HiPEAC Conference
22nd January 2020, Bologna, Italy

CERBERO: Cross-layer modEl-based fRamework for multi-oBjective dEsign of Reconfigurable systems in unceRtain hybRid envirOnments

CERBERO Overview, Concept and Methodologies

Francesca Palumbo

Università degli Studi di Sassari

Horizon 2020
European Union funding
for Research & Innovation

CERBERO Goal

CERBERO:
Cross-layer modEl-based fRamework for multi-oBjective dEsign of Reconfigurable systems in unceRtain hybRid envirOnments

- Integrated *model-based methodology* and *framework* for *multi-objective* design of *Cyber Physical Systems*
- Continuous *runtime optimization* of *Cyber Physical Systems* by means of *(self-)adaptivity strategy*

CERBERO Final Event @ HiPEAC 2020

SESSION 1 – CERBERO OVERVIEW

- Advancement on (dataflow) MoCs
- CERBERO Interoperability Framework (CIF)
- Key Performance Indicators
- CERBERO Adaptation Loop
- Formal methods in the CERBERO Toolchain

Practical Work – VMs are available!

SESSION 2 - HANDS on “CERBERO Interoperability Framework”

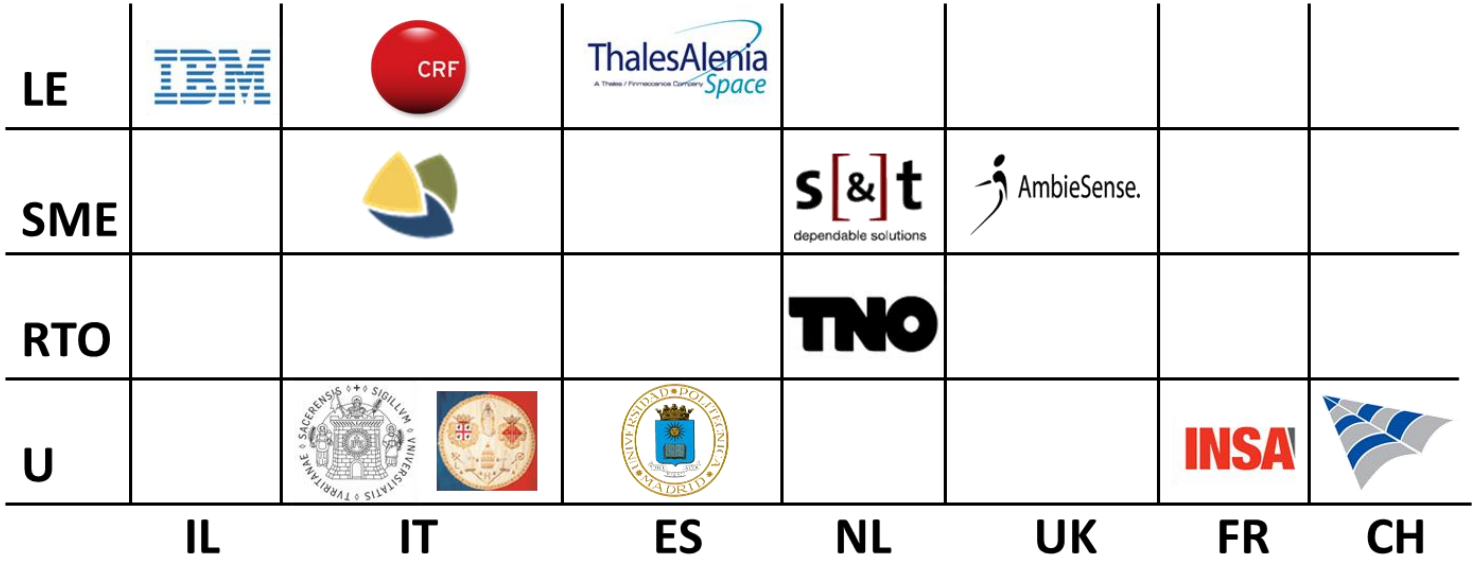
SESSION 3 - HANDS on “Adaptation over Heterogeneous Computing Infrastructures”

SESSION 4 - Impact, Demo and Clustering

- The CPSwarm H2020 CPS Project
- Market Trends and Exploitation Potentials for CPS
- Overview of CERBERO demonstrators
  - Self-healing system for Planetary Exploration
  - Smart Traveling for Electric Vehicles, Speakers
  - Ocean Monitoring, Speaker

CERBERO

Consortium: 12 partners from 7 countries



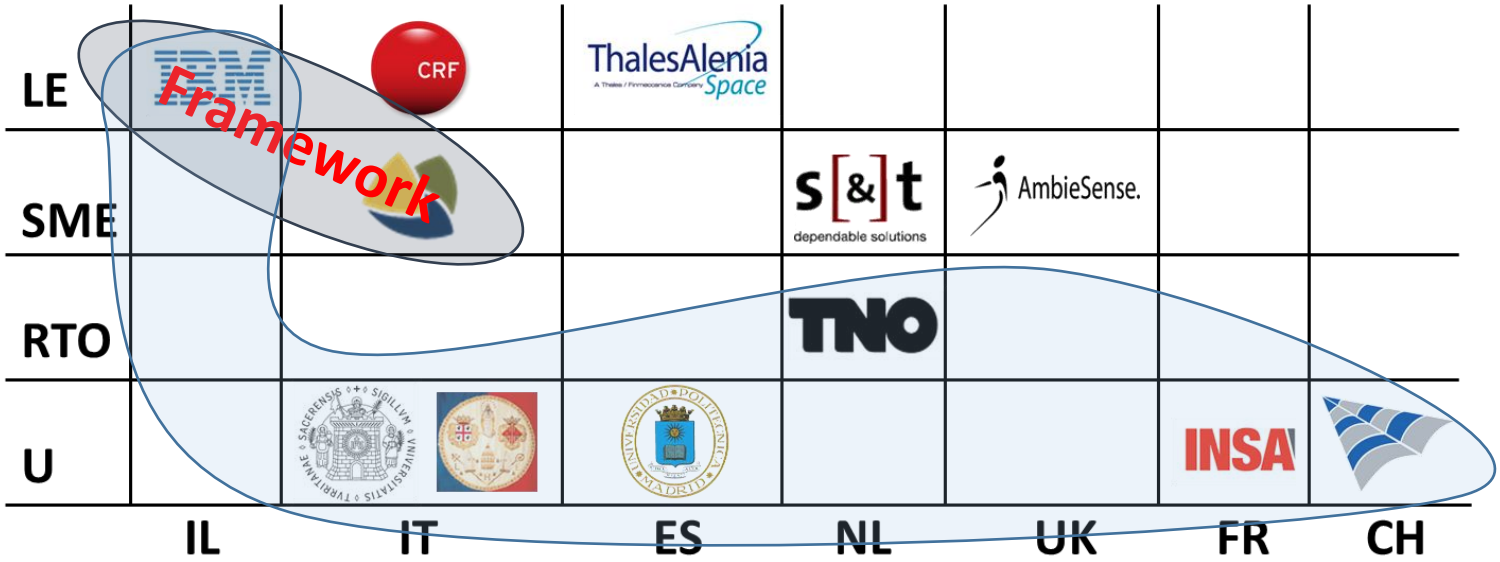
Started: January 1, 2017

Duration: 36 months

+ 2 additional months for dissemination and exploitation events

CERBERO

To build Cognitive Cyber Physical Systems



Components and Technology Providers

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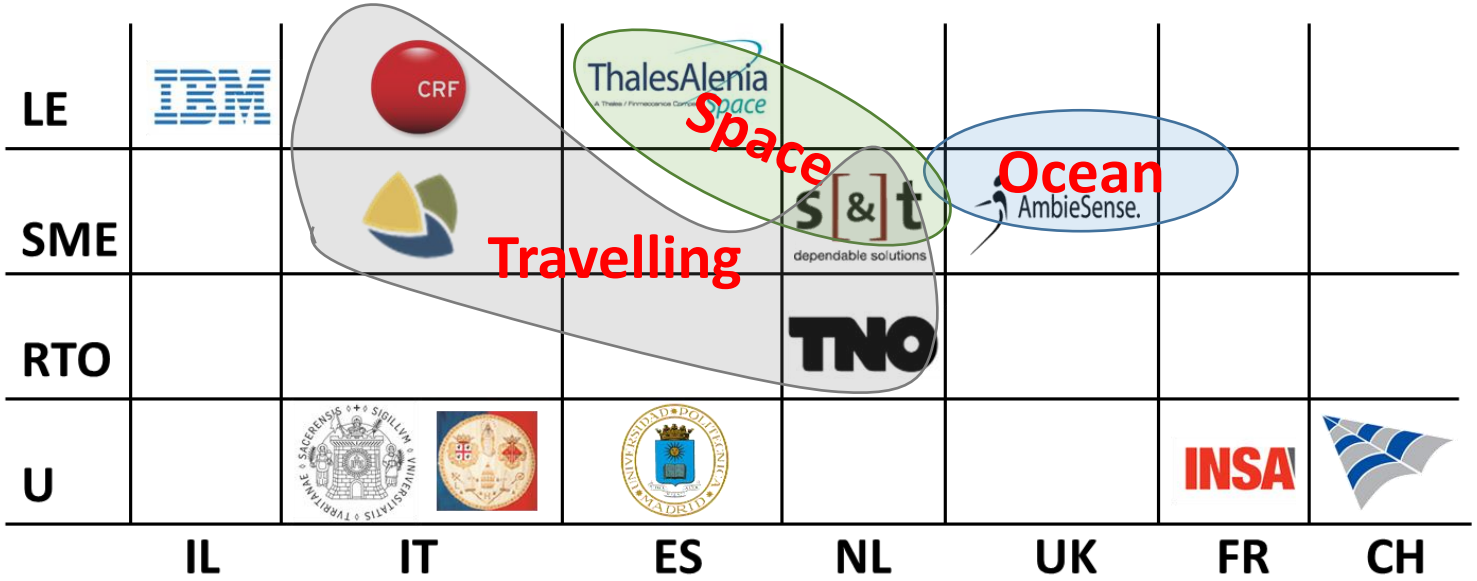
CERBERO

and evaluate by 3 use cases



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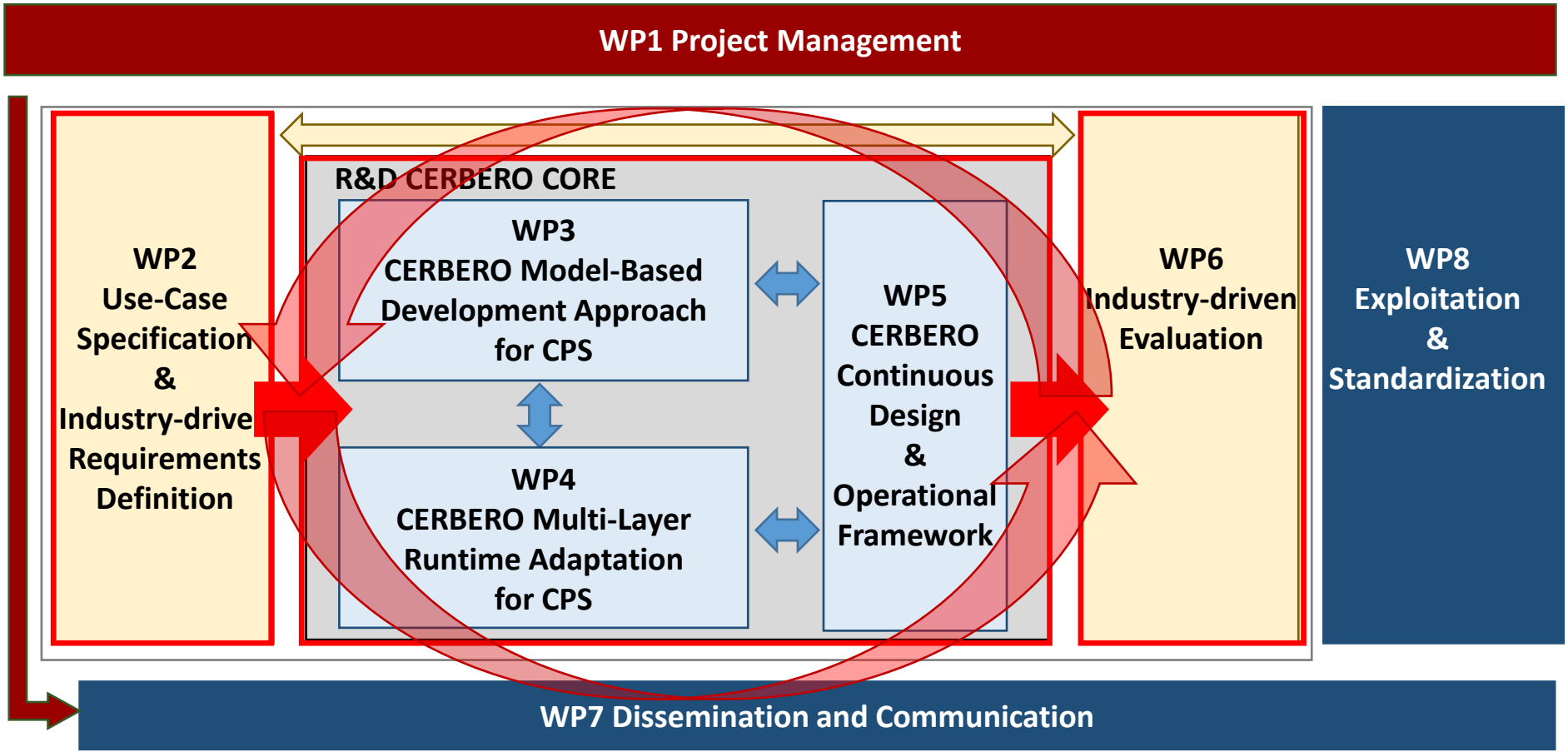
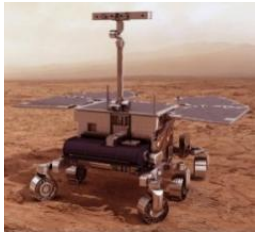
Industry Driven Development Approach



CERBERO Use Cases



Self-Healing System for Planetary Exploration:

- Accessing a new technology for computing purposes in Space Applications
  - Controller of **a robotic arm** implemented over a **FPGA**.
  - Operation under **harsh environmental conditions**
  - **Self-healing** and s**elf-adaptive** capabilities

Ocean Monitoring:

- An **unmanned vehicle** is meant to perform different tasks
  - **Information Storage** and Information **Fusion models**
  - **Video Enhancement** strategies
  - **Individual** and **fleet self-operation, power management** and **navigation**

Smart Travelling for Electric Vehicle:

- **Improve reactiveness** of the **electric vehicles** to perturbations.
  - **Virtual Reality** simulated environment for driver support in electric vehicles
  - **Highly networked** scenario composed of heterogeneous concurrent subsystems
  - **Autonomy** and support for **adaptability**

Use Case 1: Planetary Exploration

- **Challenges**:
  - Improve computing **robustness;**
  - Enable **correction** capabilities.

- **Infrastructure:**
  - **Heterogeneous** embedded computing platform.

- **What is requested to CERBERO:**
  - **Minimize the designer effort;**
  - Computing level **(self-)adaptive run-time management**;
  - **Trade-off** among resiliency, high performance and energy efficiency.

Use Case 2: Ocean Monitoring

- **Challenges**:
  - Current **solutions** are not **specific for marine applications**;
  - **Vision/sensing challenges** are not addressed.

- **Infrastructure:**
  - Smart **multi-lenses** camera system.

- **What is requested to CERBERO:**
  - **Minimize the effort** for system-level analysis;
  - New adaptive image processing methods for **video enhancing;**
  - System-level **(self-)adaptive run-time management.**

Use Case 3: Smart Travelling

- **Challenges:**
  - Incremental development of a **reactive and hybrid CPSoS.**
- **Infrastructure:**
  - SoS with **physical and virtual** components.
- **What is requested to CERBERO:**
  - **Testing different driving experience;**
  - SoS **(self-)adaptive run-time management;**
  - Strong **real-time guarantees** during execution of the tests.

CERBERO Challenges: What

ST

OM

PE

Level of Abstraction

System in the loop simulation	Multi-Objective Run-Time Optimisation	Run-Time SoS Level Adaptation
System Level Early Stage Design Space Exploration (DSE)	Multi-Objective Run-Time Optimisation	Run-Time System Level Adaptation
Computing Level Early Stage DSE & Components Depl.	Multi-Objective Run-Time Optimisation	Run-Time Computing Level Adaptation

Tool Integration

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CERBERO Challenges: How

ST

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PE

Level of Abstraction

CERBERO Interoperability Framework

System in the loop simulation	Multi-Objective Run-Time Optimisation	Run-Time SoS Level Adaptation
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Computing Level Early Stage DSE & Components Depl.	Multi-Objective Run-Time Optimisation	Run-Time Computing Level Adaptation

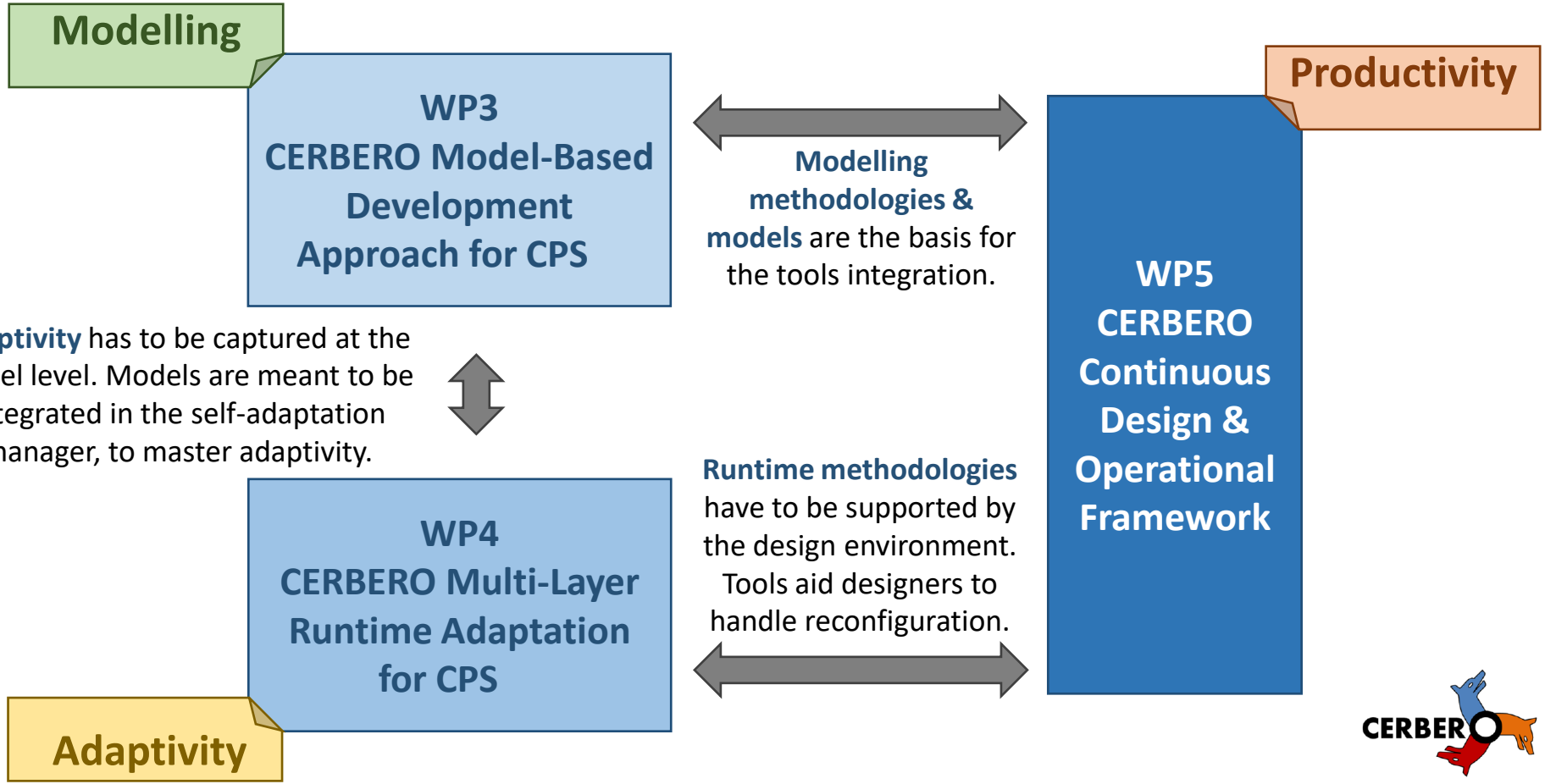
Tool Integration

CERBERO FRAMEWORK COMPONENTS

KPI-DRIVEN MODEL-BASED OPTIMISATION

MULTI-LEVEL SELF-ADAPTATION

CERBERO R&D core



Challenge #1

Modelling CPS

Models of Computation have limits in express adaptive systems and their properties.

Separation of concerns simplifies complexity and heterogeneity, but may lead to miss important cross-domain interactions.

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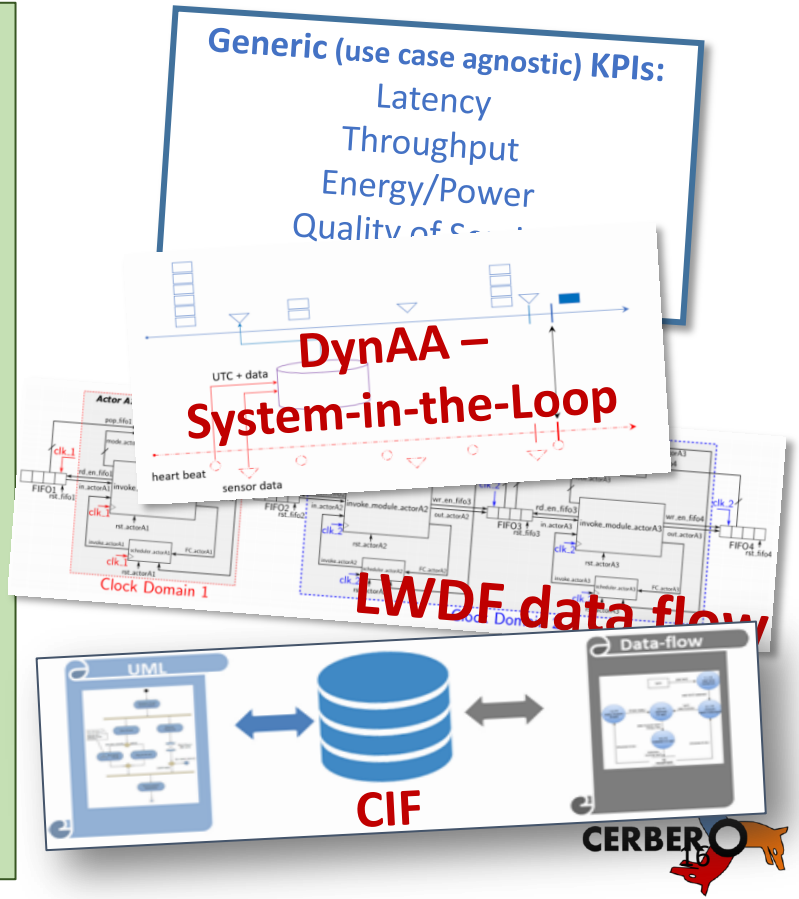
CERBERO R&D Core: Modelling [WP3]

CERBERO major activities & outcomes:

- Classified a relevant set of ***generic and re-usable Key Performance Indicators*** (KPIs).
- Surveyed/improved ***Models of Computation*** to access/overcome their features/limitations: focus on adaptivity.
- Semantic integration approach: ***CERBERO Interoperability Framework*** (***CIF***):
  - To make layers talk through KPIs.
  - To improve tools interoperability.



CERBERO R&D Core: Modelling [WP3]

CERBERO major activities & outcomes:

- Classified a relevant set of ***generic and re-usable Key Performance Indicators*** (KPIs).
- Surveyed/improvement ***Models of Computation*** to access their features/limitations: focus on adaptivity.
- Integral approach for modelling the different abstraction levels: ***CERBERO Cyber-Physical Intermediate Format*** (***CIF***):
  - To make layers talk through KPIs.
  - To improve tools interoperability.

RELATED AGENDA

SESSION 1:

- Advancement on (dataflow) MoCs
- CERBERO Interoperability Framework (CIF)
- Key Performance Indicators

SESSION 2:

HANDS on "CERBERO Interoperability Framework"

Challenge #2

Heterogeneity and Flexibility in CPS

CPS are requested to be reactive and dynamic:

- to adapt to internal and external triggers;
- to satisfy multiple, concurrent and competing requirements.

Self-adaptation is primarily defined and addressed at the software level.

Self-Adaptation

Self-adaptation: ***runtime*** action ***changing structure, functionality and/or parameters of a system***, according to environment, user or self-sensing info.

[F.D. Macías-Escrivá, et al. "*Self-adaptive systems: A survey of current approaches, research challenges and applications*" In Expert Systems with Applications, 2013]

System self-adaptation: combination of ***awareness*** and ***reconfiguration***.

- Reconfiguration decided *inside the CPS (CPSoS)* by a *self-adaptation manager (hierarchy of managers)*.
- Decisions taken *on the basis of KPI* measurements and estimations.

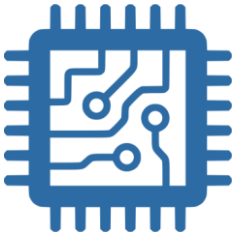
Triggers for Adaptation

ENVIRONMENTAL AWARENESS: Influence of the **environment** on the system, i.e. daylight vs. nocturnal, radiation level changes, etc.

- **Sensors**.

USER/EXTERNALLY-COMMANDED: **System-User** interaction, i.e. user preferences, commands from SoS managers (the boss), etc.

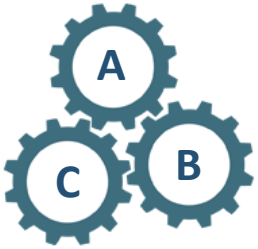
- **Human-machine interfaces**.



SELF-AWARENESS: The **internal status** of the system varies while operating and may lead to reconfiguration needs, i.e. chip temperature variation, low battery.

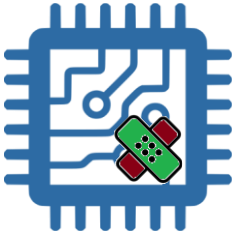
- **Status monitors**.

Types of Adaptation



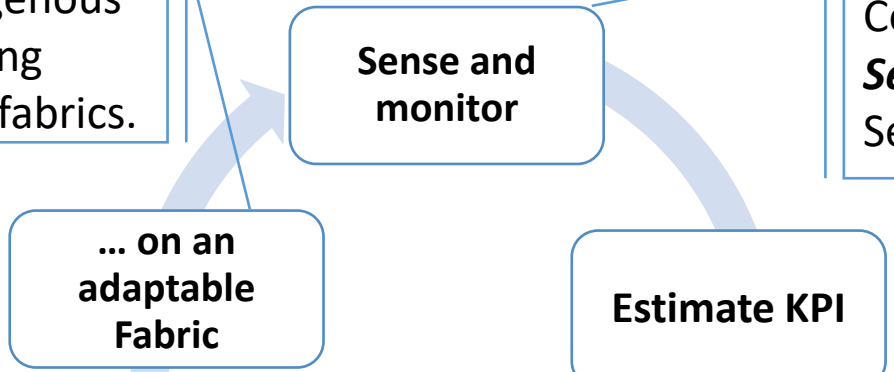
FUNCTIONALITY-ORIENTED:
When the CPS mission or the data being processed change.

EXTRA-FUNCTIONAL REQUIREMENTS-ORIENTED:
The functionality is fixed, but different performance are required.



REPAIR-ORIENTED:
For safety and reliability purposes, adaptation may be used in case of faults.

Adaptation Loop



Sense the world (PHY): Context awareness
Sense the system (CYB): Self-awareness

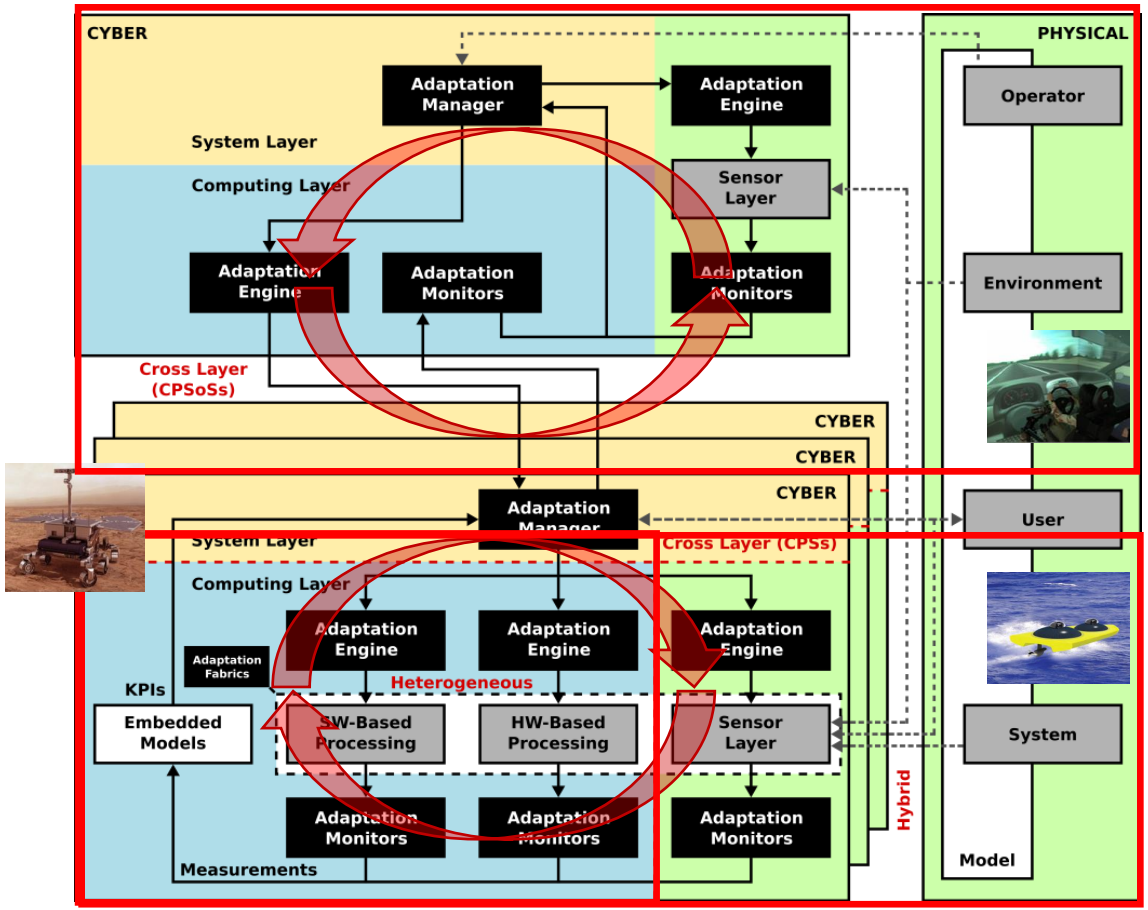
Estimate Performance/quality/ energy: runtime models

Analyse & Decide: Change task – Optimize - Repair

Command Adaptation: Put in place the actions for the required adaptation

Adapt: Reconfigure the heterogenous and multi-level computing infrastructure. Multiple fabrics.

Self-Adaptive Multi-Level Infrastructure



Planetary Exploration

Smart Travelling

Ocean Monitoring

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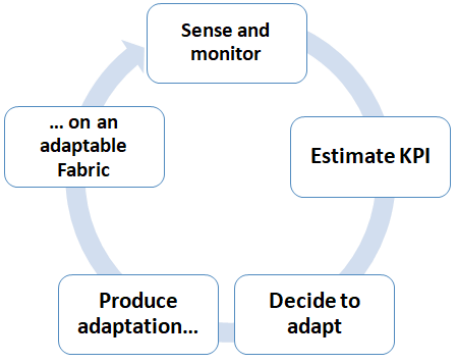
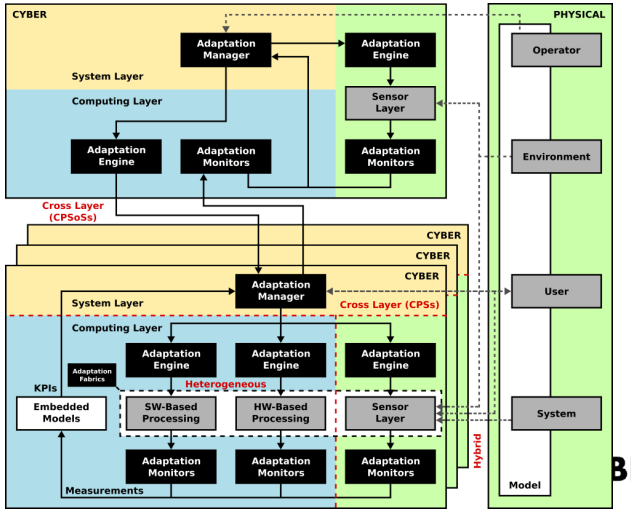
CERBERO R&D Core: Adaptivity [WP4]

CERBERO major activities & outcomes:

- Formalization of the **self-adaptation loop**.
- Definition of the **CERBERO Self-Adaptive Multi-Level Infrastructure**.
- Novel approaches at loop components level:
  - **monitors, manager, reconfigurable fabric**;
  - **sensor/Information fusion** techniques.





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RELATED AGENDA

SESSION 1:

- CERBERO Adaptation Loop

SESSION 3:

HANDS on "Adaptation over Heterogeneous Computing Infrastructures"

Challenge #3

Model-based Engineering and Design Tools

Despite their big promise, model-based frameworks are not as popular as it could be expected.

Modeling, maintenance, and interoperability overhead are not addressed in a satisfactory way.

Adaptivity is poorly supported.

Surveyed tool @ Project Start

	M	O	D	G	S
Simulink/Stateflow (www.mathworks.nl/products/simulink)	x		x	x	x
Modelica/Dymola (www.3ds.com)	x		x		x
SysML (www.sysml.org)	x		x		
MARTE (www.omgmarte.org)	x		x		
SCADE (www.esterel-technologies.com/products/scade-suite/)	x		x	x	x
gPROMS (www.psenterprise.com/gproms.html)	x	x			x

M=Modelling, O=Optimization, D=Design, G= code Generation, S=Simulation

Adaptivity Support!

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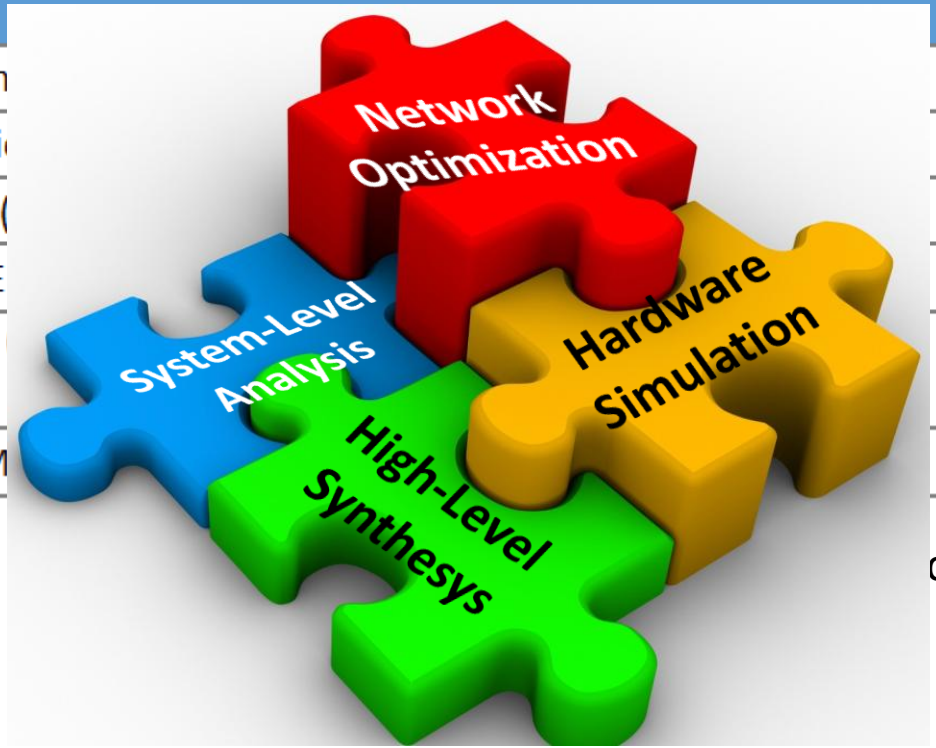
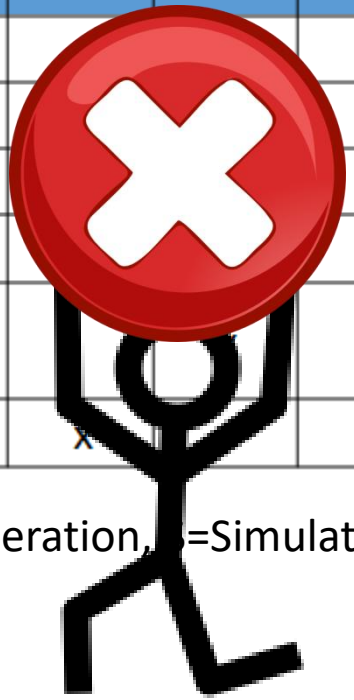
Tool Integration Nightmare

	M	O	D	G	S
Simulin	x			x	x
Modeli	x				x
SysML (	x				
MARTE	x				
SCADE suite/)	x			x	x
gPROM	x	x			x





code Generation, =Simulation

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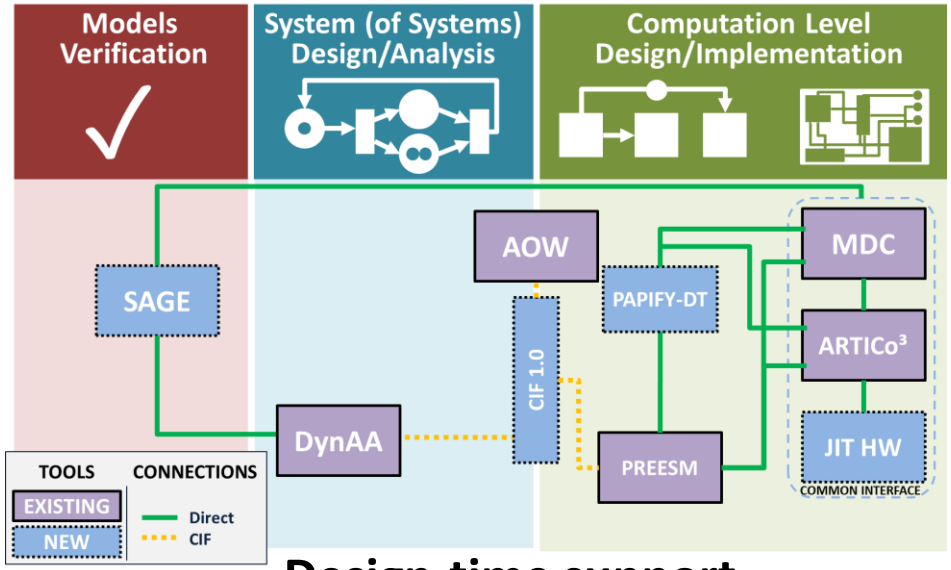
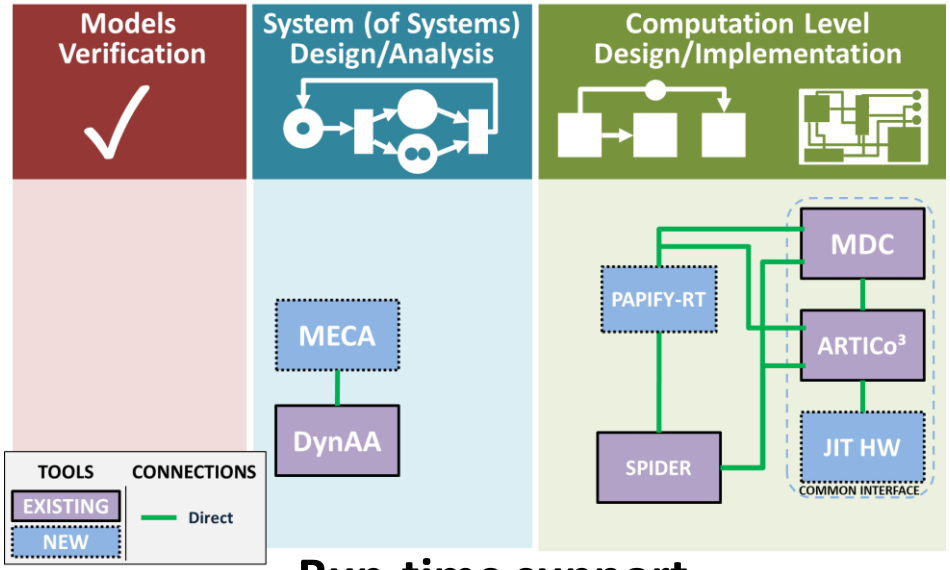
CERBERO Framework

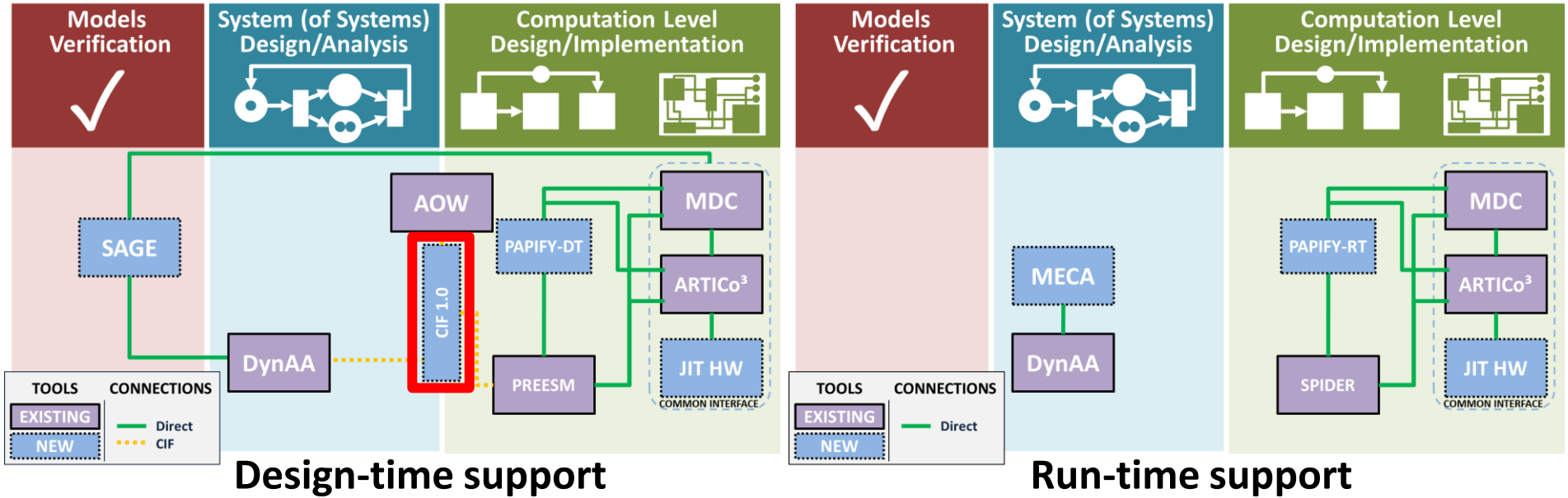


Design-time support



Run-time support

CERBERO Framework – Tool Integration



Design-time support **Run-time support**

CERBERO Interoperability Framework

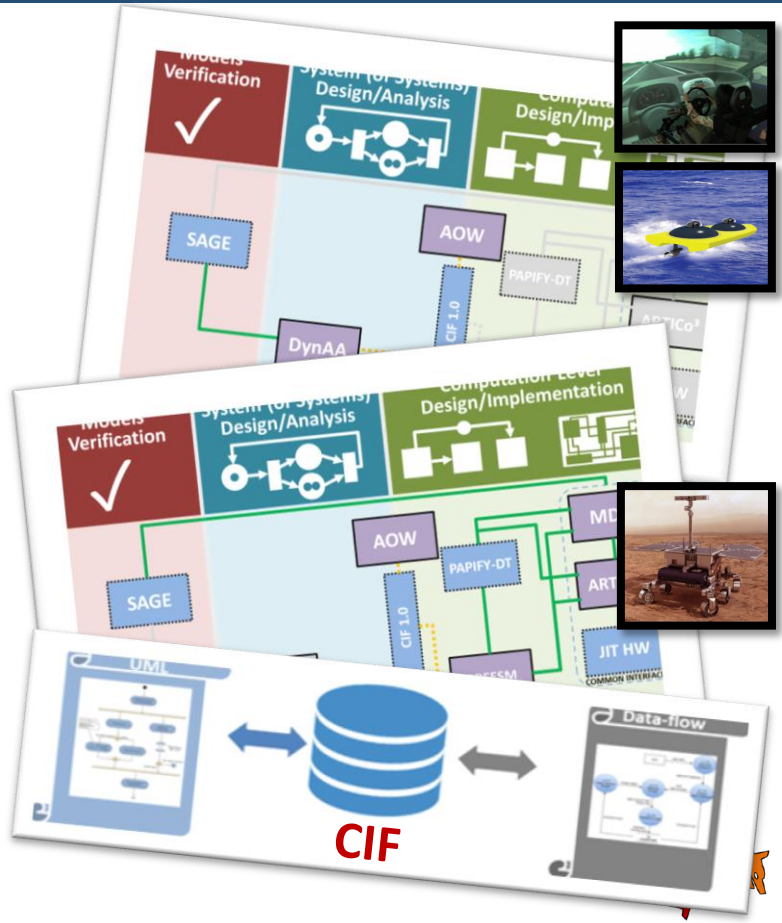
Combination of data or information from multiple heterogeneous sources

Presented to the **NBMP Group** at the **125th MPEG Meeting**.

CERBERO R&D Core: Design Productivity [WP5]

CERBERO major activities & outcomes:

- Use Case needs/targets **scouting** and Use-case to tool **mapping**.
- **Design/enhance/develop** components, with special emphasis on adaptivity support.
- **Framework Integration**.



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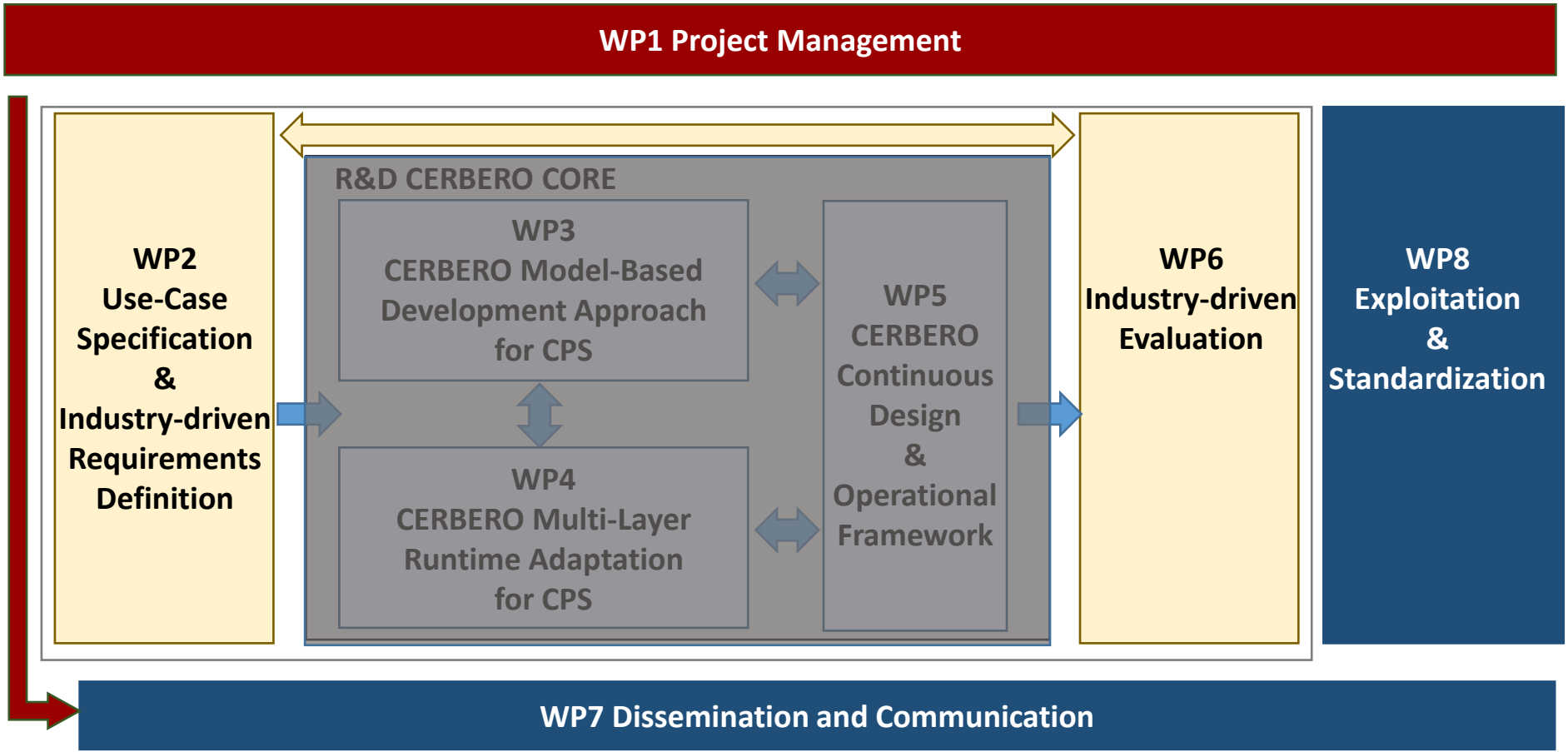

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[1] M. Masin, et al. Cross-layer design of reconfigurable cyber-physical systems , in Proc of Design Automation and Test 2017

[2] F. Palumbo, et al. Cross-layer modEl-based fRamework for multi-oBjective dEsign of Reconfigurable systems in unceRtain hybRid envirOnments, in Proc of. ACM International Conference on Computing Frontiers 2019

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