MODELING FOR SUSTAINABILITY

Or *How to Make Smart CPS Smarter?*

WORKSHOP MODELS@RUNTIME @ MODELS, OCTOBER, 2018

An earlier version of this talk is available at http://goo.gl/ksGq4N

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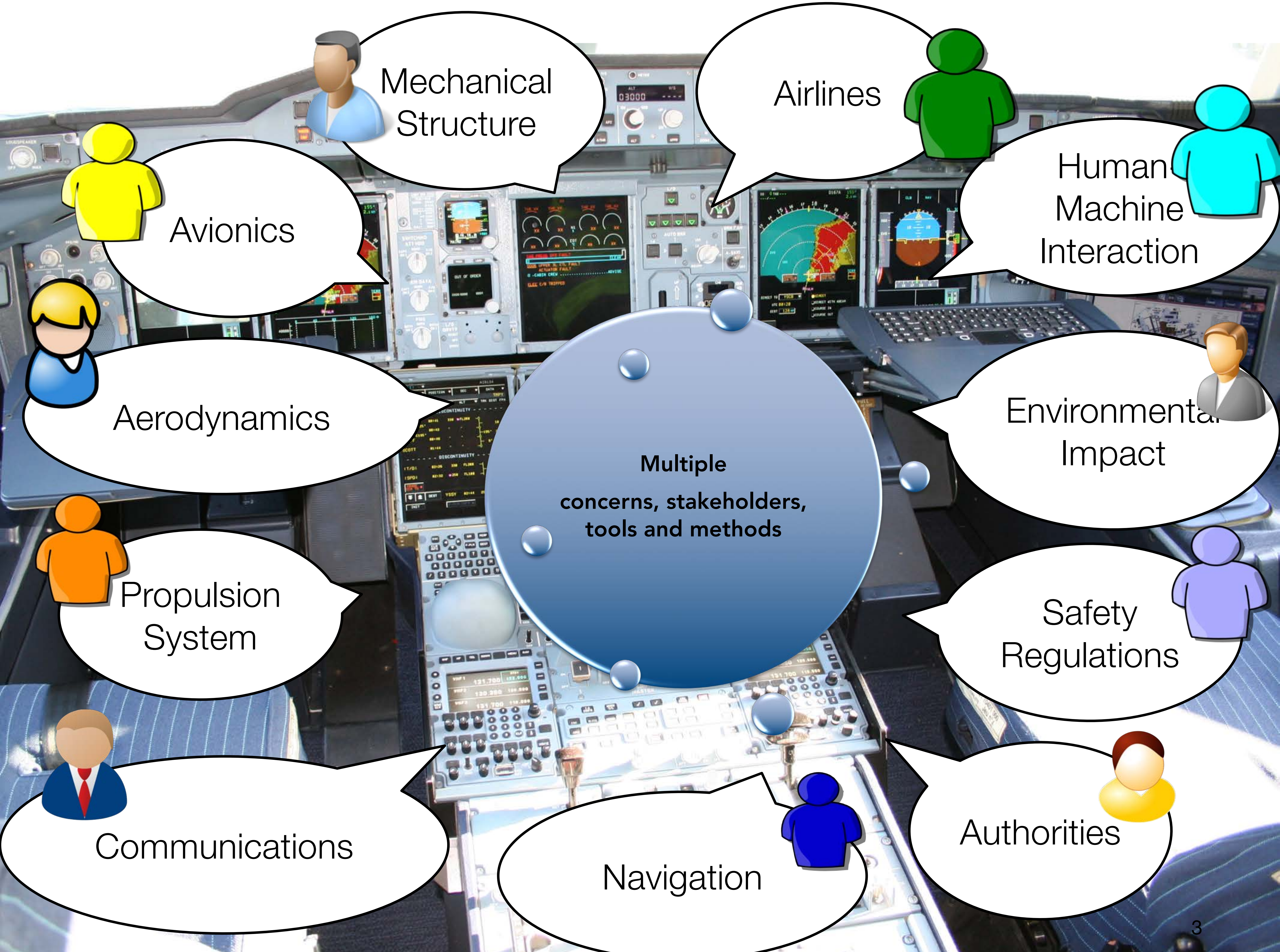
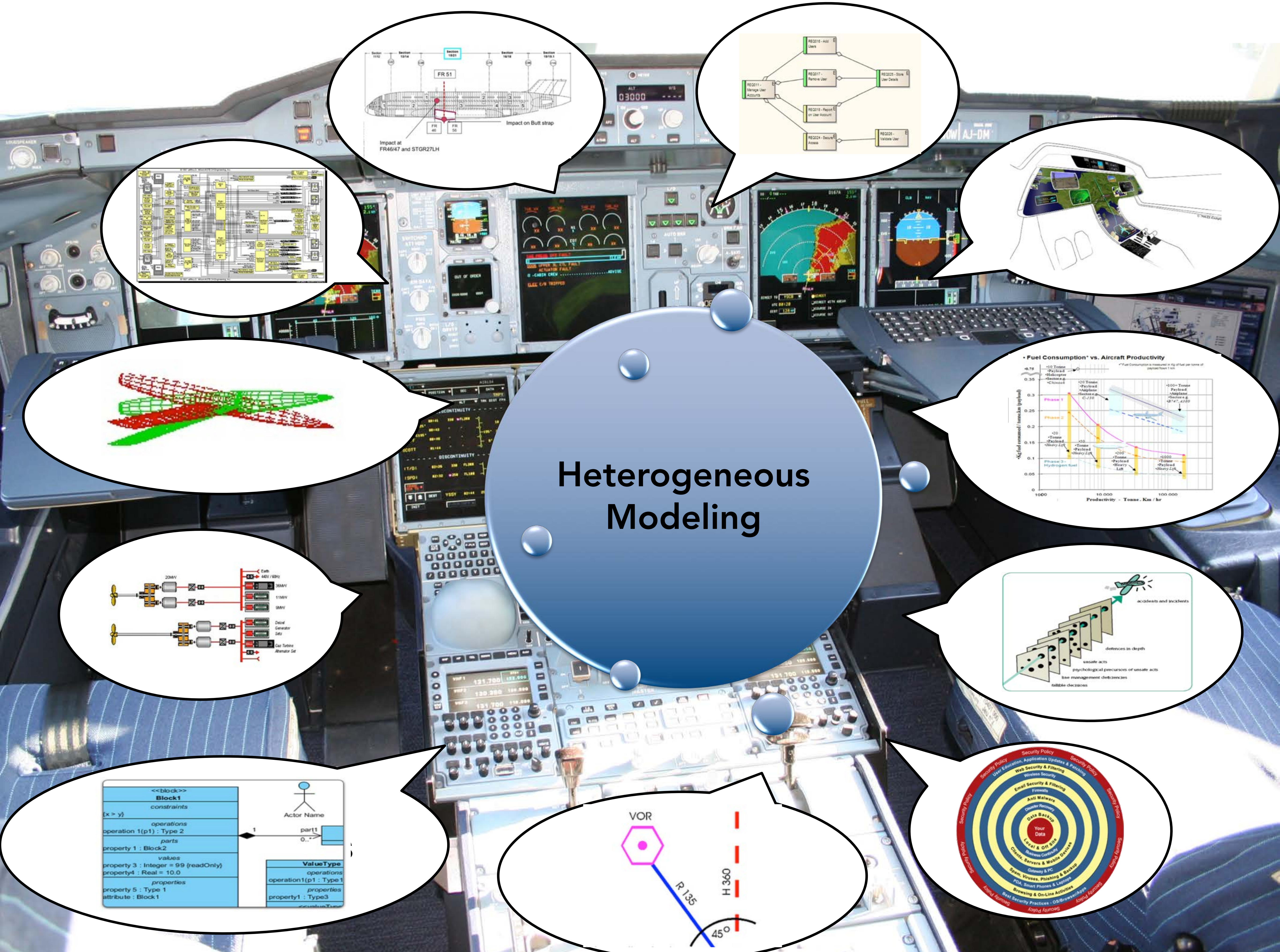
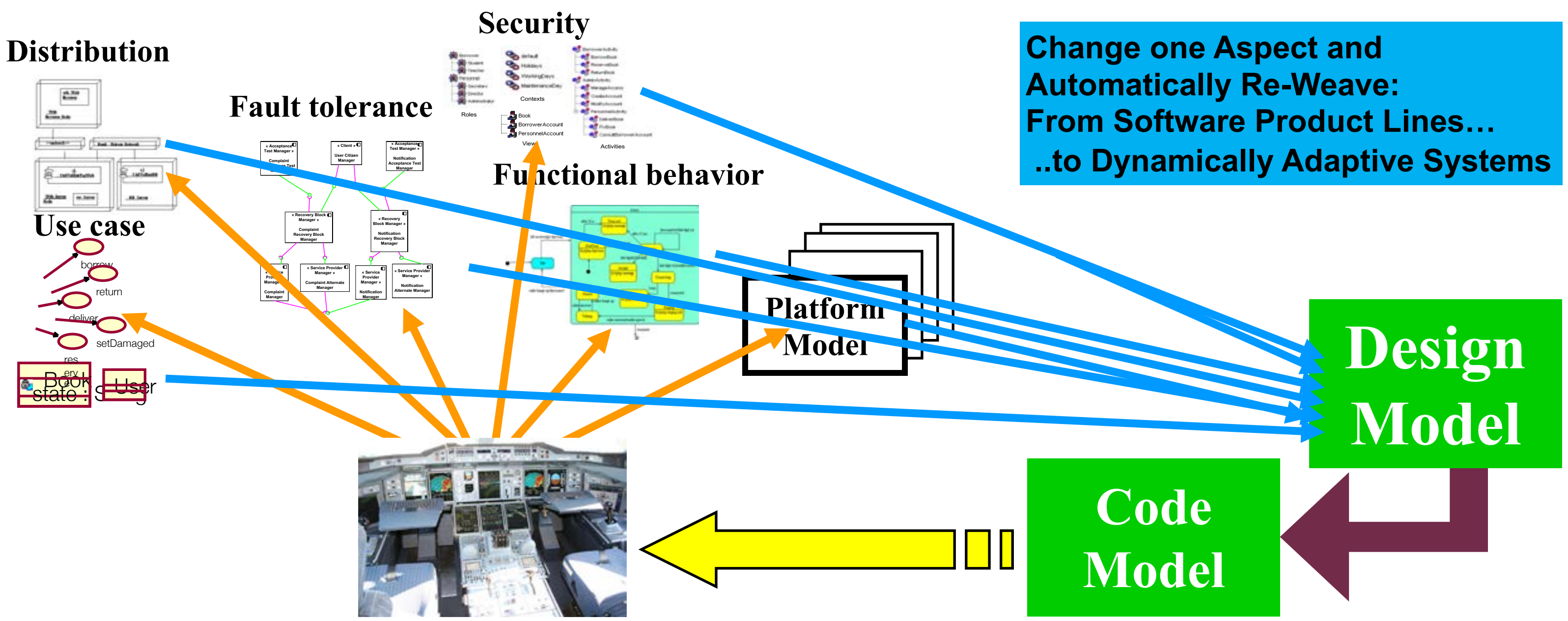
Complex Software-Intensive Systems

- Multi-engineering approach
- Domain-specific modeling
- High variability and customization
- Software as integration layer
- Openness and dynamicity


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


Heterogeneous Modeling
FR 51
Impact on Butt strap
Impact at FR46/47 and STGR27LH
Fuel Consumption* vs. Aircraft Productivity
Productivity - Tonne . Km / hr
accidents and incidents
defences in depth
unsafe acts
psychological precursors of unsafe acts
line management deficiencies
fallible decisions
<<block>>
Block1
constraints
{x > y}
operations
operation 1(p1) : Type 2
parts
property 1 : Block2
values
property 3 : Integer = 99 {readOnly}
property4 : Real = 10.0
properties
property 5 : Type 1
attribute : Block1
Actor Name
part1
ValueType
operations
operation1(p1 : Type1
properties
property1 : Type3
VOR
R 135
H 360
45°
Security Policy
Your Data

Model-Driven Engineering



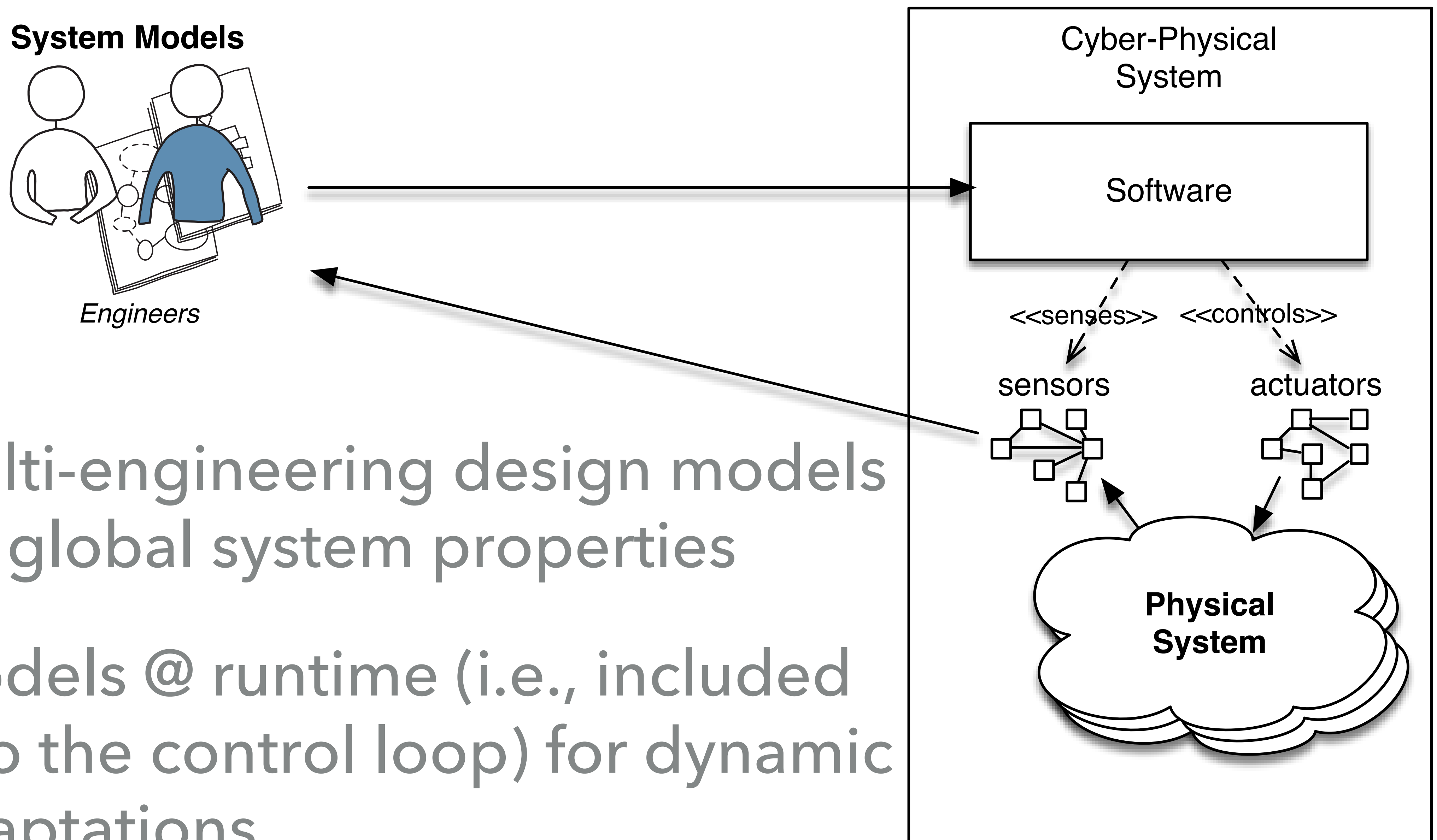
"Perhaps surprisingly, the majority of MDE examples in our study followed domain-specific modeling paradigms"

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

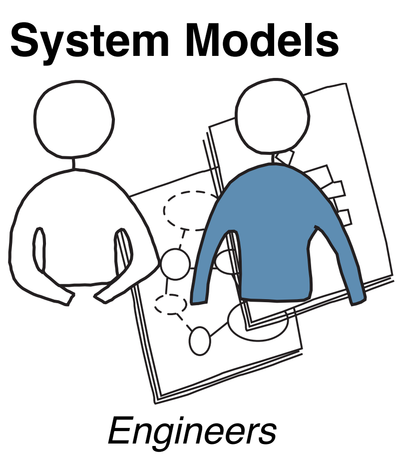
- software design models for functional and non-functional properties

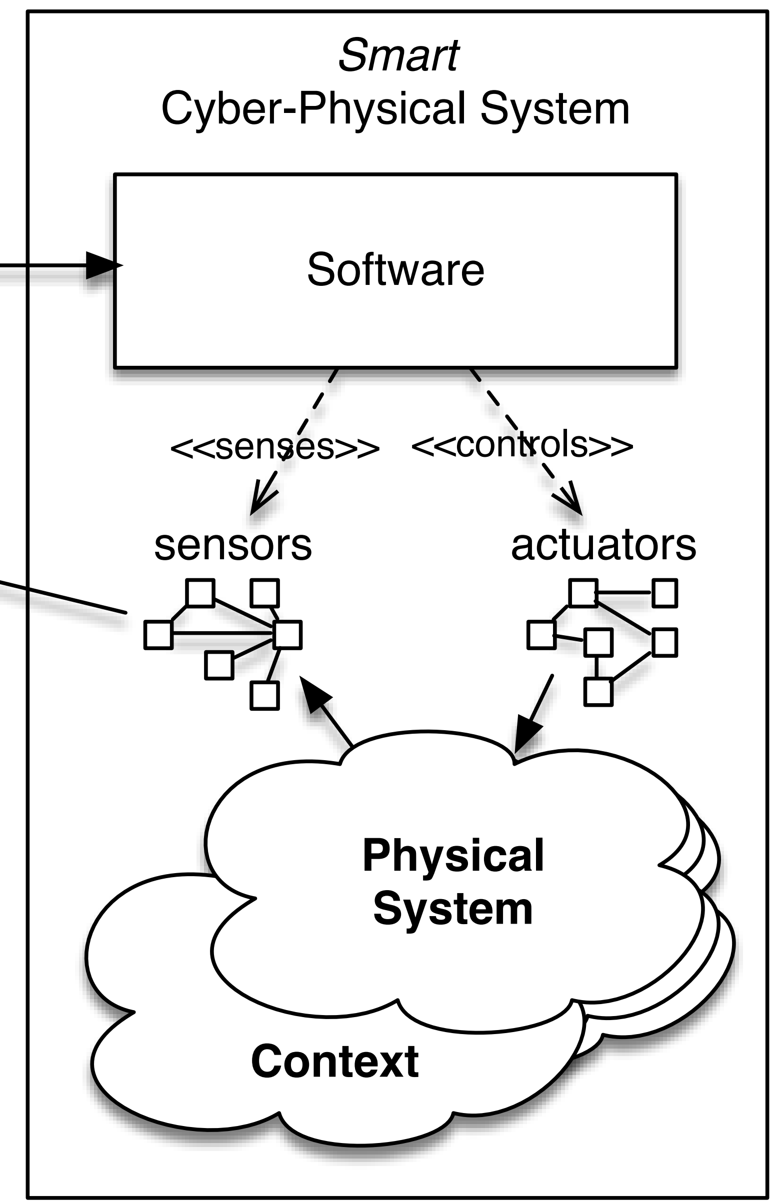
To Cyber-Physical Systems



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

To Smart Cyber-Physical Systems

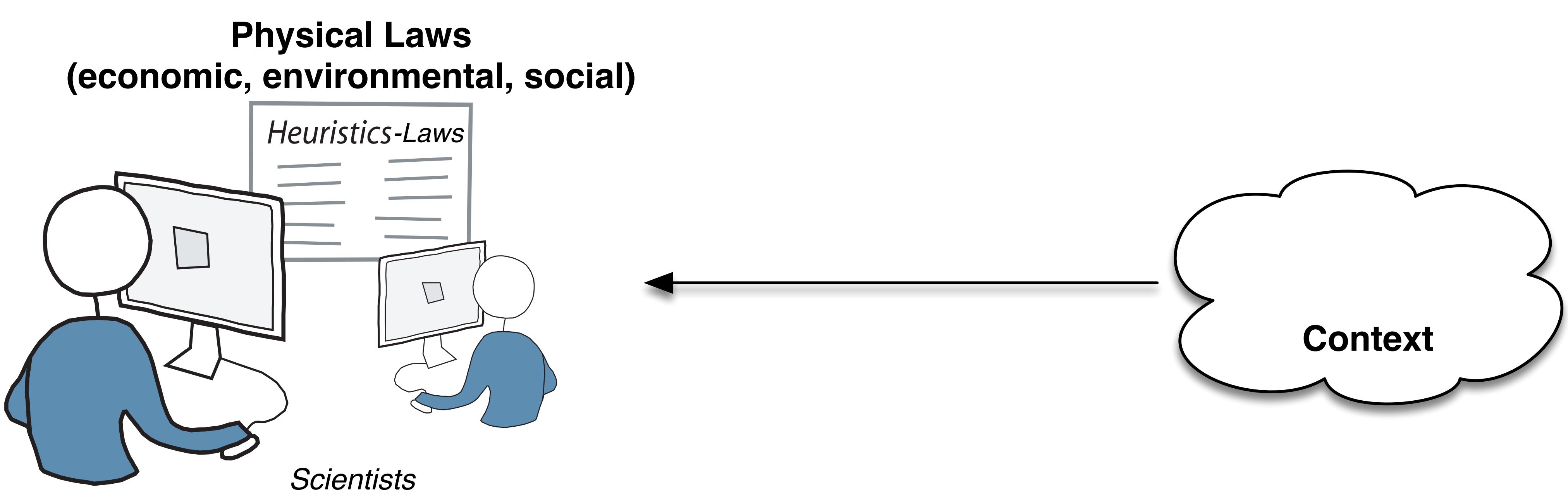




- **analysis models** (incl. large-scale simulation, constraint solver) of the surrounding context related to global phenomena (e.g. physical, economical, and social laws)
- **predictive models** (predictive techniques from AI, machine learning, SBSE, fuzzy logic)
- **user models** (incl., general public/community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

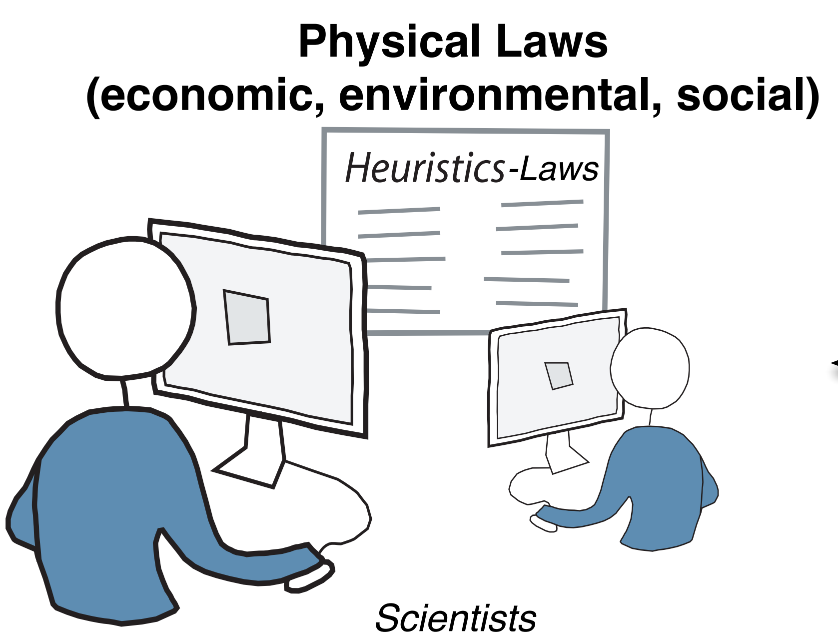
What about Scientific Modeling?

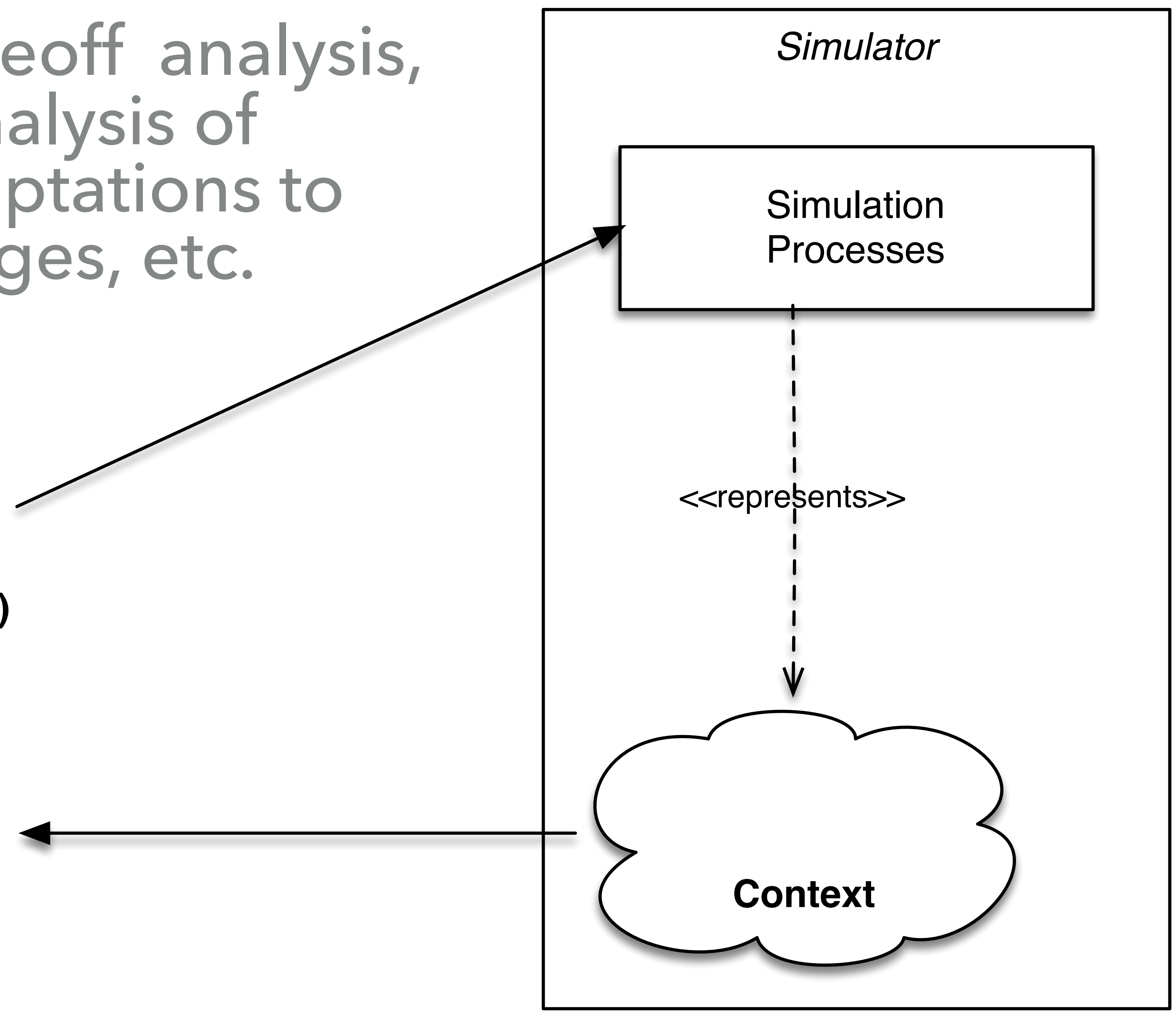
- Models (computational and data-intensive sciences) for analyzing and understanding physical phenomena



What about Scientific Modeling?

- **Simulators** for tradeoff analysis, what-if scenarios, analysis of alternatives and adaptations to environmental changes, etc.





Towards Unifying Modeling Foundations

- Convergence of *engineering* and *scientific* models
  - Prescriptive requires descriptive models
  - Descriptive requires prescriptive models

- Grand Challenge: a modeling framework to support the integration of data from sensors, open data, laws, regulations, scientific models (computational and data-intensive sciences), engineering models and preferences.

- Domain-specific languages (DSLs) for socio-technical coordination
  - to engage engineers, scientists, decision makers, communities and the general public
  - to integrate analysis/predictive/user models into the control loop of smart CPS

Sustainability Systems

- Sustainability systems are smart-CPS managing resource production, transport and consumption for the sake of sustainability
  - Ex: smart grids, smart city/home/farming, etc.

- Sustainability systems
  - must balance trade-offs between the social, technological, economic, and environmental pillars of sustainability
  - involve complex decision-making with heterogeneous analysis models, and large volumes of disparate data varying in temporal scale and modality

MDE for Sustainability Systems

- Scientific models are used to understand sustainability concerns and evaluate alternatives (what-if/for scenarios)

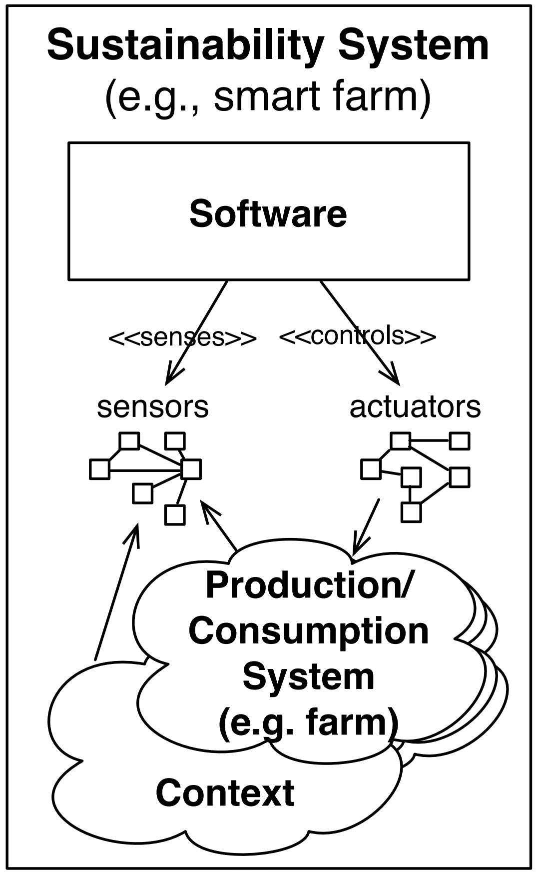
- Engineering models are used to support the development and runtime adaptation of sustainability systems.

How to integrate engineering and scientific models in a synergistic fashion to support informed decisions, broader engagement, and dynamic adaptation in sustainability systems?

Modeling for Sustainability
B. Combemale, B. Cheng, A. Moreira, J.-M. Bruel, J. Gray
In *MiSE @ ICSE*, 2016

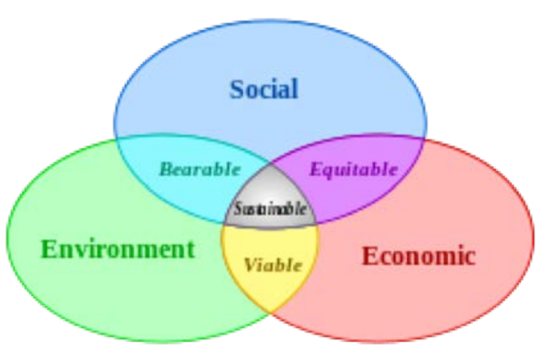
The Sustainability Evaluation ExperienceR (SEER)

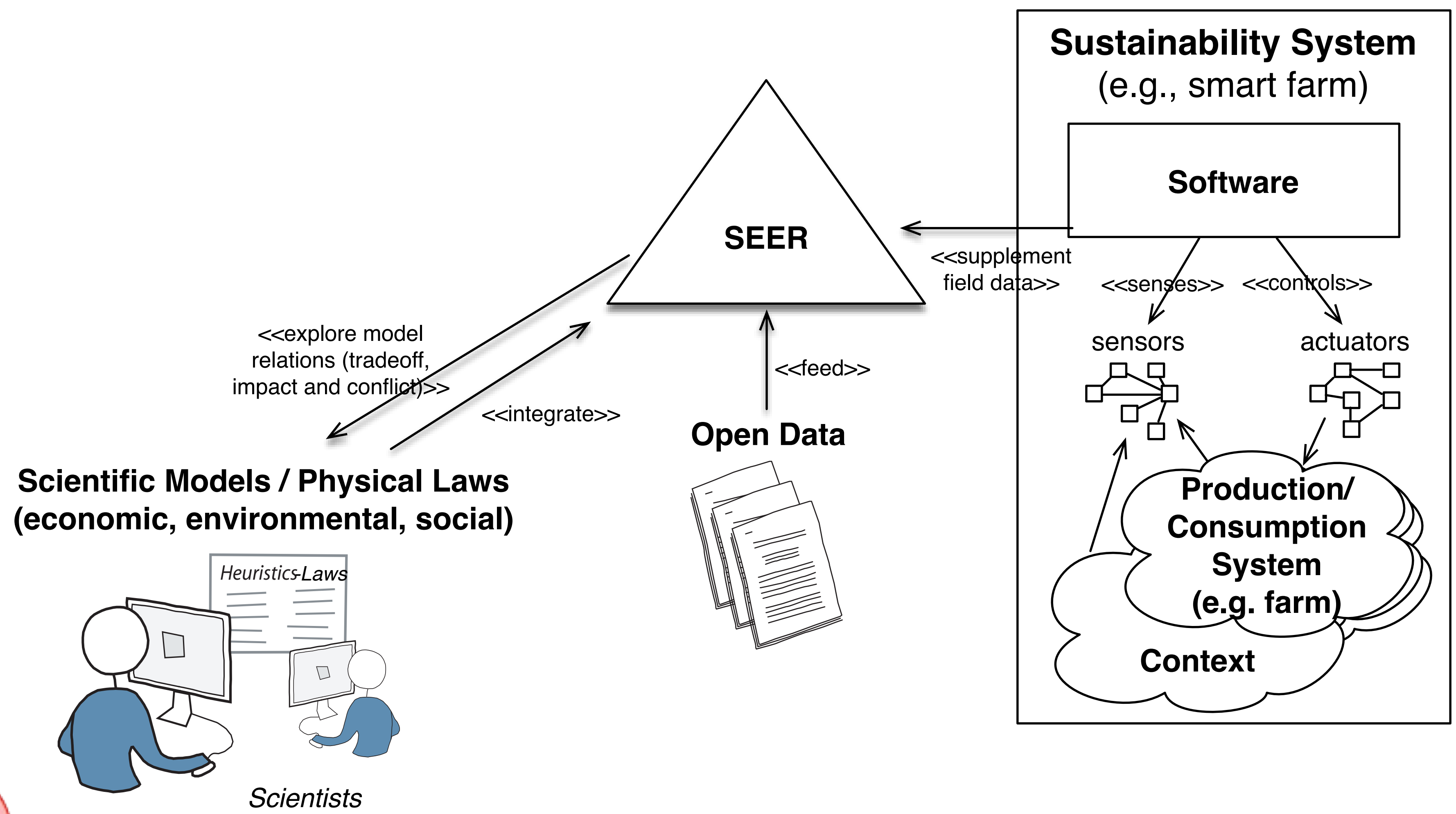
- Smart Cyber-Physical Systems



The Sustainability Evaluation ExperienceR (SEER)

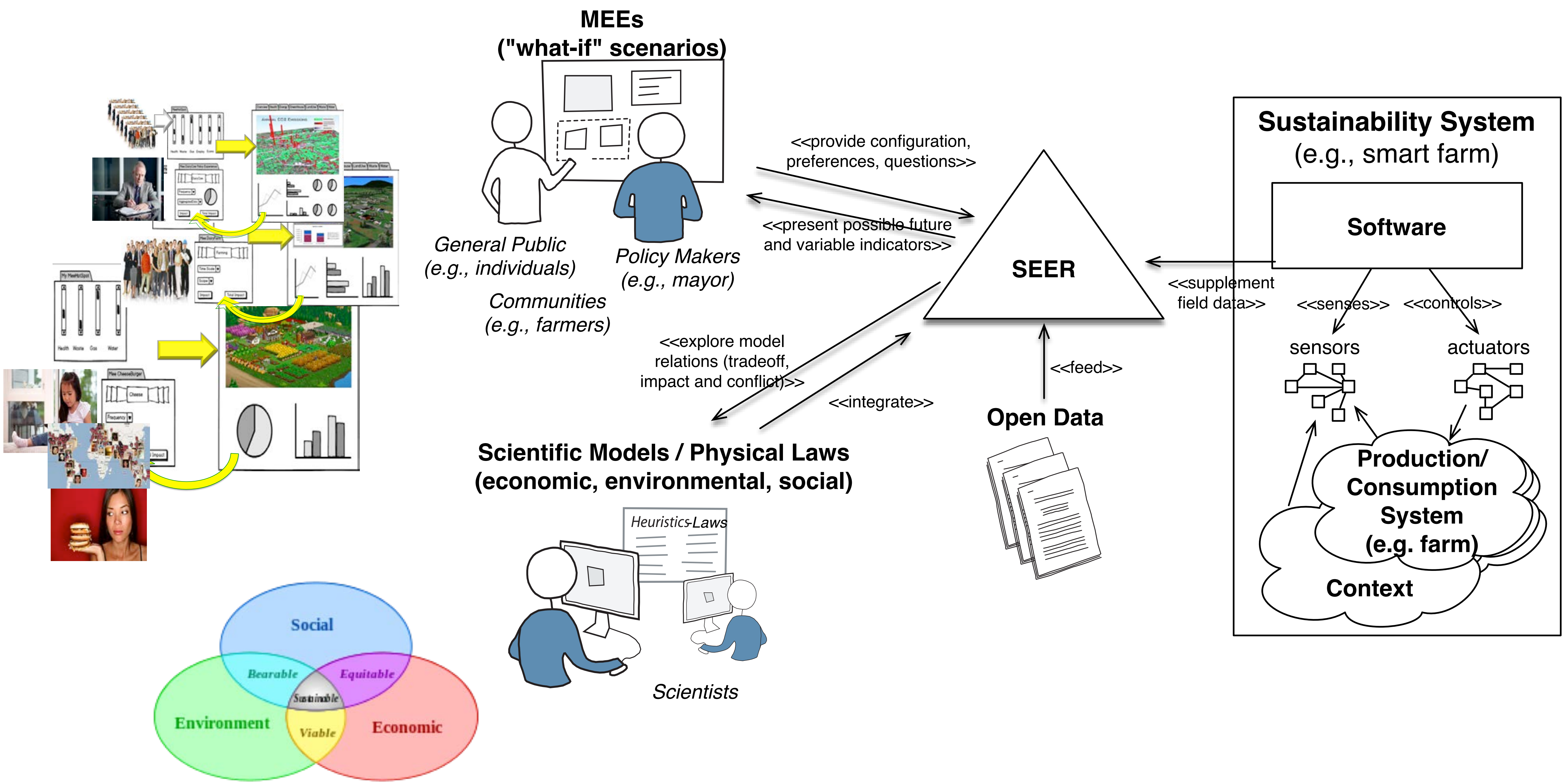
- Based on informed decisions
  - with environmental, social and economic laws
  - with open data





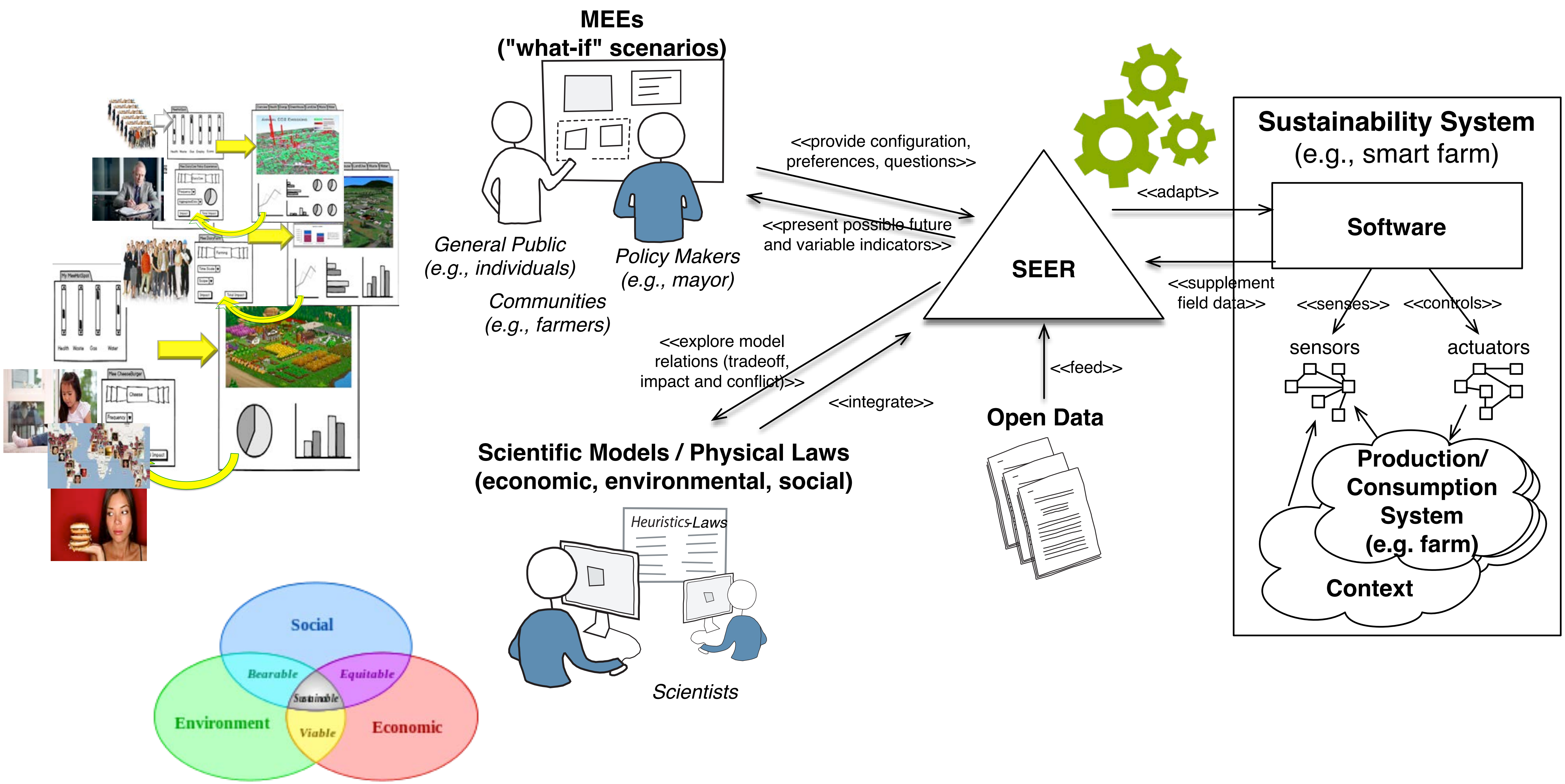
The Sustainability Evaluation ExperienceR (SEER)

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



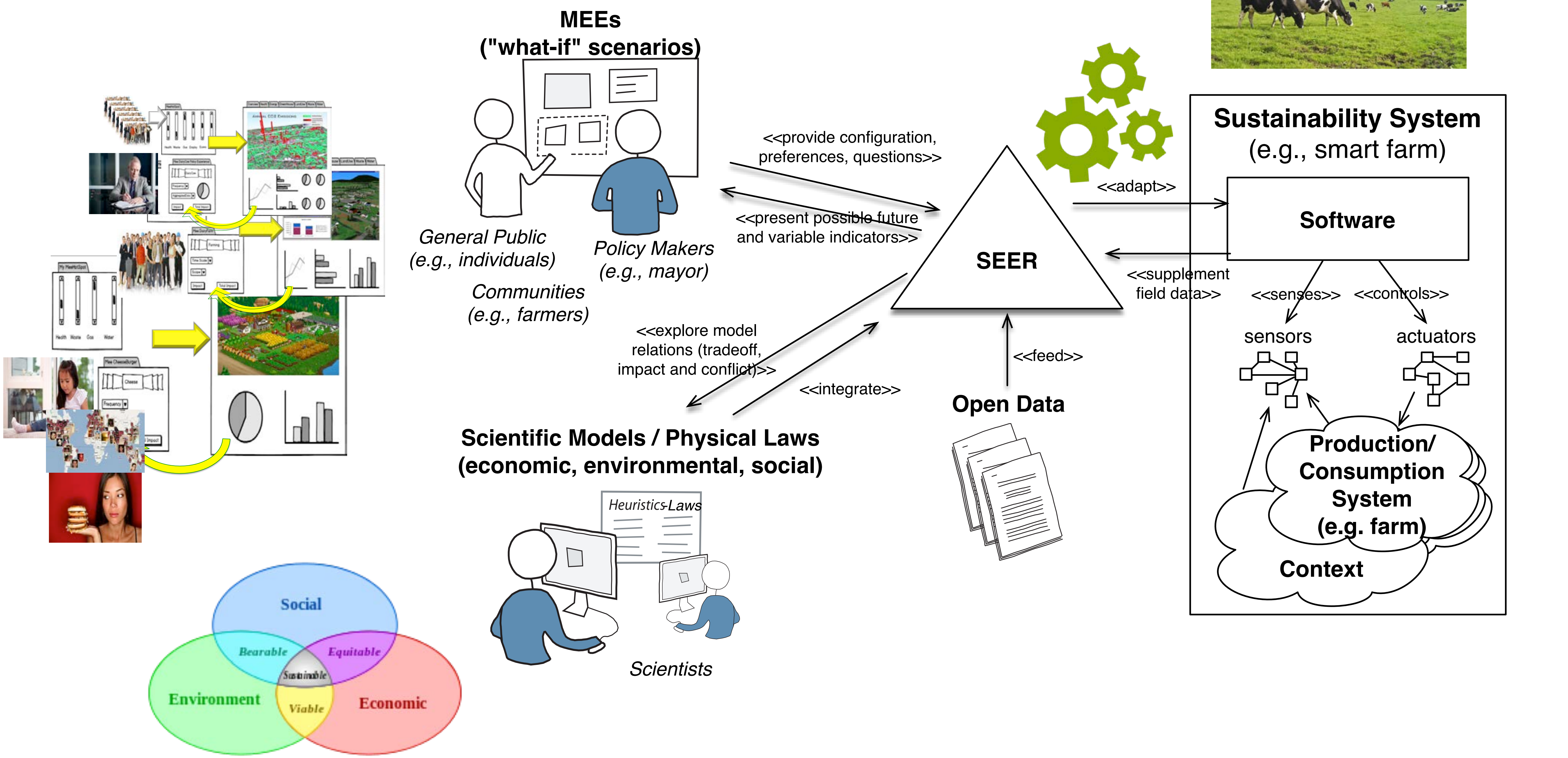
The Sustainability Evaluation ExperienceR (SEER)

- Supporting automatic adaptation
  - for dynamically adaptable systems



The Sustainability Evaluation ExperienceR (SEER)

- Application to health, farming system, smart grid…

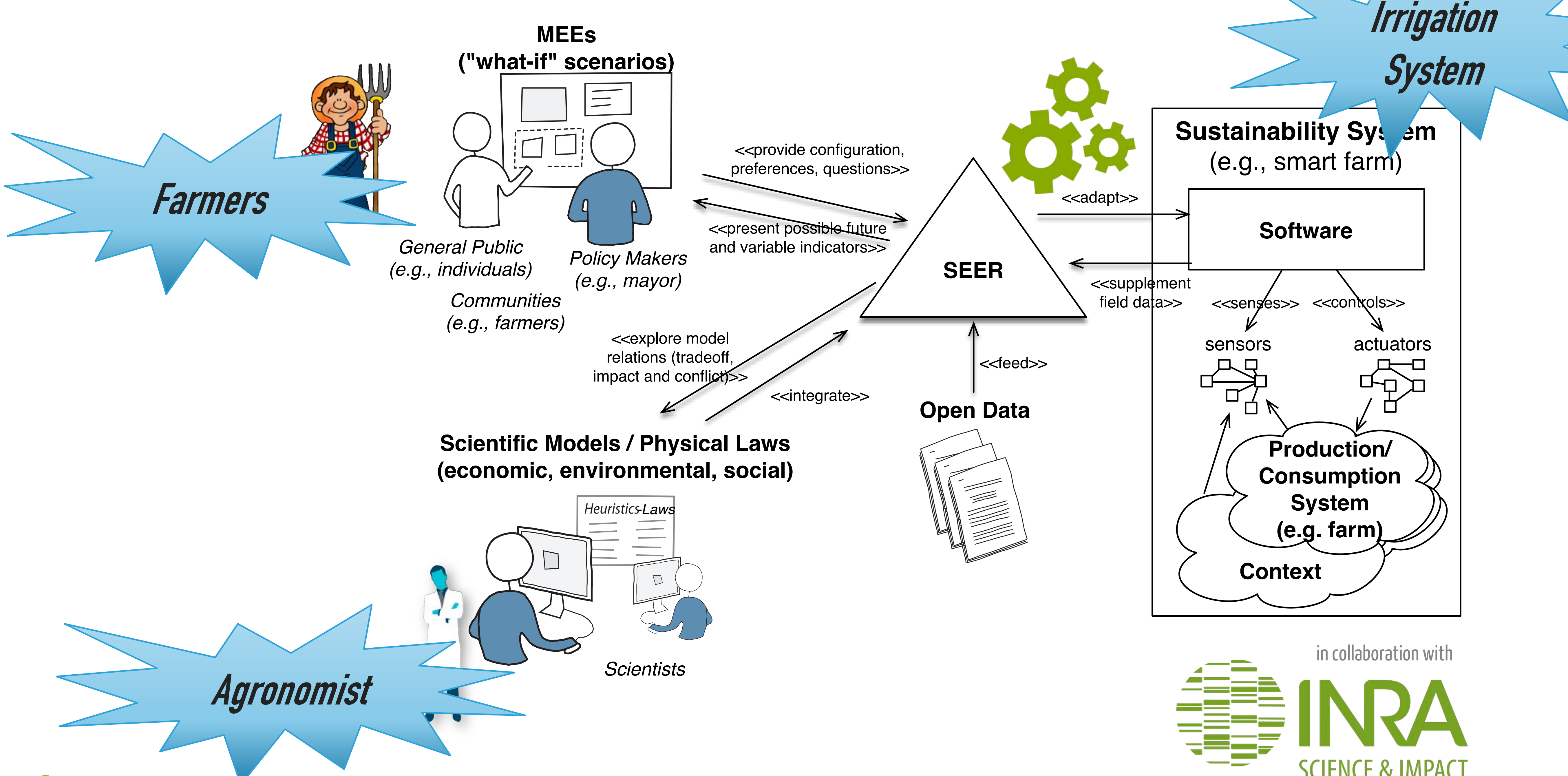


The Sustainability Evaluation ExperienceR (SEER)

MDE in Practice for Computational Science

Jean-Michel Bruel, Benoit Combemale, Ileana Ober, Hélène Raynal

In *International Conference on Computational Science (ICCS)*, 2015



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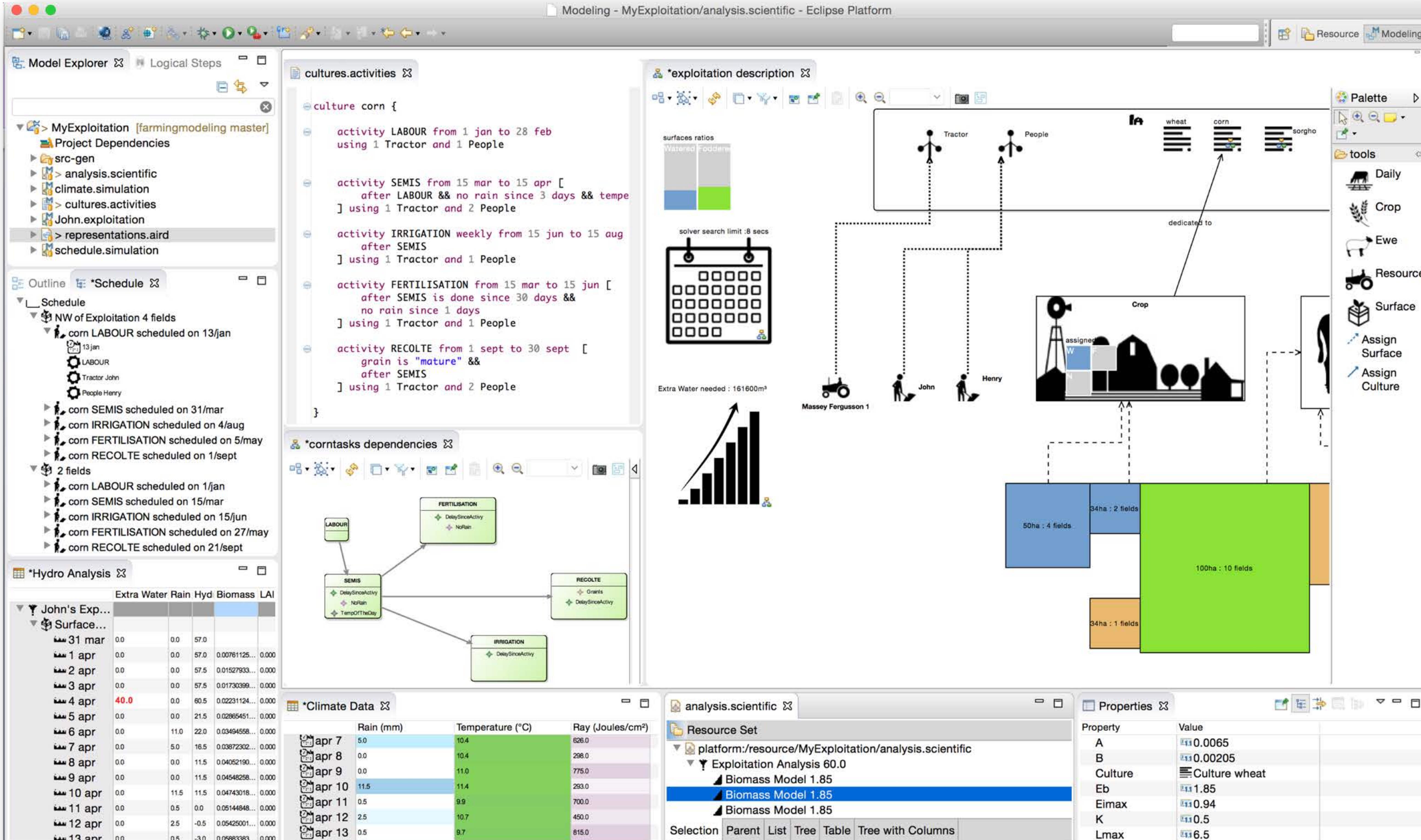
FARMING SYSTEM MODELING



https://github.com/gemoc/farmingmodeling

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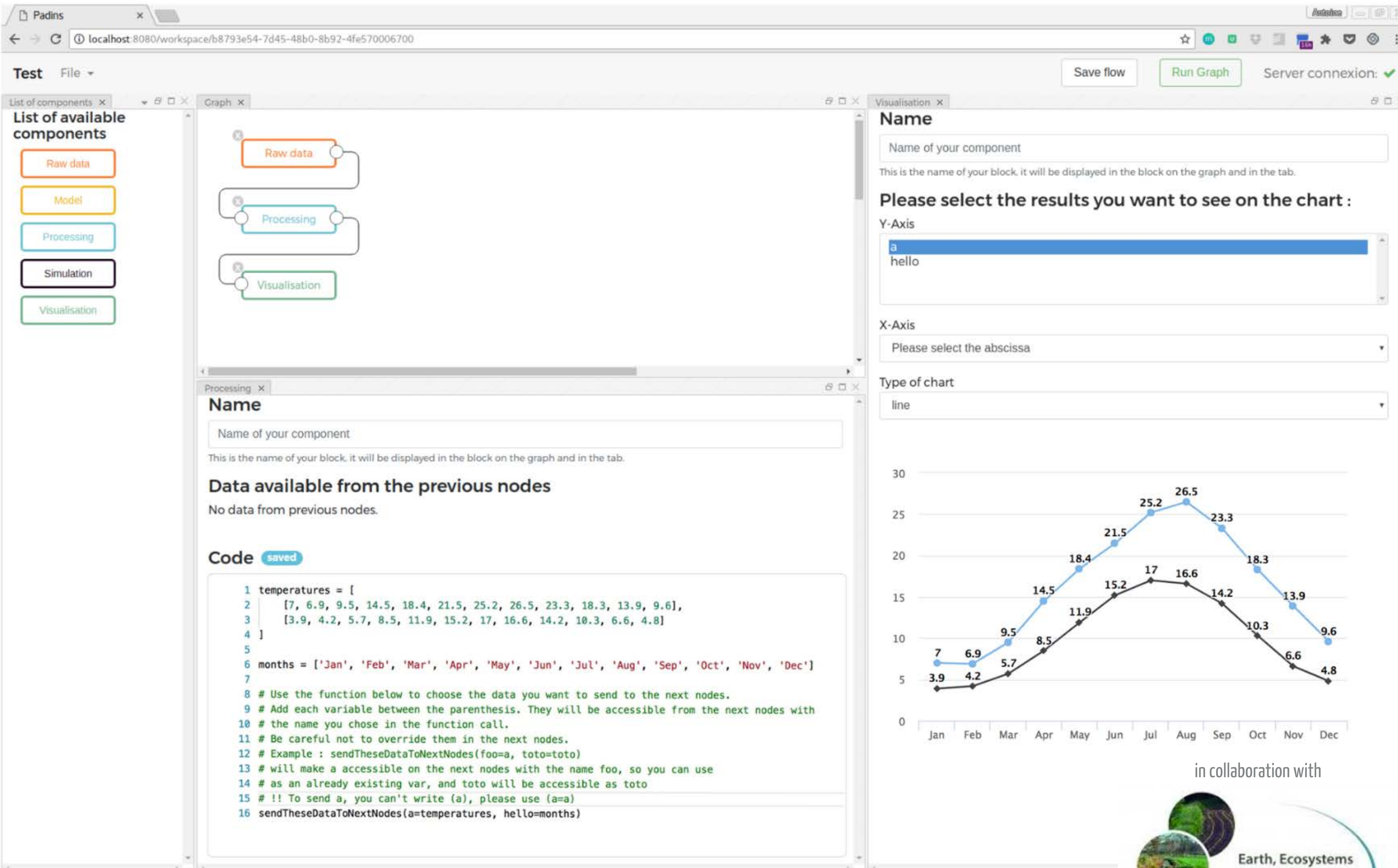
WATER FLOOD PREDICTION



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Take Away Messages

- From MDE to SLE
  - Language workbenches support DS(M)L development
- On the globalization of modeling languages
  - Integrate heterogeneous models representing different engineering concerns
  - Language interfaces to support structural and behavioral relationships between domains (i.e., DSLs)
- From software systems to smart CPS
  - Interactions with the physical world limited to (i.e., fixed, in closed world) control laws and data from the sensors
  - What about the broader context in which the system involves?
    - Physical / social / economic laws
    - Predictive models
    - Regulations, user preferences

Conclusion

- Integration of scientific models in the control loop of smart CPS is key to provide more informed decisions, a broader engagement, and eventually relevant runtime reconfigurations

- SEER is a particular instantiation of such a vision for sustainability systems

Open Challenges

- Diversity/complexity of DSL relationships
  - Far beyond structural/behavioral alignment, refinement, decomposition
  - Separation of concerns vs. Zoom-in/Zoom-out

- Live and collaborative (meta)modeling
  - Minimize the round trip between the DSL specification, the model, and its application (interpretation/compilation)
  - Model experiencing environments (MEEs): what-if/for scenarios, trade-off analysis, design-space exploration

- Integration of analysis and predictive models into DSL semantics
  - Towards unpredictable languages
    - *Specify the correctness envelope to avoid over-specification*
    - *Identify plastic computation zones*
    - *Vary the execution flow of the program*