SysML modeling for embedded systems design optimization

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Context & objectives

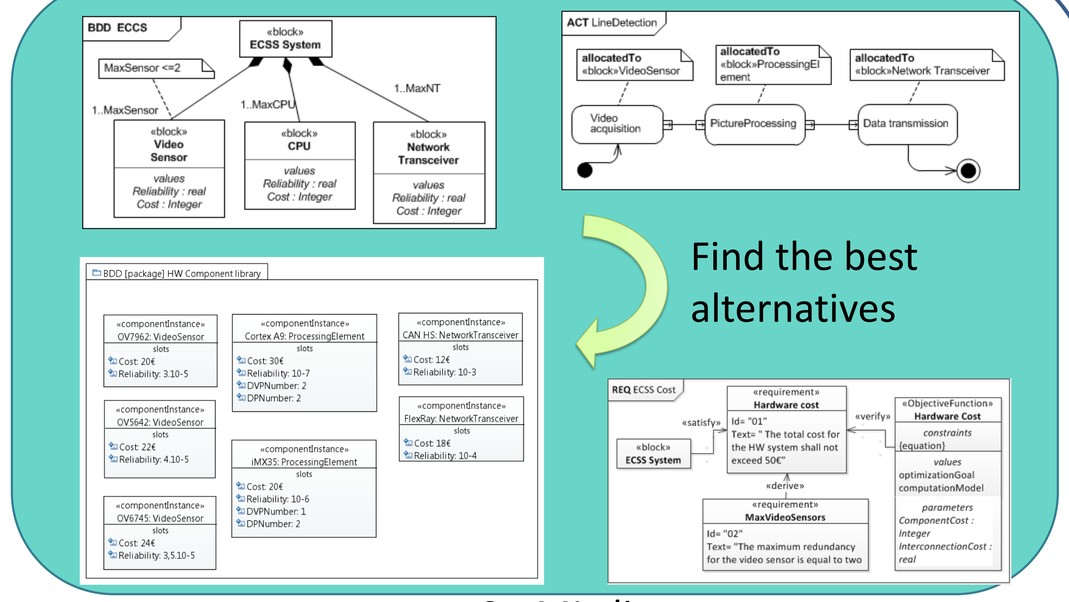
Context

- Embedded system design
- Model-Based Systems Engineering
- SysML Language
- Many design alternatives and constraints

Objectives

- Finding the set of optimal architectures with component selection and redundancy level
- Starting from SysML diagrams
- Minimizing system cost and failure rate

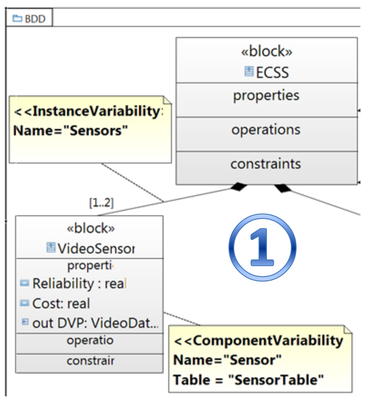
$$\min[f_1(x), f_2(x), \dots f_n(x)]$$

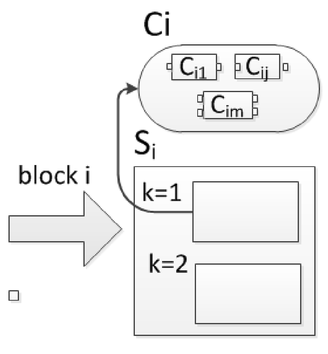


SysML diagrams

SysML Modeling Steps

1. Instance and component variability are added to the model with new stereotypes
2. Constraints modeling with discrete variables
3. Objectives functions : reliability and cost





$$\forall i \in S, j \in C_i, k \in S_i$$

$$a_{ijk} = \begin{cases} 1 \text{ if component } C_{ij} \text{ is used in position } k \\ \quad \text{of subsystem } S_i \\ 0 \text{ otherwise;} \end{cases} \quad (1)$$

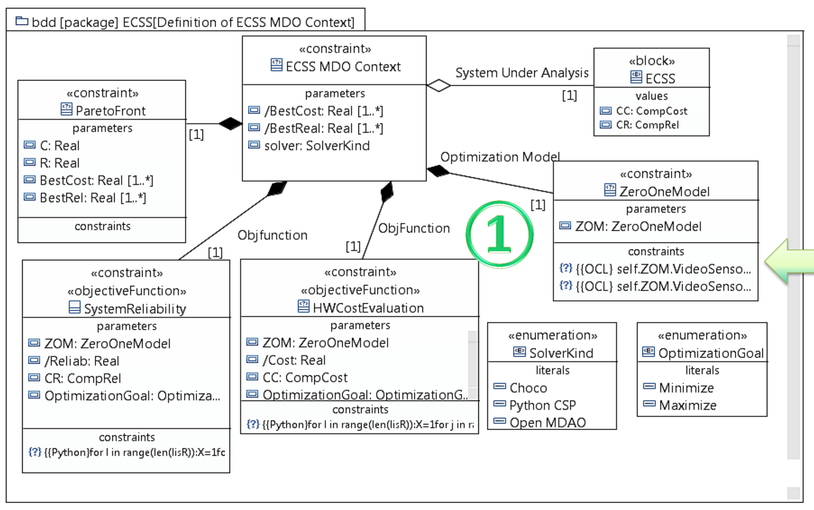
$$\forall i, j \quad \sum_k a_{ijk} \leq 1 \quad (2)$$

$$\max R = \prod_i \left[1 - \prod_{j,k} [1 - a_{ijk} r_{ij}]\right] \quad (3)$$

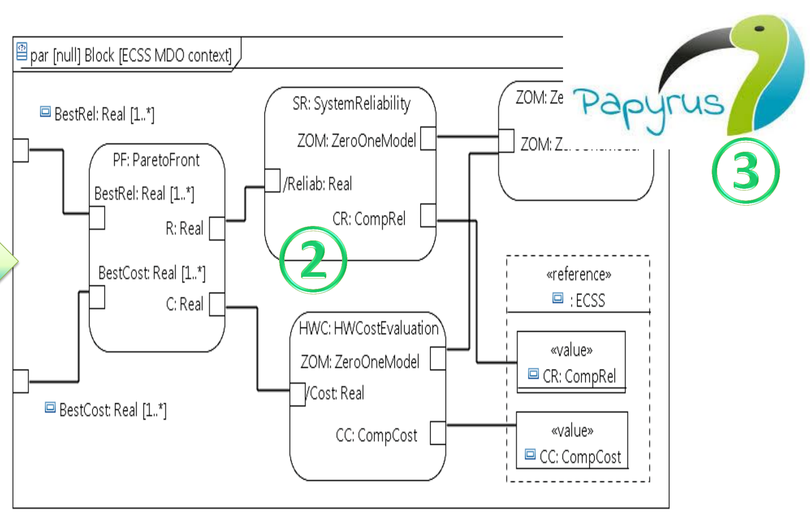
$$\min C = \sum_{i,j,k} c_{ij} \left[a_{ijk} + exp\left(\theta_i \sum_k a_{ijk}\right)\right]$$

Optimization context

1. Multi Domain Optimization (MDO) context diagram
2. Parametric diagram with constraint blocks representing equations and binding parameters
3. Built with Papyrus SysML tool from CEA



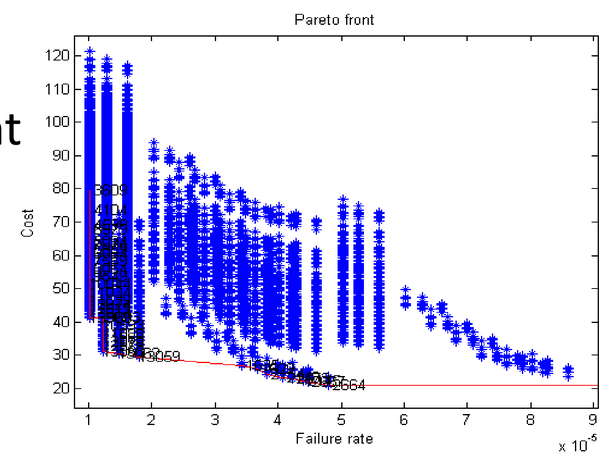
BDD diagram for MDO context definition



Parametric diagram

Results

- The SysML Model is transformed into a Constraint Satisfaction Problem (CSP)
- The CSP problem is solved with a Python solver (*Labix*)
- The Pareto front shows the optimal solutions



Pareto Front

Sol.	Sens.	CPU	Trans.	Cost (€)	FR (10^{-5})
1	S1+S1	CPU1	T4+T1	30.32	1.48
2	S1+S3	CPU1	T1+T1	35.09	1.22
3	S1+S3	CPU1+ CPU1	T1+T1	41.28	1.02

Configurations selected by end-user

Institut Supérieur de l'Aéronautique et de l'Espace
SUPAERO
ESTACA ÉCOLE D'INGÉNIEURS
Groupe Isae