UPR 2.0

Review, Update and Pathway for UPR 1.0 Evolution

UPR: UML Profile for ROSETTA

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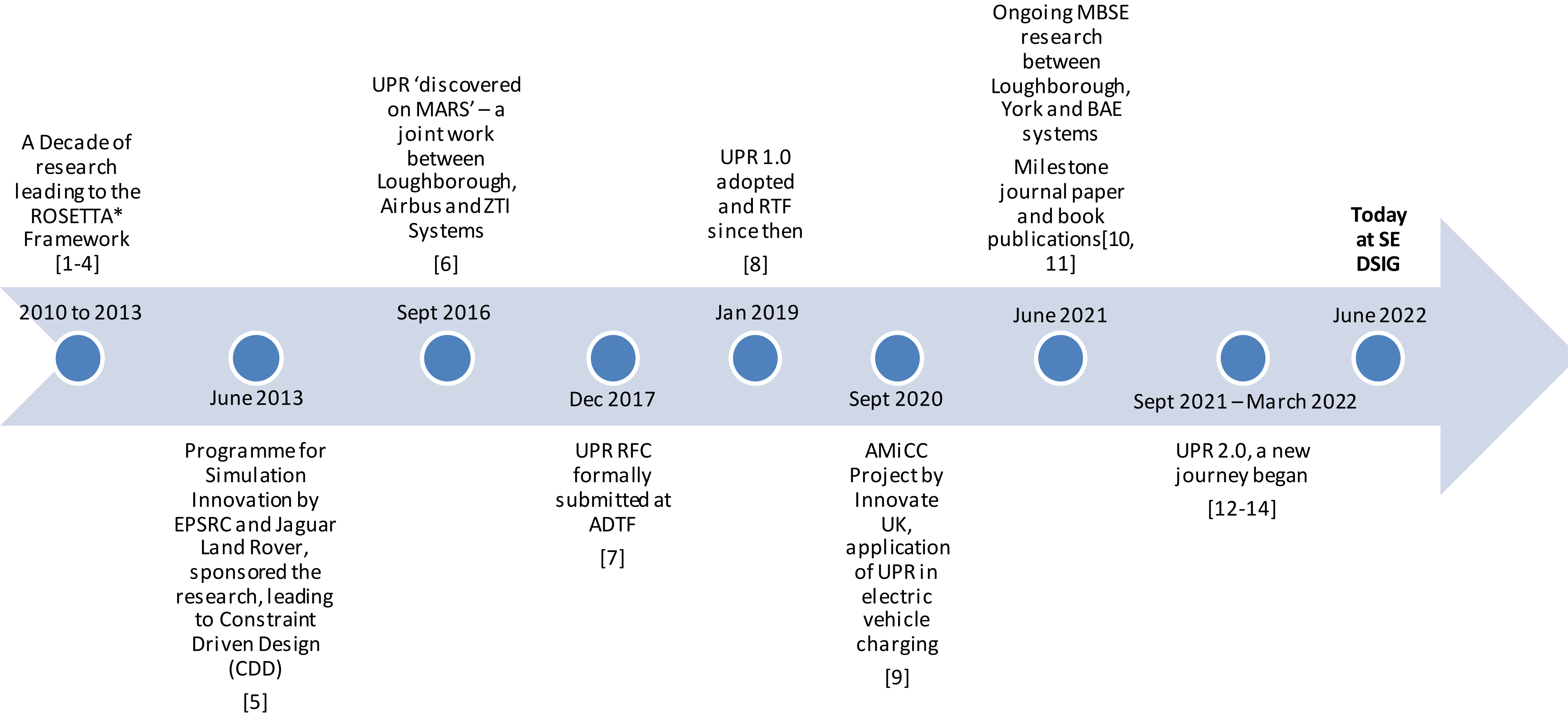
Key Milestones



ROSETTA: Relational Oriented Systems Engineering and Technology Trade-off Analysis

Agenda

- An Overview of UPR 1.0
- Current Work and Strategy
  - Complex Constraints
  - Model Synchronisation
- Discussions

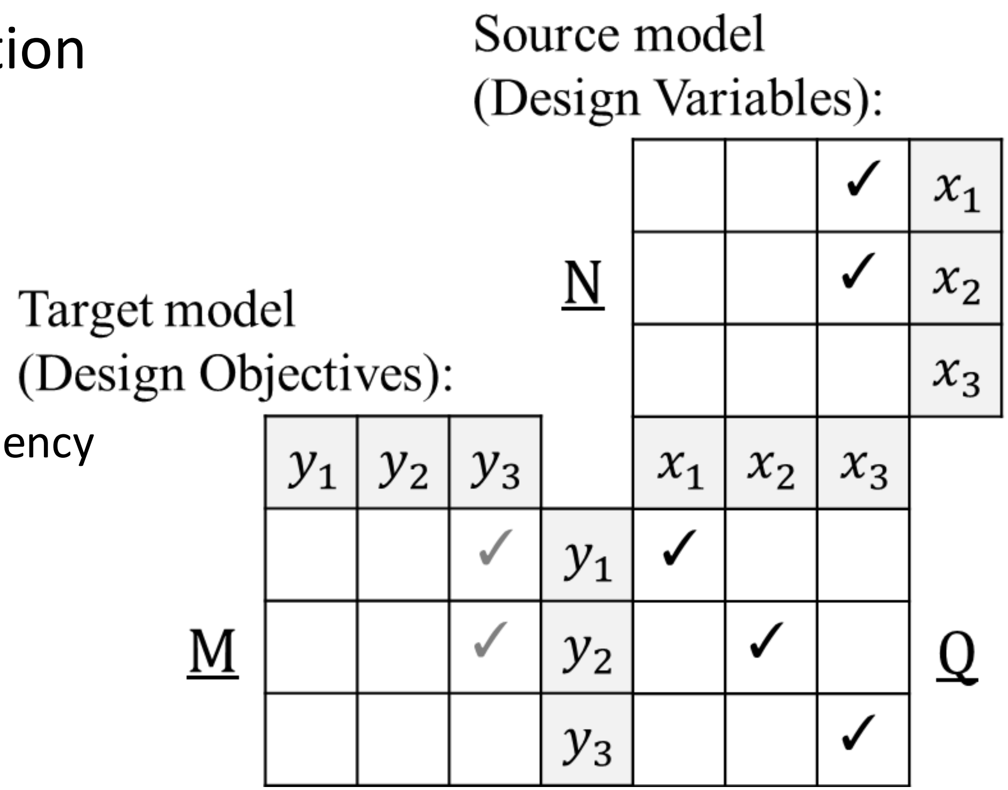
UPR 1.0

- The aims of UPR 1.0 were to
  - Fill the gaps by *accessing, structuring and integrating* information across multiple system models for support of CDD
  - Identify conflicting and harmonious requirements
  - Support optimization and transformation of System Architecture into Detailed Design
- UPR 1.0 proposed
  - 10 stereotypes, and 1 library
  - Facilitating annotation of models to identify information
  - But the *intent is Not* to define new analysis techniques

CDD: constraint driven design

The ROSETTA Framework

- A mathematical framework, depicted in matrices. (See Clause 6.2 for more details [6], and [1-4] for research publications)
- Relational Transformation (see ad/2022-03-13)
  - Unary
    - CDD
  - Binary
    - Requirement dependency



$(y_i, y_j) \in \boldsymbol{M}$ with $(y_i, x_k), (y_j, x_l) \in \mathbf{Q}$ implies $(x_k, x_l) \in \boldsymbol{N}$

Constraint Driven Design (CDD) in UPR 1.0

UPR 1.0 facilitates the modelling of metric constraints for CDD [6]

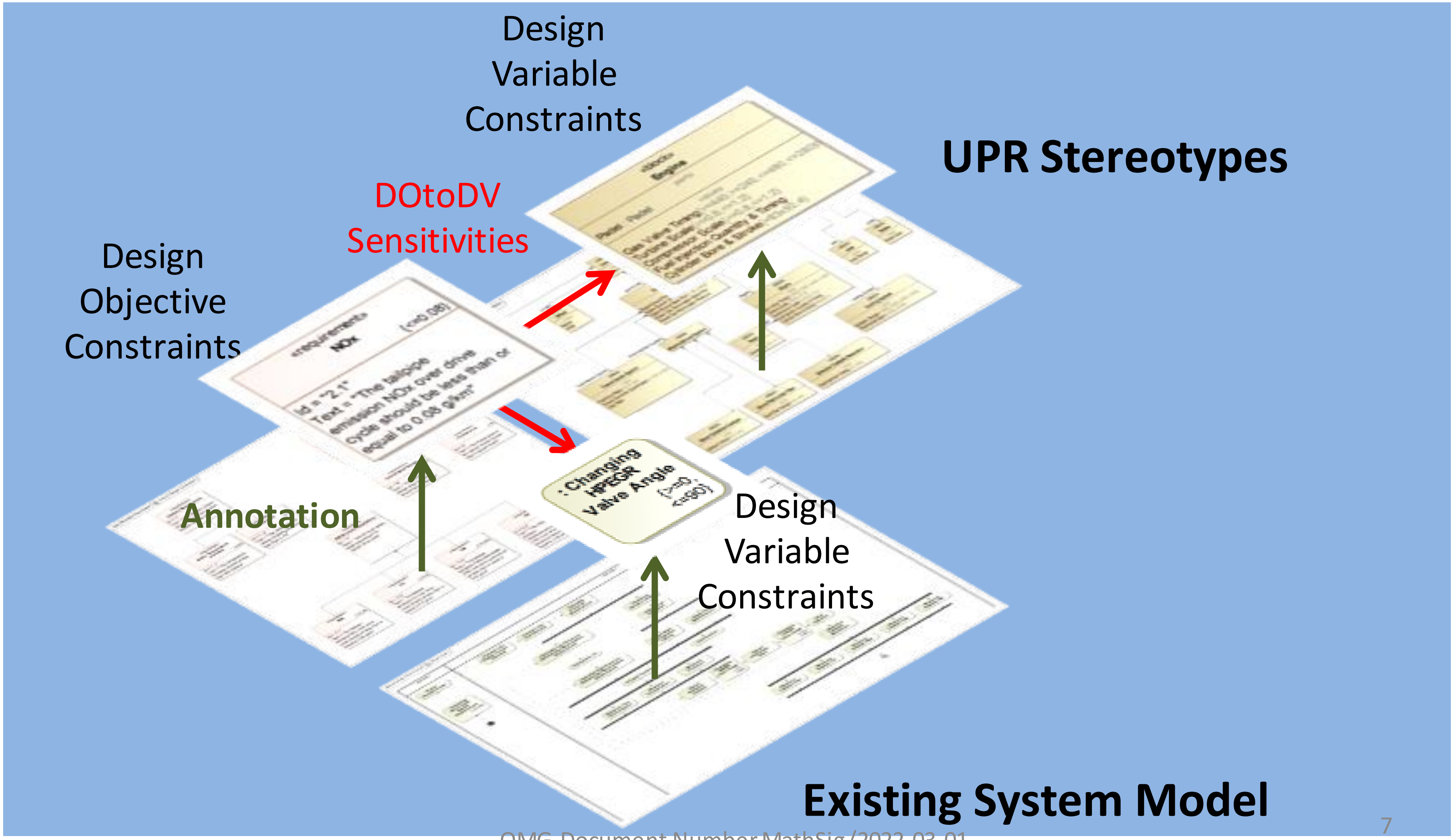
- A *Variable* is a measurable attribute that represents an element being constrained and can take on a range of real values.
- A *Constraint* is a constant that limits the values of a variable.
- A *Comparison Operator*, such as ‘<‘, is used to model constraints.

A *Design Objective* is a measurable attribute of a system that the system is intended to have or achieve e.g., a requirement.

A *Design Variable* is a variable under the design authority of the engineer. It imparts system properties that achieve objectives e.g., a vehicle speed of > 100 mph can be achieved by reduced weight.

UPR for CDD Modeling

Model annotation for information extraction



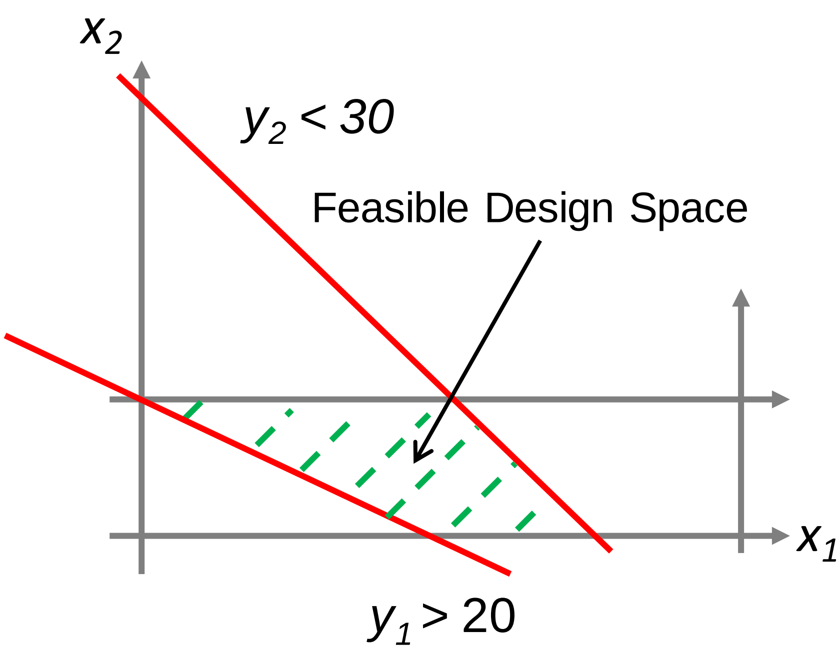
Constraint Driven Design

Information required

Mathematical Viewpoint

ROSETTA seeks to access and annotate key information from MBSE System Model.

Design algorithms use the information a Feasible Design Space to seek solutions.



Information Required

Design Objective Constraints:
$y_1, \ldots, y_m$

Design Variables: $x_1, \ldots, x_n$
with ***Design Ranges***
$S_1, S_2, \ldots$

Analytic Equations:

$$y_1 = \mathrm{W}_1(x_1, \ldots, x_n)$$
$$y_2 = \mathrm{W}_2(x_1, \ldots, x_n)$$
$$\ldots$$
$$y_m = \mathrm{W}_m(x_1, \ldots, x_n)$$

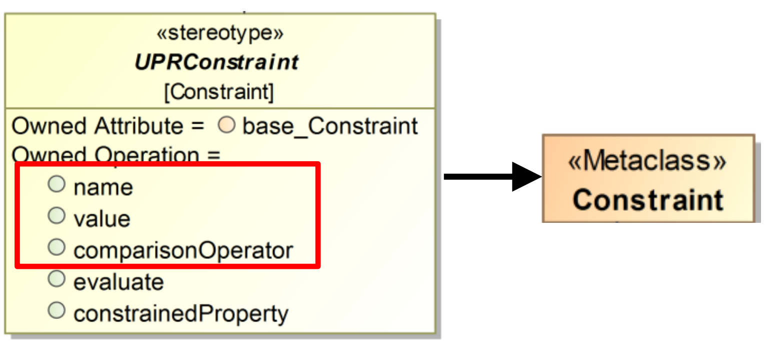
Feasible Design Space expressed in terms of ***Feasible Ranges***

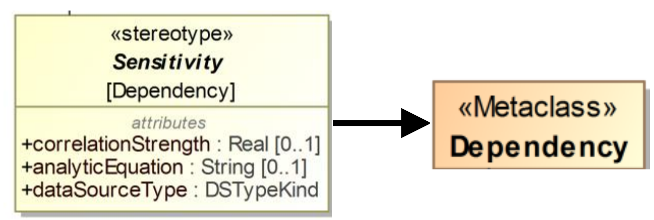
Capturing CDD information using UPR Stereotypes

UPR Foundation & Operator Library

- UPRConstraint & Sensitivity (Clause 7)

  Extend UML Constraint and UML Dependency to facilitate the modeling of Design Constraint and Design Variable; the mathematical relations between them.

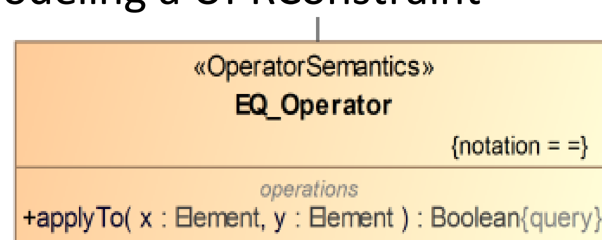




- Operator Library (Clause 8)

  A library of comparison operators to be used for modeling a UPRConstraint

  e.g. =, >, <, etc.

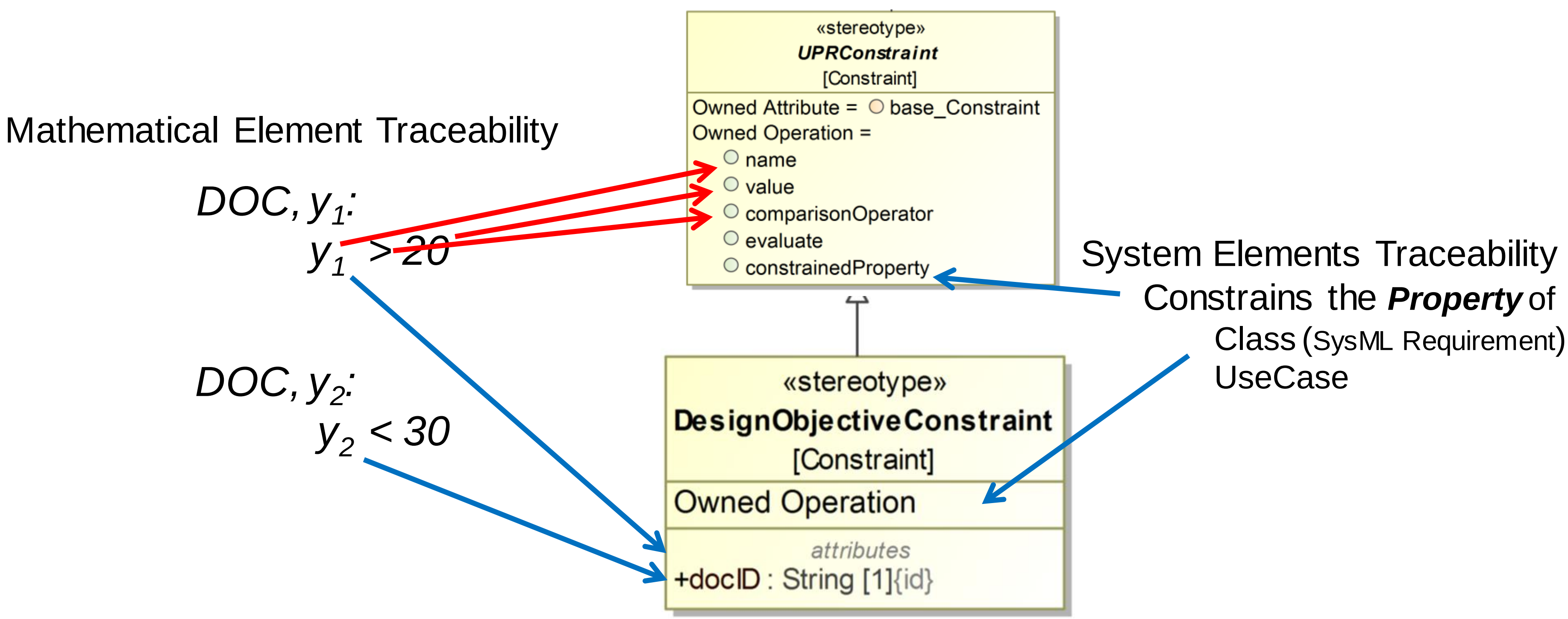


Capturing CDD information using UPR Stereotypes

Design Constraints

- Design Constraints Package (Clause 9):
  - Design Constraint extends UPRConstraint using

    2 additional operations and 1 attribute for model annotation and traceability



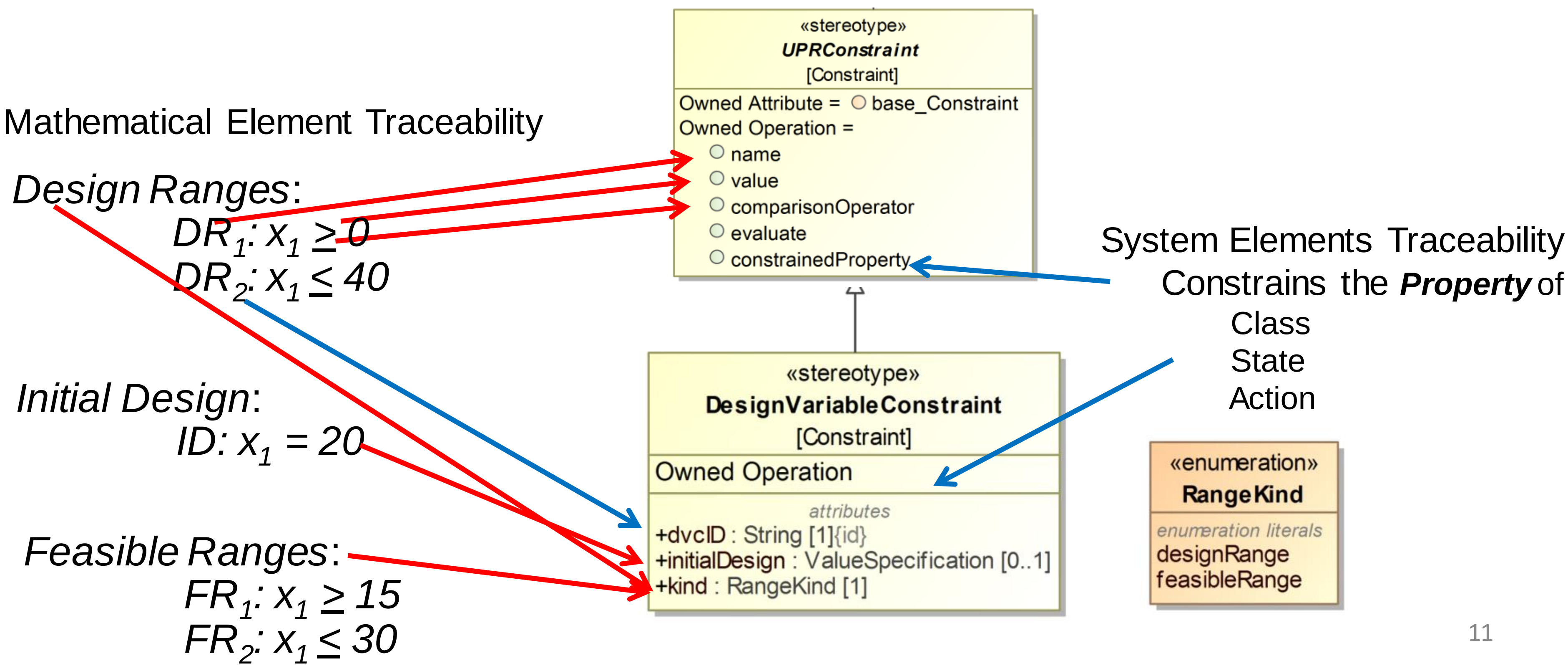
DOC: Design Objective Constraint

Capturing CDD information using UPR Stereotypes

Design Variables

- Design Variable Package (Clause 10):
  - Design Variable extends UPRConstraint using

    2 additional operations and 3 attributes for model annotation and traceability

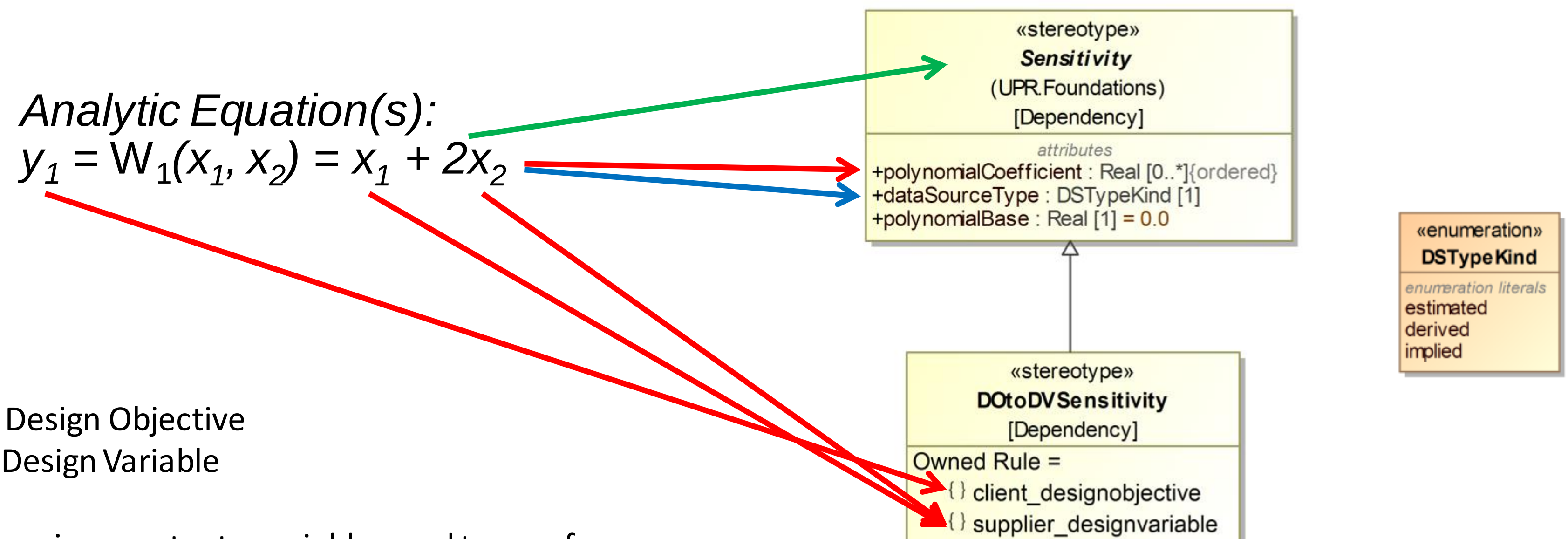


Capturing CDD information using UPR Stereotypes

Analytic Equations

- Relational Structure and Design Modeling (Clause 11):
  - DO to DV Sensitivity extends Sensitivity to model relations between Design Constraint and Design Variable using

    3 additional rules and 1 (refined) attributes for model annotation and traceability
  - *Object oriented modeling of "mathematical models" **

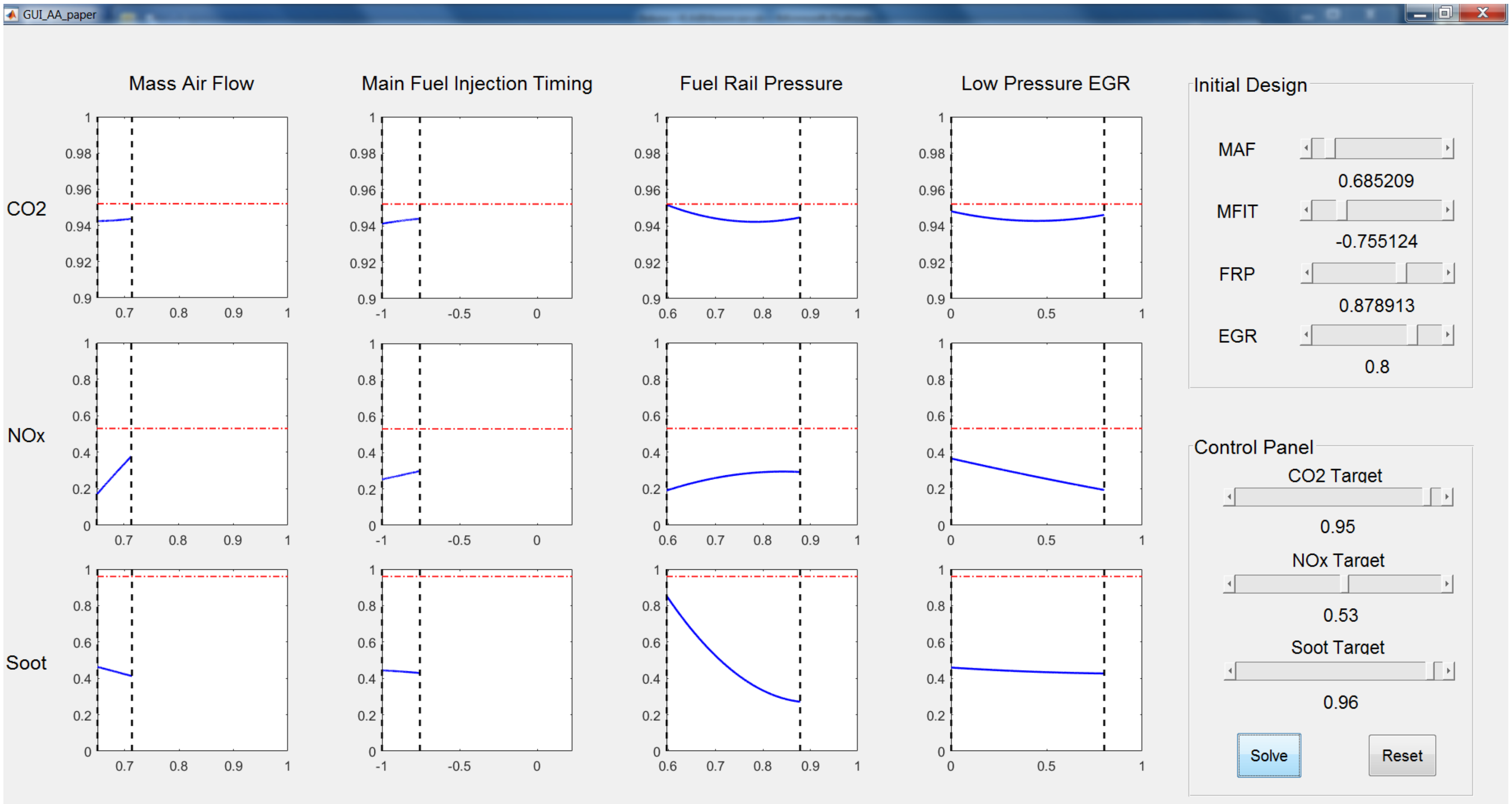


DO: Design Objective
DV: Design Variable

* ... using constants, variables, and types of mathematical expressions (e.g. RSE)

ROSETTA Mathematical Analyses Capability*

Implementation algorithms for RT-U transformations



*A multi-design objective and multi-design variable design problem with three engine emission targets: CO2, NOx and Soot

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Application of UPR to Electric Vehicle(EV) Charging

[Home - AMiCC - Amicable Charging Research Project (projectamicc.com)](projectamicc.com)

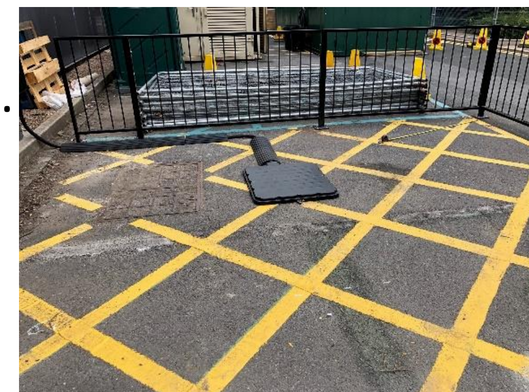
AMiCC is a commercialisation project for EV wireless charging supported by Innovate UK and funded by the Office for Zero Emission Vehicles (OZEV).

UPR facilities are being developed for metric constraints but are also needed for logical constraints (e.g., topologies).

Design objective constraints include
- Rate of power transfer
- Electromagnetic field strength

Design variable constraints include
- VA size and circuit topologies
- Cooling for power transfer
- Communication protocols

Ground assembly for WPT

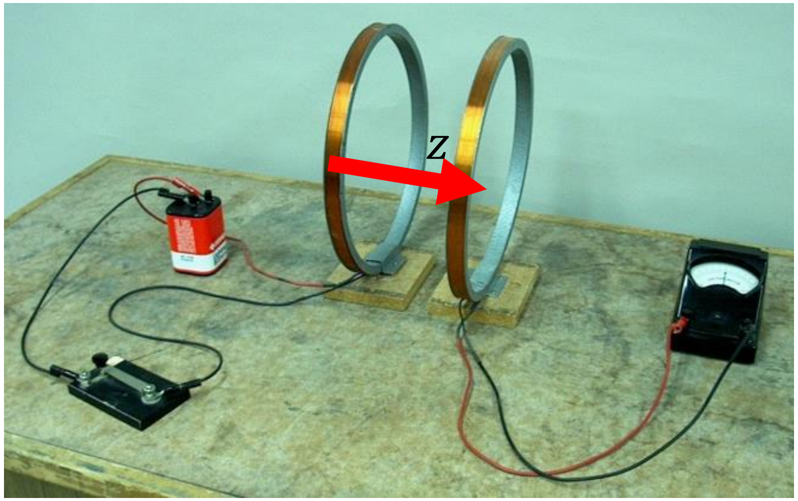


EV retrofitted with VA, VIU and HMI for WPT

VA: Vehicle assembly *GA: Ground assembly*
WPT: Wireless power transfer
VIU: Vehicle interface unit
HMI: Human Machine Interface

Experimental Setup for Wireless Power Transfer (WPT)

- Similar physics compared with transformers
  - Primary coils generate magnetic field which then induces current in the secondary coil
  - Magnetic Flux Density $B_p = \frac{\mu_0 N a^2 I_p}{2(a^2+z^2)^{3/2}}$
- Design Objectives:
  - Magnetic Flux Density emitted by the primary coil
  - Power Transferred to secondary coil
- Design Variables
  - Current in the primary coils
  - Separation of the coils
  - Radius of the coils (fixed)
  - Number of turns in the primary coil (fixed)



Wireless Charing for Electric Vehicle (EV)

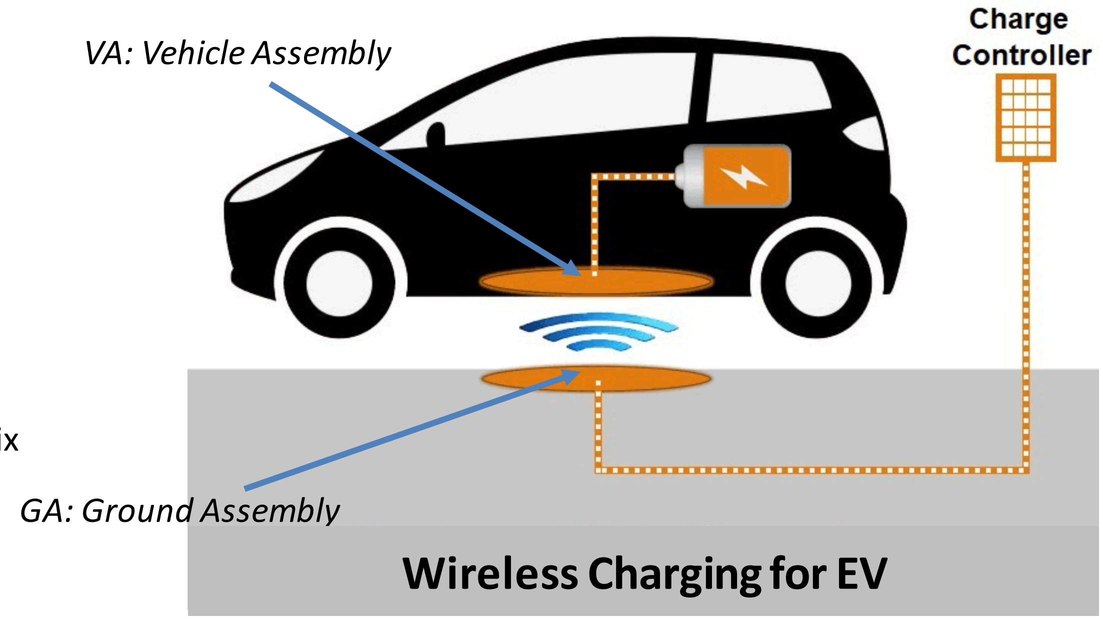
Recall y_2: Power Transferred, now with EVs

$P = \omega I_{GA}^2 k^2 LQ = c_0 I_{GA}^2 k^2$, where

- ω: Operating Frequency (fixed)
- I: GA Current
- k: **Coupling Coefficient**
- L: GA Inductance (fixed)
- Q: Quality Factor (fixed)

k depends on structural properties which are a mix of

- discrete variables, e.g. logical circuit topology
- continuous variables, e.g. lateral misalignment



Complex System Design Solutions

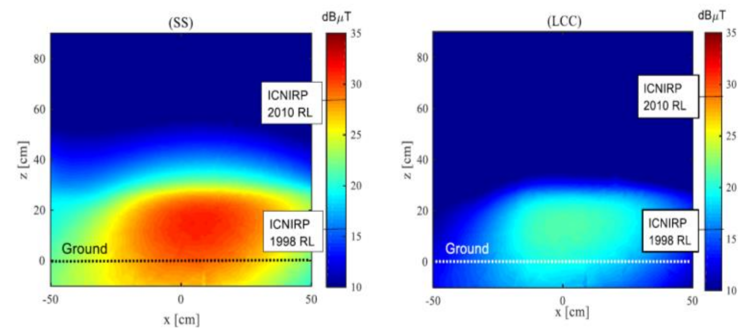
Example of Electromagnetic Field Emissions[1]

- Parts of the problem that can be 'understood' by conventional CDD:

  → Design of continuous nature e.g.,

  B as function of GA & VA *separation*

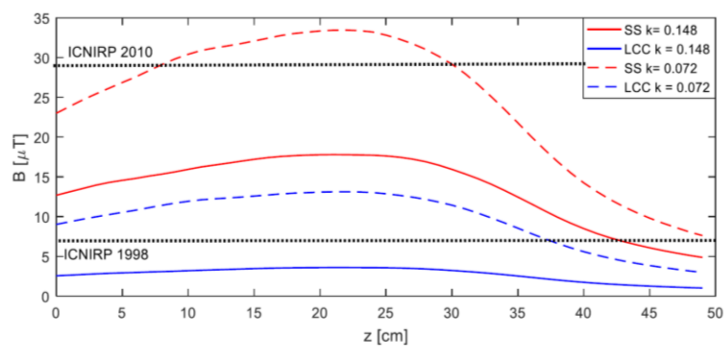
  B as function of GA & VA *alignment*



- Parts of the problem that requires further 'development' in CDD capability:

  → Design of a discrete nature

  B as function of coupling factor



[1]Campi T, Cruicani S, Maradei F, Feliziani M. Magnetic Field during Wireless Charging in an Electric Vehicle According to Standard SAE J2954. Energies. 2019;12:1795

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Context & Motivation

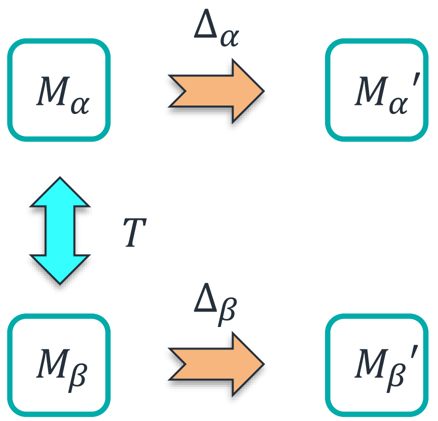
- Model-based Systems Engineering offers machine readable, traceable models
- Models enable the realisation of Digital Threads
- Practical Challenge:
  - How to handle changes?
- What we would like to explore:
  - How could the UPR formalism facilitate synchronisation of models?

Model Synchronisation

- Two **consistent** models, M_α and M_β
- A change made to a M_α, denoted as Δ_α
- Synchronisation means

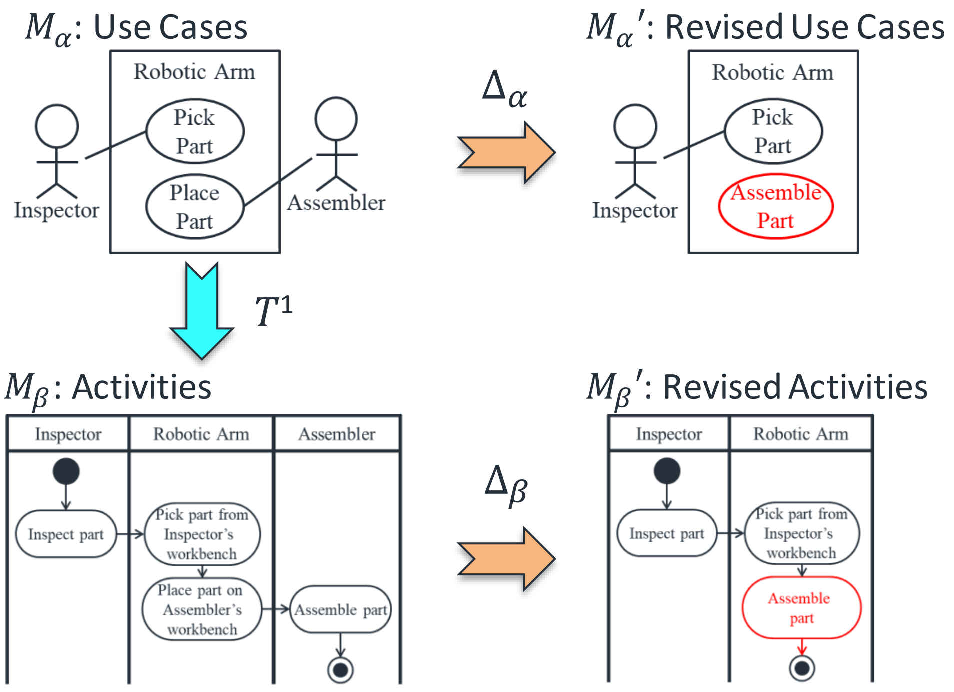
a change Δ_β is mandatory to M_β in order to maintain the consistency between $M_\alpha{}'$ and $M_\beta{}'$

- Issues with manual synchronisation: labour intensive, error-prone, lacking generality & repeatability
- Hence: Semi-automated, model transformations, T, following a **joint cognitive** approach



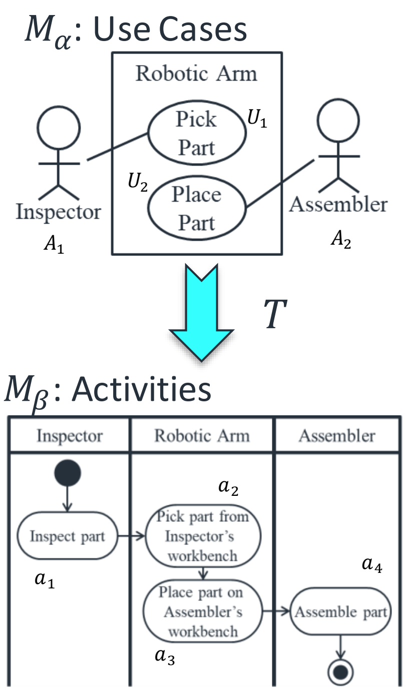
A Concrete Example

- Scenario:
  - Inspector checks the part, if OK
  - Robotic Arm then **picks** the part and **places** it on Assembler's workbench
  - Assembler finally assembles the part
- Change to functionality:
  - From Pick & Place, to Pick & Assemble
- Benefit:
  - Higher efficiency with reduced safety risks



[1]Dickerson & Ji, *Essential Architecture and Principles of Systems Engineering*, Chapter 5

Synchronising Models

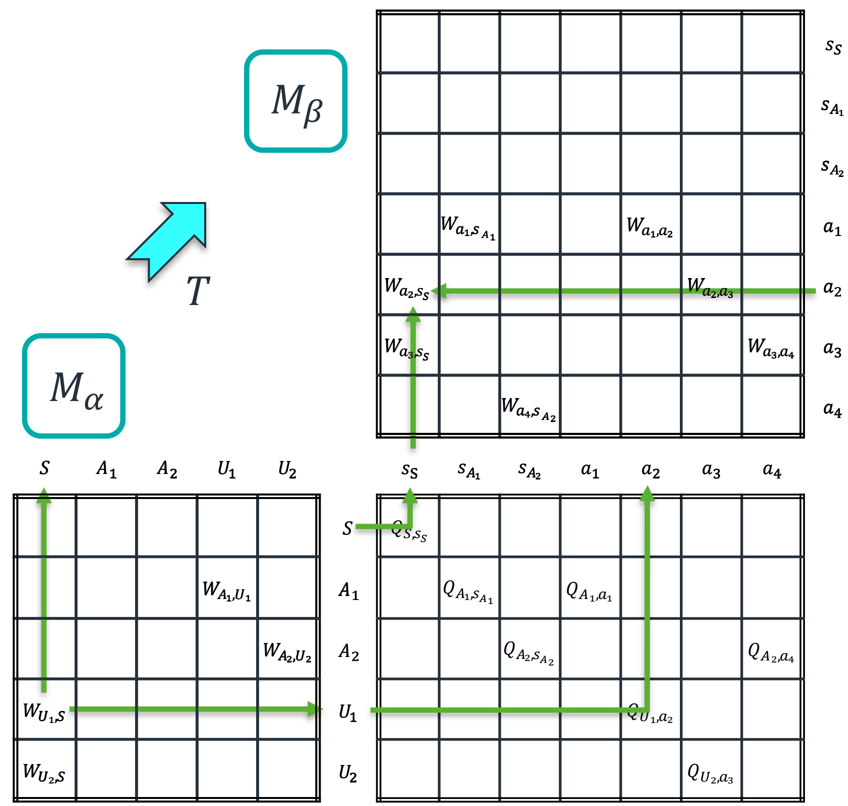


Matrix Representation

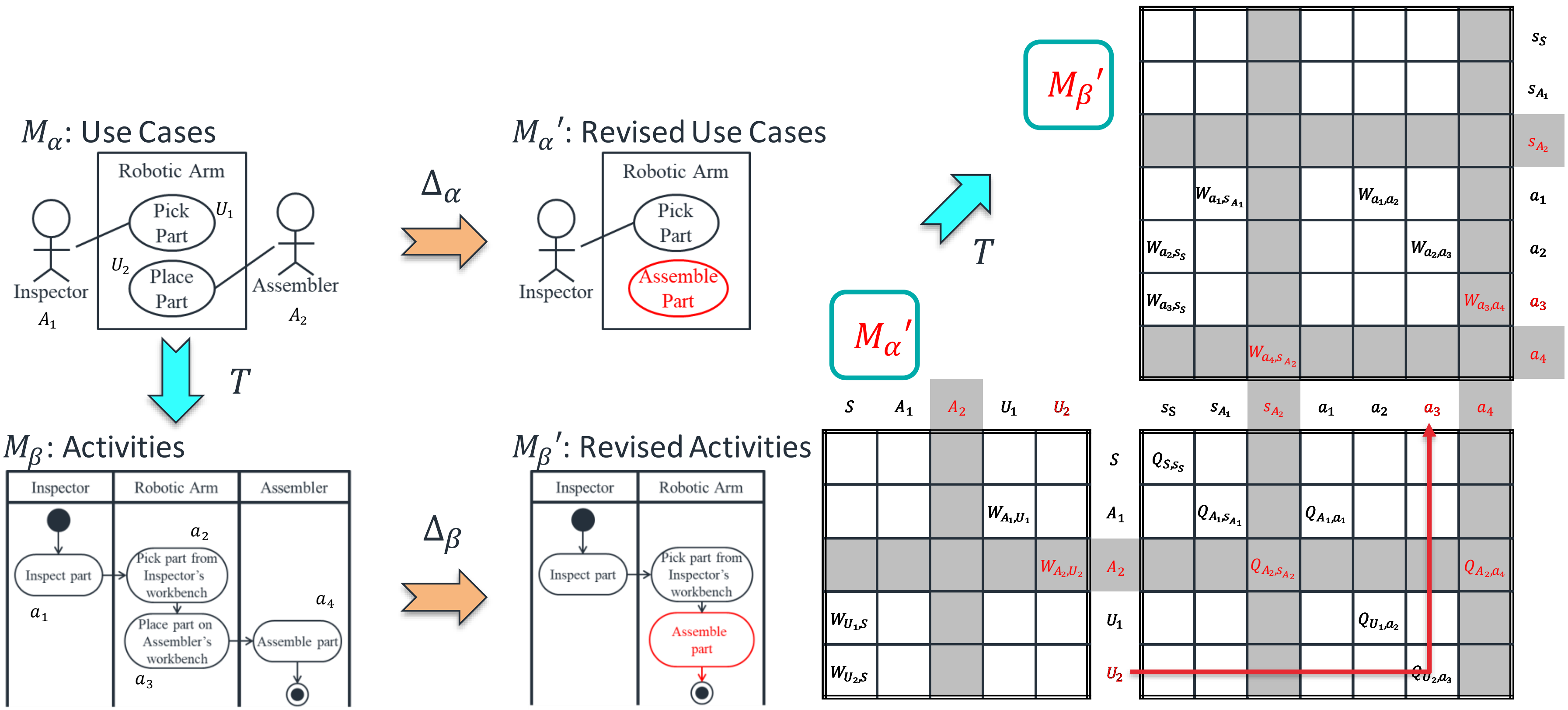
- Row/Column Headers: **model elements**
- Matrix element: **dependencies**
- $W_{i,j}$: **in-model dependencies,**

  e.g., A_1 is associated with U_1
- $Q_{i,j}$: **cross-model dependencies**

  e.g., A_1 is concordant with s_{A_1}



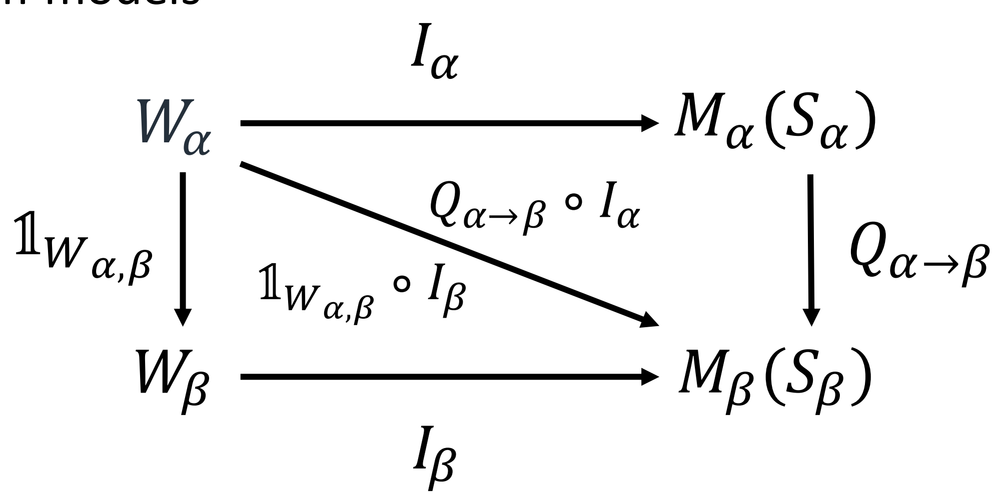
Synchronising Changes



A Supporting Mathematical Formalism [15]*

Synchronisation achieved through structure preserving transformations:

- Semantic Transformation, $Q_{\alpha \to \beta}$ that preserves one structure into another, e.g. Use Case to Activity Diagram, but without populated content
- Interpretation, I_α and I_β, that interpret domain knowledge into the structure to make them models



*Preprint available soon

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Pathway for UPR 1.0 Evolution

- Scope of evolution is beyond UPR 1.0 RTF due to
  - Inclusion of logical constraints, as seen in EV studies
  - Supporting CDD automation
  - Exploring structure preserving transformations for
    - Model Synchronisation
    - Model Synthesis

- Pathways
  - UPR 2.0; or
  - Merge into with SysML 2 in a later RTF?
  - Collaboration with SE DSIG & Ontology PSIG

References, up to UPR 1.0 adoption

[1] Dickerson, C.E. and D. Mavris, "Relational Oriented Systems Engineering (ROSE): Preliminary report," in Proc. IEEE SoSE '11, Albuquerque, 2011.

[2] Dickerson, C.E., "A relational oriented approach to system of systems assessment of alternatives for data link interoperability," *IEEE Systems Jo*urnal, 16 May 2013.

[3] Mavris, D., K. Griendling and C. Dickerson, "Relational-Oriented Systems Engineering and Technology Trade-off Analysis Framework," *AIAA Journal of Aircraft*, 28 August 2013.

[4] Dickerson, C.E., and D. Mavris, "A Brief History of Models and Model Based Systems Engineering and the Case for Relational Orientation," *IEEE Systems Journal*, vol. 7, no. 4, 2013.

[5] D. Battersby, C. Dickerson, and S. Ji (with Jaguar Land Rover), "Calibration system and method", U.K. patent publication number GB2555617A, 9th May 2018

[6] Profiling a Software Architecture for the Relational Oriented Systems Engineering Technology Trade-off and Analysis Framework (ROSETTA), OMG Document No. mars/16-09-14, https://www.omg.org/members/cgi-bin/doc?mars/16-09-14.pptx

[7 UPR: UML Profile for ROSETTA Summary Report OMG Document No. mars/17-12-16, https://www.omg.org/members/cgi-bin/doc?mars/17-12-16.pptx

[8]"UPR: UML Profile for ROSETTA", adopted by the OMG on 22nd June 2018, https://www.omg.org/spec/UPR/1.0/PDF

References, the new journey

[9] AMiCC (AMiCalbe Charging), www.projectamicc.com

[10] Dickerson, Charles E. et al, 2021. "Architecture definition in complex system design using model theory." *IEEE Systems Journal* 15, no. 2: 1847 – 1860.

[11] Dickerson, C.E. and Siyuan Ji, *Essential Architecture and Principles of Systems Engineering.* Boca Raton Florida: CRC Press Auerbach Publication, September 2021.

[12] Update and Pathway for UPR 1.0 Evolution, OMG Document No. mars/21-09-19, https://www.omg.org/members/cgi-bin/doc?mars/21-09-19.pptx

[13] Review, Update and Pathway for UPR 1.0 Evolution, OMG Document No. ad/22-03-13, https://www.omg.org/members/cgi-bin/doc?ad/22-03-13.pptx

[14] UML Profile for ROSETTA (UPR), Architecture Specification with Structures and Transformations, OMG Document No. ontology/22-03-02, https://www.omg.org/members/cgi-bin/doc?ontology/22-03-02.pptx

[15] S. Ji, C. Dickerson and M. Wilkinson, 'Structure Preserving Transformations for Practical Model-based Systems Engineering', to be submitted to ISSE2022