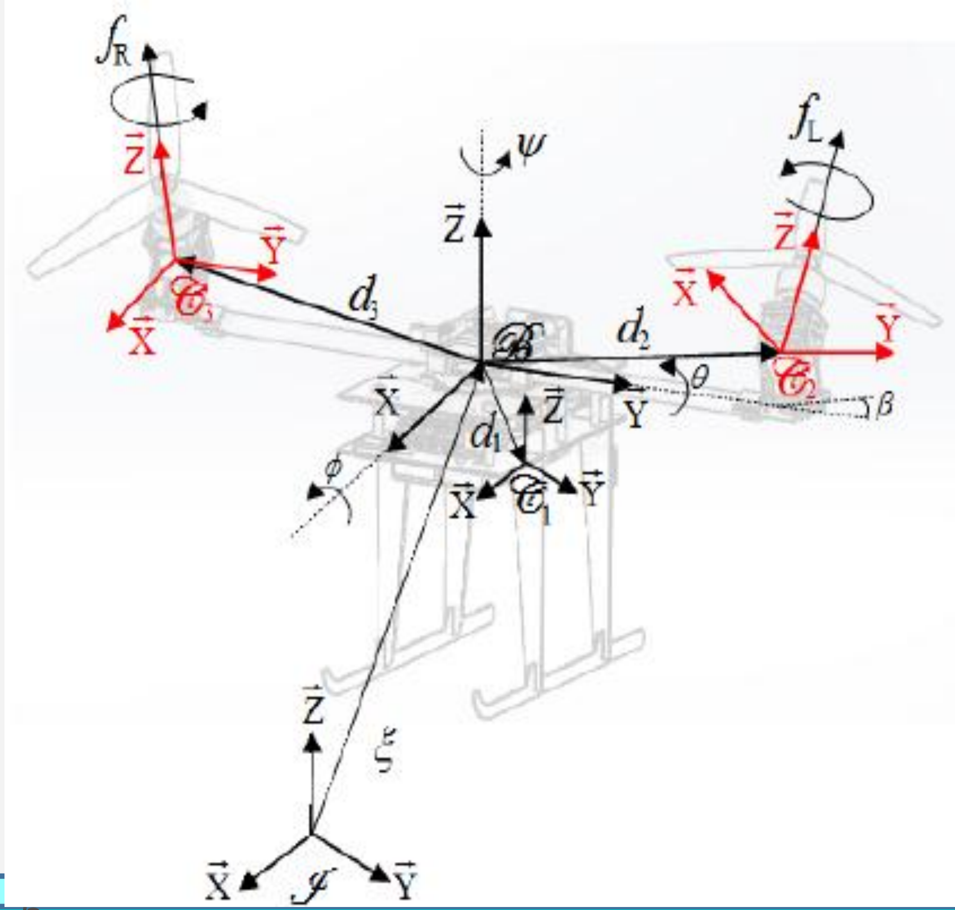


CPS Design Process

Different types of models:

(1/3) Physical Plant Model

– Analytical model from the device to be controlled



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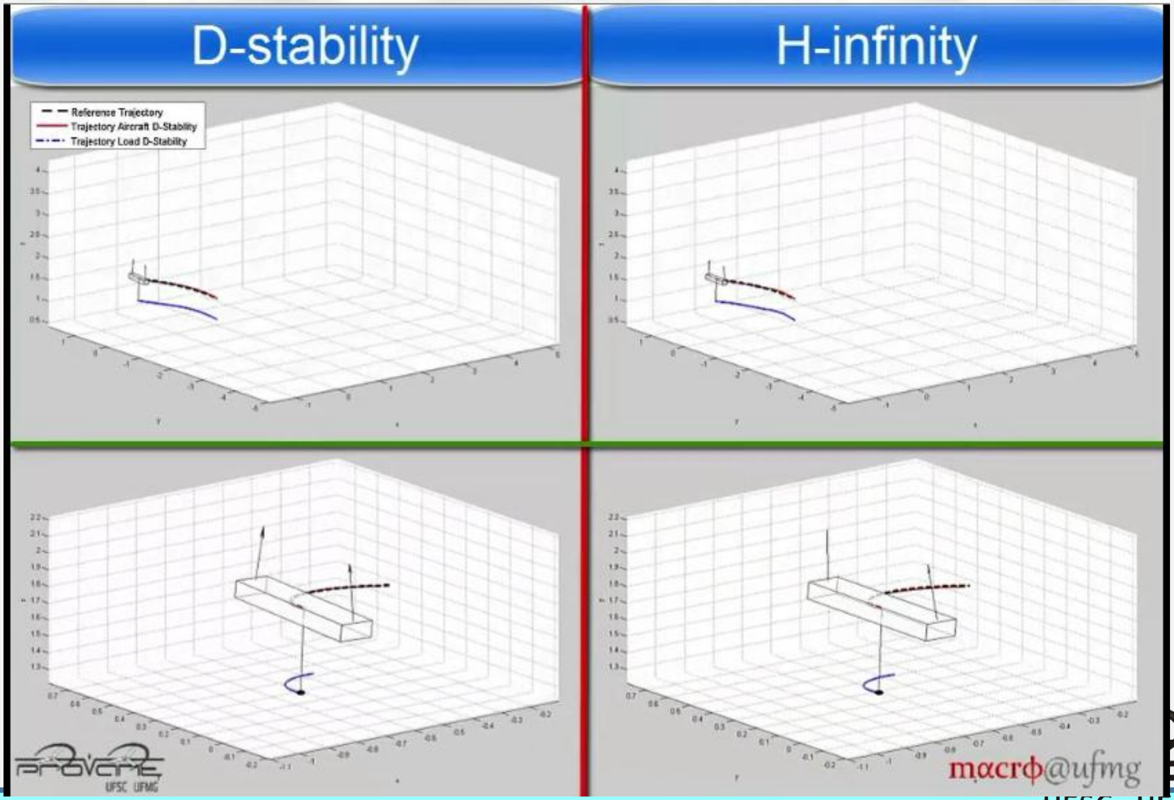
CPS Design Process

Different types of models:

(2/3) Functional Model

- System Operating Modes
- Control Algorithms



CPS Design Process

Different types of models:

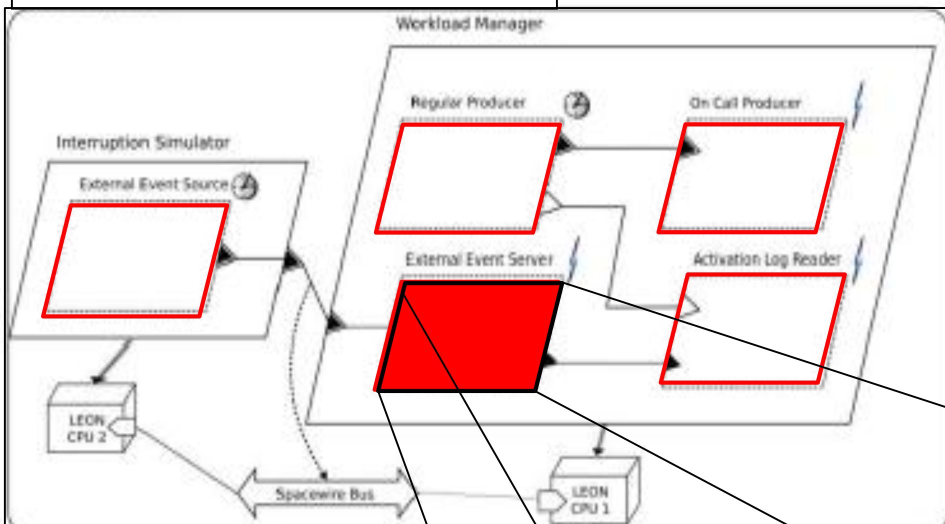
(3/3) Architectural Model

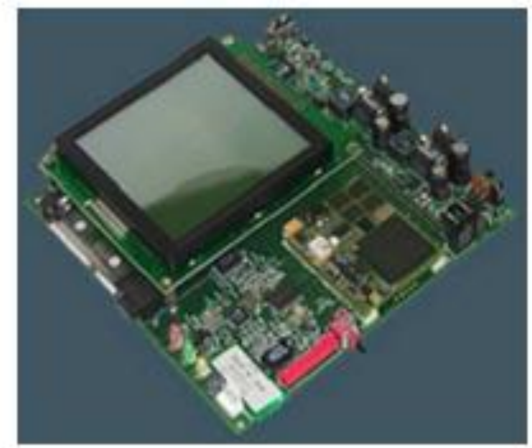
- Software organization (processes, threads, communication)
- Target architecture
- Software deployment (on target architecture)

CPS Design Process

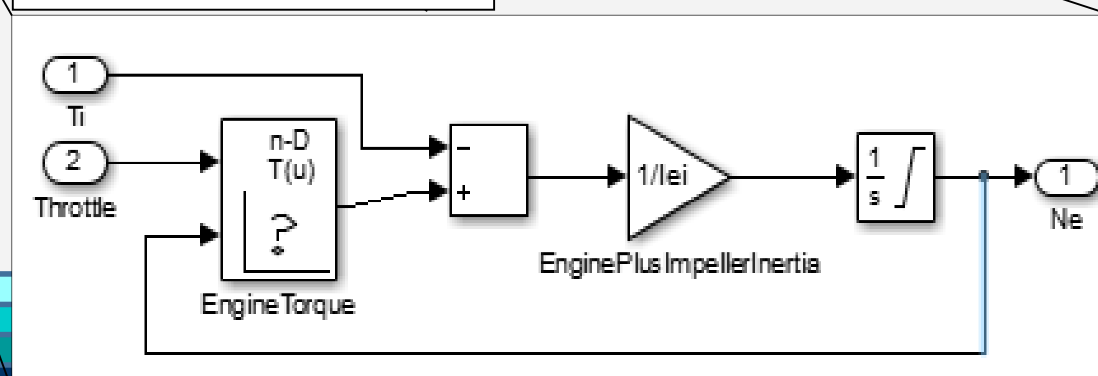
(3/3) Architectural Model

Architectural Model





Functional Model



Paper Scope

- Address how to perform the transition from simulation model to the implementation model;
- Replace the analytical (physical) model, that represents the physical devices, for the real sensors and actuators;
- Provide adequate tool support for the design process;

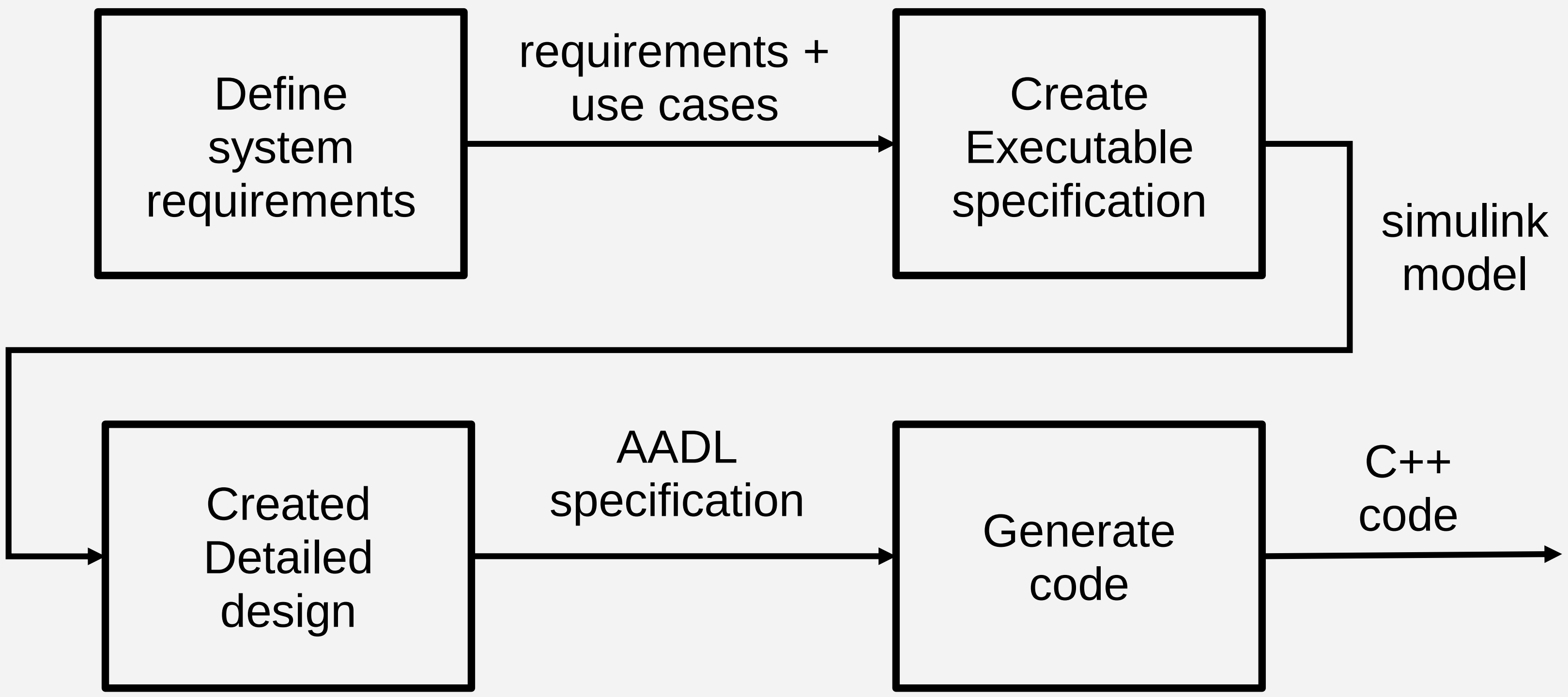
Why Simulink?

- Robust tool that support the design of discrete and continuos systems:
- Component library to support the systems design;
- Provide interface with the embedded platforms;
- Support system simulations and analysys;

Why AADL?

- Language that support the specification of the system architecture;
- Provide structures to represent and integrate software and hardware components;
- Support analysis of different system properties;

Research Contextualization



Main activities and artifacts of the adopted method to develop CPS (from Passarini et. al 2015)

- Approach does not comprise the generation of the set of sensors and actuators needed by the CPS;

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Proposed Approach - ECPSModel

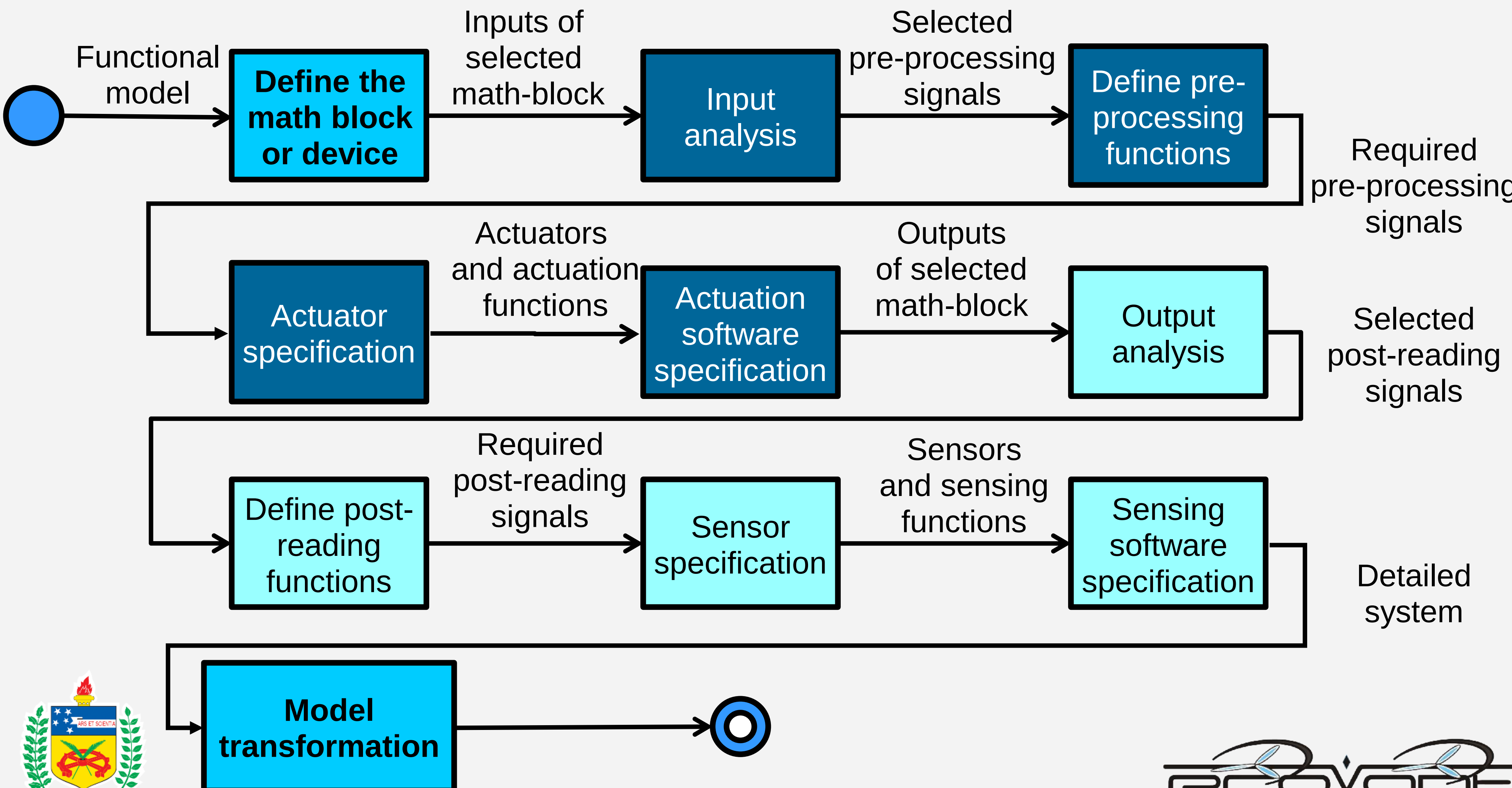
- Extends previous approach, allowing to represent sensors and actuators characteristics before model transformation

  - Define the set of input devices (sensors) and output devices (actuators)

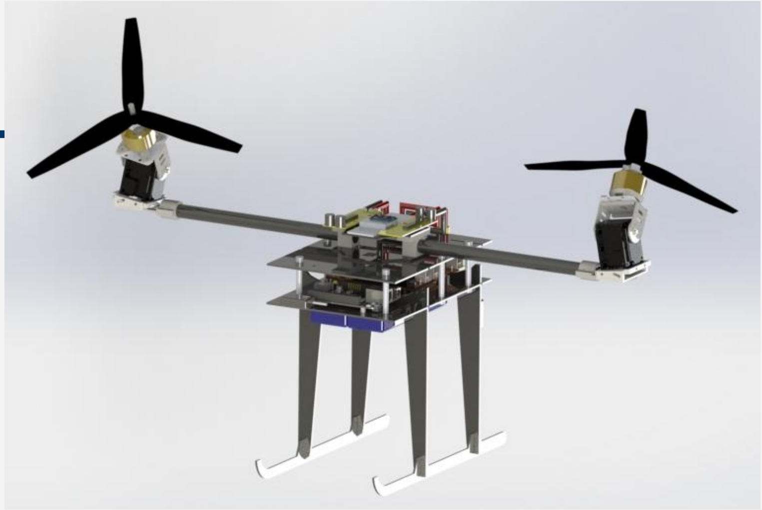
  - Specify the required sensing and actuating functions;

  - Organize the functions and devices in a software structures;

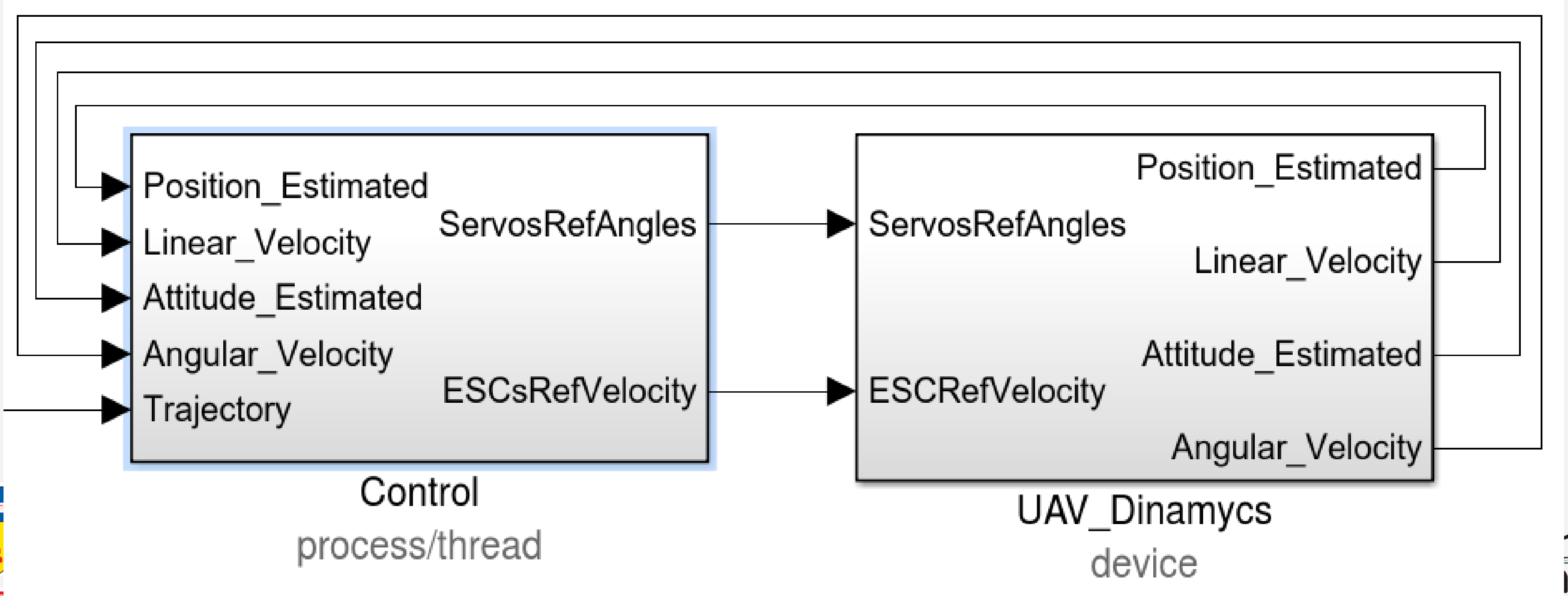
Proposed Approach - ECPSModel



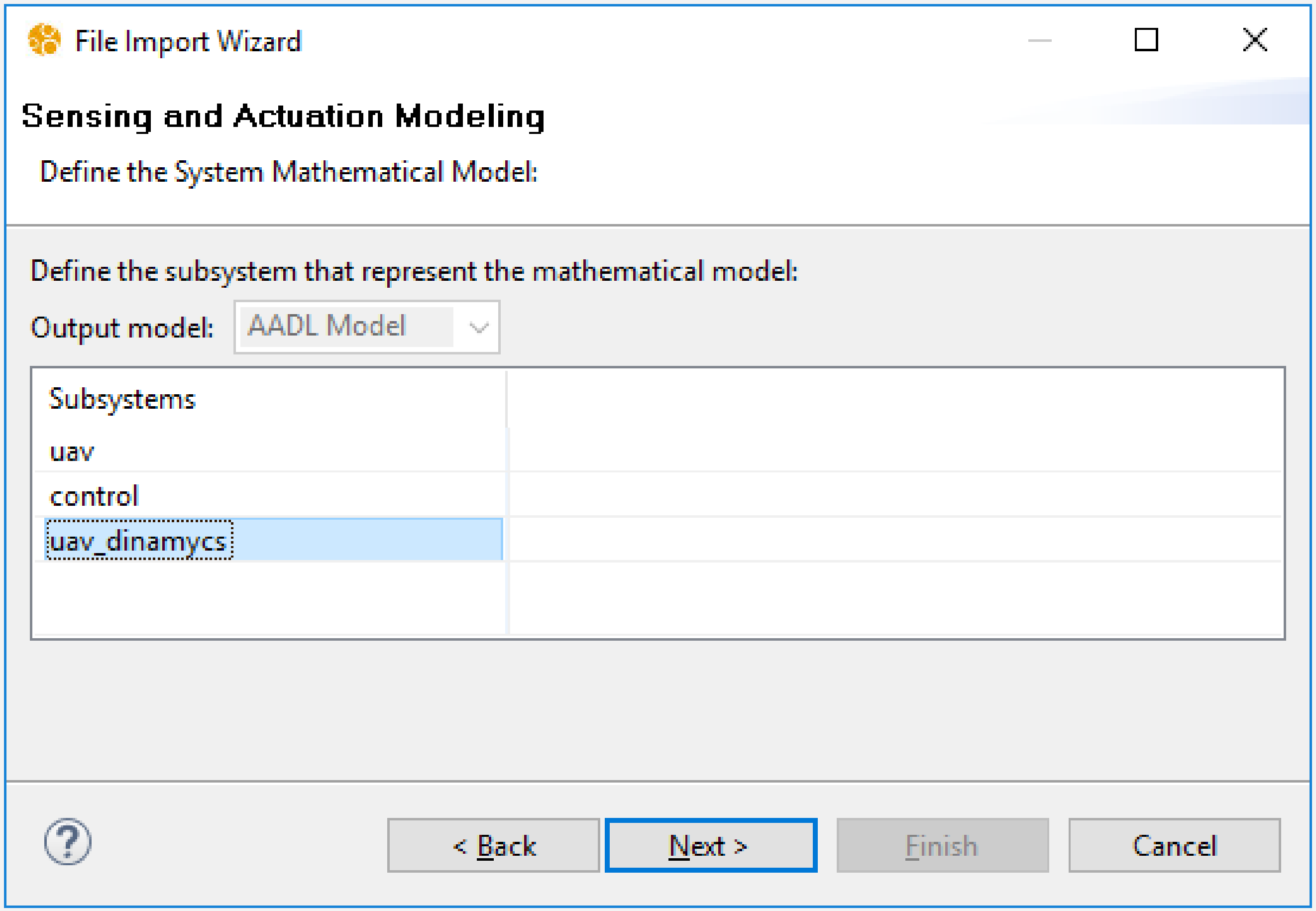
Case Study



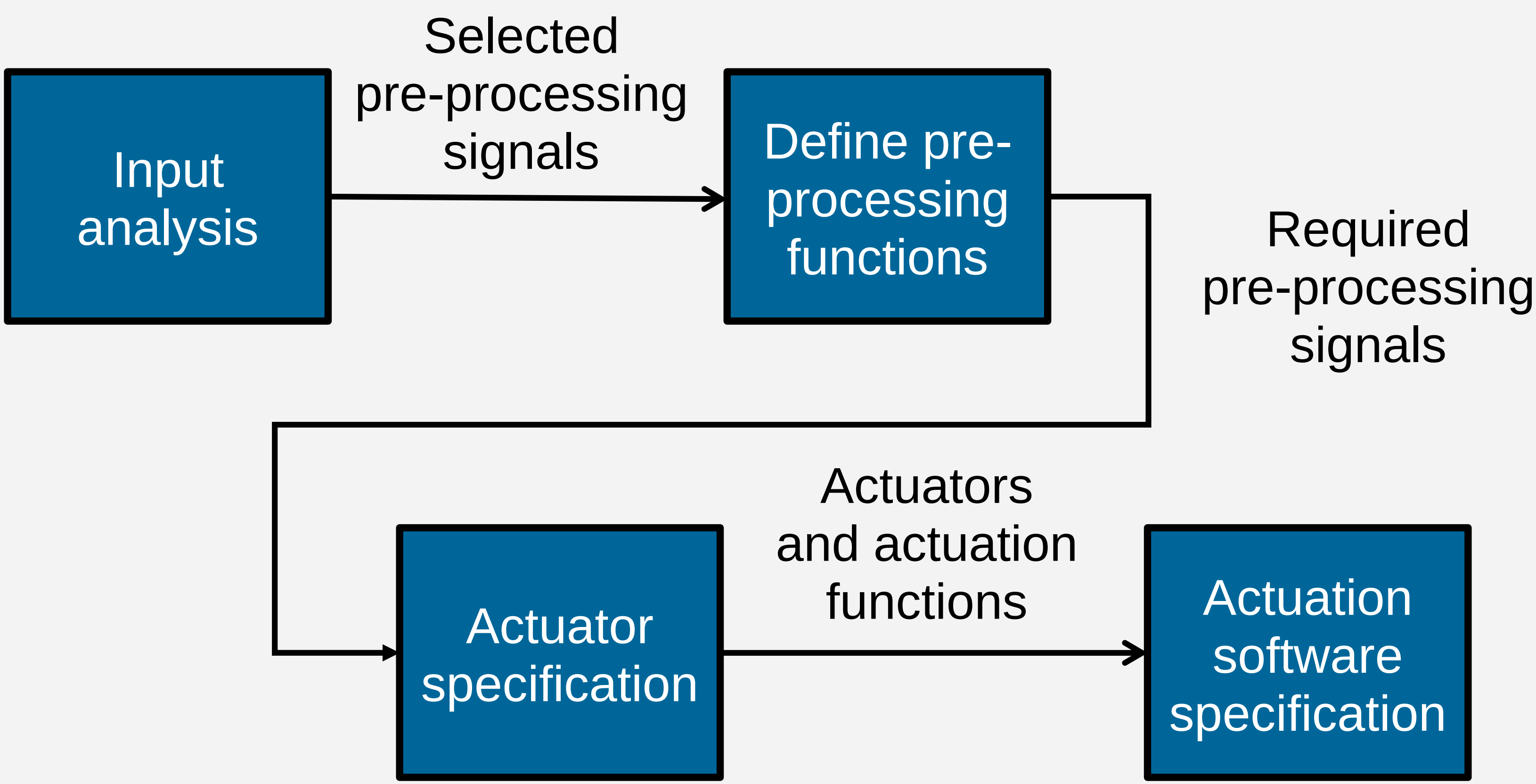
- Bi-rotor tilt-rotor UAV;
- Functional model is composed by two blocks;



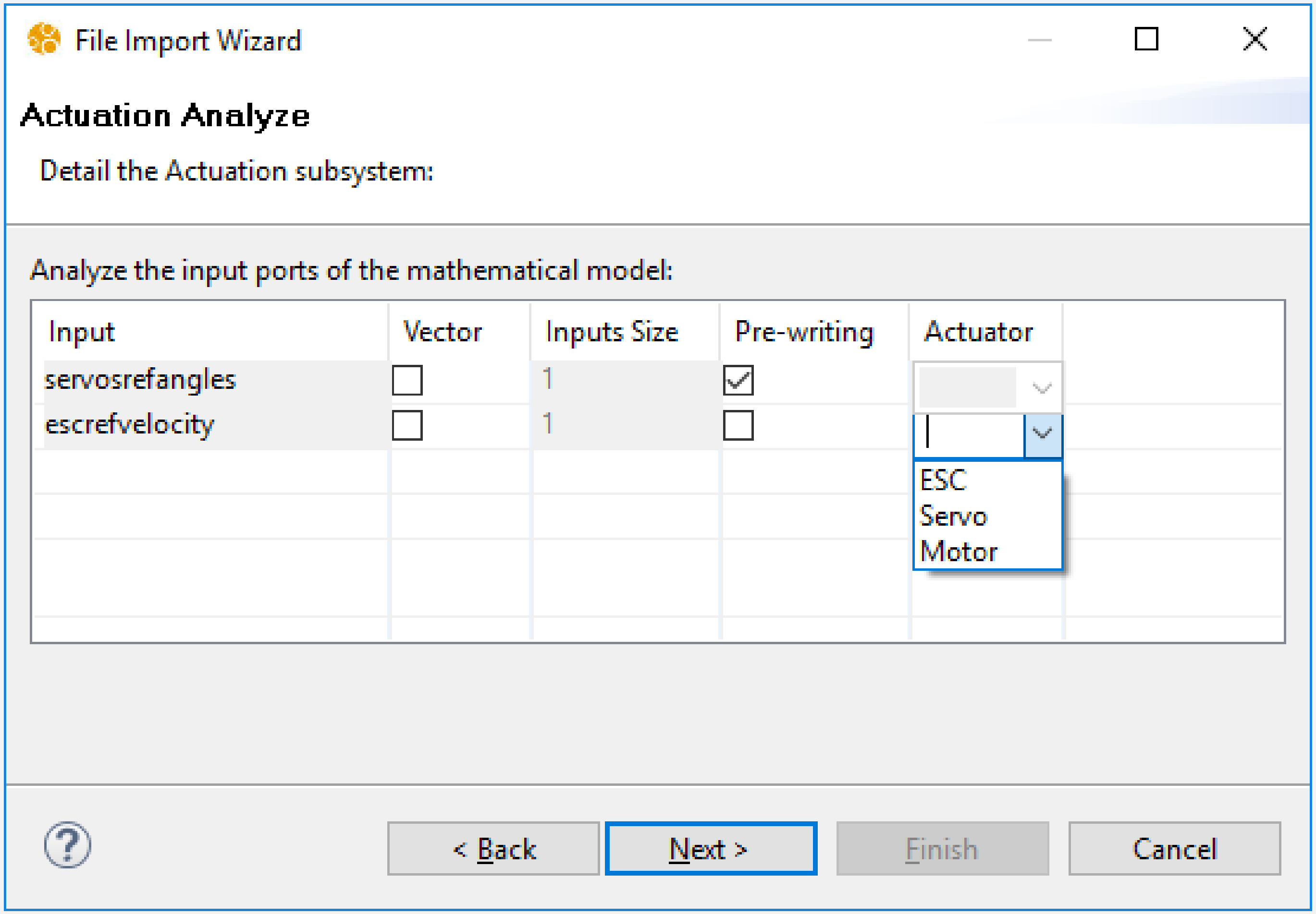
Select the mathematical block



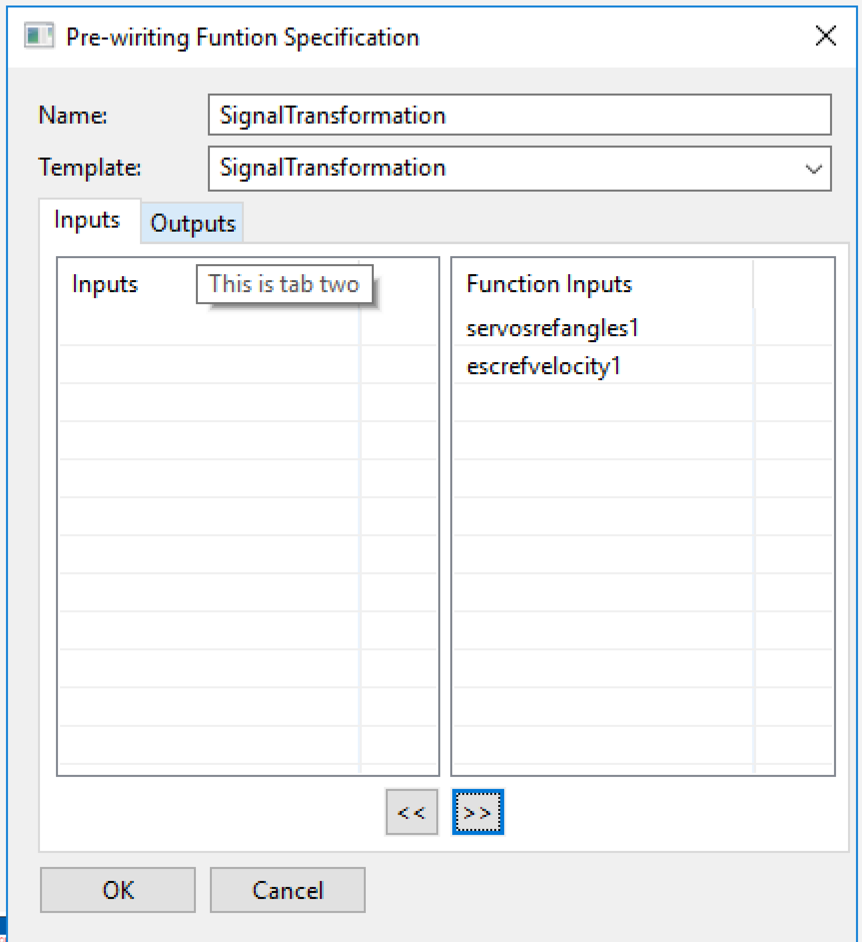
Actuation definition

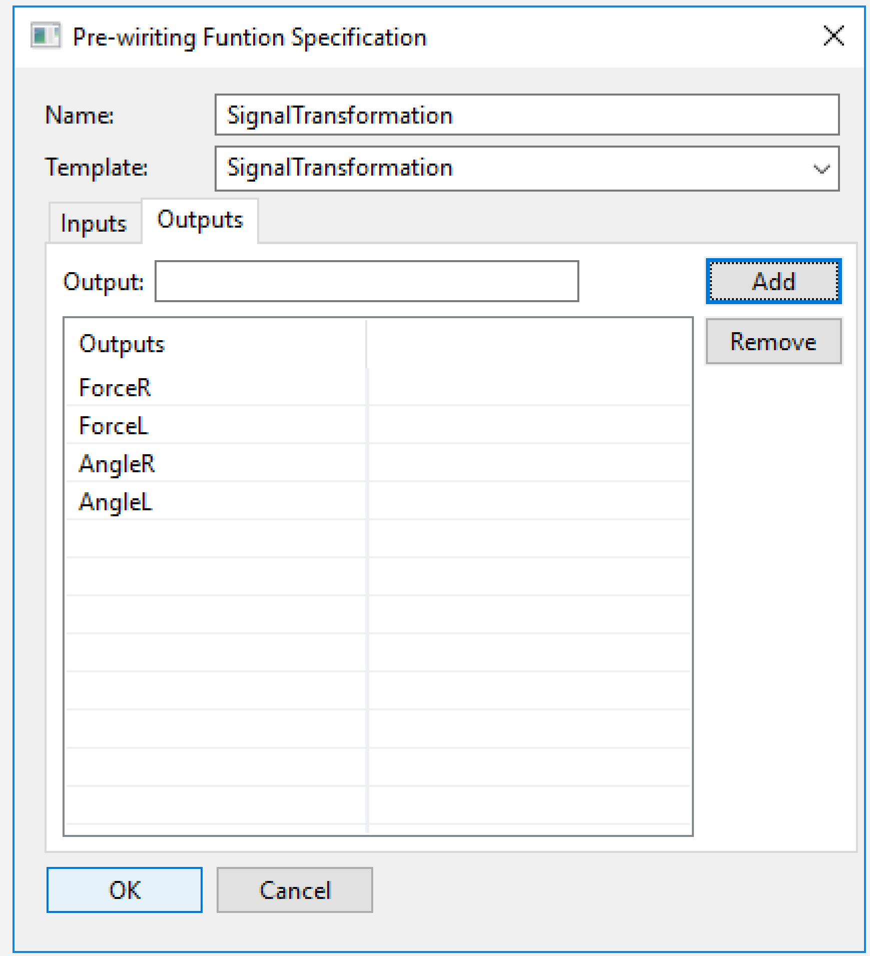


Input analysis

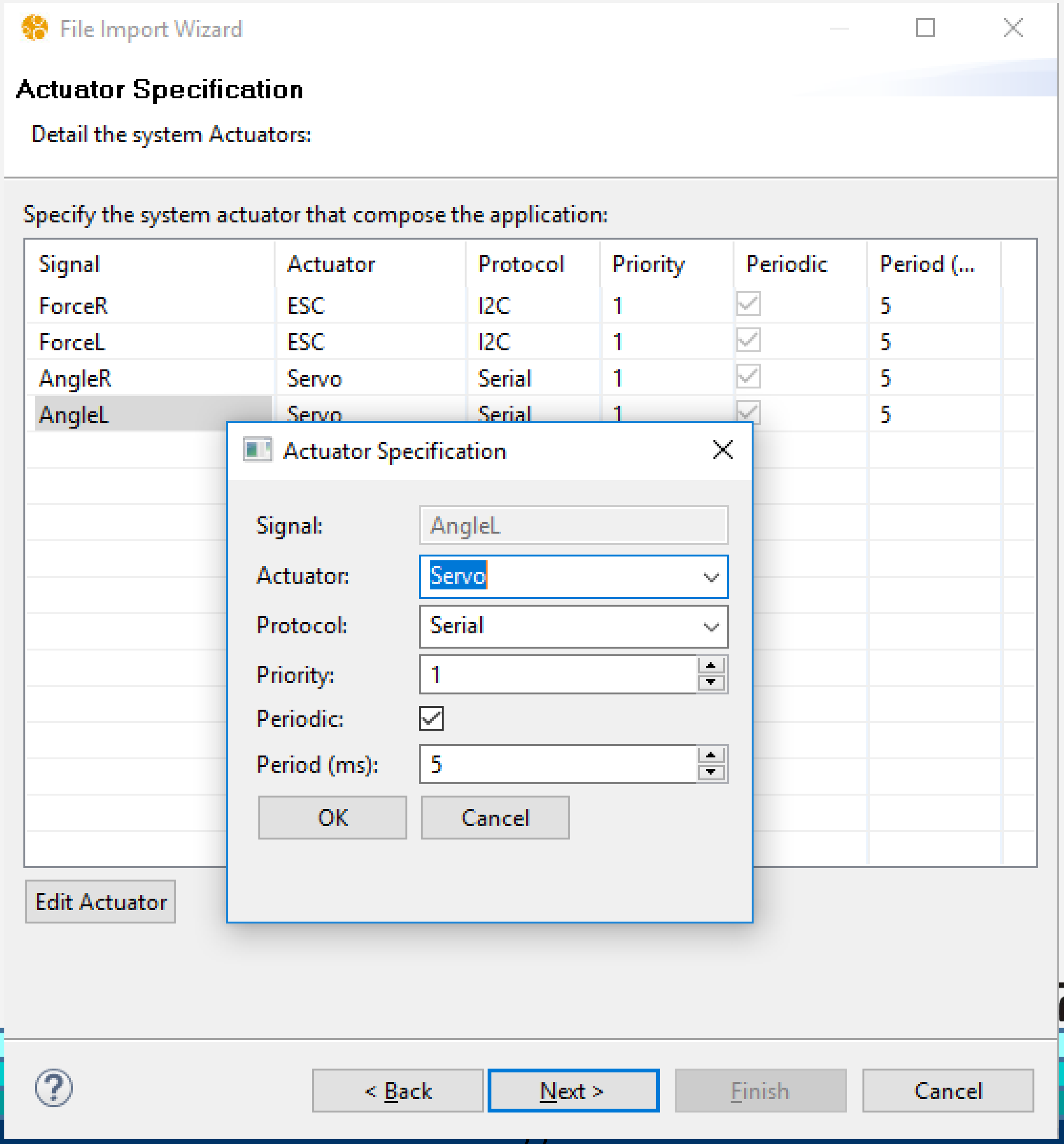


Define pre-processing functions

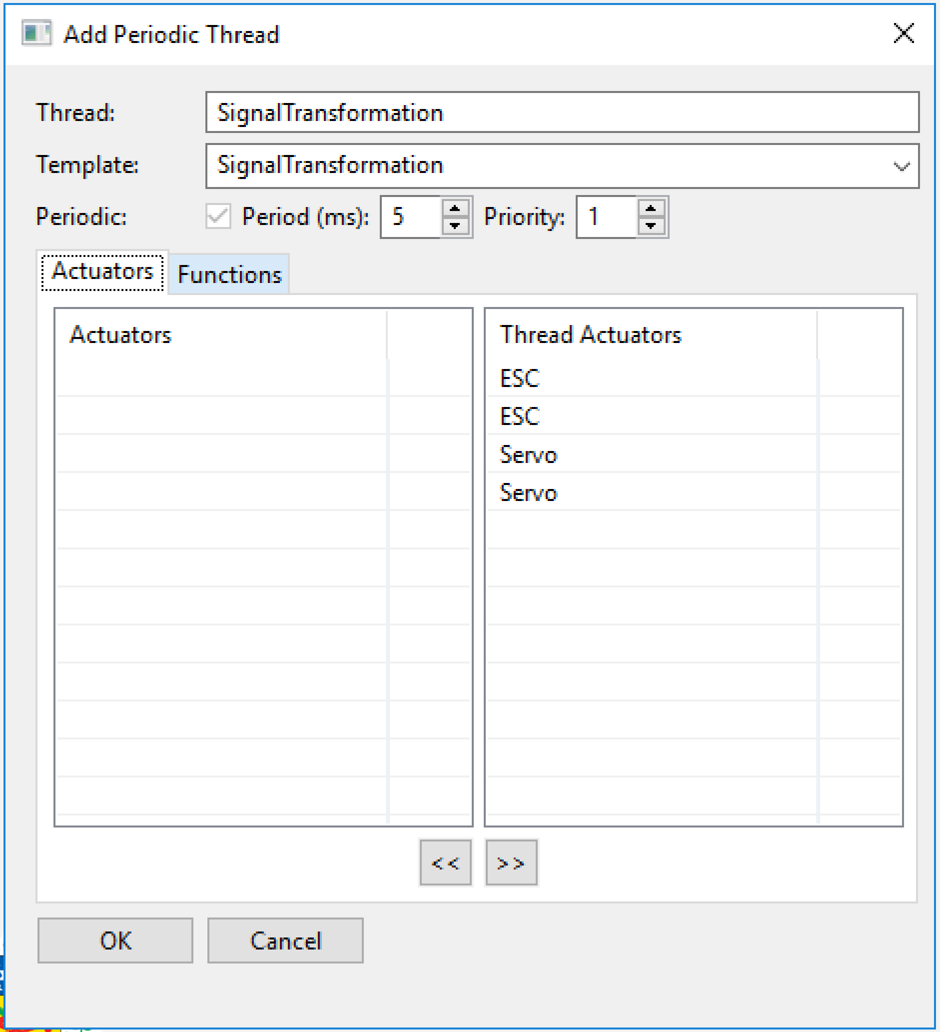


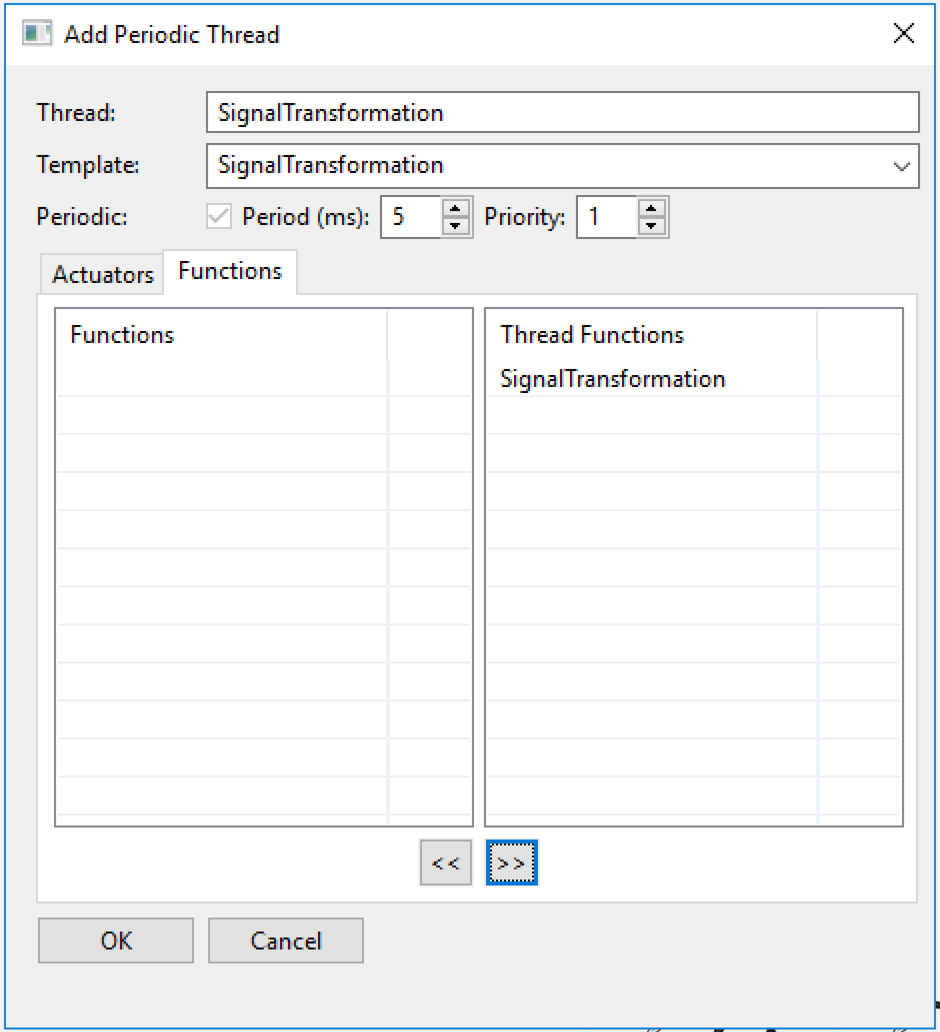


Actuators specification

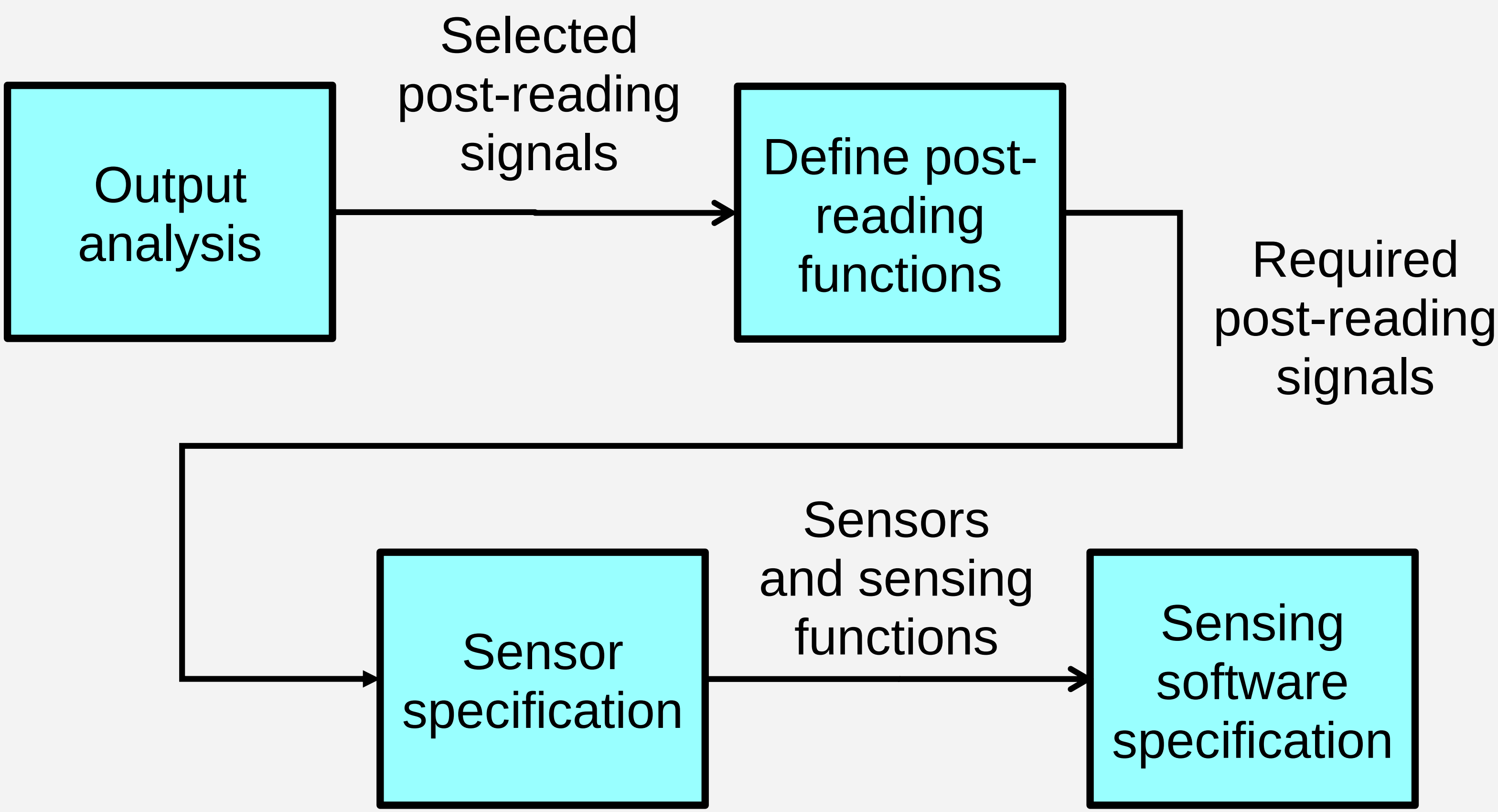


Actuation software specification

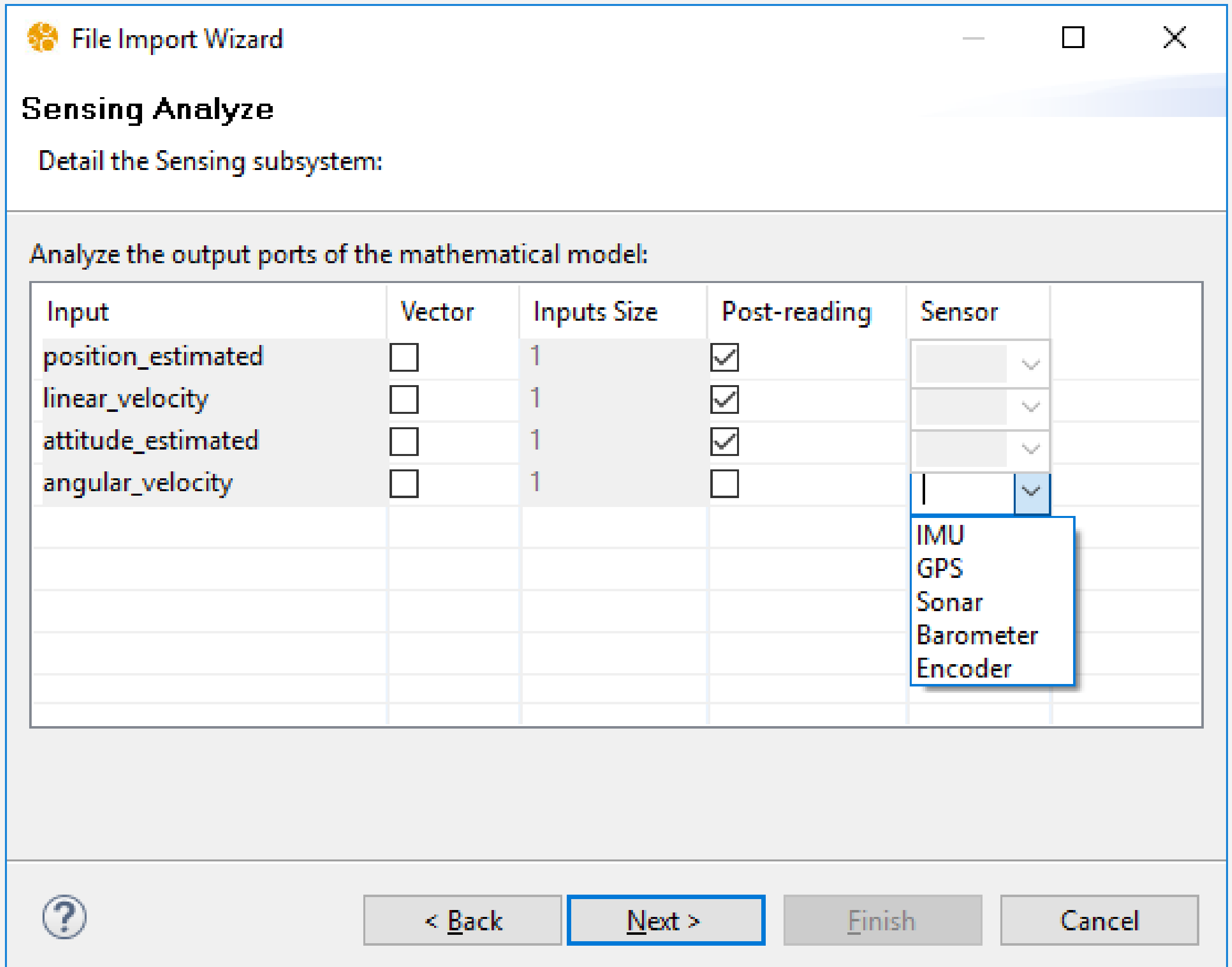




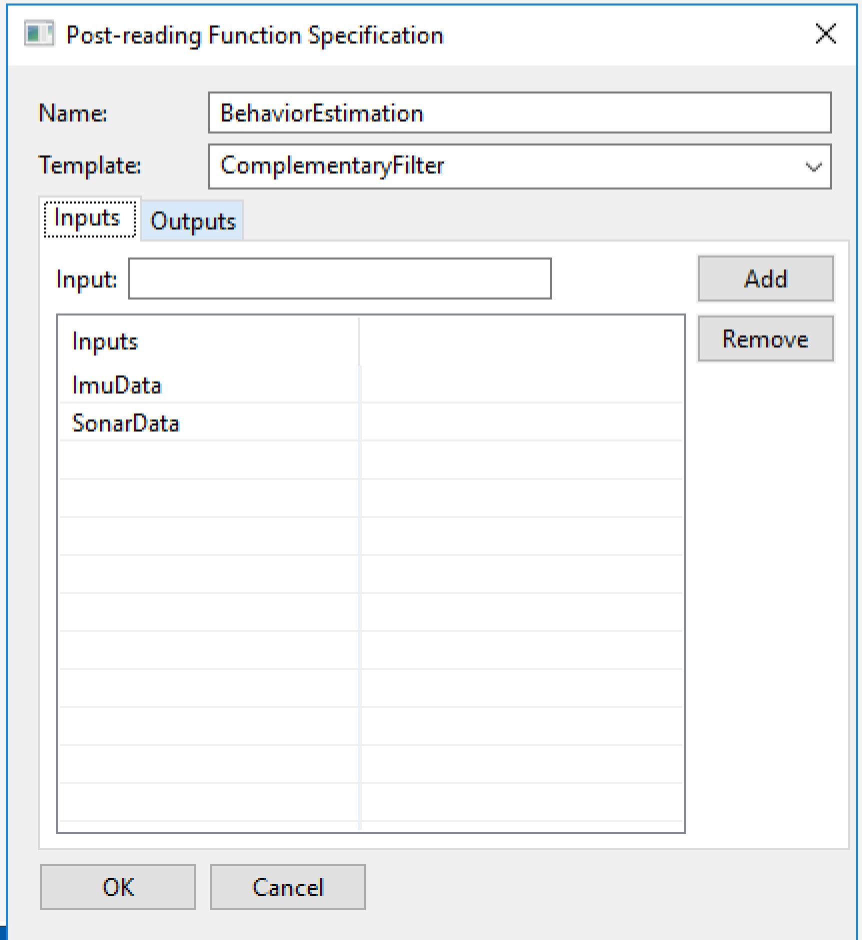
Sensing definition

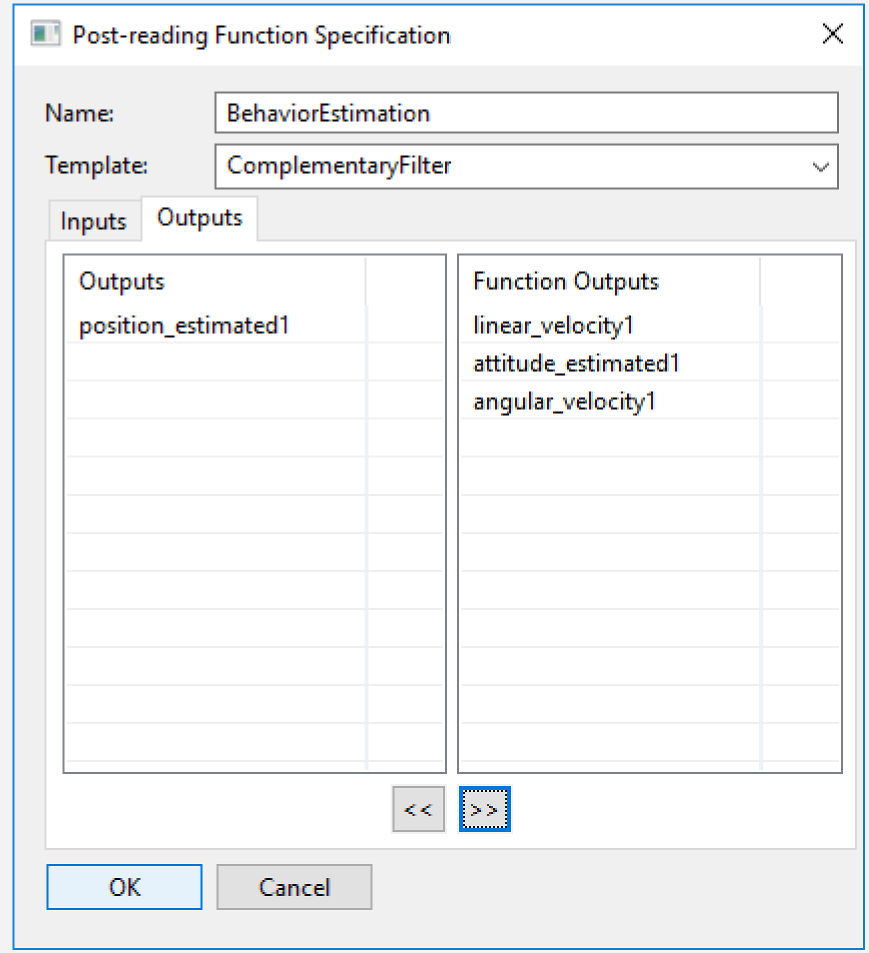


Output analysis

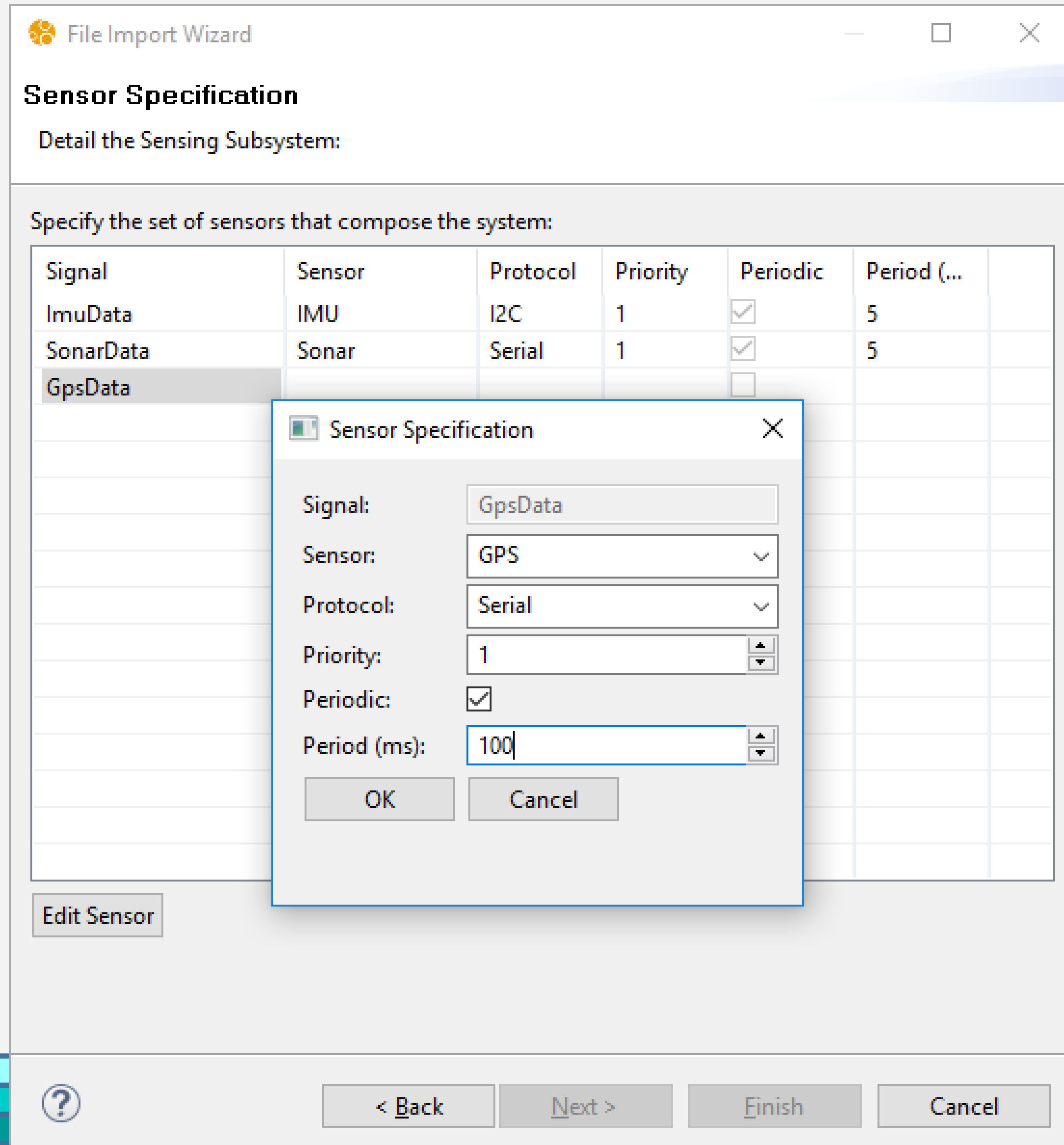


Define post-reading functions

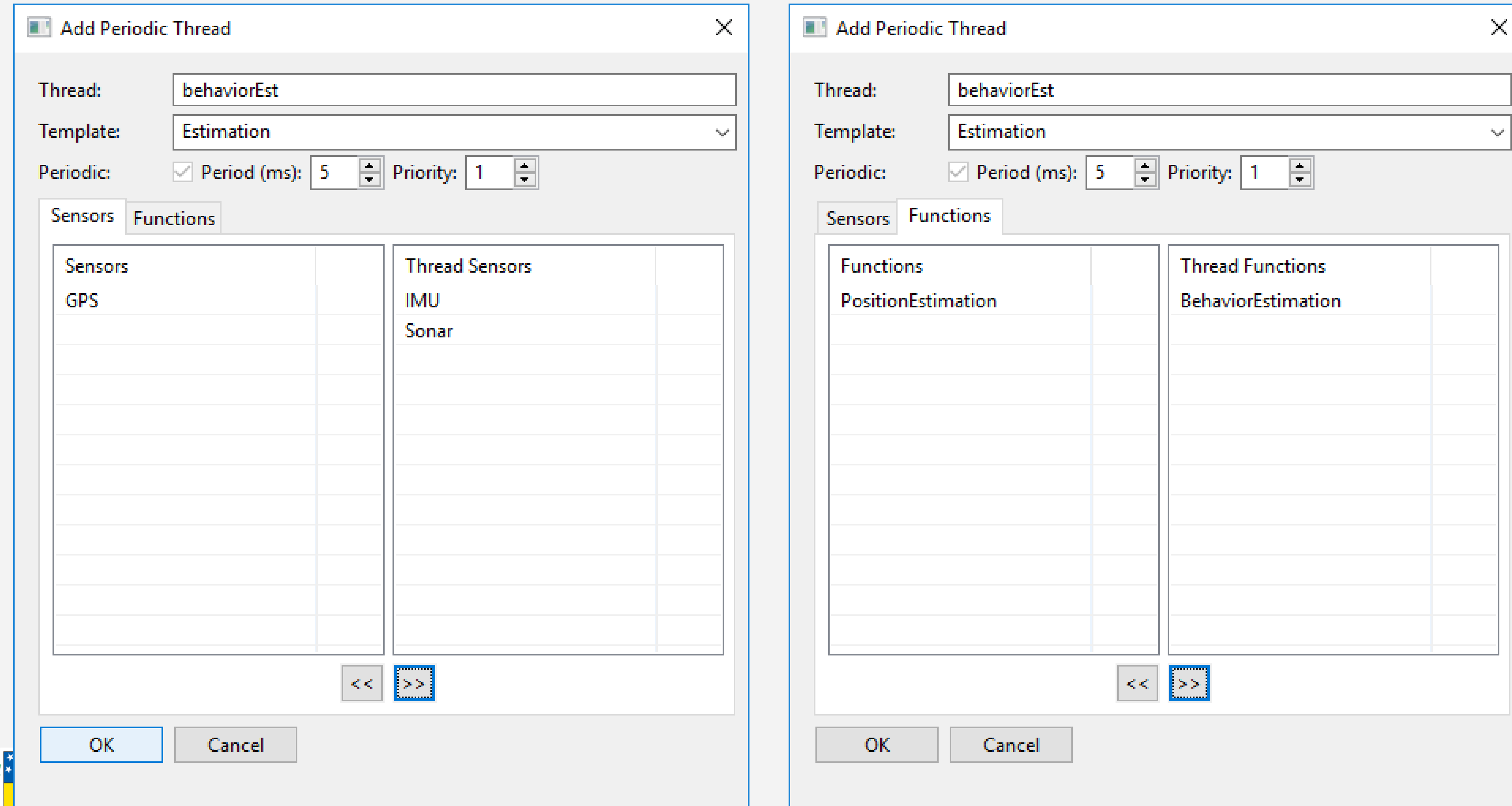




Sensor specification



Sensing software specification



Generated output model

```
1  SYSTEM IMPLEMENTATION UAV.impl
2    SUBCOMPONENTS
3      --PROCESS
4      pi_control: PROCESS p_control.impl;
5      pi_sen_act: PROCESS p_sen_act.impl;
6      --DEVICE
7      di_esc_r: DEVICE d_esc.impl;
8      di_esc_l: DEVICE d_esc.impl;
9      di_servo_r: DEVICE d_servo.impl;
10     di_servo_l: DEVICE d_servo.impl;
11     di_gps: DEVICE d_gps.impl;
12     di_sonar: DEVICE d_sonar.impl;
13     di_imu: DEVICE d_imu.impl;
14   CONNECTIONS
15     C1: PORT di_gps.position -> pi_sen_act.position;
... Here goes all the connections (lines 16 to 35)
35 END UAV.impl;
```

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Generated output model

```
1  PROCESS IMPLEMENTATION p_est_act.impl
2    SUBCOMPONENTS
3      ti_signalTransformation: THREAD t_signalTransformation.impl;
4      ti_behaviorEst: THREAD t_behaviorEst.impl;
5      ti_positionEst: THREAD t_positionEst.impl;
6    CONNECTIONS
7      C1: PORT distance -> ti_behaviorEst.distance;
... Here goes all the connections (lines 8 to 25)
26 END p_est_act.impl;
```

Generated output model

```
THREAD IMPLEMENTATION t_behaviorEst.impl
CALLS
  Mycalls: {
    P_Spg : SUBPROGRAM behaviorEstimation;
  };
PROPERTIES
  Dispatch_Protocol => Periodic;
  Period => 5ms;
  Deadline => 5ms;
END t_behaviorEst.impl;
```

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Conclusions

- ECPSModeling tool was created to support the automated design of CPS;
- Systematize the design process of sensing and actuation subsystems;
- Generated AADL model integrate control algorithms, estimation filters and the system devices.
- Use of Design-Space Exploration techniques in order to generate more elaborated models;
- Integrate verification methods to evaluate and guarantee the system properties.

Thank you

Questions ?

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