#### Modeling for Smart Cyber-Physical Systems Application to Farming Systems

#### Benoit Combemale (Inria & Univ. Rennes 1)

http://people.irisa.fr/Benoit.Combemale benoit.combemale@irisa.fr @bcombemale

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







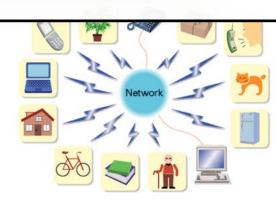




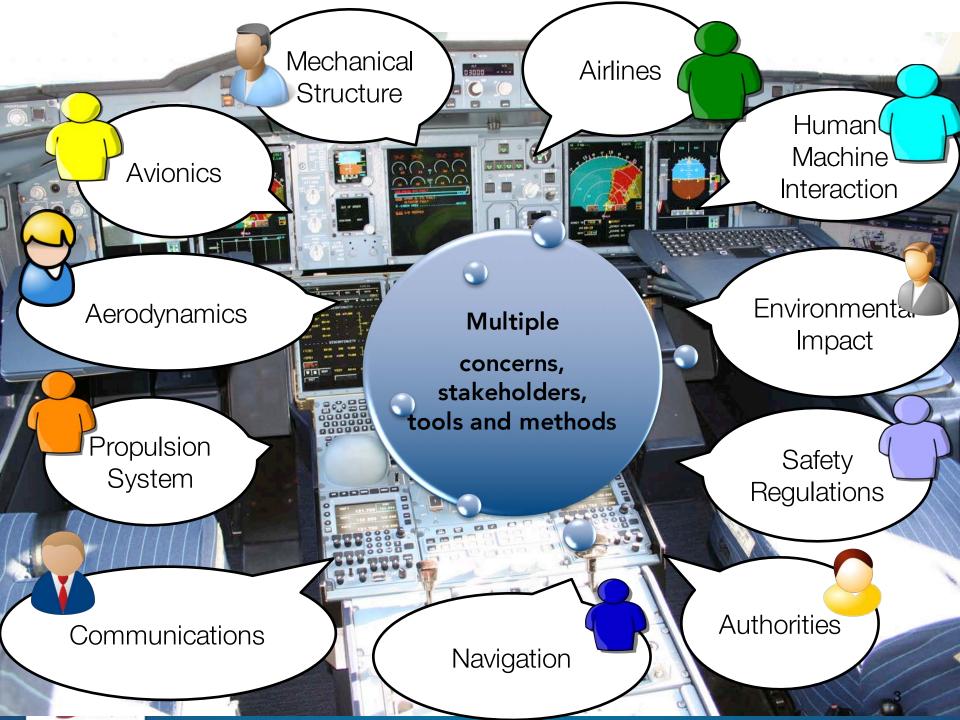
# **Complex Software-Intensive Systems**

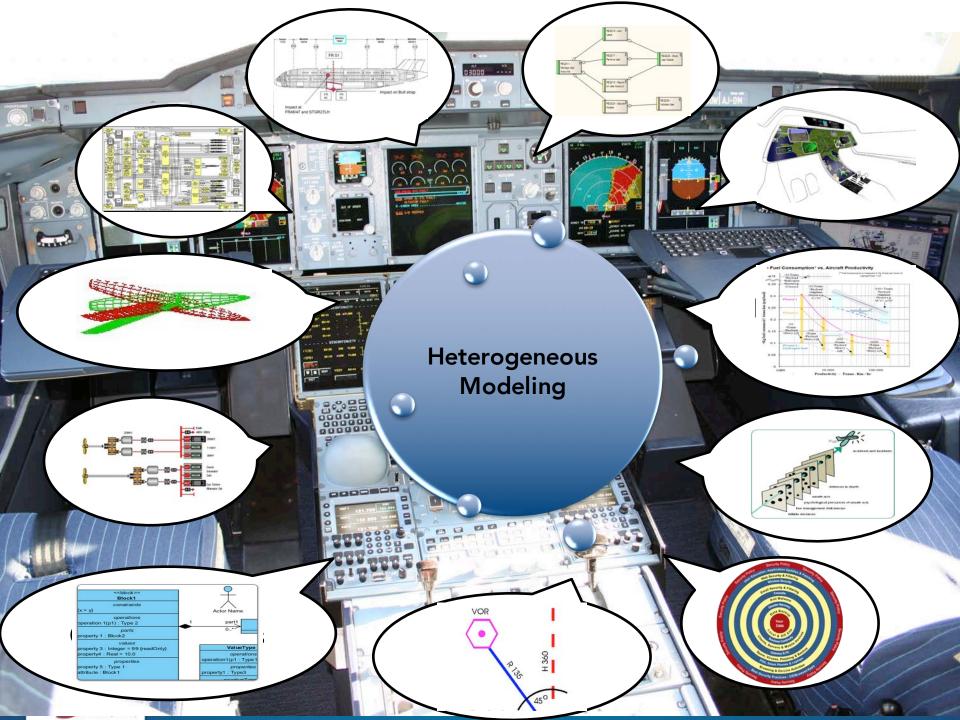
- Multi-engineering approach
  - Some forms of domain-specific modeling
  - Software as integration layer
- **Openness and dynamicity**



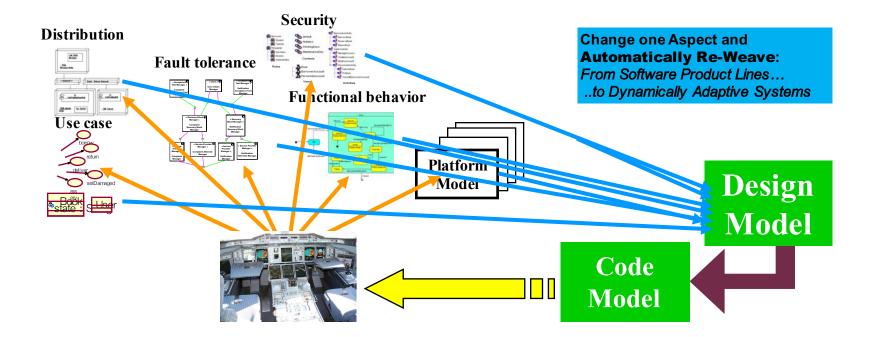






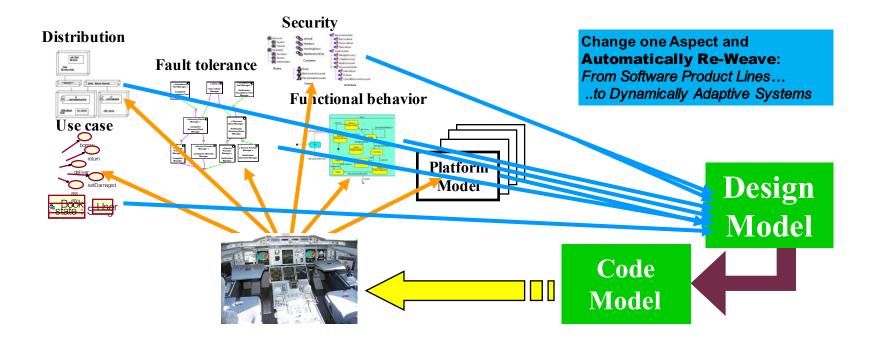


# **Model-Driven Engineering (MDE)**





# **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.



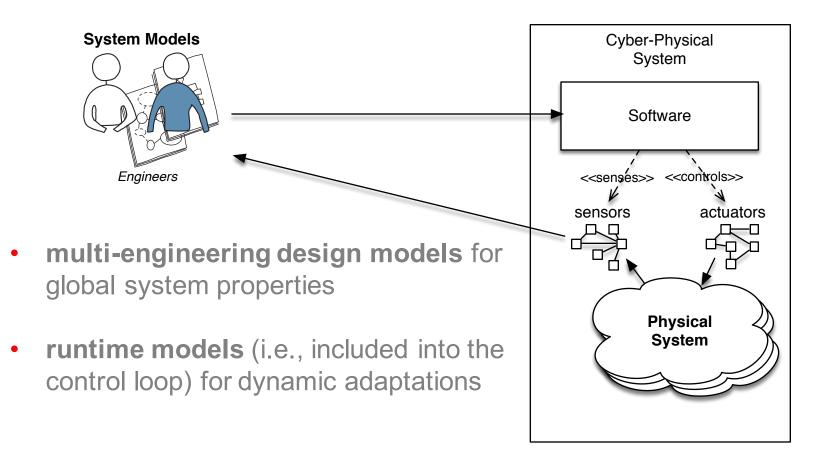
# From <u>Software</u> Systems



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

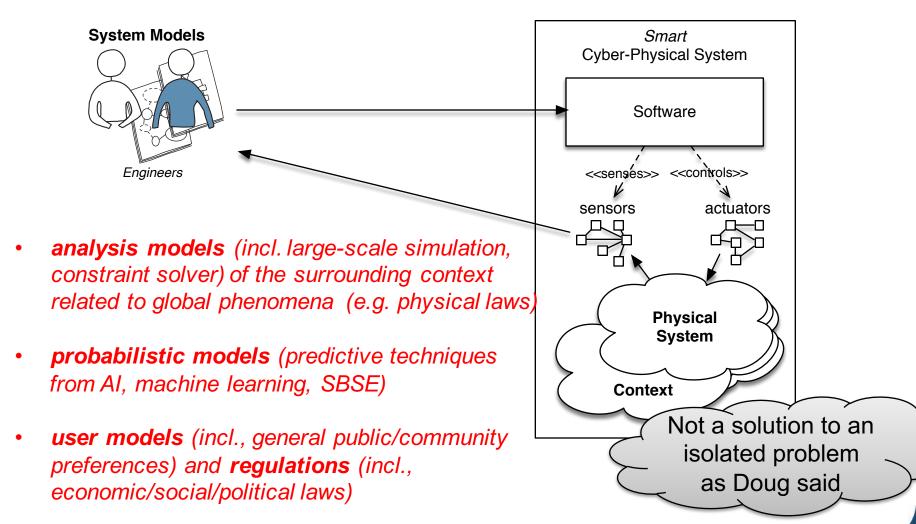


# To Cyber-Physical Systems



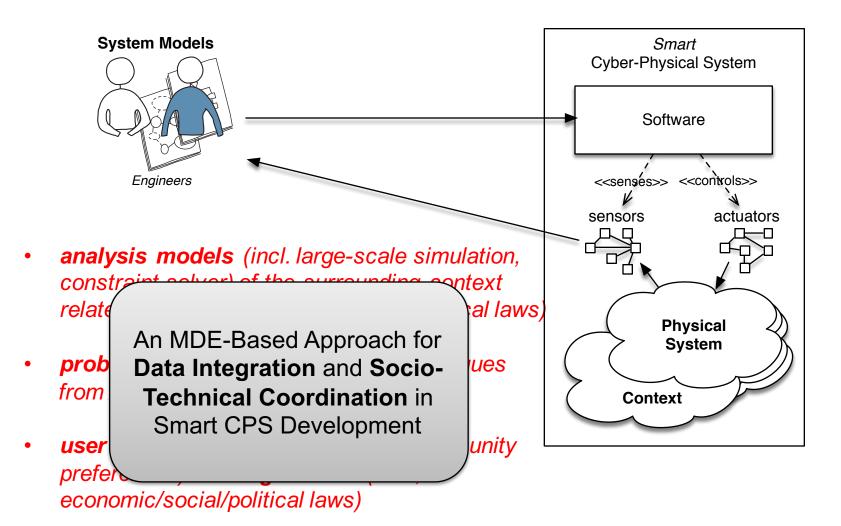


# To Smart Cyber-Physical Systems





# To Smart Cyber-Physical Systems





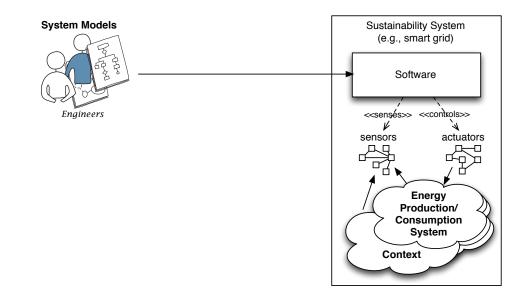
# A MDE-based approach to develop Smart CPS

- 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.



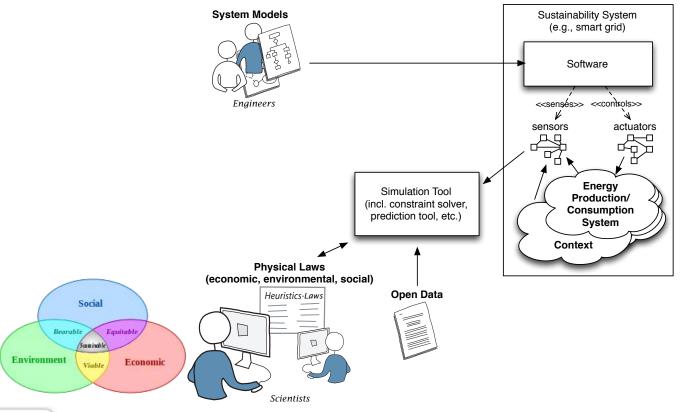
Cyber-Physical Systems





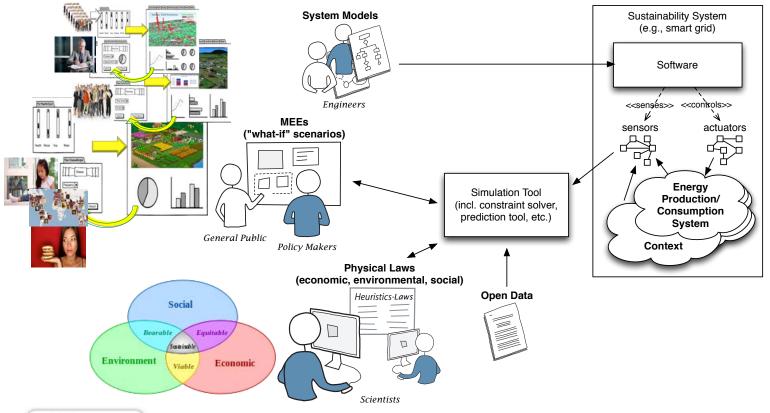
Modeling for Smart CPS – B. Combemale (INRIA & Univ. Rennes 1) – Jan. 2016

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



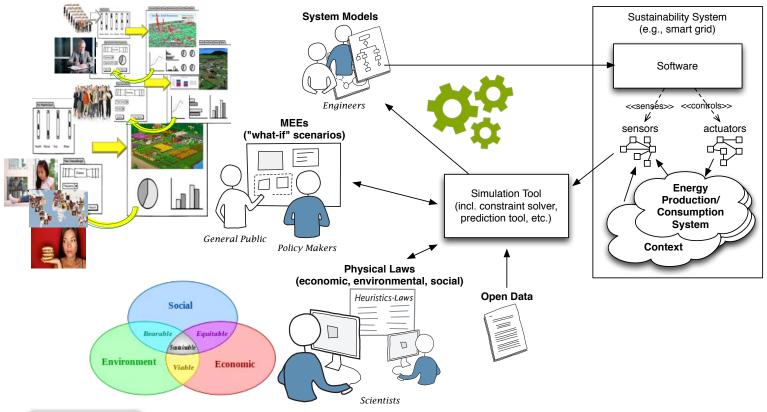


- Providing a broader engagement
  - with "what-if" scenarios for general public and policy makers



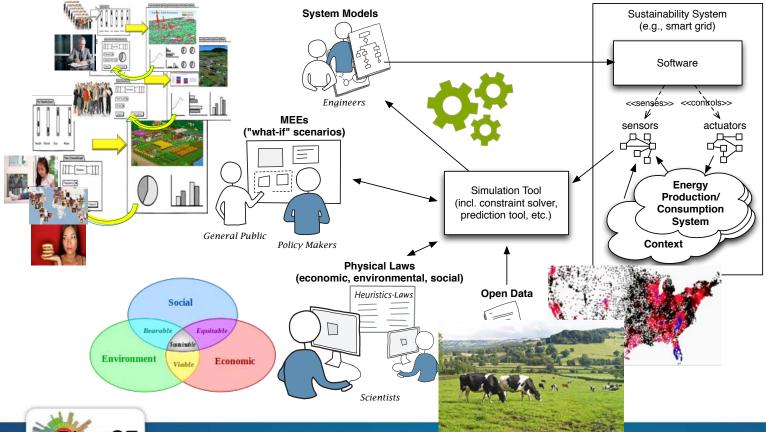


- Supporting automatic adaptation
  - for dynamically adaptable systems





• Application to health, farming system, smart grid...

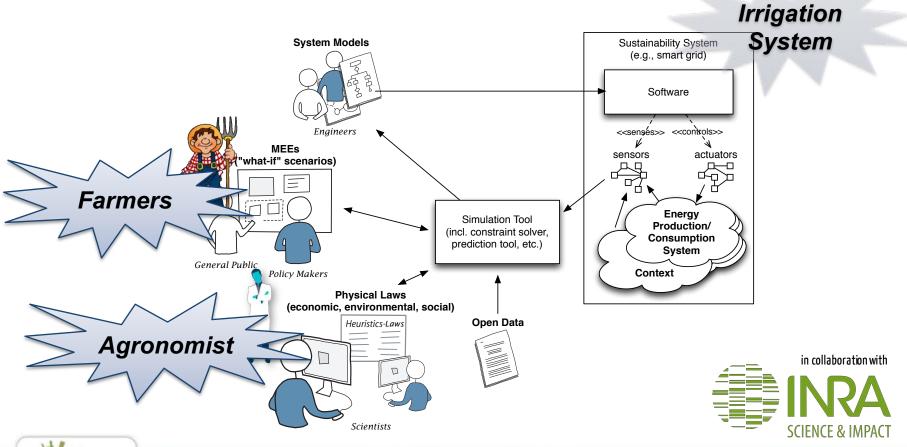




#### **Farming System Modeling**

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

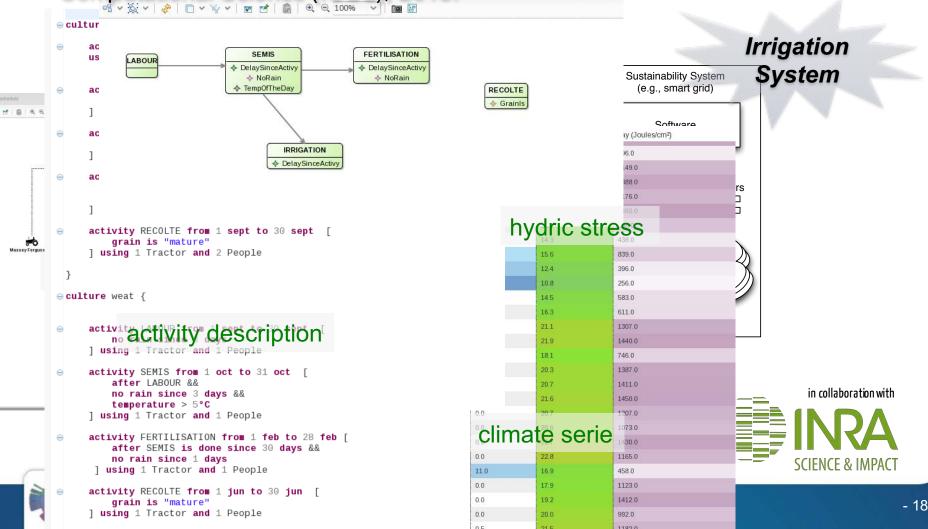




#### **Farming System Modeling**

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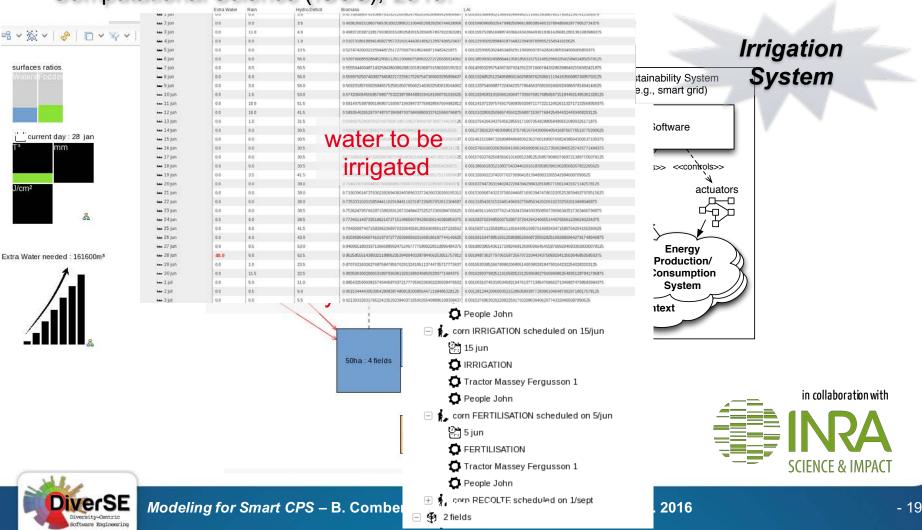
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#### **Farming System Modeling**



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



# Farming System Modeling Generic

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#### 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



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# **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



Gema

# **Globalization of Modeling Language**



- Context: new emerging DSML in open world
  - $\Rightarrow$  impossible *a priori* unification
  - $\Rightarrow$  require *a posteriori* globalization
- Objective: socio-technical coordination to support interactions across different system aspects
  - $\Rightarrow$  Language-based support for technical integration of multiples domains
  - $\Rightarrow$  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), <u>http://worrydream.com/ClimateChange</u>

