Modeling for Smart Cyber-Physical Systems

Application to Farming Systems

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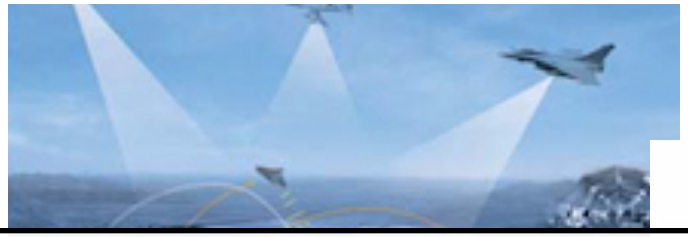
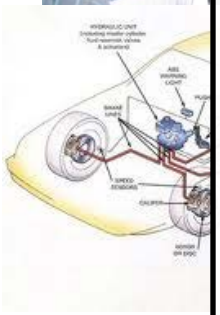
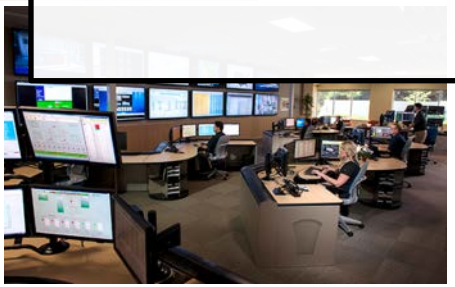
in collaboration with OBEO, INRA, and IRIT
with the support of the GEMOC initiative

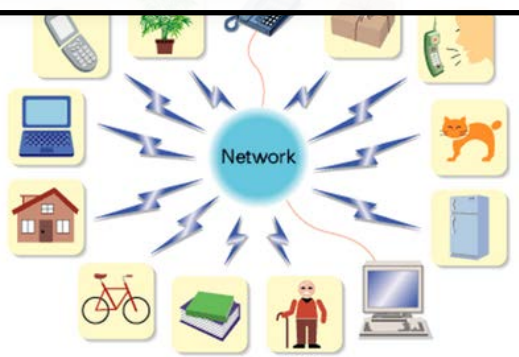
Thanks to many discussions with Betty Cheng, Jeff Gray and Ana Moreira

Complex Software-Intensive Systems

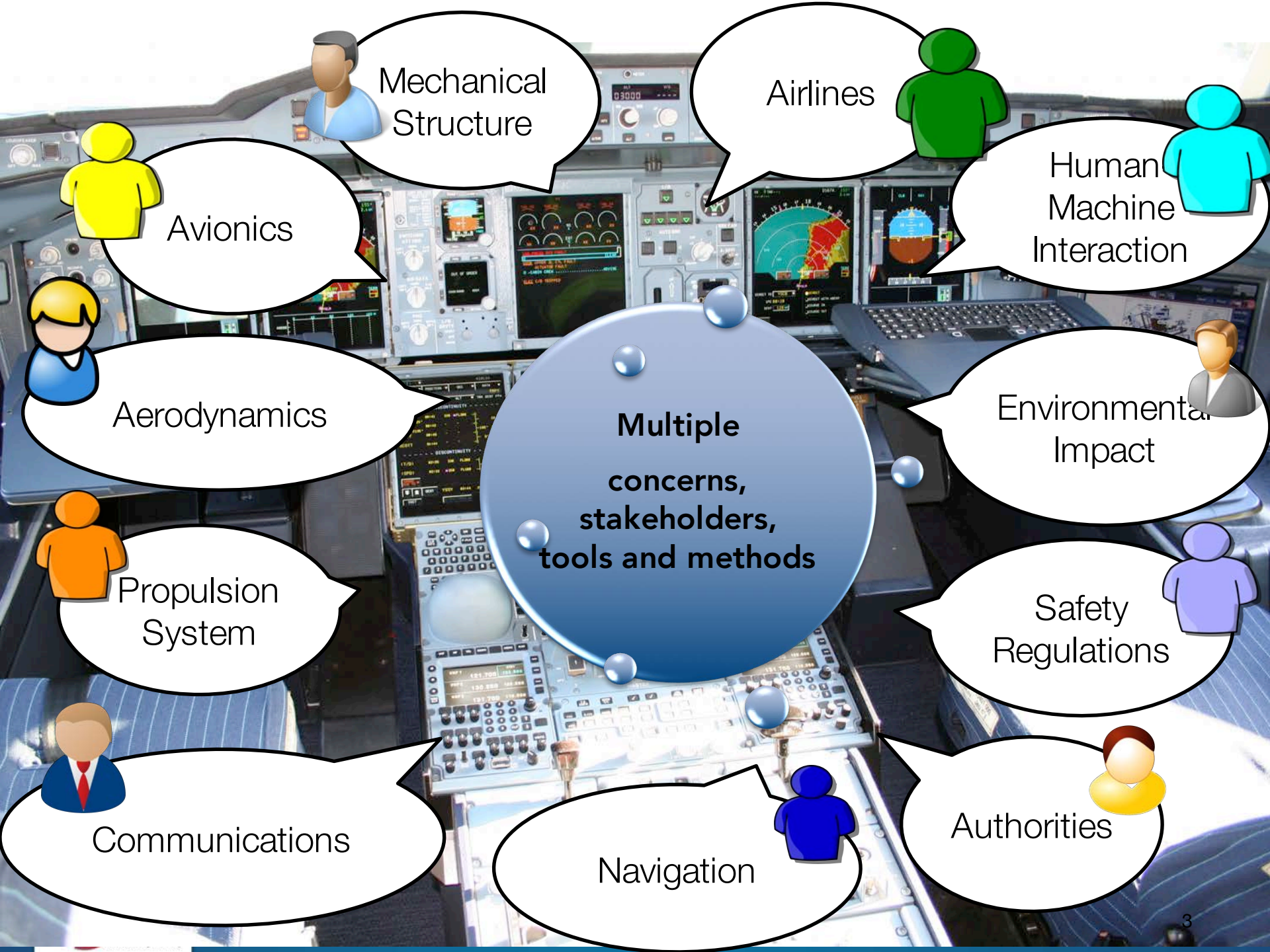




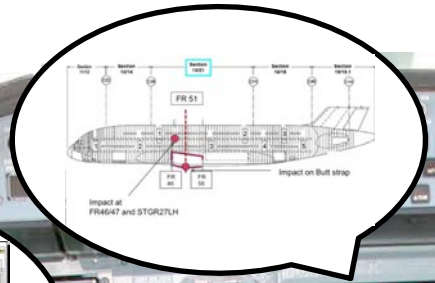


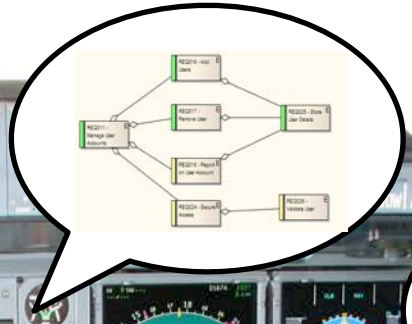


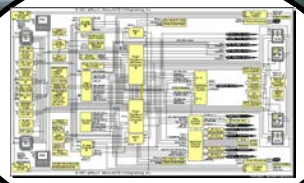
- Multi-engineering approach
- Some forms of domain-specific modeling
- Software as integration layer
- Openness and dynamicity

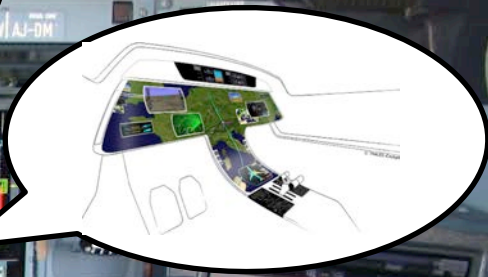

Mechanical Structure
Airlines
Avionics
Human Machine Interaction
Aerodynamics
Multiple
concerns, stakeholders, tools and methods
Environmental Impact
Propulsion System
Safety Regulations
Communications
Navigation
Authorities

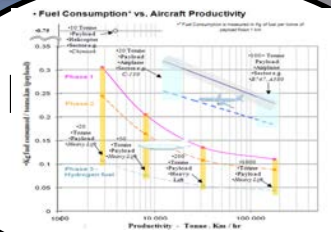
Heterogeneous Modeling

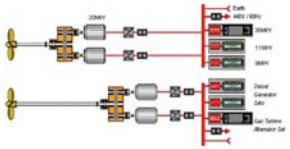


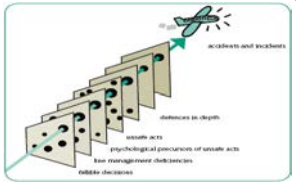


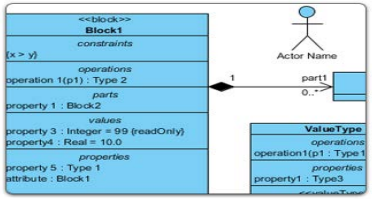


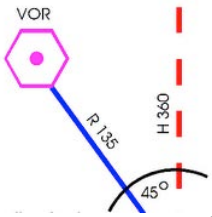




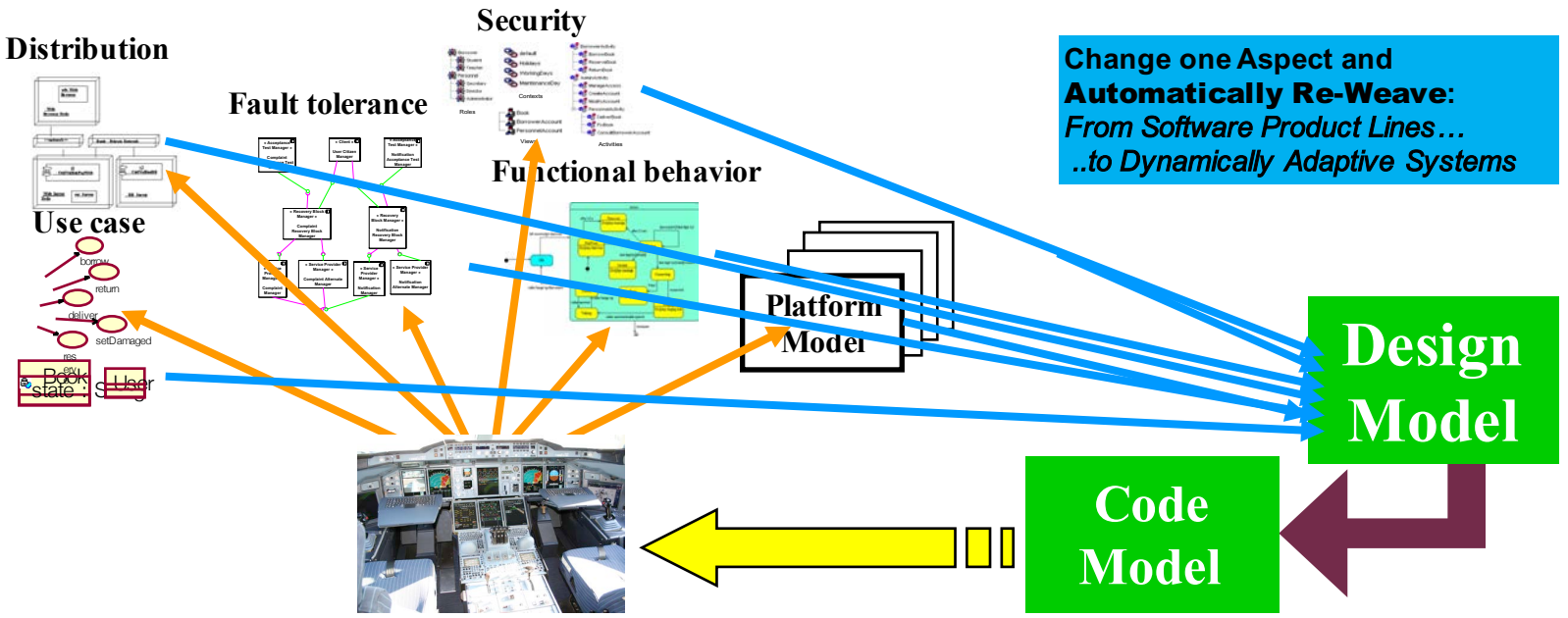




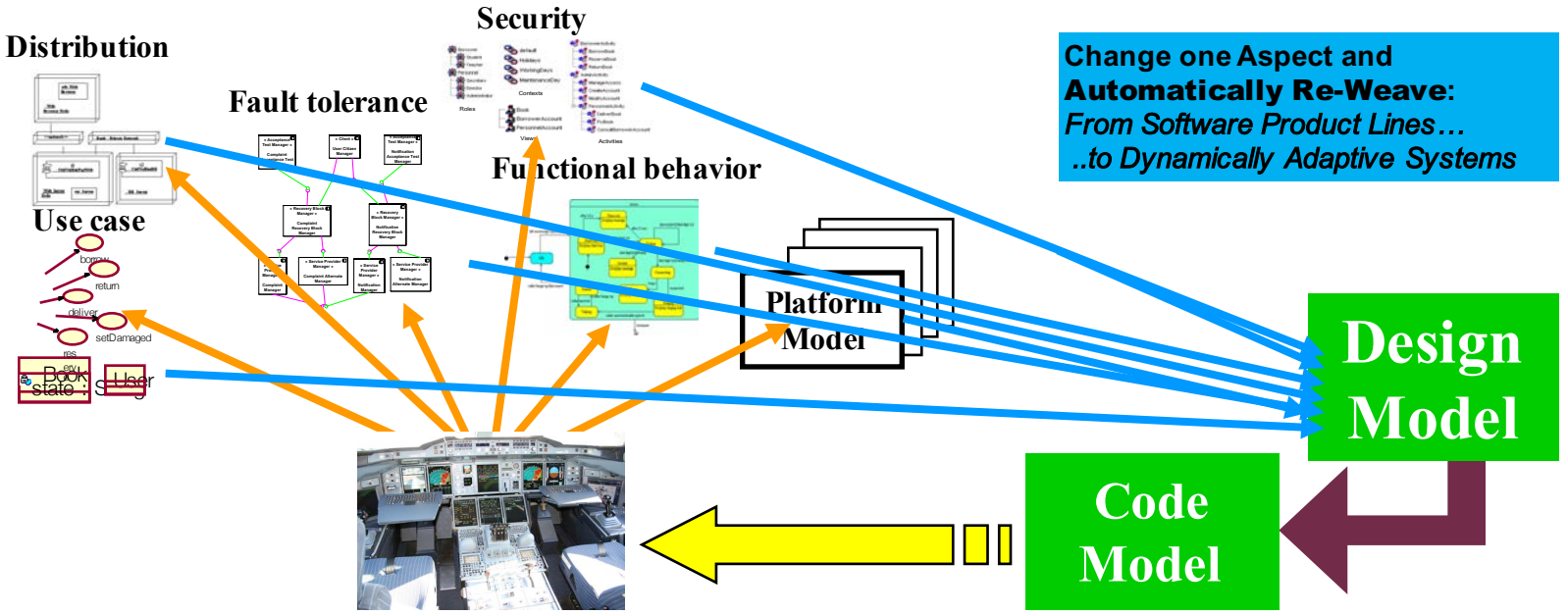




Model-Driven Engineering (MDE)



Model-Driven Engineering (MDE)



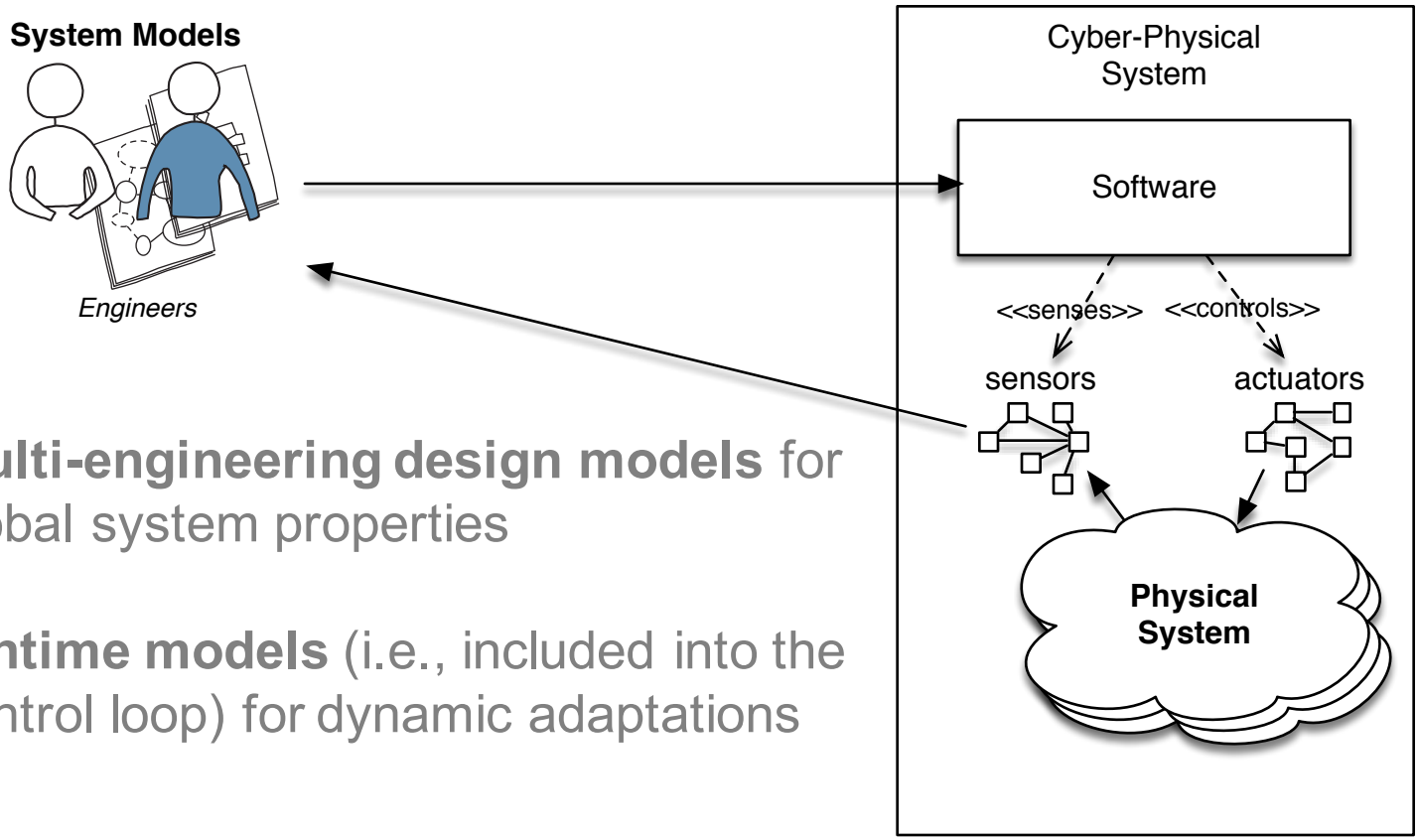
"Perhaps surprisingly, the majority of MDE examples in our study followed domain-specific modeling paradigms"

J. Whittle, J. Hutchinson, and M. Rouncefield, "*The State of Practice in Model-Driven Engineering*," IEEE Software, vol. 31, no. 3, 2014, pp. 79–85.

From Software Systems

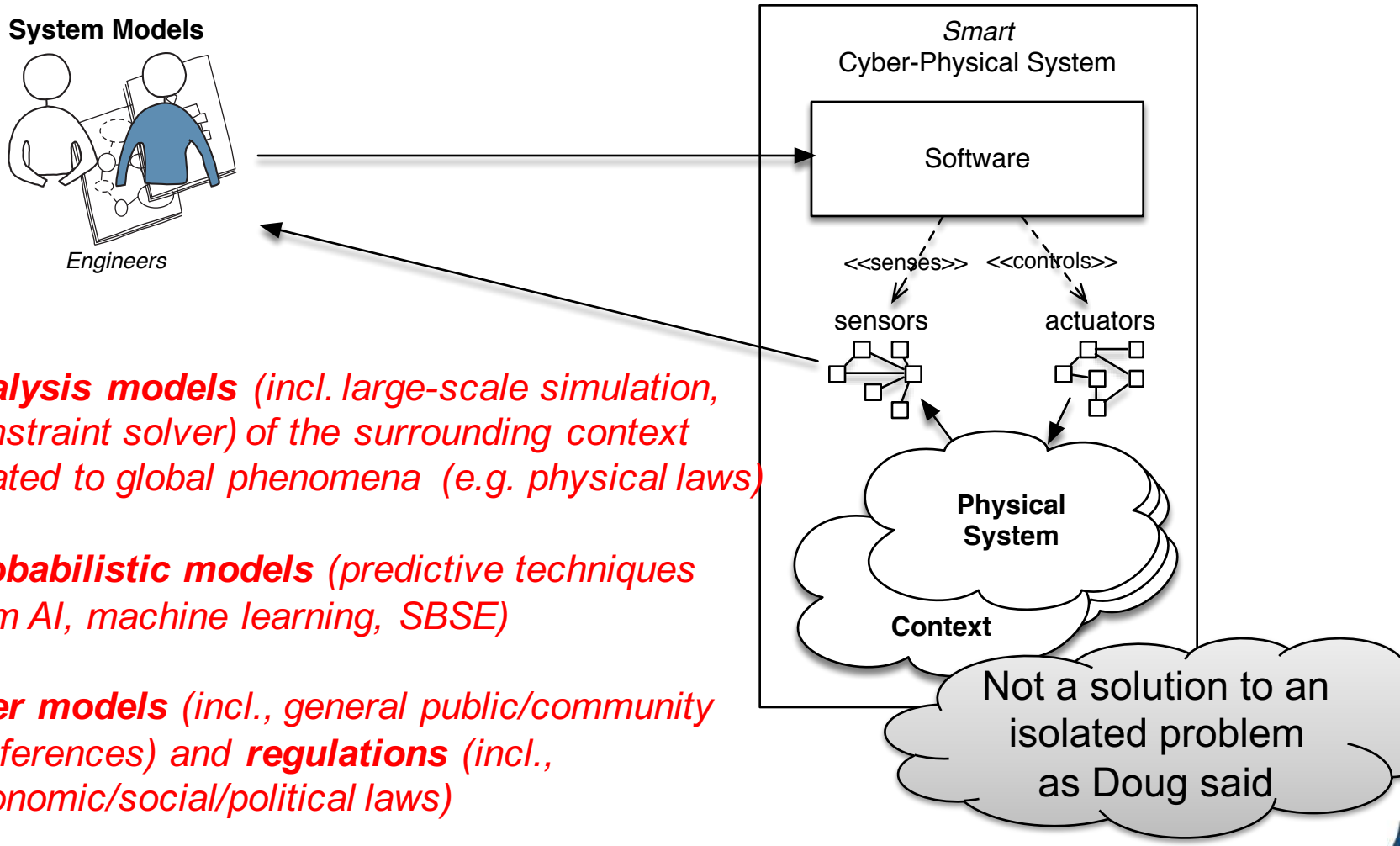
- **software design models** for functional and non-functional properties

To Cyber-Physical Systems



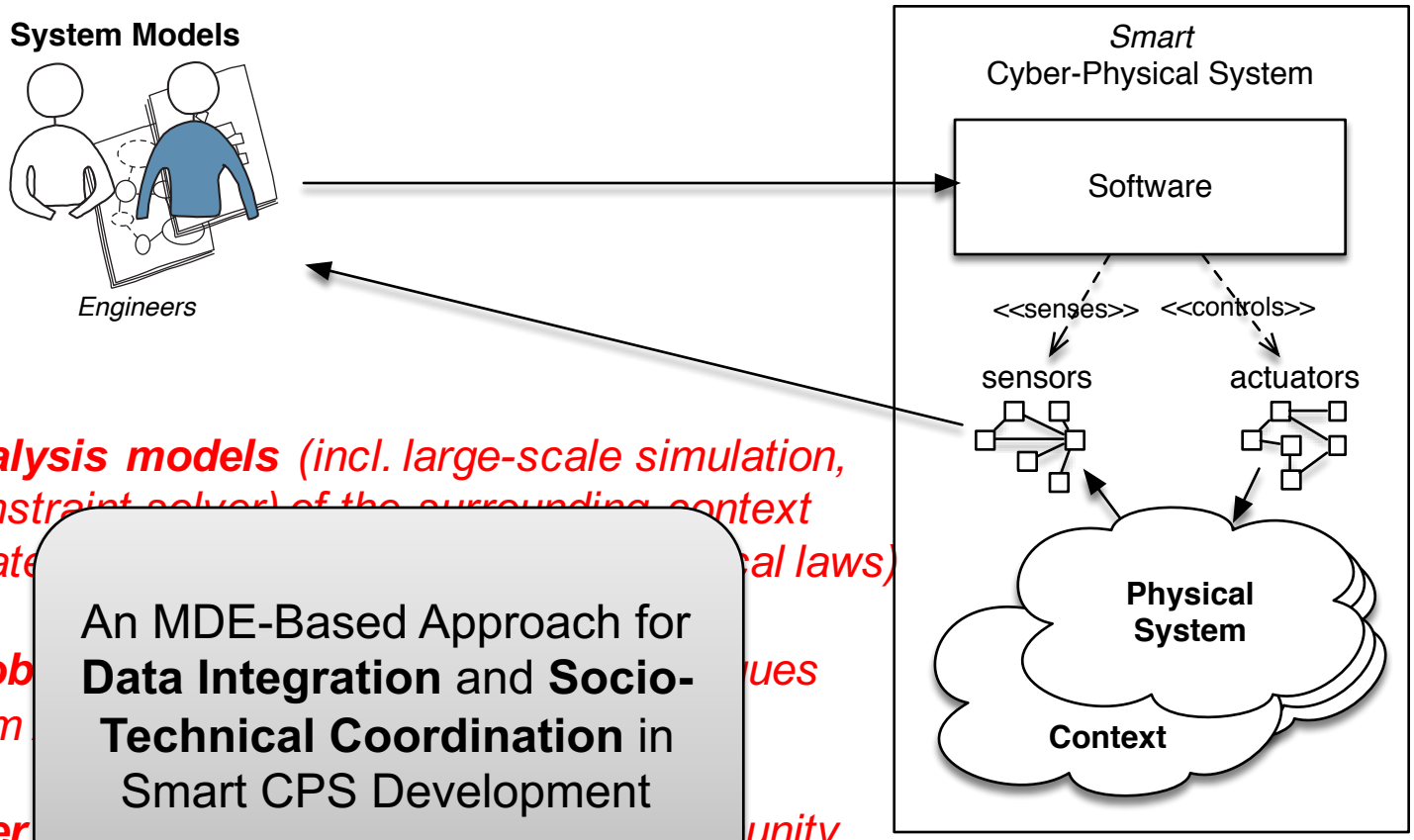
- **multi-engineering design models** for global system properties
- **runtime models** (i.e., included into the control loop) for dynamic adaptations

To Smart Cyber-Physical Systems



- ***analysis models*** *(incl. large-scale simulation, constraint solver) of the surrounding context related to global phenomena (e.g. physical laws)*
- ***probabilistic models*** *(predictive techniques from AI, machine learning, SBSE)*
- ***user models*** *(incl., general public/community preferences) and* ***regulations*** *(incl., economic/social/political laws)*

To Smart Cyber-Physical Systems



- ***analysis models*** *(incl. large-scale simulation, constraint solver) of the surrounding context relate… …cal laws)*
- ***prob…*** *…ues from …*
- ***user…*** *…unity prefere… … economic/social/political laws)*

An MDE-Based Approach for **Data Integration** and **Socio-Technical Coordination** in Smart CPS Development

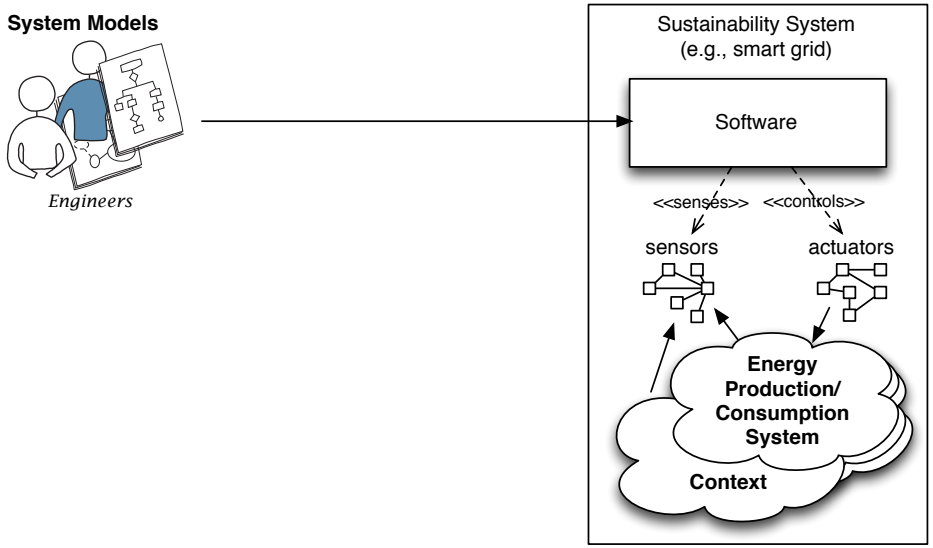
A MDE-based approach to develop Smart CPS

- Convergence of engineering and scientific models
- A modeling framework to support the integration of data from sensors, open data, laws/regulation, scientific models, engineeering models and preferences.
- Domain-specific languages for socio-technical coordination
  - to engage engineers, scientist, decision makers, communities and general public
  - to integrate analysis/probabilistic/user models into the control loop of smart CPS

Benoit Combemale, Betty Cheng, Ana Moreira, Jean-Michel Bruel, Jeff Gray, *"Modeling for Sutainability,"* INRIA Research Report, 2015.

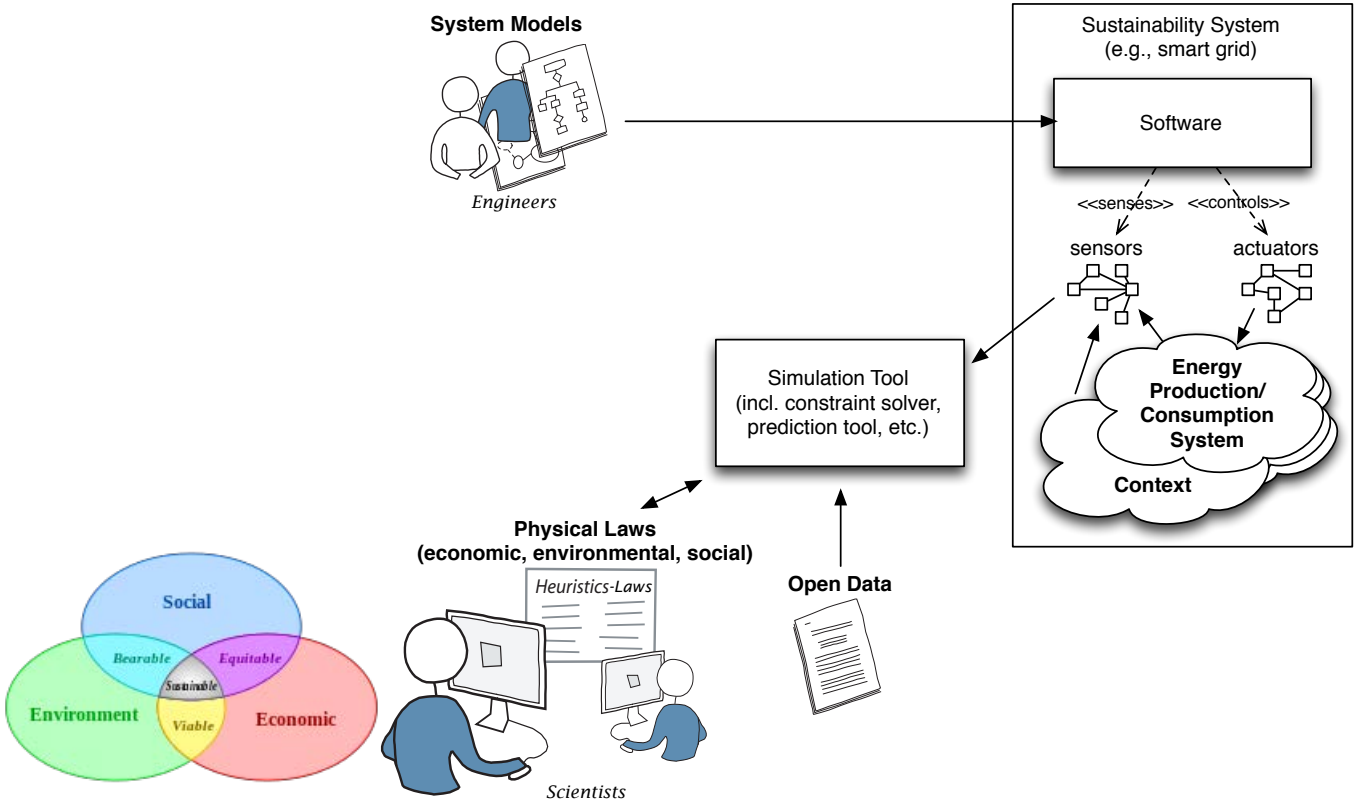
Using MDE in Smart-CPS Development

- Cyber-Physical Systems



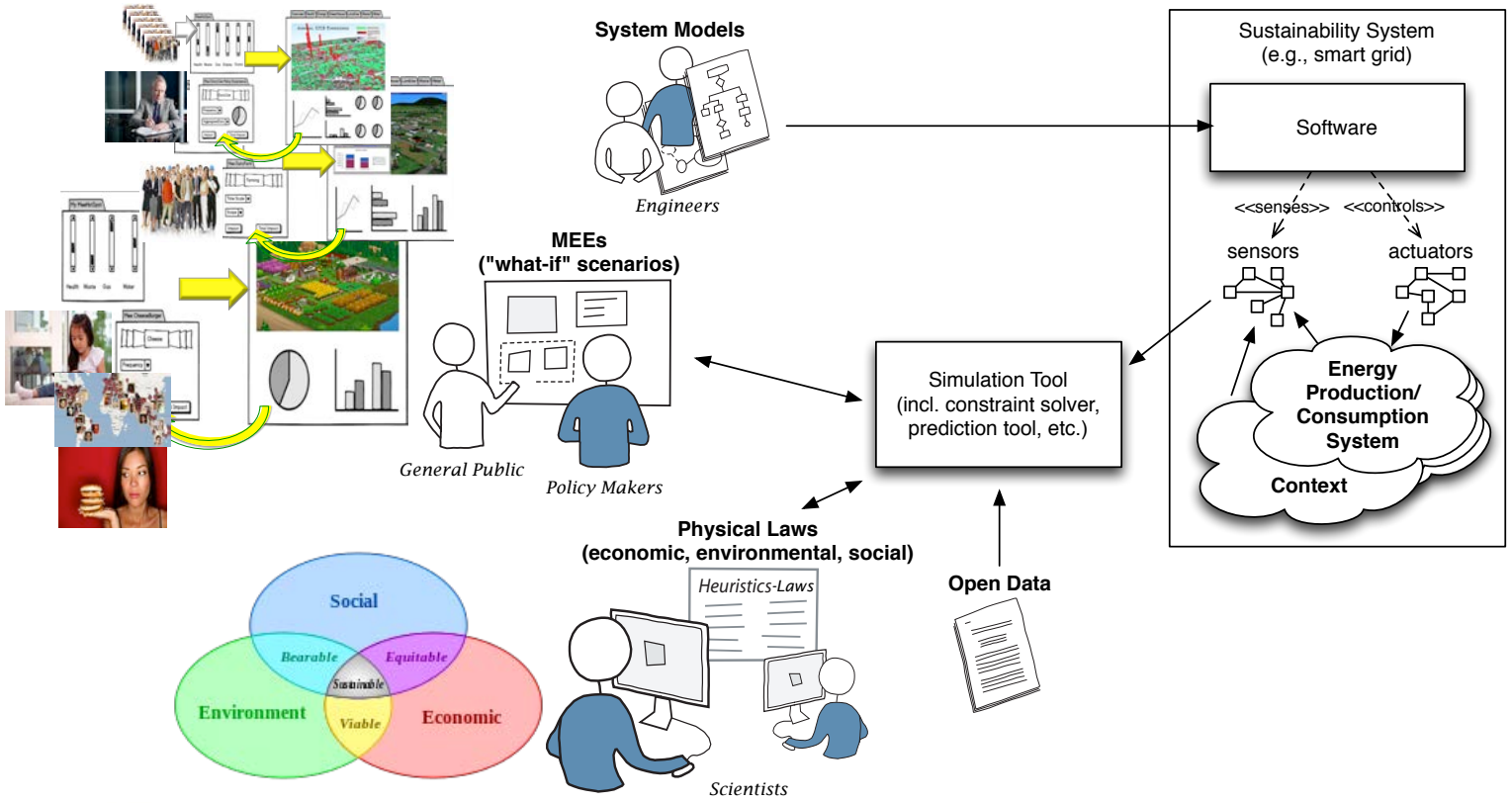
Using MDE in Smart-CPS Development

- Based on **informed decisions**
  - with environmental, social and economic laws
  - with open data



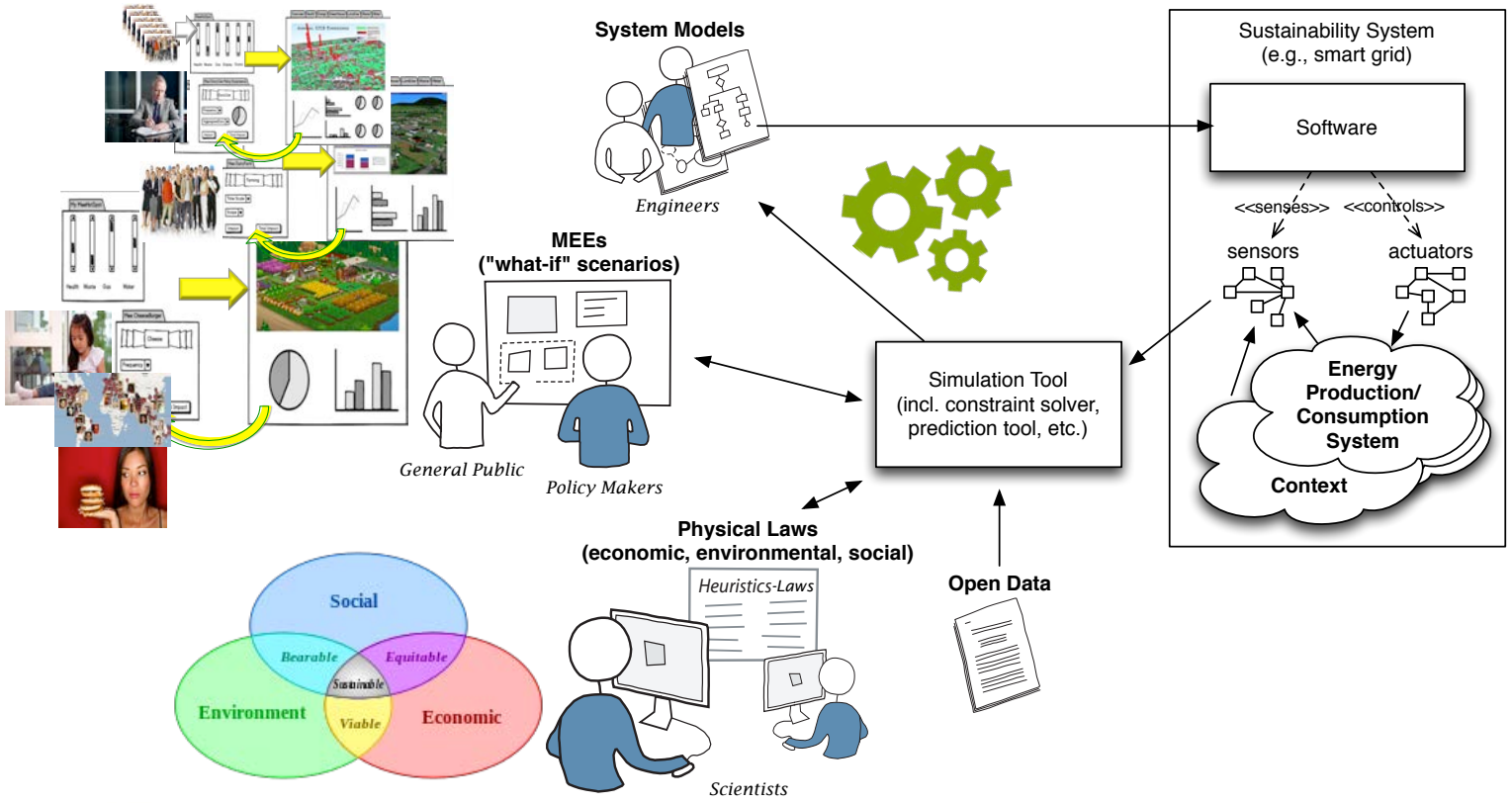
Using MDE in Smart-CPS Development

- Providing a **broader engagement**
  - with "what-if" scenarios for general public and policy makers



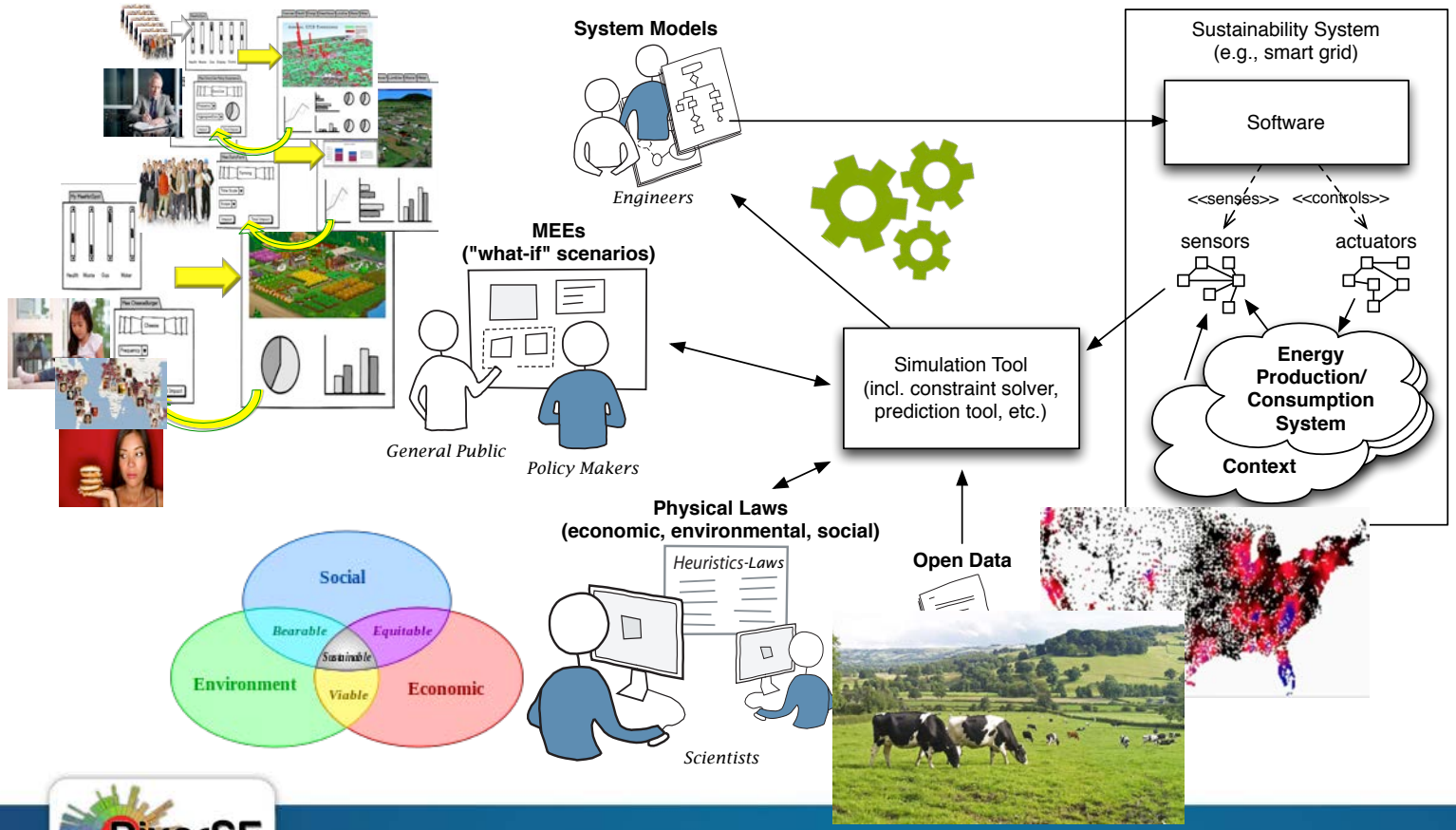
Using MDE in Smart-CPS Development

- Supporting **automatic adaptation**
  - for dynamically adaptable systems



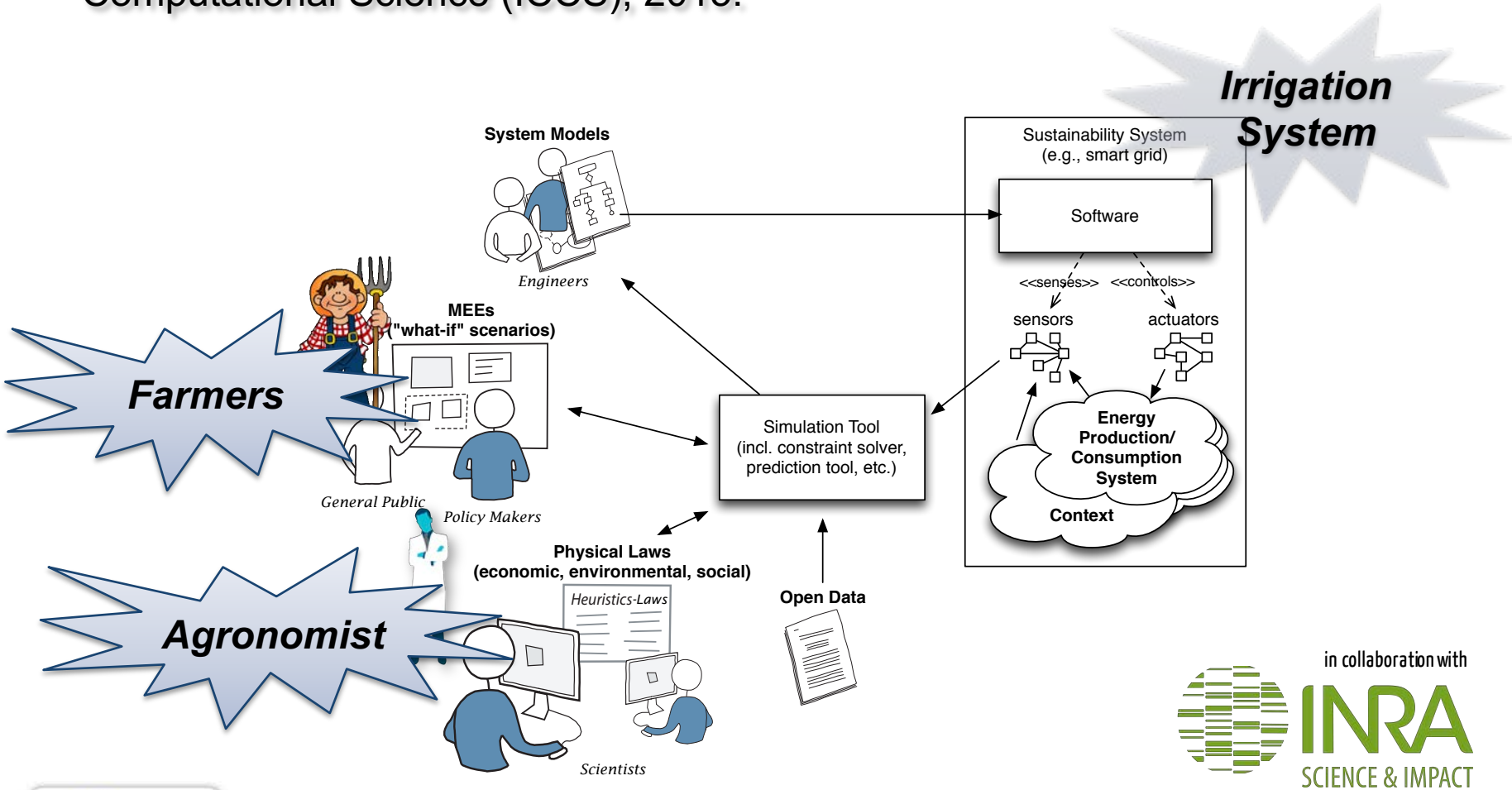
Using MDE in Smart-CPS Development

- Application to health, farming system, smart grid…



Farming System Modeling

Jean-Michel Bruel, Benoit Combemale, Ileana Ober, Hélène Raynal, *"MDE in Practice for Computational Science,"* International Conference on Computational Science (ICCS), 2015.



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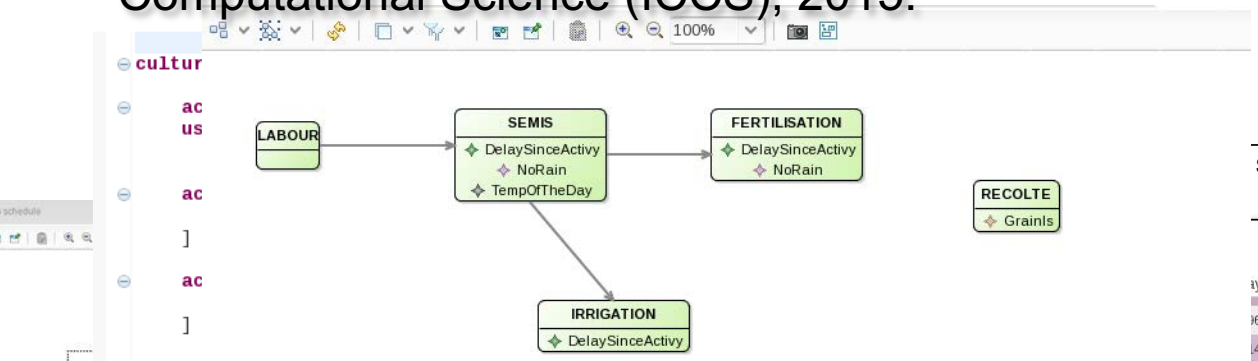


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culture

    ac
    us

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    ]

    ac

    ]

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    ]

    activity RECOLTE from 1 sept to 30 sept  [
        grain is "mature"
    ] using 1 Tractor and 2 People

}

culture weat {

    activity LABOUR from 1 sept to 30 sept  [
        no rain since 3 days
    ] using 1 Tractor and 1 People

    activity SEMIS from 1 oct to 31 oct  [
        after LABOUR &&
        no rain since 3 days &&
        temperature > 5°C
    ] using 1 Tractor and 1 People

    activity FERTILISATION from 1 feb to 28 feb [
        after SEMIS is done since 30 days &&
        no rain since 1 days
     ] using 1 Tractor and 1 People

    activity RECOLTE from 1 jun to 30 jun  [
        grain is "mature"
    ] using 1 Tractor and 1 People
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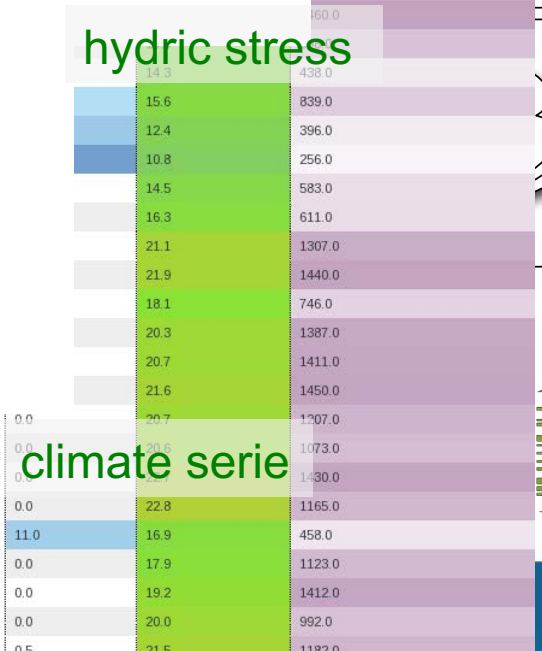
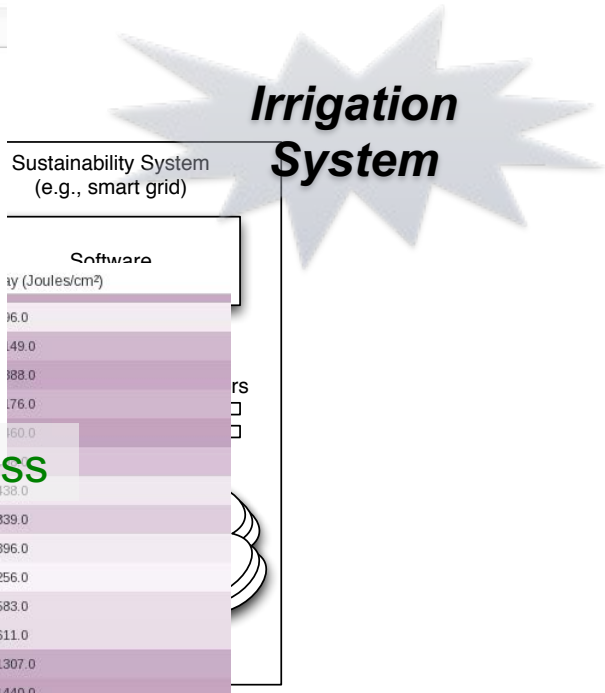
activity description





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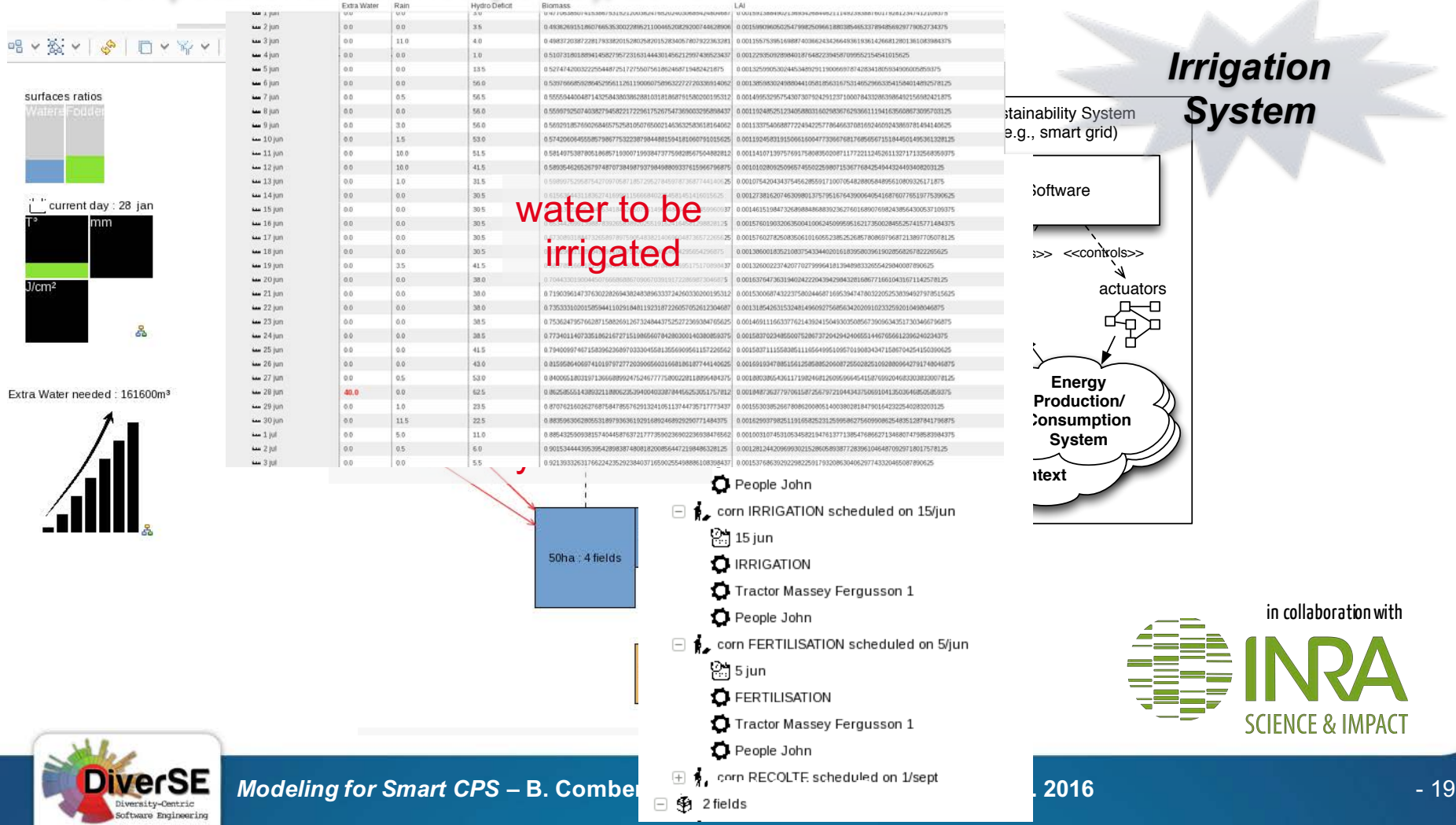

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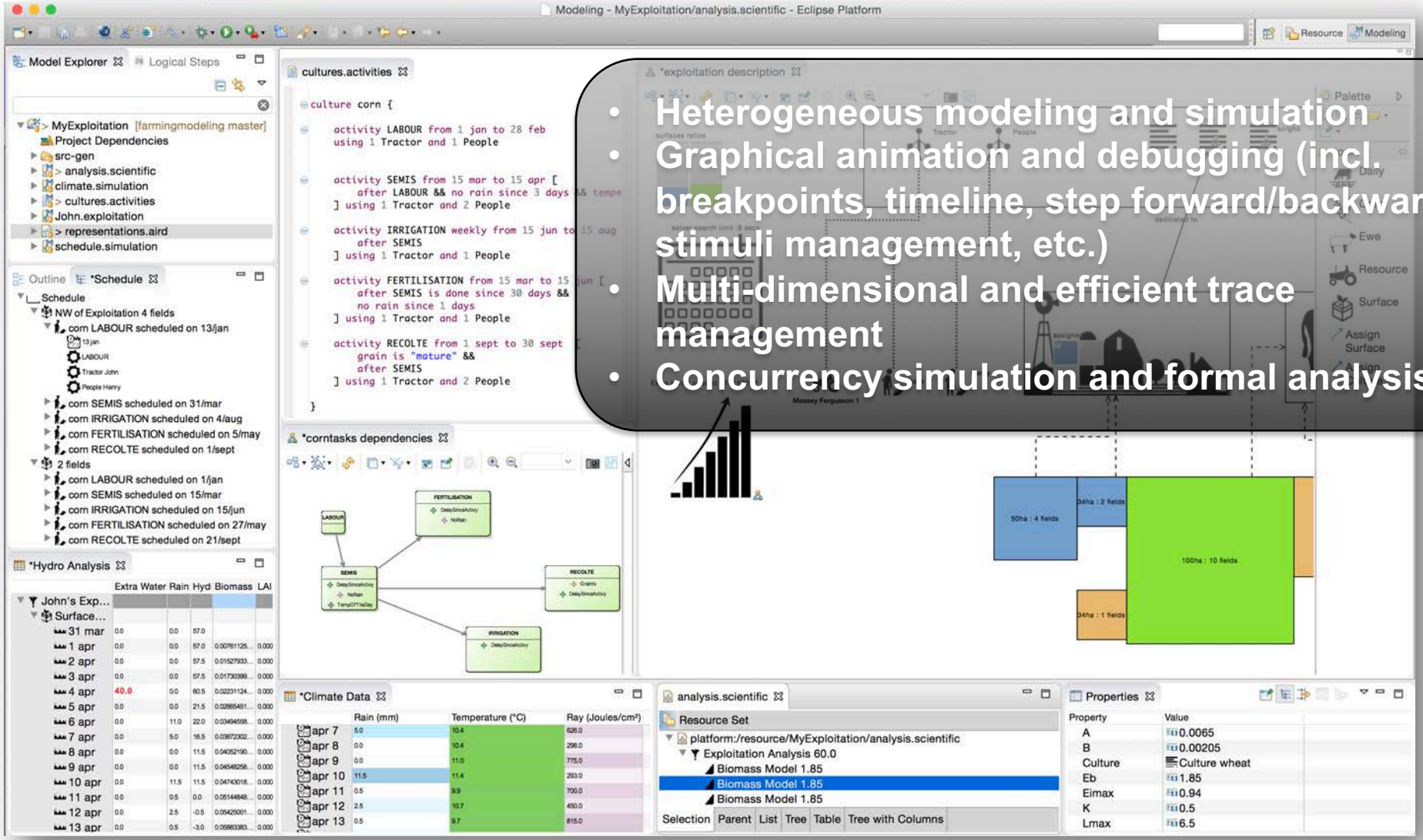
Farming System Modeling



- Heterogeneous modeling and simulation
- Graphical animation and debugging (incl. breakpoints, timeline, step forward/backward, stimuli management, etc.)
- Multi-dimensional and efficient trace management
- Concurrency simulation and formal analysis

https://github.com/gemoc/farmingmodeling

Globalization of Modeling Languages

Challenge:

- DSMLs are developed in an independent manner to meet the specific needs of domain experts,
- DSMLs should also have an associated framework that regulates interactions needed to support collaboration and work coordination across different system domains.

Benoit Combemale, Julien DeAntoni, Benoit Baudry, Robert B. France, Jean-Marc Jezequel, Jeff Gray, "*Globalizing Modeling Languages*," Computer, vol. 47, no. 6, pp. 68-71, June, 2014

Globalization of Modeling Languages

Supporting coordinated use of modeling languages leads to what we call the globalization of modeling languages, that is, the use of multiple modeling languages to support the socio-technical coordination required in systems and software engineering.

Betty H. C. Cheng, Benoît Combemale, Robert B. France, Jean-Marc Jézéquel, Bernhard Rumpe, "*Globalizing Domain-Specific Languages*", Springer 2015, ISBN 978-3-319-26171-3

Globalization of Modeling Language

- Context: new emerging DSML in open world
  - ⇒ impossible *a priori* unification
  - ⇒ require *a posteriori* globalization

- Objective: socio-technical coordination to support interactions across different system aspects
  - ⇒ Language-based support for technical integration of multiples domains
  - ⇒ Language-based support for social translucence

Betty H. C. Cheng, Benoît Combemale, Robert B. France, Jean-Marc Jézéquel, Bernhard Rumpe, "*Globalizing Domain-Specific Languages*", Springer 2015, ISBN 978-3-319-26171-3

Open Challenges (just of few!)

- Diversity/complexity of DSL relationships
  - far beyond structural and behavioral alignment, refinement, decomposition
  - Separation of concerns *vs.* Zoom-in/Zoom-out
- Live and collaborative modeling
  - minimize the round trip between the DSL specification, the model, and its application (interpretation/compilation), and support personalization (views, properties...)
  - *Model experiencing environnements*
- Integration of analysis and probabilistic models into DSL semantics

"If you believe that language design can significantly affect the quality of software systems, then it should follow that language design can also affect the quality of energy systems. And if the quality of such energy systems will, in turn, ***affect the livability of our planet****, then it's critical that the language development community* ***give modeling languages the attention they deserve****."*

− Bret Victor (Nov., 2015), http://worrydream.com/ClimateChange