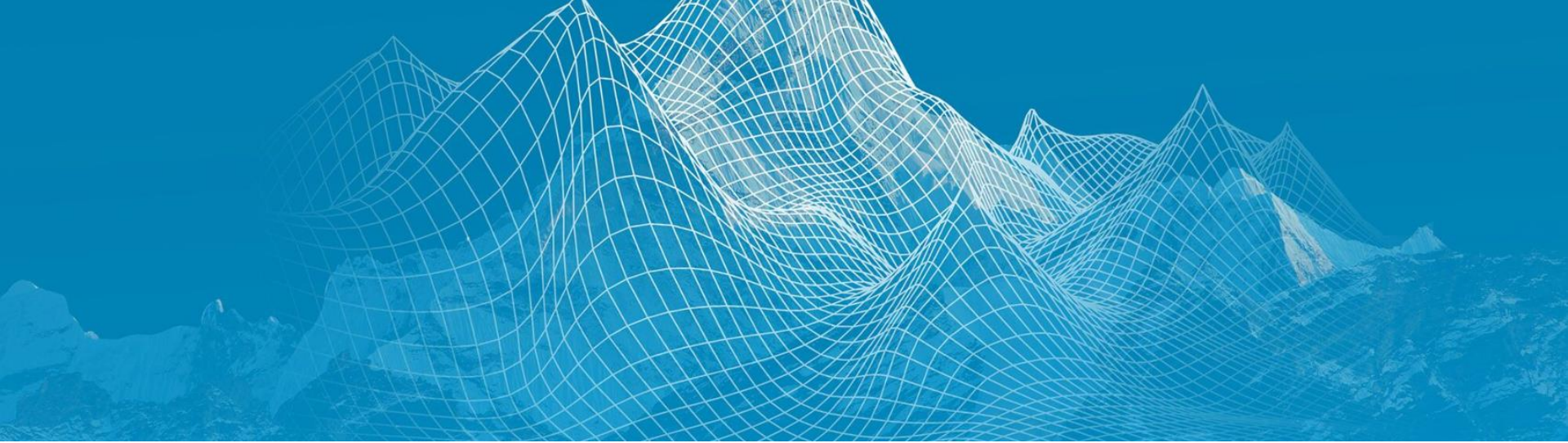


FROM MBSE TO MDSE

How Digitalization impacts Systems Engineering

INCOSE, 14 April 2020, Marc Hamilton

ALTRAN

HOW DIGITIZATION OF SYSTEMS ENGINEERING IMPACTS THE SYSTEM ENGINEER

- Systems engineering is in a transformation process based on the data use (an authoritative source of truth) and collaboration using models (collaborative integrated modeling environments).

  [INSIGHT vol 23/issue1]

→ So, how can we let the computer do our work?

WHOAMI

Marc Hamilton

- Altran
  - MDE Expert
  - Business Consultant MDE Expertise Center

- High Tech Systems Center (Eindhoven Technical University)
  - Fellow
    - Focus theme Digital Engineering
    - System Thinking
    - Digital Twinning

Background: Computer Science (master)

ALTRAN

The Global Leader in Engineering and R&D Services

ALTRAN

Undisputed. Globally.

Altran is the undisputed global leader in Engineering and R&D services.

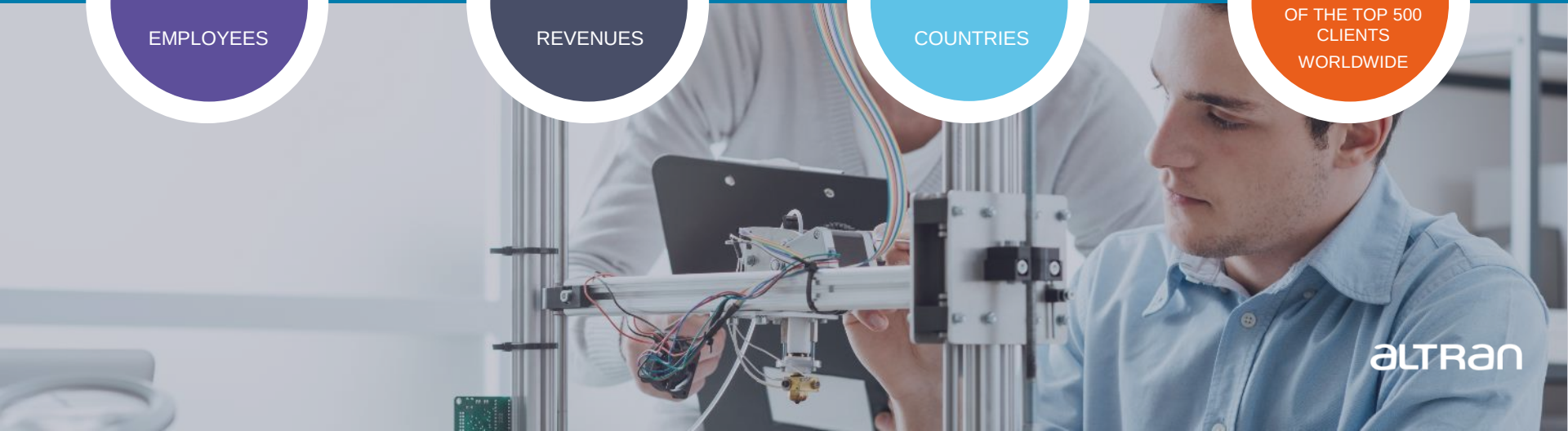
Altran's expertise is well known. This enables us to offer our clients a new way to innovate by developing the products and services of tomorrow. Our global network helps us work alongside them on every link in the value chain, from conception to industrialization and operations.

50,000+
EMPLOYEES

c.€3.2 bn
REVENUES

35+
COUNTRIES

300
OF THE TOP 500 CLIENTS WORLDWIDE



OUR INNOVATION KNOWS NO BOUNDARIES.
WE WORK WITH GLOBAL INNOVATION LEADERS ACROSS INDUSTRIES.

PSA GROUPE · AIRBUS · DASSAULT AVIATION · ALSTOM · EDF · Whirlpool · gsk · NOKIA · Qualcomm · IBM · BNP PARIBAS

SAFRAN · THALES · BOMBARDIER · ENGIE · PHILIPS · SANOFI · Telefónica · ASML · airbnb · NATIXIS

BOSCH · ROLLS ROYCE · LEONARDO · SNCF · Jabra GN · Johnson & Johnson · vodafone · ERICSSON · AXA

ALTRAN

3 expertise domains to engineer tomorrow

Our Global Service Lines help the world's largest innovators engineer the products and services of tomorrow by leveraging our experts, labs, tools and frameworks around the globe.

Product & Systems Engineering

40% of engineers

- Product Design & Development
- Systems Engineering
- Mechanical Engineering
- Silicon, Electronics & Embedded Systems
- Testing & Compliance

Digital & Software

35% of engineers

- Digital Experience Design
- Software Product Engineering & Cybersecurity
- IT & OT Systems Integration
- Advanced Network Technology & IoT
- Data Analytics & AI

Industrial Operations

25% of engineers

- Manufacturing Engineering & Technology
- Supply Chain & Quality Management
- Operations & Asset Management
- Network Operations & Transformation
- Product Support & Sustenance

ALTRAN

Key Facts Altran Netherlands

€90 million Revenues (2019)

>900 employees

7 locations

- Utrecht
- Eindhoven
- Helmond
- Hengelo
- Leek
- The Hague
- Zwolle

NL supports 10 out of 15 Global Service Lines

Our Global Service Lines help the world's largest innovators engineer the products and services of tomorrow by leveraging our experts, labs, tools and frameworks around the globe.

Product & Systems Engineering

40% of engineers

- Product Design & Development
- Systems Engineering
- Mechanical Engineering
- Silicon, Electronics & Embedded Systems
- Testing & Compliance

Digital & Software

35% of engineers

- Digital Experience Design
- Software Product Engineering & Cybersecurity
- IT & OT Systems Integration
- Advanced Network Technology & IoT
- Data Analytics & AI

Industrial Operations

25% of engineers

- Manufacturing Engineering & Technology
- Supply Chain & Quality Management
- Operations & Asset Management
- Network Operations & Transformation
- Product Support & Sustenance

ALTRAN

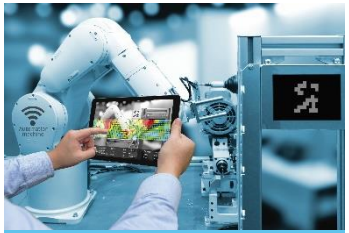
NL Innovation Tracks

Digital transformation & Innovation Strategy

- Ideation methodologies
- Problem solving technics
- Roadmapping
- Servitization
- Design thinking
- Business model challenge
- Building inventive organizations

Future of engineering

- Agile transformation
- MBSE Tooling
- Legacy software unwinding
- Tech radar (AI, Blockchain, ML)
- Engineering automation
- Formal method validation & verification
- Intelligent Testing



Factory of the future

- Sensoring
- Digital twin
- Robots
- VR / AR / MR
- Virtual factory
- Modelling & Code generation
- IoT architecture and analytics

Future of Healthcare

- Quality control & validation
- Regulatory compliance
- Data science & Analytics
- Therapeutic device development
- Patient monitoring
- Digital imaging

Future of mobility

- E-mobility
- Battery developments
- E-component modelling
- Autonomous architecture
- Sensor developments
- V2X communication
- ADAS/AD
- Drones

ALTRAN

FuSE

SE IS RAPIDLY CHAINGING

ALTRAN

INSIGHT - MARCH 2O20
VOLUME 23 / ISSUE 1

The “**AI4SE**” and “**SE4AI**” labels have become metaphors for an upcoming rapid evolutionary phase in the systems engineering Community.

- **AI4SE** applies augmented intelligence and machine learning techniques to support systems engineering practices.
  - Goals in such applications include achieving scale in model construction and confidence in design space exploration.

- **SE4AI** applies systems engineering methods to learning based systems’ design and operation.

Key research application areas include developing principles for learning-based systems design, life cycle evolution models, and model curation methods.

ALTRAN

INSIGHT 23/1: SERC RESEARCH

Mission area's

Digital engineering enables these

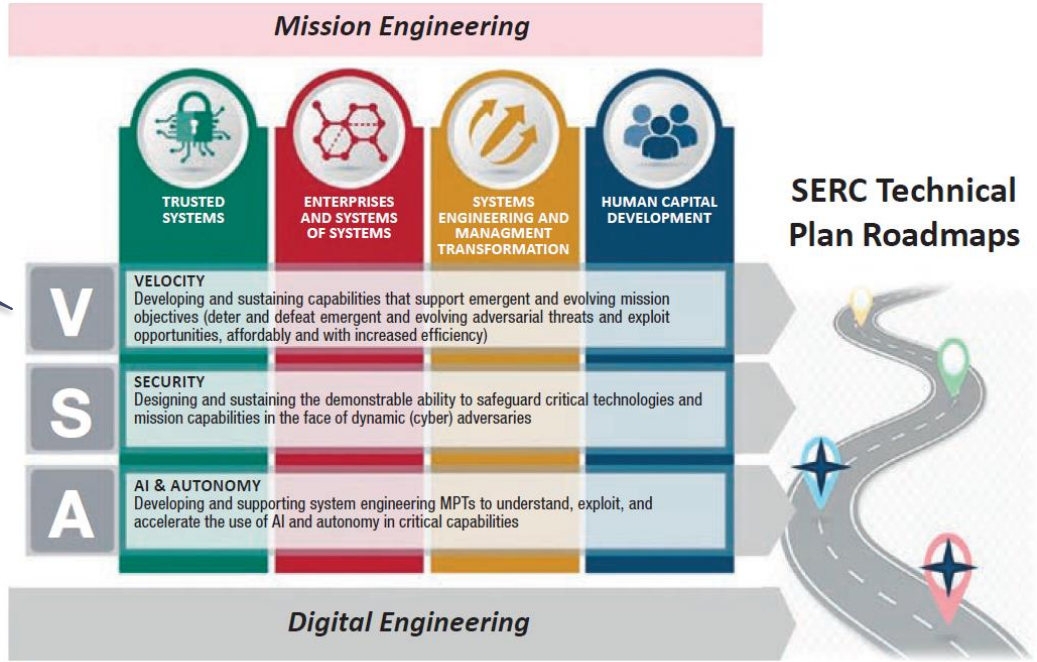


Figure 1. SERC research areas and missions

ALTRAN

INSIGHT 23/1: DIGITAL ENGINEERING AS THE ENABLER

Digital Engineering transforms systems engineering from *document-based* methods and artifacts to *linked digital data and models*

- Digital engineering forms the basis for all three SERC crosscutting missions and resulting research roadmaps.

- Systems engineering is in a transformation process based on the data use (an authoritative source of truth) and collaboration using models (collaborative integrated modeling environments).

ALTRAN

INSIGHT 23/1:

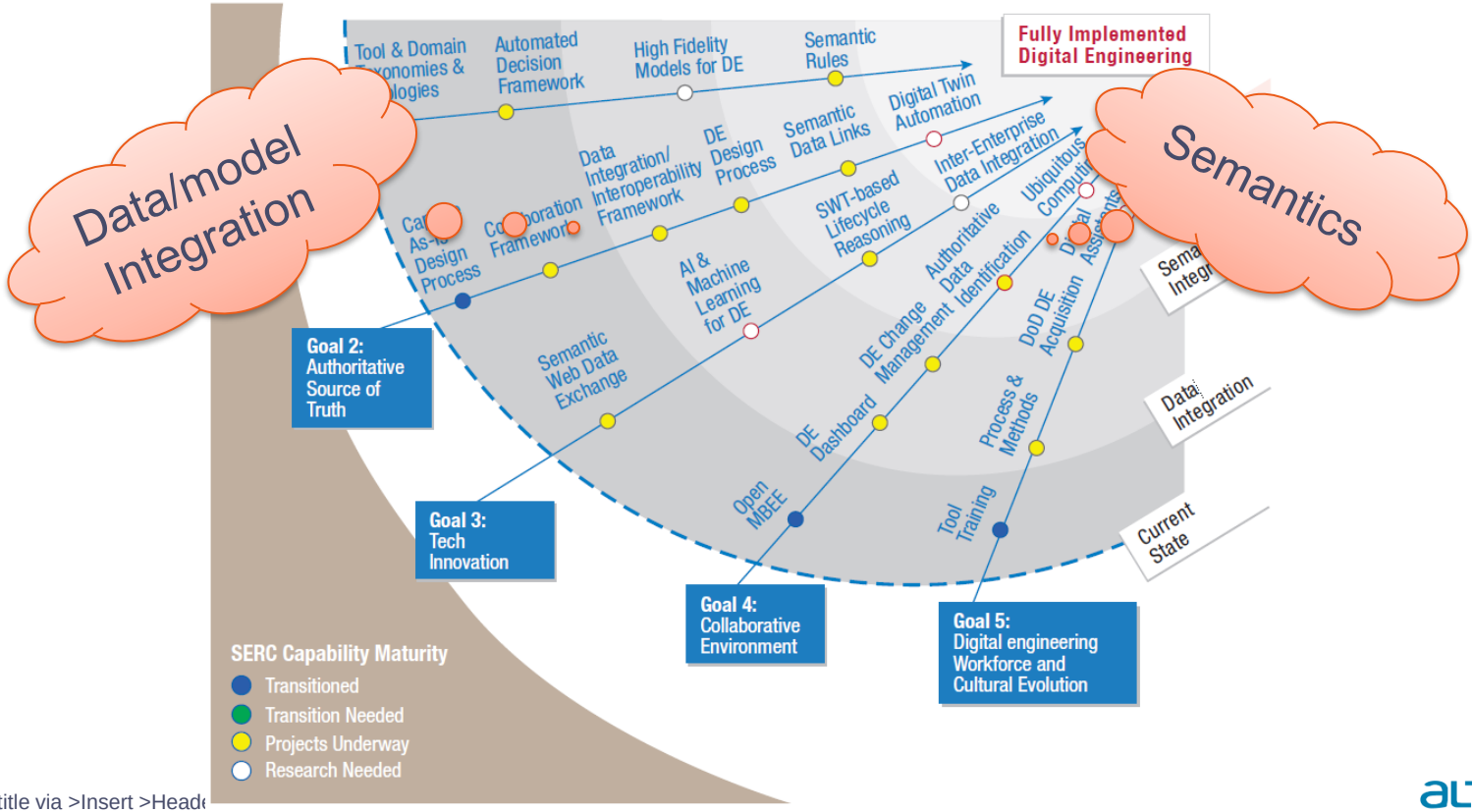


Figure 2. SERC digital engineering roadmap

INSIGHT 23/1:

Systems Engineering Process Evolution through Digital Engineering – the evolution of systems engineering process to learning technologies and automation and the transition to a digital engineering data driven basis for engineering which allows automation and learning.

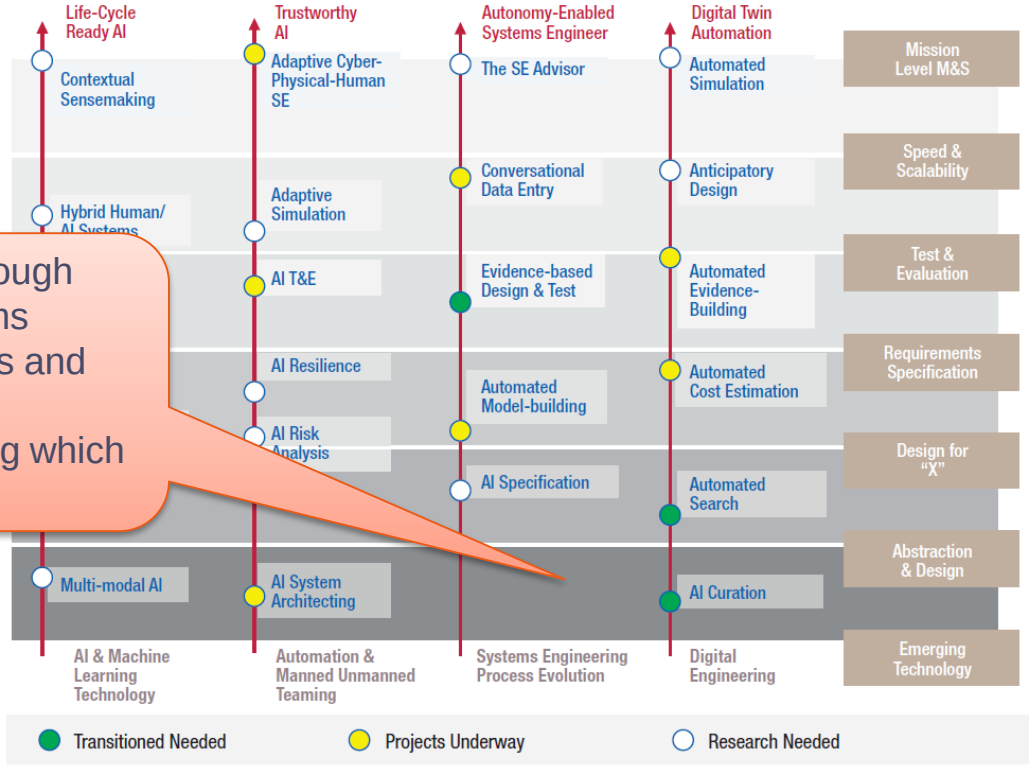


Figure 4. SERC AI and autonomy roadmap

ALTRAN

INCOSE SE HANDBOOK

- 4.3.2.2 : Characteristics and Attributes of Good Requirements
  - Unambiguous : “… A *glossary* should be used…”
- 7.6 : Knowledge Management (KM)
  - *Taxonomy*
  - *Domain models*, domain architecture patterns

ALTRAN

CAPTURING DOMAIN KNOWLEDGE

- Lexicon [List of terms]
- Controlled vocabulary [Controlled list of permitted terms]
- Glossary [Terms + definitions in natural language]
- Taxonomy [Glossary + Concepts hierarchy]
- Thesaurus [Thesaurus + non-hierarchical relations]
- Ontology [Domain specific formalized thesaurus for computerized interpretation]
  - E.g. SWT (OWL), Metamodeling (MOF)

Enriched: with behavioral descriptions
- *Domain models, Object-event models, System models*

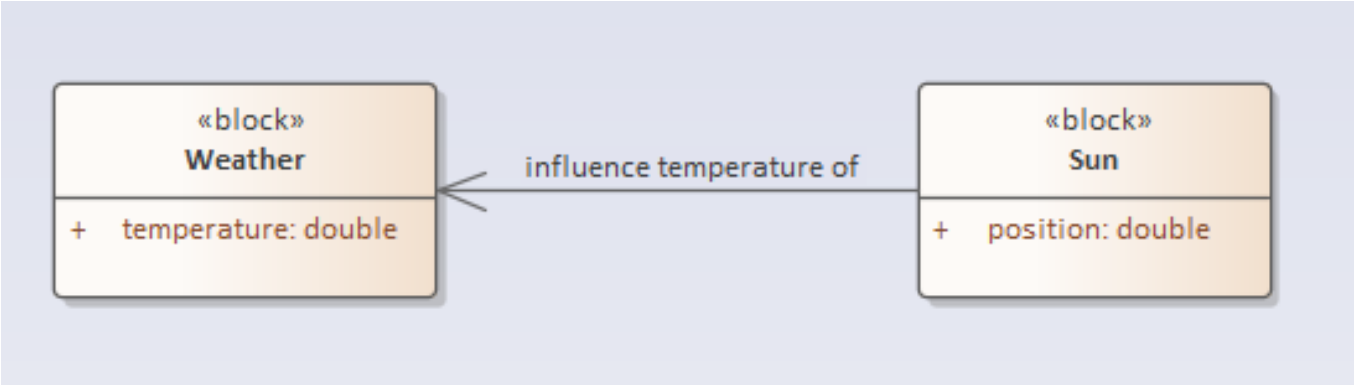
Capture Semantics: Mapping Ontologies
- Transformations, Inference, Reasoning
- Upper / Basic / Foundation (formal) Ontologies (BFO, DOLCE)

ALTRAN

MBSE

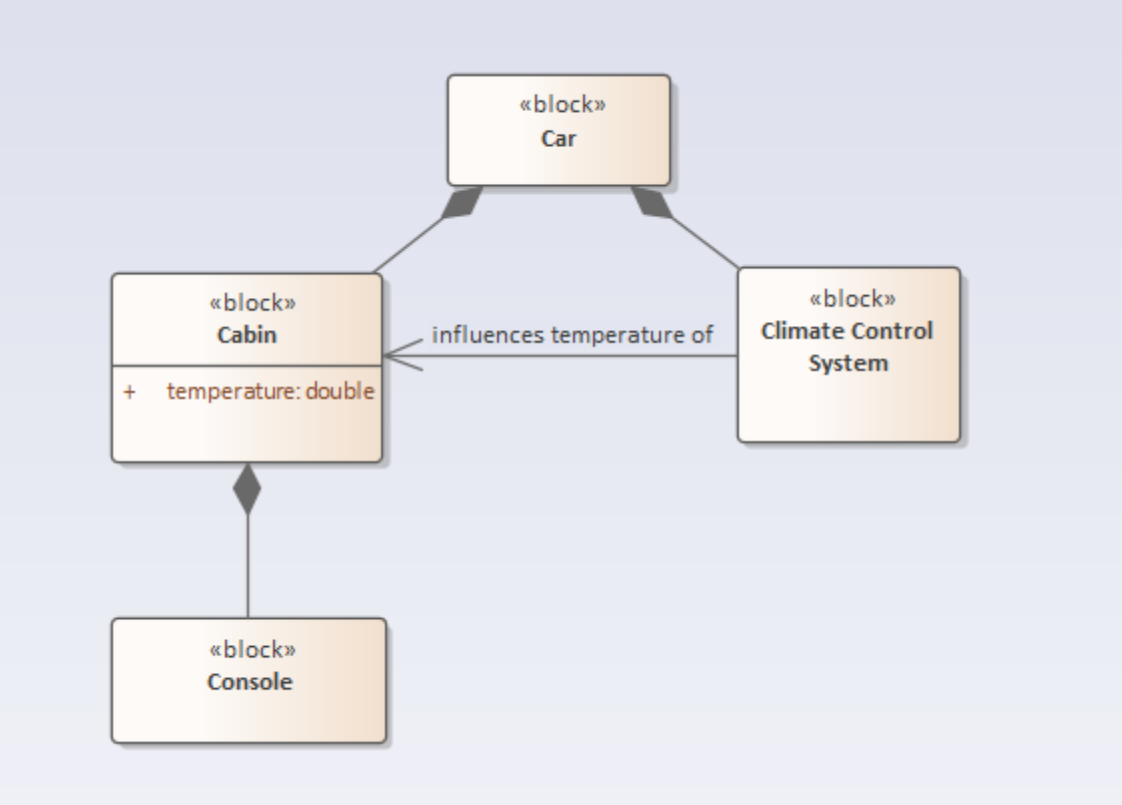
WE NEED TO MODEL, BUT HOW?

SYSML



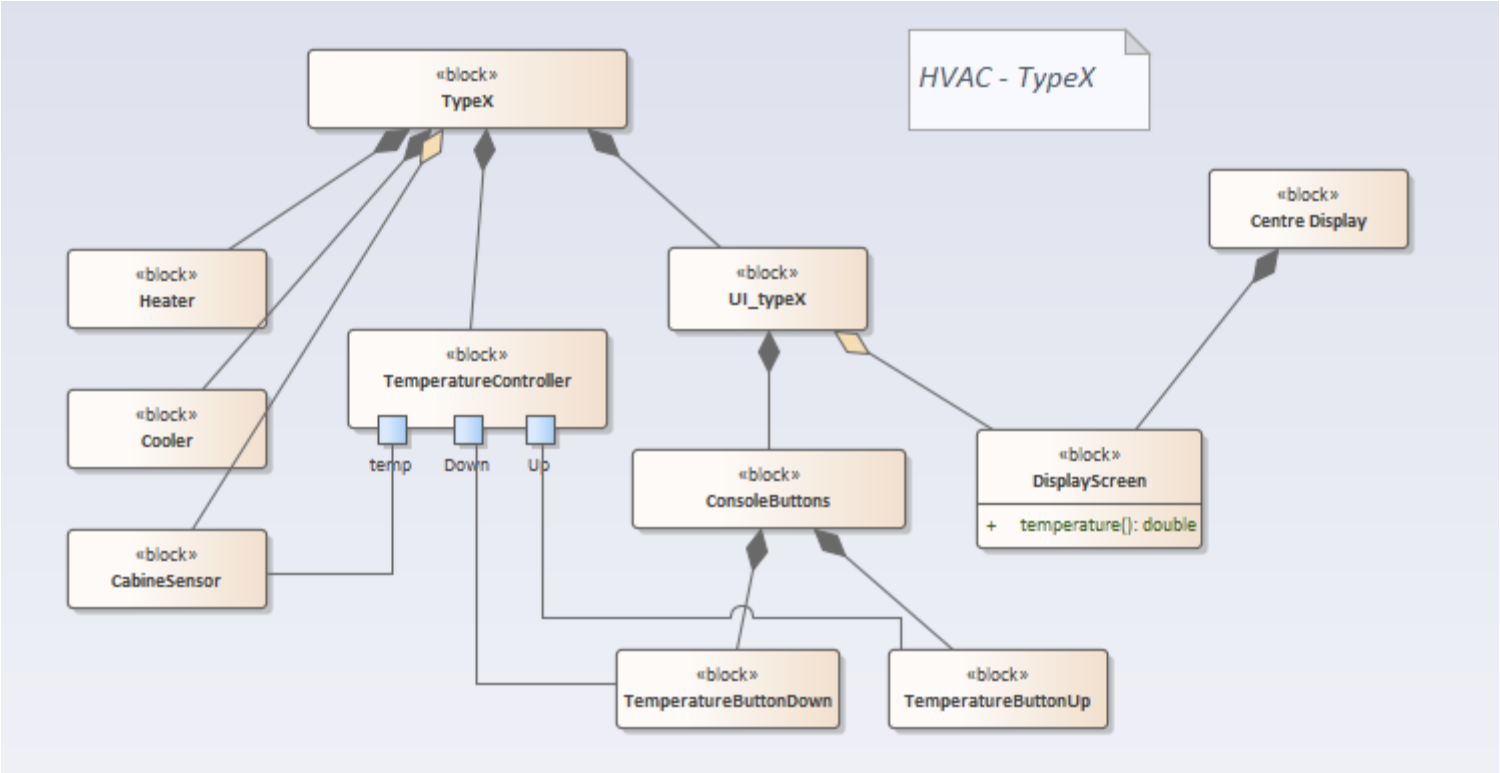
ALTRAN

SYSML



ALTRAN

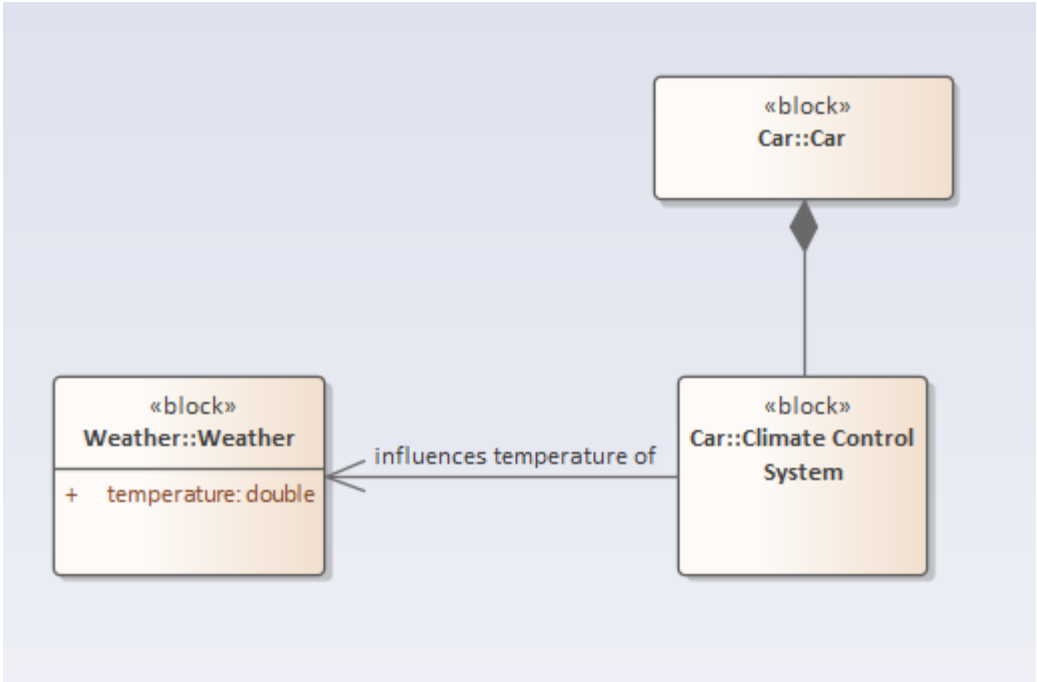
SYSML



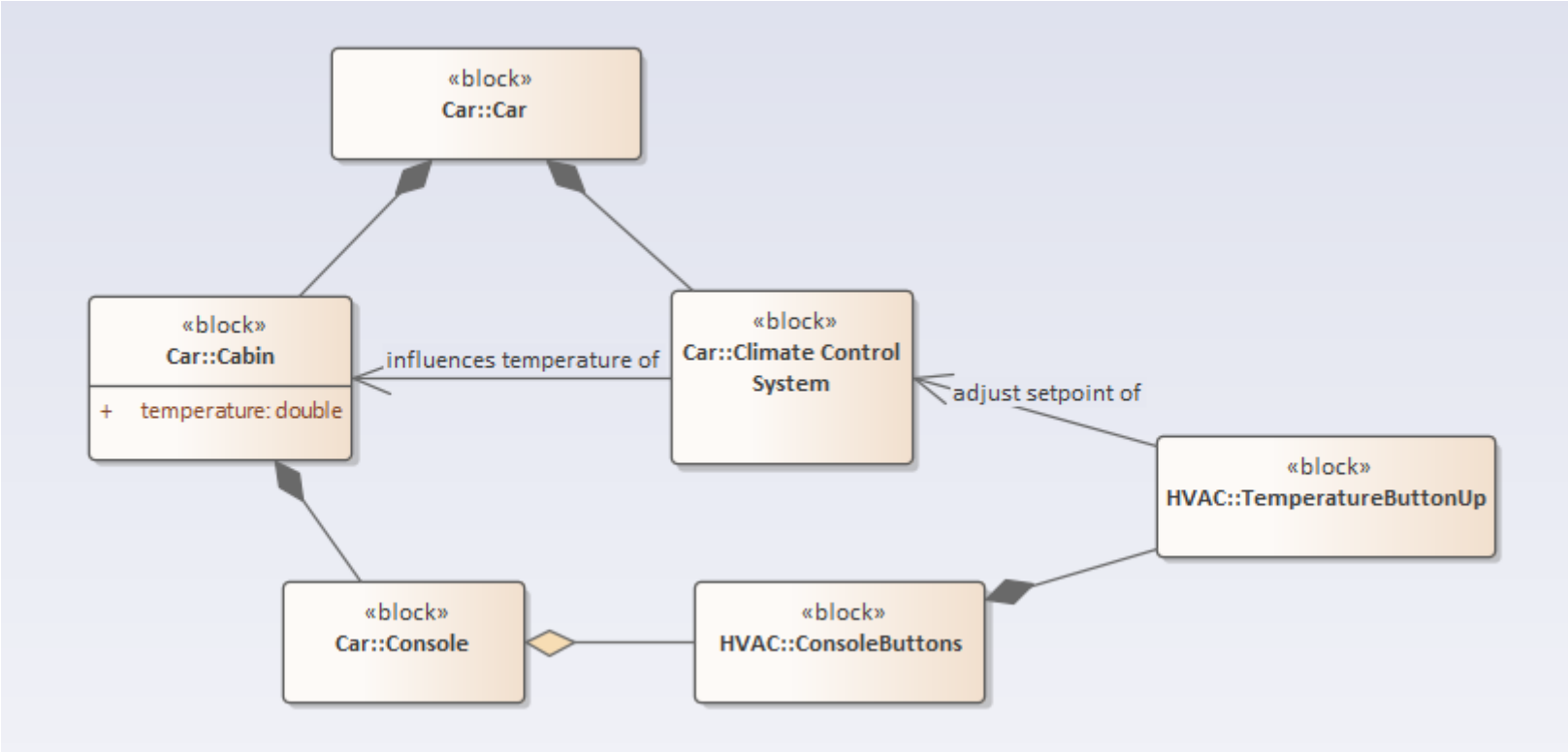
Heating Ventilation and Air Conditioning

ALTRAN

SYSML?

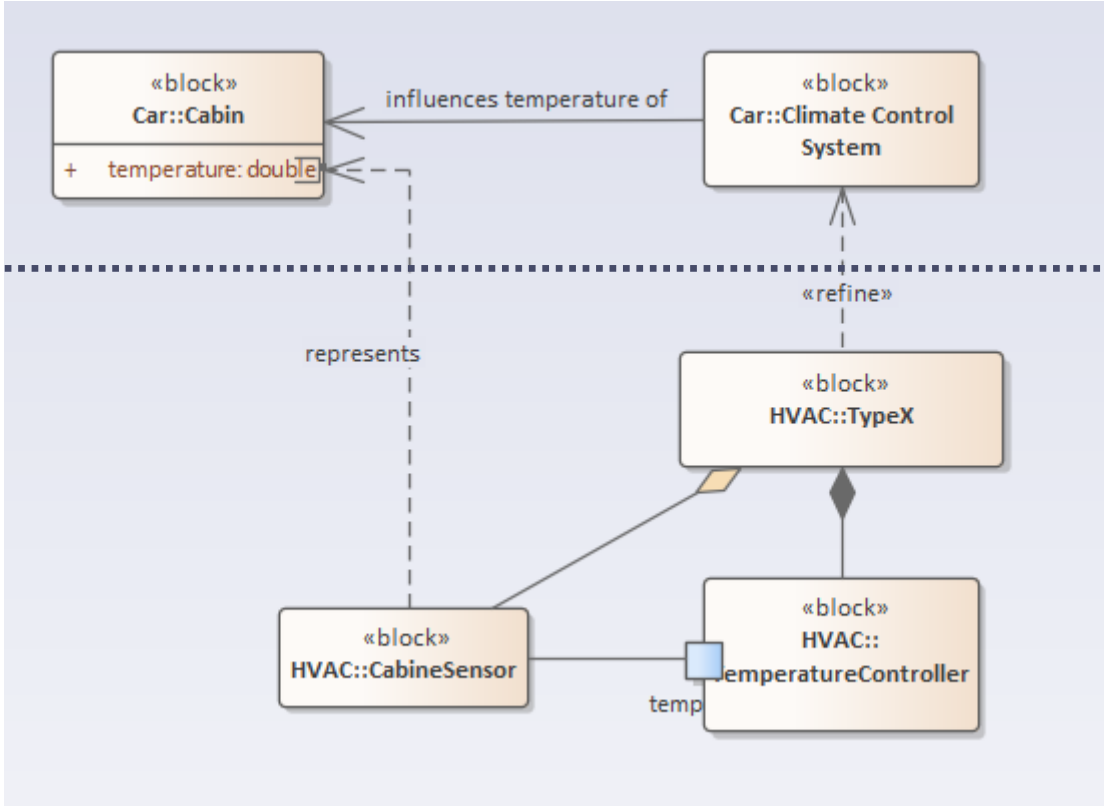

«block»
Car::Car
«block»
Weather::Weather
+ temperature: double
influences temperature of
«block»
Car::Climate Control System

SYSML?



ALTRAN

SYSML



“problem”

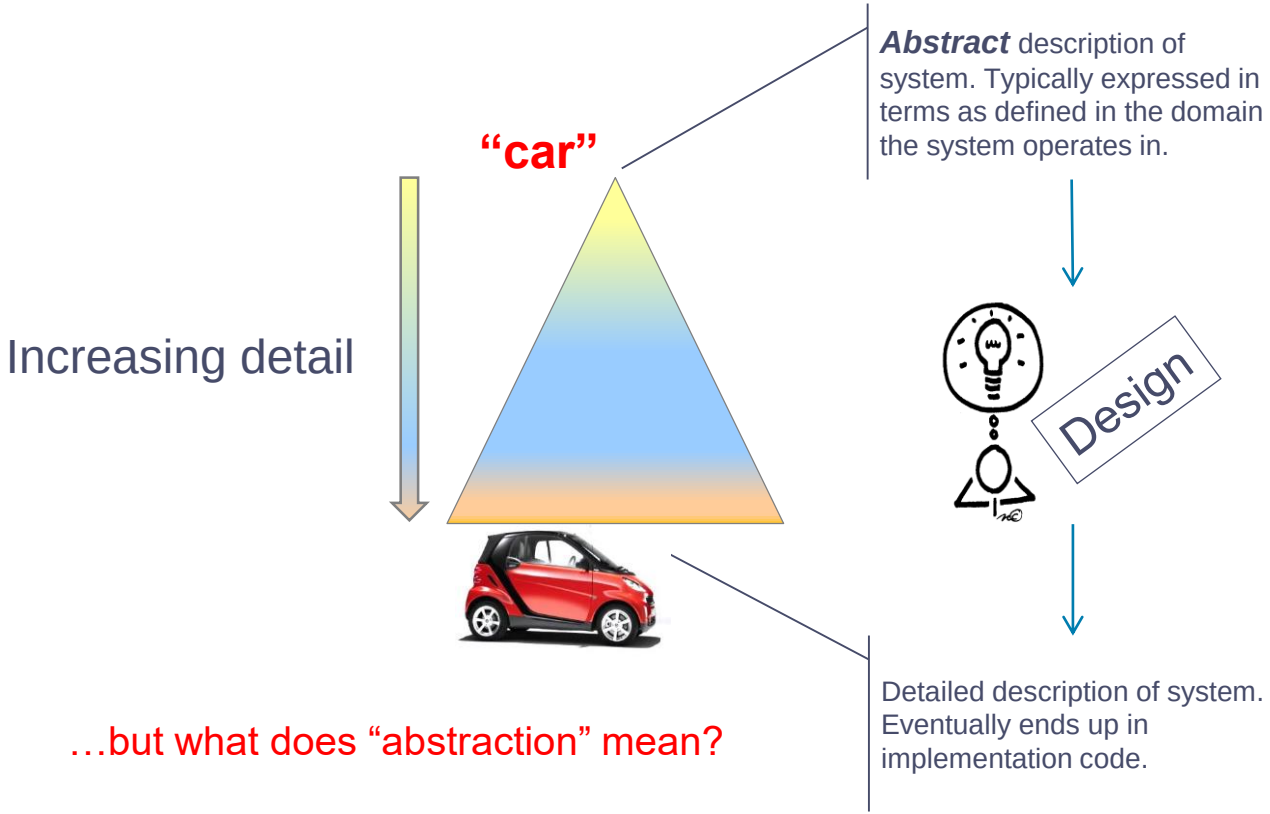
“solution”

ALTRAN

ENGINEERING AND LANGUAGES

- Engineering is an exercise in language translations.

THE ENGINEERING PYRAMID



…but what does "abstraction" mean?

ALTRAN

ENGINEERING ABSTRACTIONS

Uses Terminology of

car
brakes
doors
engine
ADAS
HVAC

Conceptual

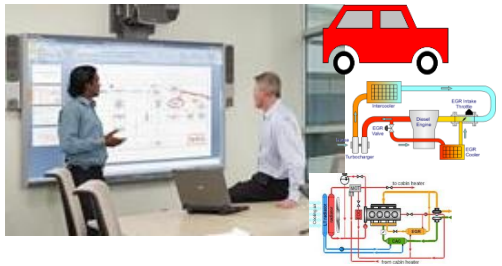
What is the need ('common' domain concepts)

specifies

conforms to

How to address the need (engineering context specific design concepts, contextual jargon)

Logical*



specifies

conforms to

"Code"/"CAD"

Physical Manifestation

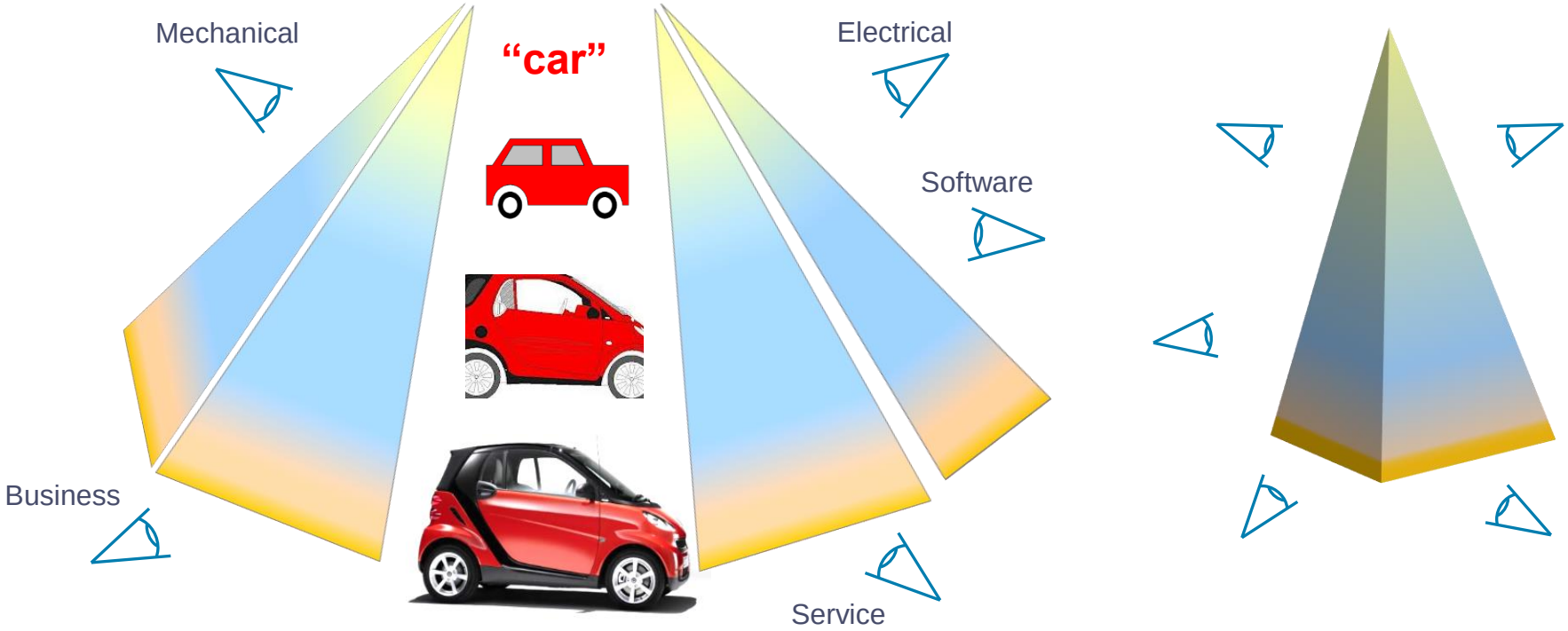
Physical

How is the system realized (generic realization concepts, GPL, CAD)

*can be multiple levels

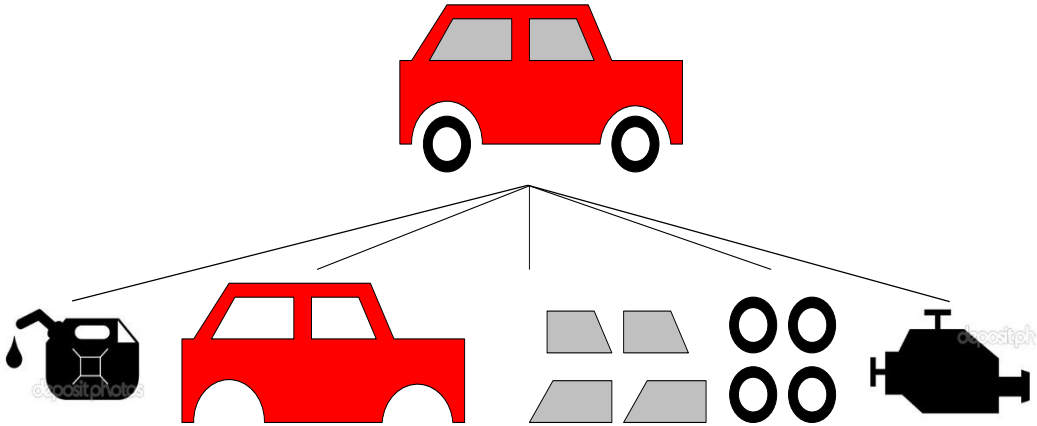
ALTRAN

ENGINEERING PYRAMID – COMBINED VIEWPOINTS



ALTRAN

DECOMPOSITION / AGGREGATION / ASSEMBLY

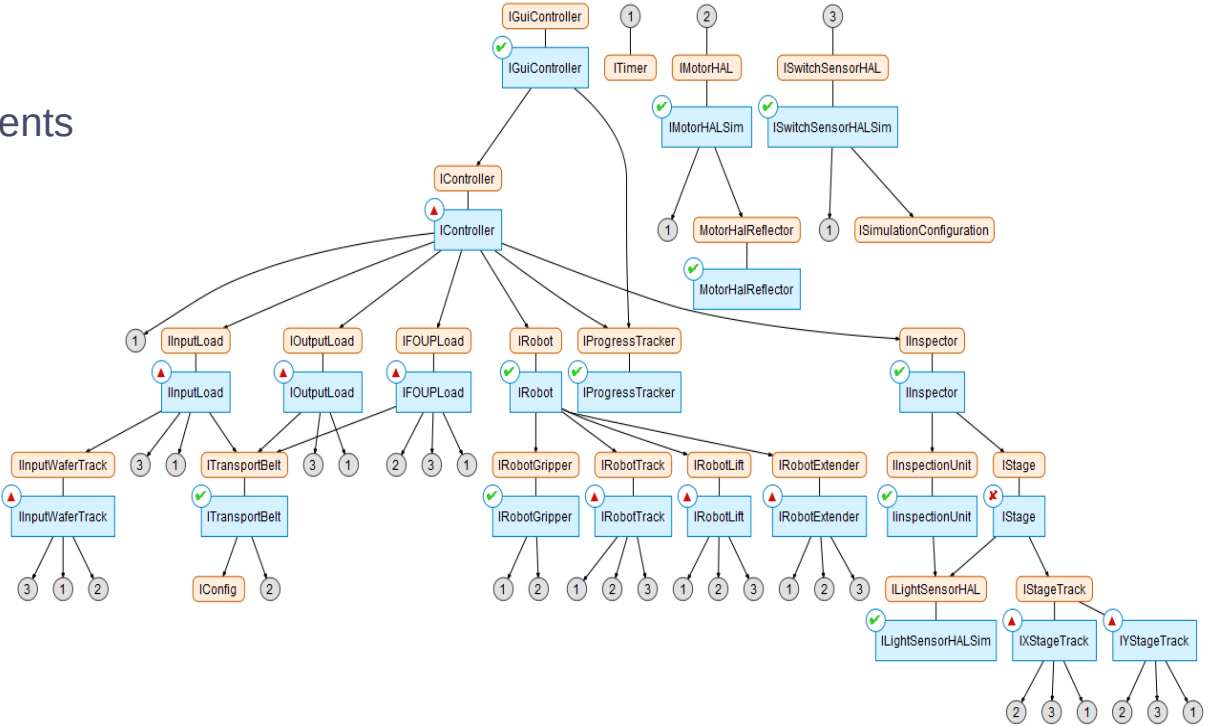


- Language concept
  - Adding detail in the same language
  - Allows for blackbox/whitebox reasoning

ALTRAN

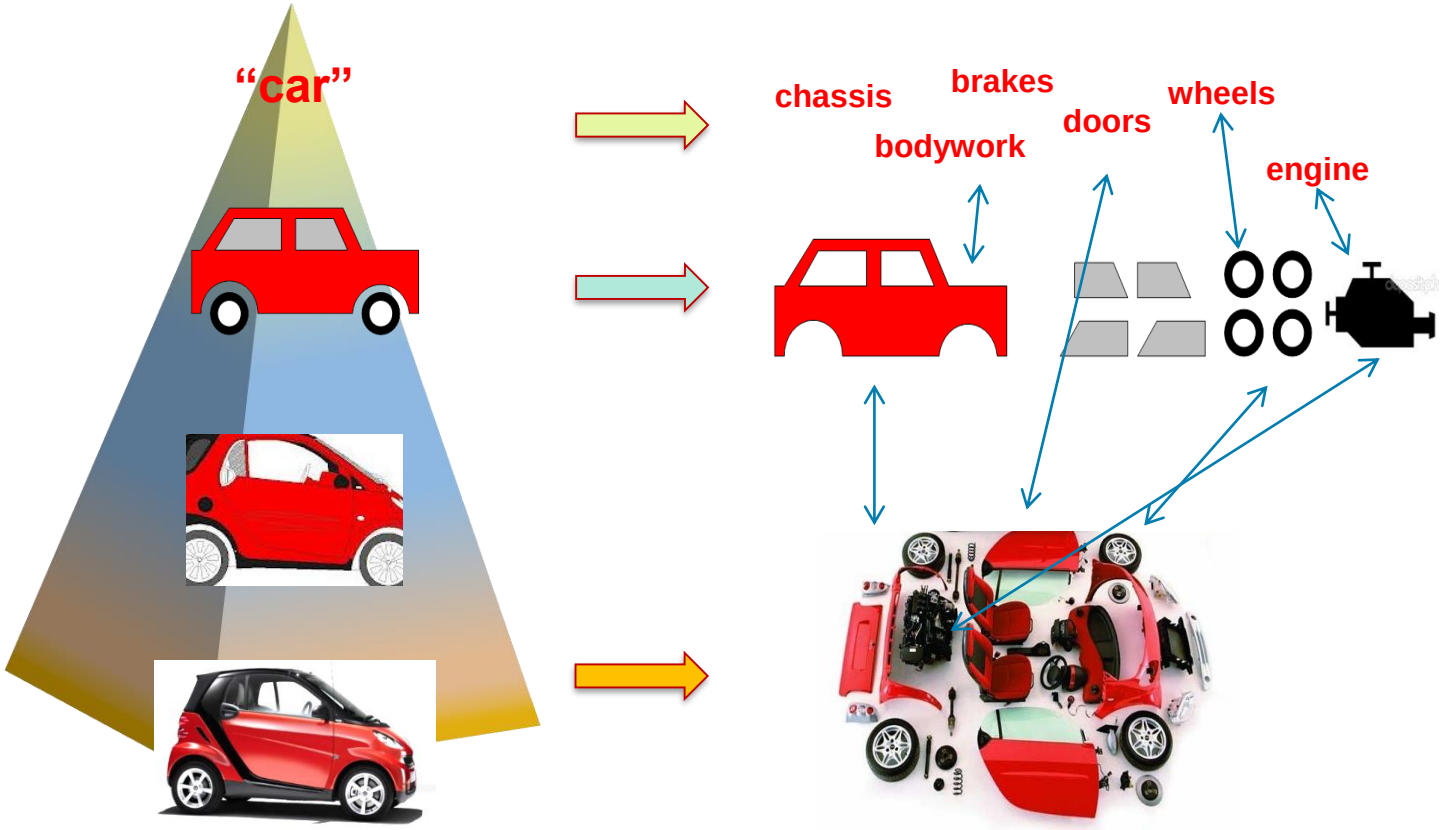
DECOMPOSING SOFTWARE

- Functions
- Classes
- Libraries
- Components



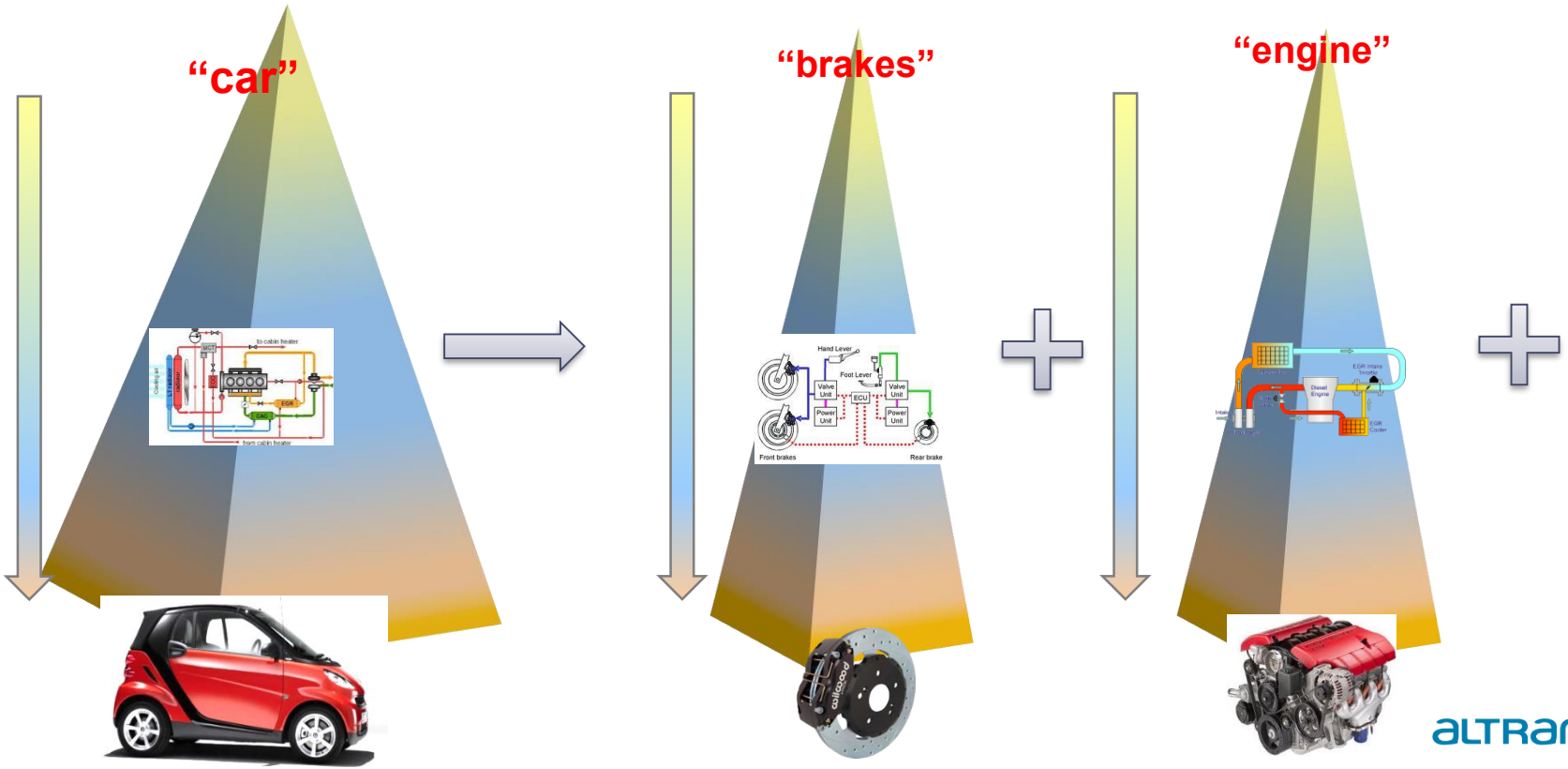
ALTRAN

SO ABSTRACTION ≠ COMPOSITION



ALTRAN

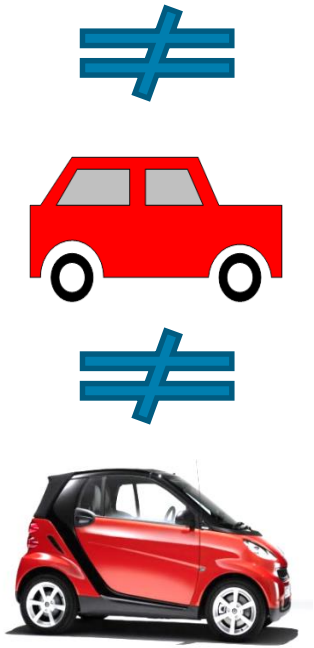
DELEGATION / COTS / SYSTEM OF SYSTEMS



ALTRAN

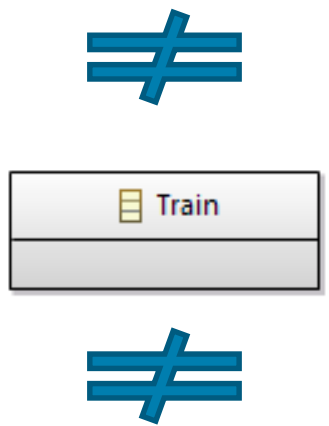
SEMANTIC LEVELS

“car”



Refinement

“train”




```
public class Train {

}
```

ALTRAN

BRIDGING LANGUAGES

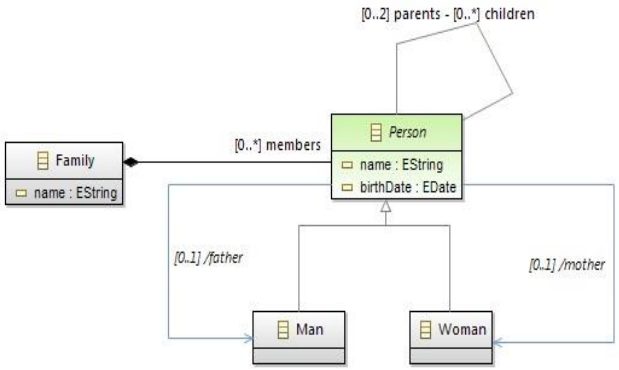
- Original language concept is transformed to target language
- We have to choose a valid representation, limiting the solution space
- In fact, we loose “intent”

- In e.g. UML, this is called “refinement” (a “later” semantics level)

❖ We need to represent human intentions or semantics.

ONTOLOGIES / DOMAIN SPECIFIC LANGUAGES

- For a specific domain, we can create a new language, capturing the concepts that are relevant:
- Abstract Syntax (Ontology)

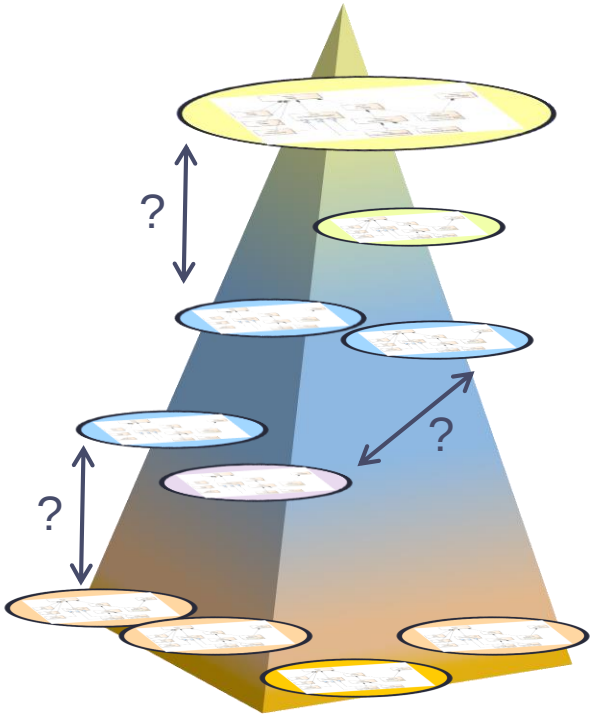


- Concrete Syntax (Representation in Editors/Storage)

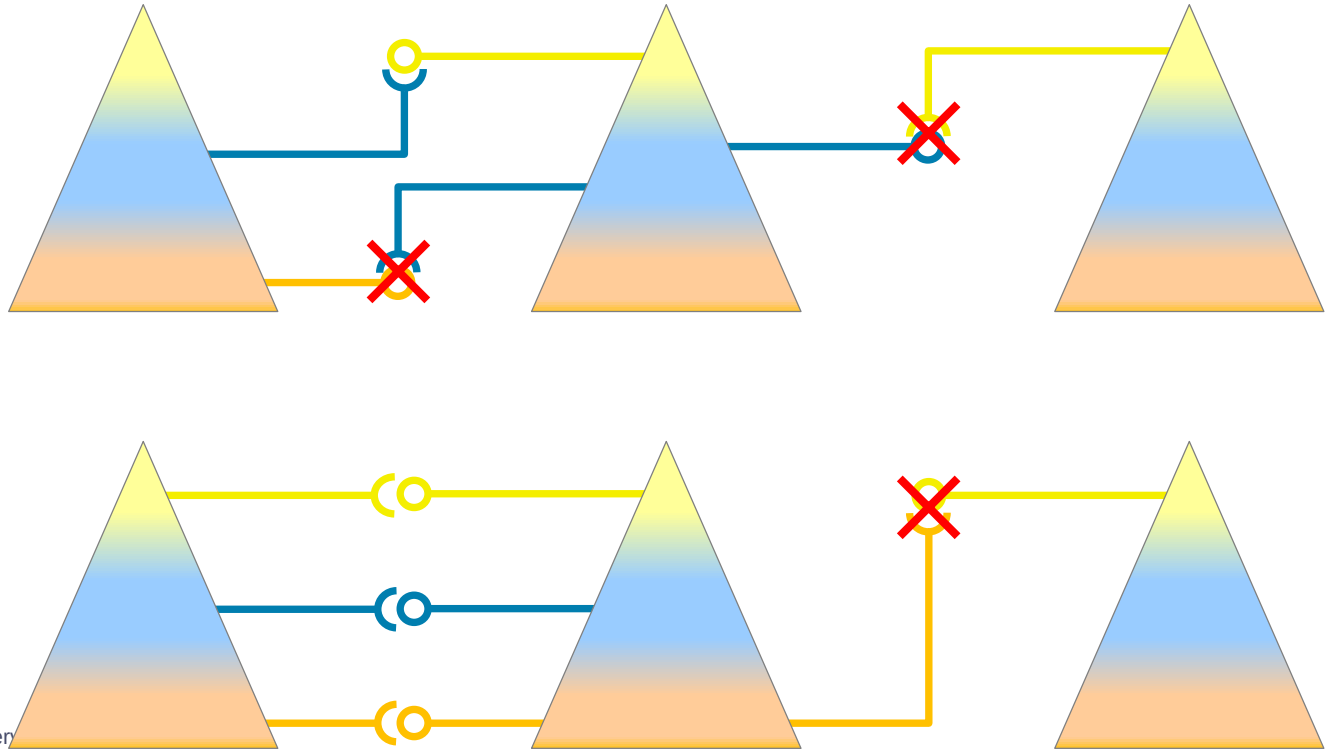
```
Man John {
   mother = Mary;
}
```


```
<persons xsi:type="Man" mother="//@persons.1" name="John"/>
<persons xsi:type="Woman" name="Mary"/>
```

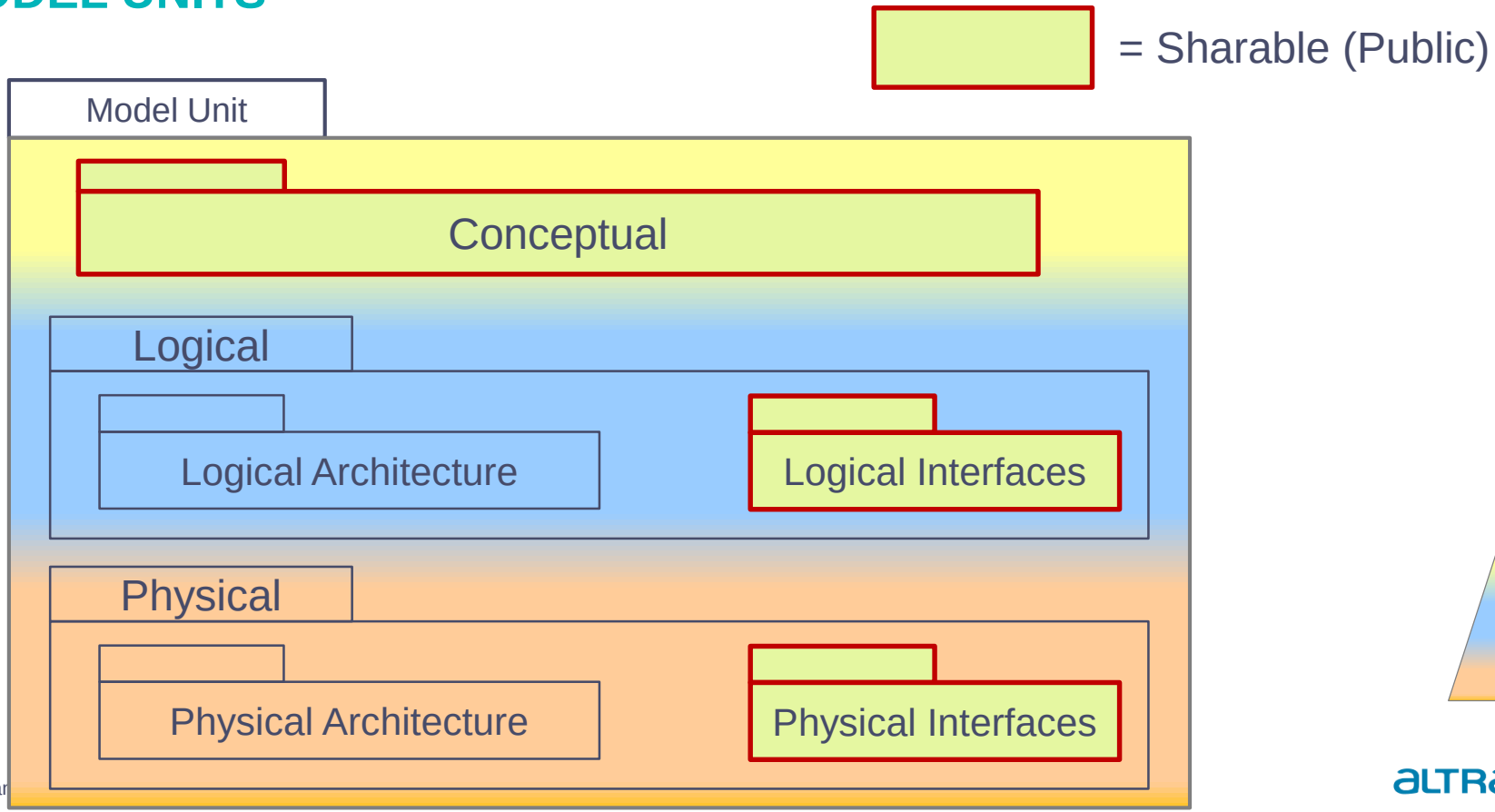
ONTOLOGIES EVERYWHERE



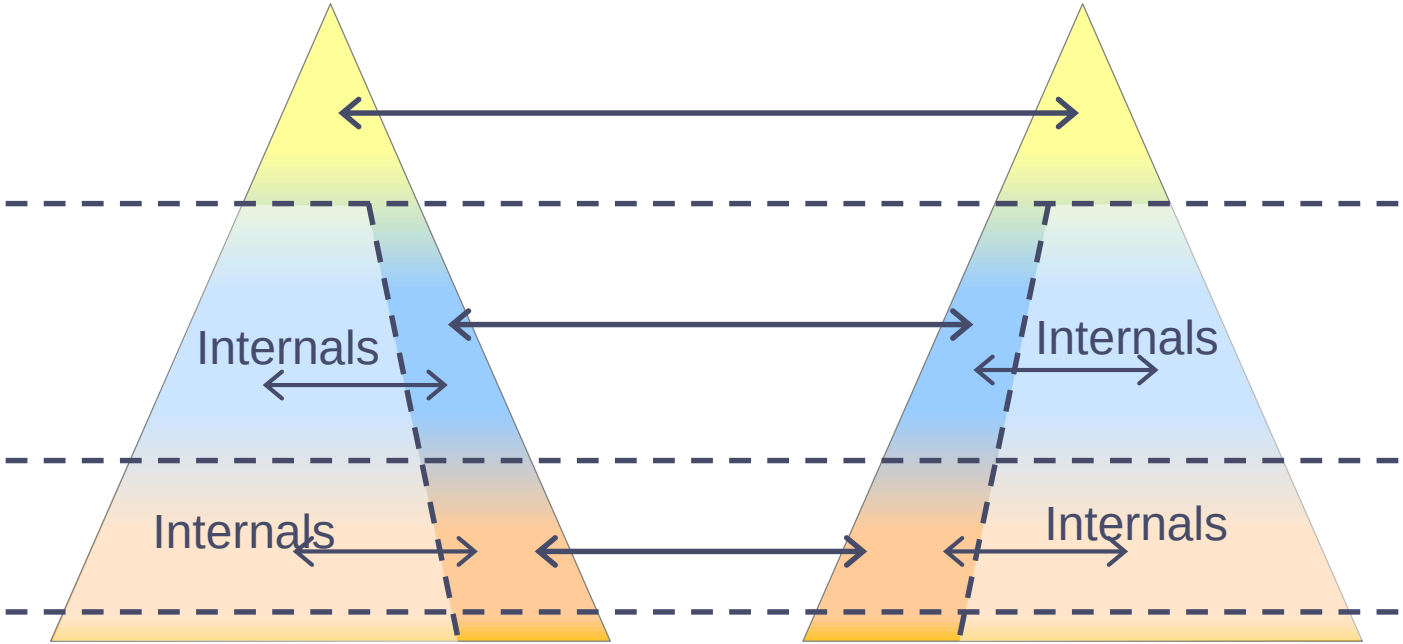
MODELING LEVELS



MODEL UNITS

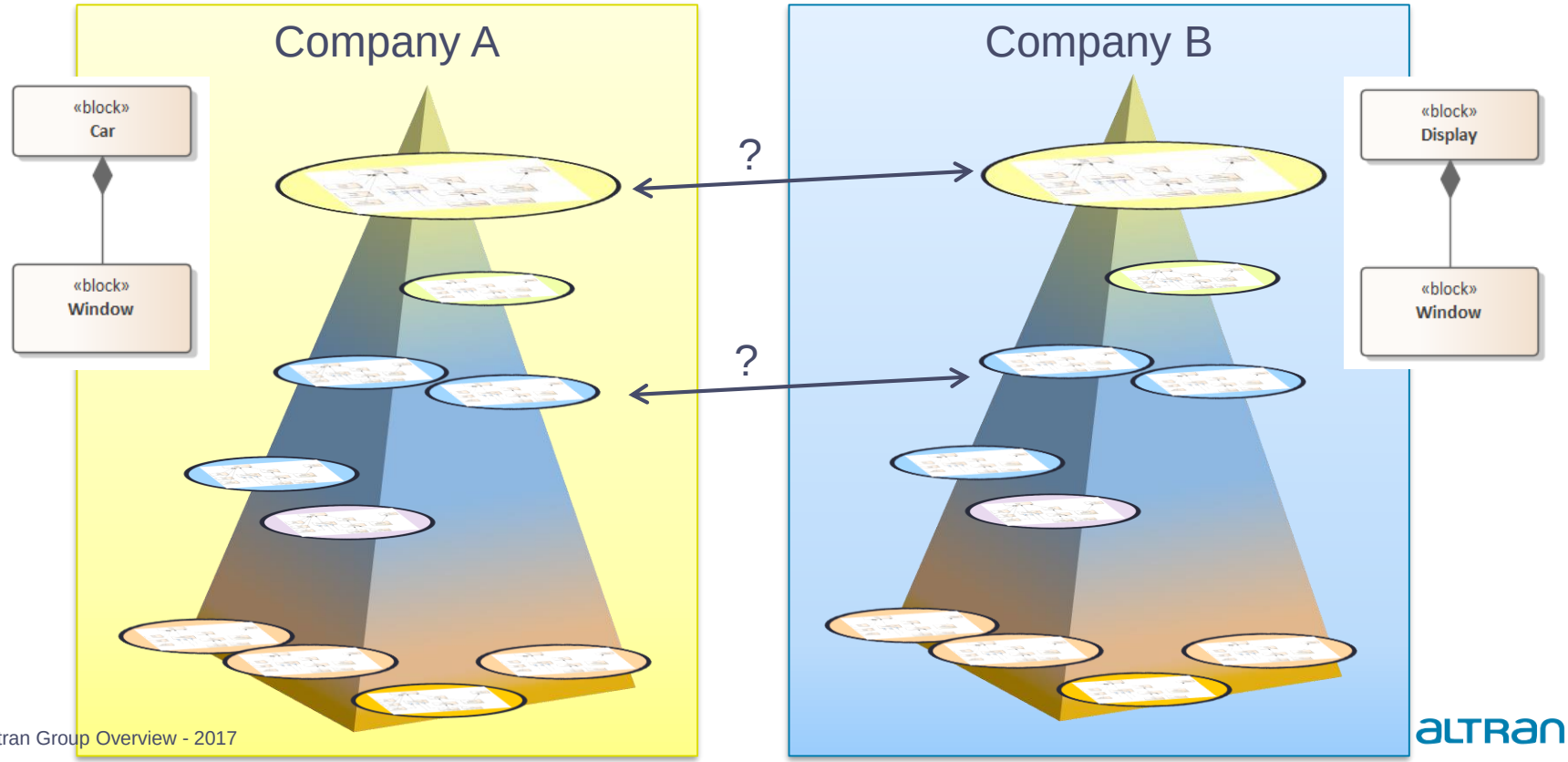

= Sharable (Public)
Model Unit
Conceptual
Logical
Logical Architecture
Logical Interfaces
Physical
Physical Architecture
Physical Interfaces

MODEL UNIT CONNECTIONS



Model Interfacing

ONTOLOGIES CONTEXT

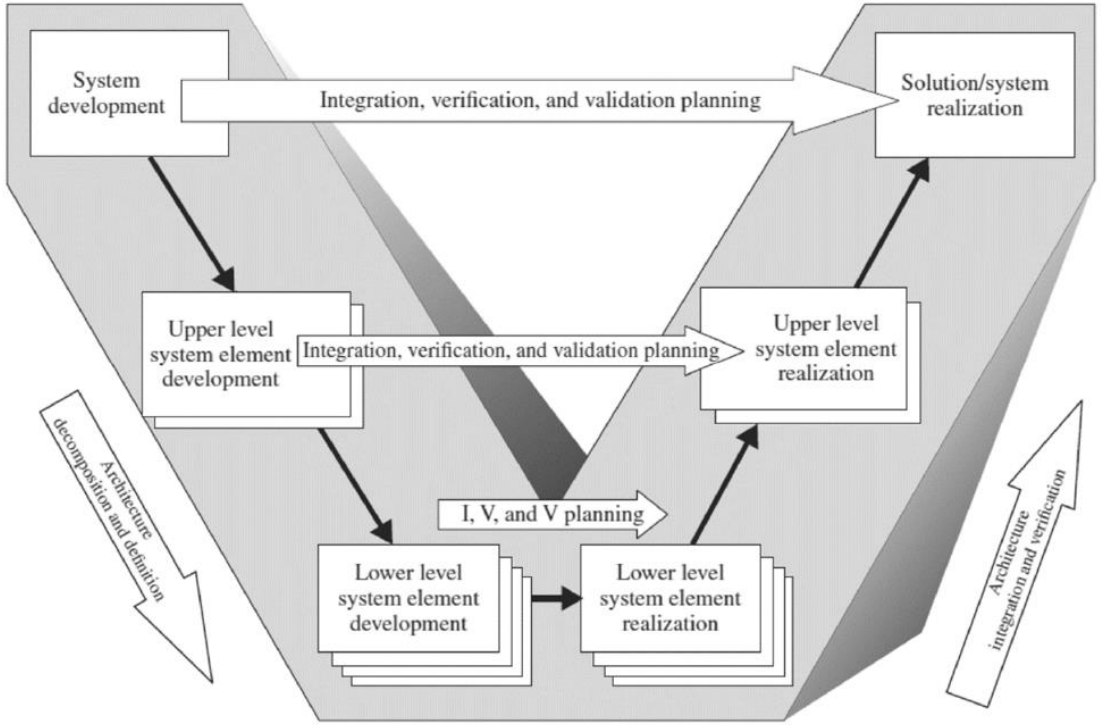


Engineering

PYRAMIDS AND THE V-MODEL

ALTRAN

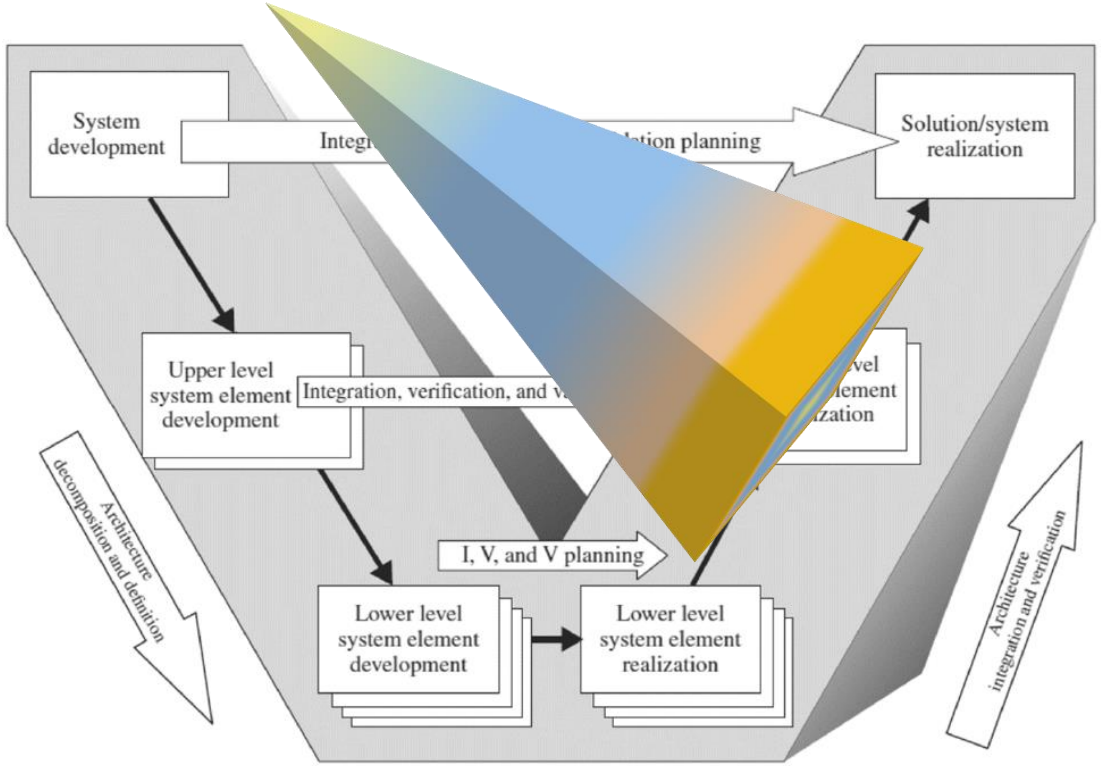
V-MODEL



INCOSE
“Vee Model”
(2015)

ALTRAN

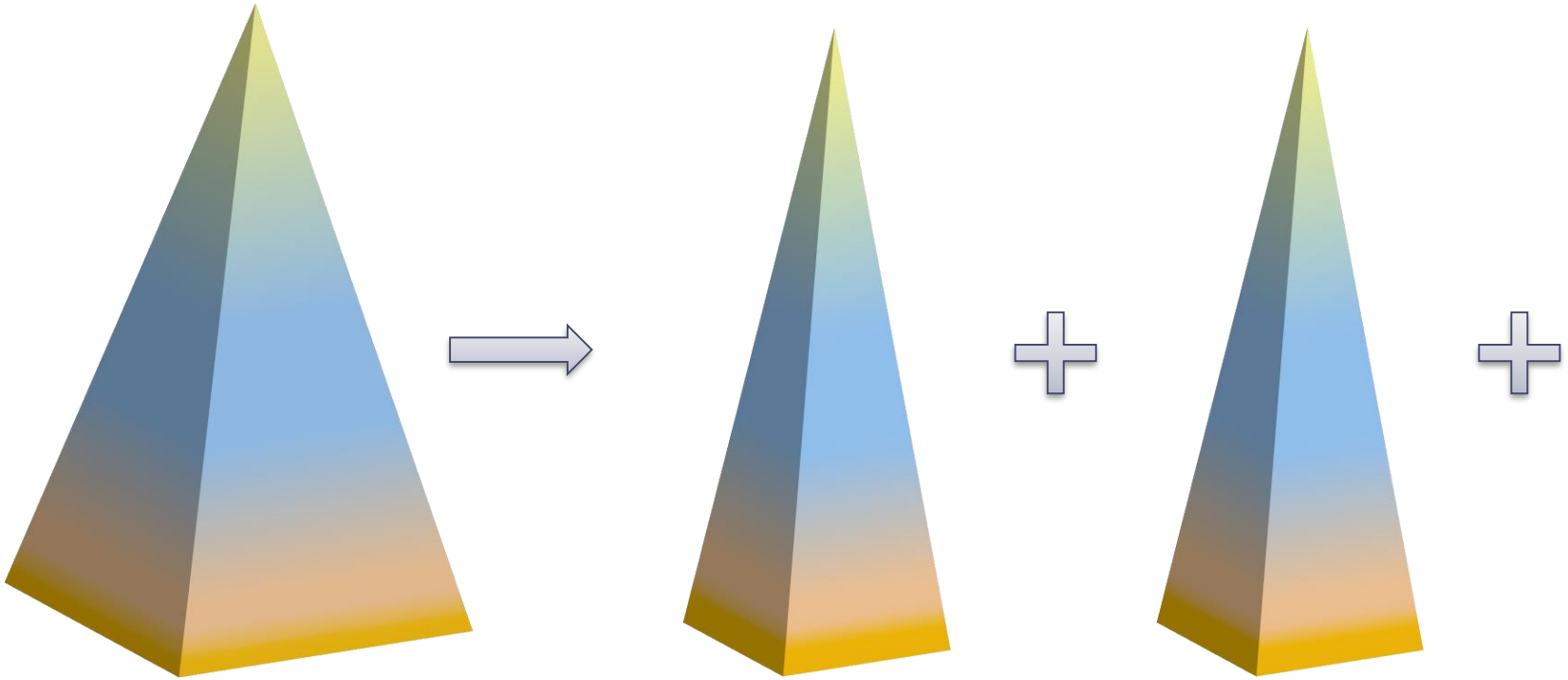
V-MODEL



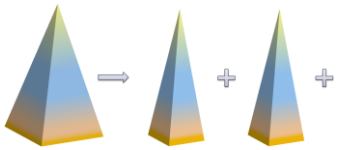
INCOSE
“Vee Model”
(2015)

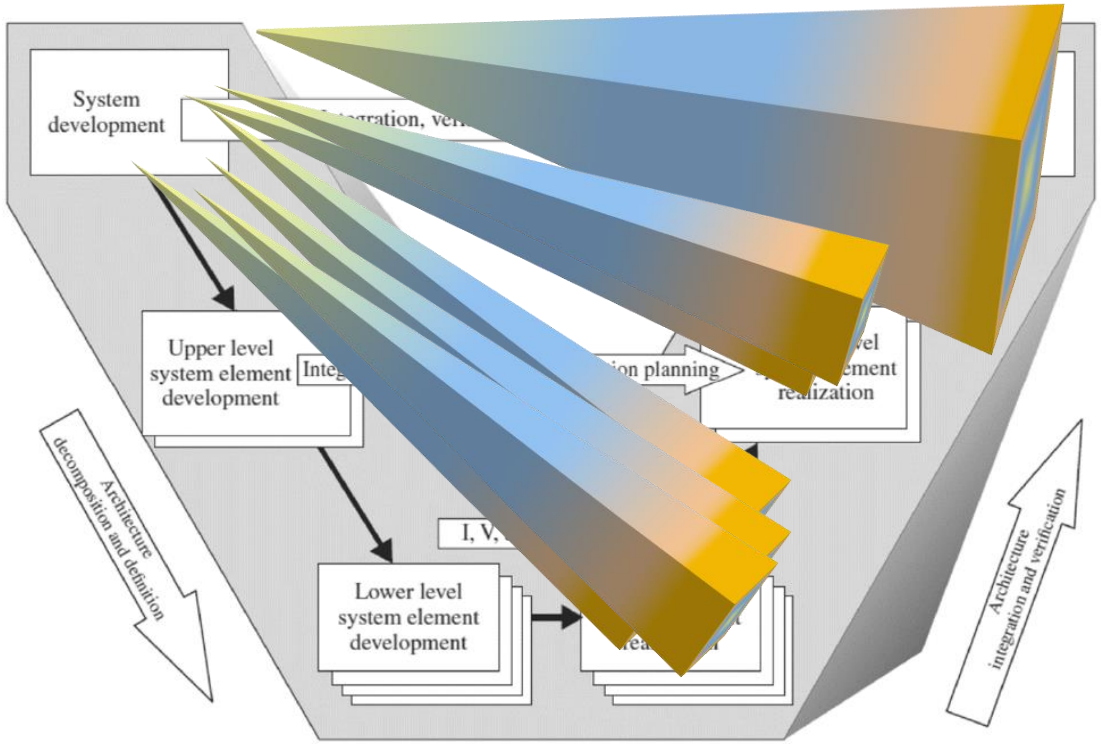
ALTRAN

DECOMPOSITION / DELEGATION



V-MODEL





ALTRAN

(con)FuSE

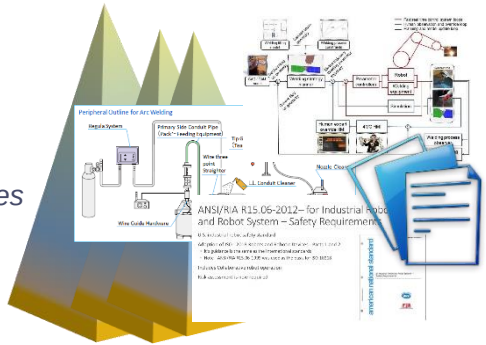
THE FUTURE SYSTEMS ENGINEER

ALTRAN

ROLE OF THE SYSTEM ENGINEER

- System concepts
  - Develop / standardize in system domain ontologies
- Manage the Model/Data Integration process
  - Identify the relevant domains
  - Define the relations between models/data
- Integration is a continuous process
  - Virtual integration -> Digital Twinning
  - Analysis and V&V in early stages on integrated models
- Digitization: *Systems engineering requires Engineering systems*
  - The System Engineer becomes the Orchestrator

AUTOMATION OF SYSTEMS ENGINEERING



Reference Architectures

Engineering Organization or Product-Line Design Concepts, Experience, Guidelines, Standards, Utilities, …

Standardize company / context specific IP and experience in DSL technology

DSL technology applies IP and experience to automatically transform intentions to solutions

Concept/System Design

Solution Design

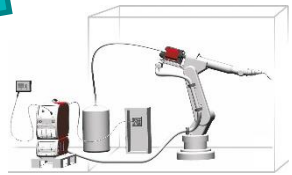
Depending on the organizations scope even generate a solution design in terms of solution technologies

Apply DSL technology to generate a solution

Sketch product to create in high level "intention-based" DSLs

Adjust high level DSL design to tune solution

provide early feedback

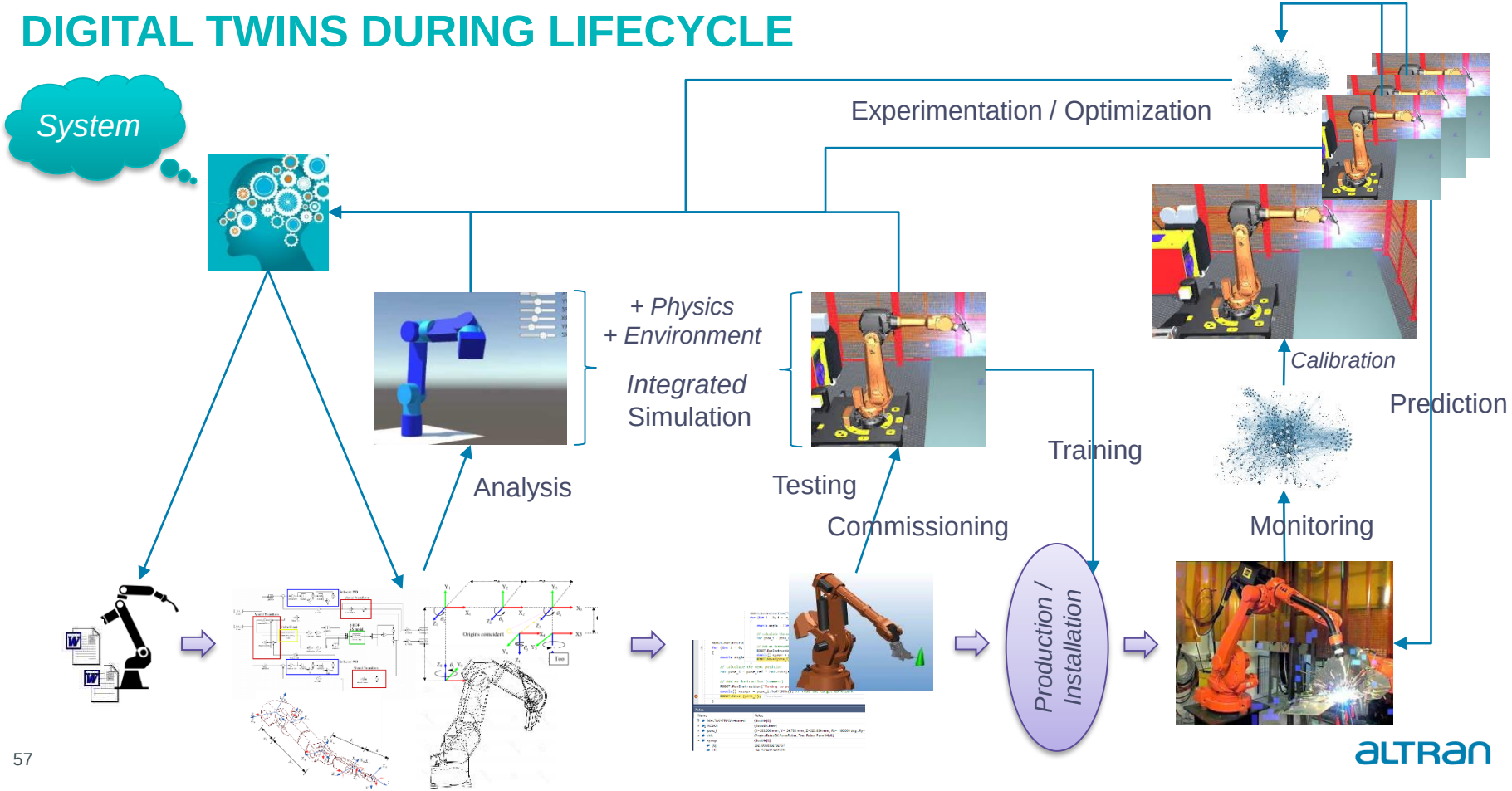


Concept Simulation

DSL = Domain Specific Language

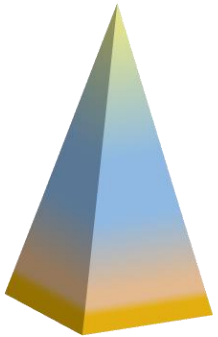
ALTRAN

DIGITAL TWINS DURING LIFECYCLE



ALTRAN

SYSTEMS ENGINEERING?



Conference on Knowledge Discovery, Knowledge Engineering and Knowledge Management

http://www.keod.ic3k.org/

ALTRAN

THANK YOU