HIL'16 summer school
Lille, 1-2 September 2016
http://l2ep.univ-lille1.fr/hil2016/

« Energetic Macroscopic Representation for organization of HIL simulation »

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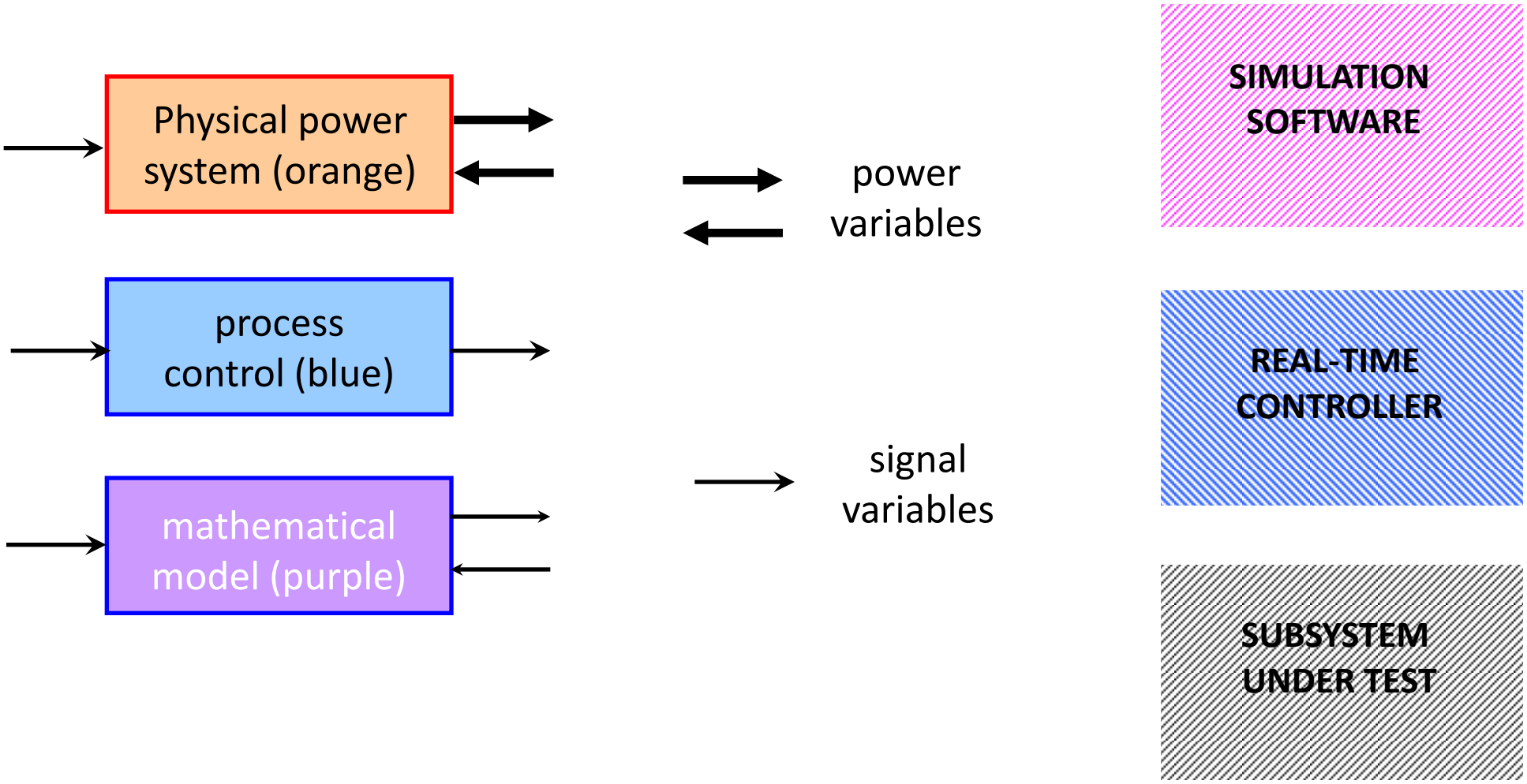
(L2EP, University Lille1)

1. ***Energetic Macroscopic Representation***

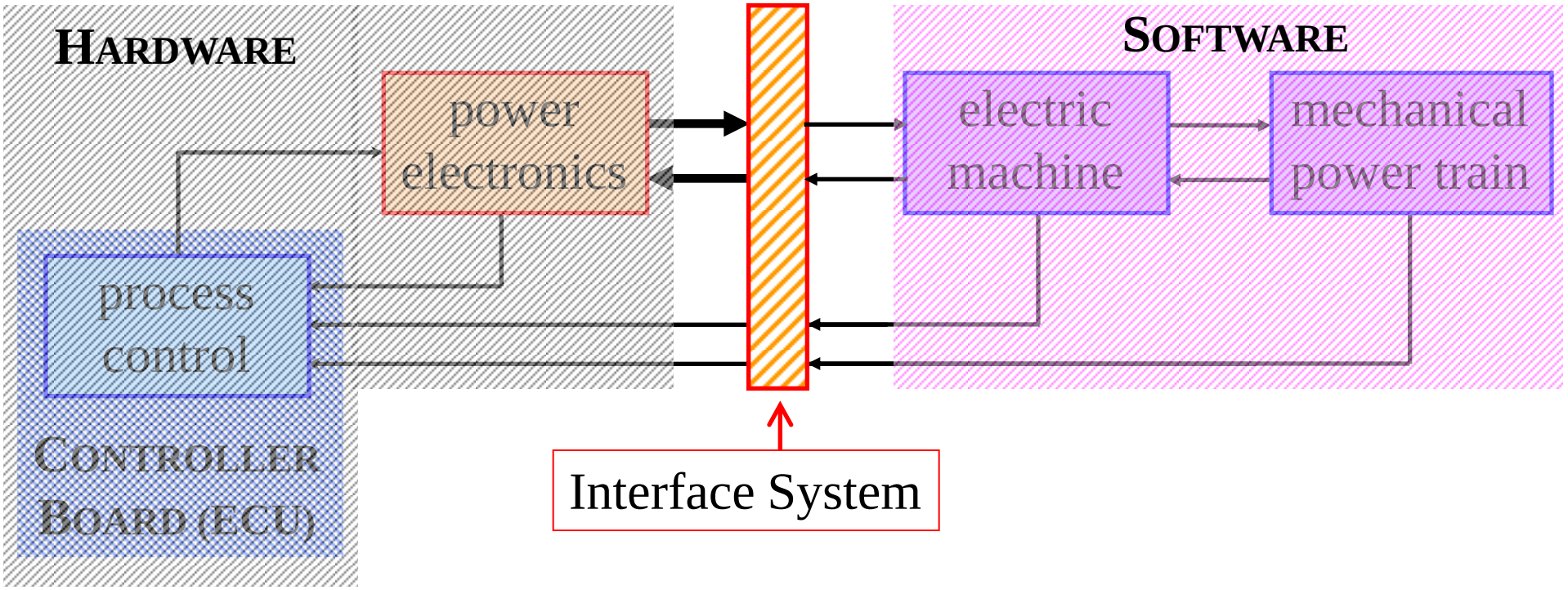
2. ***HIL simulation using EMR***

3. ***Example of an Electric Vehicle***

Graphical rules



HIL simulation:
Includes a hardware part, a software part and a specific interface



many different subsystems have to be connected.

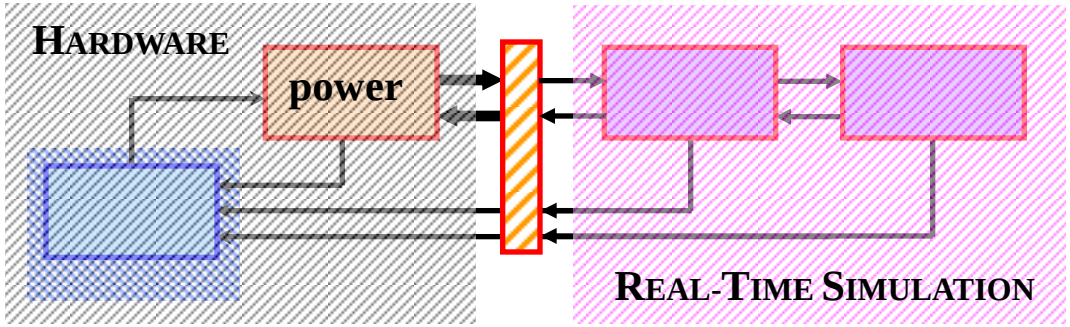
[Bouscayrol 11]

HIL simulation =

Hardware (energy conversion) → energetic model

\+ Models computed in real-time → causal model

in dynamic interactions → dynamic model



How to organize in the right way
the numerous subsystems to be connected ?

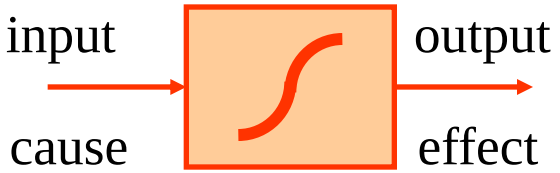
1. Energetic Macroscopic Representation (EMR)

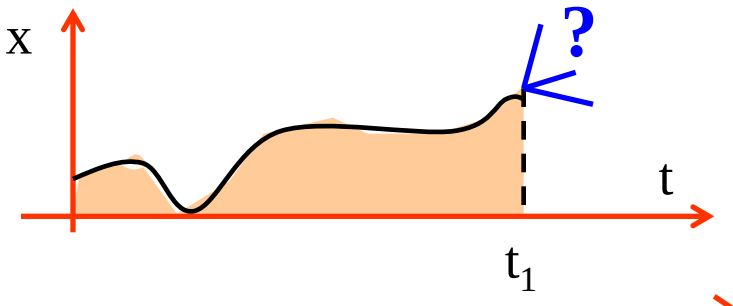
.....

- **Model organization**
- **Control organization**

Causality principle

Principle of causality
physical causality is integral





$\int xdt$ ⇨ area

OK in real-time

⇩

knowledge of past evolution

slope ⇦ $\frac{dx}{dt}$

impossible in real-time

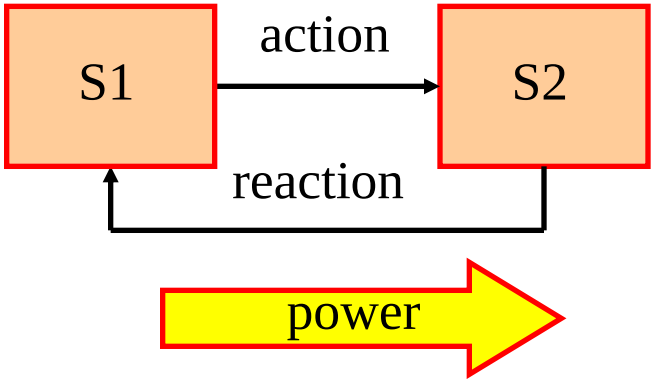
⇩

knowledge of future evolution

[Iwasaki 96] [Hautier 04]

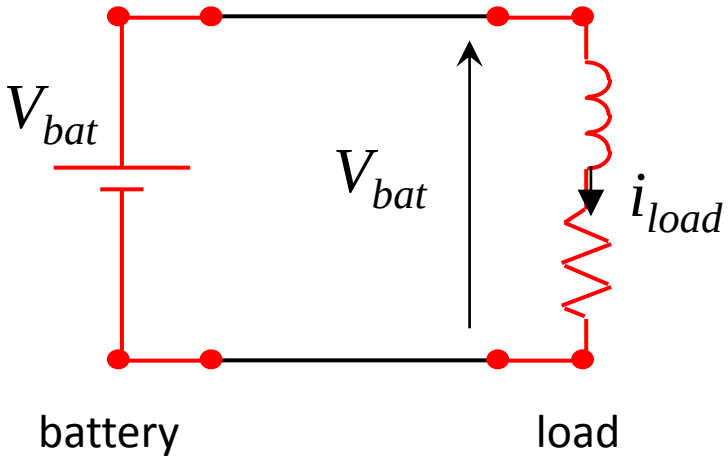
Interaction principle

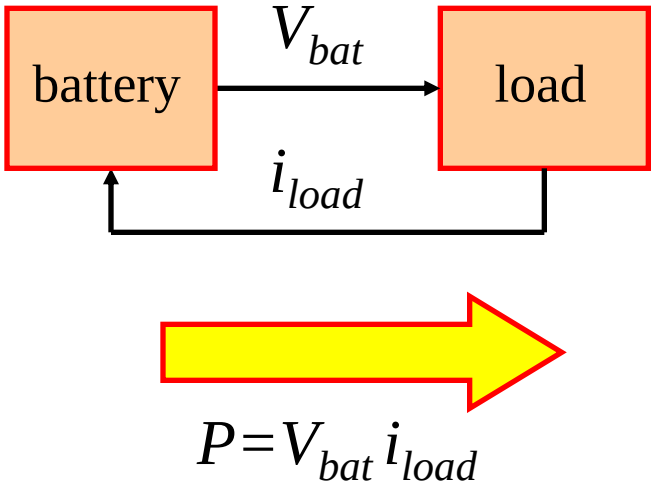
Interaction principle
Each action induces a reaction



Power exchanged by S1and S2 = action x réaction

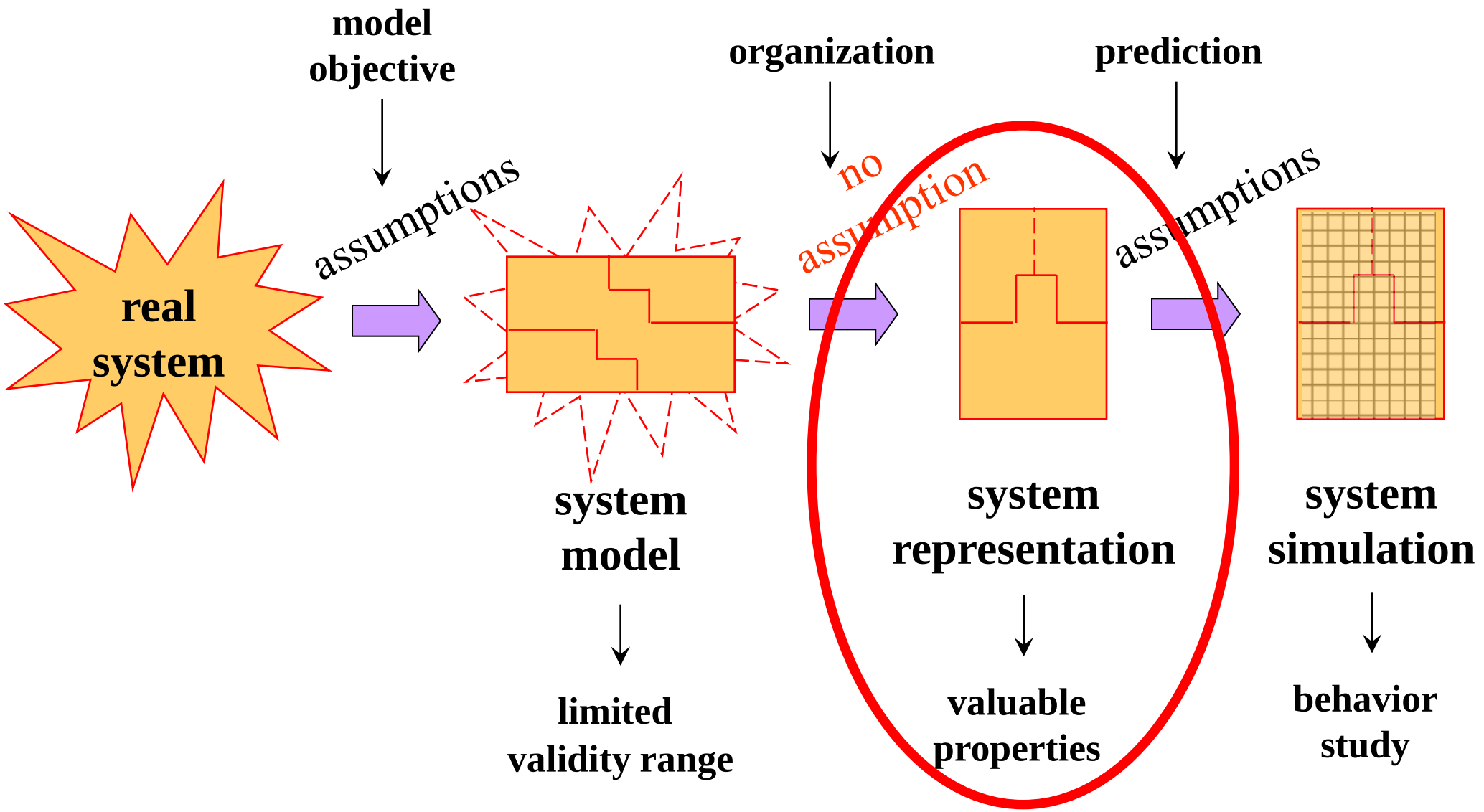
Example

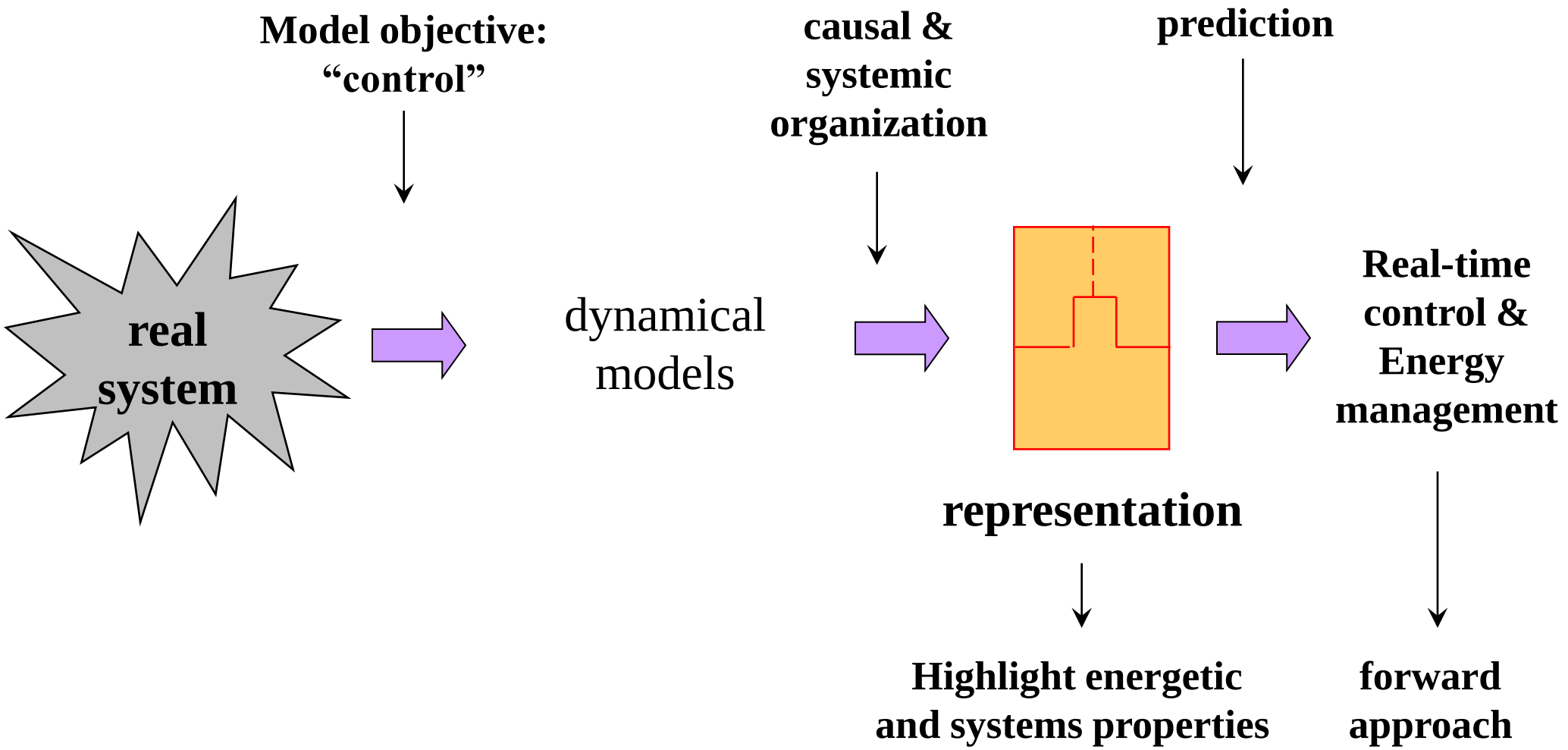




[Paynter 61] [Bouscayrol 00]

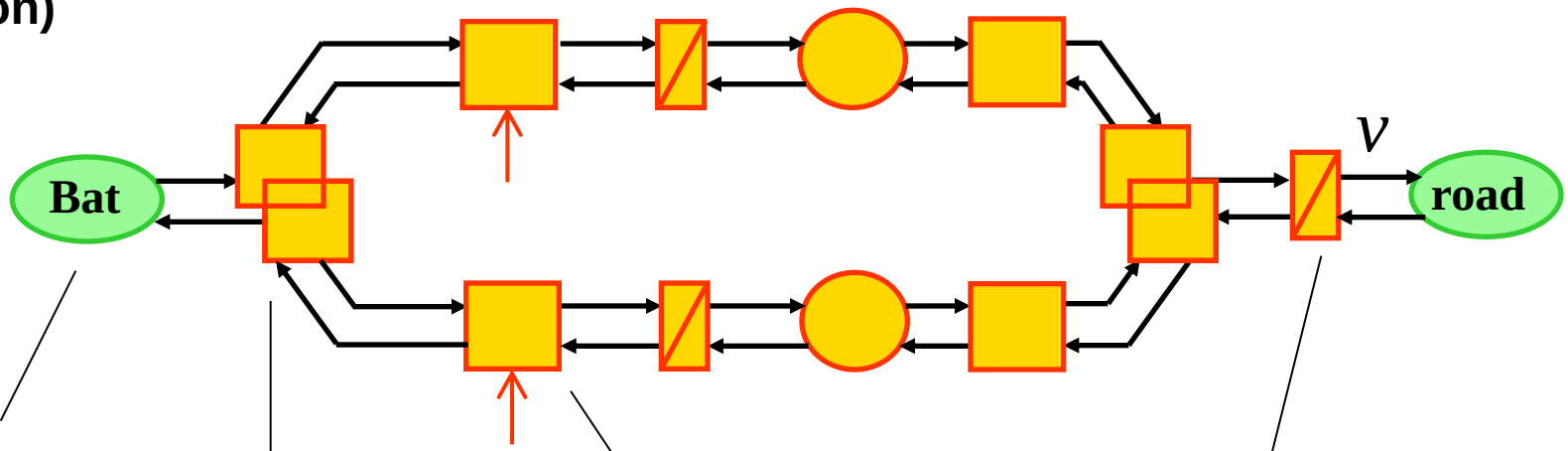
Modeling vs. Representation




Model objective:
"control"
causal &
systemic
organization
prediction
real
system
dynamical
models
representation
Real-time
control &
Energy
management
Highlight energetic
and systems properties
forward
approach

Energetic Macroscopic Representation (EMR)

EMR
(graphical description)
=
organization
of models of
complex systems

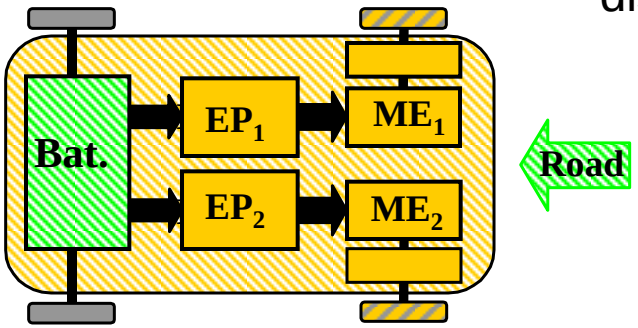


source element (outside the system)

coupling element (energy distribution)

conversion element (energy tuning)

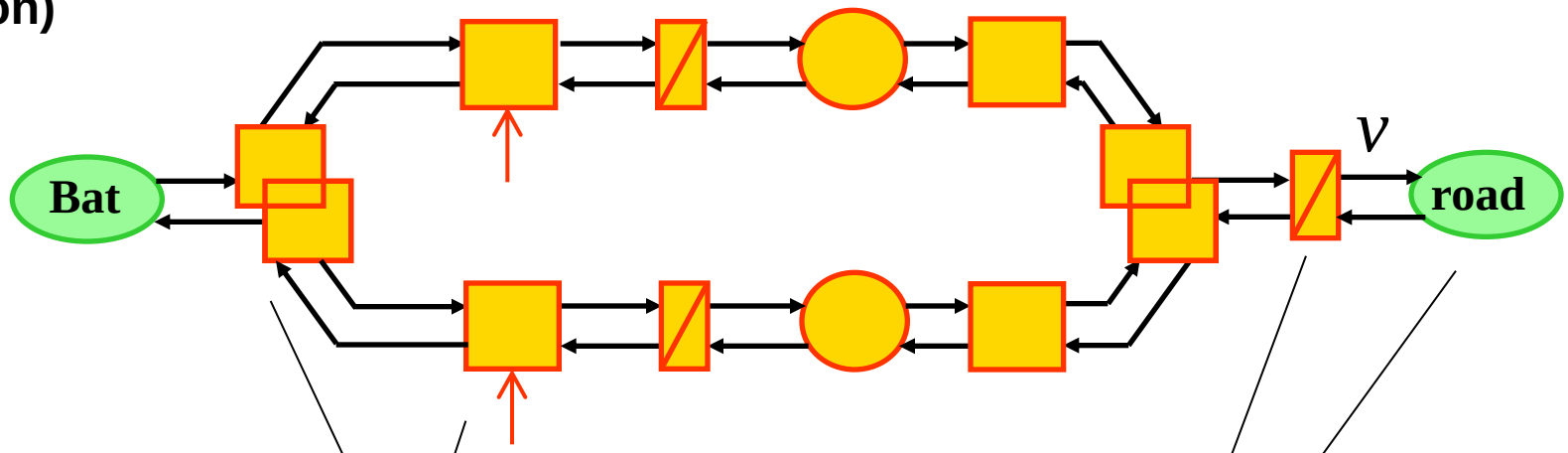
accumulation element (energy storage)



[Bouscayrol 00, 12]

Energetic Macroscopic Representation (EMR)

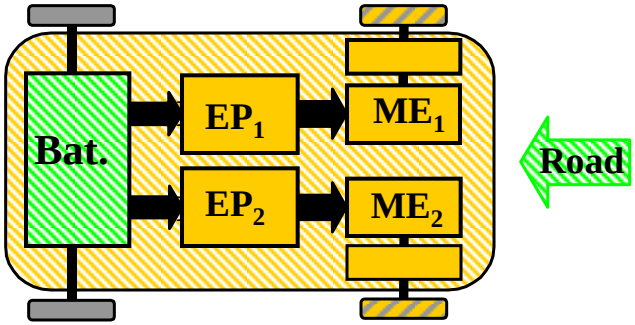
EMR
(graphical description)
=
organization
of models of
complex systems



Action / reaction variables

floating I/Os (imposed by other elements)

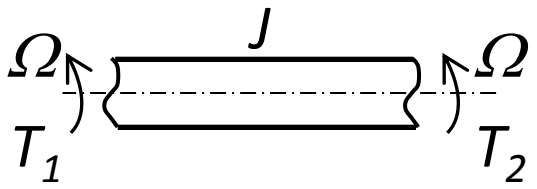
Fixed I/Os (imposed by the internal Causality)



only the physical integral causality is authorized!

Example of EMR element

Structural description

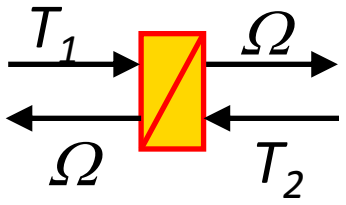


Rotating shaft

Initial relationship $T_1 = J \frac{\mathrm{d}}{\mathrm{dt}} \Omega + f\Omega + T_2$ (Ω state variable)

causal relationship $\Omega = \frac{1}{2} \int (T_1 - f\Omega - T_2)dt$ (output as an integal function of inputs)

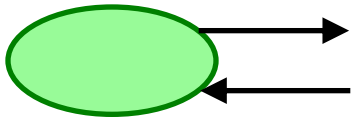
functional description (EMR)



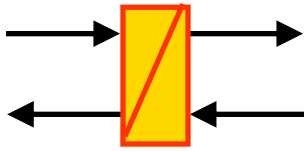
accumulation element (Ω output at both sides) $E = \frac{1}{2} J \Omega^2$

EMR = organization of the model in respect with the interaction and causality principles

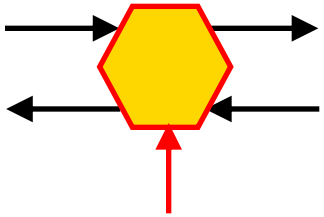
Only 4 energetic functions



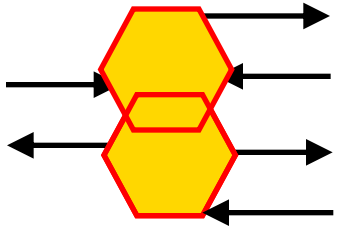
Energy source



Energy accumulation



Energy conversion (potential tuning)



Energy distribution

all elements connected by action/ reaction (power link) (interaction)

all power I/O defined by accumulation elements (causality)

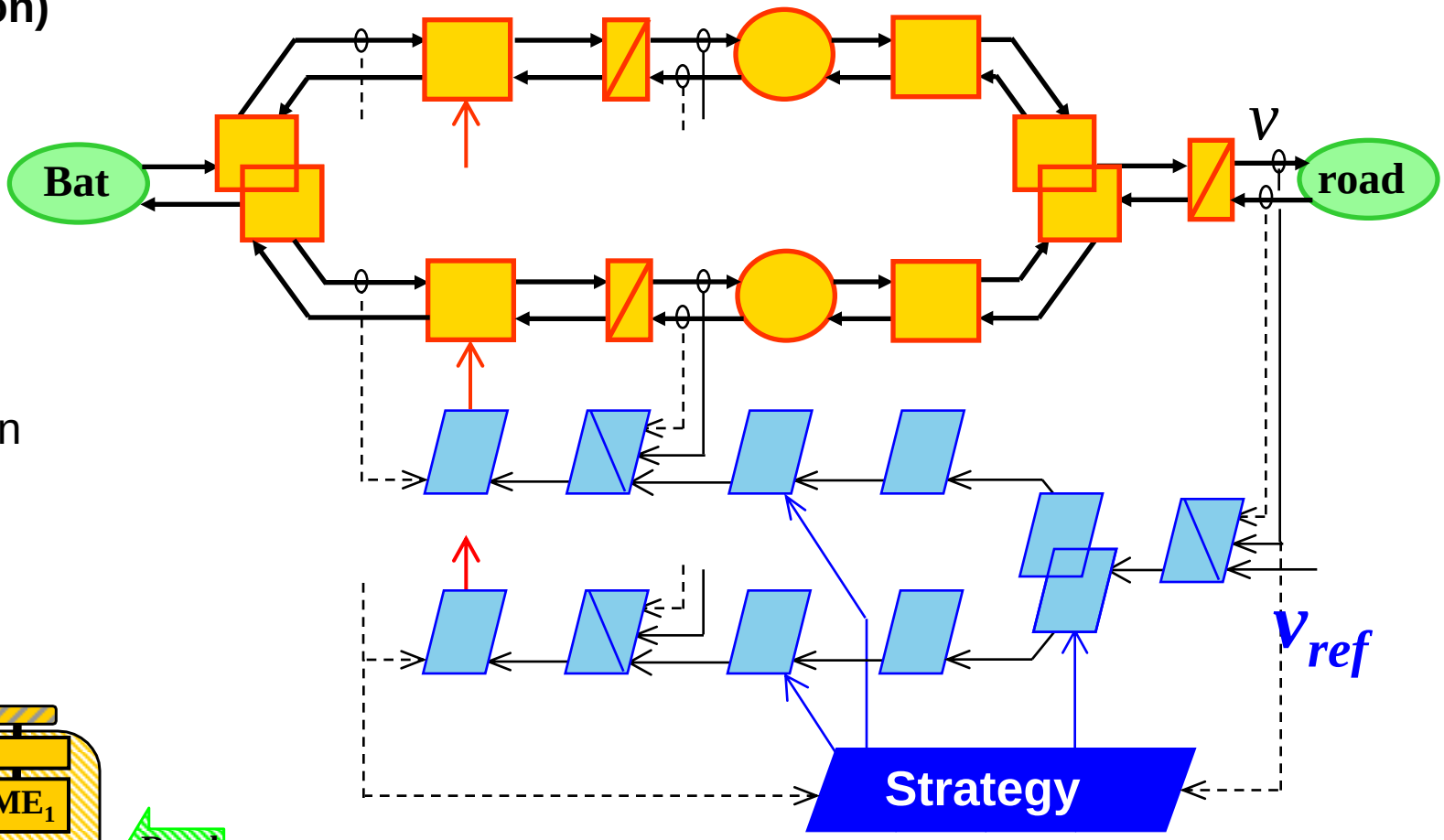
only conversion elements can have tuning inputs

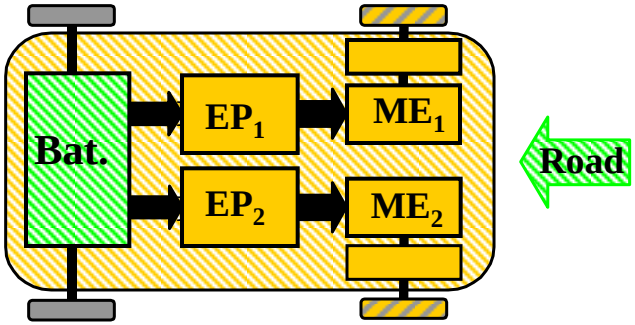
element association according the holistic principle (Systemics)

Inversion-based control scheme

EMR
(graphical description)
=
organization
of models of
complex systems

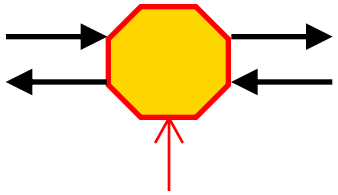
Systematic deduction
of organization of
control schemes





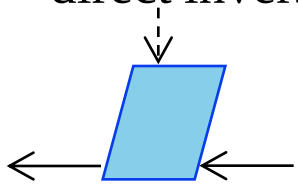
Inversion of EMR elements

conversion element



$$y(t) = k\,u(t) \longrightarrow u_{ref}(t) = \frac{1}{k}\,y_{ref}(t)$$

direct inversion



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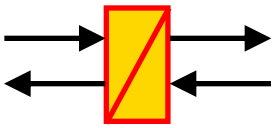
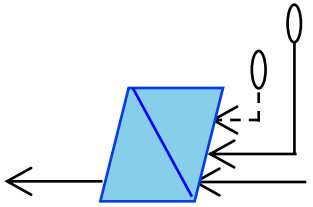
accumulation element



$$y(t) = \int u(t)\,dt$$

closed-loop control

$$u_{ref}(t) = C(t)\left[y_{ref}(t) - y_{meas}(t)\right]$$



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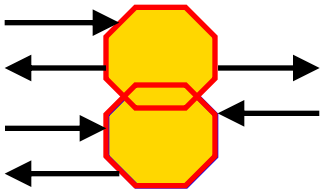
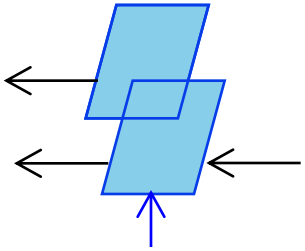
coupling element



$$y(t) = u_1(t) + u_2(t)$$

$$\begin{cases} u_1(t) = k_D(t)\,y(t) \\ u_2(t) = (1 - k_D(t))\,y(t) \end{cases}$$

distribution criteria

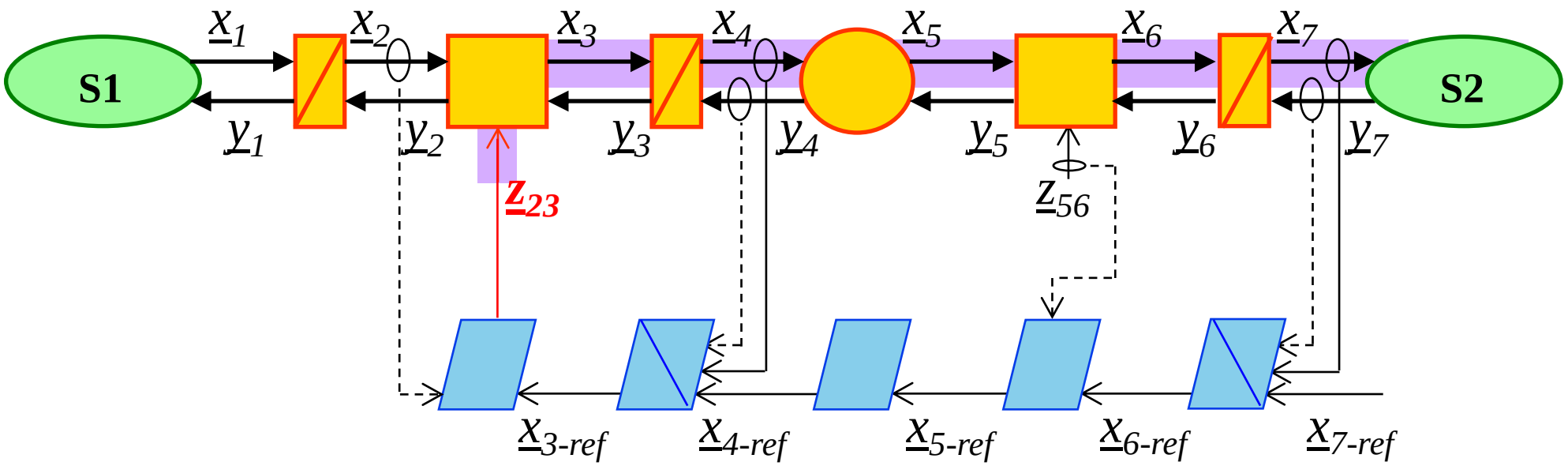


[Hautier 04] [Bouscayrol 12]

Maximal Control Structure

1. EMR of the system
2. Tuning path
3. Inversion step-by-step

Strong assumption: all variables can be measured!



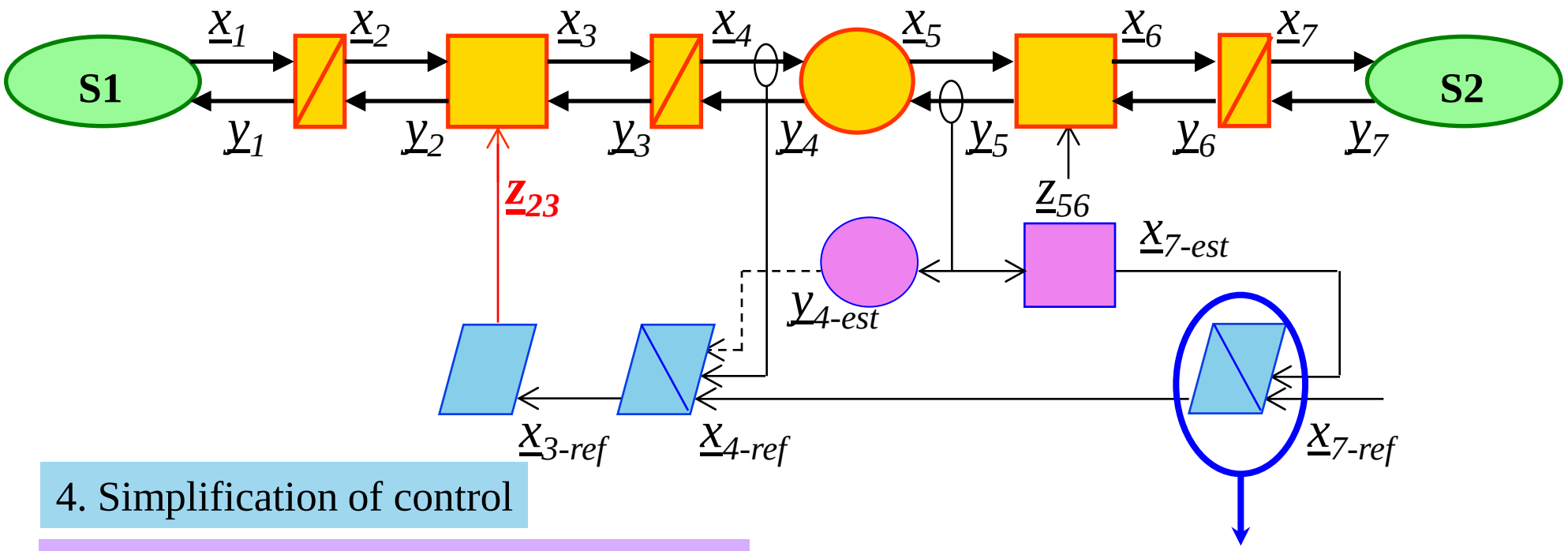
Maximal Control Structure (or scheme):
- maximum of sensors
- maximum of operations

Example:
- 4 sensors
- 2 closed-loop controllers

Practical Control Structure

1. EMR of the system
2. Tuning path
3. Inversion step-by-step

Strong assumption: all variables can be measured!



4. Simplification of control
5. Estimation of non-measured variables
6. Tuning of controllers

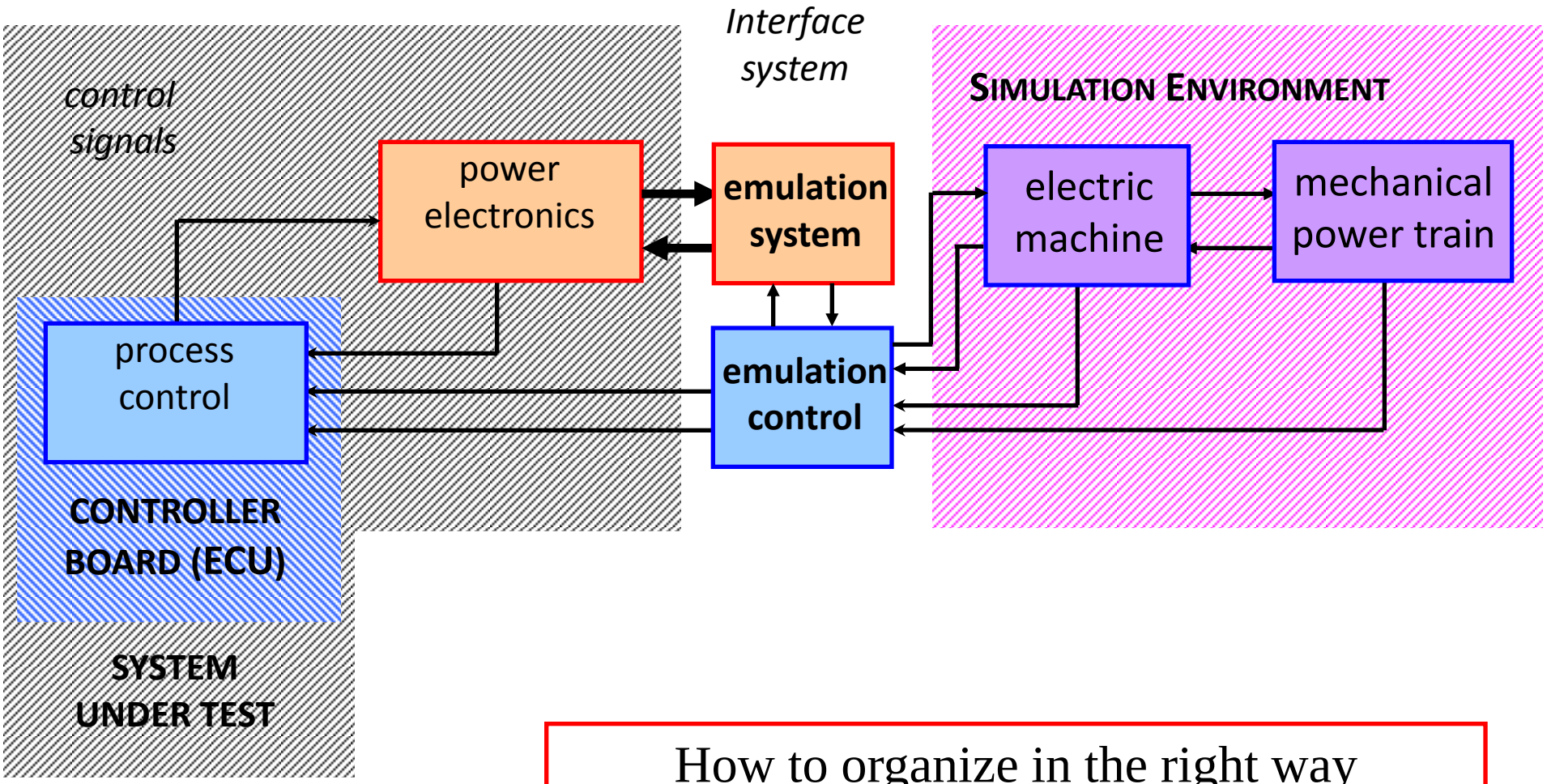
PI / PID / fuzzy controller?
Calculation of parameters?

2. EMR for organization of HIL simulation

.....

- **EMR for control**
- **EMR for HIL**

Power HIL simulation



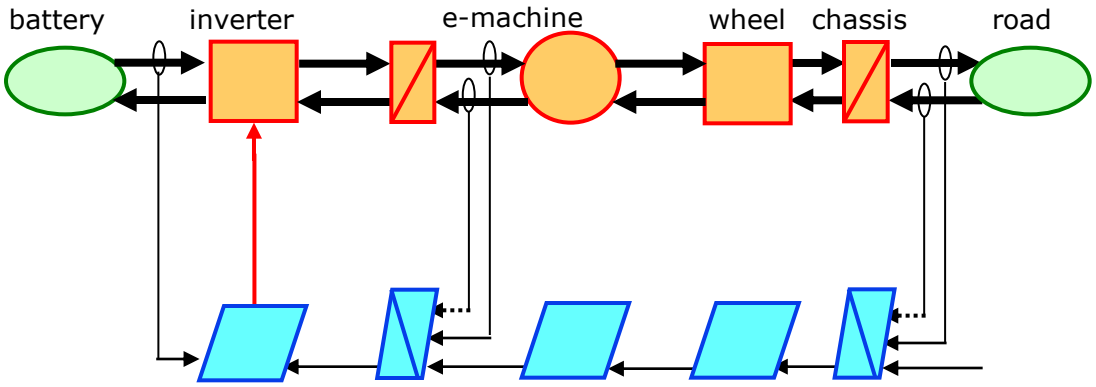
How to organize in the right way
the numerous subsystems to be connected ?

HIL simulation using EMR

Objective: test of new power subsystem before implementation in a real vehicle

Systematic organization using EMR:

- organization of the numerous subsystems
- definition of the interface subsystem



Example of an EV

power

control

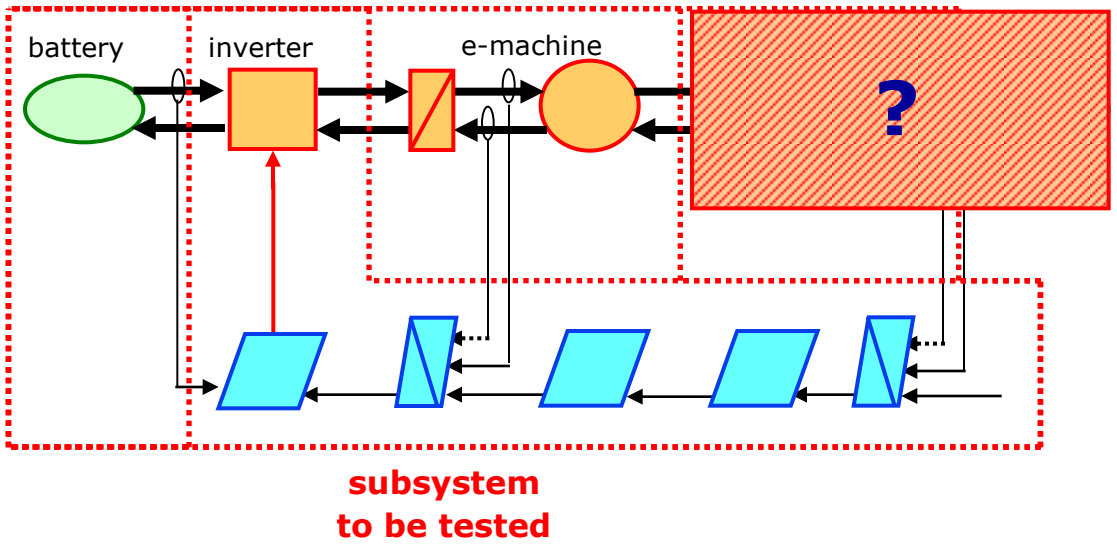
HIL simulation using EMR (2)

Objective: test of new power subsystem before implementation in a real vehicle

Systematic organization using EMR:

- organization of the numerous subsystems
- definition of the interface subsystem

Different objectives = different Power HIL simulation



Example of an EV

power

control

HIL simulation using EMR (2)

Objective: test of new power subsystem before implementation in a real vehicle

Systematic organization using EMR:

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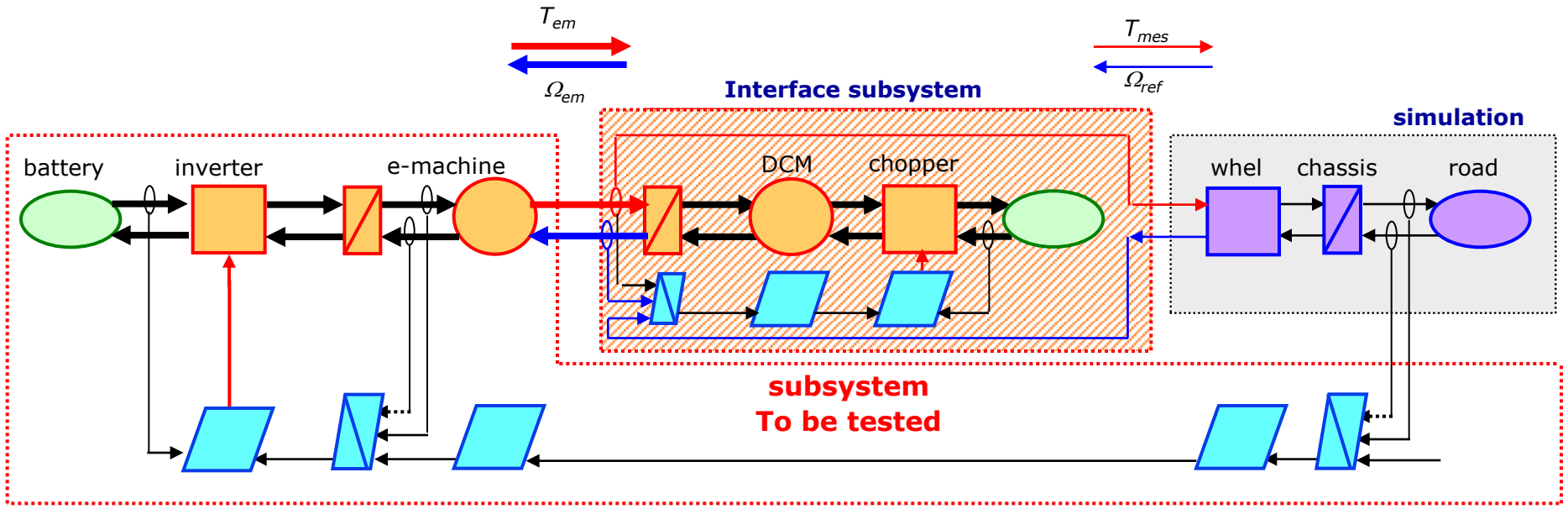


Example of an EV

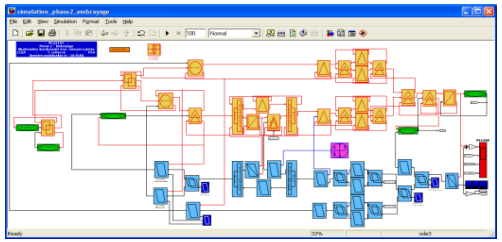
power | control | model

Example of HIL simulation of a HEV

Objective of the "electricity & vehicle" (eV) platform of the control team:
real-time validation of energy management of new vehicle concepts
for more efficient and less pollutant transportation systems

study of a new vehicle	**pre-validation on the "eV" platform**	validation on a real prototype
• **EMR** methodology • simulation (EMR library)	• flexible power and control devices • **HIL simulation**	• real vehicle • IBC and EMS integration

Ex: PhD of T. Letrouvé (double parallel HEV of PSA)



Simulation of the 3008 HY4 using EMR

HIL simulation of the 3008 HY4 traction system (« ev » platform)

PSA PEUGEOT CITROËN

validation of the control on the 3008 HY4 prototype

3. Example of a EV traction system

.....

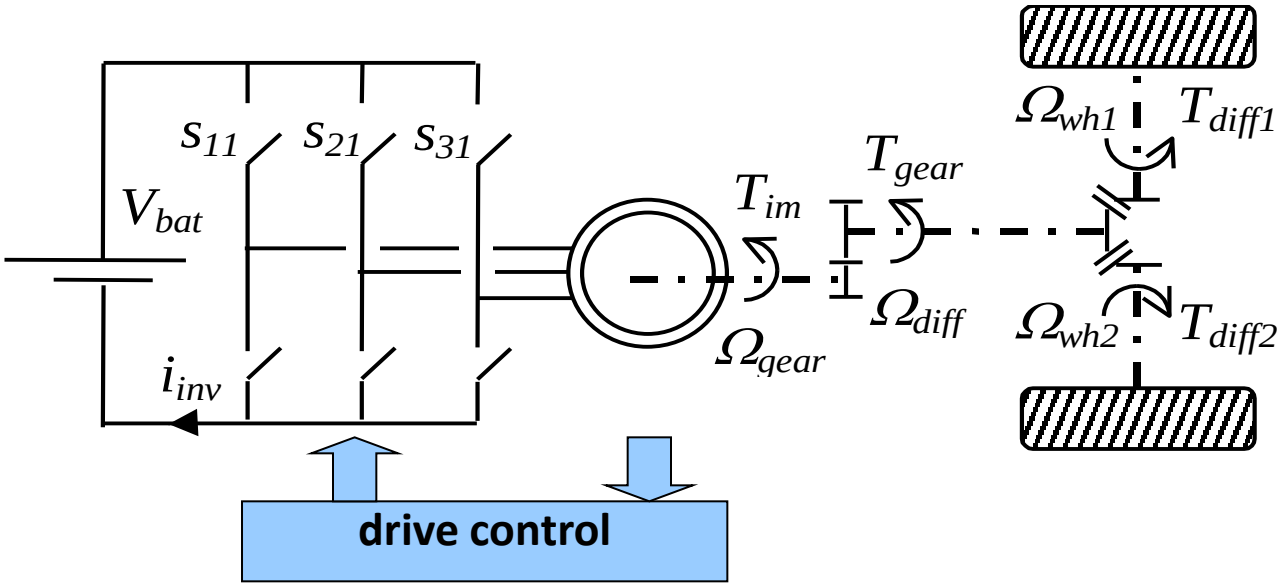
- **EMR of the studied EV**
- **HIL simulation of the studied EV**

electricity
& Vehicles

Université de Lille 1 SCIENCES ET TECHNOLOGIES

L2EP Laboratoire d'électrotechnique et d'électronique de puissance de Lille

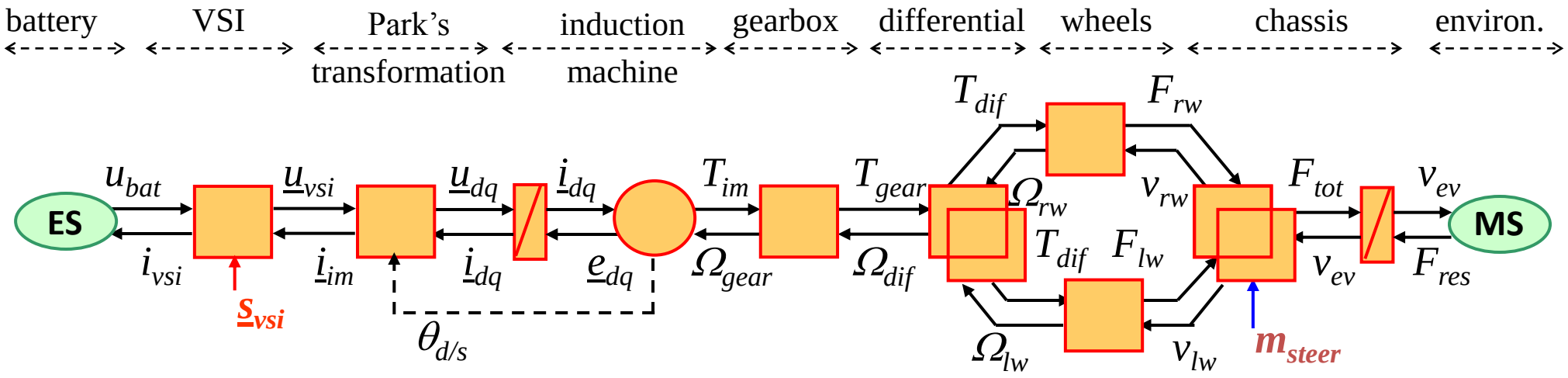
Traction of the studied EV: VSI + Induction machine + differential + 2 driven wheels

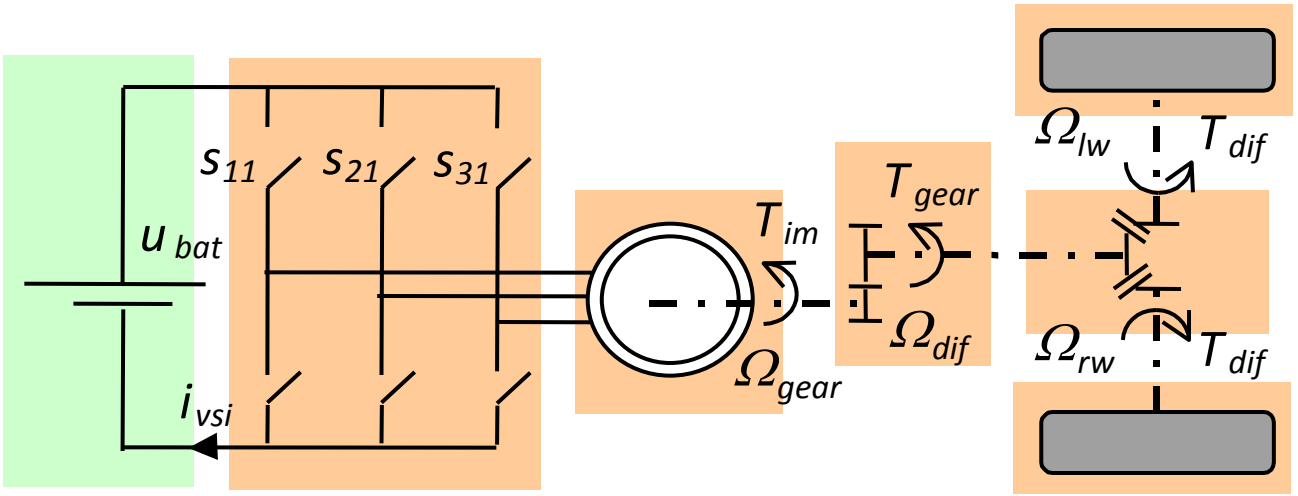


Drive implementation for an Electric Vehicle ?

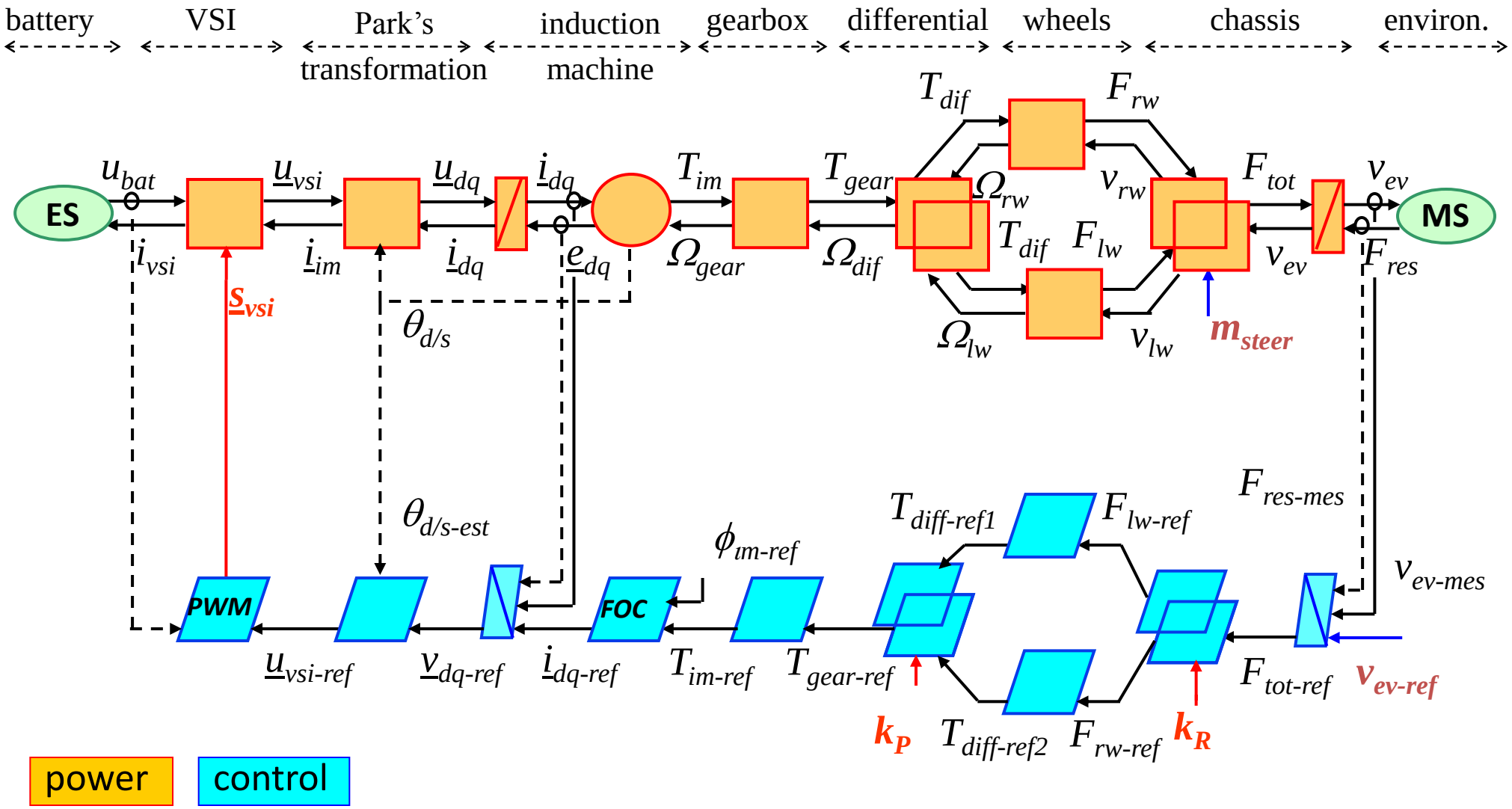
1. Simulation of the EV (drive + vehicle dynamics)
2. Test of the actual traction drive — **HIL simulation**
3. Test of the whole prototype

EMR of the studied system

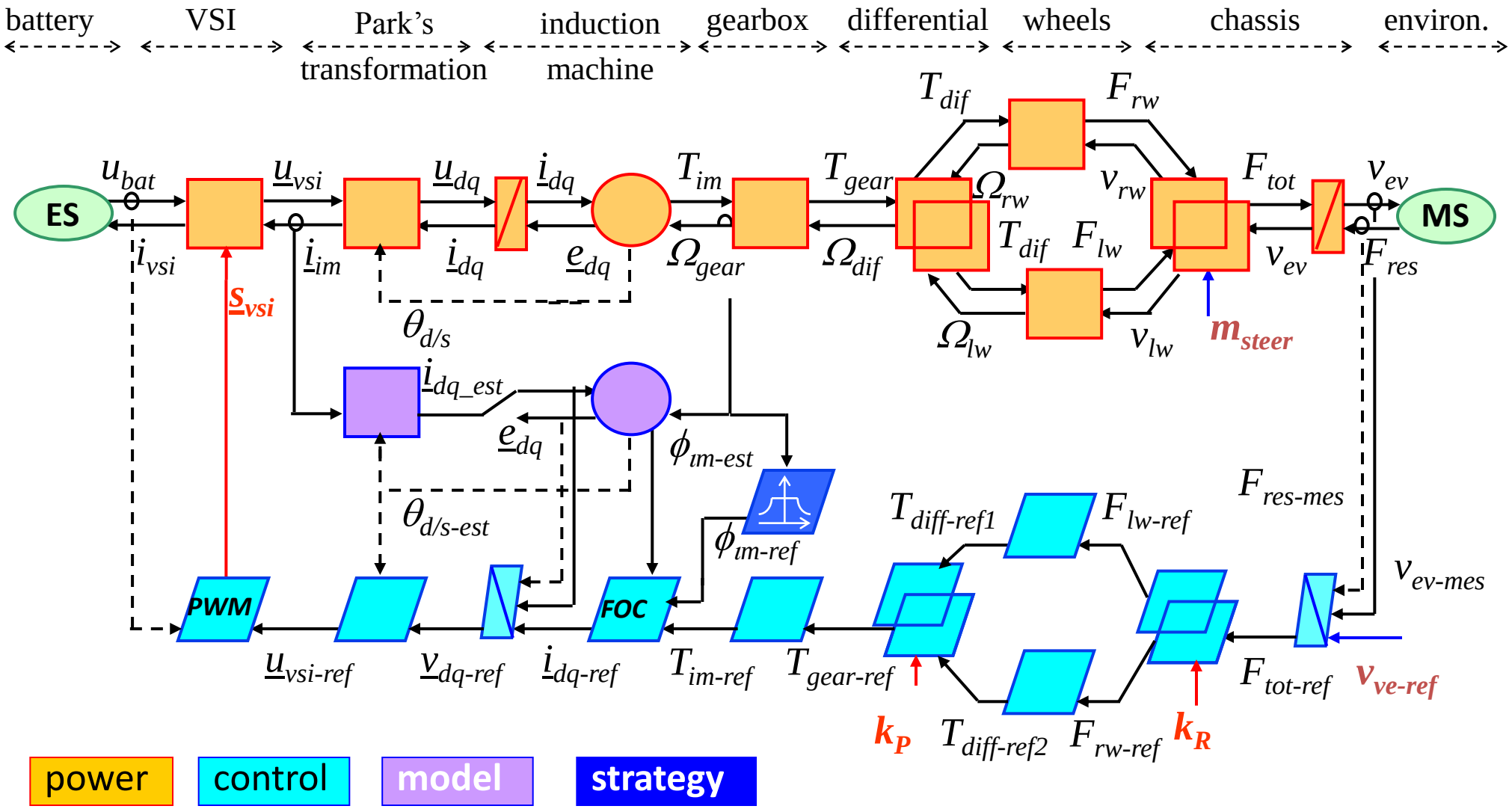




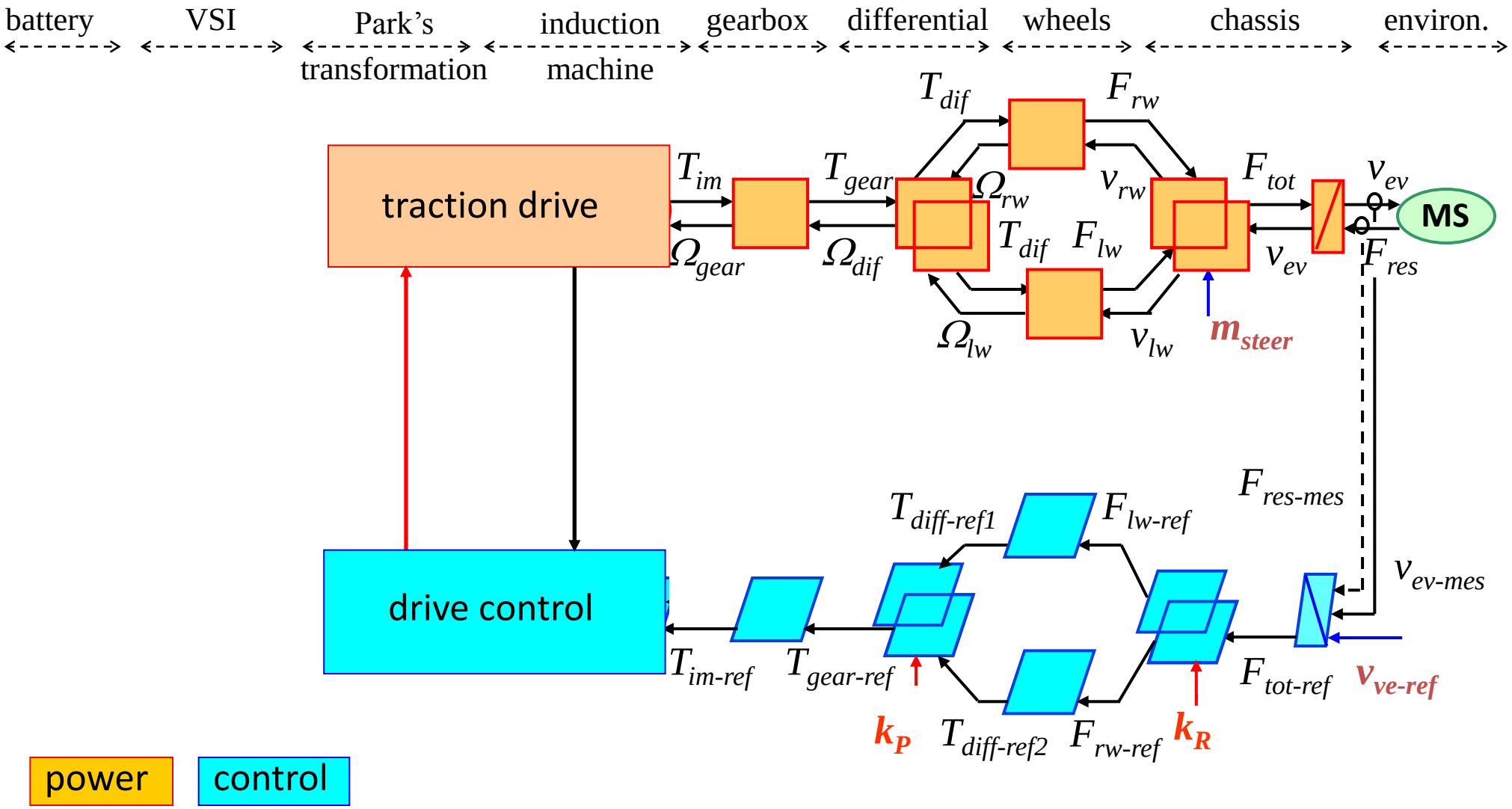
Maximum control scheme



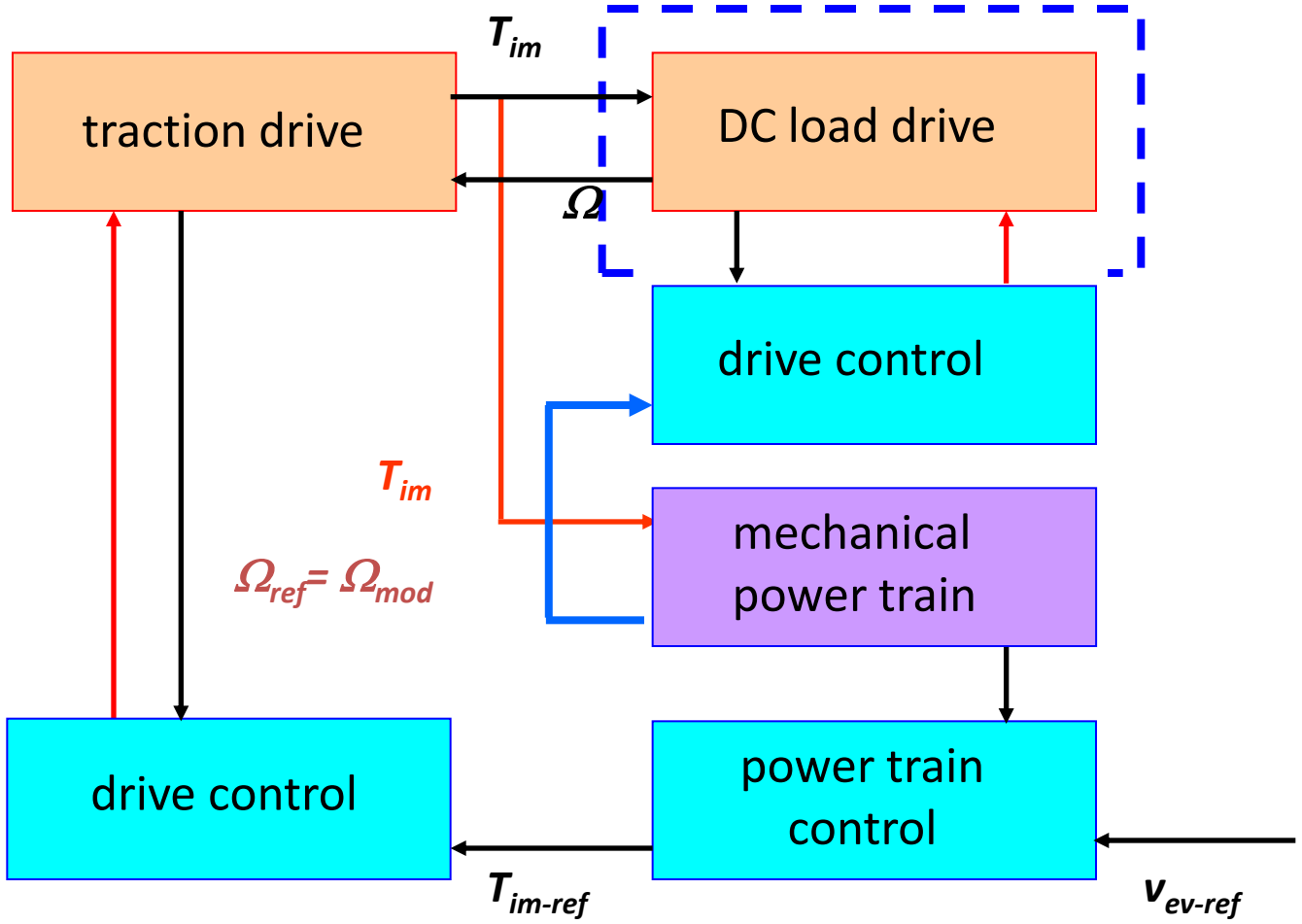
Practical control scheme



Synthetic description

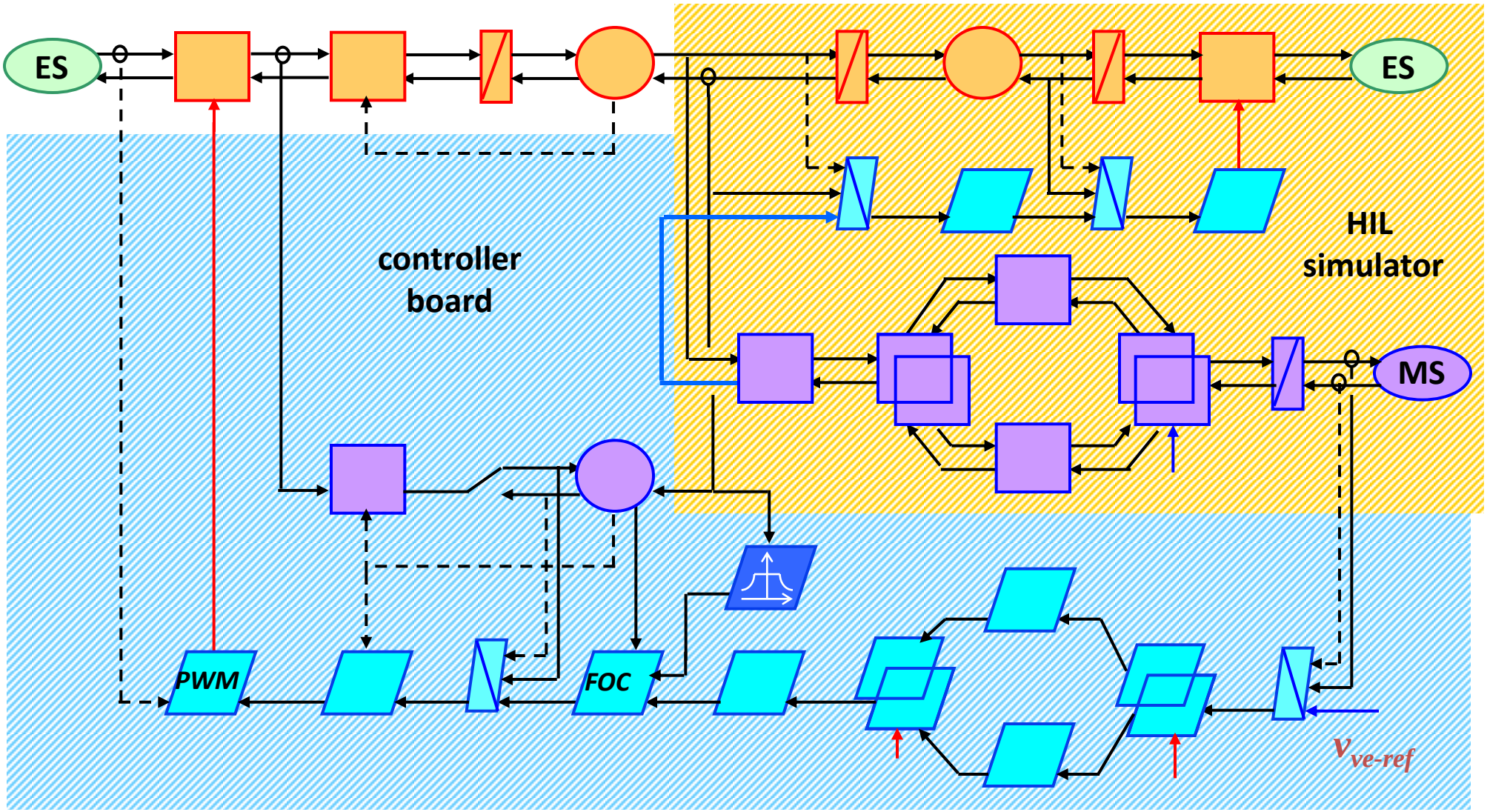


HIL simulation organization

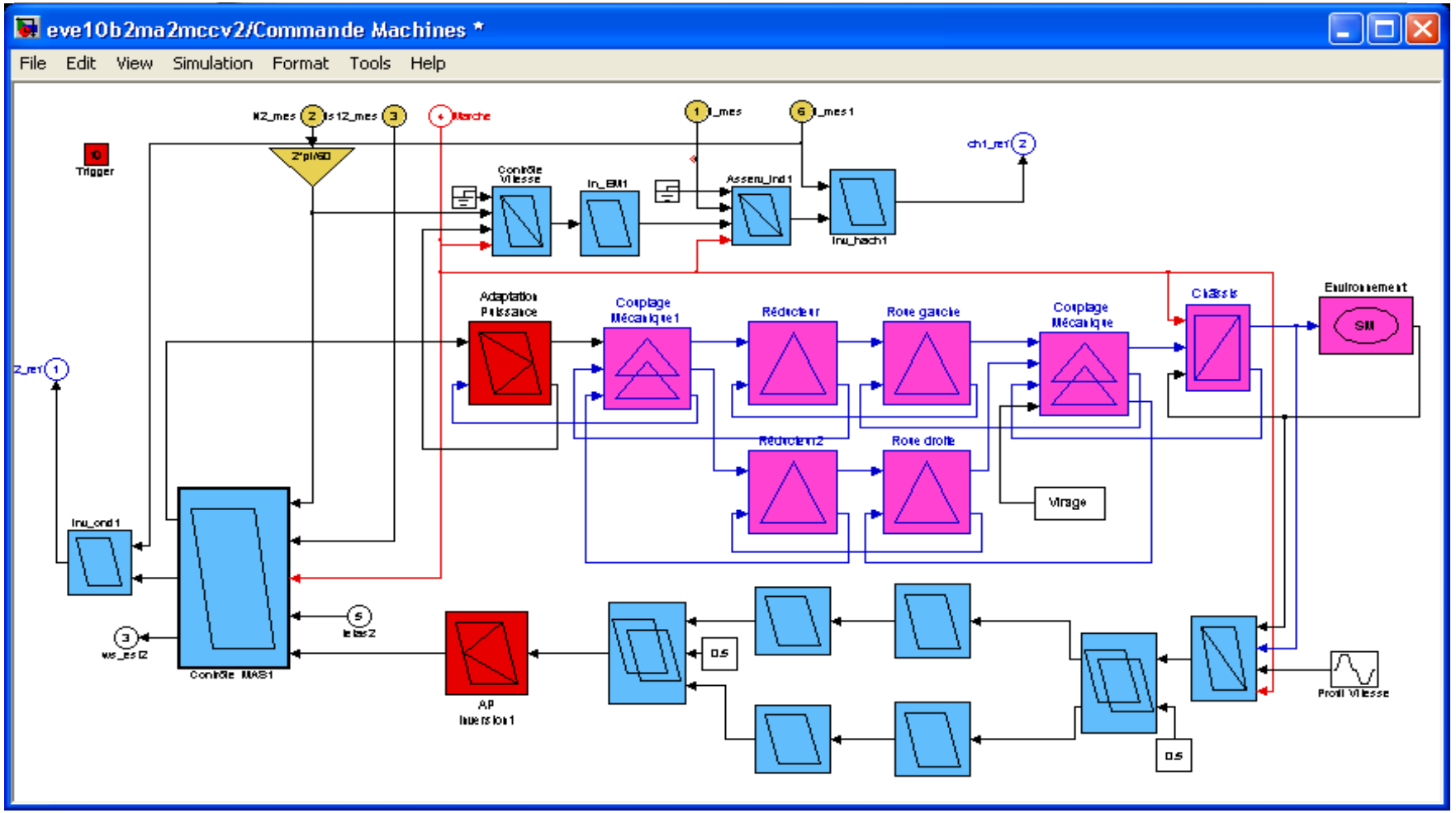


power | control | model

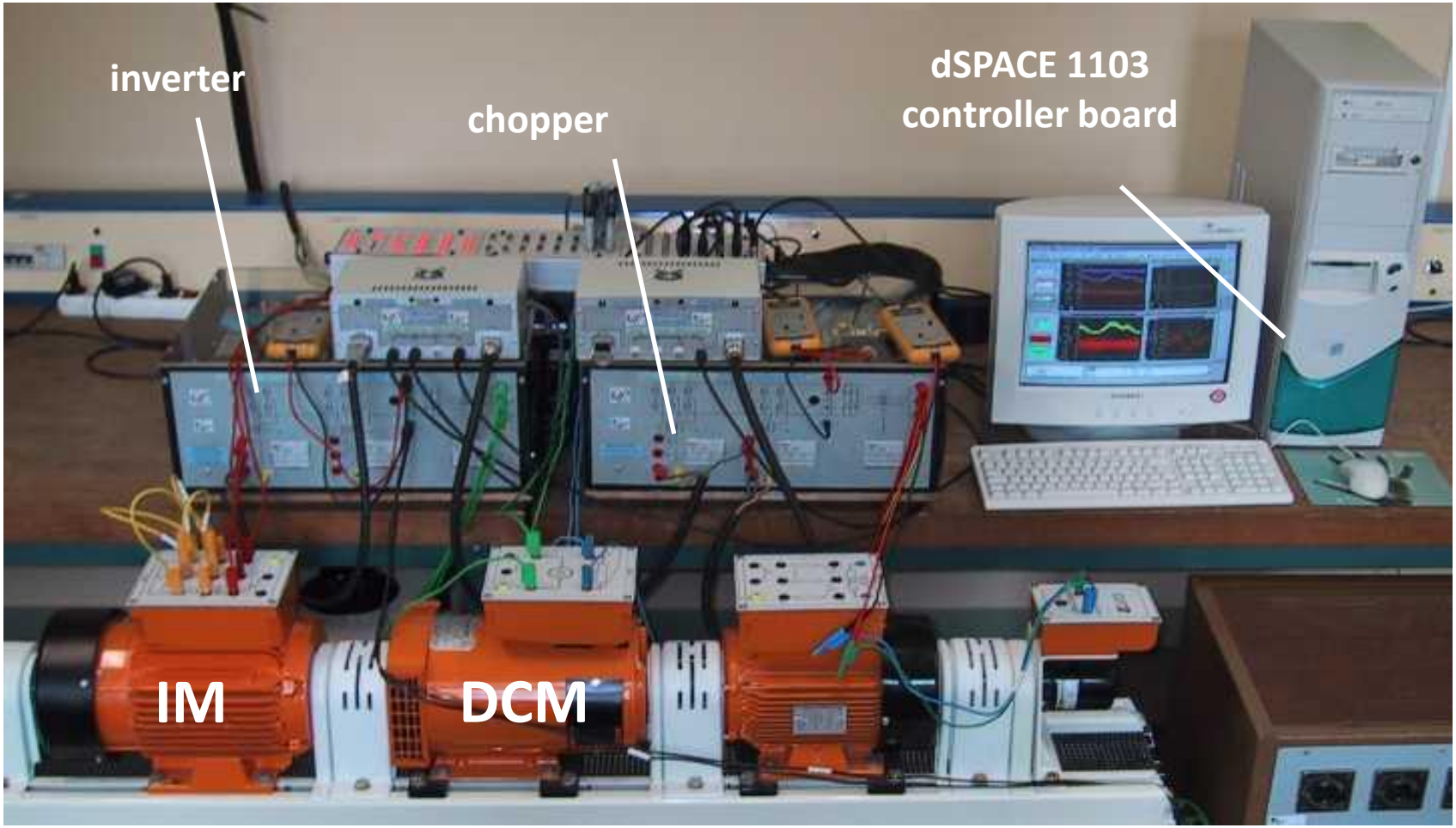
Details on the HIL simulation



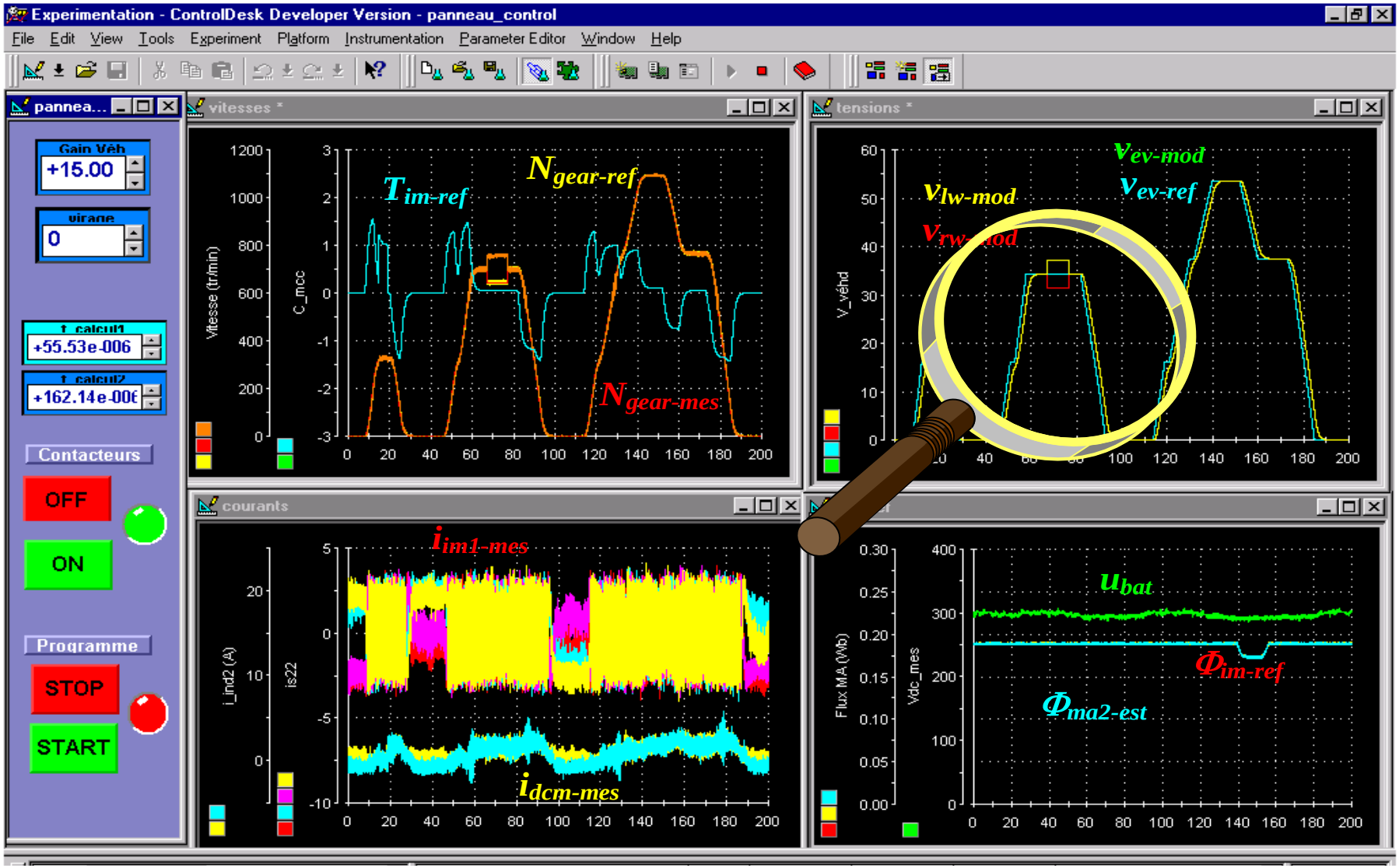
Experimental set-up



Experimental set-up

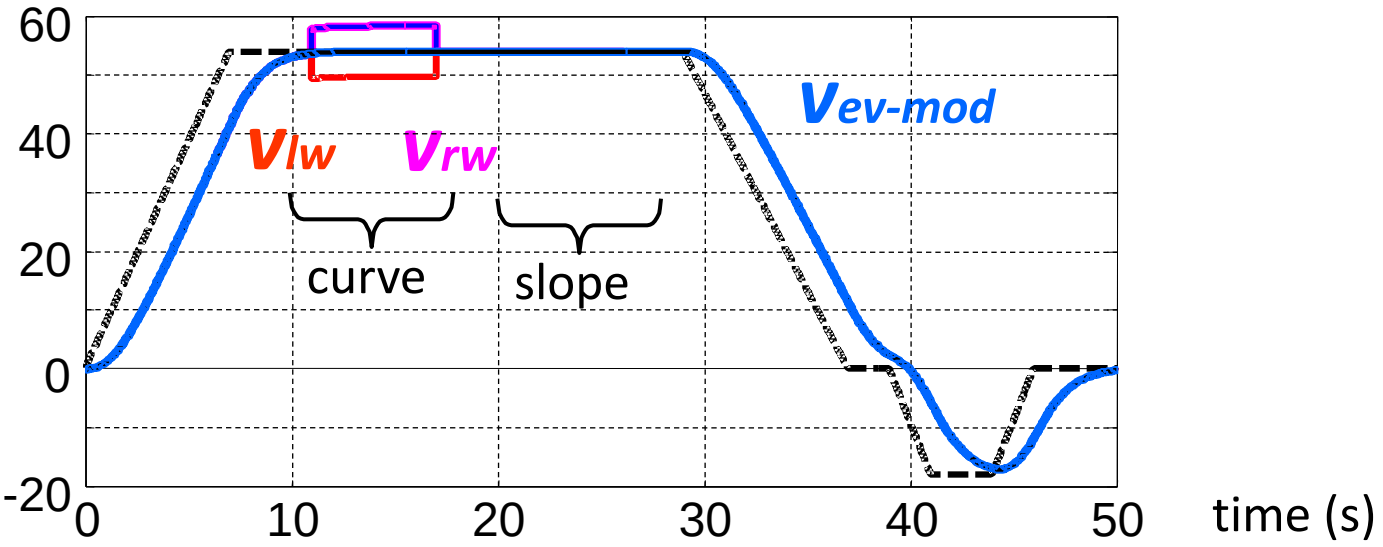


Experimental results for an ECE driving cycle

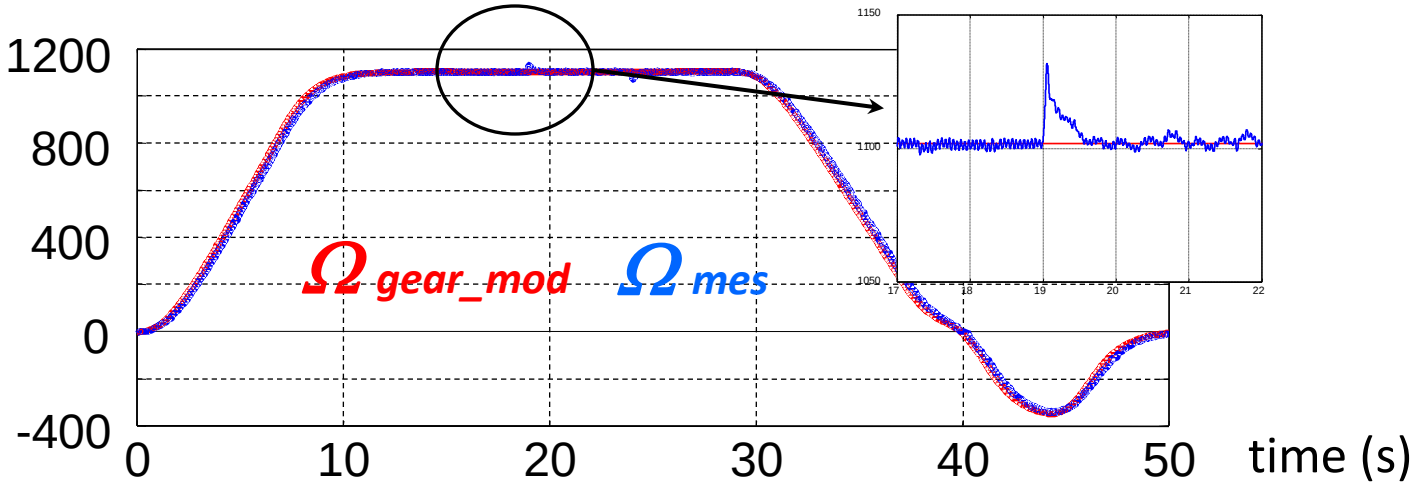


Validation of the HIL simulation

velocities (km/h)



speeds (rpm)



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