SoSECIE Webinar

Welcome to the
2020 System of Systems Engineering Collaborators
Information Exchange (SoSECIE)

We will start at 11AM Eastern Time

You can download today's presentation from the SoSECIE Website:

https://mitre.tahoe.appsembler.com/blog

To add/remove yourself from the email list or suggest a future topic or speaker, send an email to sosecie@mitre.org

NDIA System of Systems SE Committee

- **Mission**
  - To provide a forum where government, industry, and academia can share lessons learned, promote best practices, address issues, and advocate systems engineering for Systems of Systems (SoS)
  - To identify successful strategies for applying systems engineering principles to systems engineering of SoS
- **Operating Practices**
  - Face to face and virtual SoS Committee meetings are held in conjunction with NDIA SE Division meetings that occur in February, April, June, and August

NDIA SE Division SoS Committee Industry Chairs:

Mr. Rick Poel, Boeing

Ms. Jennie Horne, Raytheon

OSD Liaison:

Dr. Judith Dahmann, MITRE

Simple Rules of Engagement

- I have muted all participant lines for this introduction and the briefing.
- If you need to contact me during the briefing, send me an e-mail at sosecie@mitre.org.
- Download the presentation so you can follow along on your own
- We will hold all questions until the end:
    - I will start with questions submitted online via the CHAT window in Teams.
    - I will then take questions via telephone; State your name, organization, and question clearly.
- If a question requires more discussion, the speaker(s) contact info is in the brief.

Disclaimer

- MITRE and the NDIA makes no claims, promises or guarantees about the accuracy, completeness or adequacy of the contents of this presentation and expressly disclaims liability for errors and omissions in its contents.
- No warranty of any kind, implied, expressed or statutory, including but not limited to the warranties of non-infringement of third party rights, title, merchantability, fitness for a particular purpose and freedom from computer virus, is given with respect to the contents of this presentation or its hyperlinks to other Internet resources.
- Reference in any presentation to any specific commercial products, processes, or services, or the use of any trade, firm or corporation name is for the information and convenience of the participants and subscribers, and does not constitute endorsement, recommendation, or favoring of any individual company, agency, or organizational entity.

2020-2021 System of Systems Engineering Collaborators Information Exchange Webinars

Sponsored by MITRE and NDIA SE Division

December 1, 2020

Achieving System Integration through Interoperability in a large System of Systems (SoS)

Mr. Oliver Hoehne

2021-2022 System of Systems Engineering Collaborators Information Exchange Webinars

Sponsored by MITRE and NDIA SE Division

January 26, 2021

Addressing the Sustainable Development Goals with a System-of-Systems for Monitoring Arctic Coastal Regions

Evelyn Honoré-Livermore, Roger Birkeland and Cecilia Haskins

February 23, 2021

Interface Management- the Neglected Orphan of Systems Engineering

Paul Davies

March 9, 2021

Distributed Architecture for Monitoring Urban Air Quality: A Systems Engineering Approach

Adrián Unger, Tom McDermott and Philip Dewire

April 6, 2021

Holistic architecture description for a future Global Health Assurance Systems of Systems

Adrián Unger

Achieving System-of-Systems Interoperability Levels Using Linked Data and Ontologies

Jakob Axelsson, Mälardalen University & RISE Research Institutes of Sweden
jakob.axelsson@mdh.se

SoS common concerns

Klein and van Vliet (2013): Survey of 200 research papers on SoS architecture.

- **Interoperability** (45)
- Security (14)
- Evolution (13)
- Performance (9)
- Safety (8)
- Testability (6)
- Quality of service (5)
- Reusability (5)
- Risk (5)

Bianchi et al. (2015): Survey of 40 research papers on SoS quality attributes.

- **Interoperability** (14)
- Security (14)
- Performance (14)
- Reliability (13)
- Safety (10)
- Availability (8)
- Maintainability (6)
- Complexity (5)
- Dependability (5)

Interoperability

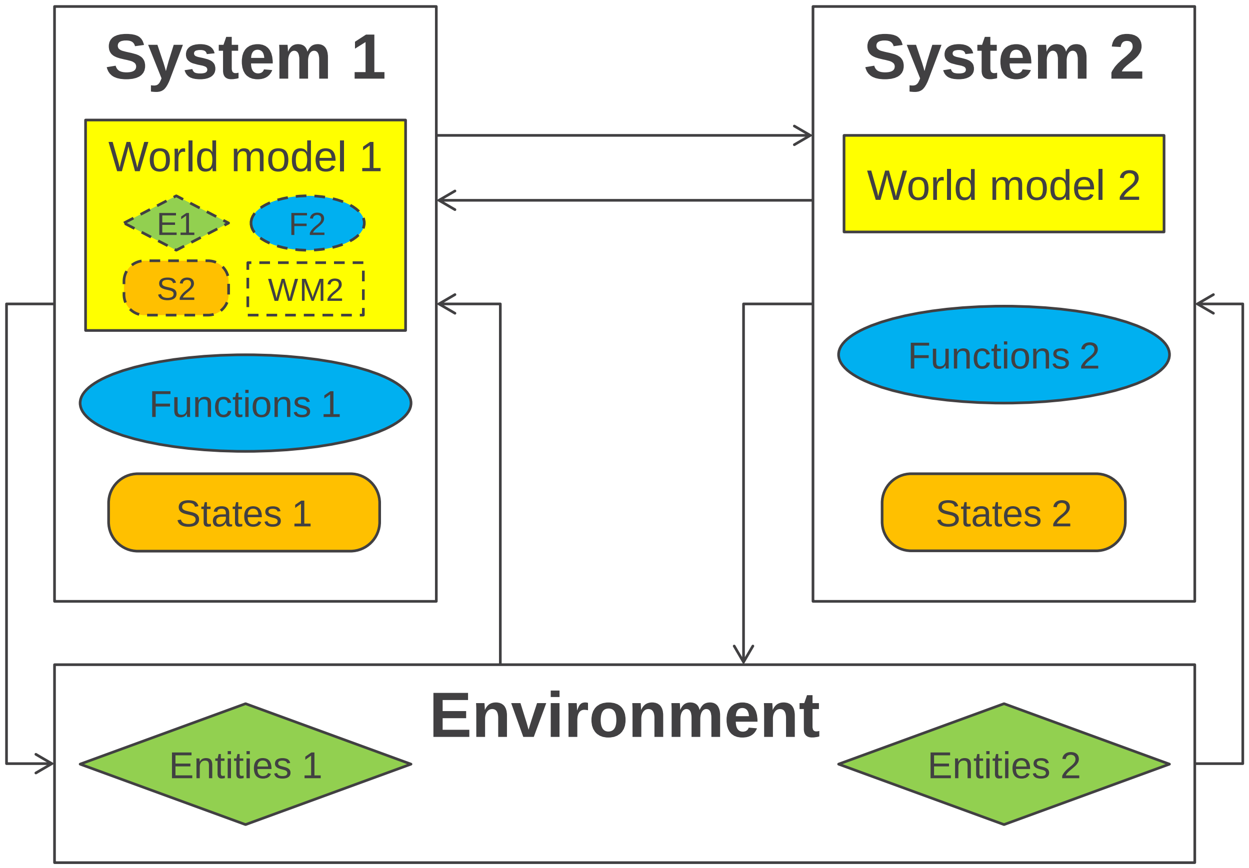
"The ability of two or more systems or components to exchange information and to use the information that has been exchanged."

(IEEE standard glossary of software engineering terminology, 1990)

SoS engineering considerations

- Analysis: Levels of Conceptual Interoperability Model (LCIM).
- Technology: Linked data and ontologies.
- Trade-offs: Functionality vs. performance and lifecycle cost.

A basic system(-of-systems) model

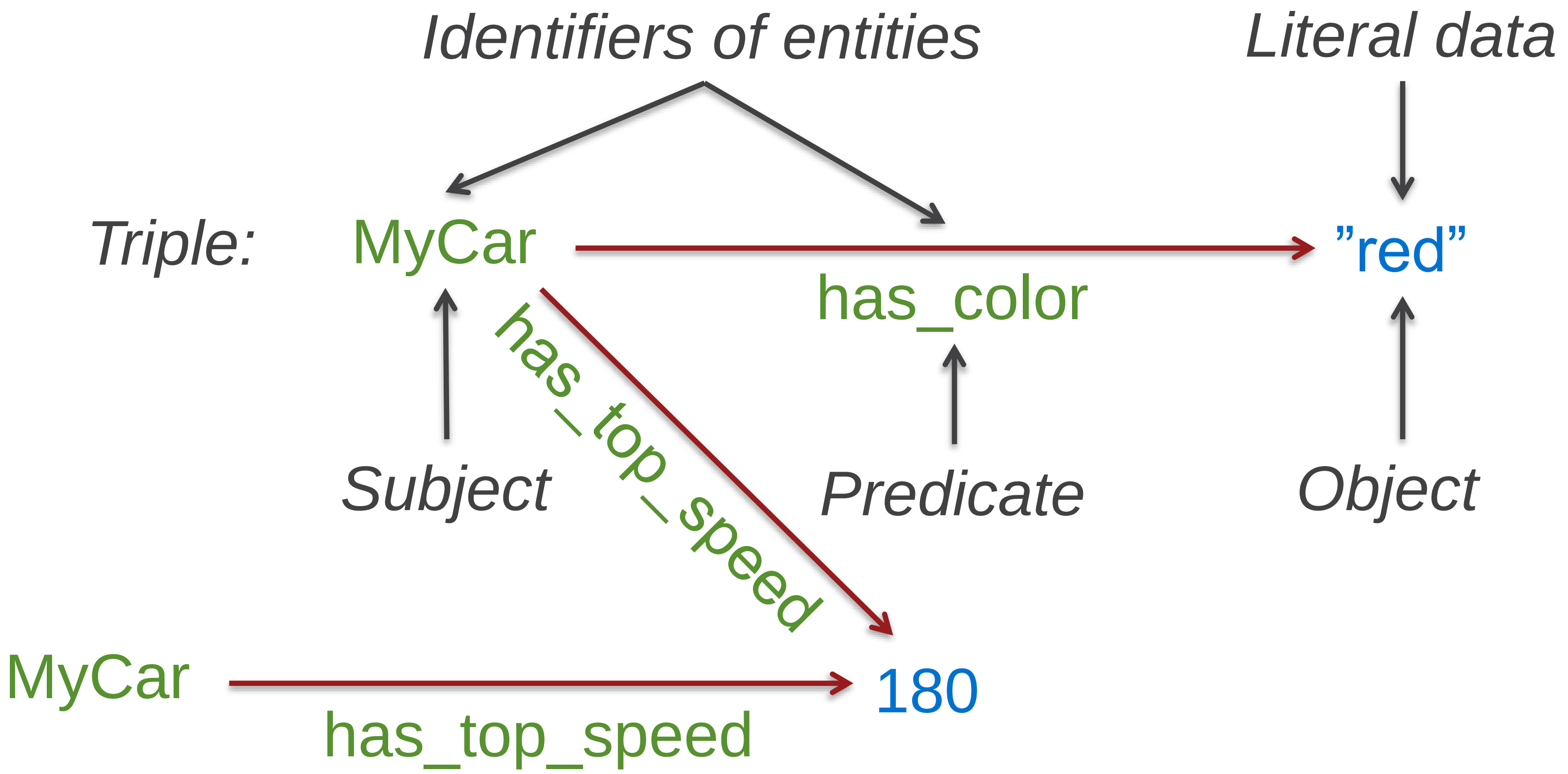


Levels of conceptual interoperability (LCIM)

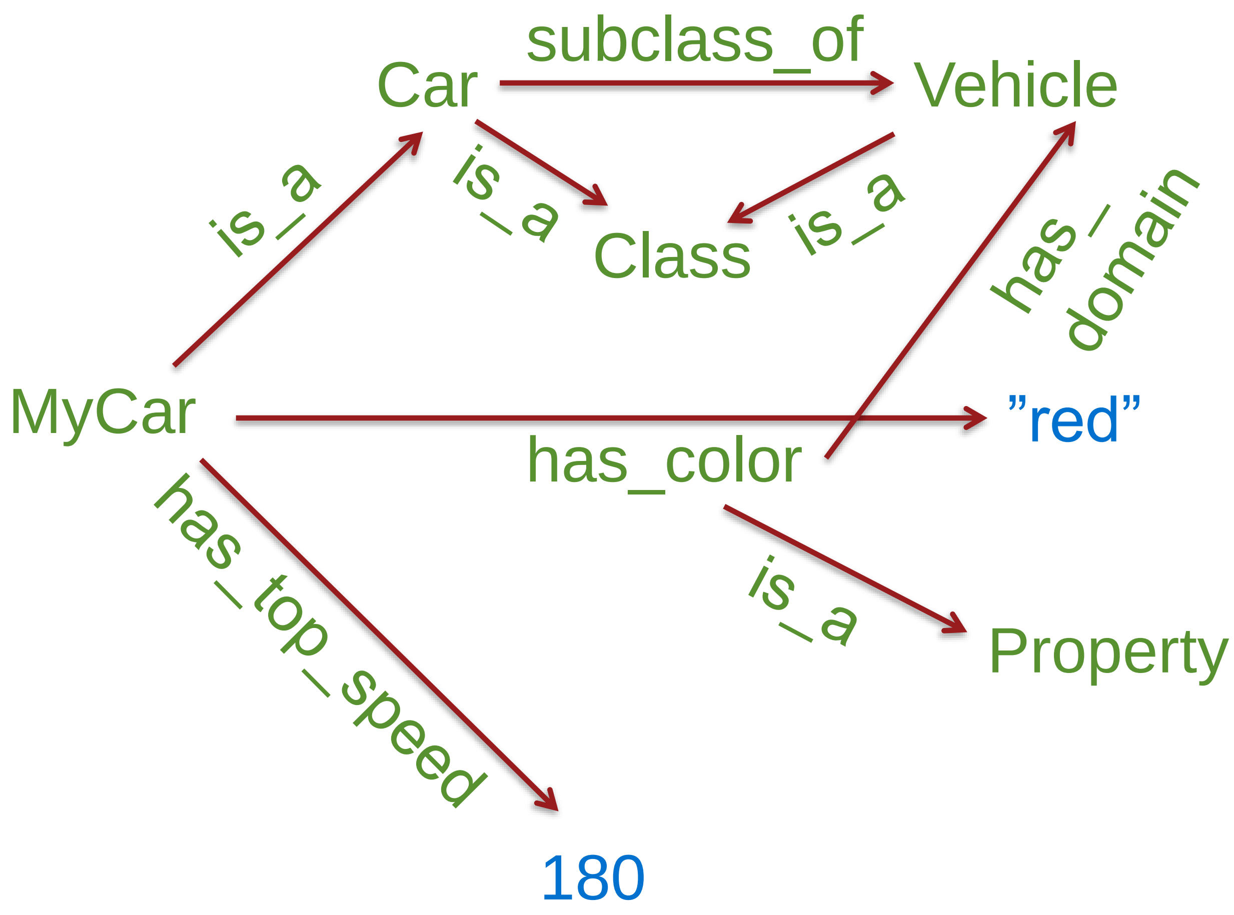
Level	Layer	Premise	Information defined
6	Conceptual	Conceptual model	Assumptions, constraints
5	Dynamic	Execution model	Effect of data
4	Pragmatic	Workflow model	Use of data
3	Semantic	Reference model	Meaning of data
2	Syntactic	Data structure	Structured data
1	Technical	Communication protocol	Bits and bytes
0	No	No connection	None

(Tolk et al., 2006; Wang et al., 2009)

Semantic web: Linked data



Semantic web: Ontologies



Level 1: Technical interoperability

Level	Layer	Premise	Information defined
6	Conceptual	Conceptual model	Assumptions, constraints
5	Dynamic	Execution model	Effect of data
4	Pragmatic	Workflow model	Use of data
3	Semantic	Reference model	Meaning of data
2	Syntactic	Data structure	Structured data
1	Technical	Communication protocol	Bits and bytes
0	No	No connection	None

Level 1: Technical interoperability

- Transferability of data
- Open Systems Interconnection (OSI) model
- Internet/WWW protocols:
  - IoT
  - Cloud

Level 2: Syntactic interoperability

Level	Layer	Premise	Information defined
6	Conceptual	Conceptual model	Assumptions, constraints
5	Dynamic	Execution model	Effect of data
4	Pragmatic	Workflow model	Use of data
3	Semantic	Reference model	Meaning of data
2	Syntactic	Data structure	Structured data
1	Technical	Communication protocol	Bits and bytes
0	No	No connection	None

Level 2: Syntactic interoperability

- Serialization of linked data:
  - XML, Turtle, Json, etc.
- Triple databases:
  - In memory or persistent.
  - SPARQL query language.

Level 3: Semantic interoperability

Level	Layer	Premise	Information defined
6	Conceptual	Conceptual model	Assumptions, constraints
5	Dynamic	Execution model	Effect of data
4	Pragmatic	Workflow model	Use of data
3	Semantic	Reference model	Meaning of data
2	Syntactic	Data structure	Structured data
1	Technical	Communication protocol	Bits and bytes
0	No	No connection	None

Level 3: Semantic interoperability

- Basic ontology concepts (metamodel):
  - Classes, subclasses, instances
  - Properties
- UML and SysML.
- Reasoning.

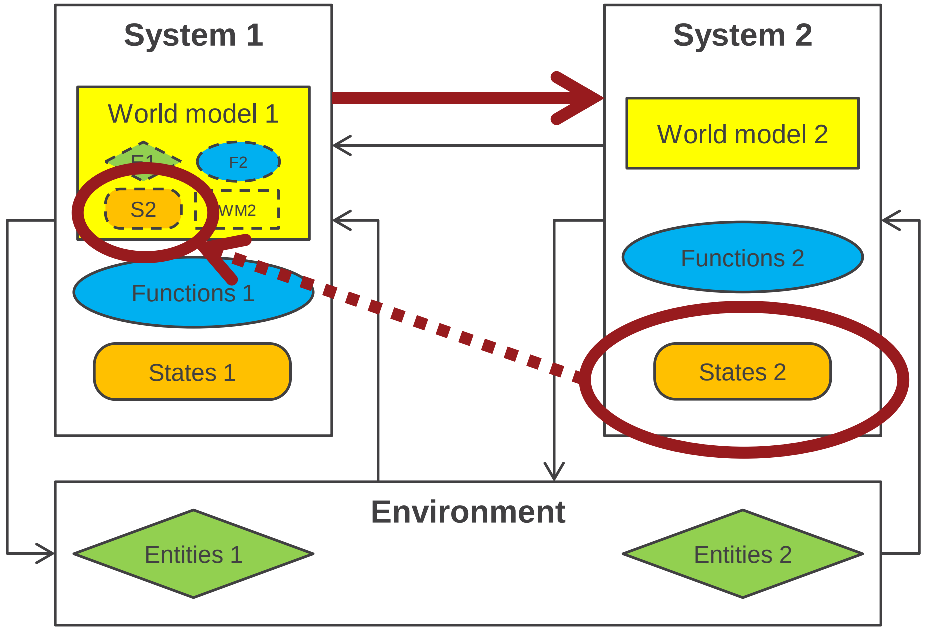
Levels 4: Pragmatic interoperability

Level	Layer	Premise	Information defined
6	Conceptual	Conceptual model	Assumptions, constraints
5	Dynamic	Execution model	Effect of data
4	Pragmatic	Workflow model	Use of data
3	Semantic	Reference model	Meaning of data
2	Syntactic	Data structure	Structured data
1	Technical	Communication protocol	Bits and bytes
0	No	No connection	None

Level 4: Pragmatic interoperability

World model:

- States and transitions
- Workflows
- Modes
- Configurations
- Services offered



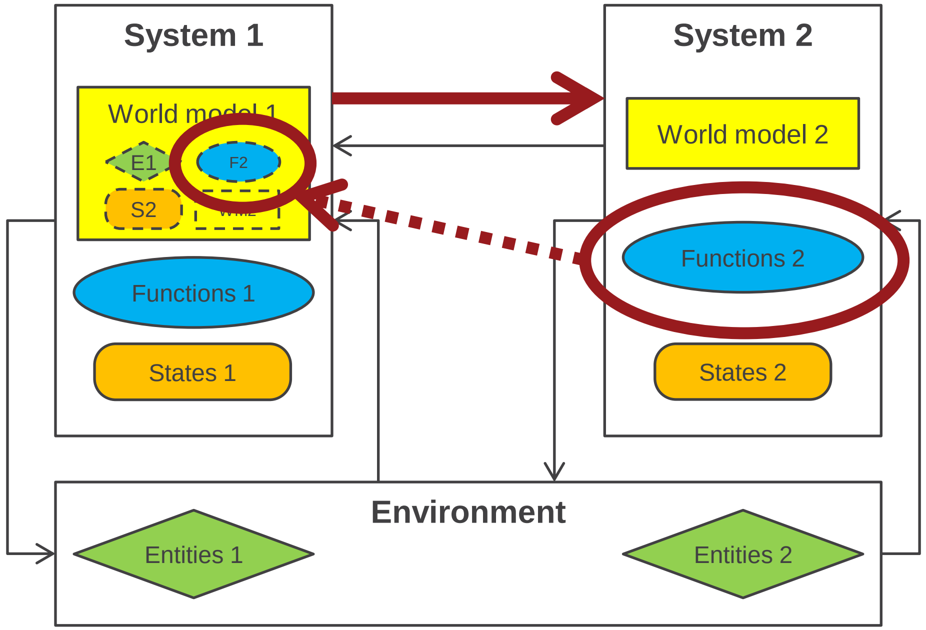
Levels 5: Dynamic interoperability

Level	Layer	Premise	Information defined
6	Conceptual	Conceptual model	Assumptions, constraints
5	Dynamic	Execution model	Effect of data
4	Pragmatic	Workflow model	Use of data
3	Semantic	Reference model	Meaning of data
2	Syntactic	Data structure	Structured data
1	Technical	Communication protocol	Bits and bytes
0	No	No connection	None

Level 5: Dynamic interoperability

World model:

- Functions
- Missions
- Capabilities
- Properties



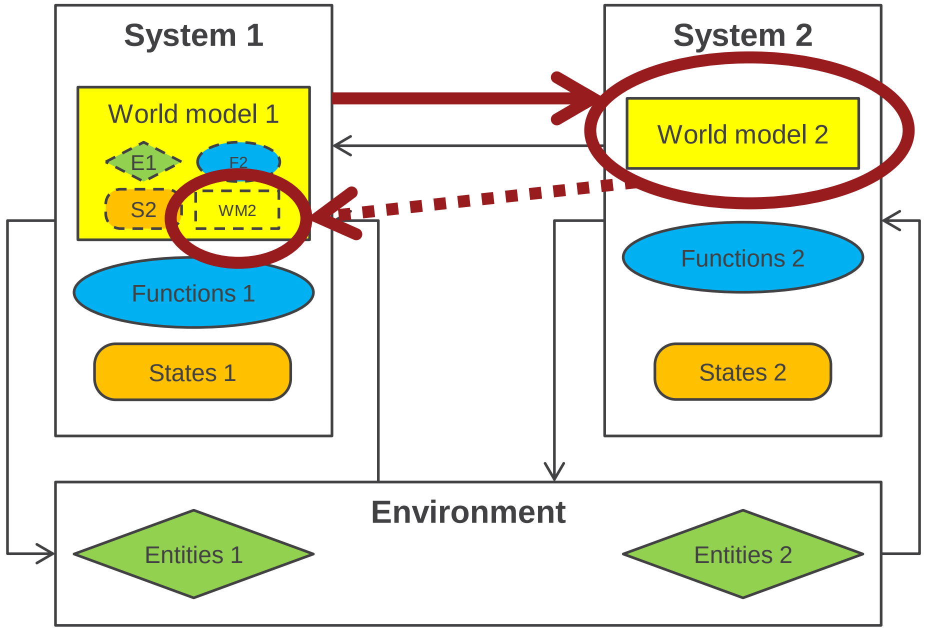
Levels 6: Conceptual interoperability

Level	Layer	Premise	Information defined
6	Conceptual	Conceptual model	Assumptions, constraints
5	Dynamic	Execution model	Effect of data
4	Pragmatic	Workflow model	Use of data
3	Semantic	Reference model	Meaning of data
2	Syntactic	Data structure	Structured data
1	Technical	Communication protocol	Bits and bytes
0	No	No connection	None

Level 6: Conceptual interoperability

World model:

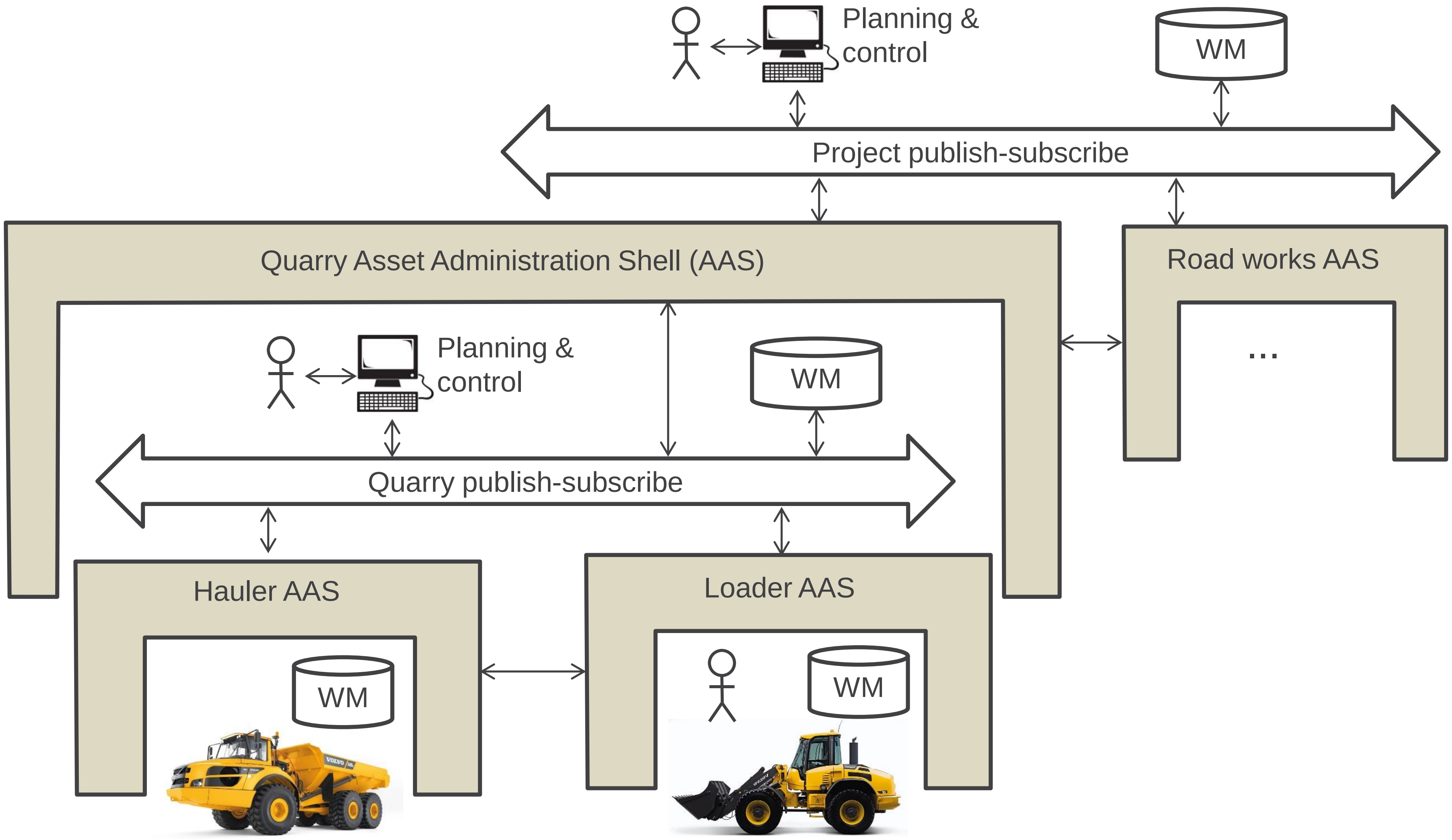
- Mutual awareness of other systems' knowledge.
- If I know that you know my plans, I can expect you to act in a different way.
- Laws of parsimony and requisite variety.



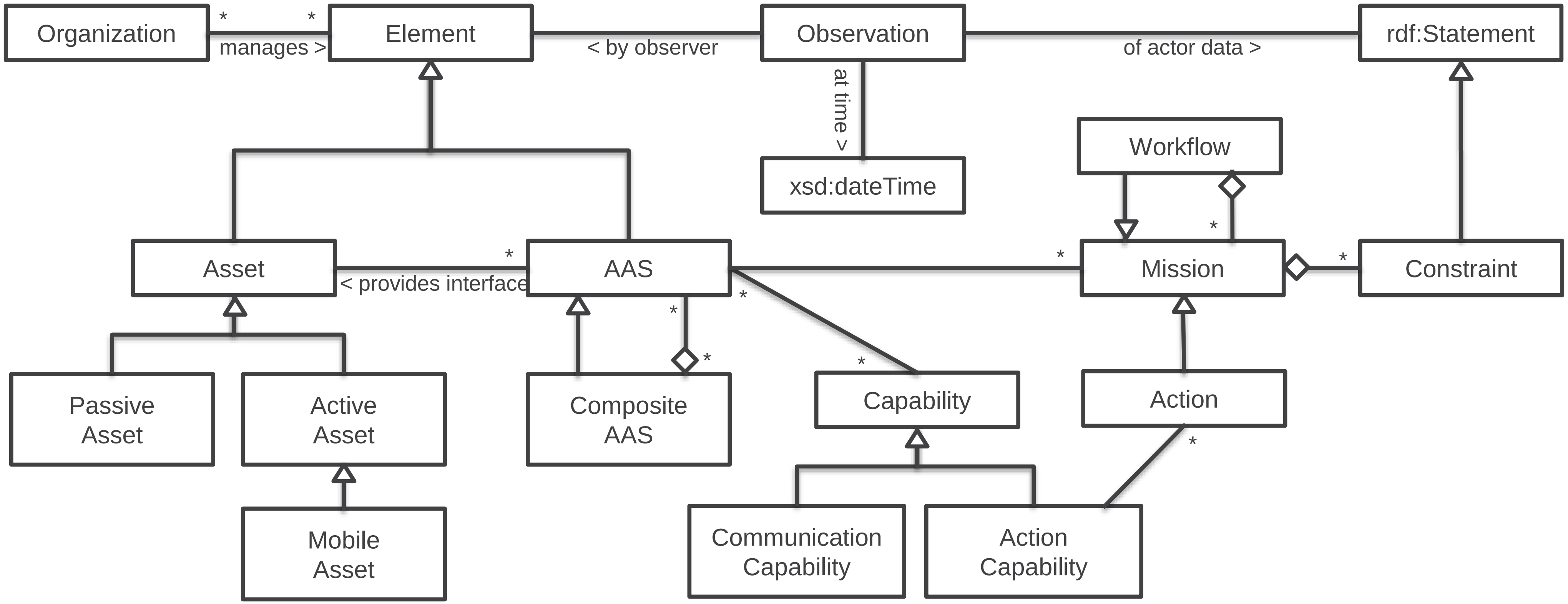
Example: Road construction

- Objective:
  - Improve productivity.
- Hypothesis:
  - Increased coordination of machines, and more access to information in real-time is the key aspect.
- Approach:
  - Industry 4.0 concepts for connectivity.
  - Lean techniques for reducing wastes.
  - Framework for real-time production control on all levels.

Road construction: SoS architecture



Ontology



Organization
*
*
manages >
Element
< by observer
Observation
of actor data >
rdf:Statement
at time >
xsd:dateTime
Workflow
*
Asset
*
< provides interface
AAS
*
Mission
*
Constraint
*
*
*
Passive Asset
Active Asset
Composite AAS
*
Capability
Action
*
Mobile Asset
Communication Capability
Action Capability

Discussion

- Cost of using linked data:
  - Memory, communication, computation.
- Value of data, willingness to share.
- Open Services for Lifecycle Collaboration (OSLC).
- Digital twins.
- Industry 4.0.

Conclusions

- Interoperability is a cornerstone of SoS engineering.
- Trade-off: functionality vs. performance and lifecycle cost.
- Analysis: Levels of conceptual interoperability.
- Technology: Linked data and ontologies.
  - Standardized
  - Reusable software libraries
  - Focus effort on domain ontologies
  - Model-based systems engineering