A Model-driven development framework for highly Parallel and EneRgy-Efficient computation supporting multi-criteria optimisation

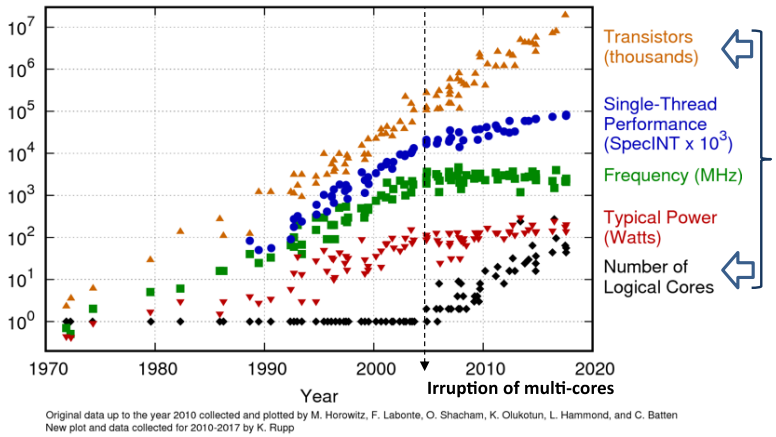
Project Overview

AMPERE Final Event Webinar

Eduardo Quiñones — BSC
27 June 2023

The AMPERE project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 871669

Heterogeneous and Parallel Computing



Original data up to the year 2010 collected and plotted by M. Horowitz, F. Labonte, O. Shacham, K. Olukotun, L. Hammond, and C. Batten
New plot and data collected for 2010-2017 by K. Rupp

Heterogeneous and Parallel computing becomes key to cope with performance requirements


Avionics


Space


Automotive

Network of HW/SW components that **must** operate **correctly** in response to its inputs from both **functional** and **non-functional** perspectives

Massively parallel systems that operate **as fast as possible**


Genomics


Weather


Big data

HPC Domain (~300W)


NVIDIA A100
(GPU-based)


AMD Instinct™ MI
(GPU-based)


Intel® Xeon® Series
(40-core)


AMD EPYC™ Series
(up to 64-core)

Embedded Domain (~10-20W)


NVIDIA Jetson Family
(GPU-based)


Kalray MPPA Coolidge
(80-core fabric)


Xilinx Versal
(FPGA-based with DFX)

Heterogeneous and Parallel Computing in Embedded Systems

Performance: complex computations at high speed

Real-time: end-to-end response time within budget

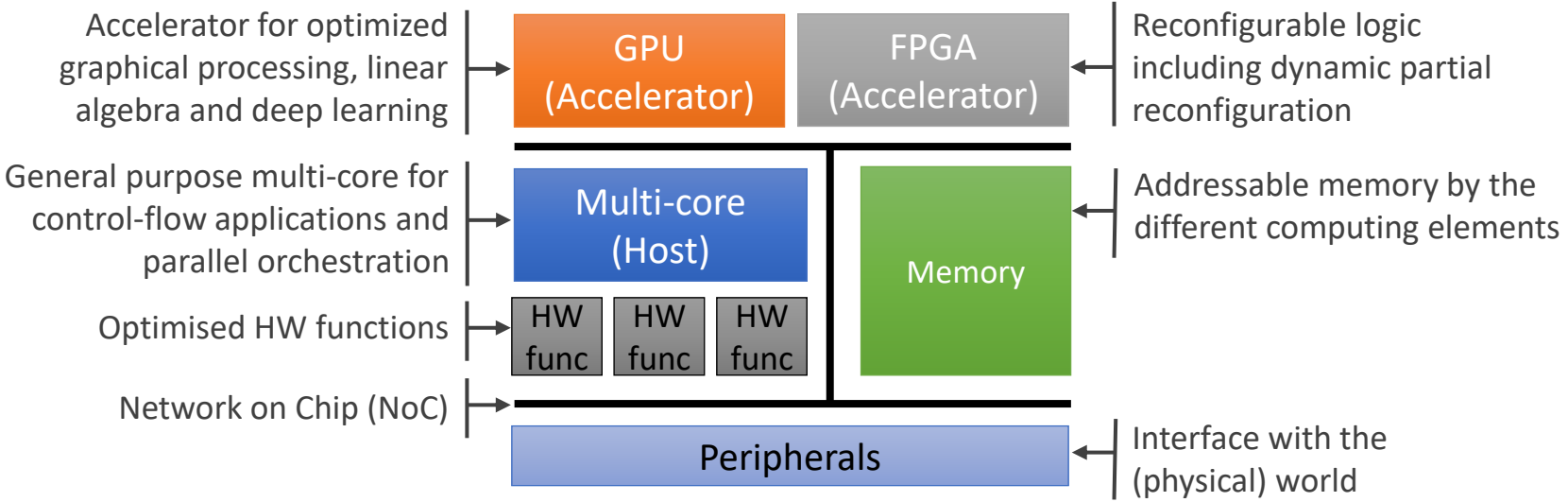
Power/Thermal: energy/temperature within budget

Safety: guarantee correctness and integrity of operation

Security: prevent external elements from affecting correctness and integrity

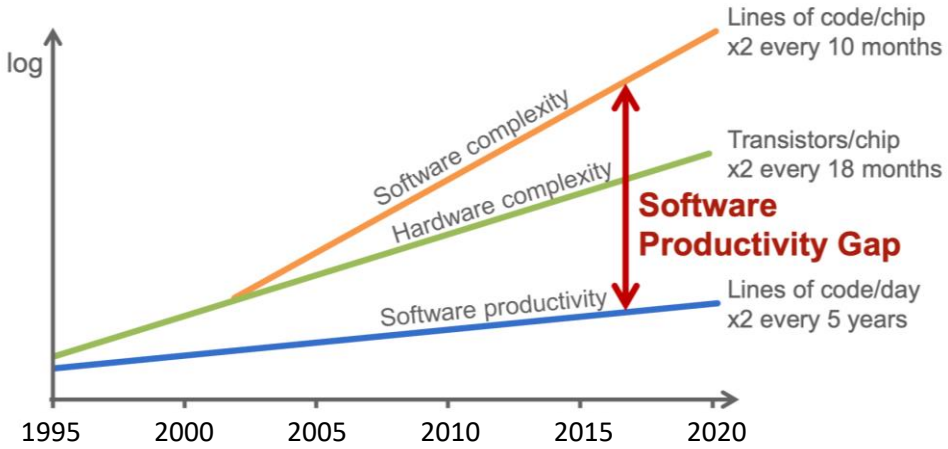
Heterogeneous and Parallel Computing

Host-centric paradigm: The parallel computation is orchestrated by the general-purpose multi-core



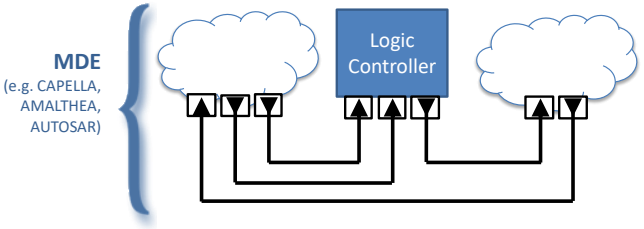
The SW Productivity Gap

1. *Efficiently exploit parallelism* and achieve the required performance
2. *Reason* about the functional and non-functional correctness



Source: ITRS & Hardware-dependent Software, Ecker et al., Springer

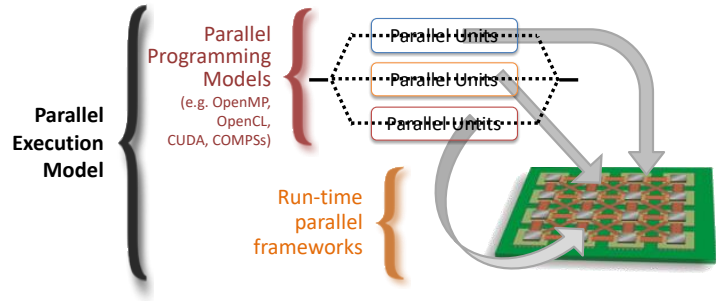
Addressing Complexity on System Development



Model Driven Engineering (MDE) in Embedded Systems

1. Construction of complex systems
2. **Formal verification** of functional and non-functional requirements (NFR) with **composability** features
   - Suitable Correct-by-construction paradigm by means of code generation
3. Only for single-core execution or with **very limited parallel support**

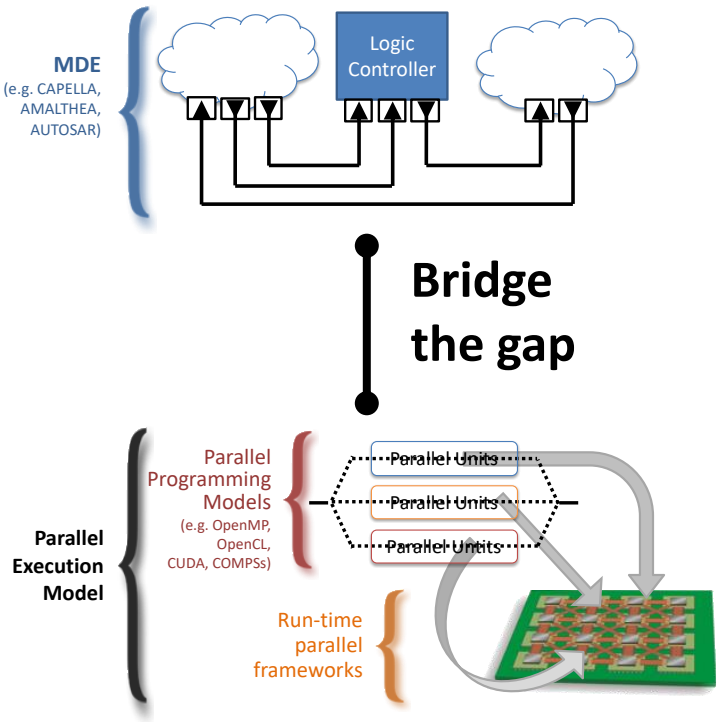
Gap between the MDE used for CPS and the PPM supported by parallel platforms



Parallel Programming Models (PPM) in HPC

1. Mandatory for **SW productivity** in terms of
   - Programmability: Parallel abstraction while hiding HW complexities
   - Portability: Compatibility multiple HW platforms
   - Performance: Exploiting parallel capabilities of underlying HW
2. **Efficiet offloading** to HW acceleration devices for an energy-efficient parallel execution

AMPERE's Vision

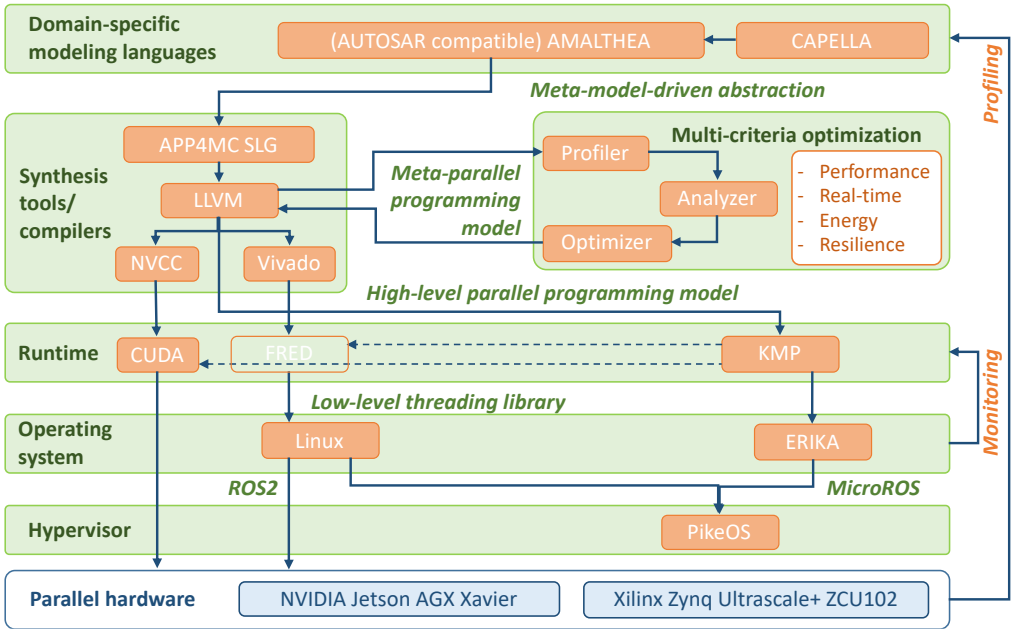


1. **Synthesis methods** for an efficient generation of parallel source code, while keeping NFR and composability guarantees
2. **Run-time parallel frameworks** that guarantee system correctness and exploit the performance capabilities of parallel architectures
3. **Integration** of parallel frameworks into MDE frameworks

AMPERE's Main Contribution

A **novel software architecture** capable of

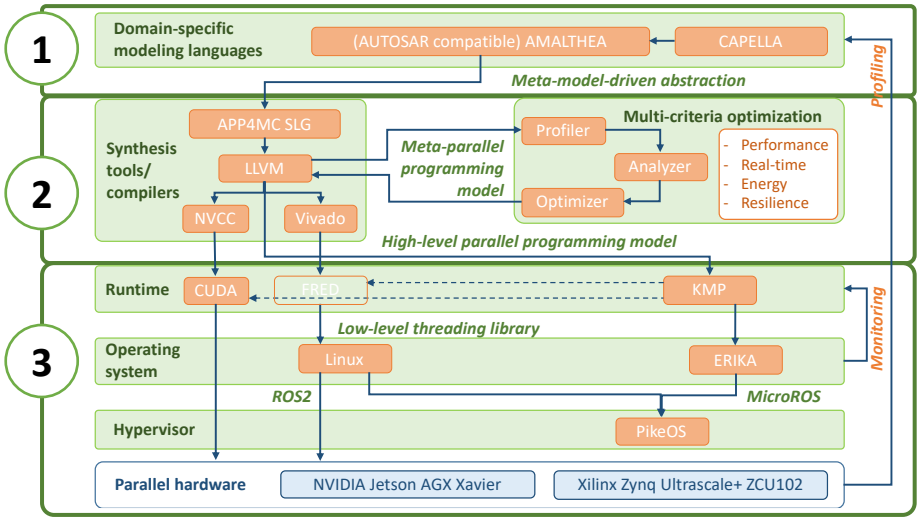
1. Capturing the component definition and NFR for the system model and transform it to parallel constructs
2. Fulfillment of NFR described in the CPS description
   - Real-time response, energy-efficiency, resiliency and safety and cyber-security
3. Efficient usage of advance parallel and heterogeneous embedded architectures

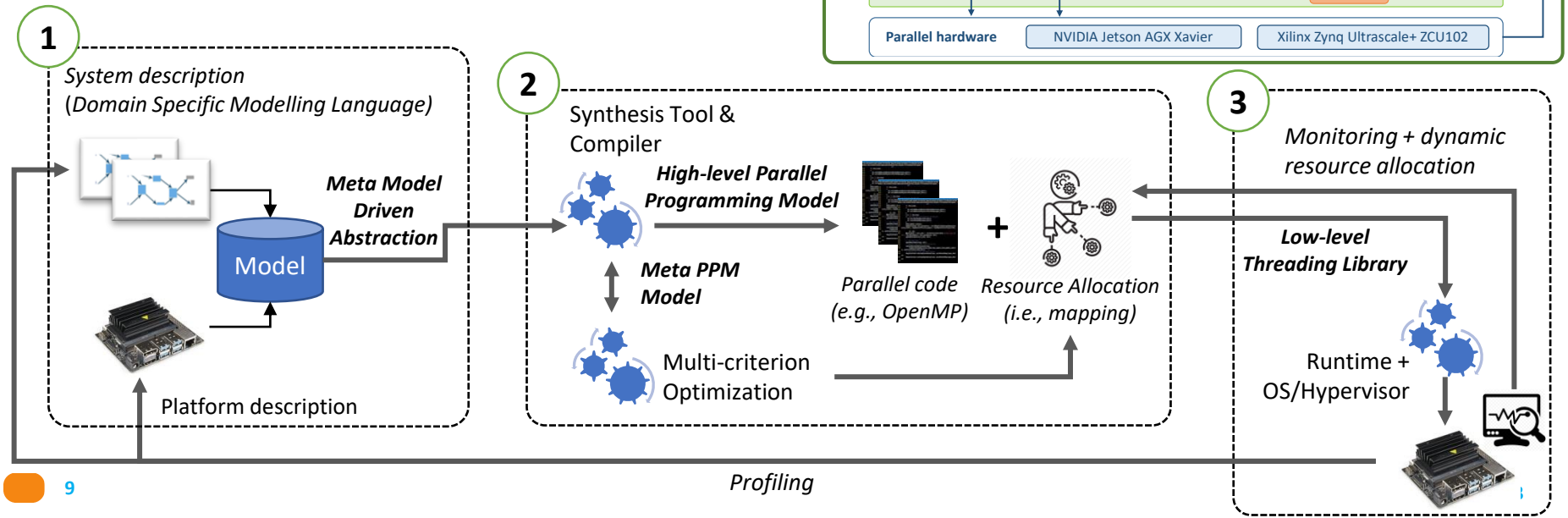


https://ampere.bsc.es/software-ecosystem

Productivity = + **Programmability** + **Portability/Scalability** + **(Guaranteed) Performance**

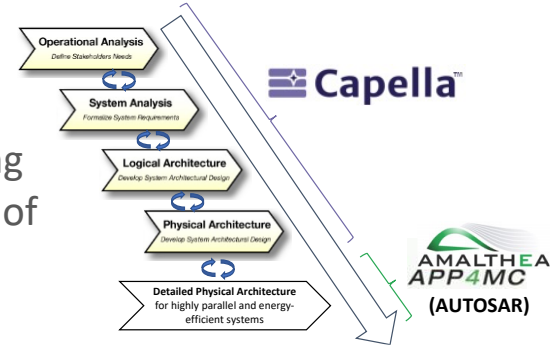
AMPERE's Workflow Overview

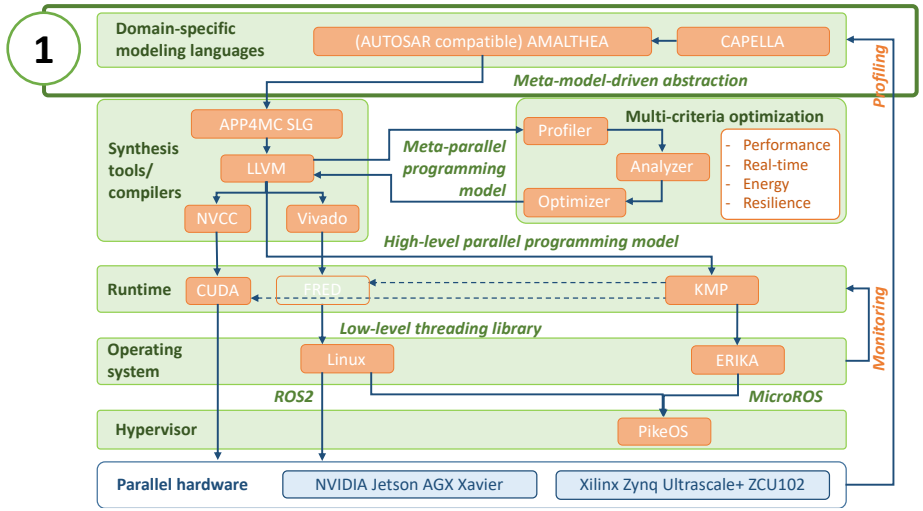


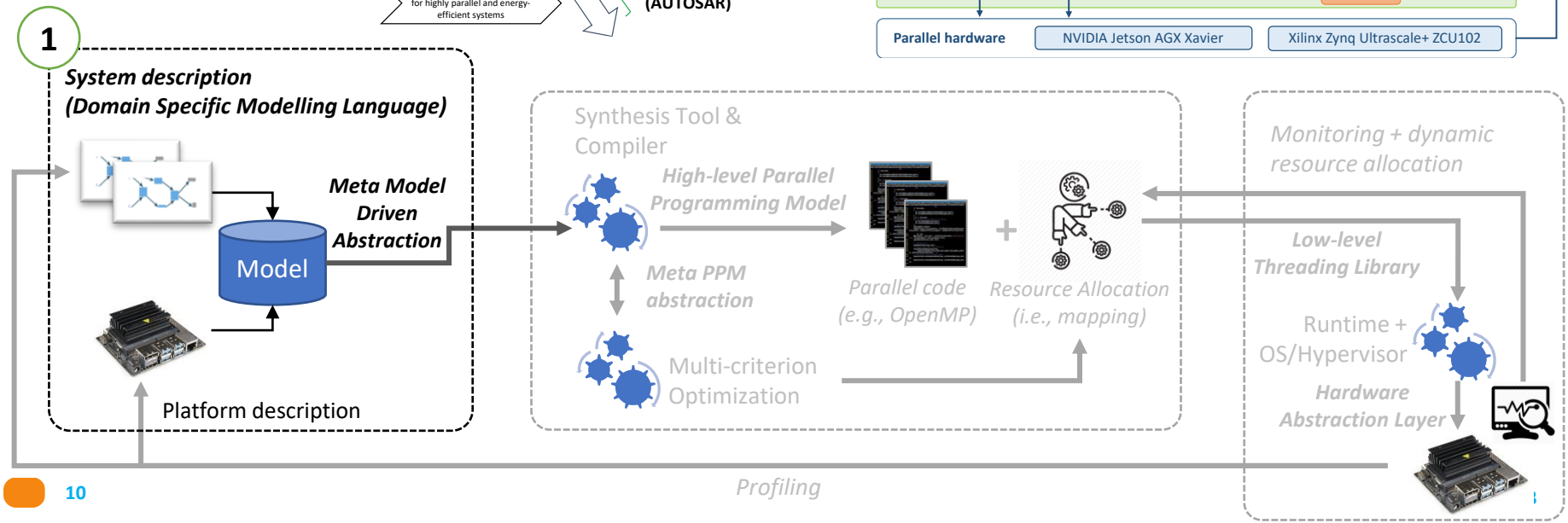


AMPERE's Workflow Overview

DSML addressing different phases of the V-Model







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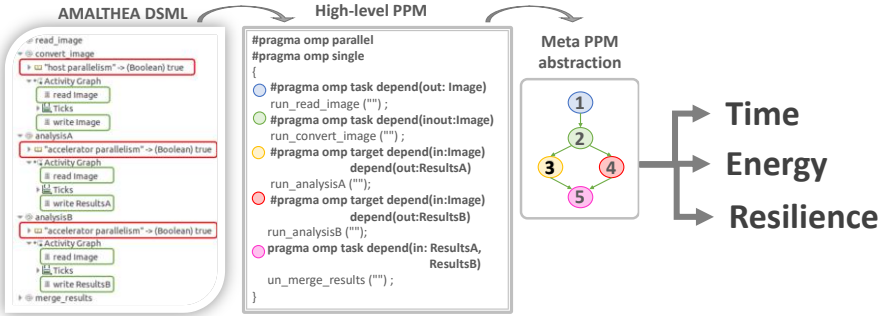
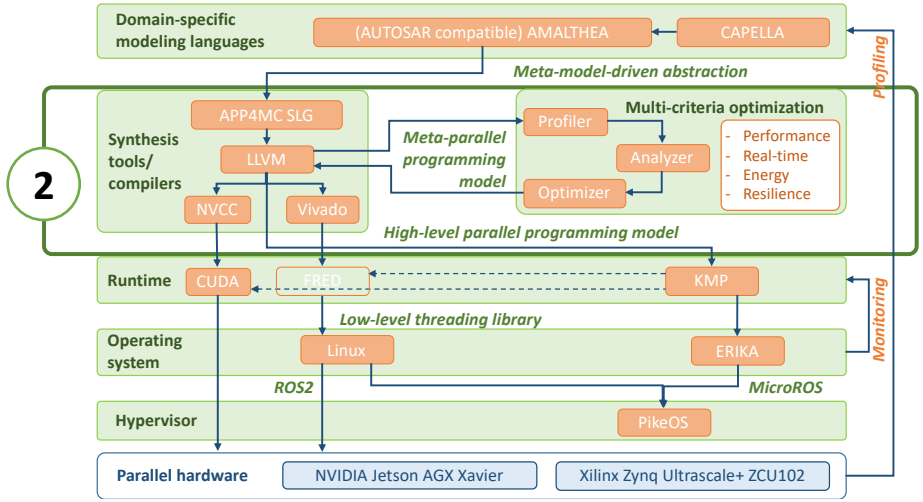
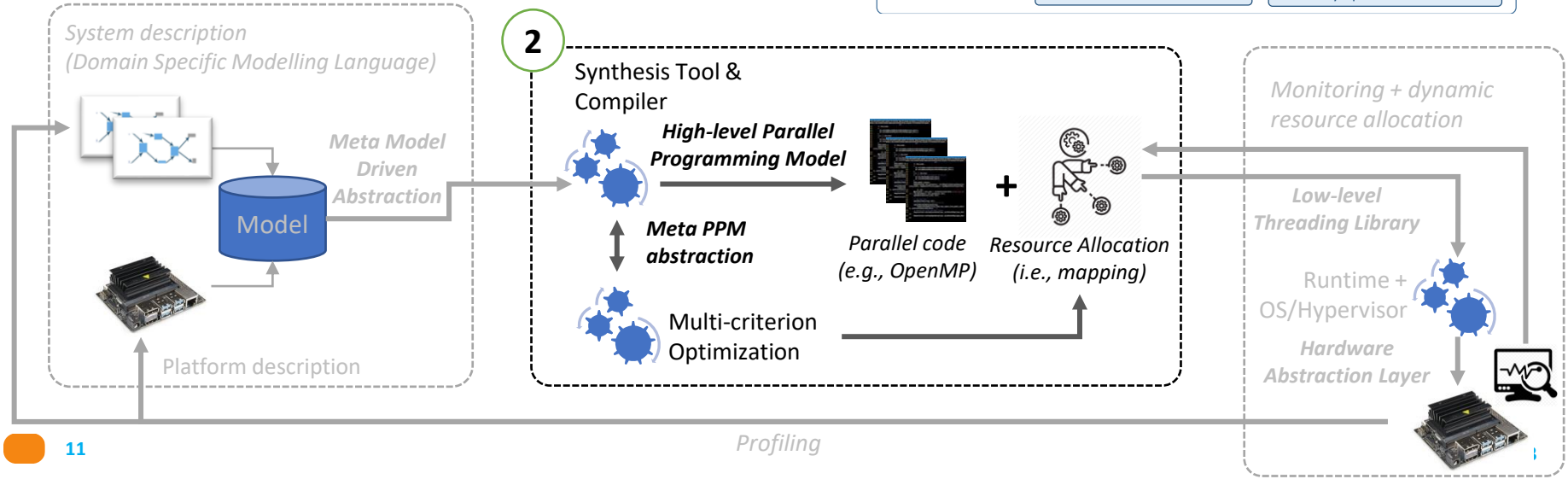


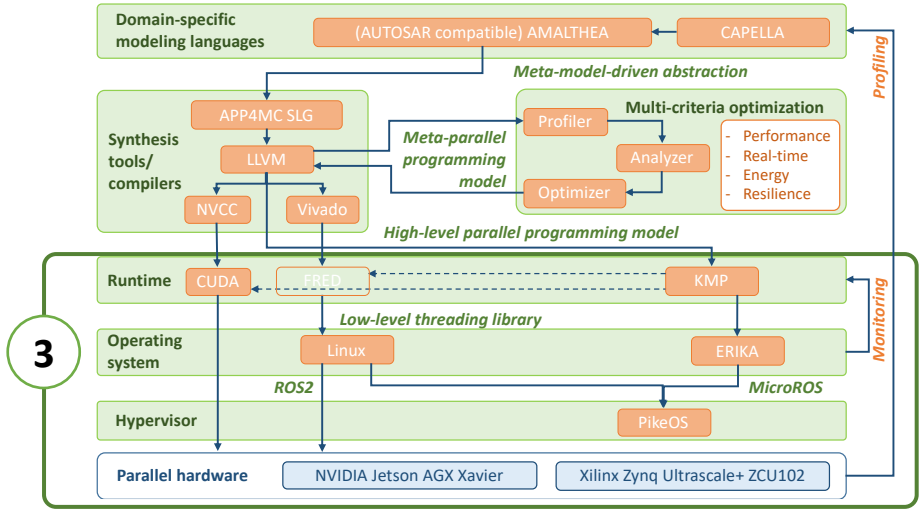


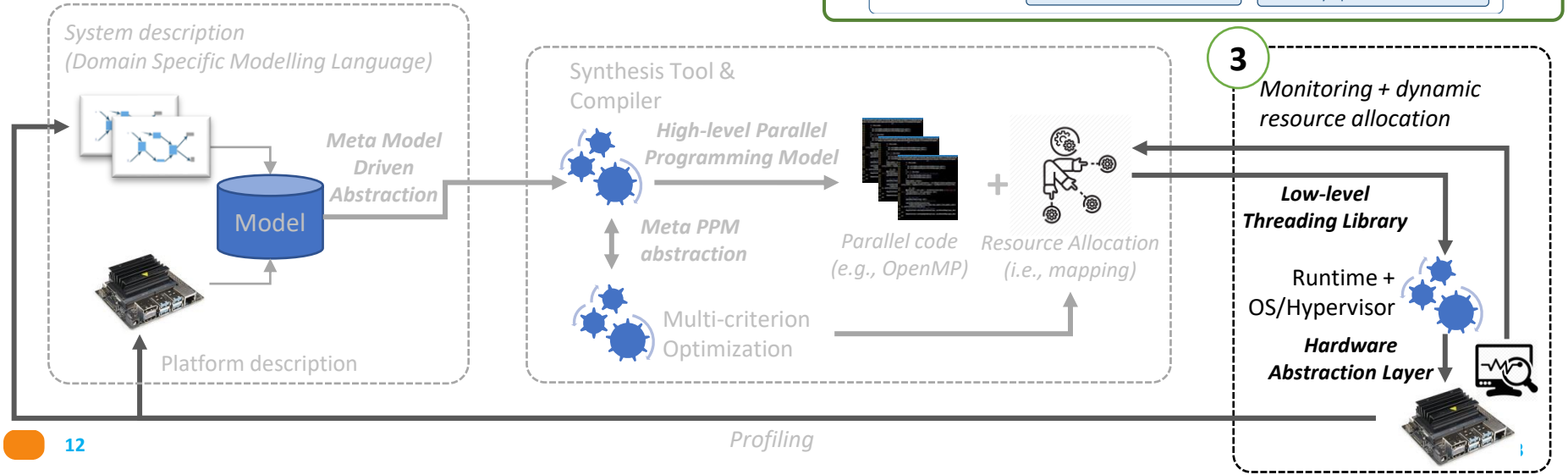


AMPERE's Workflow Overview

Runtime Monitoring and Implementation of

- Time
- Energy
- Resilience
- Safety and Security





AMPERE Use-cases

Obstacle Detection and Avoidance System (ODAS)

- ADAS functionalities based on data fusion coming from tram vehicle sensors

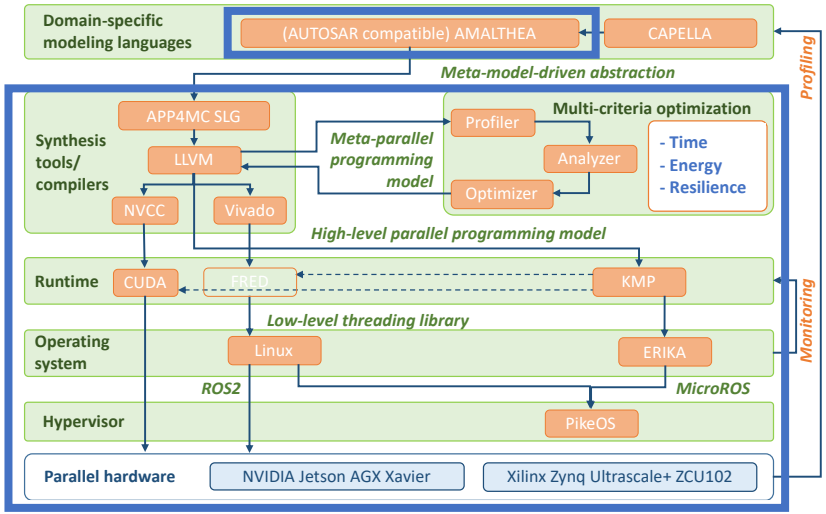
Predictive Cruise Control (PCC)

- Extends Adaptive Cruise Control (ACC) functionality by calculating the vehicle's future velocity curve using the data from the *electronic horizon*
- Improve fuel efficiency (in cooperation with the powertrain control) by configuring the driving strategy based on data analytics and AI

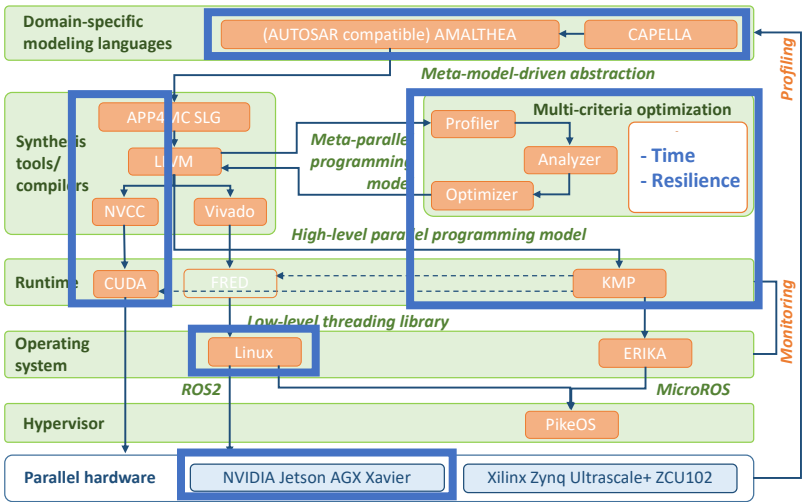
The AMPERE Software Architecture: A Modular Design

- **AMPERE aims to support different “instances” of the SW architecture**
  - Increase exploitation opportunities

*SW Architecture applied to **PCC***



*SW Architecture applied to **ODAS***



Thank you

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