



EUROPEAN COOPERATION
IN SCIENCE & TECHNOLOGY

24 Nov. 2015 - 24 Nov. 2018

IC1404 - Multi-Paradigm Modelling for Cyber-Physical Systems (MPM4CPS)

Training School: processes



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18 November 2018



Blowout preventer failed

- \$ 400 Million
- Environmental damage

Software error (Operating system configuration)

- Repaired

Copper vs aluminium wiring Tool version problems

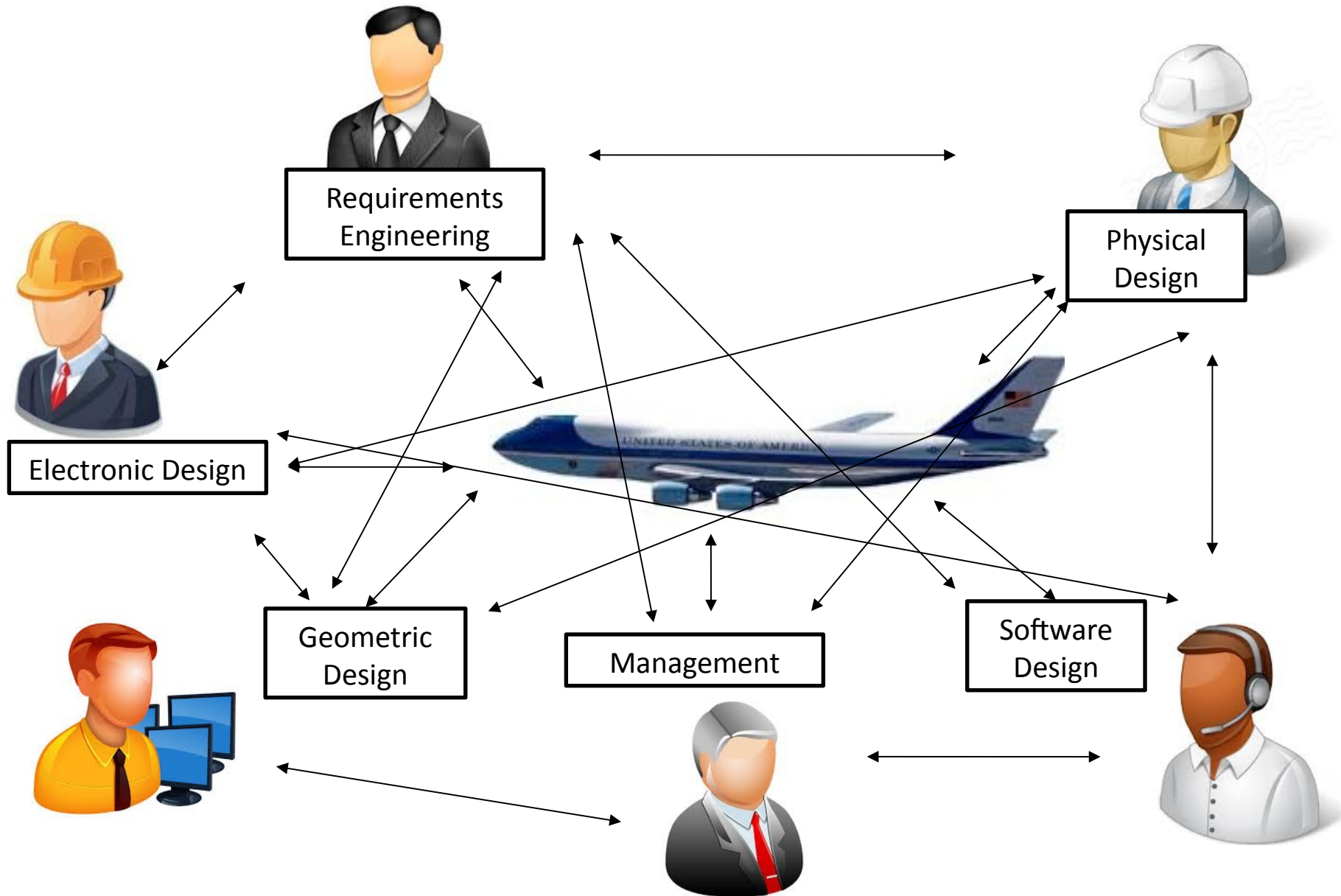
- \$ 2 billion revenue loss

Interface failure: metric vs. imperial units

- \$ 321 Million



Many Stakeholders



Number of Components

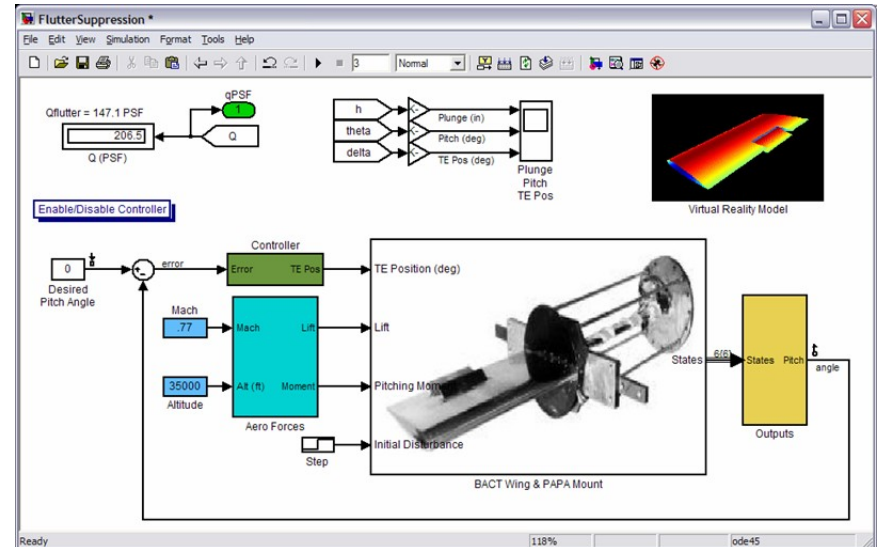
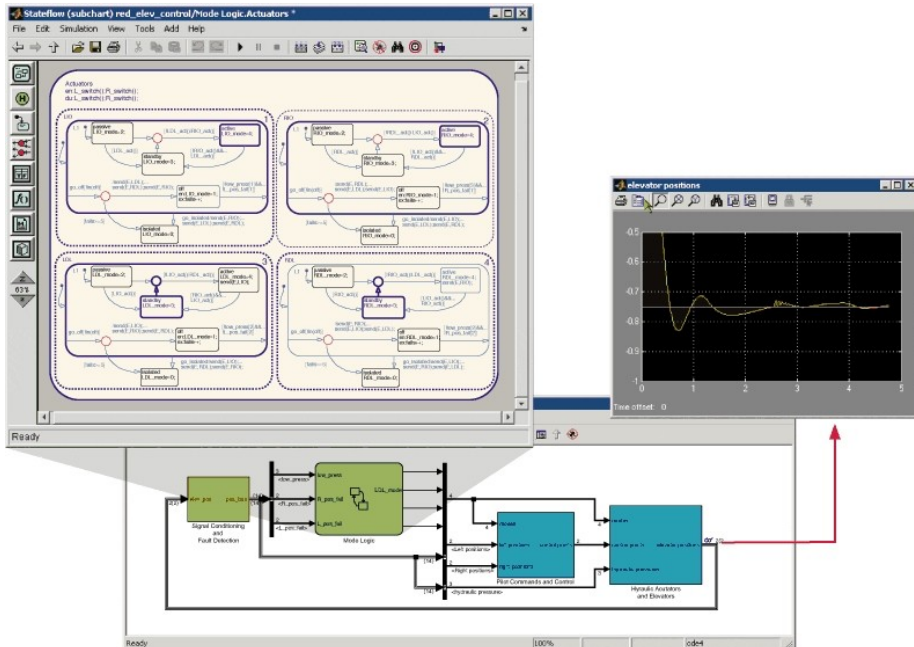
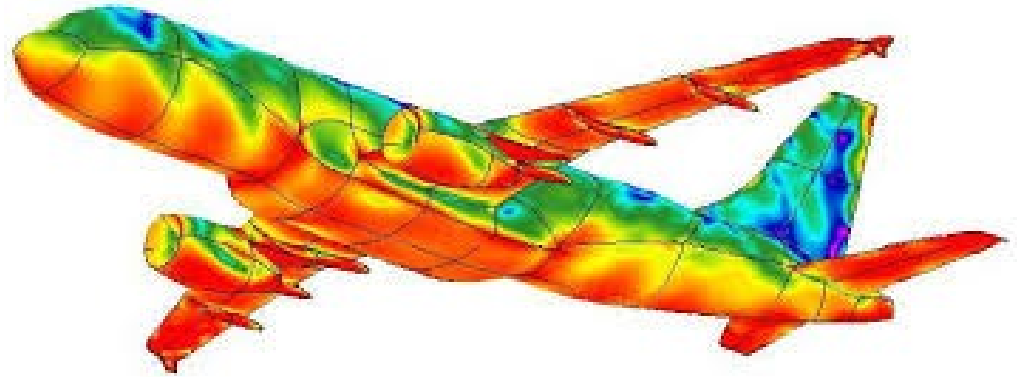


Heterogeneity

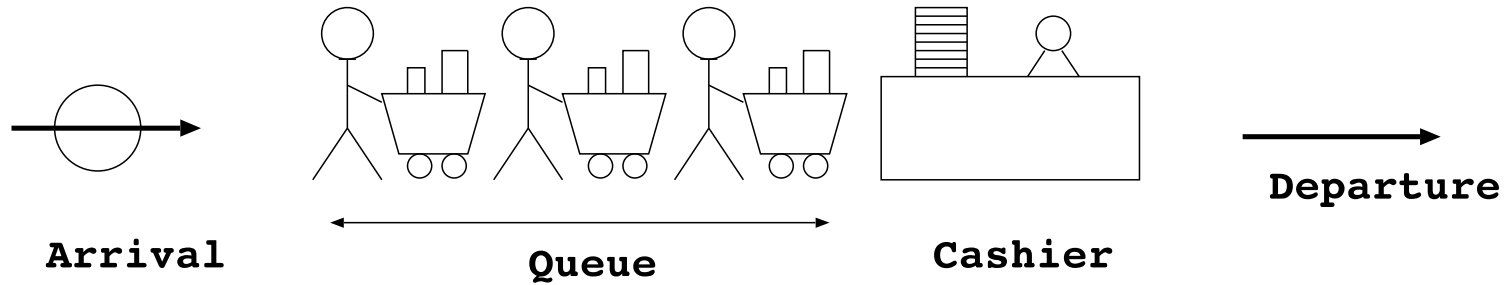


Tackle by **Multi-Paradigm Modelling (MPM)**:
explicit Modelling of all concerns/parts/...
 at the **most appropriate level(s)** of abstraction,
 using the **most appropriate formalism(s)**

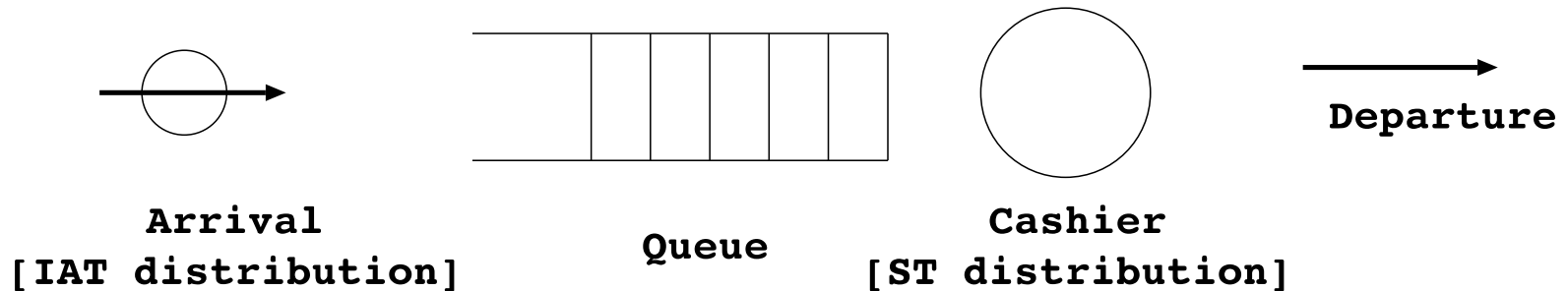
... but don't forget **processes!**



Example Process

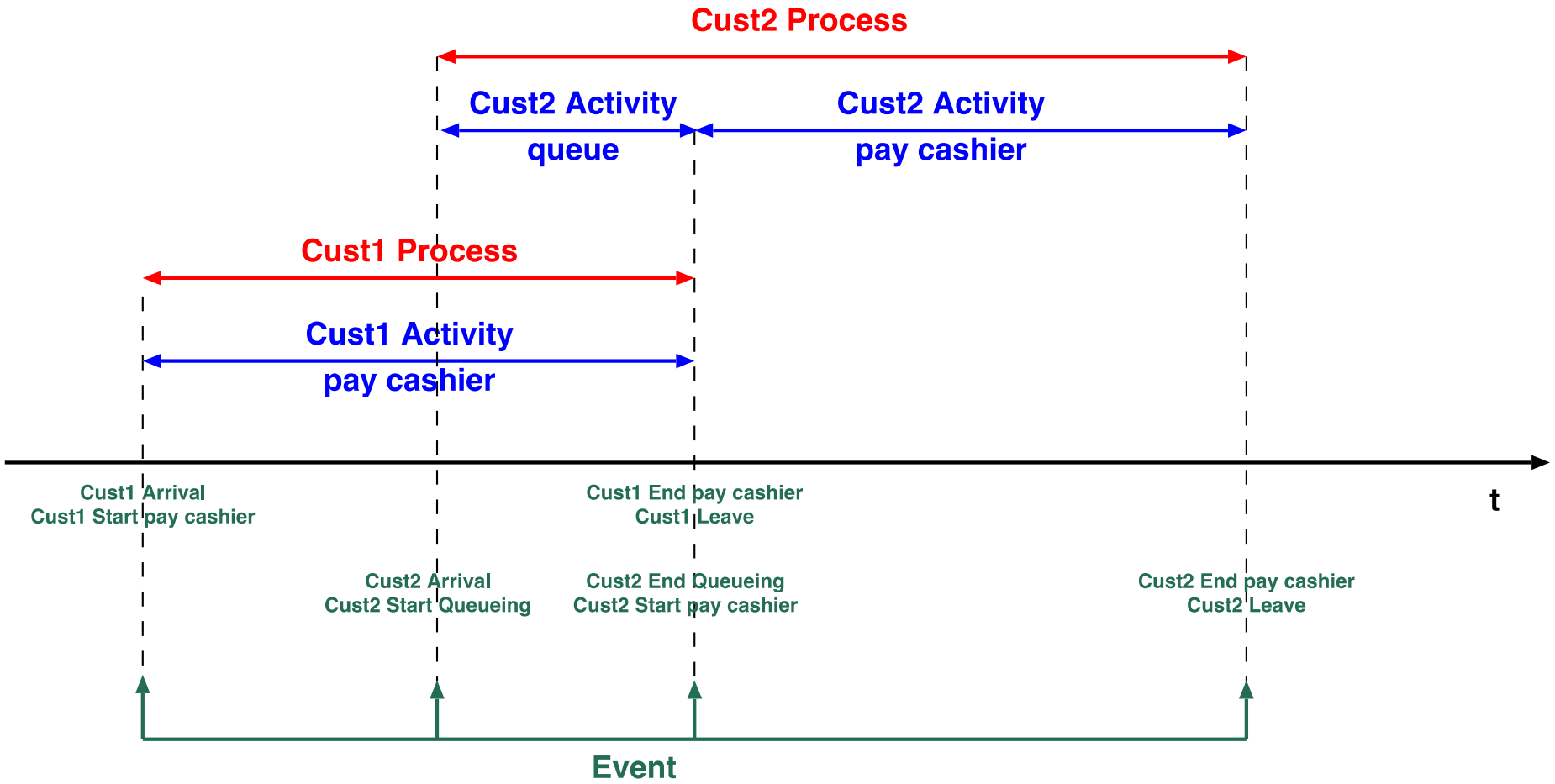


Physical View



Abstract View

Event/Activity/Process



Software Engineering Processes

“The Software Engineering **process** is the total set of Software Engineering **activities** needed to **transform** requirements into software”.

Watts S. Humphrey. Software Engineering Institute, CMU.
(portal.acm.org/citation.cfm?id=75122)

Capability Maturity Model

Processes!



From: <http://performancexpress.org/>

System Engineering Process

A logical **sequence of activities and decisions** that **transforms** an **operational need into a description** of system performance parameters and a preferred system configuration.

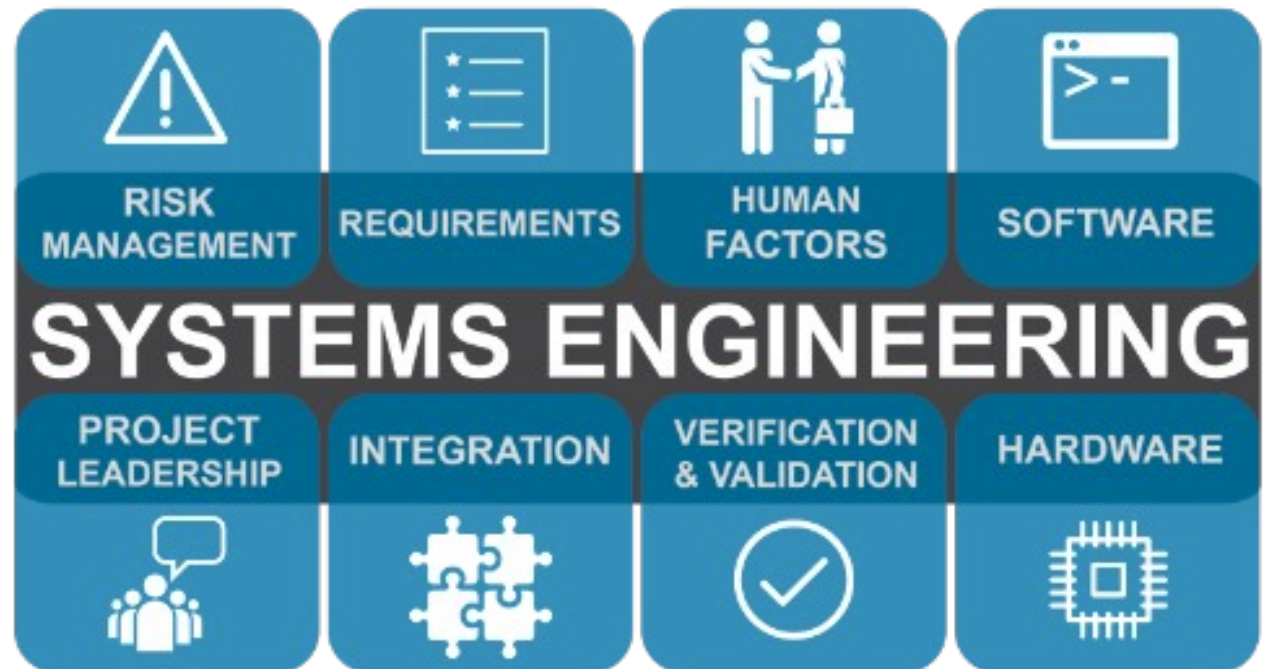
MIL-STD-499A, Engineering Management, 1 May 1974

An interdisciplinary, collaborative approach that derives, evolves, and verifies a life-cycle balanced system solution which satisfies customer expectations and meets public acceptability.

IEEE P1220, Standard for Application and Management of the Systems Engineering Process, [Final Draft], 26 September 1994



Processes!



System Engineering

Typical High-Tech Commercial Systems Integrator

Study Period				Implementation Period			Operations Period		
User Requirements Definition Phase	Concept Definition Phase	System Specification Phase	Acq Prep Phase	Source Select. Phase	Development Phase	Verification Phase	Deployment Phase	Operations and Maintenance Phase	Deactivation Phase

Typical High-Tech Commercial Manufacturer

Study Period			Implementation Period			Operations Period		
Product Requirements Phase	Product Definition Phase	Product Development Phase	Engr Model Phase	Internal Test Phase	External Test Phase	Full-Scale Production Phase	Manufacturing, Sales, and Support Phase	Deactivation Phase

ISO/IEC 15288

Concept Stage	Development Stage	Production Stage	Utilization Stage	Retirement Phase
			Support Phase	

US Department of Defense (DoD) 5000.2

A	B	C	IOC	FOC
Pre-systems Acquisition Concept and Technology Development	Systems Acquisition System Development & Demonstration		Production and Deployment	Sustainment Operations and Support (including Disposal)

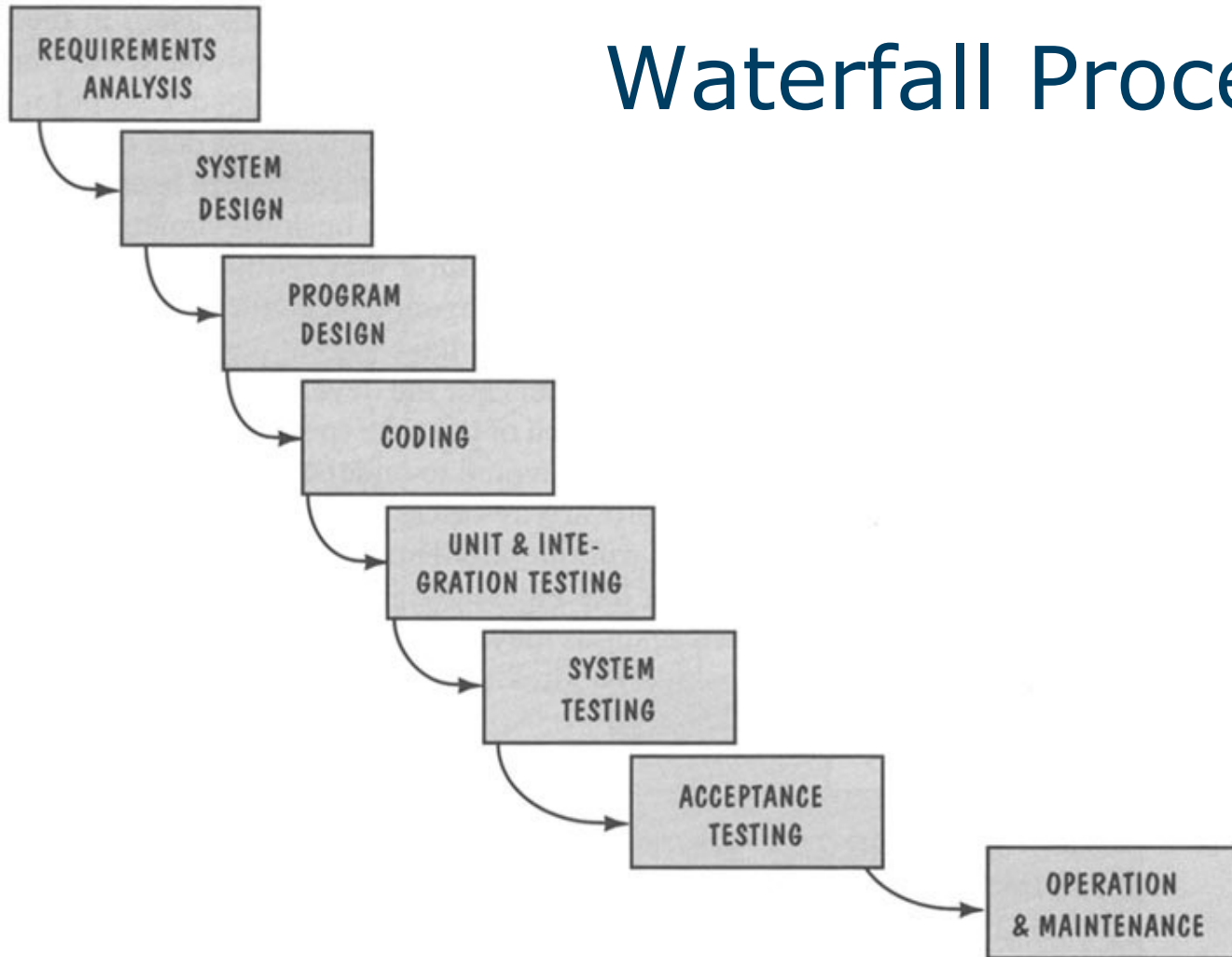
US Department of Energy (DoE)

Project Planning Period			Project Execution			Mission	
Pre-Project	Preconceptual Planning	Conceptual Design	Preliminary Design	Final Design	Construction	Acceptance	Operations

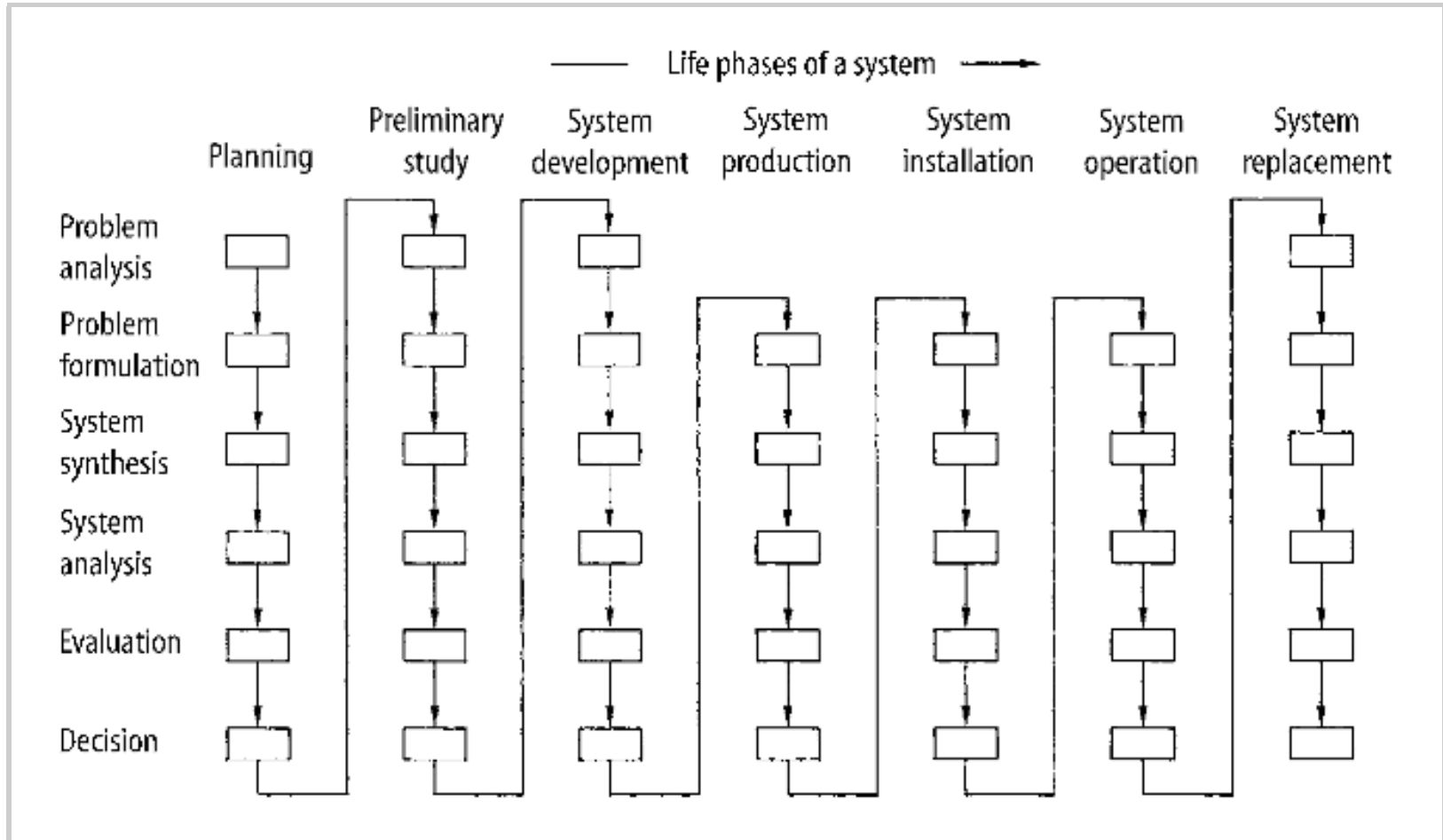


From: INCOSE, System Engineering Handbook, v3., 2006

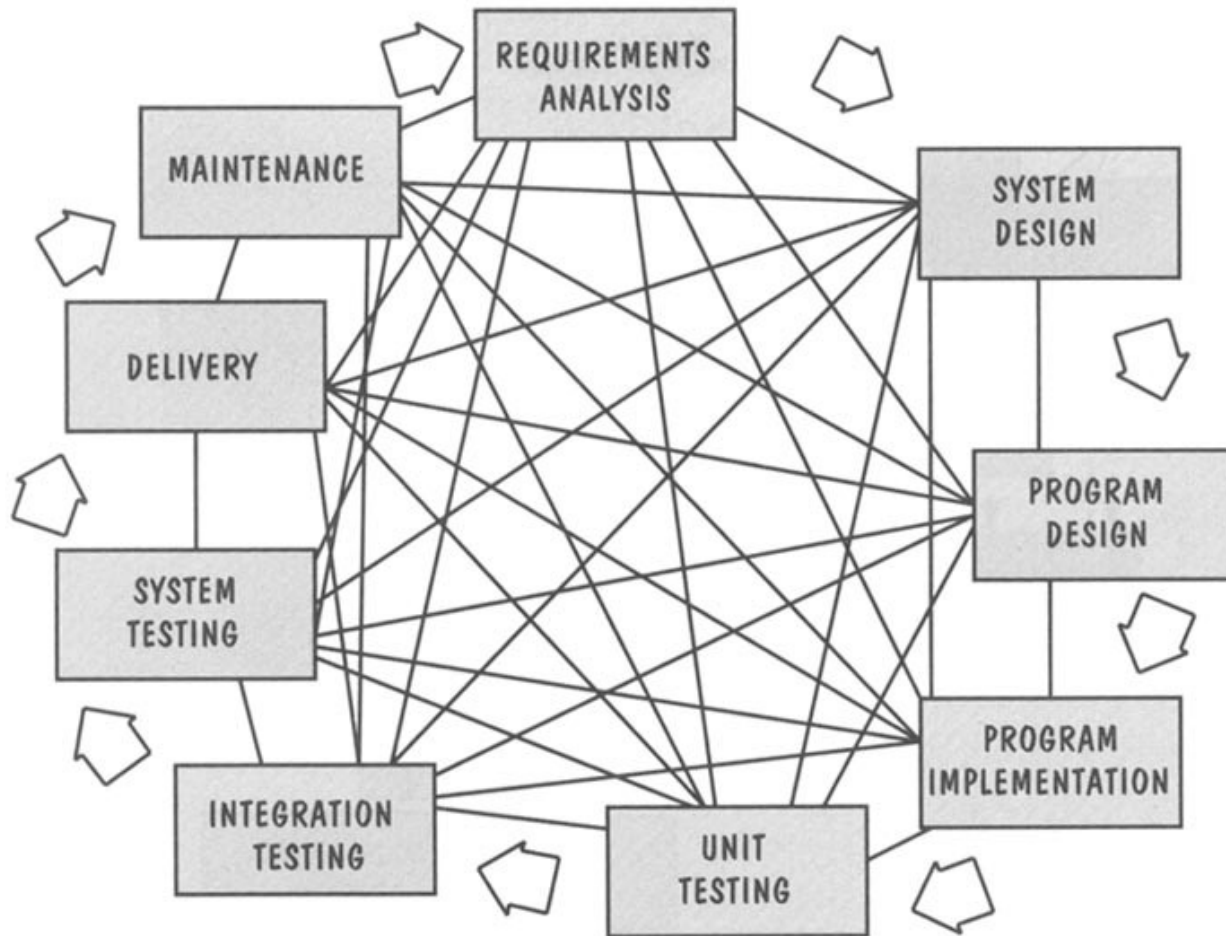
Waterfall Process



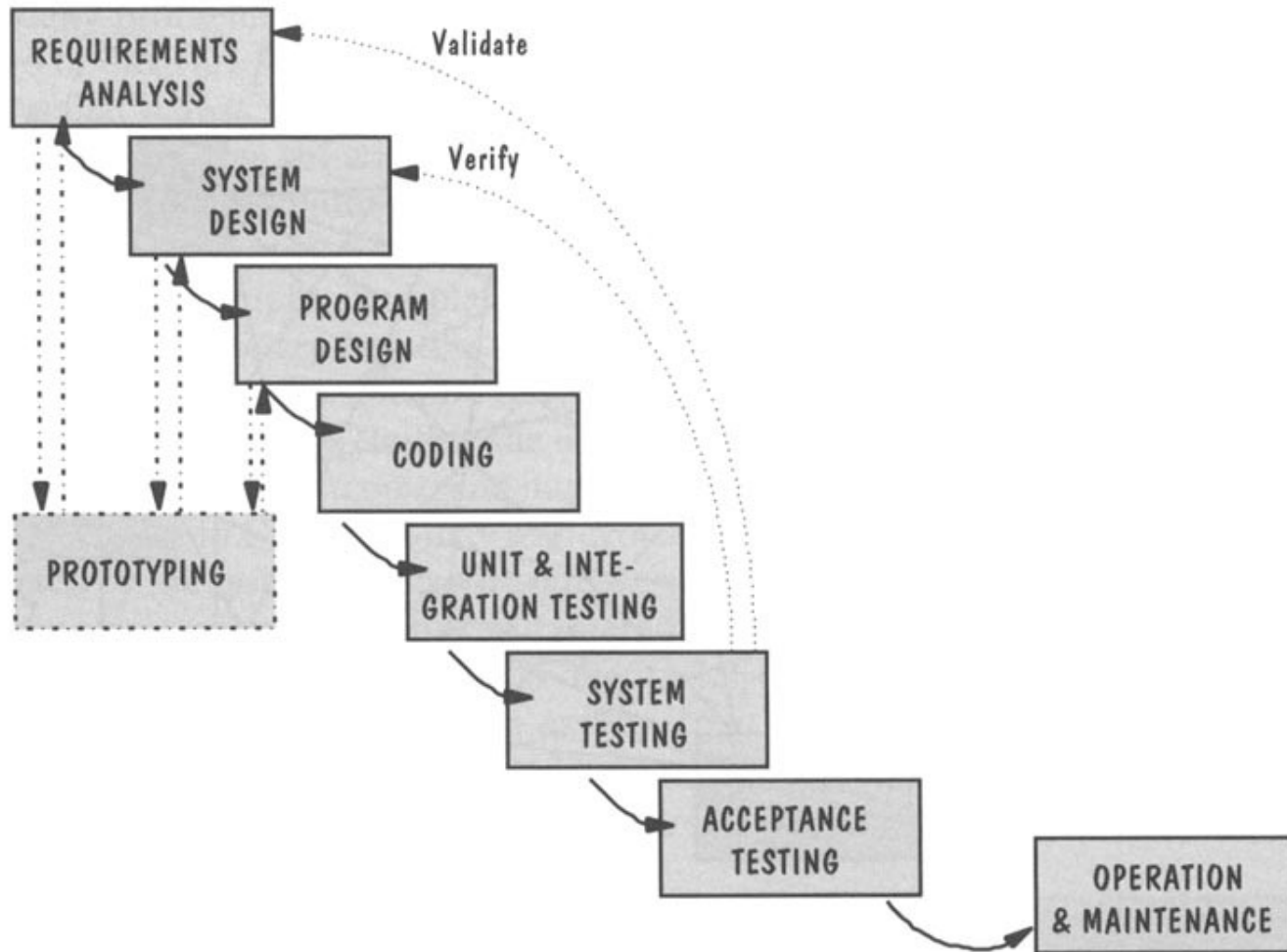
Mechanical Engineering



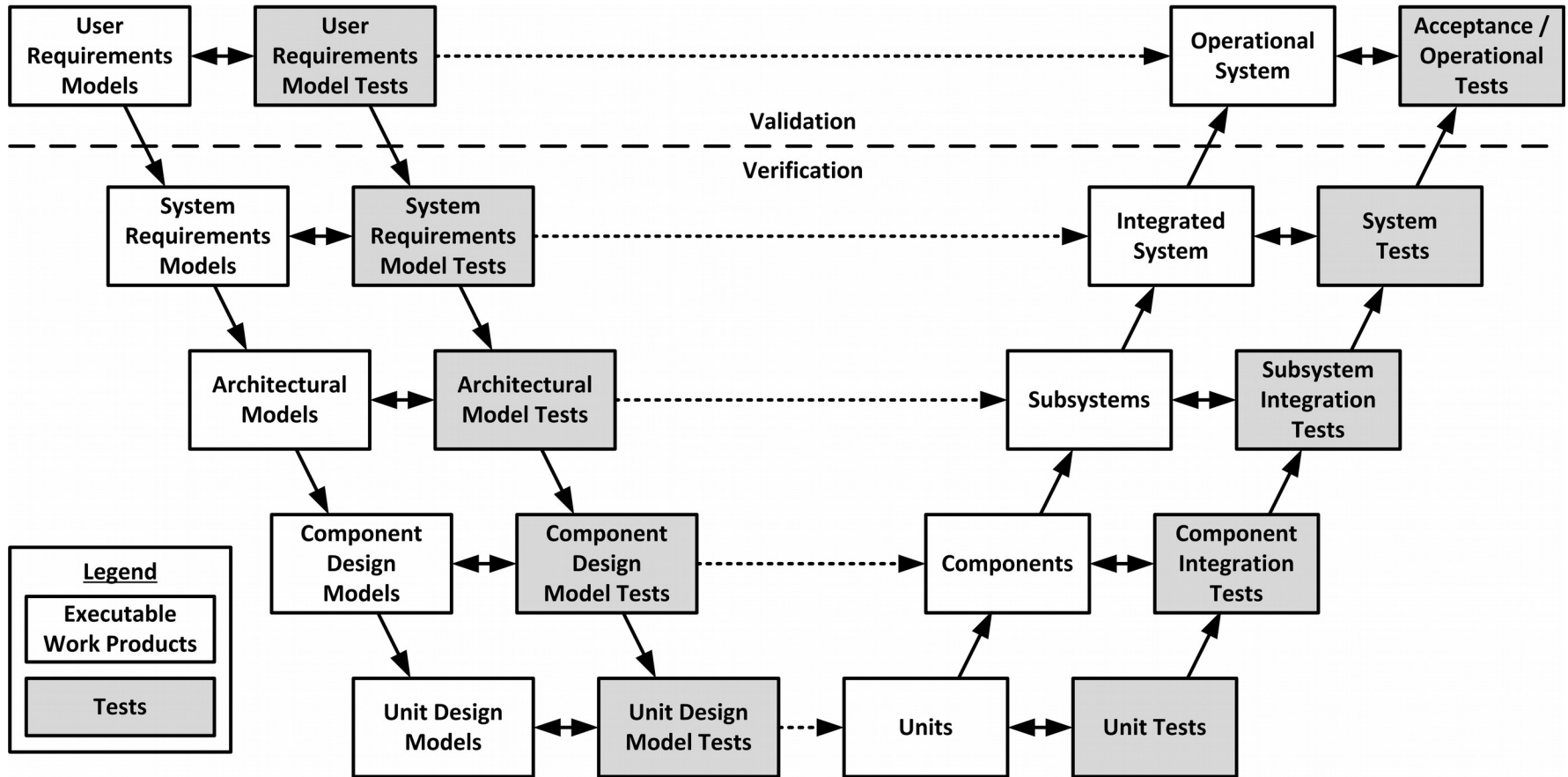
In Reality?



With Prototyping



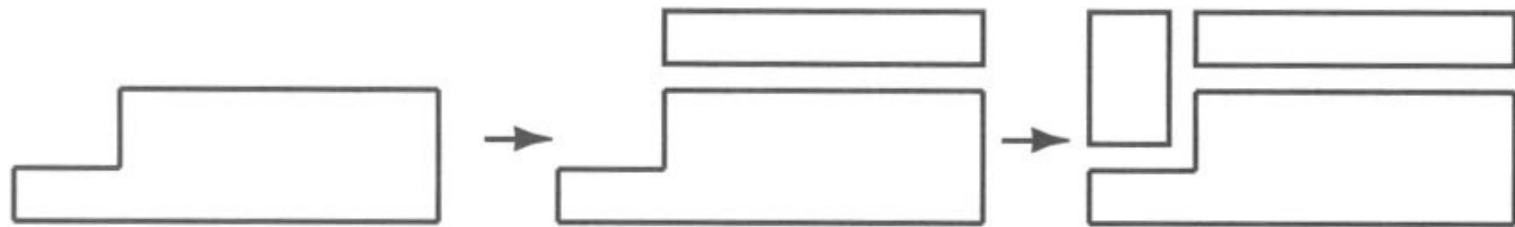
V-Model



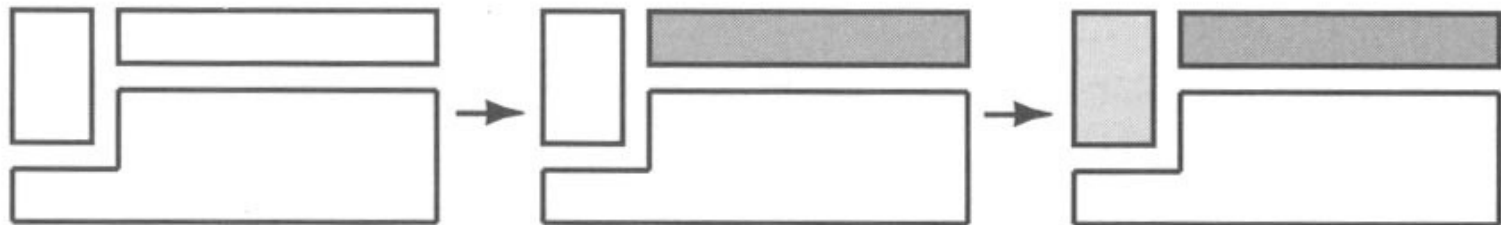
Kevin Forsberg and Harold Mooz, "The Relationship of System Engineering to the Project Cycle," in Proceedings of the First Annual Symposium of National Council on System Engineering, October 1991: 57-65.

Iterative vs. Incremental

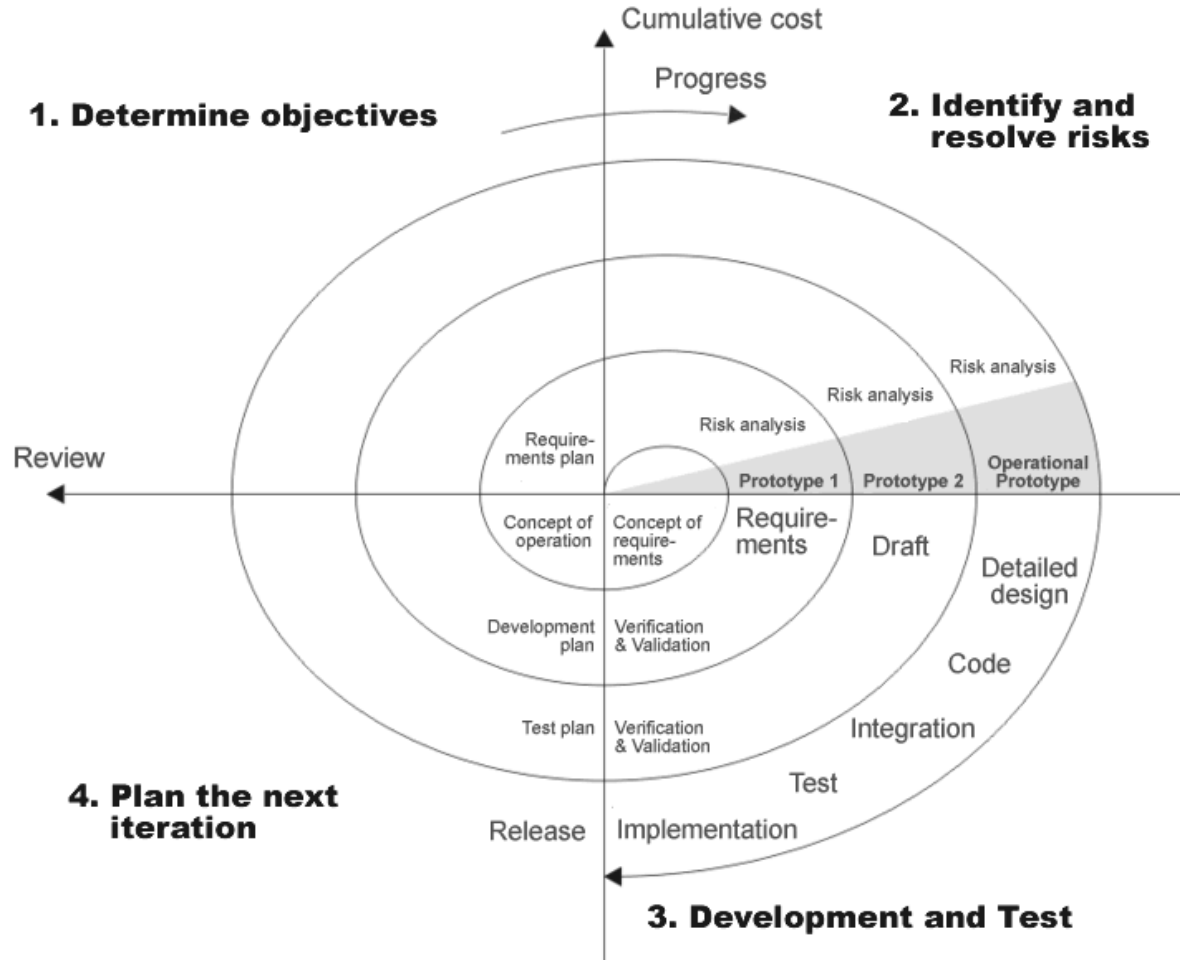
INCREMENTAL DEVELOPMENT



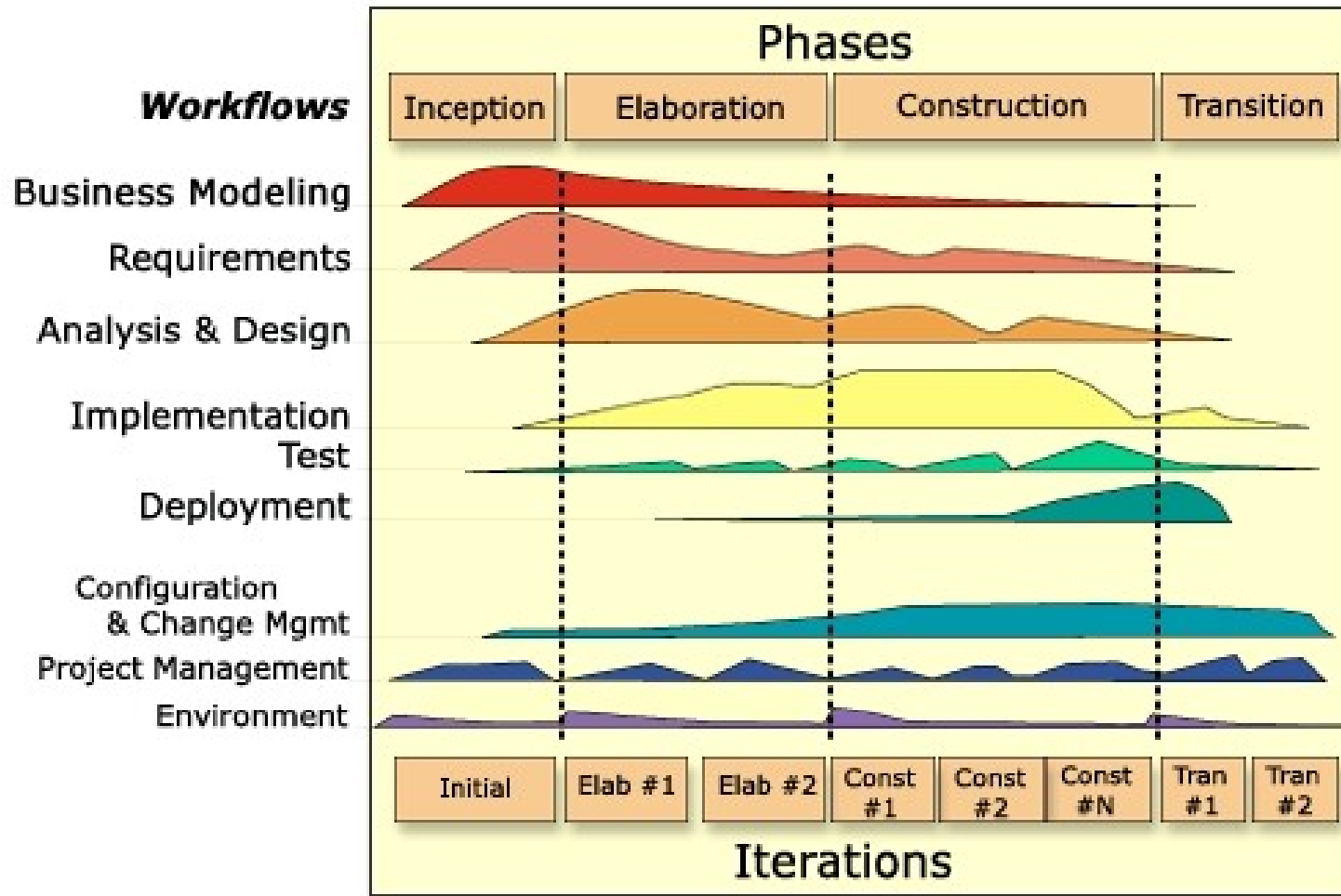
ITERATIVE DEVELOPMENT



Software Engineering



(Rational) Unified Process



Types of Process Modelling



Descriptive

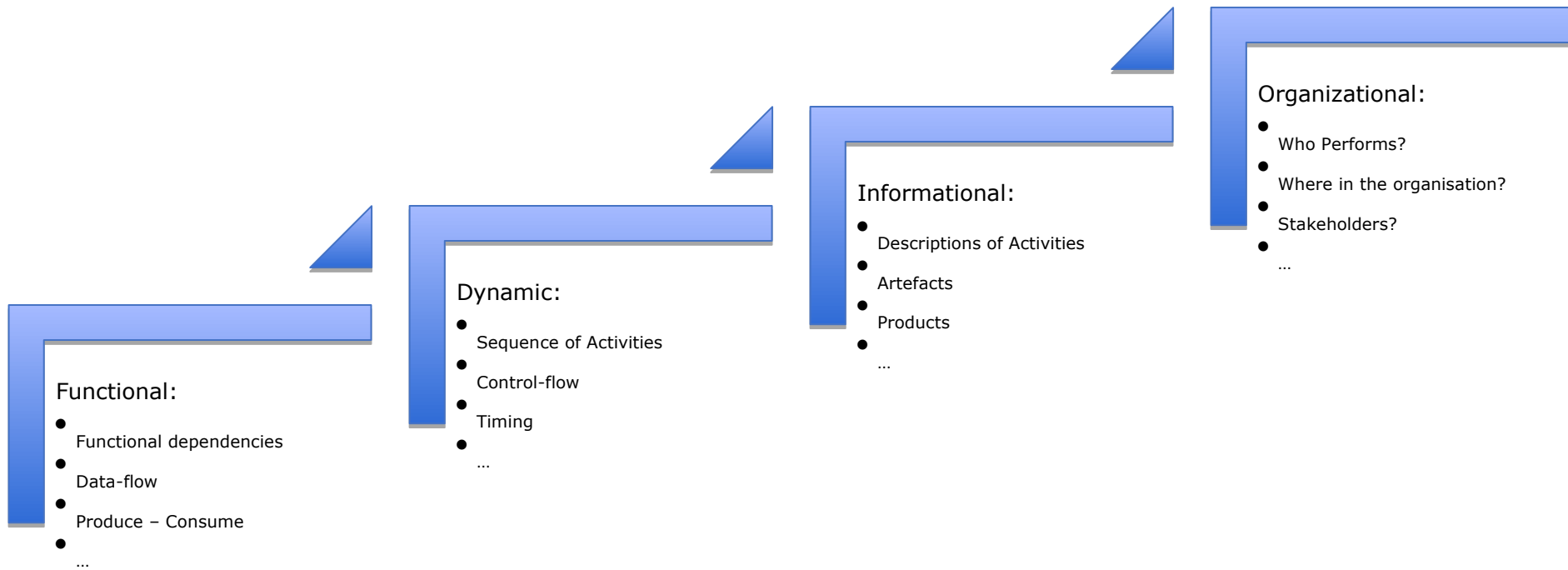


Prescriptive



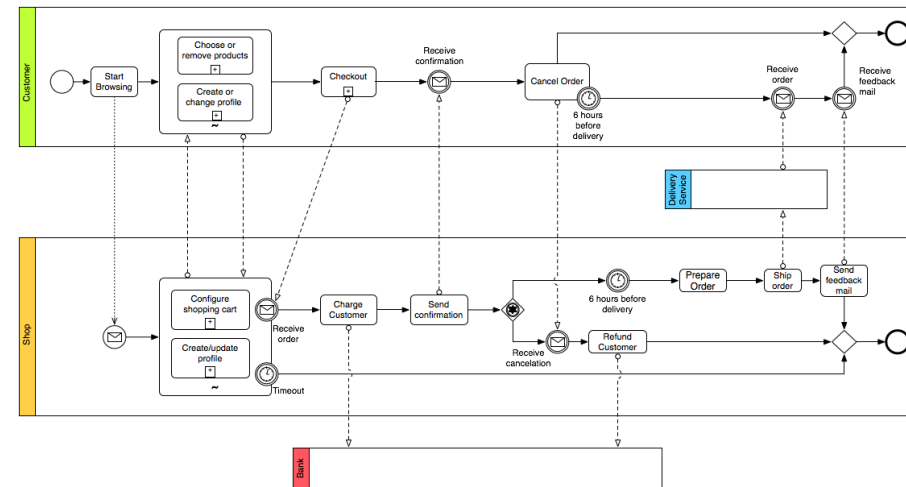
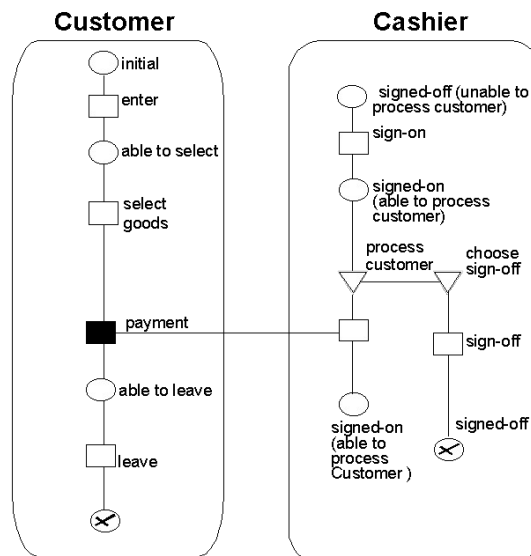
Proscriptive

Describing Processes

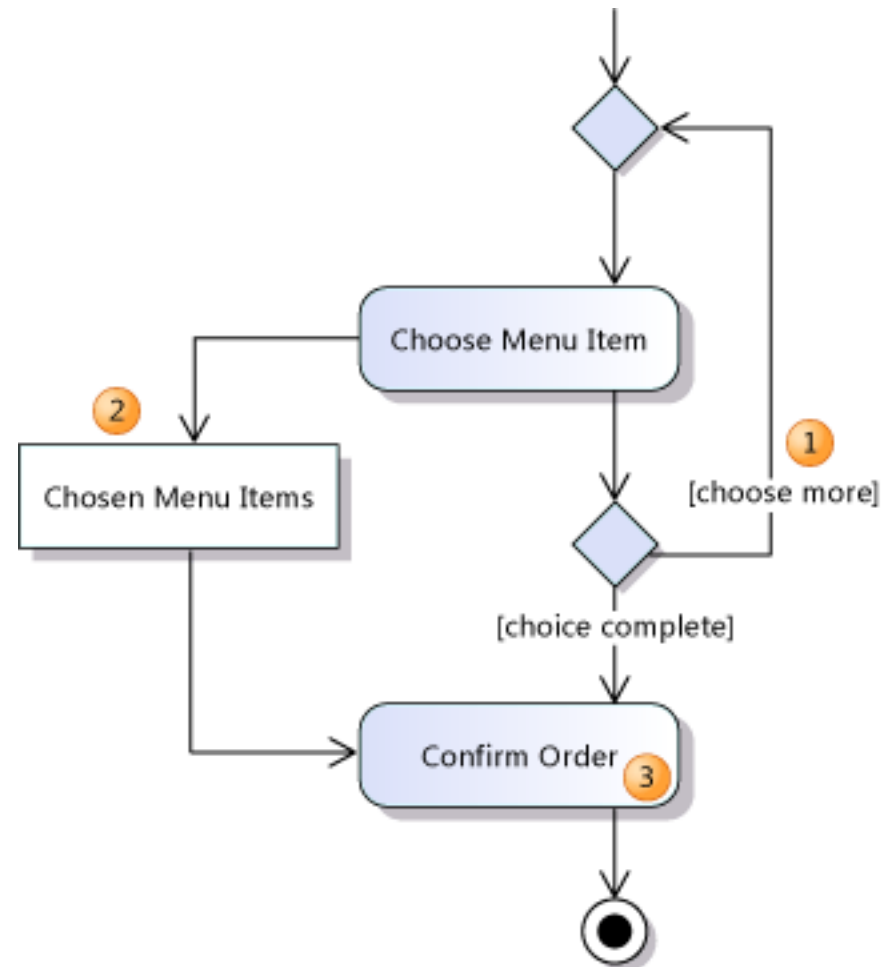
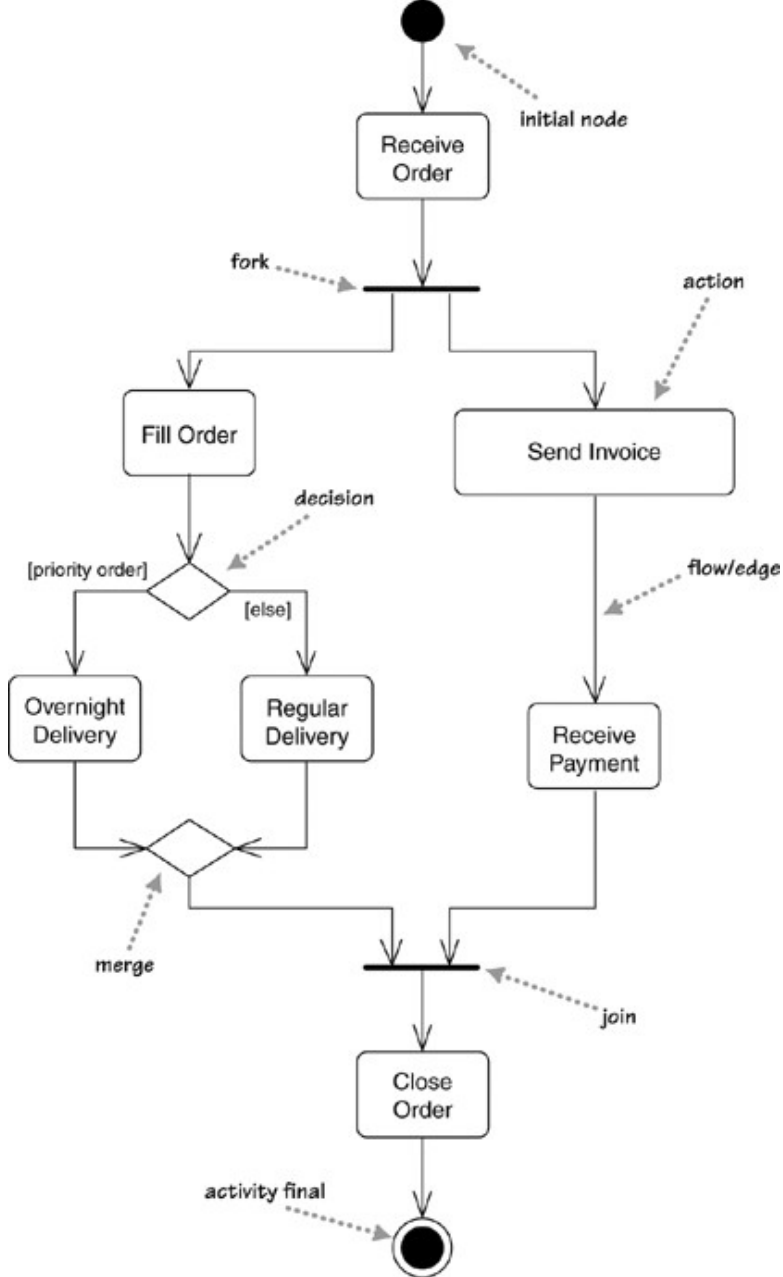


Languages!

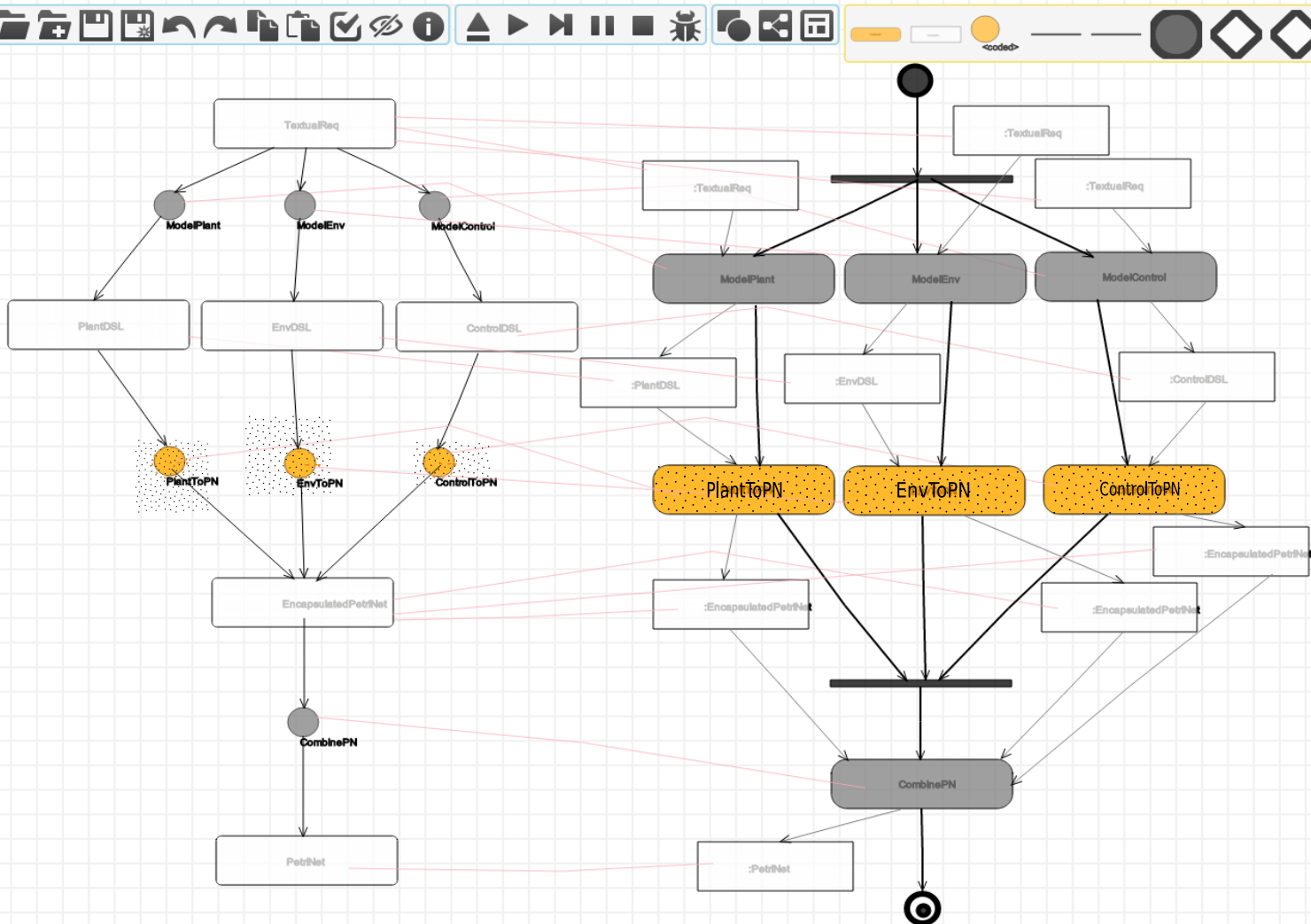
- **UML Activities**
- Business Process Modelling Notation (BPMN)
- Event Process Chains
- Petri-nets
- Role Activity Diagram
- **FTG+PM**
- Etc.



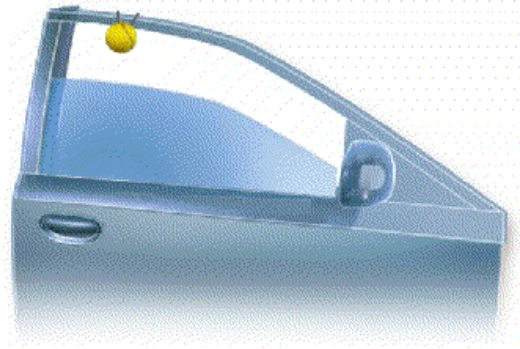
UML Activities



FTG+PM: Typing



Power Window Example



Reactive!

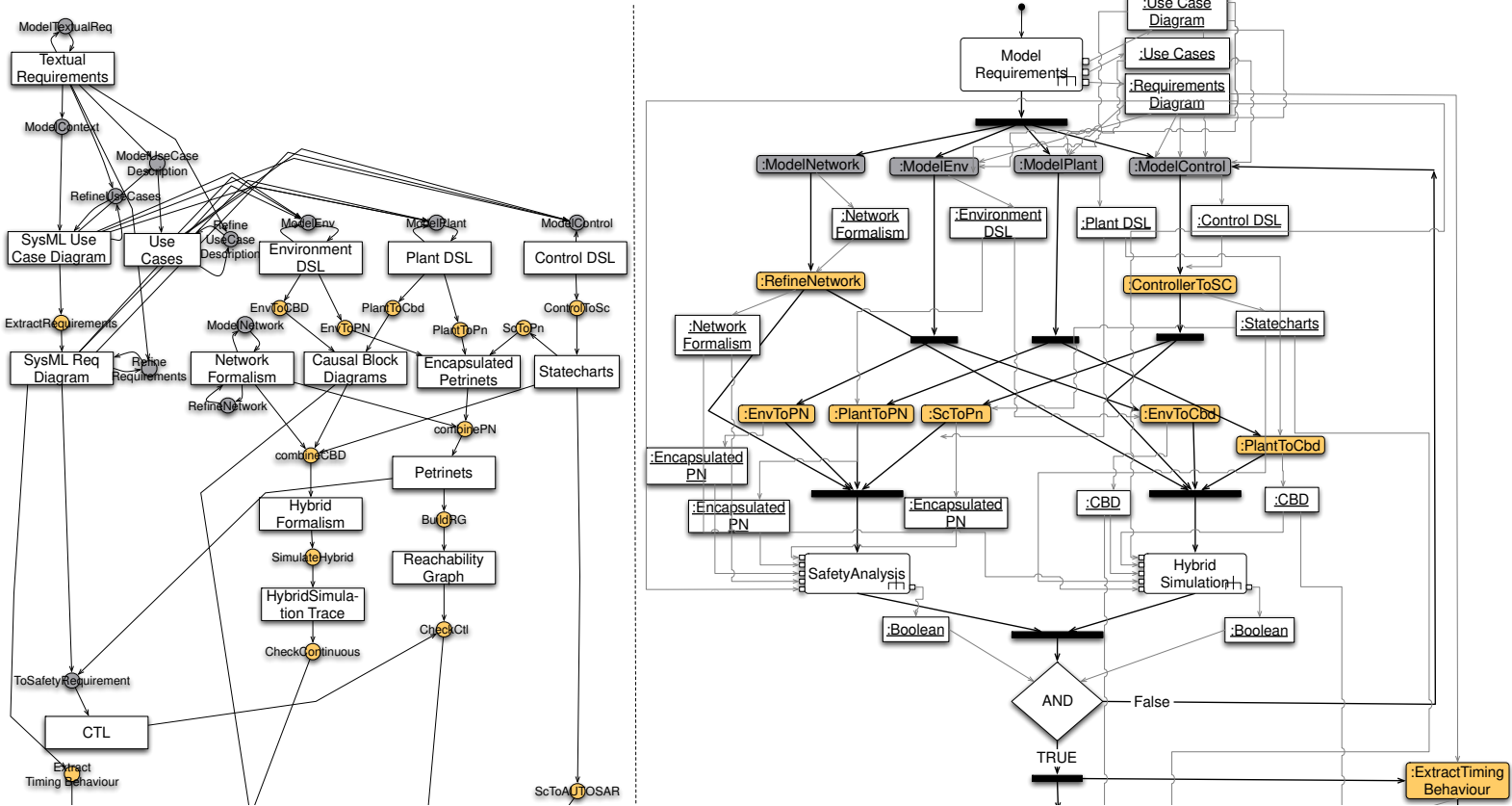
Real-time!

Distributed!

Embedded!

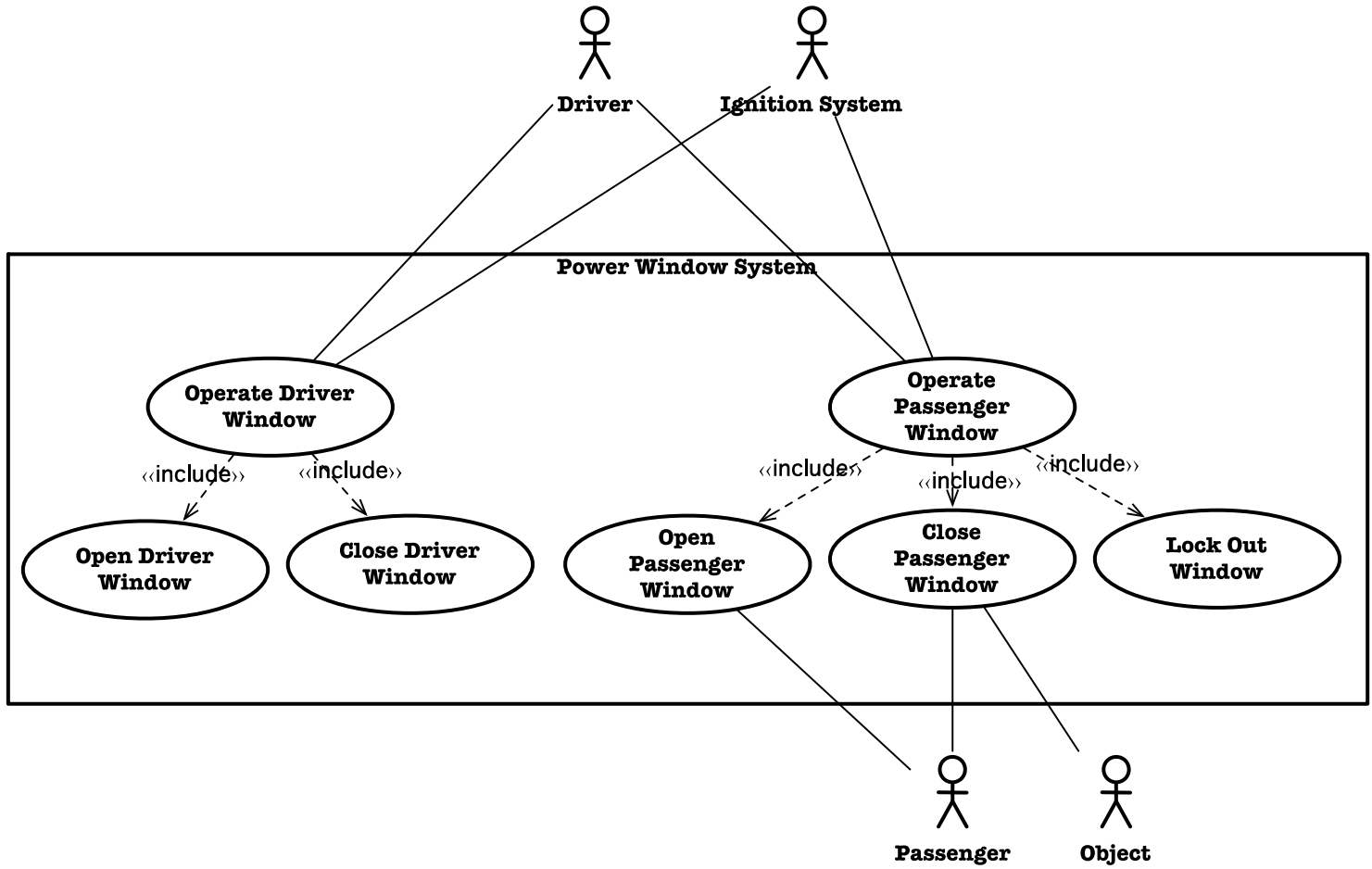
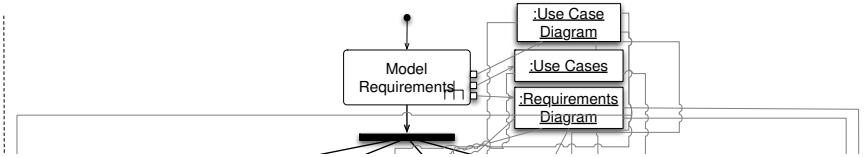
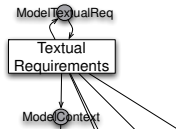
Heterogeneous!

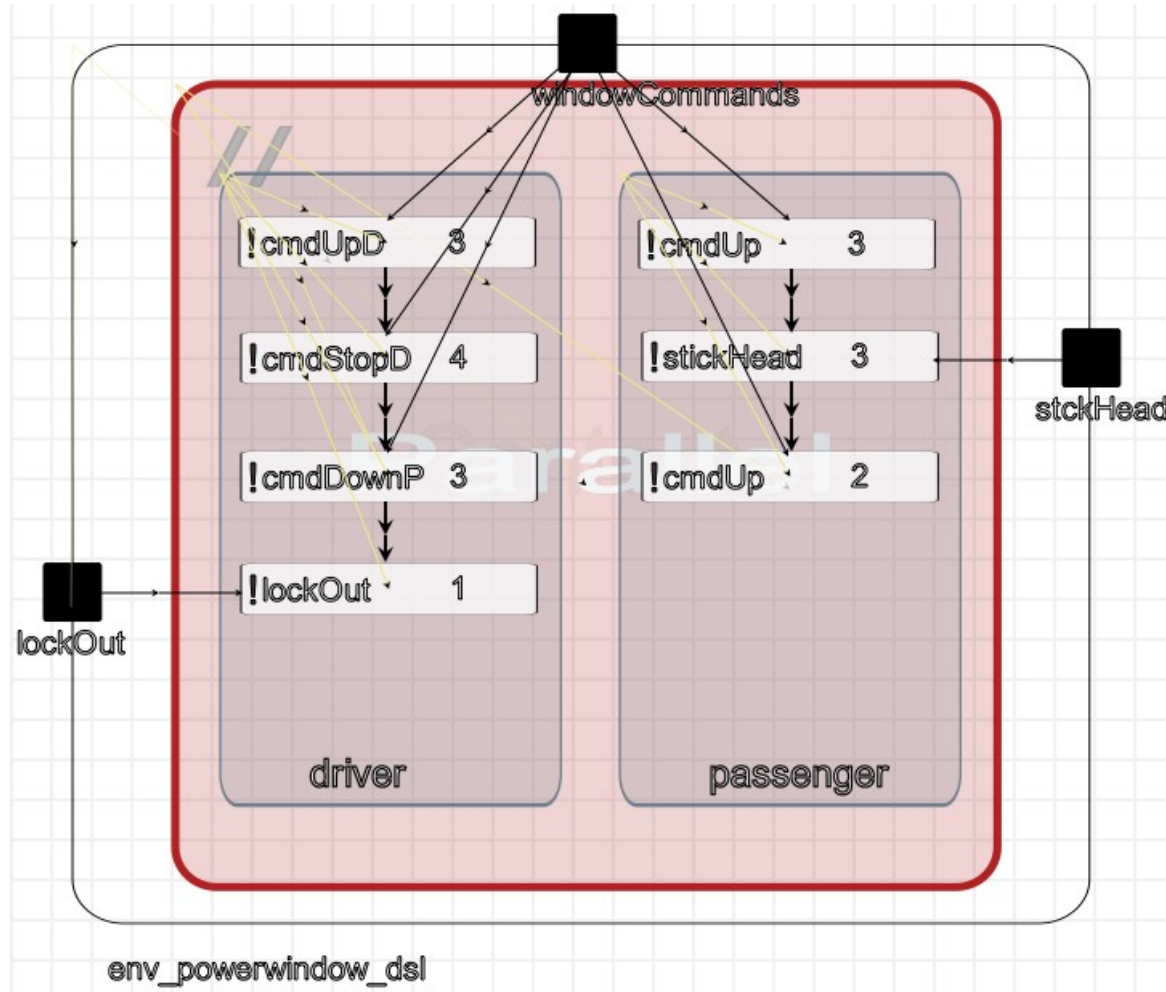
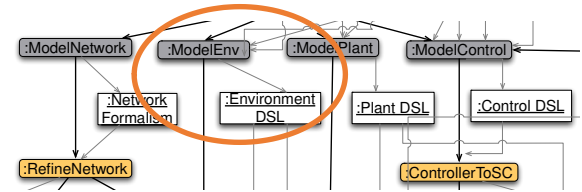
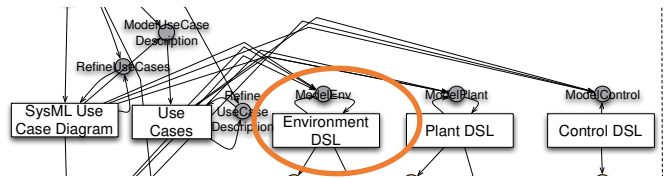
Process Modelling for MPM



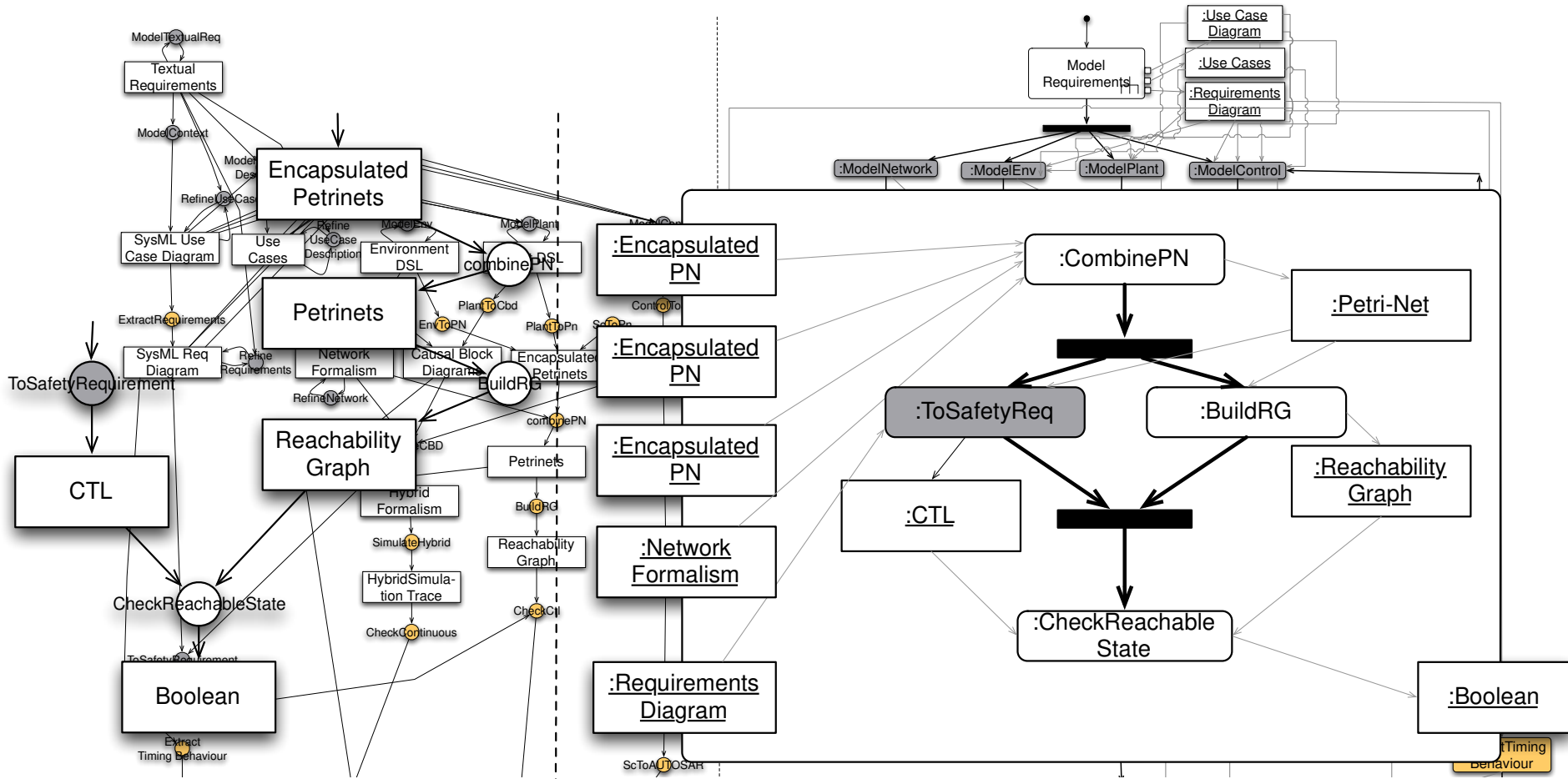
Levi Lucio, Sadaf Mustafiz, Joachim Denil, Hans Vangheluwe, Maris Jukss, FTG+PM: An Integrated Framework for Investigating Model Transformation Chains. SDL Forum 2013: 182-202

Sadaf Mustafiz, Joachim Denil, Levi Lucio, and Hans Vangheluwe; "The FTG+PM Framework for Multi-Paradigm Modelling: An Automotive Case Study"; Accepted @ MPM2012 of Models2012, 2012

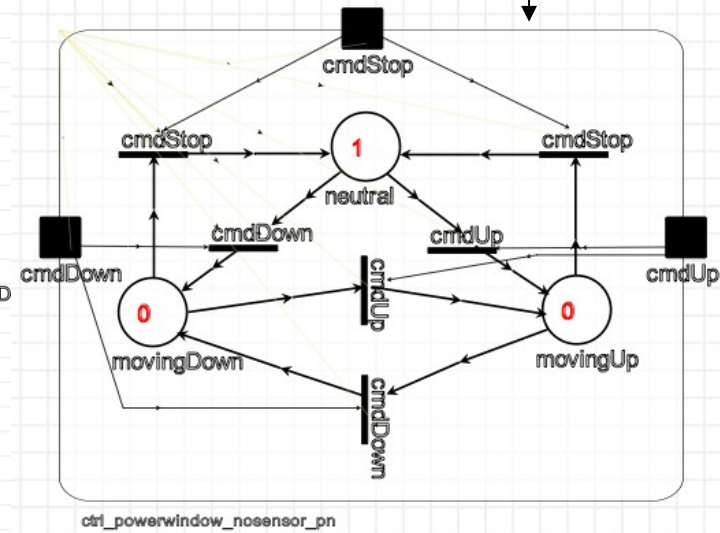
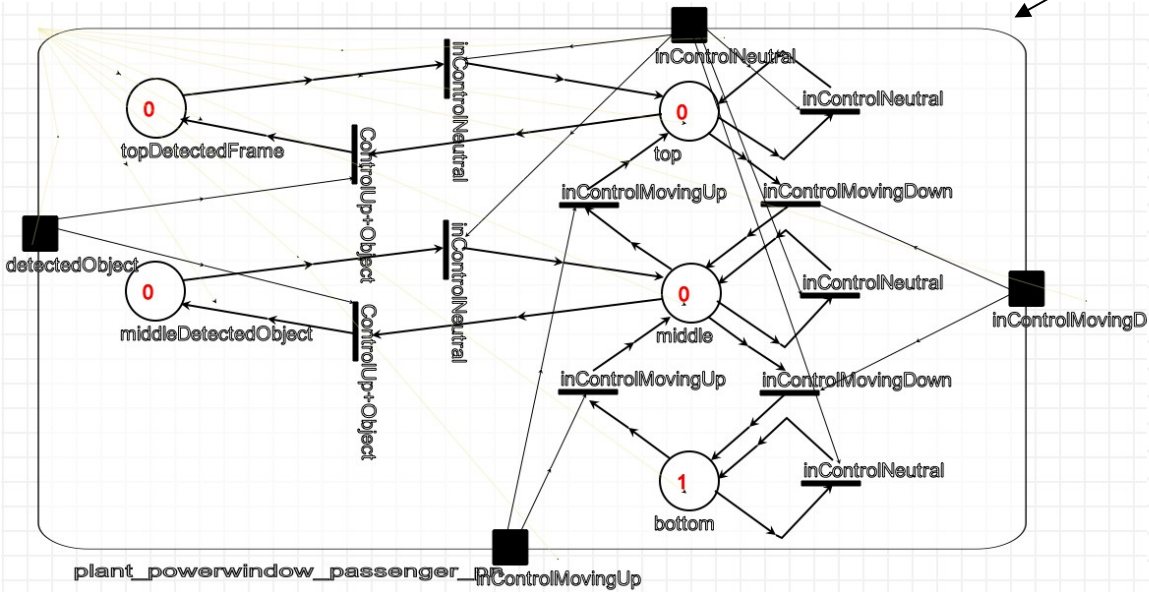
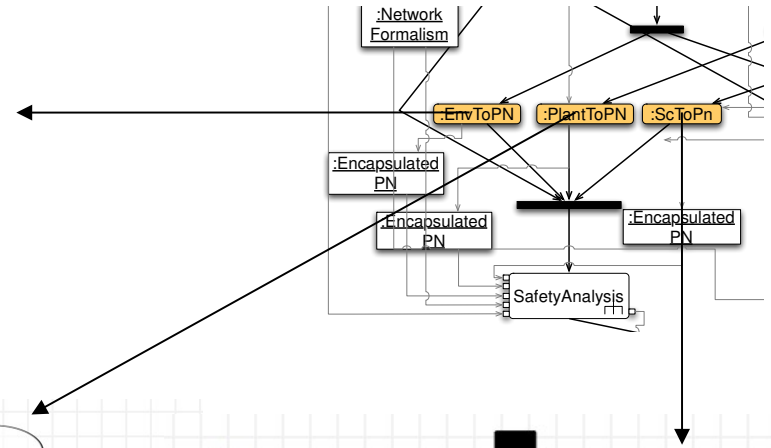
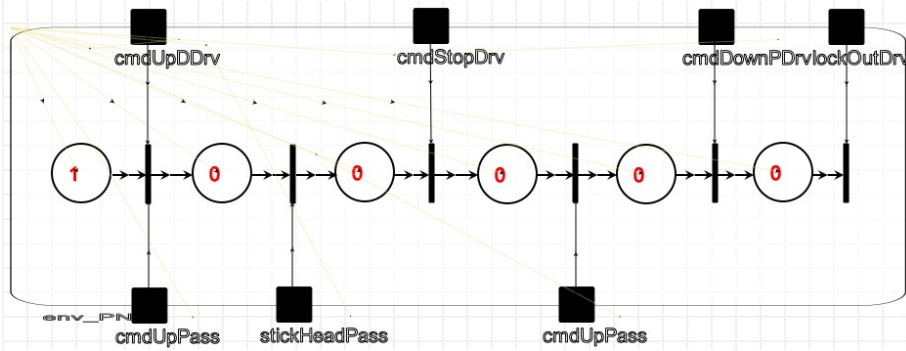




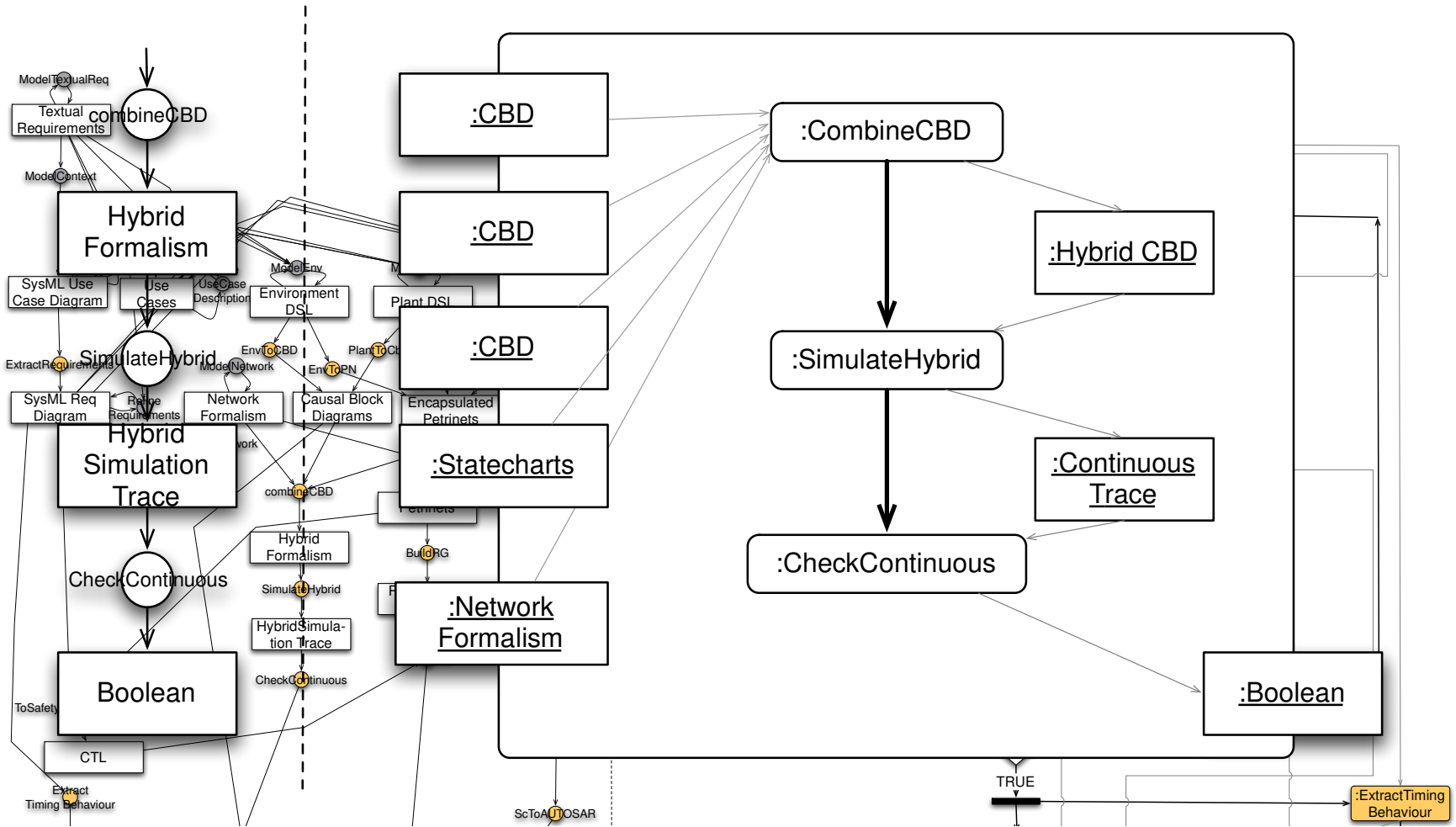
Safety Analysis



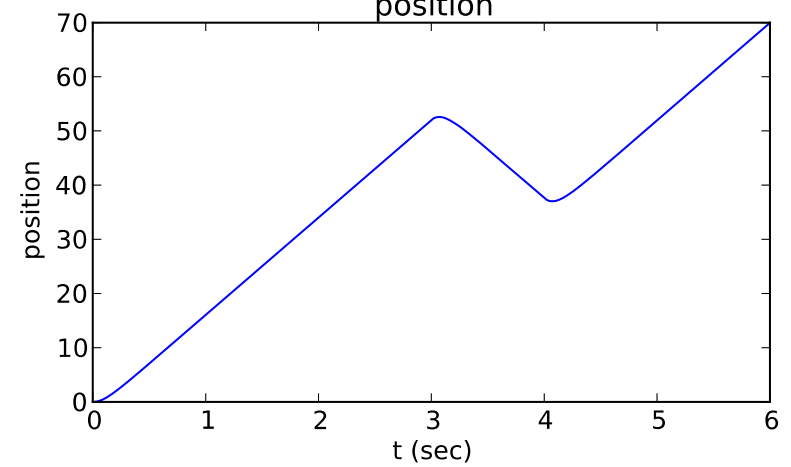
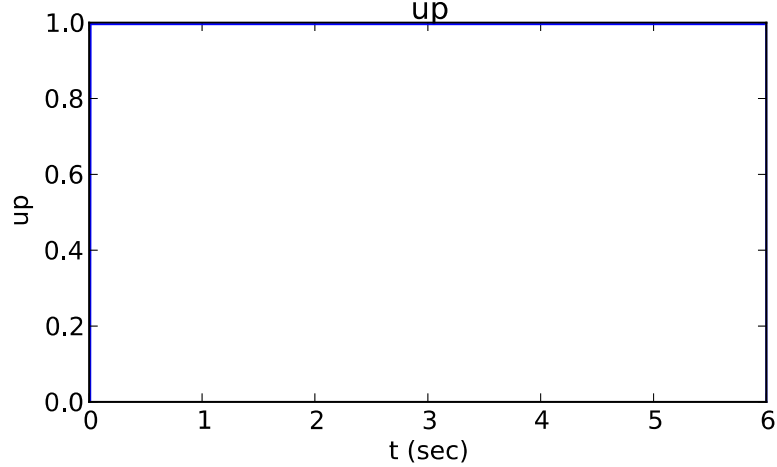
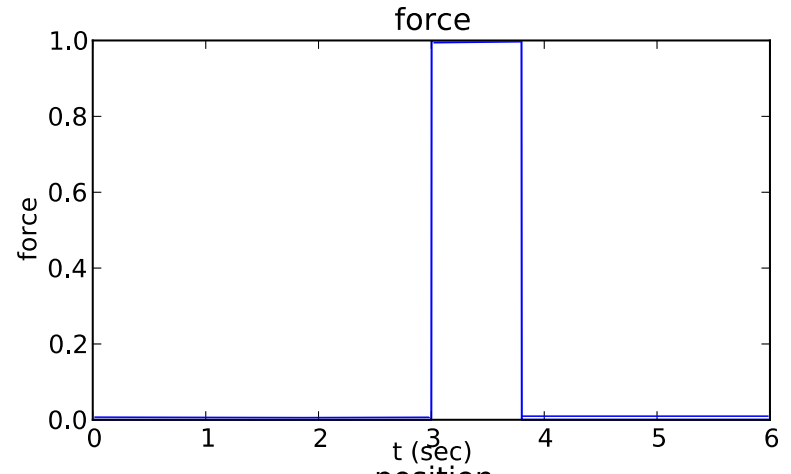
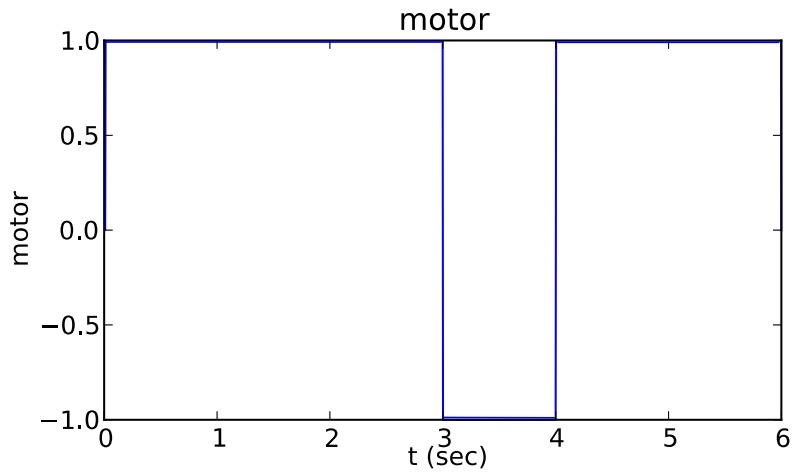
Safety Analysis Models



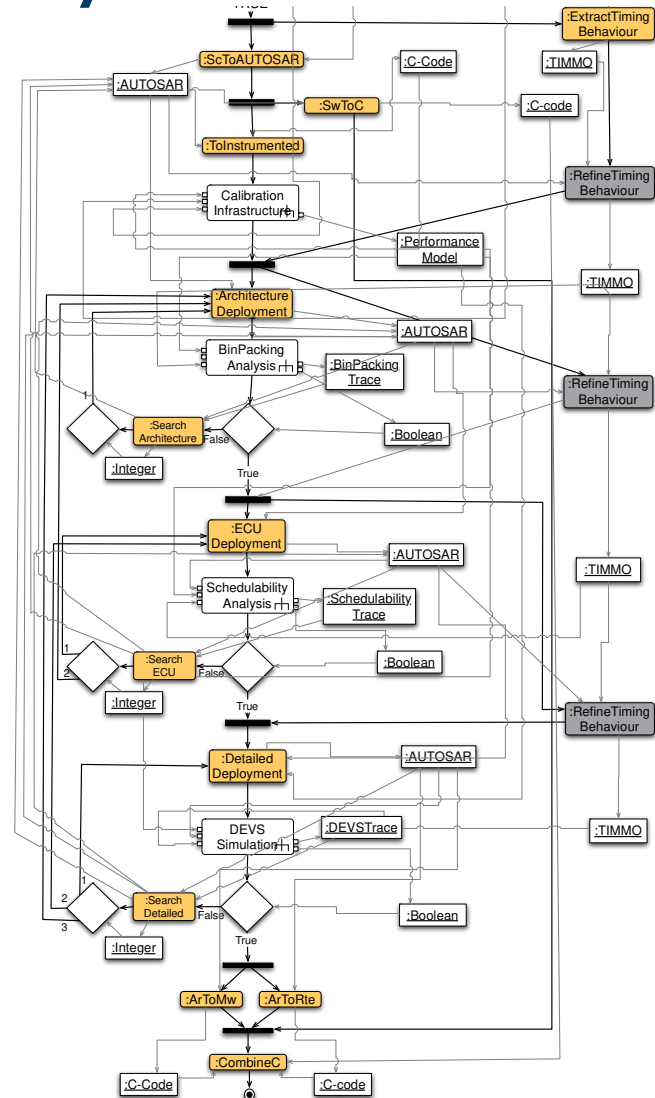
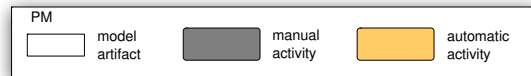
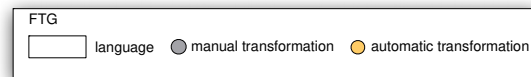
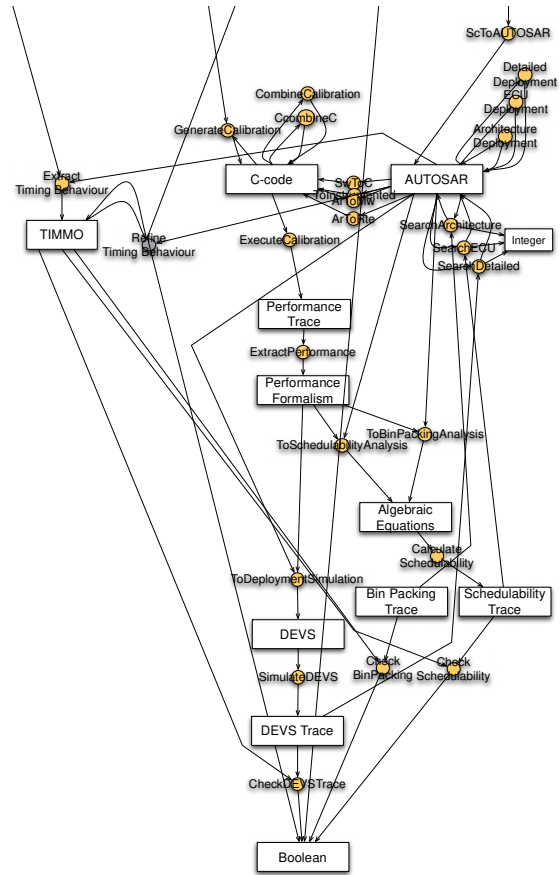
Hybrid Simulation



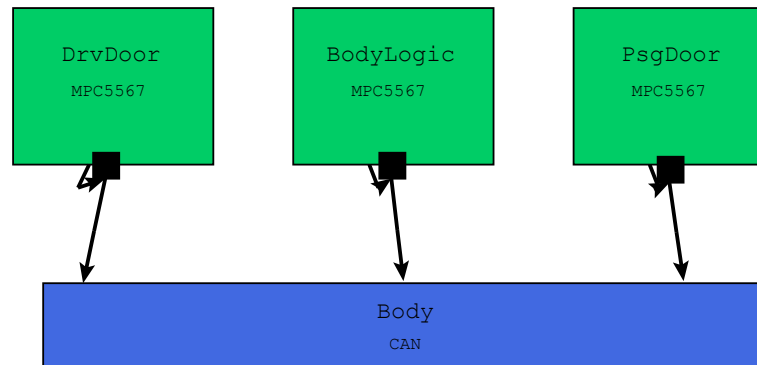
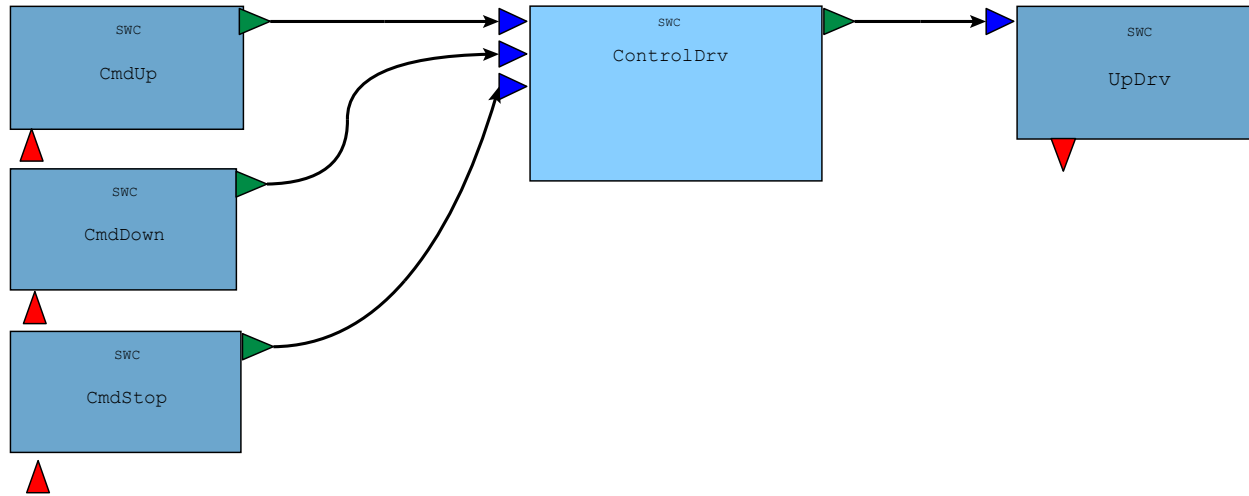
Hybrid Models and Trace



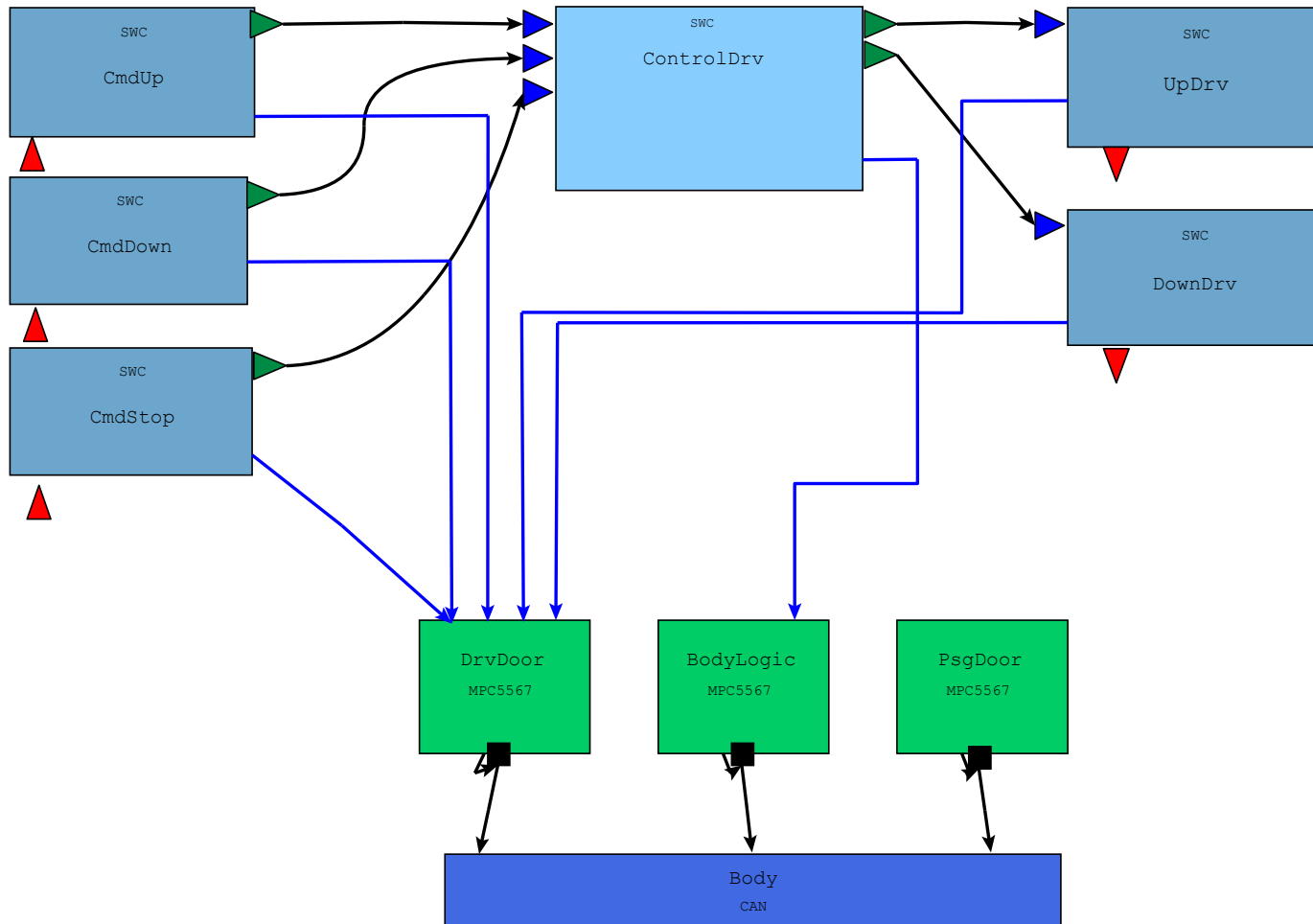
Deployment Process



Deployment

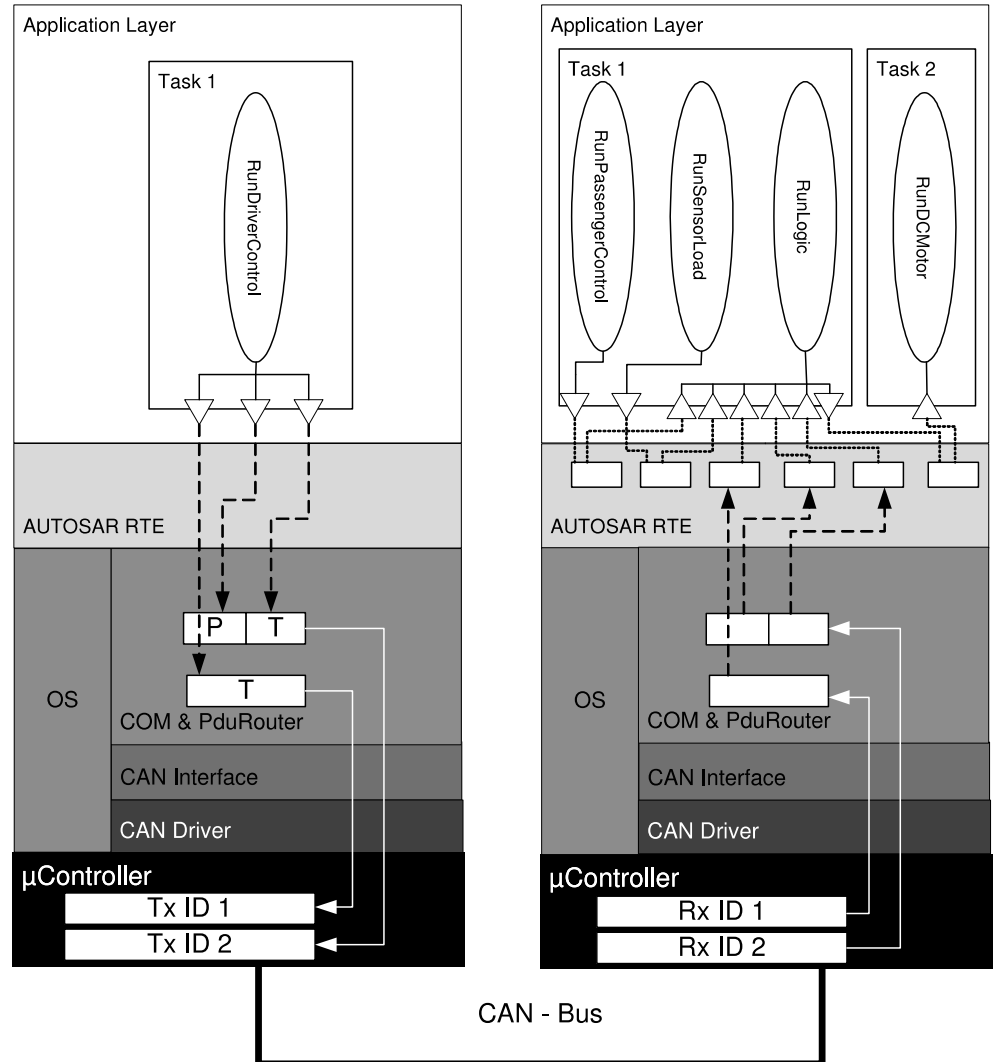


Deployment

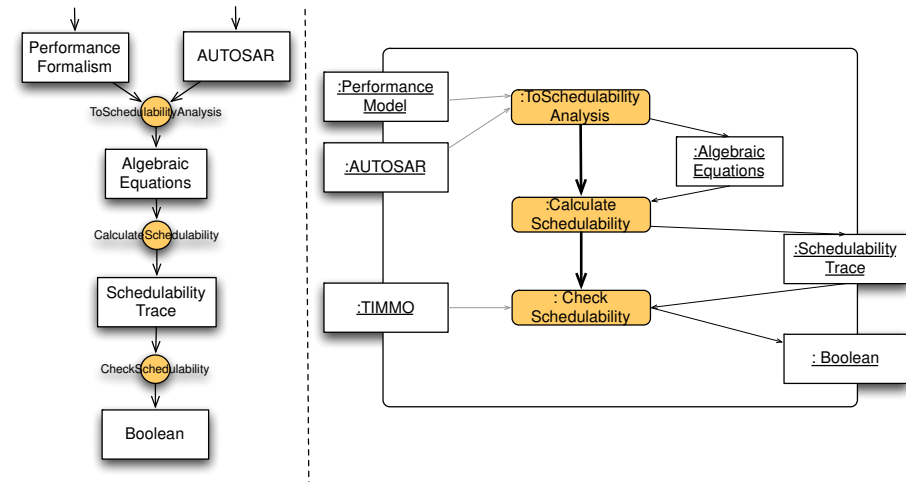
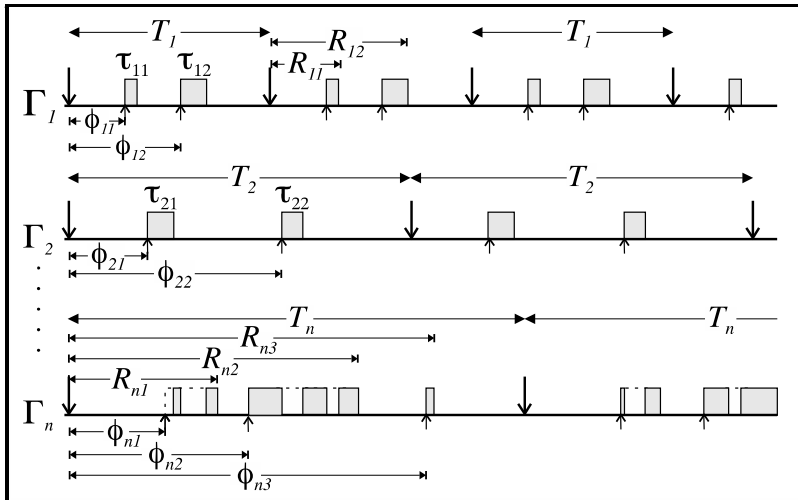
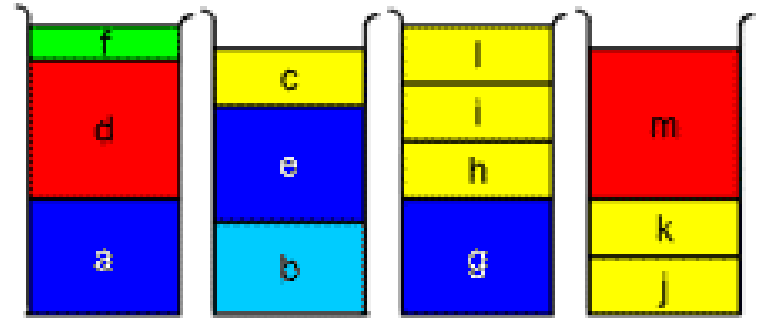
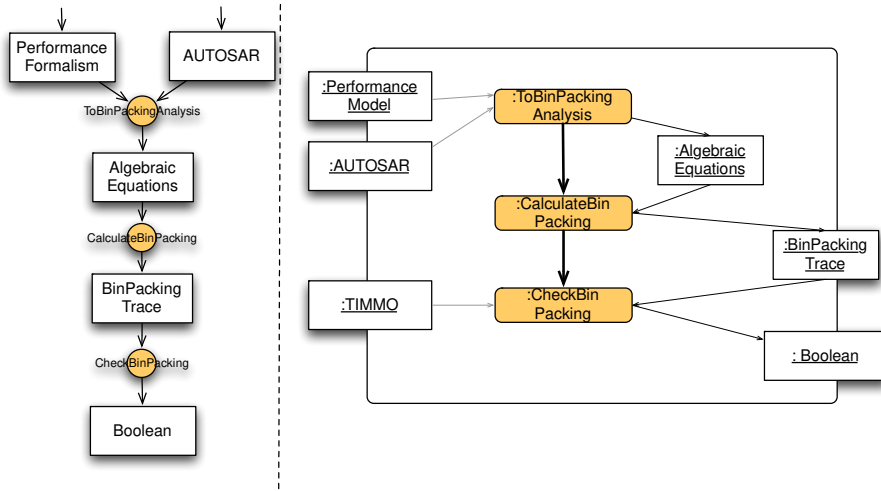


Deployment Models

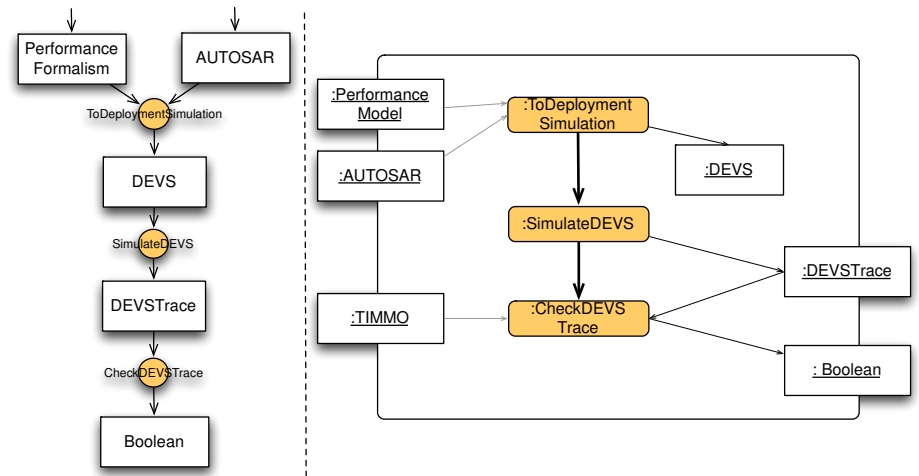
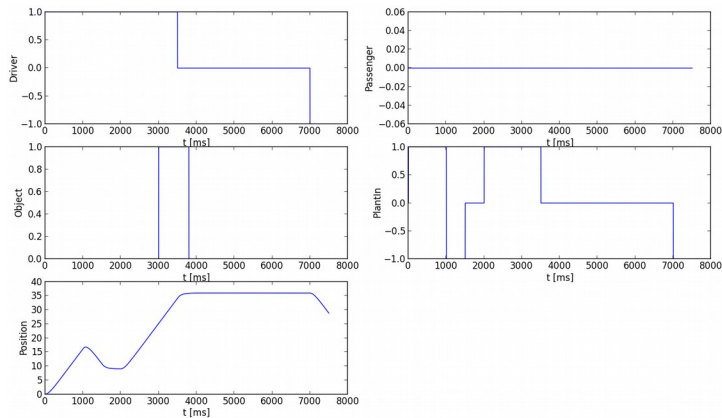
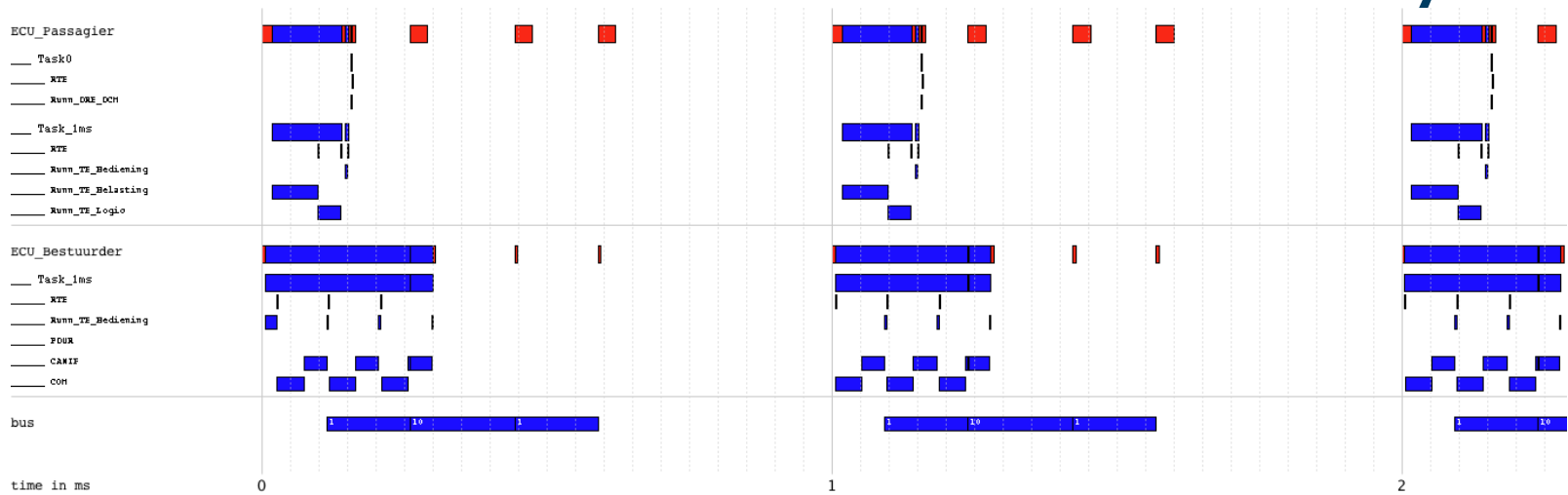
- ▼ ◆ System
 - ▼ ◆ Ecu BodyLogic
 - ▼ ◆ RTE
 - ◆ Task Task_ControlDrv_1ms
 - ▼ ◆ Rte Data Mappings
 - ◆ Rte Signal Mapping
 - ◆ Rte Signal Mapping
 - ◆ Rte Signal Mapping
 - ◆ Rte Signal Mapping
 - ◆ Rte Signal Mapping
 - ▼ ◆ Com Config
 - ◆ Rx Com Signal cmdDown_Event
 - ◆ Tx Com Signal UpDrv
 - ◆ Rx Com Signal cmdStop_Event
 - ◆ Rx Com Signal cmdUp_Event
 - ◆ Tx Com Signal DownDrv
 - ◆ Tx IPDU BodyLogic_Actions
 - ◆ Rx IPDU DrvDoor_Sensors
 - ▼ ◆ Canif Config false
 - ◆ Ipdu To Hoh Map 10
 - ◆ Ipdu To Hoh Map 14
 - ▼ ◆ Can Config false
 - ◆ Hardware Transmit Handle 0
 - ◆ Hardware Receive Handle 0
 - ▶ ◆ Ecu PsgDoor
 - ▶ ◆ Ecu DrvDoor



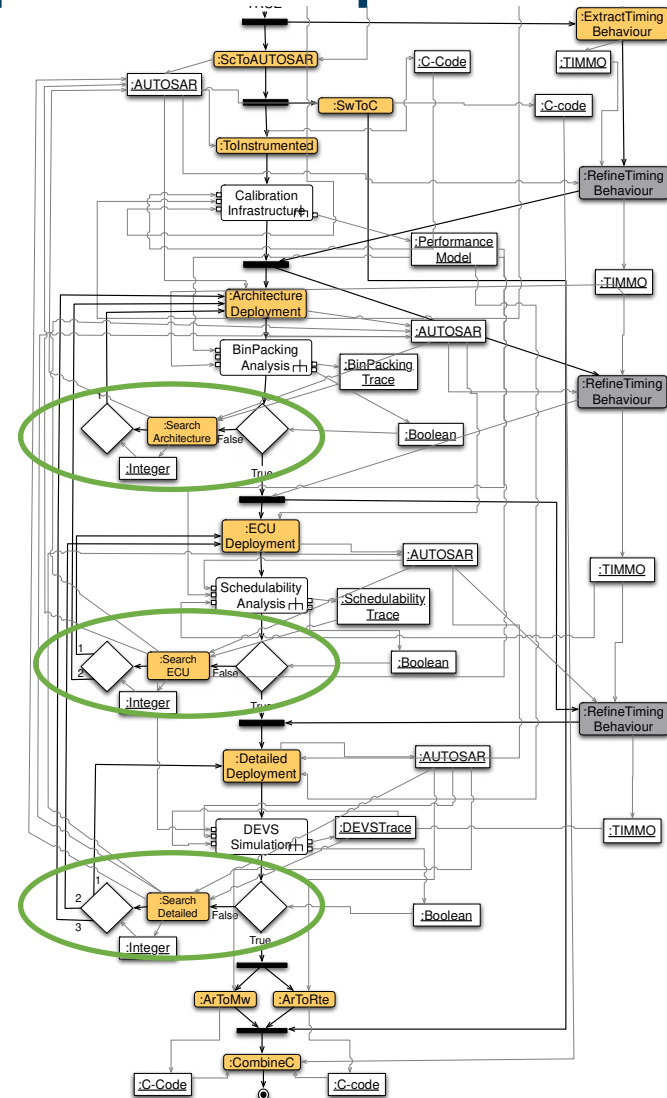
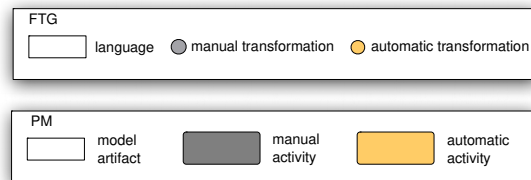
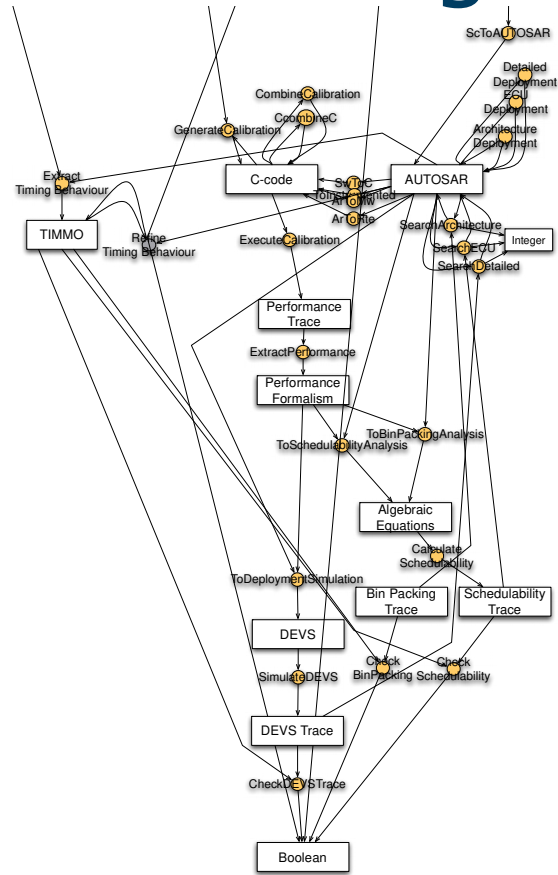
Analysis



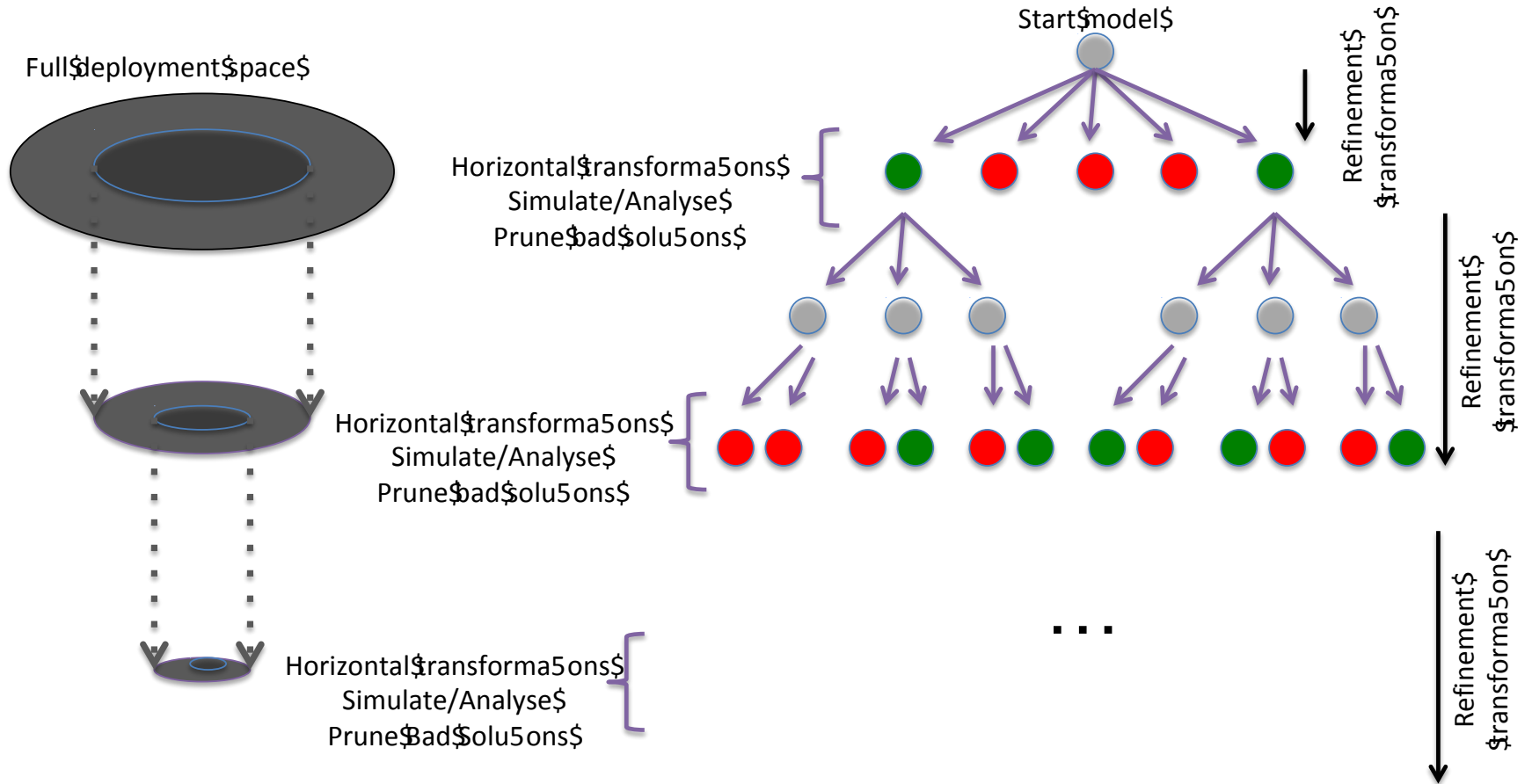
Analysis



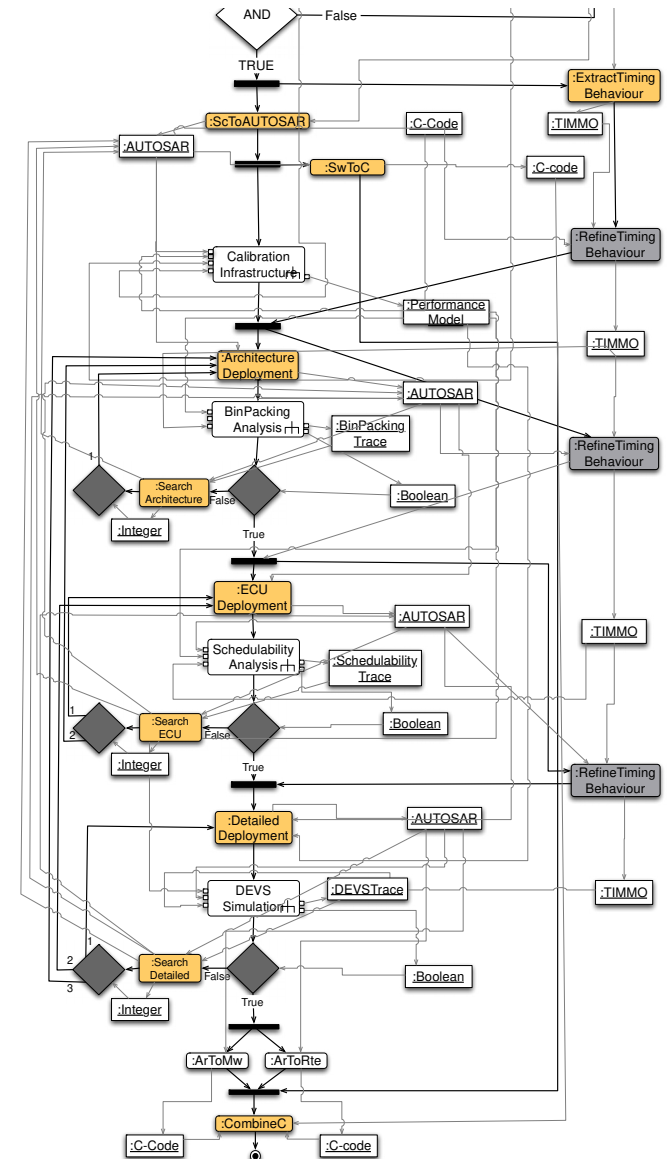
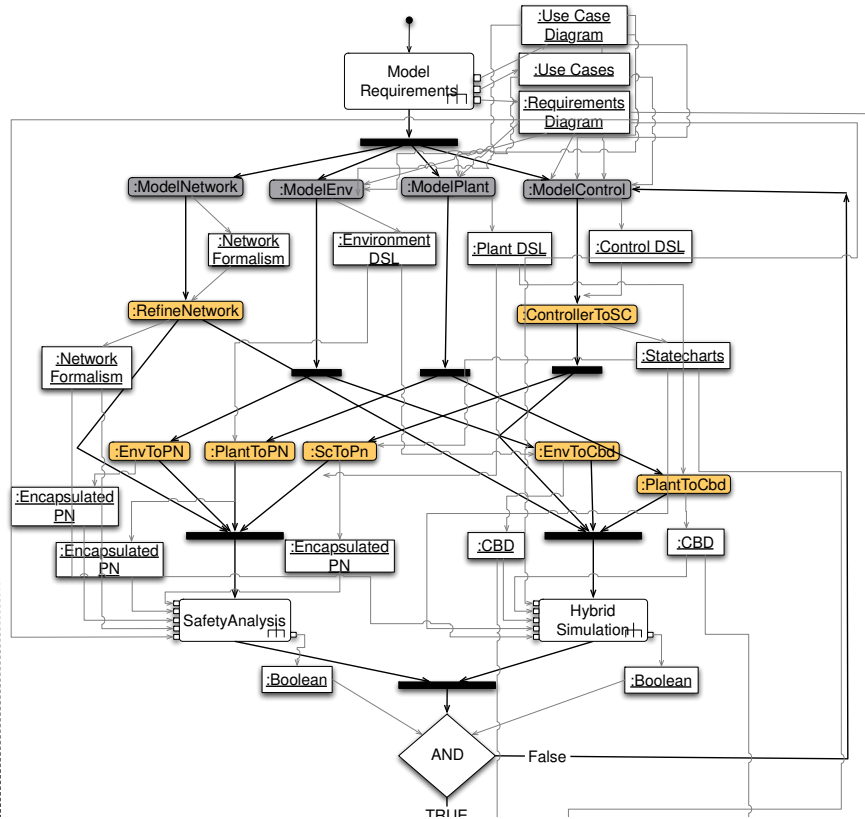
Design-Space Exploration



Design-Space Exploration



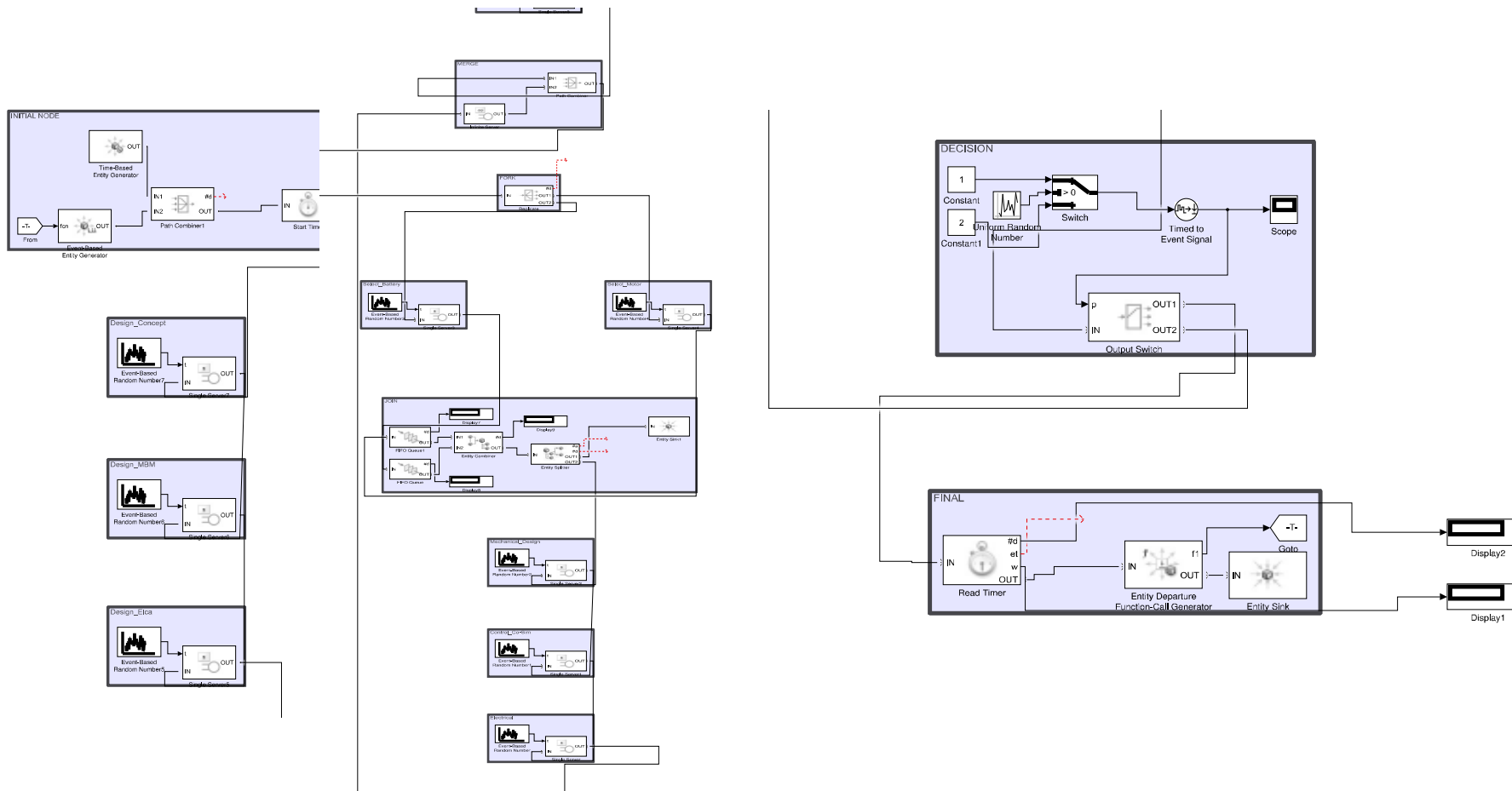
Formalism: Activity-Diagrams



Levi Lucio, Sadaf Mustafiz, Joachim Denil, Hans Vangheluwe, Maris Jukss, FTG+PM: An Integrated Framework for Investigating Model Transformation Chains. SDL Forum 2013: 182-202

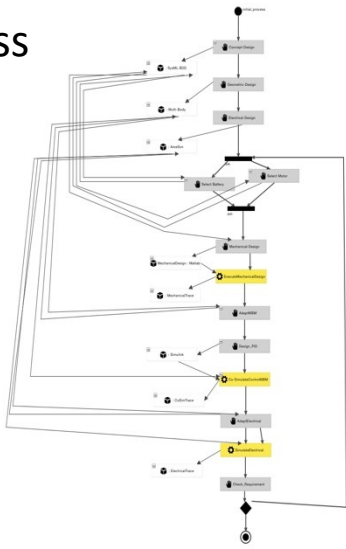
Sadaf Mustafiz, Joachim Denil, Levi Lucio, and Hans Vangheluwe; "The FTG+PM Framework for Multi-Paradigm Modelling: An Automotive Case Study"; Accepted @ MPM2012 of Models2012, 2012

simulate to get performance metrics

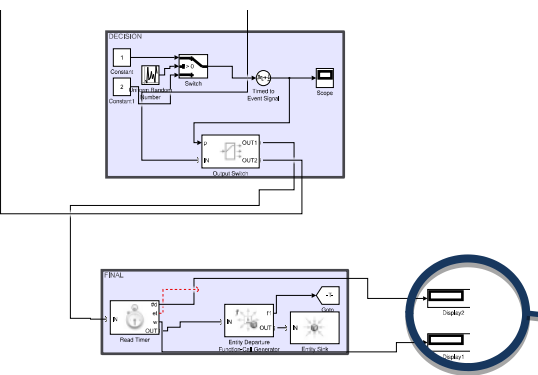


reason about consistency and time-to-market!

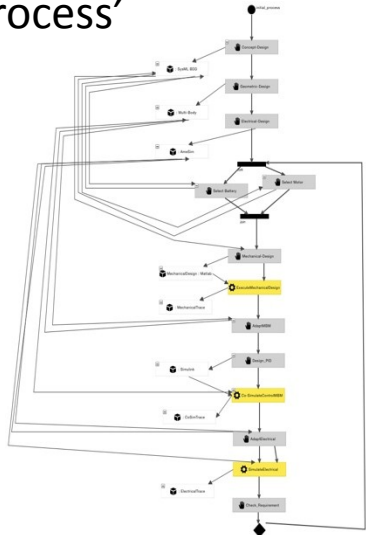
Process



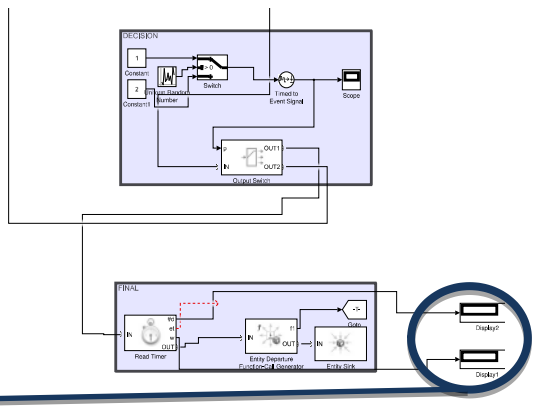
 SimEvents



Process'



 SimEvents



- Generate alternative processes
- Add consistency management activities




Compare!

Follow the process: dashboard

Cooling System Requirements Dashboard

User Guidance Hint:
Please add a requirement for the cooling system where you define the temperature thresholds as glossary

Tabular 

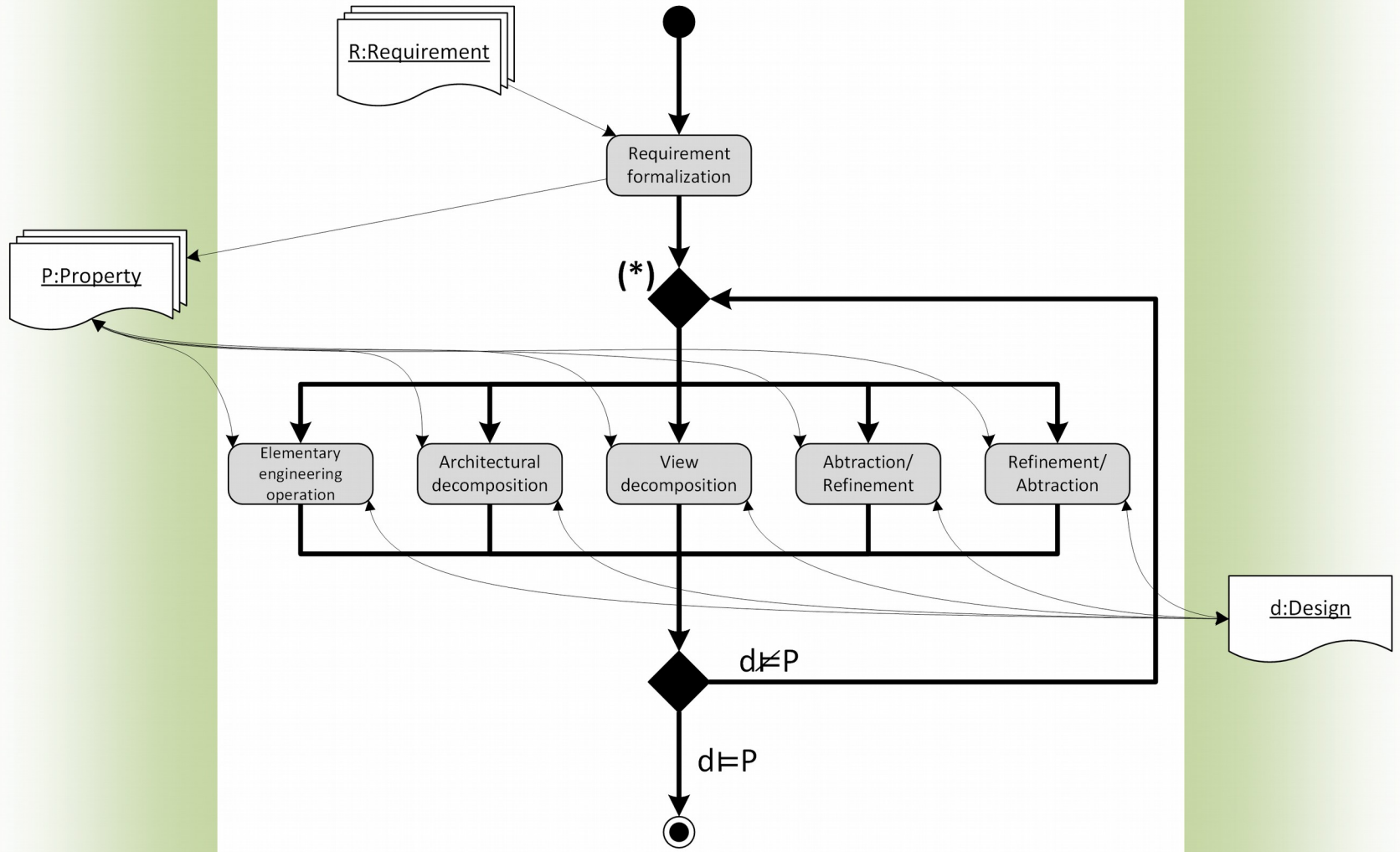
State Name	State Type	Status
Empty requirements project	Start	Visited
Empty requirement model and no gloss...	Intermediate	Current
Requirements model complete and glos...	Intermediate	ToCome
Requirements model not complete and ...	Intermediate	ToCome
Requirements model complete and glos...	Intermediate	ToCome
Empty functional behavior with Min and...	Intermediate	ToCome
Controller behavior complete	Final	ToCome

Lúcio, Levi, et al. "Process-Aware Model-Driven Development Environments.", FlexMDE@MoDELS, 2018

Properties

Process

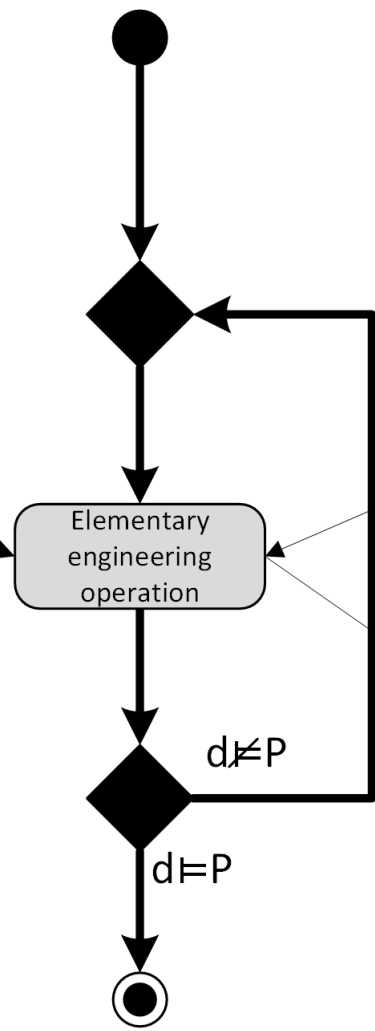
Design



Properties



Process



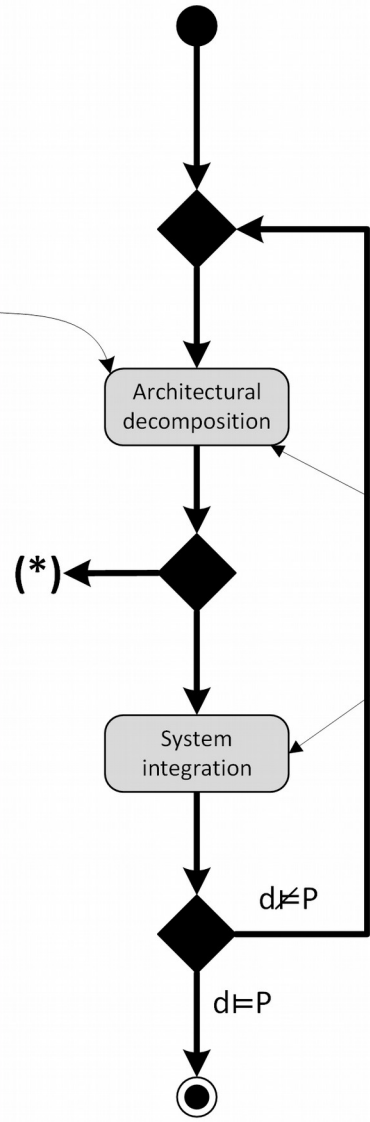
Design



Properties

Process

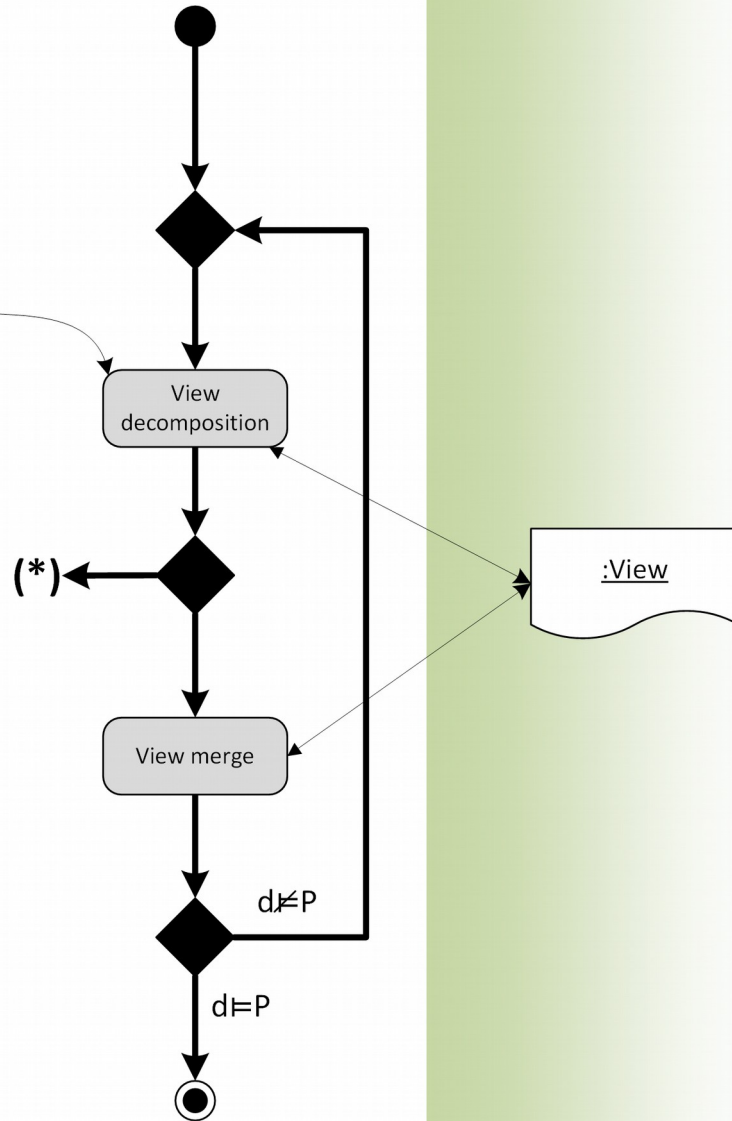
Design



Properties

Process

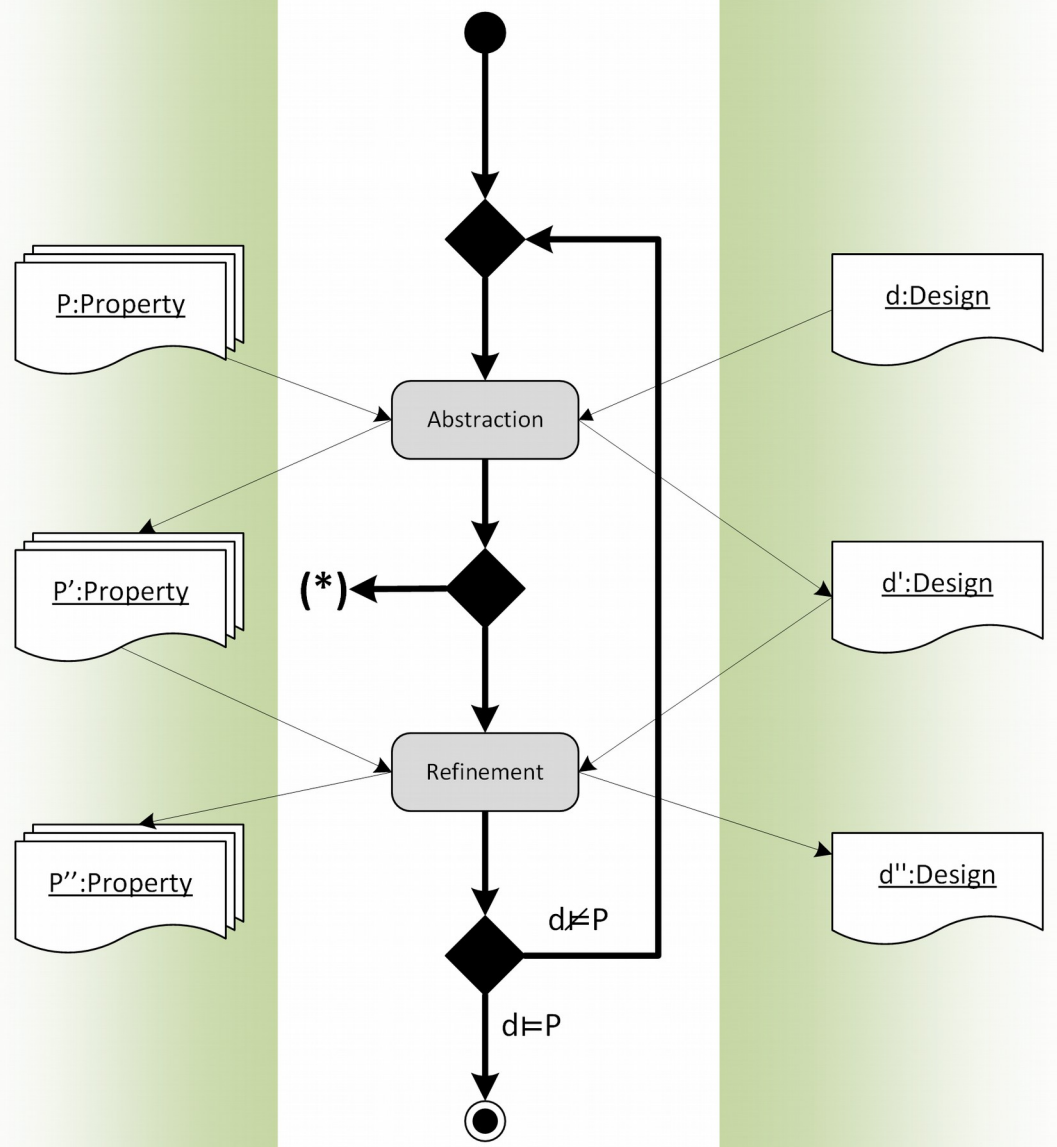
Design



Properties

Process

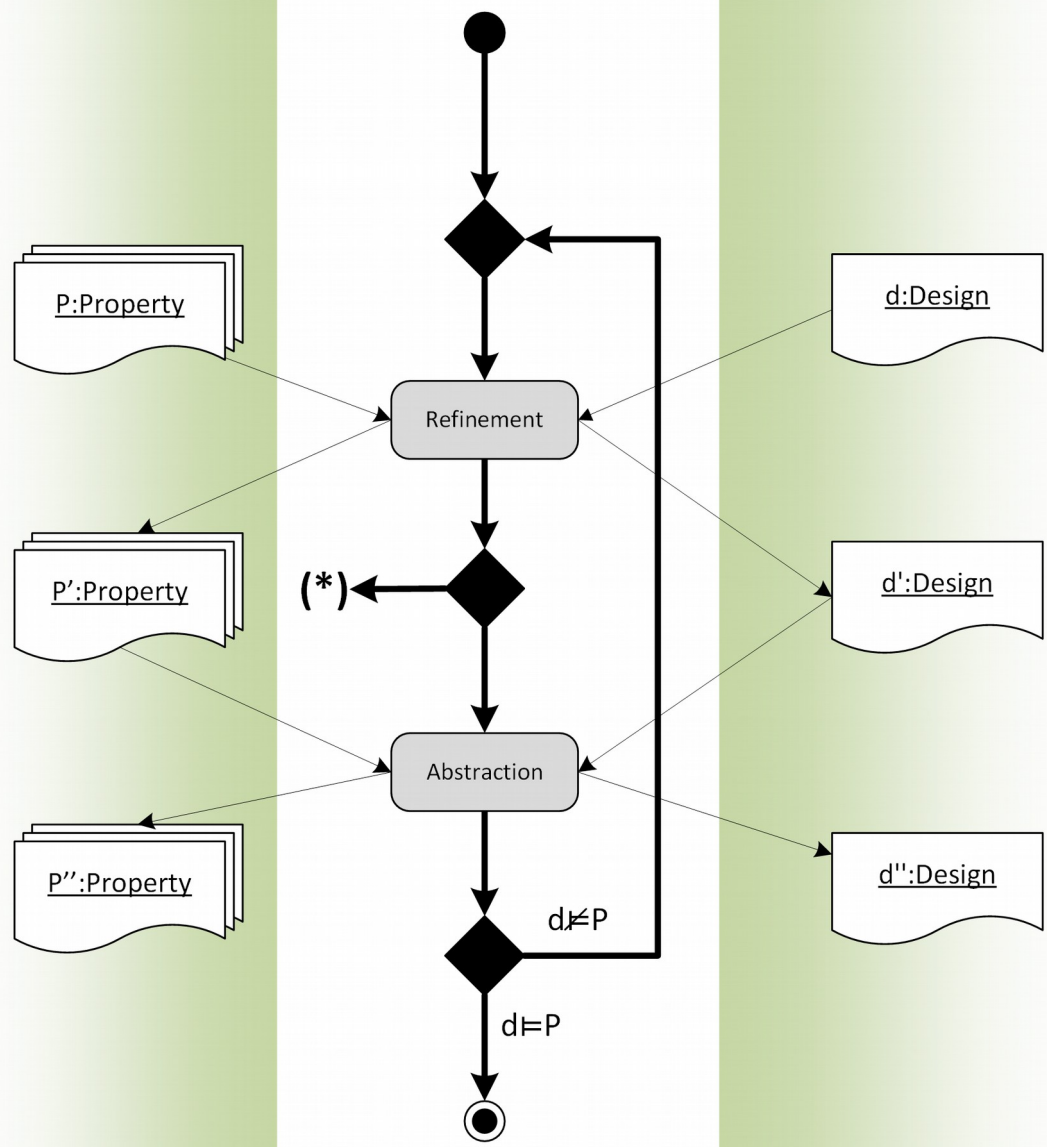
Design



Properties

Process

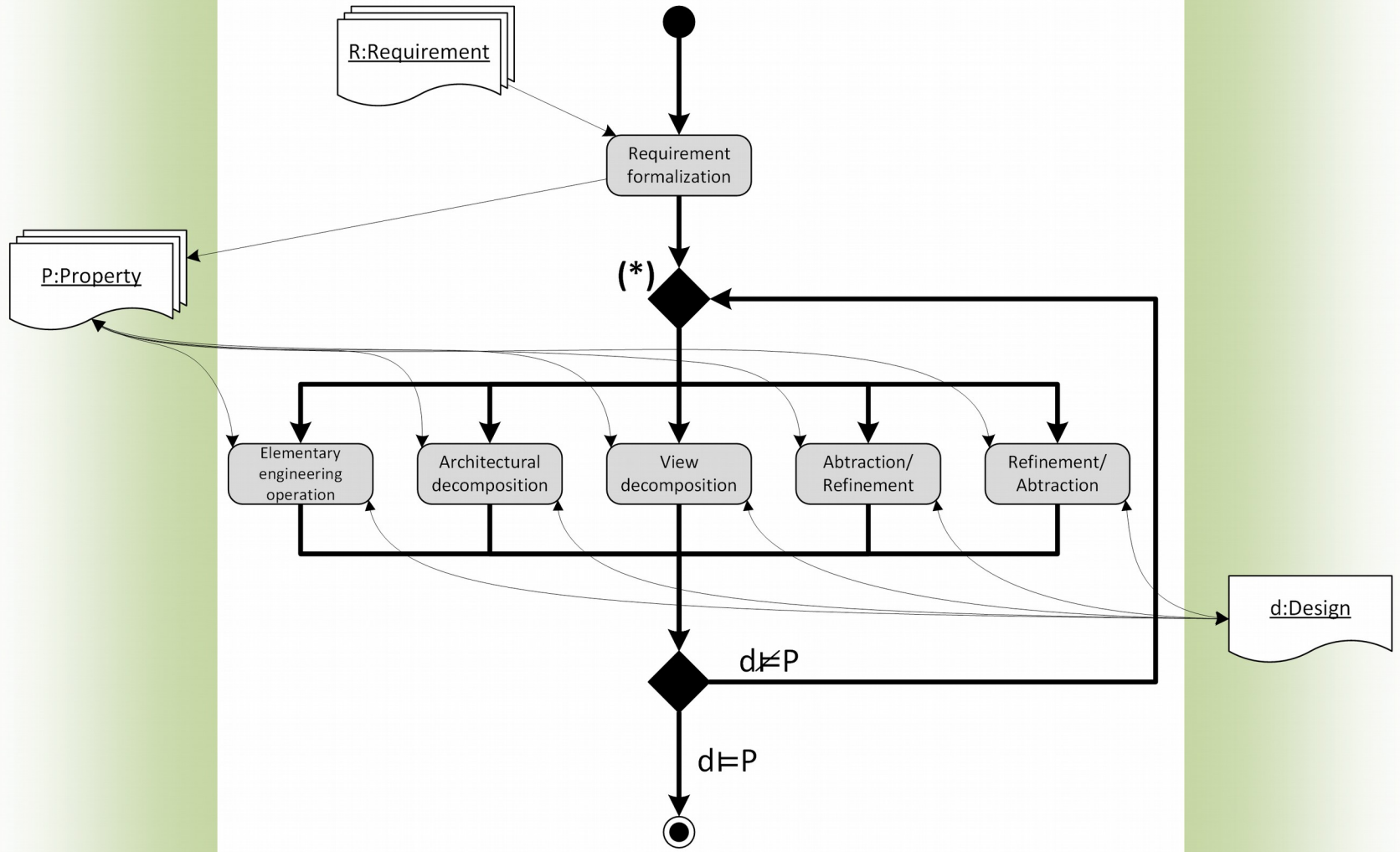
Design



Properties

Process

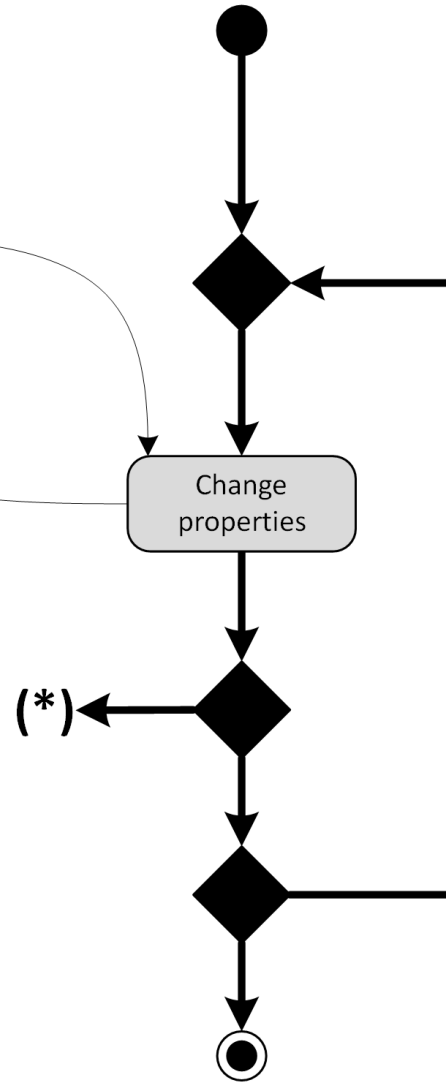
Design



Properties



Process



Design

