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Digital innovation HUBs and CollAborative Platform for cyber-physical systems

The Initial HUBCAP Models

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0.6	15-06-2020	Stefano Tonetta	Revision, updated list of models, and added summary
1.0	15-06-2020	Stefano Tonetta	Final version

Abstract

The **HUBCAP Collaborative Platform** will provide **catalogs of models** and Model-Based Design (MBD) tools for trial experiments to design and develop innovative CPS solutions with the support of MBD technology.

D6.1 consists of a set of an **initial set of models** provided by HUBCAP partners and are uploaded on the HUBCAP Collaborative Platform to constitute the contents of the first catalog of models. The catalog will continuously be enriched along the project by the HUBCAP partners, by the winners of the Open Calls, and in the future by the HUBCAP ecosystem. The number of models in the catalog contributes to the project **KPI "# of listed technology assets"**.

D6.1 is actually of **type "OTHER"**, given by the actual data uploaded in the catalog of models. The catalog can be browsed by accessing the platform. This document summarizes the contents of the catalog for the reviewer's convenience.

Contents

1. Introduction

Model-Based Design (MBD) is a method to address the design of complex systems with models. It prescribes the use of models through the development process in order to represent system structure and behaviors, providing a basis for machine-assisted analysis of system properties, and supporting design decisions through processes of refinement into implementation. The purpose is 1) to **reduce the complexity** of design **by abstraction**; 2) to **ensure the quality** of the system **by rigorous analysis** of its properties; 3) to **reduce the cost** of the development **by detecting issues** in the **early** phases of the development. MBD is quite standard in software engineering and is becoming more and more relevant in systems engineering, where it must integrate methods for control engineering and safety engineering.

MBD appears largely to be applied in domains such as aerospace where the return on investment can take decades. By contrast, SMEs require considerable flexibility to change processes to adopt MBD and may lack in-house expertise. In addition, the selection, procurement, training and deployment costs for some methods and tools can be discouragingly high. In general, it is difficult for SMEs to invest in acquiring the necessary background for example because of the high license fees from commercial vendors of MBD assets.

The **HUBCAP Collaborative Platform** will lower such barriers by providing **catalogs of models** and Model-Based Design (MBD) tools for trial experiments to design and develop innovative CPS solutions with the support of MBD technology. D6.1 consists of an **initial set of models** provided by HUBCAP partners that are uploaded on the HUBCAP Collaborative Platform to constitute the contents of the first catalog of models. This document summarizes the contents of the catalog for the reviewer's convenience.

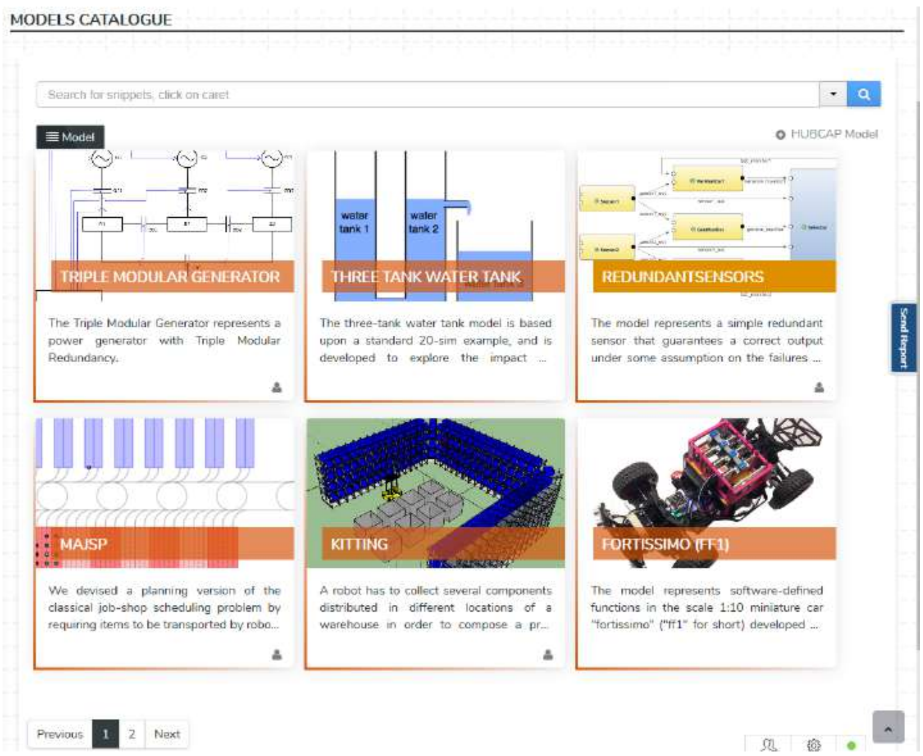

Figure 1. Screenshot of the models catalog

2. The models

The following sections report the list of modes that are currently present on the platform, with a snapshot of the related platform page.

2.1. Redundant Sensors

The model represents a simple redundant sensor that guarantees a correct output under some assumption on the failures of the two basic sensors. Some monitor components try to detect the failures, while a selector component outputs the correct value if possible. This architecture has been taken from a similar case study developed in the FoReVer project. The architecture is specified in OCRA, while the component implementation is specified in SMV.

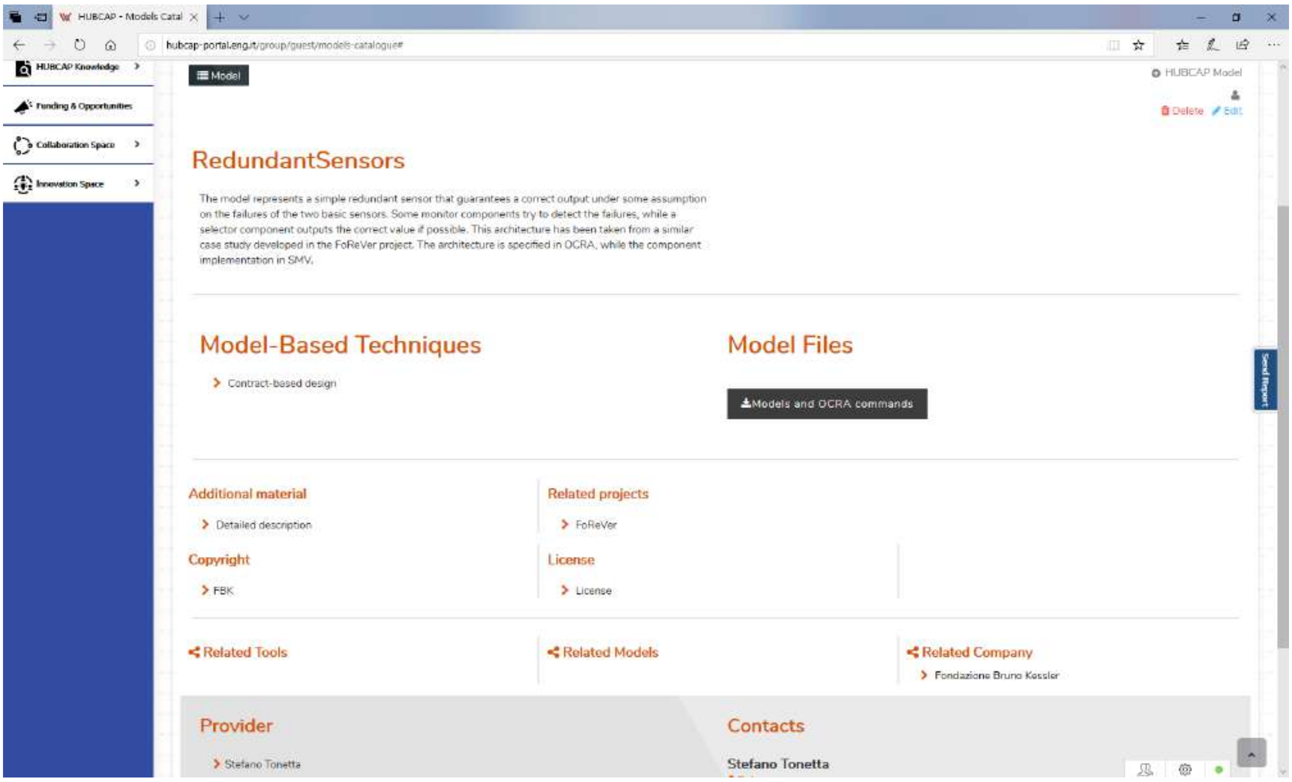

Figure 2. Screenshot of the Redundant Sensors page

2.2. Triple Modular Generator

The Triple Modular Generator represents a power generator with Triple Modular Redundancy. It can be used to try various functionalities of xSAP including Model-Based Safety Analysis (fault injection, FTA and FMEA), FDIR analysis, and TFPG.

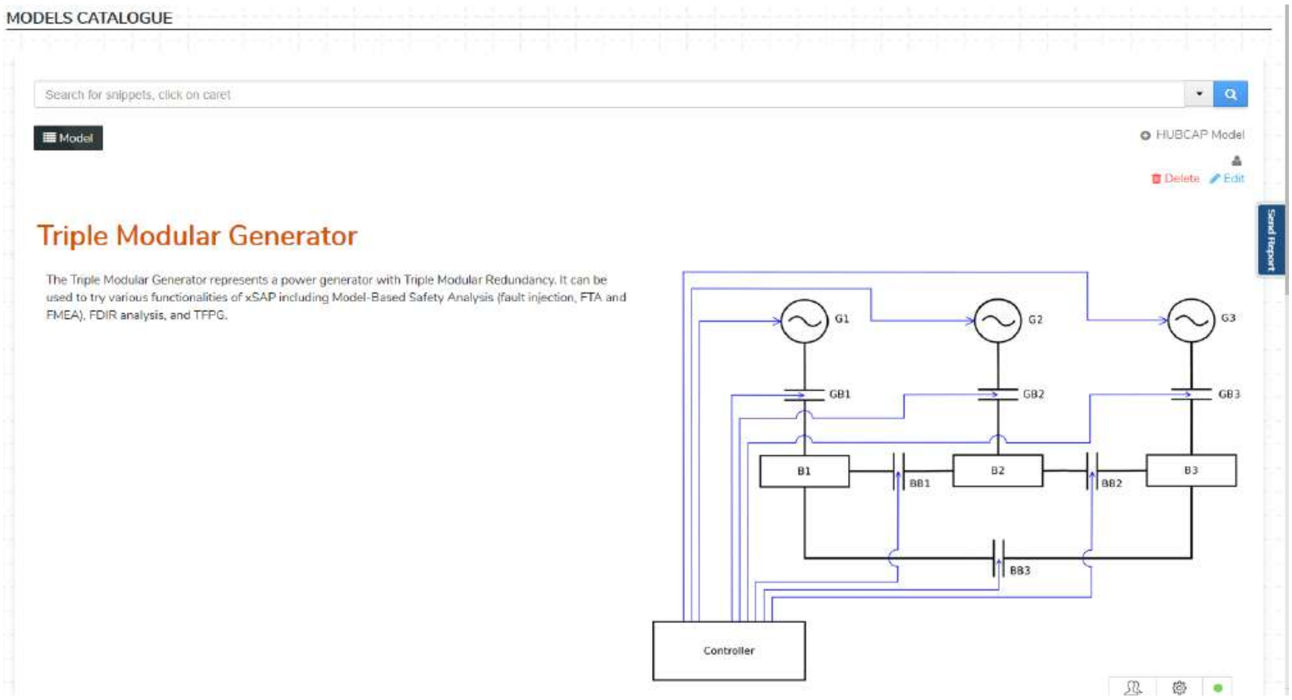

Figure 3. Screenshot of the Triple Mudular Generator page

2.3. MAJSP

We devised a planning version of the classical job-shop scheduling problem by requiring items to be transported by robots to the machines performing the jobs to be scheduled. Instances scale with the number of robots (from 1 to 3), items to be processed (from 1 to 4), positions (from 2 to 6) and jobs (from 1 to 4) for a total of 240 instances.

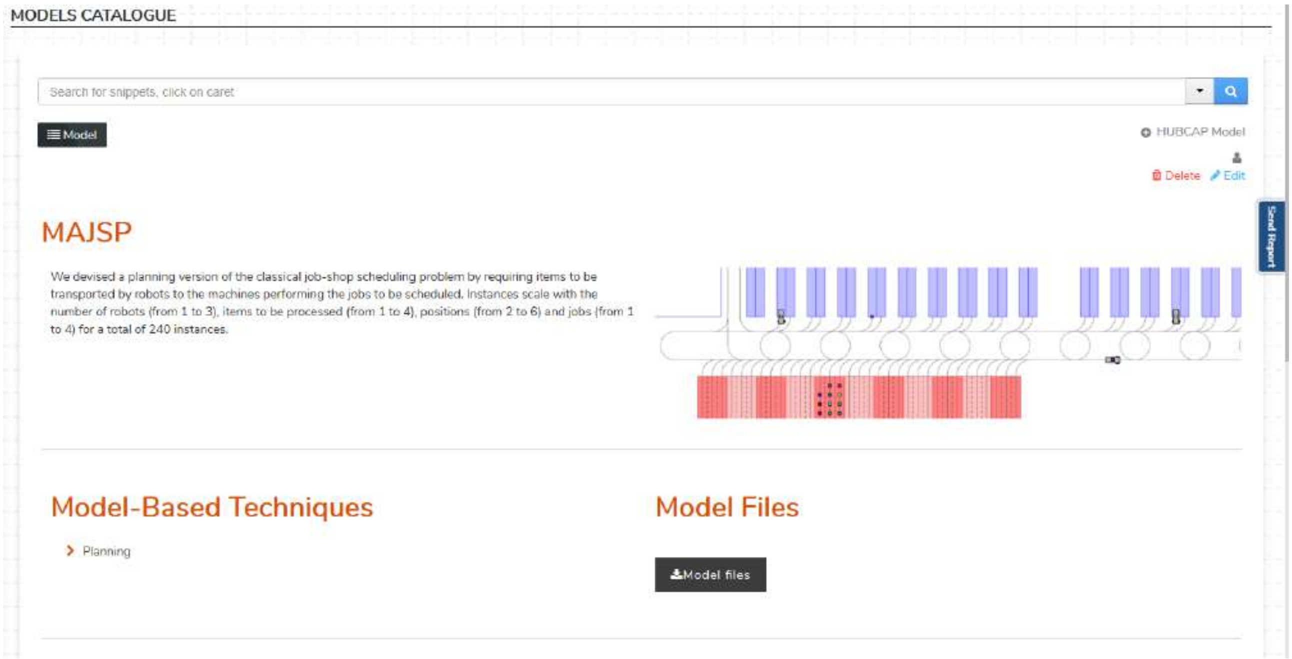

Figure 4. Screenshot of the MAJSP page

2.4. Kitting

A robot has to collect several components distributed in different locations of a warehouse in order to compose a pre-defined kit and then deliver it to a specific location synchronizing with a human operator. We created several instances of this domain by scaling the kit size up to 5 components and the number of kit to deliver (up to 3).

Figure 5. Screenshot of the Kitting page

2.5. Three Tank Water Tank

The three-tank water tank model is based upon a standard 20-sim example, and is developed to explore the impact on accuracy of multi-modelling across multiple models. The example comprises three water tanks which are filled and emptied. The first tank is filled from a source with a valve which may be turned on and off. The outflow of the first tank constitutes the inflow of the second, and so forth. A controller monitors the level of the third tank and controls a valve to a drain.

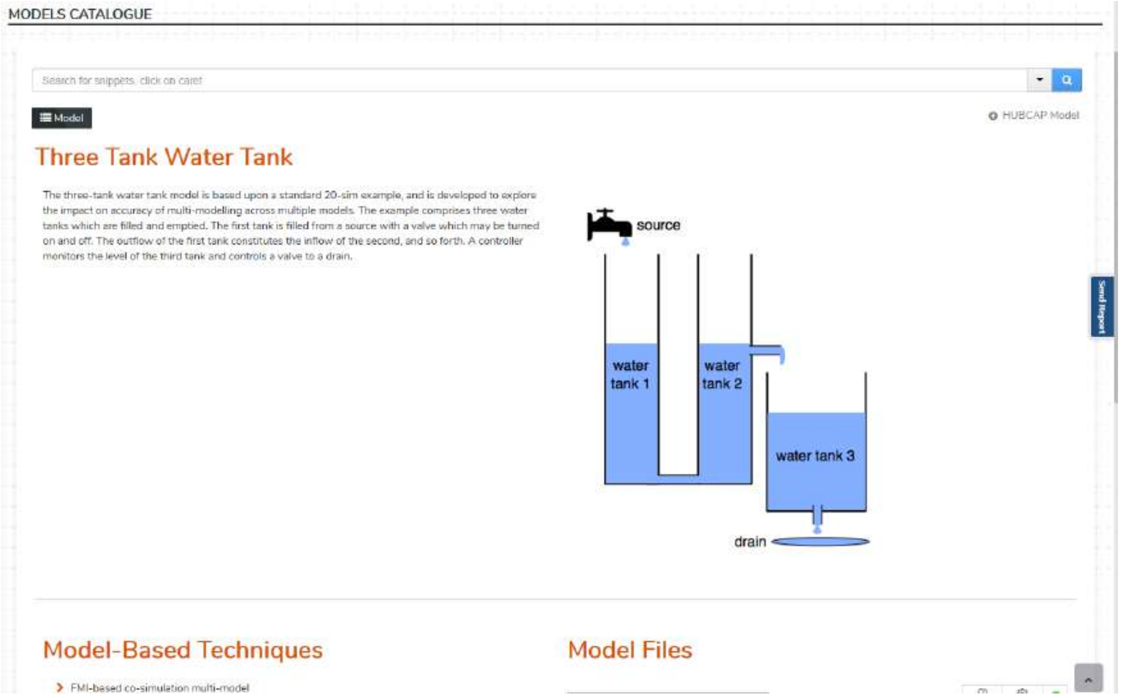

Figure 6. Screenshot of the Three Water Tank page

2.6. fortissimo (ff1)

The model represents software-defined functions in the scale 1:10 miniature car "fortissimo" ("ff1" for short) developed by fortiss' Model-Based Systems Engineering Group. The logical architecture of the model provides autonomous driving functions consisting of platooning support that combines lane keeping and a platoon control functionality where a set of cars follows a leader car. In the physical setup, the ff1's hardware platform consists of up to four Raspberry PIs, a camera, ultra-sound sensors and a laser range sensor. This part of the ff1 is represented by the technical architecture of the model. At fortiss, the ff1 and its model are used to teach students familiar in model-based development methods as well as to demonstrate research results such as design space exploration methods (e.g., calculating HW/SW deployments and rate-monotonic schedules for distributed platforms).

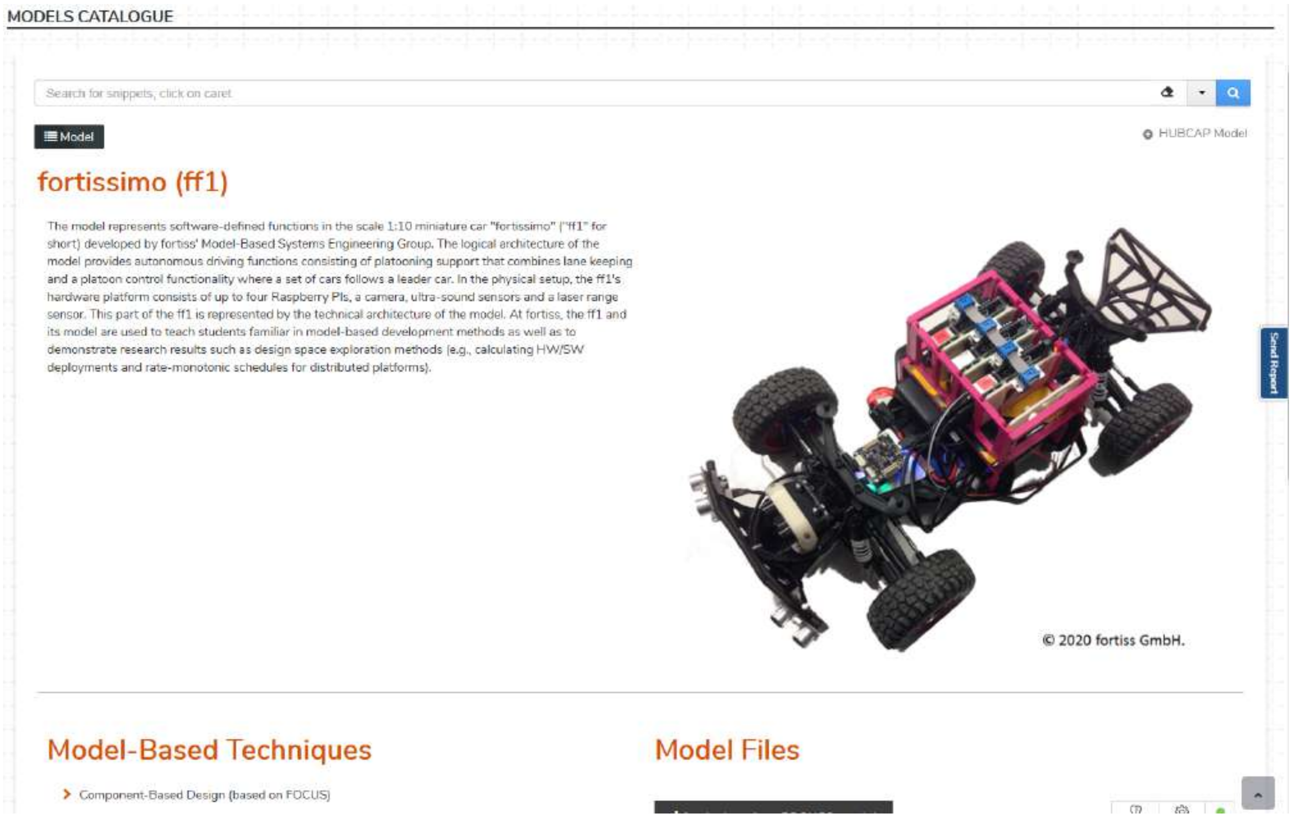

Figure 7. Screenshot of the fortiessimo page

2.7. Dual Mass Oscillator

The Dual Mass Oscillator model is a system of two masses separated by springs. See the Modelica model for an illustration.

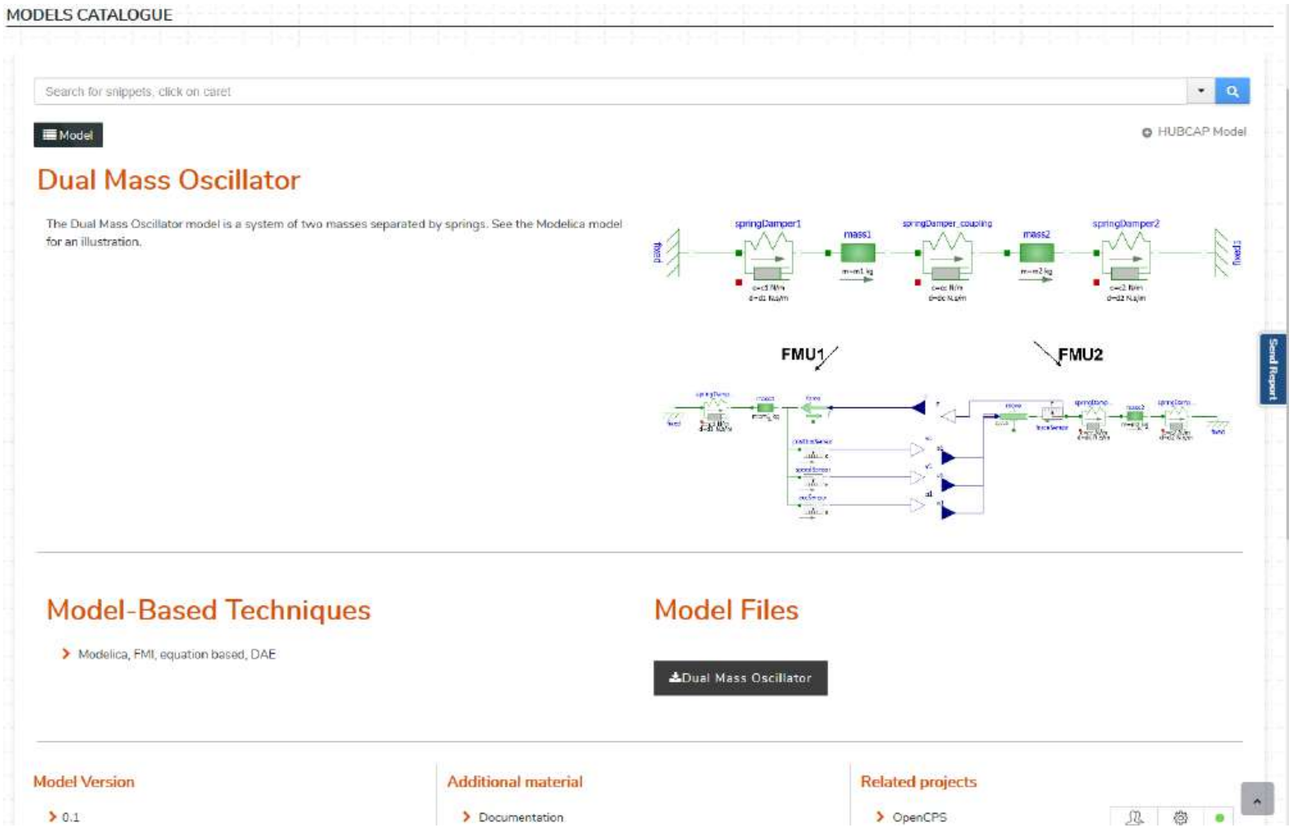

Figure 8. Screenshot of the Dual Mass Oscillator page

2.8. Line Follower Robot

This example was originally developed in the DESTECS project. The model simulates a robot that can follow a line painted on the ground. The line contrasts from the background and the robot uses a number of sensors to detect light and dark areas on the ground. The robot has two wheels, each powered by individual motors to enable the robot to make controlled changes in direction. The number and position of the sensors may be configured in the model. A controller takes input from the sensors and encoders from the wheels to make outputs to the motors. The robot moves through a number of phases as it follows a line. At the start of each line is a specific pattern that will be known in advance. Once a genuine line is detected on the ground, the robot follows it until it detects that the end of the line has been reached, when it should go to an idle state.

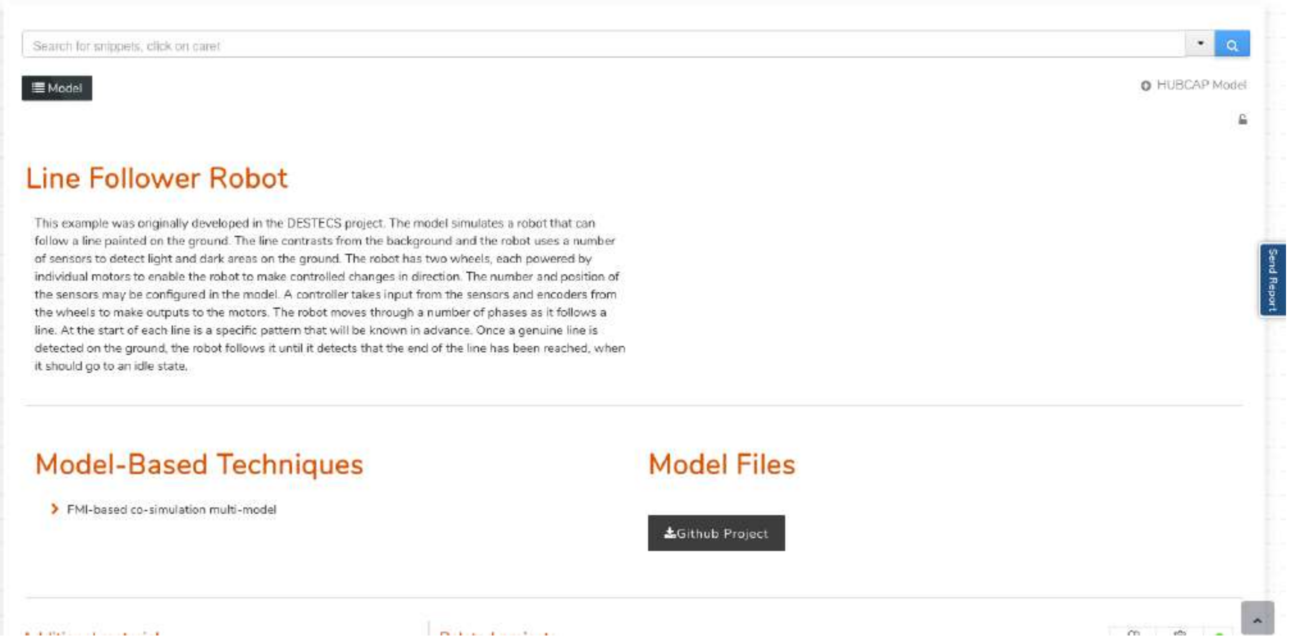

Figure 9. Screenshot of the Line Follower Robot page

2.9. Wheel Braking System

SAE Aerospace Information Report 6110, "Contiguous Aircraft/System Development Process Example," follows the development of a complex Wheel Brake System (WBS) using processes in the industry standards ARP4754A, "Guidelines for Development of Civil Aircraft and Systems," and ARP4761, "Guidelines and Methods for Conducting the Safety Assessment Process on Civil Airborne Systems and Equipment." AIR6110 employs informal methods to examine several WBS architectures which meet the same requirements with different degrees of reliability. This joint case study between FBK and Boeing enhances the AIR6110 with formal methods. First, WBS architectures in AIR6110 formerly using informal steps are recreated in a formal manner. Second, methods to automatically analyze and compare the behaviors of various architectures with additional, complementary information not included in the AIR6110 are presented. Third, an assessment of distinct formal methods ranging from contract-based design, to model checking, to model based safety analysis is provided.

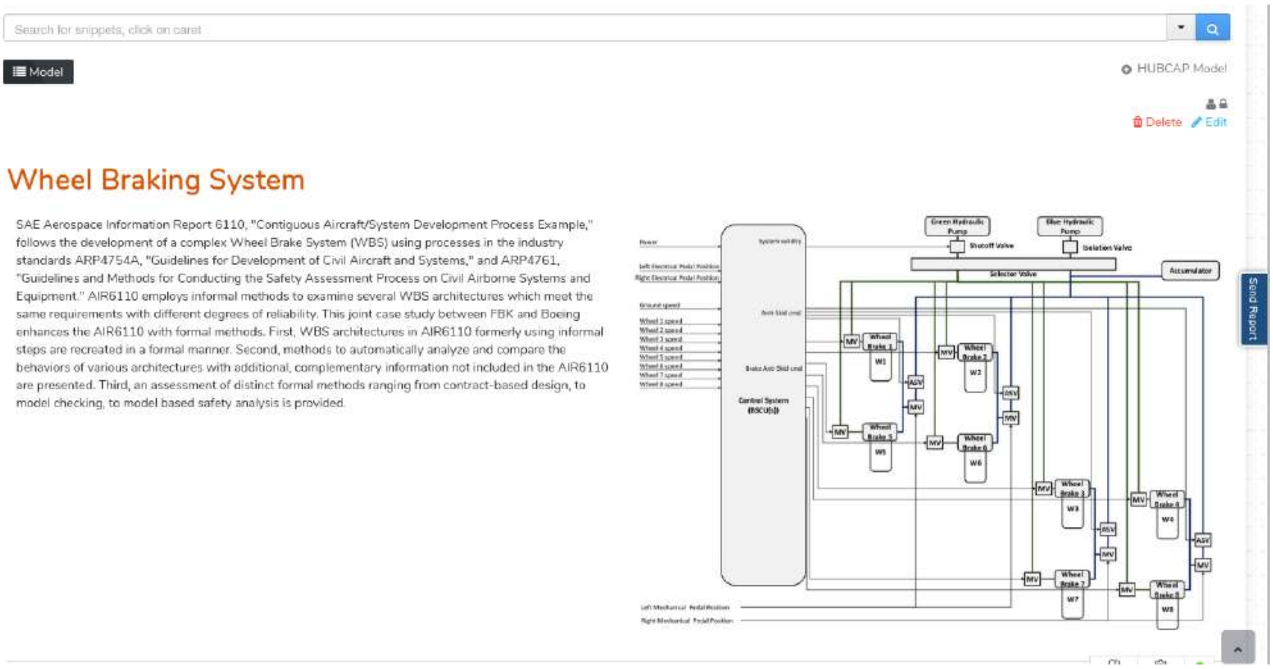

Figure 10. Screenshot of the Wheel Braking System page

2.10. Adaptive Cruise Control

The model represents a set of software-defined functions that implement an Adaptive Cruise Control. It manages the speed of a vehicle to remain at a user-defined value while keeping a user and regulation-defined distance to a potentially present front car. The logical architecture of the model provides components for filtering the data sent by distance and velocity sensors, controllers to regulate the speed and distance, and managing the states of the defined speed and distance. The platform model consists of two processing units and a bus connecting them. At fortiss, the model is used to evaluate the simulation environment of AutoFOCUS3 and design space exploration methods (e.g., calculating HW/SW deployments and time-triggered schedules for distributed platforms).

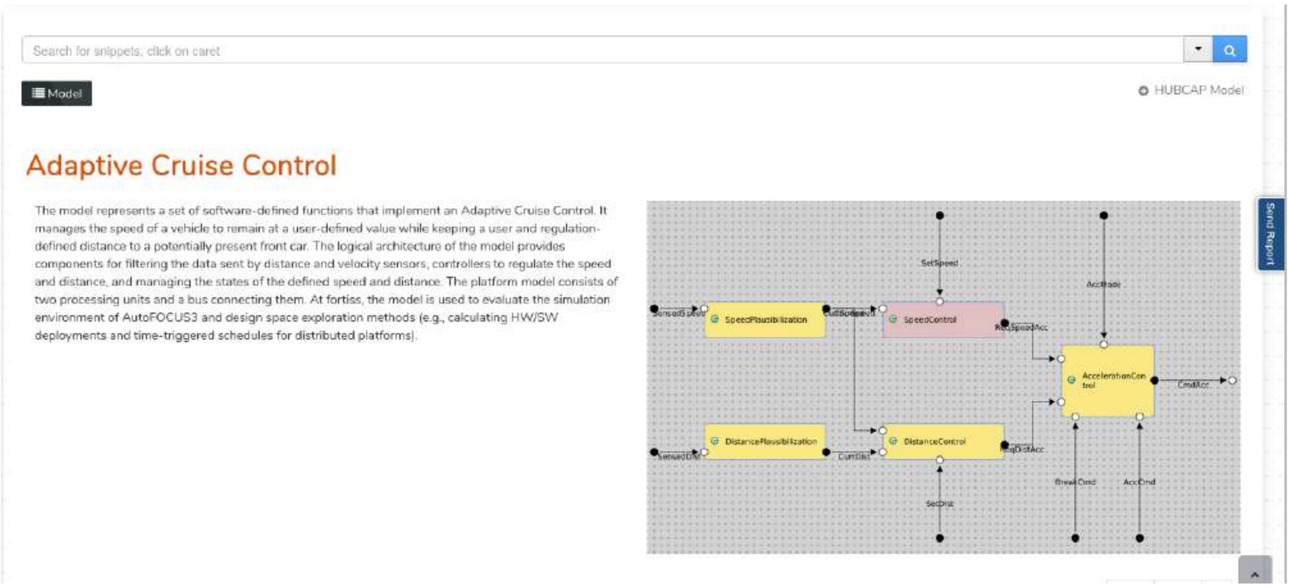

Figure 11. Screenshot of the Adaptive Cruise Control page

2.11. Multiple Emergency Ventilator

Dynamic Models of the Multiple Emergency Ventilator, a 10+ bed low-cost medical ventilation system. These models were developed using the Modelica language to support the development of the MEV system, see the MEV website for further details. The models were run successfully with the open source tool OpenModelica v. 1.16.0 and with the commercial tool Dymola v. 2020X , producing the same results.

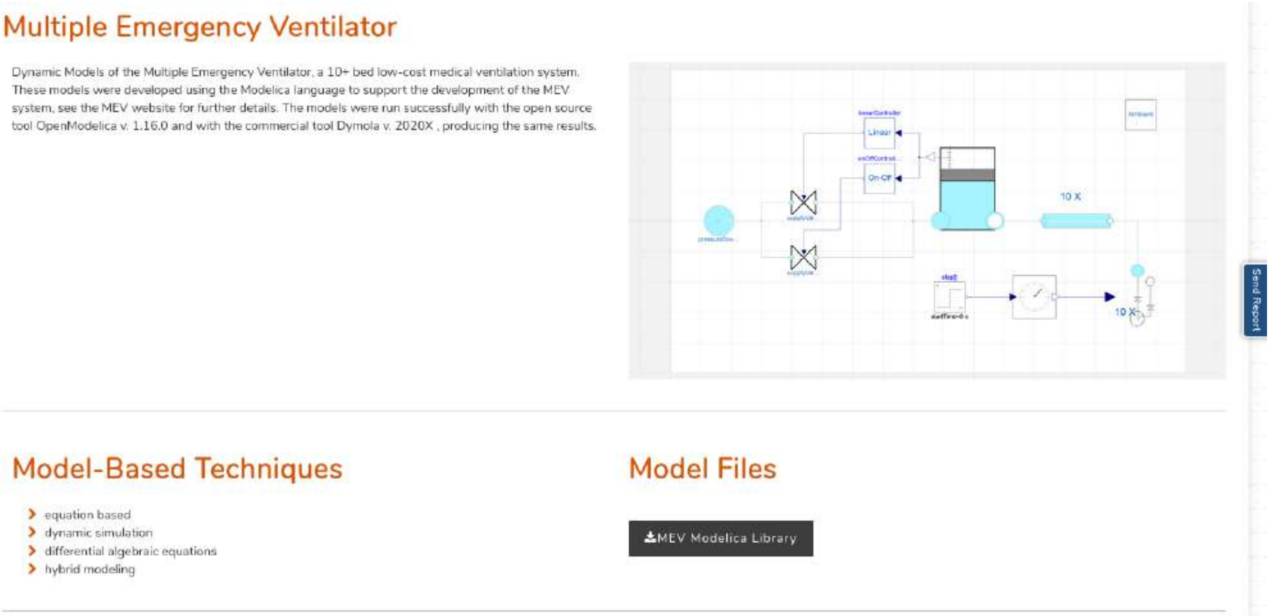

Figure 12. Screenshot of the Multiple Emergency Ventilator page

3. Summary

This document reports on the deliverable D6.1, which consists of an initial set of models that populate the models catalog on the HUBCAP platform. These models are provided by the HUBCAP partners drawing from examples related to MBD tools or by case studies developed in previous projects. Therefore, they range from simple examples useful to try some MBD tools, as well as benchmarks that can used to either to assess the scalability of the tools or to get more familiar with industrial applications, possibly to be repeated on different CPS. The models cover various application domains including control engineering, electrical engineering, automotive, and avionics. The catalog will be populated further along and beyond the project lifecycle thanks to the ecosystem that will animated the platform. The number of models in the platform is indeed contributing to the KPIs of the HUBCAP project (WP6 KPI “# of listed technology assets”).