# Tutorial: Compositional Design of Cyber-Physical Systems - The META Tool Suite

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**Abstract:** The focus of this tutorial is a methodology and supporting tool suite for the end-to-end compositional design of complex cyber-physical systems. The Open Source META (OpenMETA) tool suite developed under DARPA's Adaptive Vehicle Make (AVM) program is an integrated multi-modeling, verification and virtual prototyping environment integrated with the iFAB manufacturing foundry for the design of vehicles. The tool suite is accessible via a web-based front-end, VehicleForge that includes a model repository, collaboration front-end supporting crowed sourcing of models and access to OpenMETA backend tools. The tool suite is currently used in the DARPA's FANG design competition focusing on the drivetrain of a real-life amphibious vehicle. The tutorial will include two main sections: overview of structure of OpenMETA and demonstration/discussion of the OpenMETA design flow. The topics to be covered are the following:

(1) *Overview of the OpenMETA information architecture*. CPS design requires an elaborate information architecture including ontologies, modeling languages and standardized design data packages for transmitting information across the model repository, design tool chain, design evaluator, and foundry components. This topic reviews key components of the OpenMETA information architecture.

(2) *Semantic integration approach for modeling languages and analysis tool.* The OpenMETA design flow includes a large number of design-space exploration, composition, analysis and verification and synthesis tools with semantically overlapping modeling languages. In order to guarantee semantic consistency, OpenMETA includes a Semantic Backplane capturing the formal semantics of the modeling languages and model transformations.

(3) *Design space exploration and analysis tools*. OpenMETA employs a progressive deepening strategy that starts with static architecture exploration followed by the fully automated parametric exploration and analysis using lumped parameter dynamics. The design flow also includes probabilistic requirement verification, first principle based FEA analysis, software synthesis and requirement verification. This topic review key building blocks of the OpenMETA design flow: testbenches, model interpreters and parametric exploration tools.

*(4) Verifcation.* The OpenMETA design flow includes a suite of verification approaches from probabilistic to deterministic methods. This topic will cover the range of uncertainty propagation methods deployed in the tool suite, tools for generating probabilistic certificate of correctness, and discusses the status of deterministic verification methods and their limitaitons.

**Profile of a typical attendee**:

The tutorial will be on introductory level requiring some background in the design of mechanical and software systems. It will be particularly useful for students and practitioners who are interested in

systematic methods in model-based design, component-based CPS development, and CPS verification. The tutorial will also be useful for researchers and graduate students by pointing out open challenges, unsolved problems in composition of heterogeneous systems, formal verification using probabilistic methods and virtual prototyping. The tutorial will take advantage of the OpenMETA tool suite that is accessible via the CPS-VO Portal.