MODEL-DRIVEN *(SOFTWARE)* ENGINEERING

HACK YOUR OWN LANGUAGE!

UNIVERSITY OF RENNES, ESIR, 2025-2026

Slides adapted from materials originally created by Prof. Benoit Combemale.
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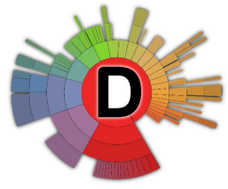
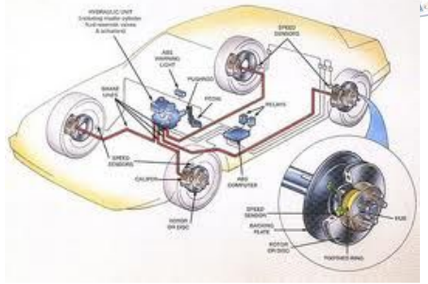
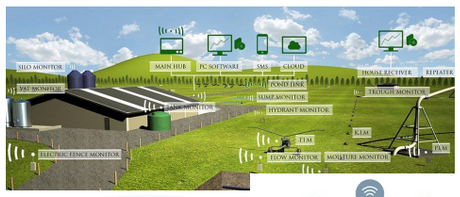
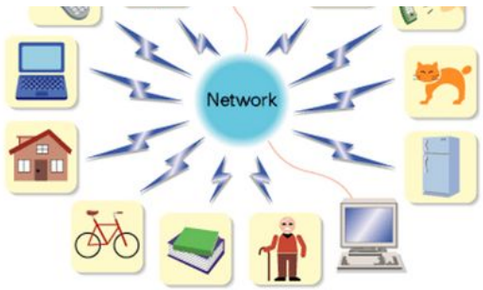


Complex Software-Intensive Systems

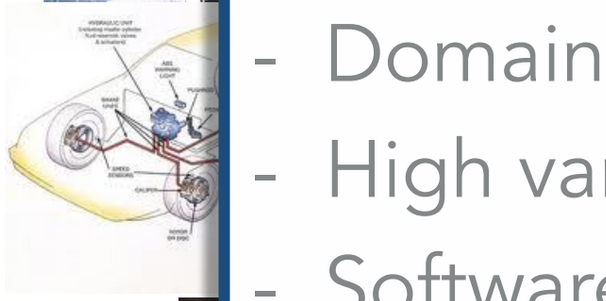


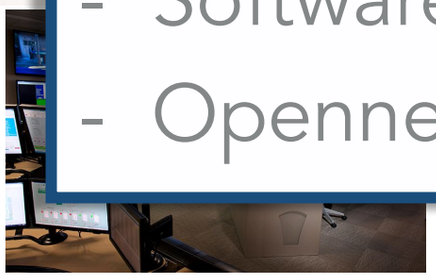
Software intensive systems

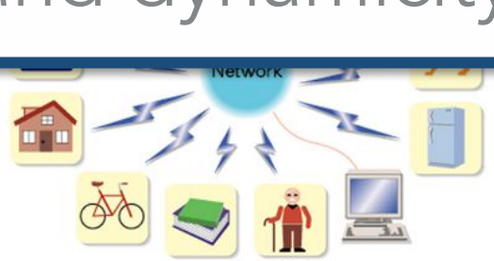




Complex Software-Intensive Systems







- Multi-engineering approach
- Domain-specific modeling
- High variability and customization
- 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

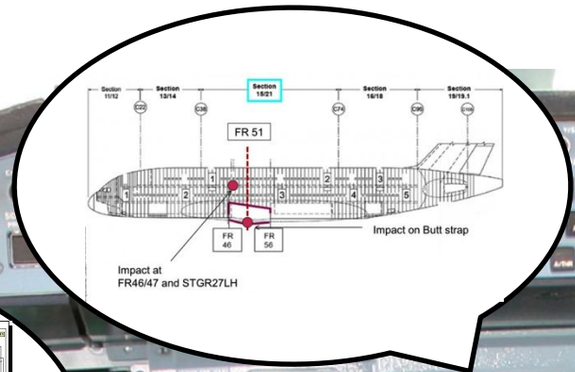
Safety Regulations

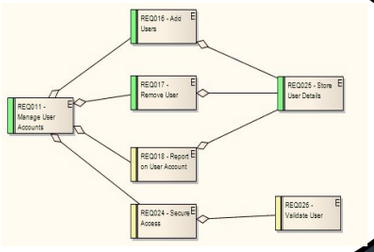
Communications

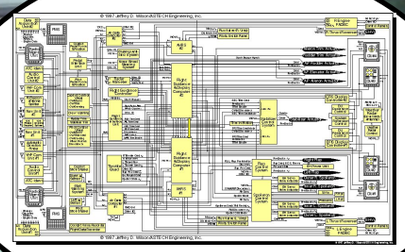
Navigation

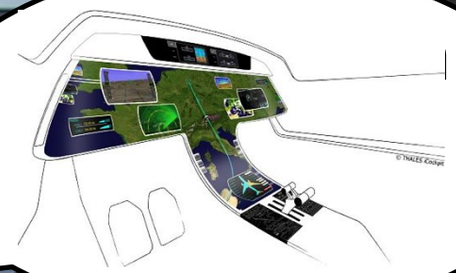
Authorities

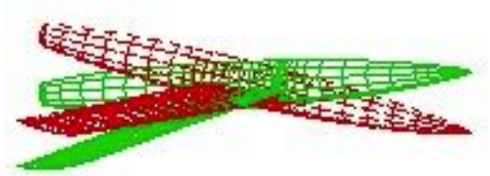
Heterogeneous Modeling

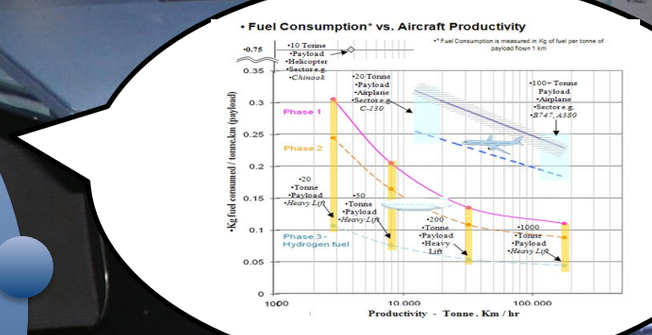


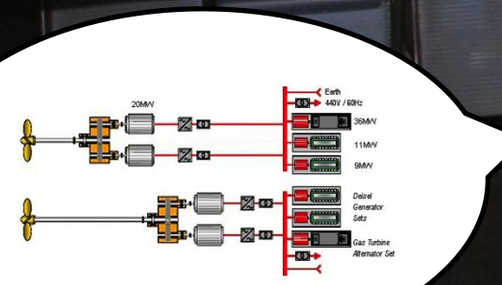


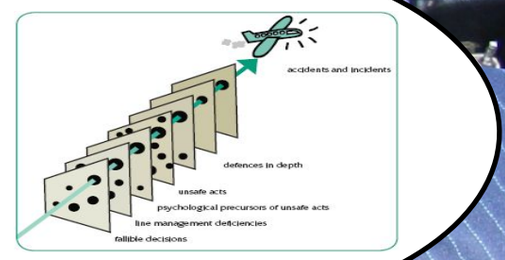


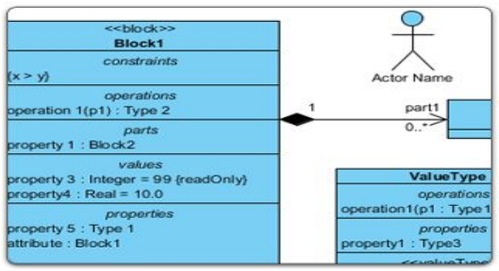


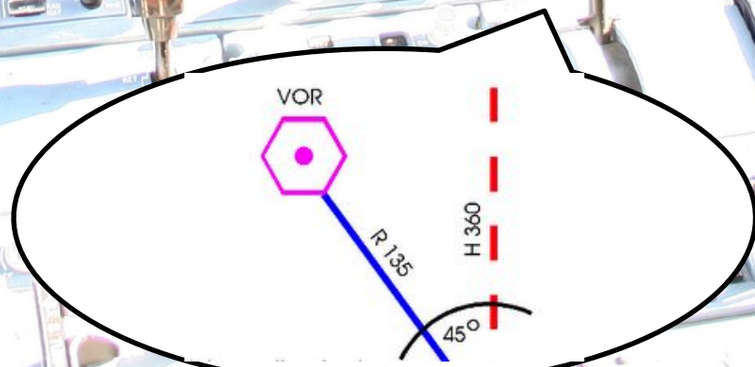


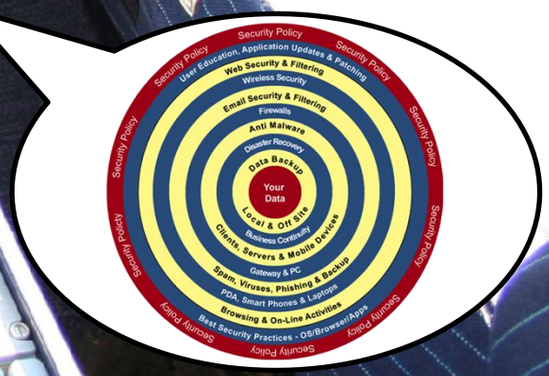










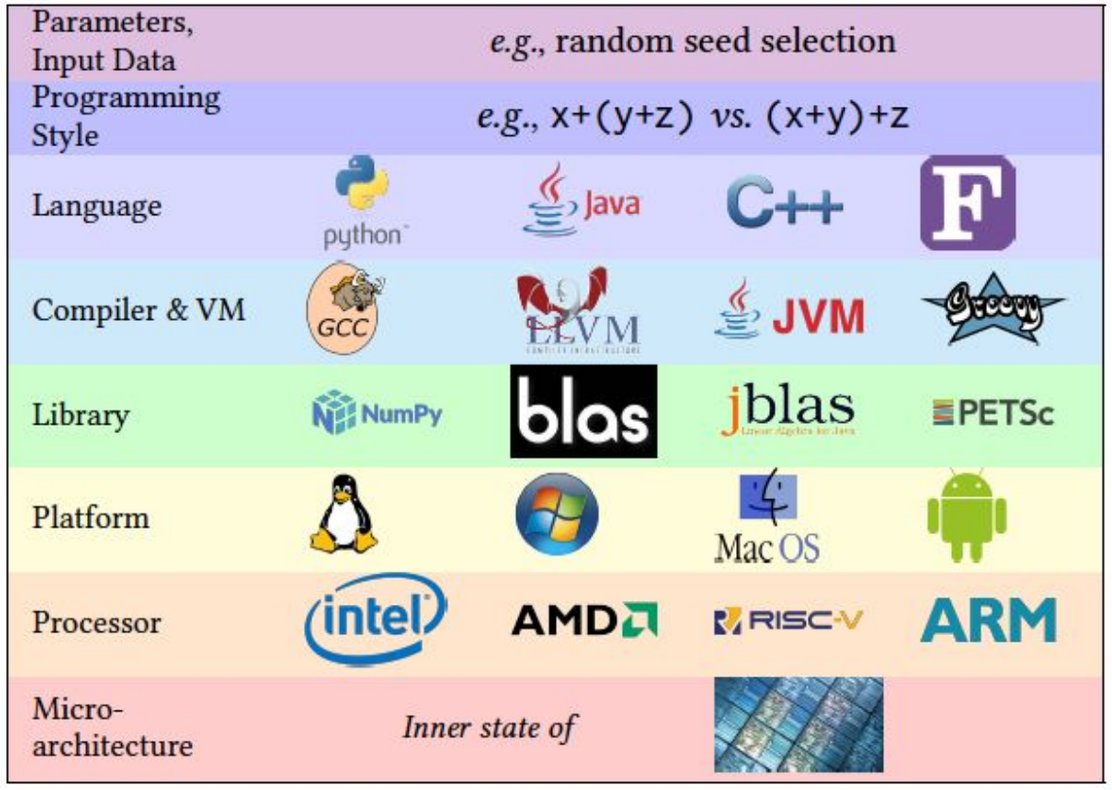


Deep Variability in Software Systems

- Variability occurs on all concerns
- Variability showcases interdependencies
- Variability impacts soft/sys properties

=> Combinatorial explosion of the epistemic and ontological variability

Deep Variability *refer to the interaction of all external "factors" modifying the behavior (including both functional and nonfunctional properties) of a software system*



Software Modeling: Why Should I Care?

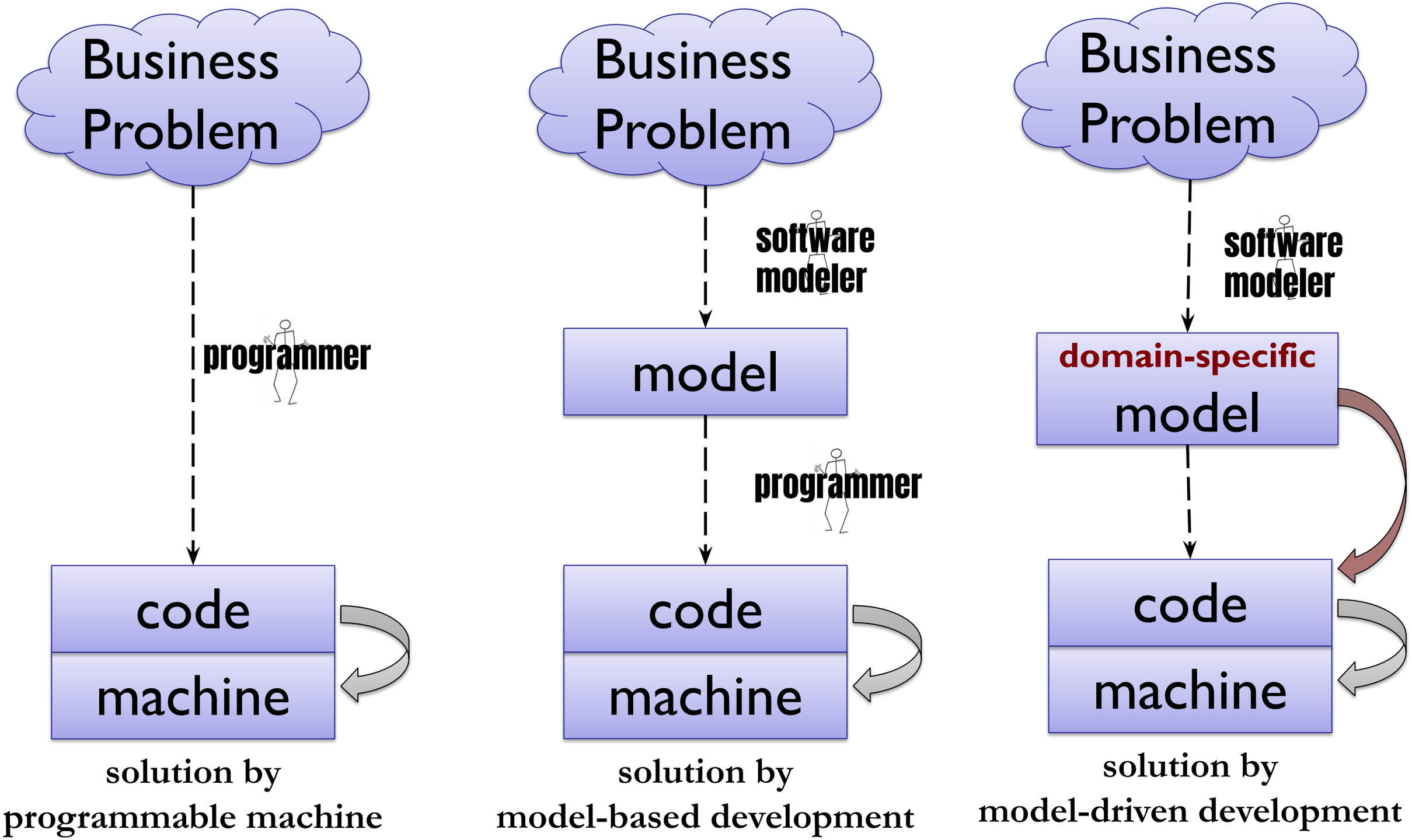
- To reflect:
  - abstract representation
  - separation of concerns
- To communicate:
  - graphical representation
  - documentation generation
- To automate development:
  - code generation
  - pattern application
  - migration
- To verify:
  - model validation and verification (e.g., simulation, model checking...)
  - model-based testing

Model and Reality in Software

- **Sun Tse:** *“Do not take the map for the reality”*
- **William James:** *“The concept 'dog' does not bite”*
- **Magritte:**

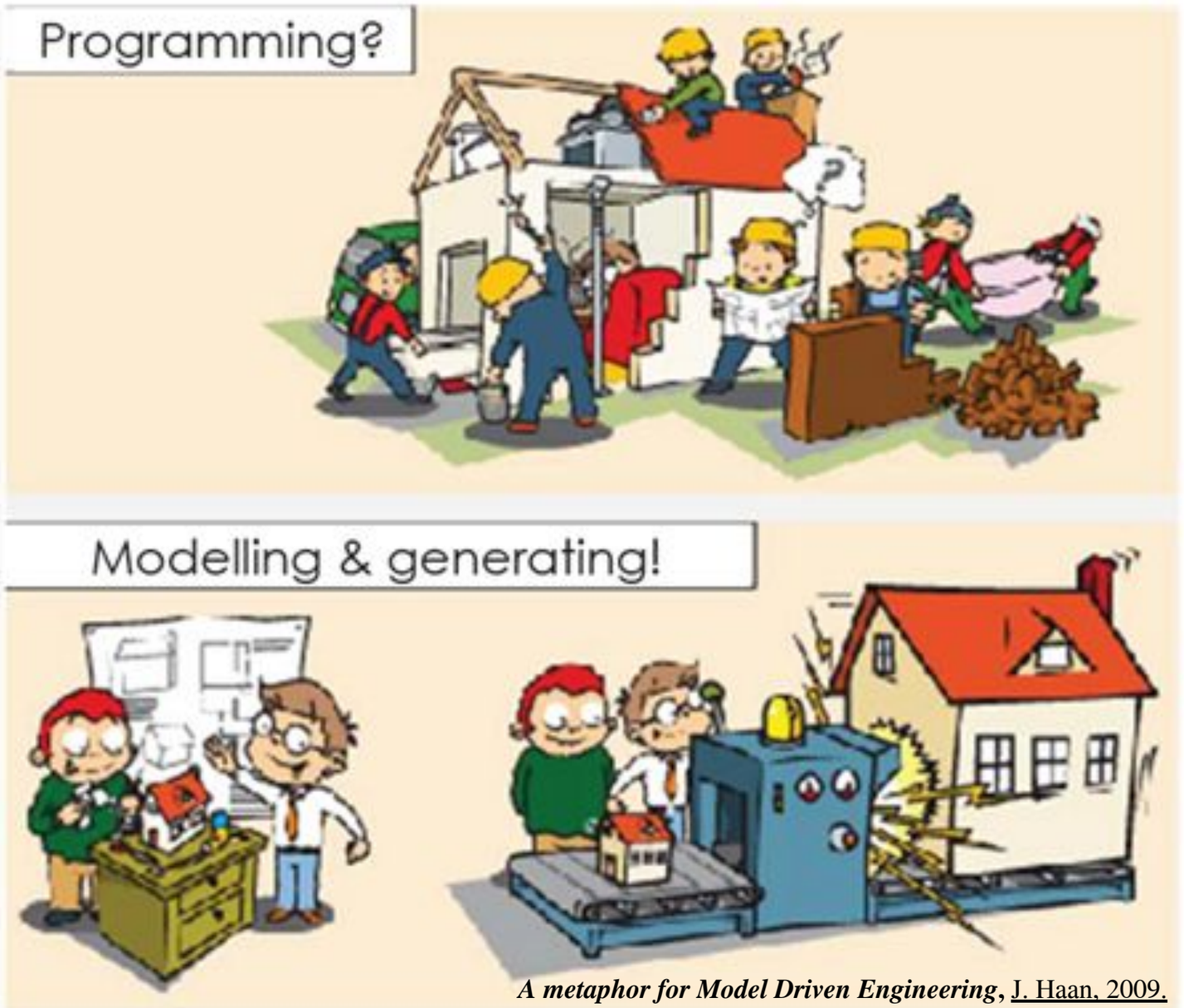
- Software Models: from contemplative to productive

Evolution in Software Modeling



From Gregor Engels (Universität Paderborn, Germany)
Panel "When will Code become Irrelevant?", MoDELS 2011.

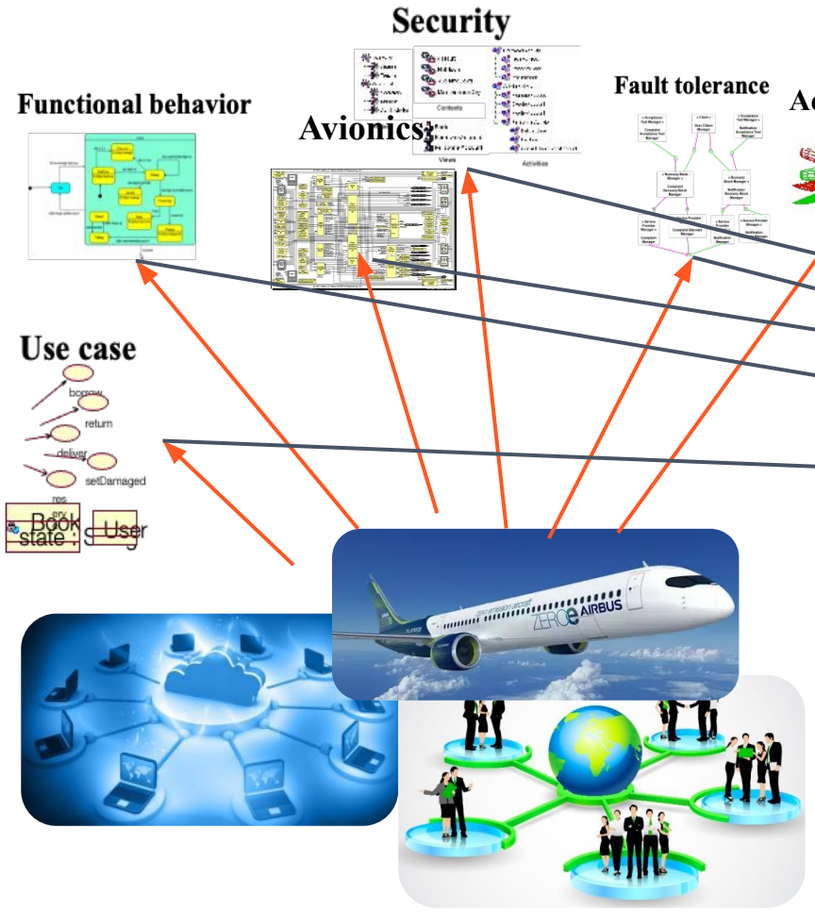
Towards Model-Driven Engineering (MDE)



***A metaphor for Model Driven Engineering*, J. Haan, 2009.**

Model-Driven Engineering (MDE)

Separation of concerns, abstraction



complex software, systems and organizations

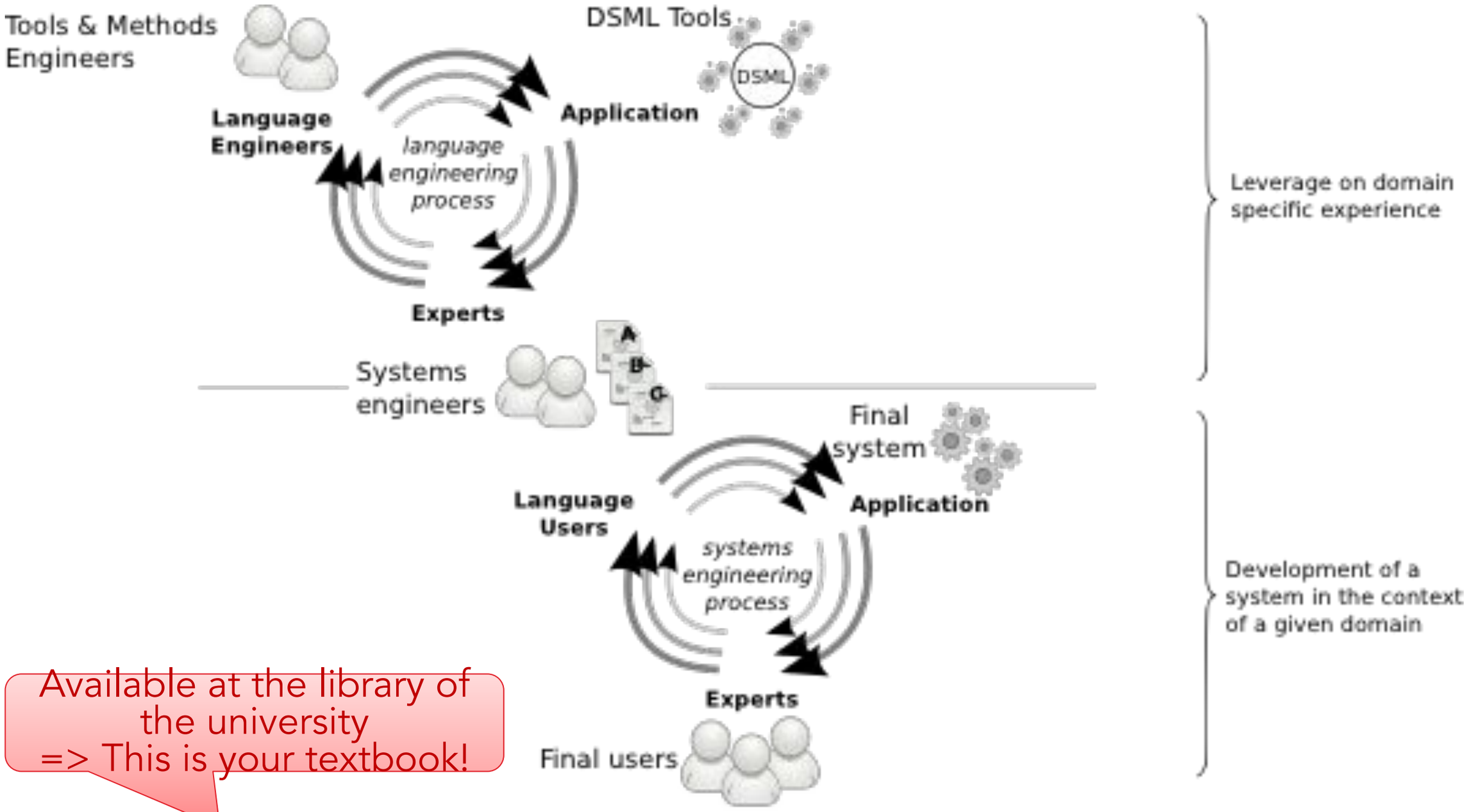
Unification power of models, from design to runtime

Design Model

Code Model

Automated analysis, simulation, development...

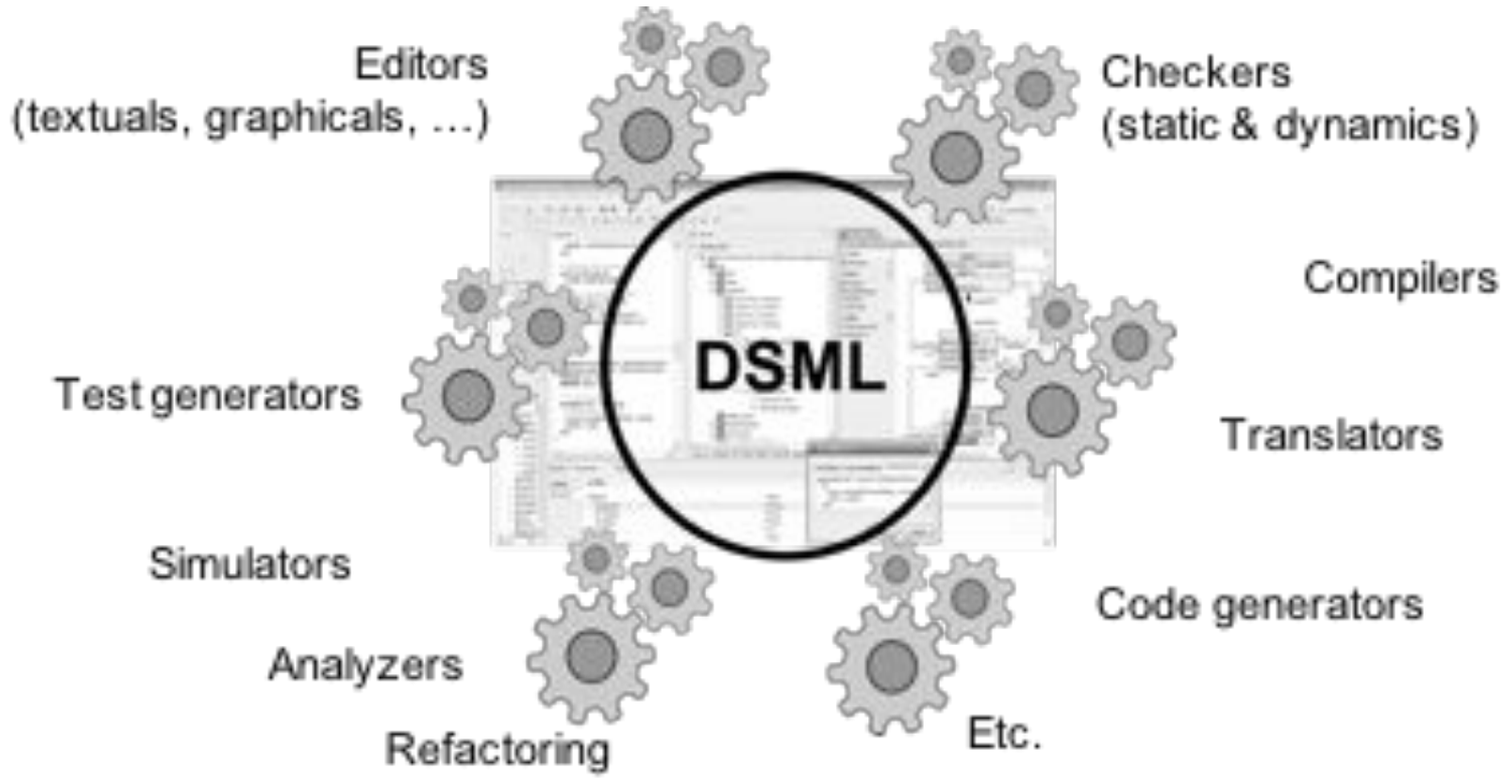
Language-Oriented Programming (LOP)



Available at the library of the university
=> This is your textbook!

Engineering Modeling Languages: Turning Domain Knowledge into Tools, by Benoit Combemale, Robert B. France, Jean-Marc Jézéquel, Bernhard Rumpe, Jim R.H. Steel, and Didier Vojtisek. Chapman and Hall/CRC, pp.398, 2016. Companion website: http://mdebook.irisa.fr

Language-Oriented Programming (LOP)



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Domain-Specific Languages (DSLs)

- Targeted to a particular kind of problem, with dedicated notations (textual or graphical), support (editor, checkers, etc.)

- Promises: more « efficient » languages for resolving a set of specific problems in a domain

Domain-Specific Languages (DSLs)

"Software Languages are Software Too"

J-M. Favre, D. Gasevic, R. Lämmel, and E. Pek. "Empirical language analysis in software linguistics," In Software Language Engineering, volume 6563 of LNCS, pages 316–326. Springer, 2011.

Software Language Engineering (SLE)

- Application of systematic, disciplined, and measurable approaches to the development, deployment, use, and maintenance of software (domain-specific) languages
- Supported by various kind of "language workbench"
  - Eclipse EMF, xText, Sirius, Melange, GEMOC, Papyrus
  - Eclipse Langium
  - Jetbrain's MPS
  - MS DSL Tools
  - Etc.
- Various shapes and ways to implement software languages
  - External, internal or embedded DSLs, Profile, etc.
  - Grammar, metamodel, ontology, etc.
- More and more literature, a dedicated Intl. conference (ACM SLE, cf. http://www.sleconf.org)…

GEMOC Studio

Language Workbench

Design and integrate your executable DSMLs

http://gemoc.org/studio

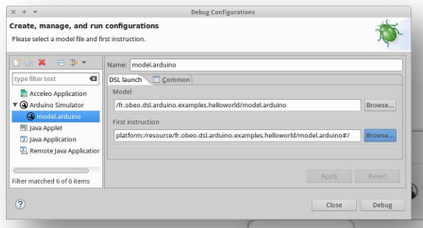
also

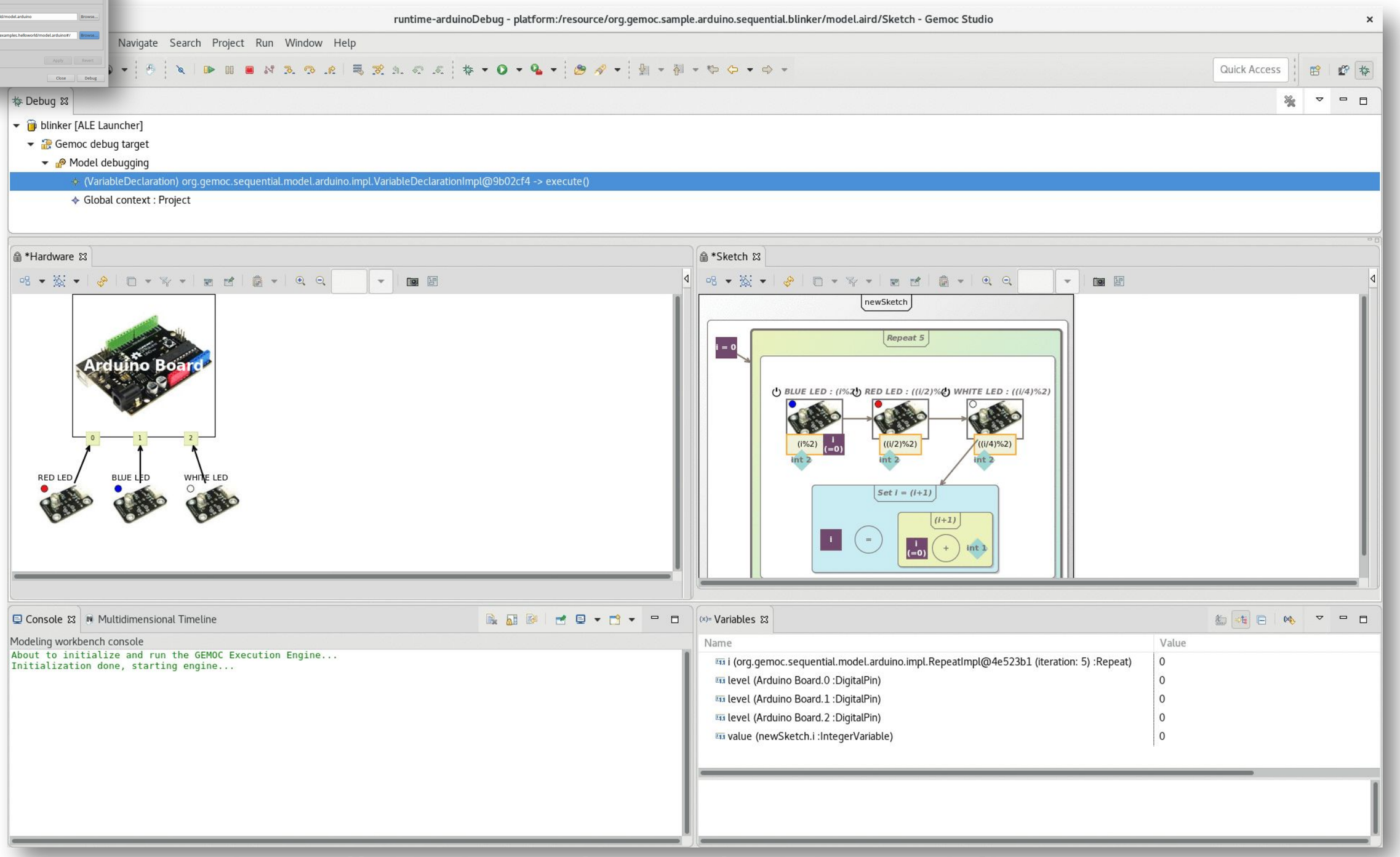
http://eclipse.org/gemoc

Modeling Workbench

Edit, simulate and animate your heterogeneous models

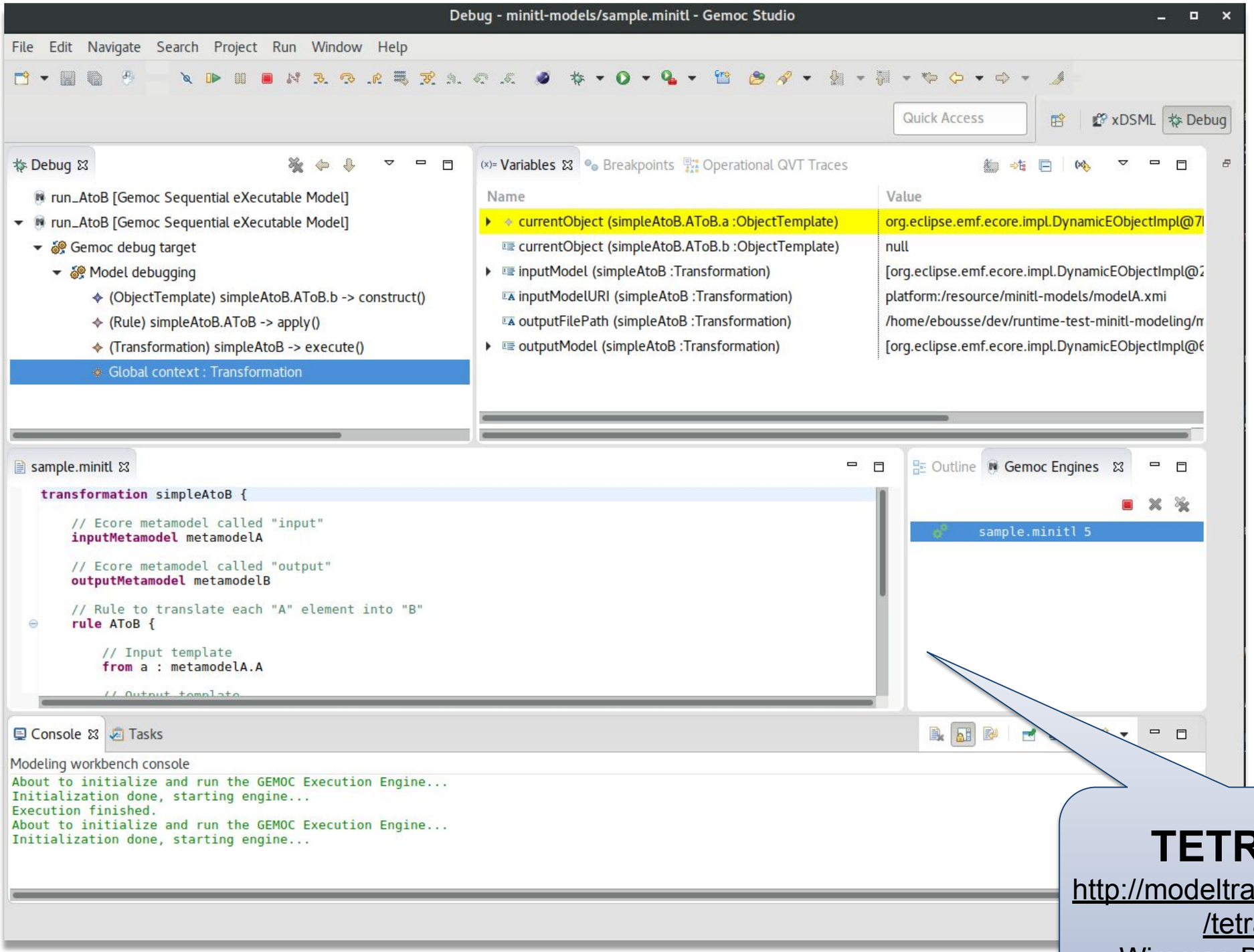
Arduino Designer





https://github.com/gemoc/arduinomodeling

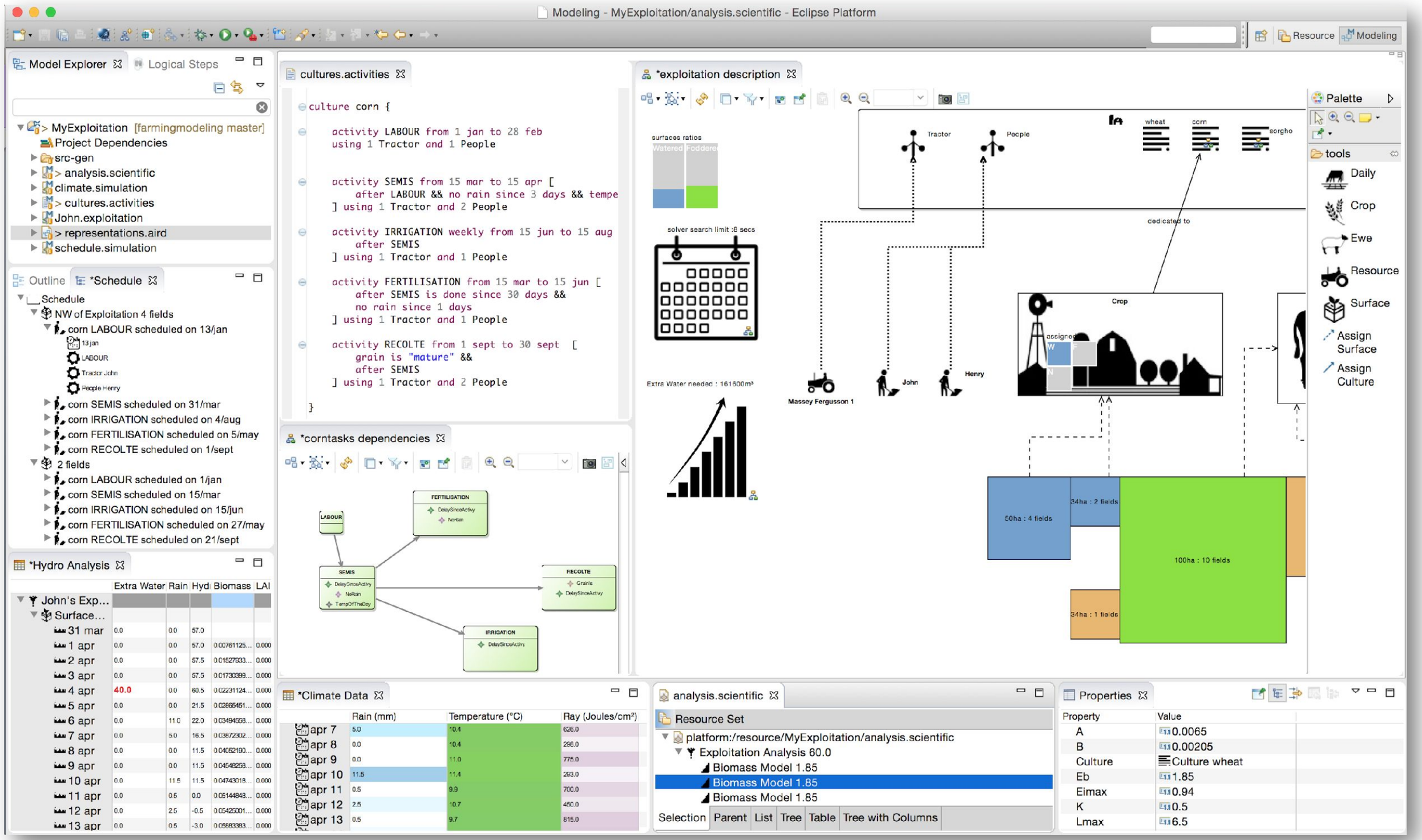
Transformation Lg Debugger



TETRABox
http://modeltransformation.net/tetrabox/
Wimmer, Bousse *et al.*

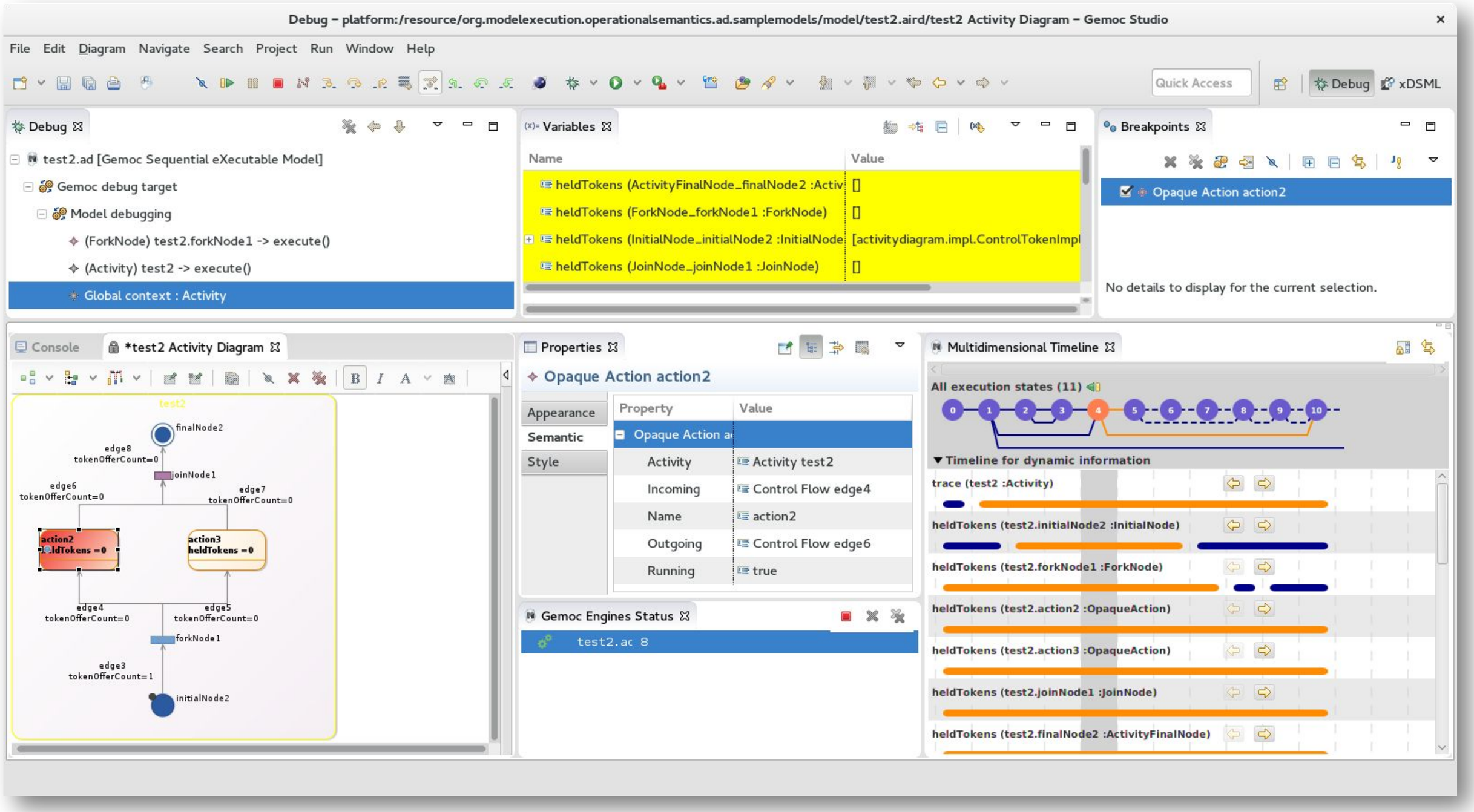
https://github.com/tetrabox/minitl

Farming System Modeling



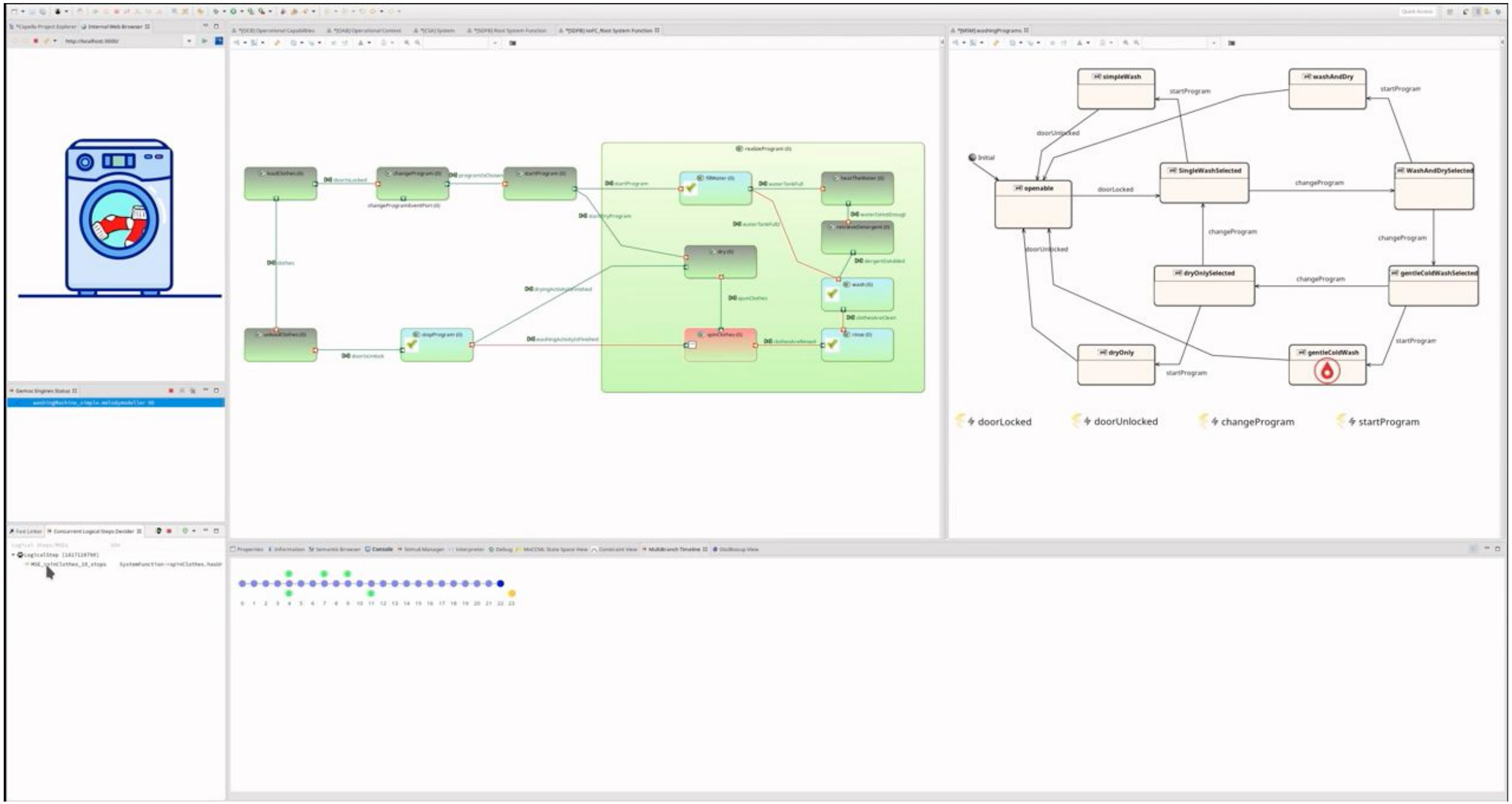
https://github.com/gemoc/farmingmodeling

UML Activity Diagram

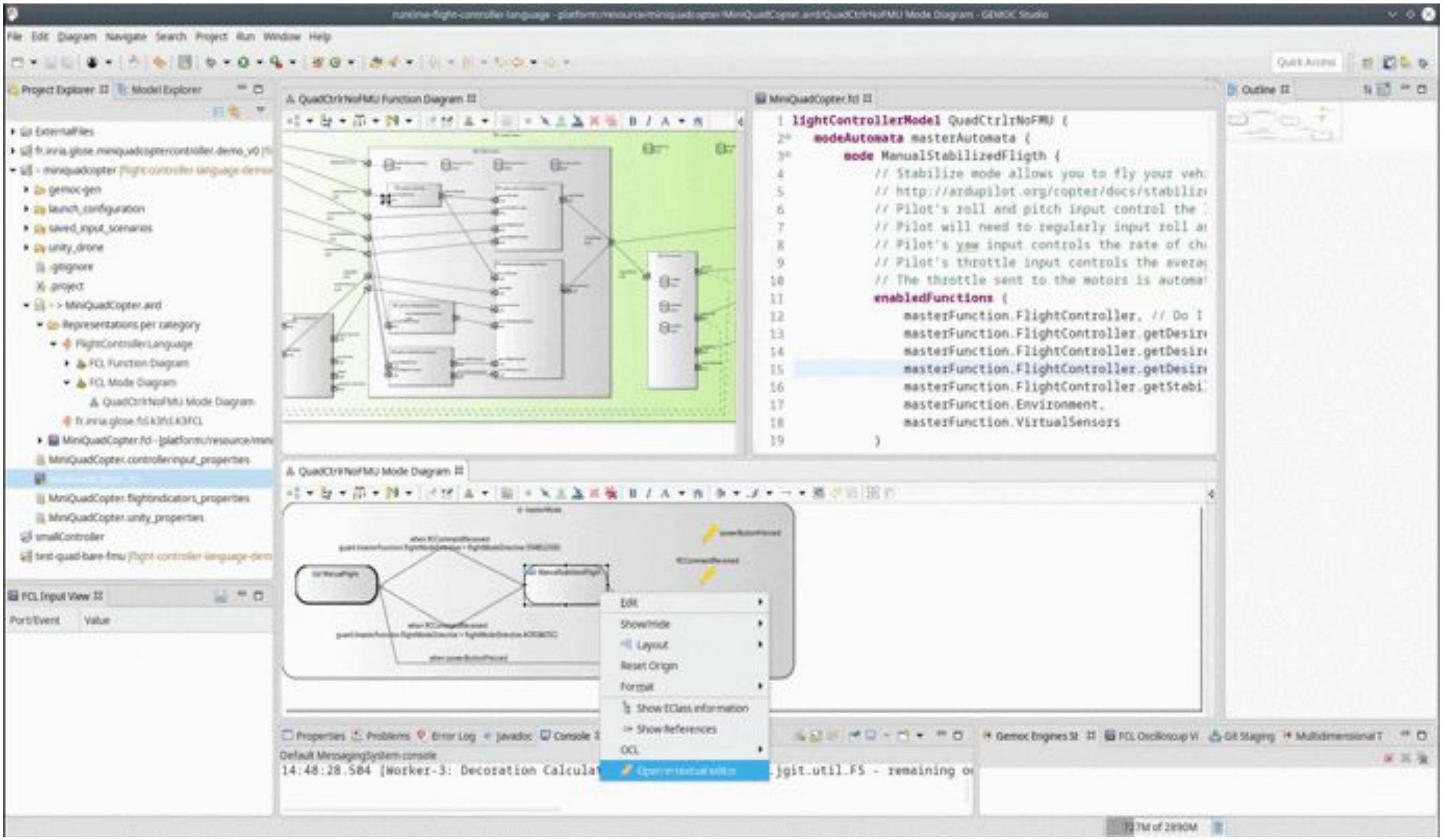


https://github.com/gemoc/activitydiagram

xCapella


simpleWash
washAndDry
startProgram
doorUnlocked
Initial
openable
doorLocked
SingleWashSelected
changeProgram
WashAndDrySelected
dryOnlySelected
gentleColdWashSelected
dryOnly
gentleColdWash
doorLocked
doorUnlocked
changeProgram
startProgram

FCL

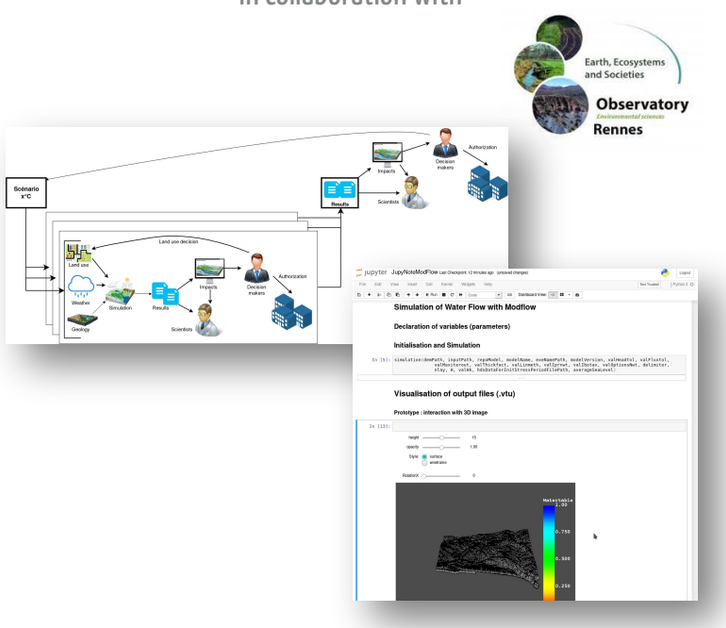

File Edit Diagram Navigate Search Project Run Window Help
Project Explorer
Model Explorer
QuadCtrlrNoFMU Function Diagram
MiniQuadCopter.fcl
1 lightControllerModel QuadCtrlrNoFMU {
2 modeAutomata masterAutomata {
3 mode ManualStabilizedFligth {
4 // Stabilize mode allows you to fly your veh
5 // http://ardupilot.org/copter/docs/stabiliz
6 // Pilot's roll and pitch input control the
7 // Pilot will need to regularly input roll a
8 // Pilot's yaw input controls the rate of ch
9 // Pilot's throttle input controls the avera
10 // The throttle sent to the motors is automa
11 enabledFunctions {
12 masterFunction.FlightController, // Do I
13 masterFunction.FlightController.getDesir
14 masterFunction.FlightController.getDesir
15 masterFunction.FlightController.getDesir
16 masterFunction.FlightController.getStabi
17 masterFunction.Environment,
18 masterFunction.VirtualSensors
19 }
Outline
QuadCtrlrNoFMU Mode Diagram
FCL Input View
Port/Event
Value
Edit
Show/Hide
Layout
Reset Origin
Format
Show EClass information
Show References
OCL
Properties
Problems
Error Log
Javadoc
Console
Default MessagingSystem-console
Gemoc Engines St
FCL Oscilloscup Vi
Git Staging
Multidimensional T

Crosscutting Challenges for Various Domains

Towards Virtual Labs

From Modeling Environment to Digital Twin

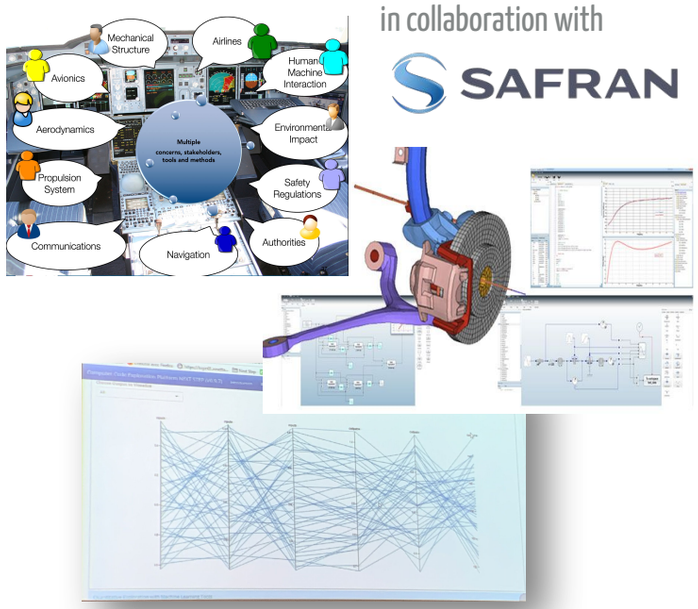
in collaboration with



Tradeoff Analysis for
Water Flood Prediction

in collaboration with

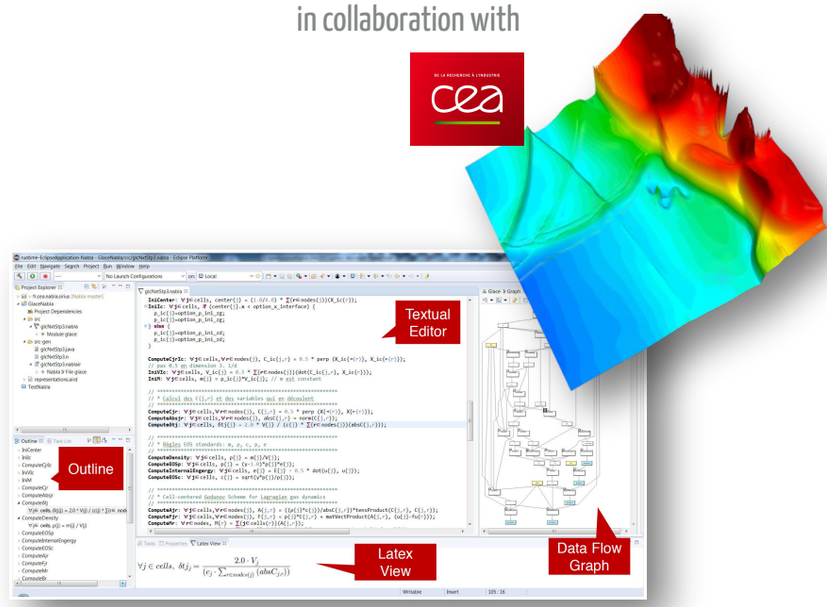
SAFRAN



Design Space Exploration
for Cyber-Physical Systems

in collaboration with

cea



High-Performance Computing
for Numerical Analysis

Content of the course

- **Metamodeling**
- **Hack your own Domain-Specific Languages**
  - **Domain model (EMF Ecore)**
  - **Textual syntaxes: Xtext/Langium**
  - **Compiler and interpreter (Xtend/Typescript)**
- **Companion webpage:**

https://stephaniechallita.github.io/ase/

Flipped classroom

- **The group prepares and presents parts of the lecture**
  - **Based on slides and textual content**
  - **During next session, students present and discuss the lecture content**
- **Finite State Machine (FSM) companion project:**
  - **Apply together concepts seen during lectures**
  - **Basic project to built-up the evaluated project**

Project: RobotML

- **Over 12 labs sessions**
- **Subject: a DSL to program robot's movements**
- **In pair**
- **Evaluation**
  - **Metamodel / 5**
  - **Concret syntaxe / 5**
  - **Semantics (compiler & interpreter) / 10**

You will learn how to

- **Automatically translate** abstract design models to executable code, test cases and documentation

- **Automatically manipulate** your model/code to analyze, transform, refactor..

- **Build or customize your own abstractions** , or even **software languages and development environments** , to build complex software-intensive systems

- Eventually **limit the accidental complexity** of industrial developments

Additionally, you will also

- **Demystify** language formalisms, paradigms and principles
- **Have a deeper insight** on some of them
- **Manage the industrial complexity** of developments and associated toolchains