The AMADEOS SysML Profile for Cyber-physical Systems-of-Systems

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Outline

- AMADEOS Conceptual modeling
  - Basic concepts and their relationships
  - Viewpoints-driven approach
- From Conceptual to SysML modeling
  - High-level representation
  - Semi-formalization into the AMADEOS profile
  - Application to toy example
- Conclusions

A Conceptual Model

- It expresses the **meaning of terms** and **concepts** used by domain experts to discuss the problem
- It ensures that problems with different interpretations of the terms and concepts cannot occur
- It is the basis for subsequent development of applications in a domain

The AMADEOS conceptual model

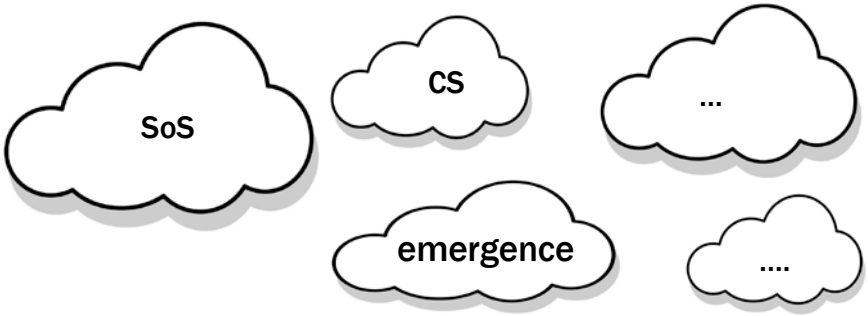
- Establishing a domain specific ontology on Cyber-physical Systems-of-Systems, serving as a vocabulary for the domain of discourse
- Forming a reference for the AMADEOS work
  - Supporting the definition of a reference architecture for SoSs
  - Supporting the definition of methodologies and techniques to be proved in a concrete case study on smart energy grids

Basic concepts and relationships

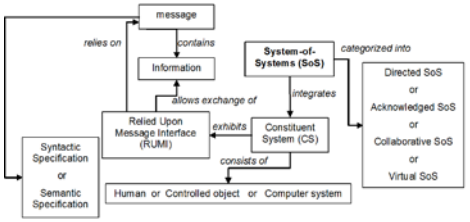
- Definition of basic SoS concepts
  - Not domain specific
  - Applicable to any SoS
- Definition of relationships among basic SoS concepts

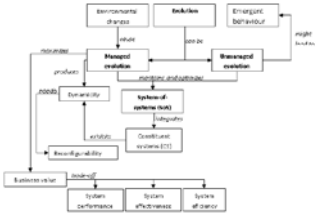
From Conceptual to SysML modeling

SoS Basic concepts

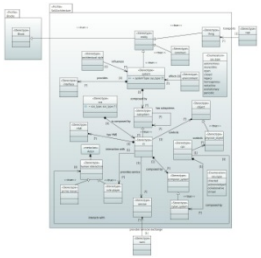


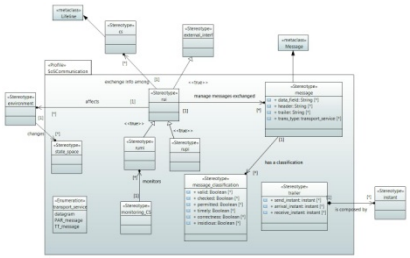
High-level representation

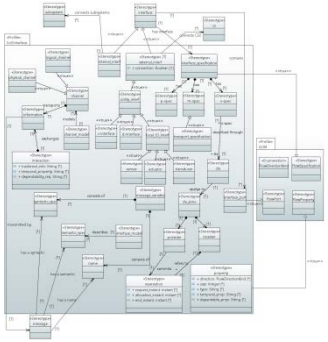




Semi-formalization







Viewpoints composing the model

- Basic concepts defined according to 7 viewpoints
  - Structure
  - Dynamicity
  - Evolution
  - Dependability and Security
  - Time
  - Multi-criticality
  - Emergence
- Viewpoints represent core AMADEOS issues
- Concepts (and viewpoints) have been integrated by defining their relationships
- Viewpoints approach facilitate the conceptual modeling itself and the design process

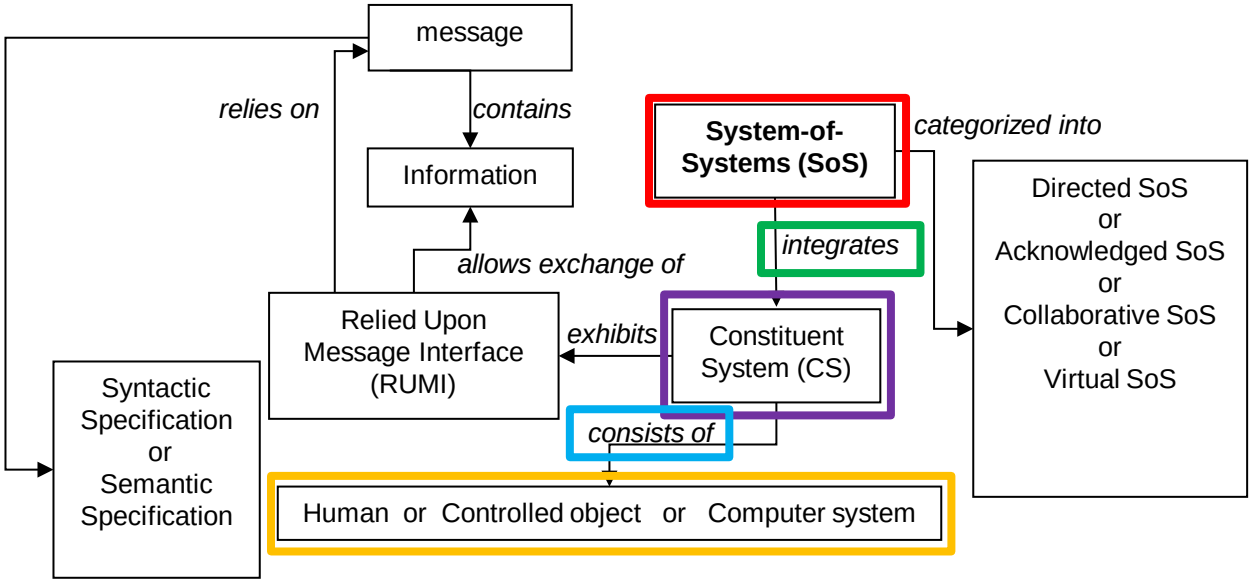
High-level representation

- Explicates relations among basic SoS concepts per viewpoint
- Supports their graphical visualization
- Semantic
  - Boxes represent concepts
  - Arrows represents semantic relationships among concepts (labels in natural language)

Relating basic SoS concepts in Structure view

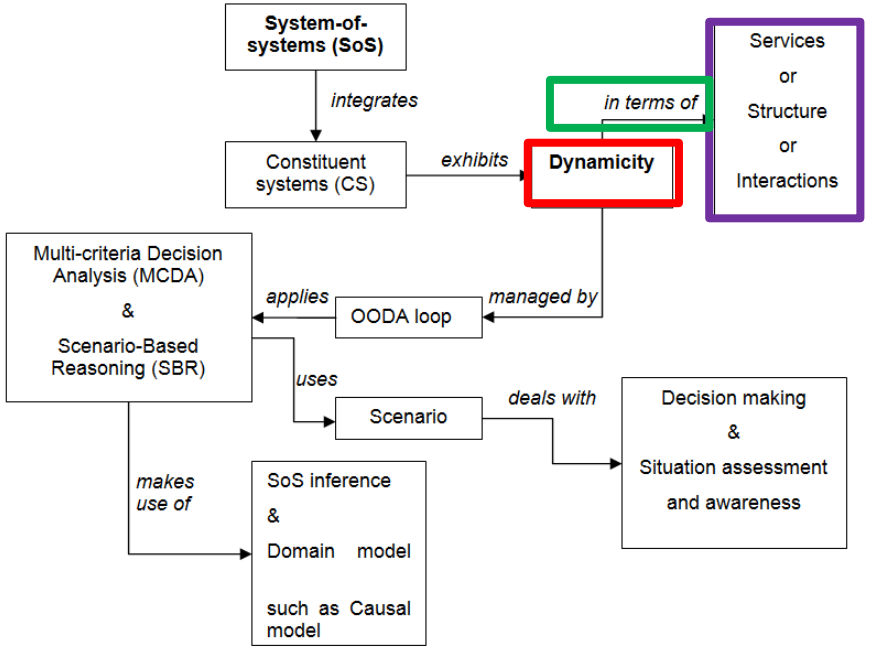
- "System-of-Systems (SoS): An SoS is an integration of a finite number of constituent systems (CS) which are independent and operable, and which are networked together for a period of time to achieve a certain higher goal."

- "Constituent System (CS): An autonomous subsystem of an SoS, consisting of computer systems and possibly of a controlled objects and/or human role players that interact to provide a given service."



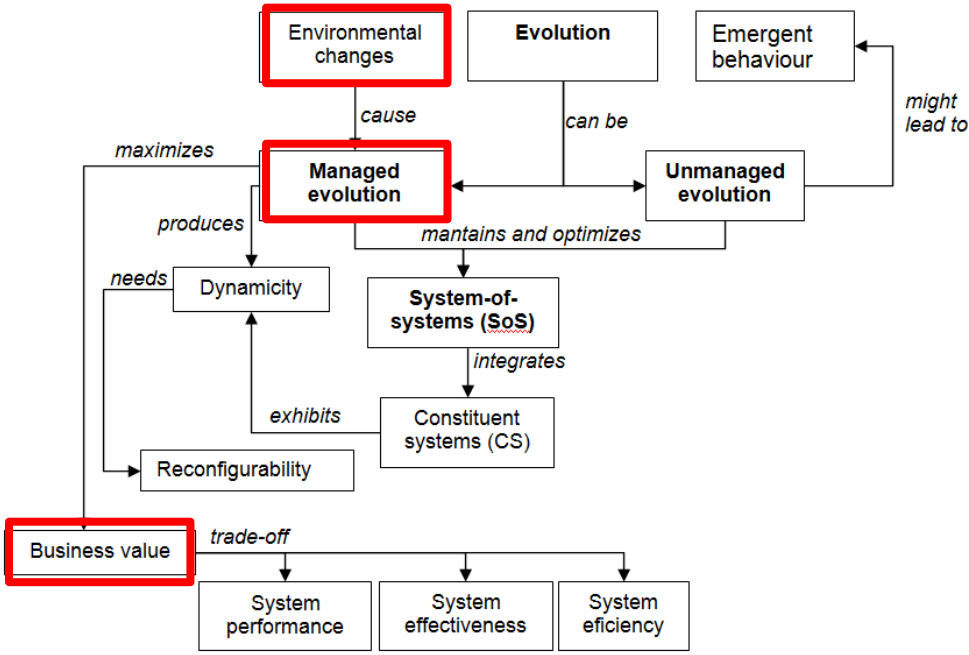
Dynamicity / Evolution

- "Dynamicity: The property of an entity that is constantly changing in terms of offered services, built-in structure and interactions with other entities."

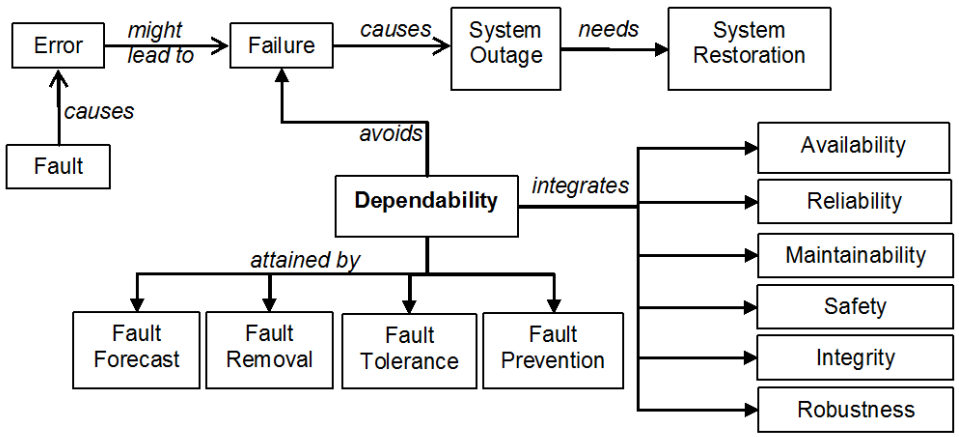


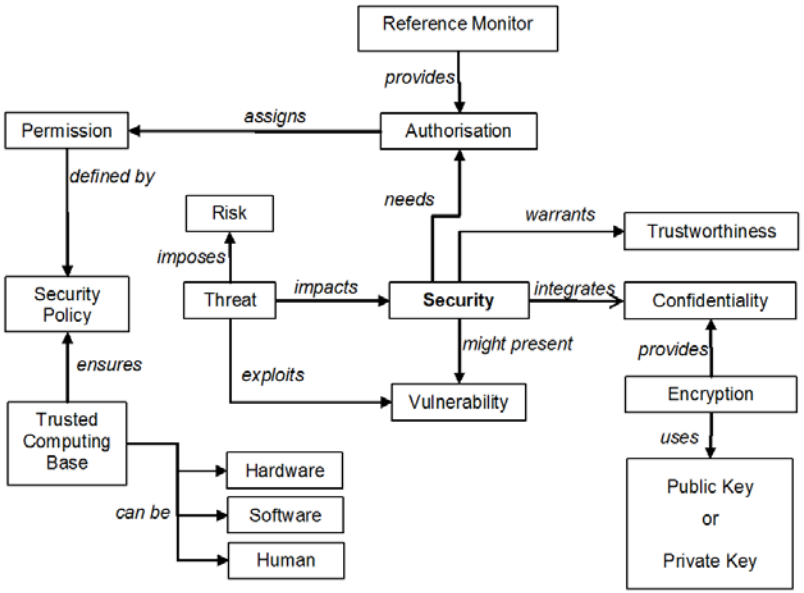
- "Managed SoS evolution: Process of modifying the SoS to keep it relevant in face of an ever-changing environment."

- "Business value: Overarching concept to denote the performance, impact, usefulness, etc. of the functioning of the SoS"

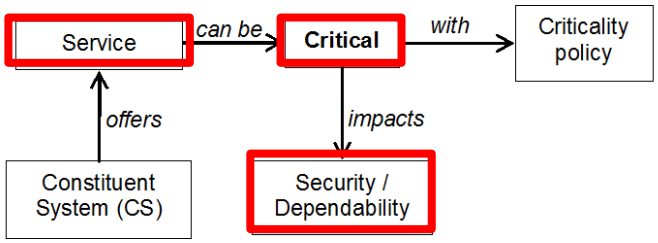


Dependability / Security / Multi-criticality





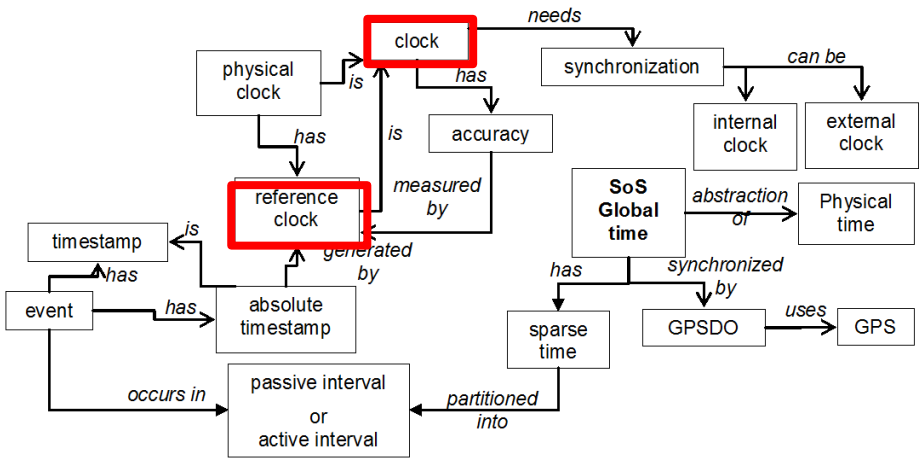
- "Critical service: A critical service is the service of a system that requires a specific criticality level."
- "Criticality level: The criticality level is the level of assurance against failure."



Time / Emergence

- Clock: A (digital) clock is an autonomous system that consists of an oscillator and a register. Whenever the oscillator completes a period, an event is generated that increments the register.

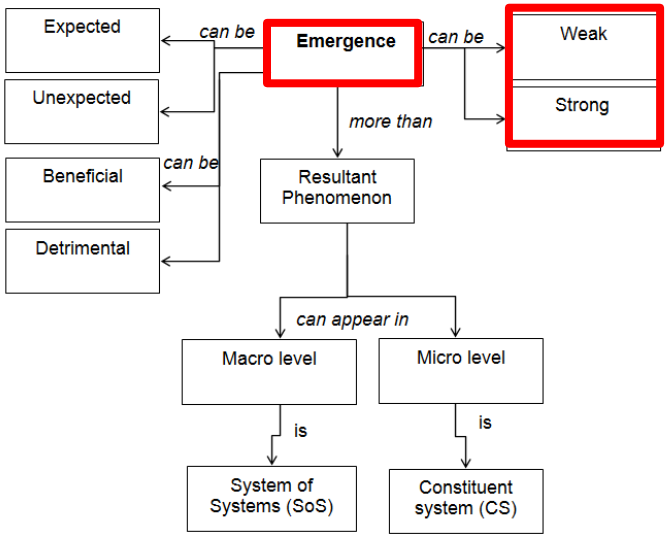
- Reference clock: A hypothetical clock of a granularity smaller than any duration of interest and whose state is in agreement with TAI.



- Emergence: A phenomenon of a whole at the macro-level is emergent if and only if it is new with respect to the non-relational phenomena of any of its proper parts at the micro level.

- Weak emergence: …if a trans-ordinal law that explains the occurrence of the emergent phenomenon at the macro level out of the properties and interactions of the parts at the adjacent micro level is known.

- Strong Emergence: … if, after a careful analysis of the emergent phenomenon, no trans-ordinal law that explains…. is known (at least at present).



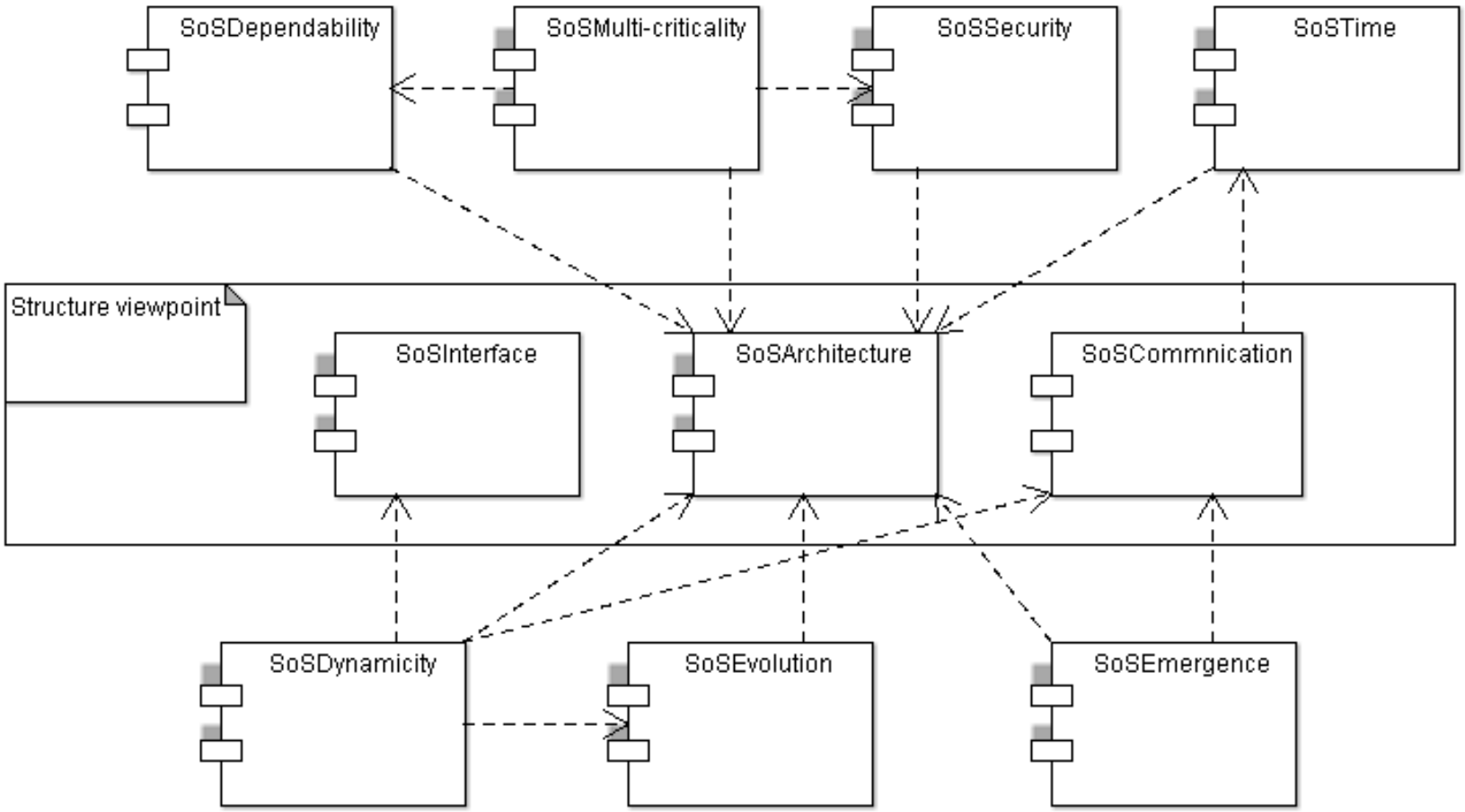
Towards a semi-formal representation

- Describe AMADEOS viewpoints via a SysML profile
- UML-like representation
  - Improve the understanding by using different levels of abstraction and different views
  - Foster information sharing and reuse among SoS stakeholders
  - Enable analysis and experimentation at early stage of the SoS lifecycle process

AMADEOS Profile: Rationale

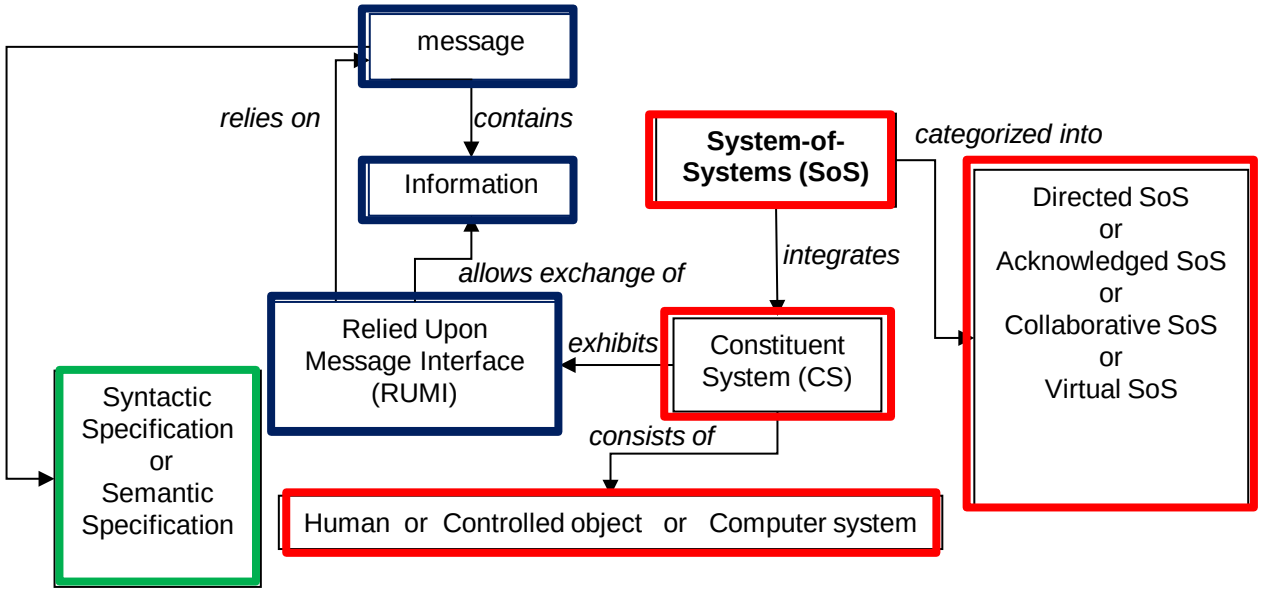
- A SysML profile to implement SoS basic concepts and their relationships
  - Strong focus on conceptual modelling
  - Capturing both SoS static structure and dynamic behavior
- The profile makes use of
  - New added constructs
  - Constructs already available in related profiles (MARTE, CONCERTO)
- Organized in viewpoints driven-components
- Profile implementation
  - Open source Eclipse integrated development environment along with Papyrus plug-in

AMADEOS profile components



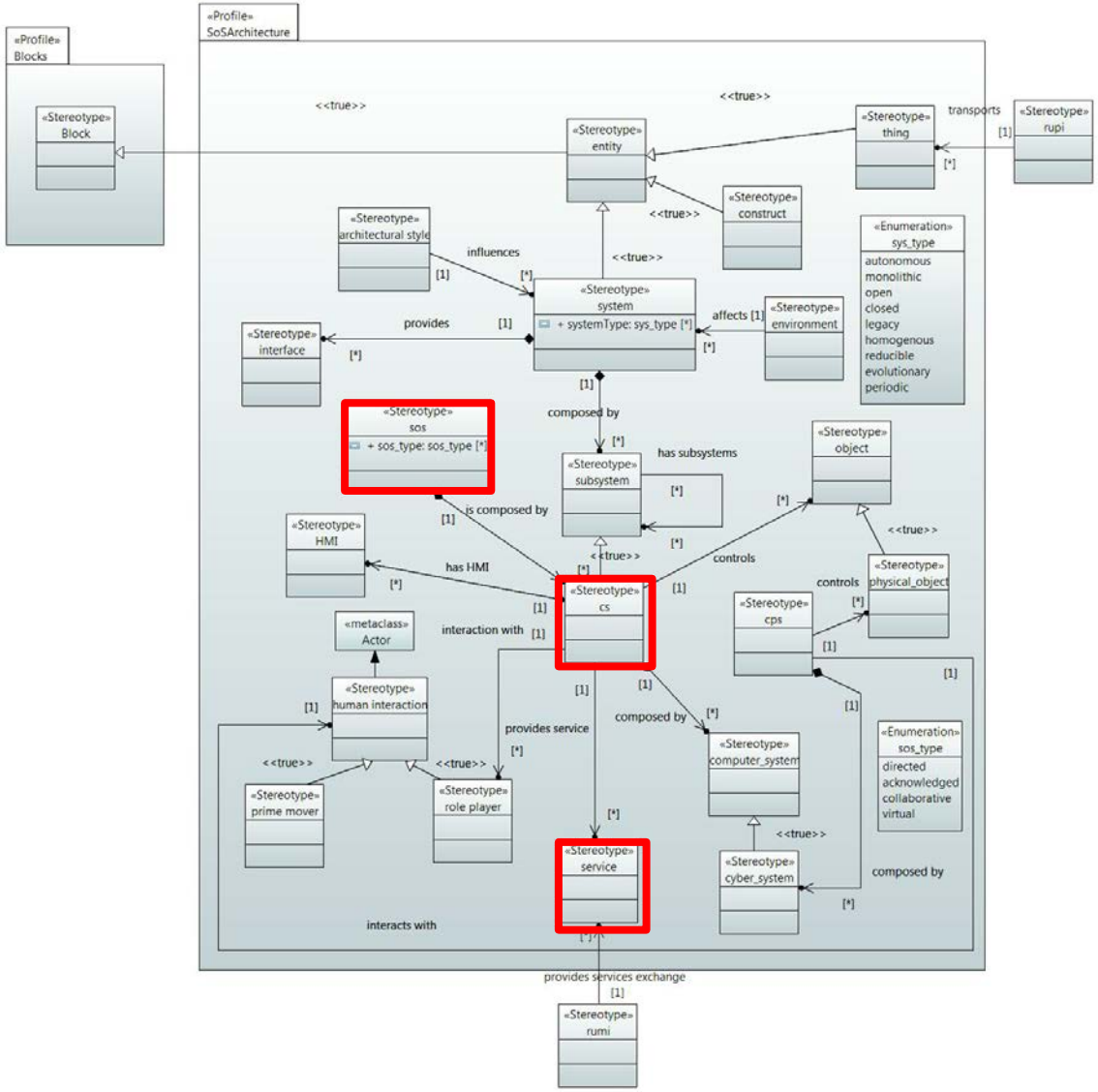
Mapping structure view into AMADEOS profile

- Starting from the high-level graphical representation of Structure…

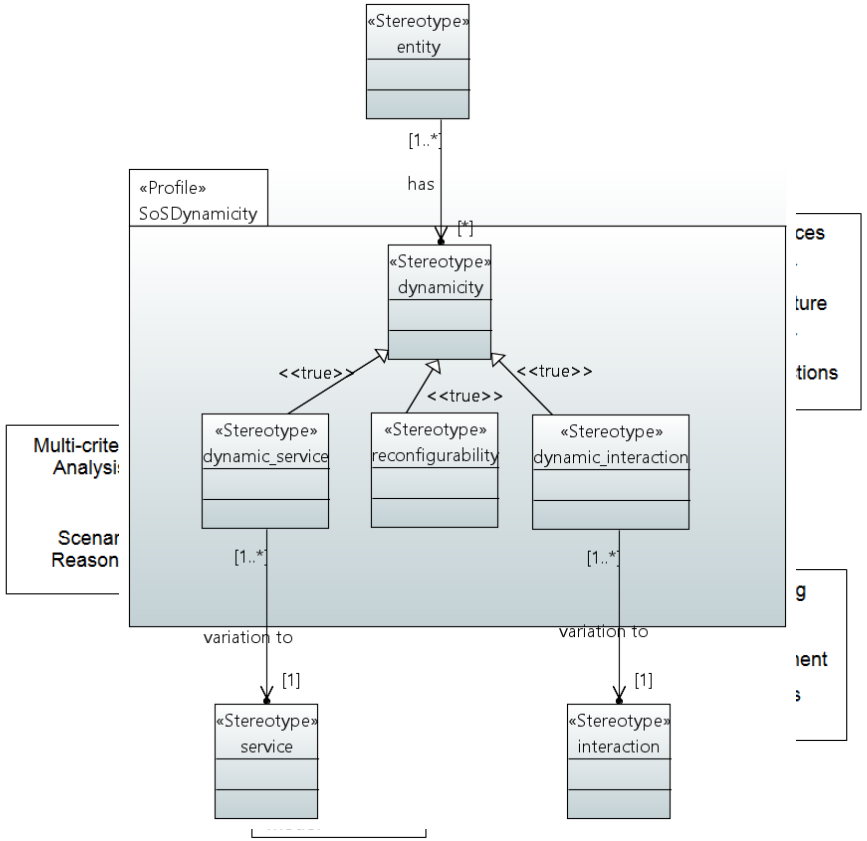


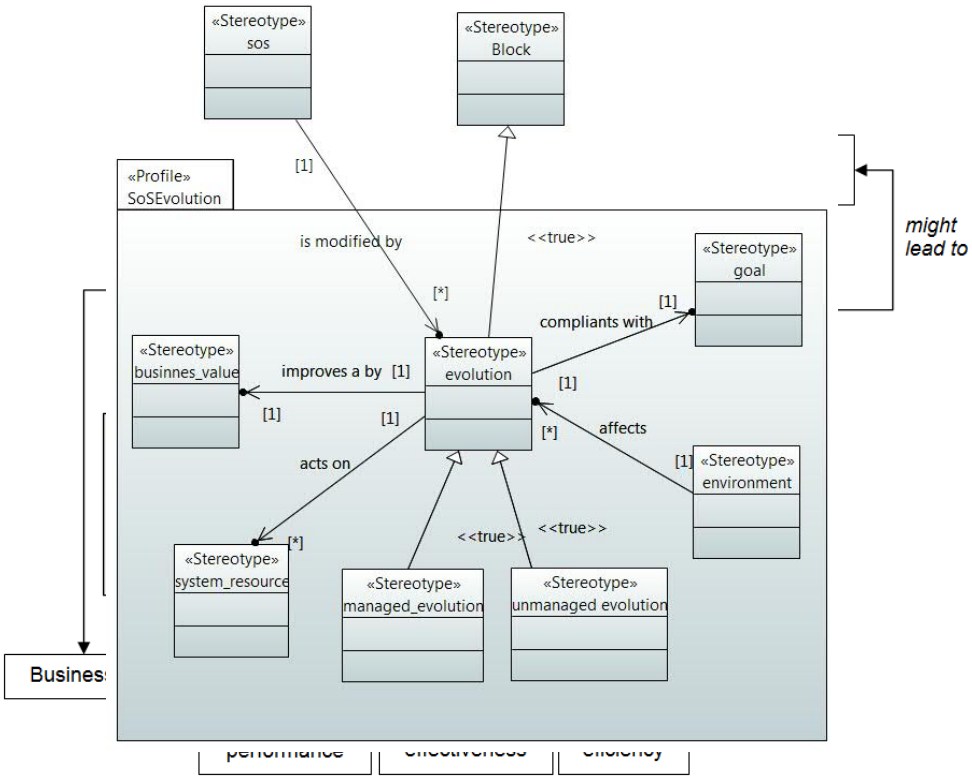
- ….we implemented three SysML profile components:
  - *SoSArchitecture* component
  - *SoSCommunication* component
  - *SoSInterface* component

SoSArchitecture / SoS Communication

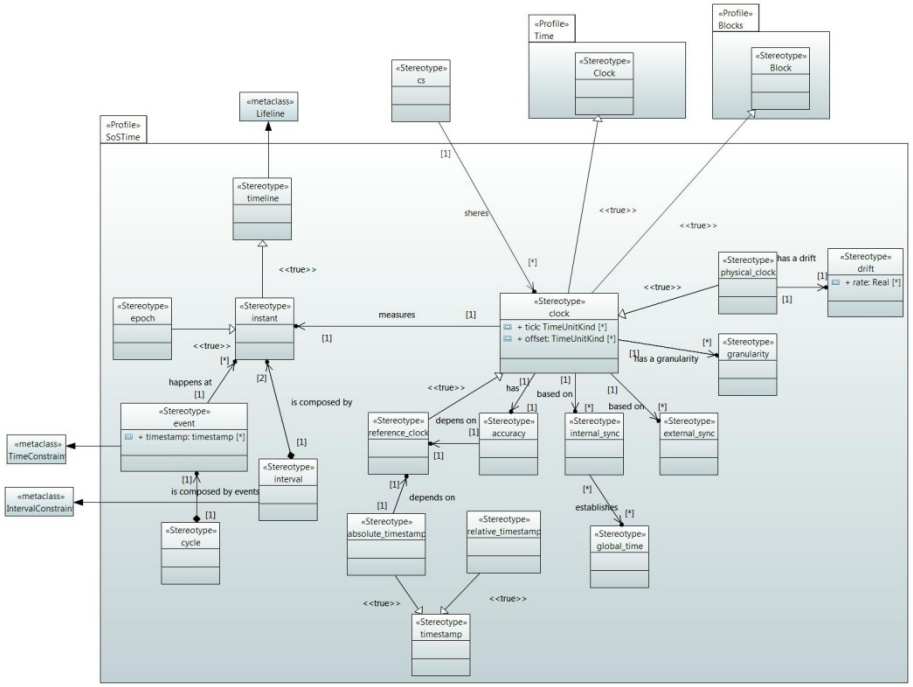


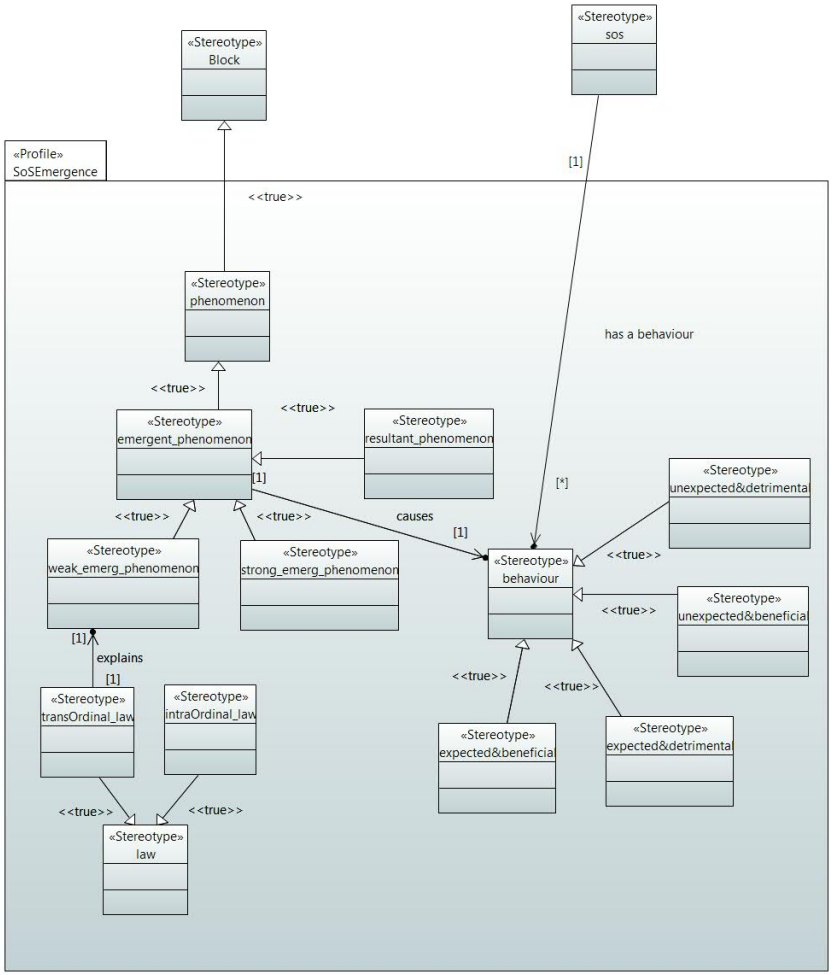
Dynamicity / Evolution





Time / Emergence

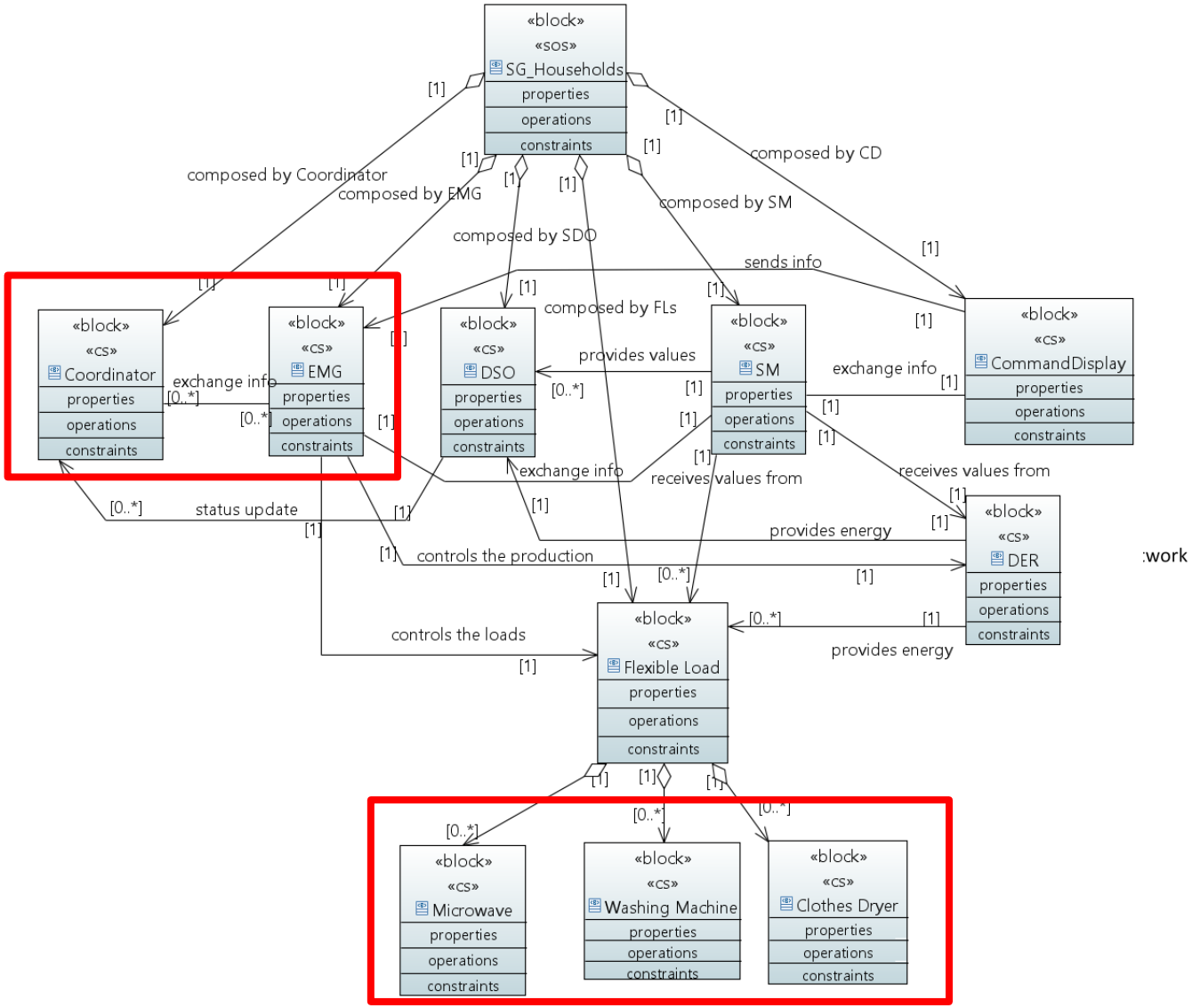




Toy Example: Smart Grid Household

- Applying the profile to a toy example to check:
  - soundness of a subsets of semi-formalized concepts
  - which concepts were missing
- Toy Example
  - Improving the efficiency and the reliability of the production and distribution of electricity in a Smart Grid
  - Keeping production and consumption rate as much balanced as possible for a set of connected households
  - Electronic appliances forward requests of energy by interacting with higher-level sub-systems which decides to grant or deny each request

Toy Example: *structure view*



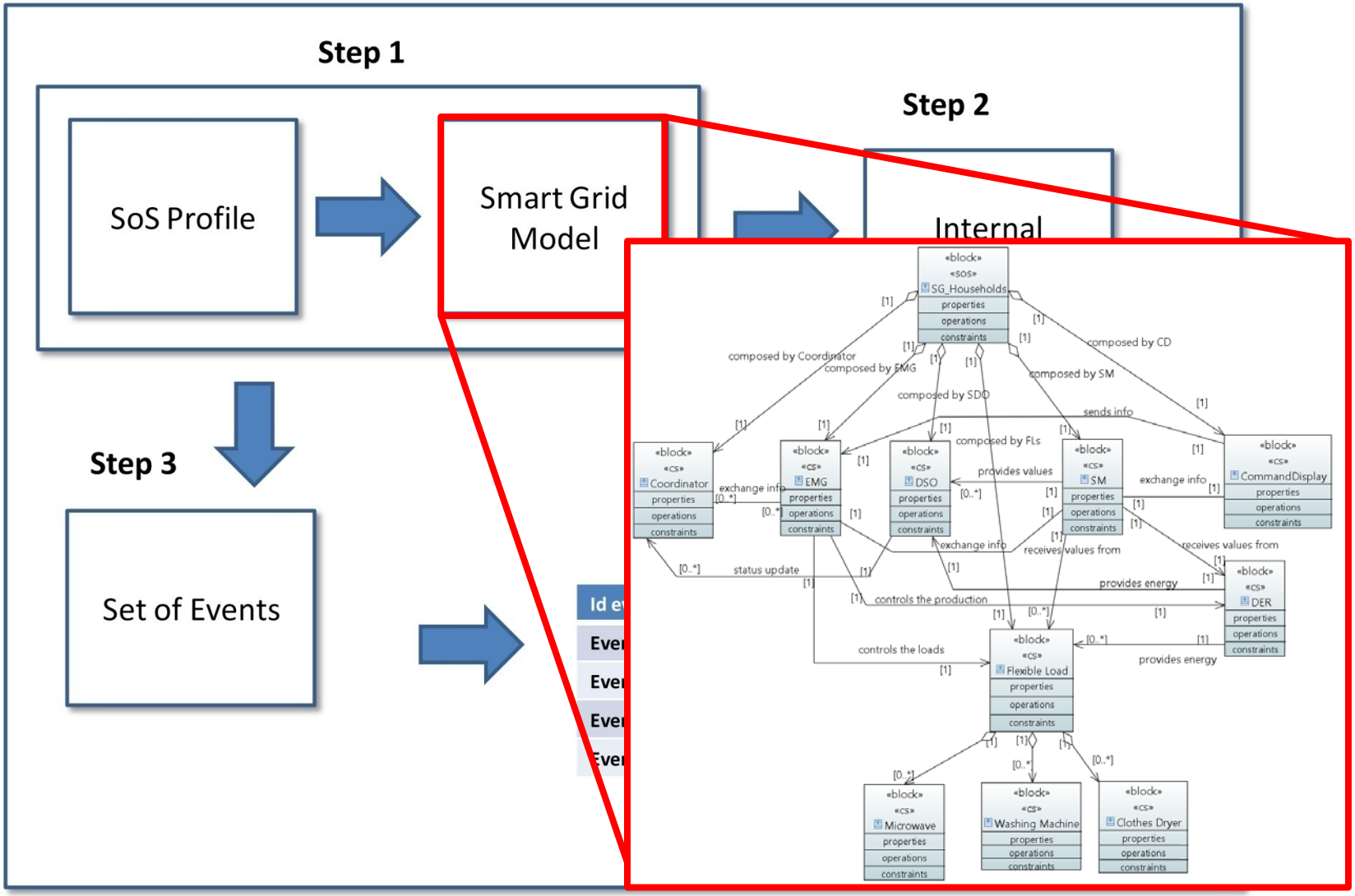
AMADEOS profile – possible applications

- Model-based definition of an SoS with AMADEOS profile
  - Platform Independent Model of an SoS
- Platform-Specific Models can be defined and used at different stages of system design and validation (MDE approaches)
- The profile can be integrated into existing SysML MDE tool-chain platforms, such as CONCERTO, Eclipse, to perform e.g.
  - System analysis
    - E.g. Hazard Analysis (HA), Failure Mode and Effect Analysis (FMEA), Fault Tree Analisys (FTA), etc.
  - Source code generation
  - System testing

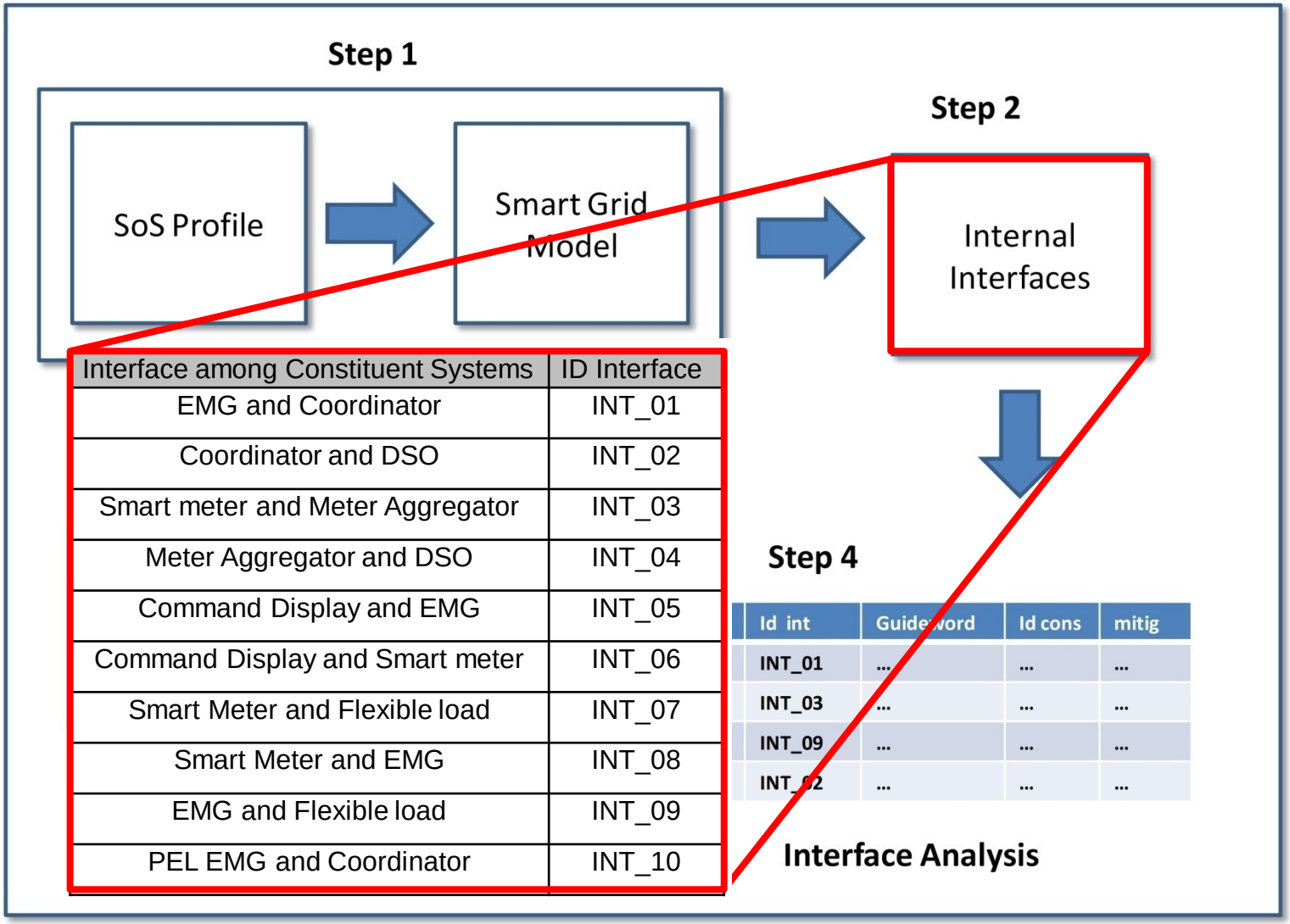
Profile application for supporting HA

- Hazard Analysis application example
  - Typically it identifies and mitigates hazards leading to detrimental situations
  - In our case, it supports the identification of emergent conditions based on the information exchanged through the interfaces
- Input:
  - Events and interfaces
- Output
  - Identification of consequences and emergent behaviors

Workflow: Profile application



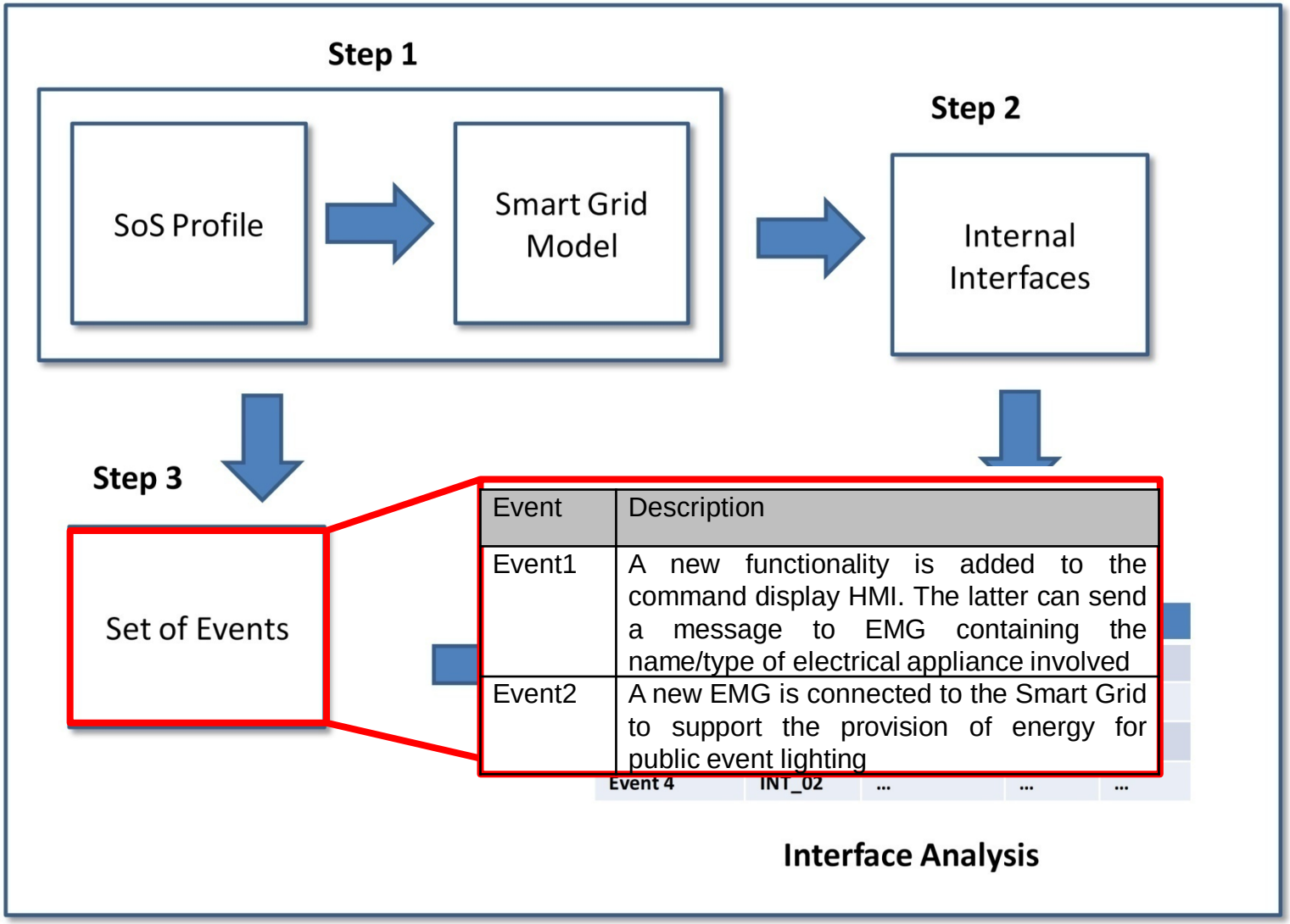
Workflow: Interface Identification



Interface among Constituent Systems	ID Interface
EMG and Coordinator	INT_01
Coordinator and DSO	INT_02
Smart meter and Meter Aggregator	INT_03
Meter Aggregator and DSO	INT_04
Command Display and EMG	INT_05
Command Display and Smart meter	INT_06
Smart Meter and Flexible load	INT_07
Smart Meter and EMG	INT_08
EMG and Flexible load	INT_09
PEL EMG and Coordinator	INT_10

Id int	Guideword	Id cons	mitig
INT_01	...	...	...
INT_03	...	...	...
INT_09	...	...	...
INT_02	...	...	...

Workflow: Events



Event	Description
Event1	A new functionality is added to the command display HMI. The latter can send a message to EMG containing the name/type of electrical appliance involved
Event2	A new EMG is connected to the Smart Grid to support the provision of energy for public event lighting

Workflow: Hazards identification

Id Event	Id Interface	Guideword	Hazard	Emergent Behavior	Consequence	Mitigation
Event 1	INT_05	More	EMG receives additional information from the new Command Display on the electrical appliance switched on	YES - beneficial	EMG can forward additional information to the Coordinator for better balancing the Smart Grid	*not needed*
Event 2	INT_10	More	The Coordinator receives a request for a very high amount of energy to support the public event lighting	YES - detrimental	Coordinator, in order to keep balanced production and consumption values, decides to limit the provision of energy for the electrical appliance	MIT_03: EMG can communicate the energy decrease to the Command Display (INT_05). The latter supports the reconfiguration of the electrical appliances

Conclusion

- Viewpoint-based conceptual modeling
  - Basic SoS concept definition
  - Representation of their semantic relationships
  - SysML semi-formalization: AMADEOS profile
- Vision for the Applicability of the profile for SoS description and analysis
- Conceptual model refinement to be continued until the end of the project

Thank You

for Your attention