MBSE in the System Design and Verification Process

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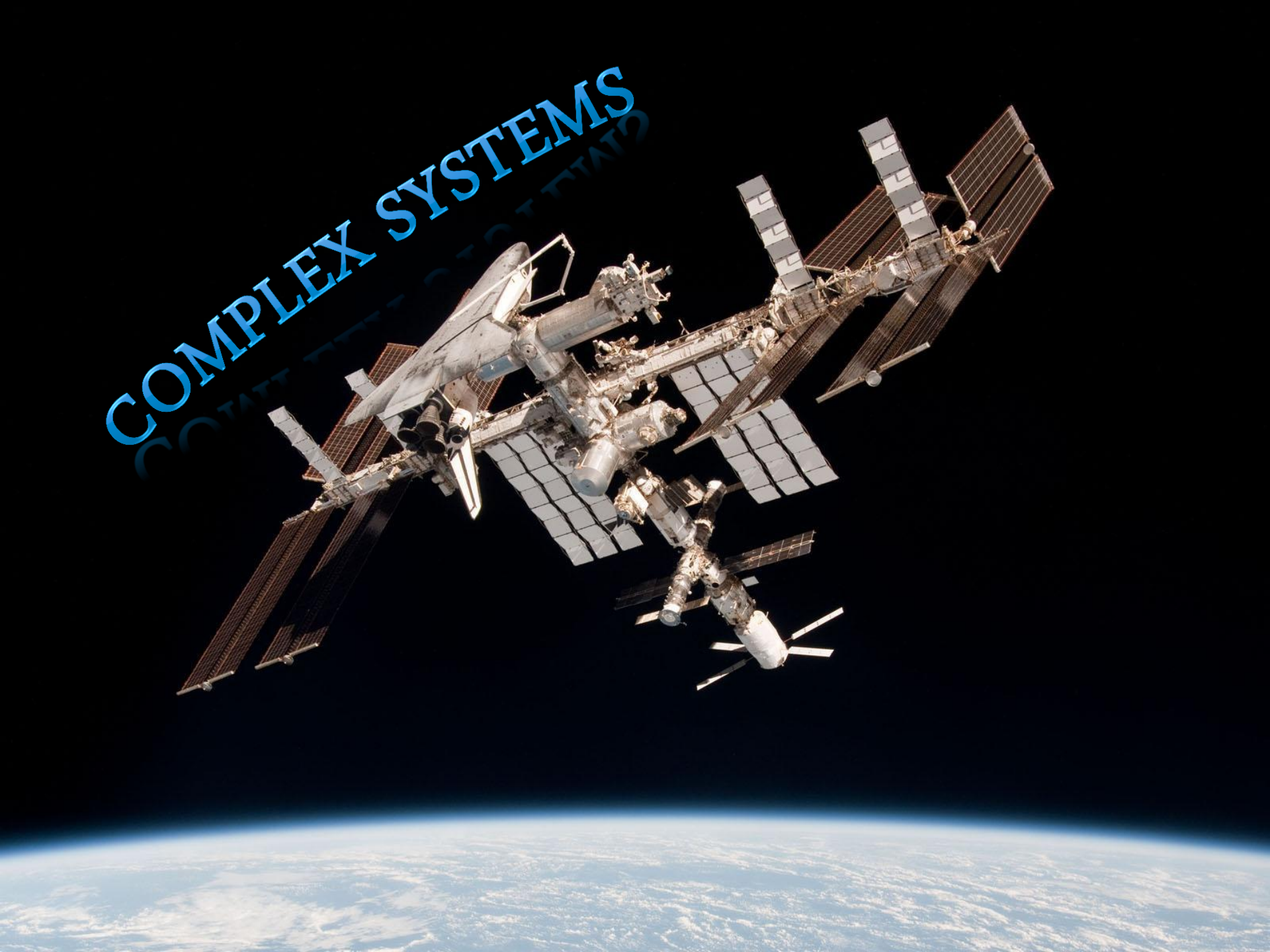
also inspired from industry and organisations like
OMG, INCOSE
Astrium, TAS, ADSE

COMPLEX SYSTEMS



What Is Systems Engineering?

A Consensus of Senior Systems Engineers

Engineering process

1. Improve the way we deliver Space Systems
    a. Manage increasing complexity
    b. Reduce cost and schedule in projects
    c. Assure quality
    d. Strengthen competitiveness

2. Development pull (what are our problems):
    a. "Stovepipe" design approaches (limited cross-sectorial harmonisation)
    b. Inconsistent System Data across actors and along project life-cycle
    c. Bottlenecks in AIT / AIV
    d. Weak initial verification leading to late problem detection
    e. Difficult handover between stakeholders (ESA / industry)

3. Technology push
    a. Model-Based System Engineering
    b. Virtual Design / Testing capabilities
    c. System modelling / simulation
    d. Standardisation

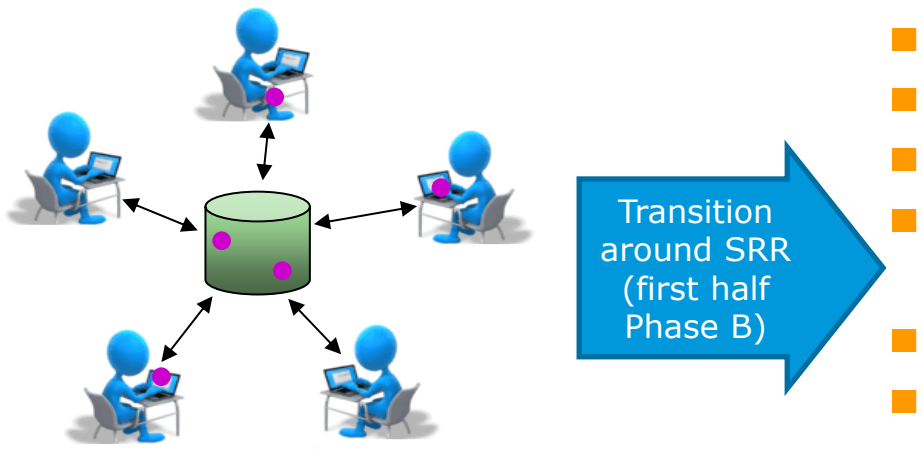
System Engineering – process standard

- ECSS-E-ST-10C: System engineering general requirements.
- Supporting HB/TM's
  - ECSS-E-HB-10-02A: Verification guidelines
  - ECSS-E-TM-20A: Product data exchange
  - ECSS-E-TM-10-21A: System modeling and simulation
  - ECSS-E-TM-10-23A: Space system data repository
  - ECSS E-TM-10-25: Engineering design model data exchange (CDF)
- OMG SysML-QUDV: Quantities, Units, Dimensions, Values (QUDV)
- OMG SiMF (Semantic Information modeling for Federations)
- Domain standards (several)
- Quality assurance & Management standards (several)
- Others.

Early vs. Later Life Cycle Phases

Early Phases (0, A)

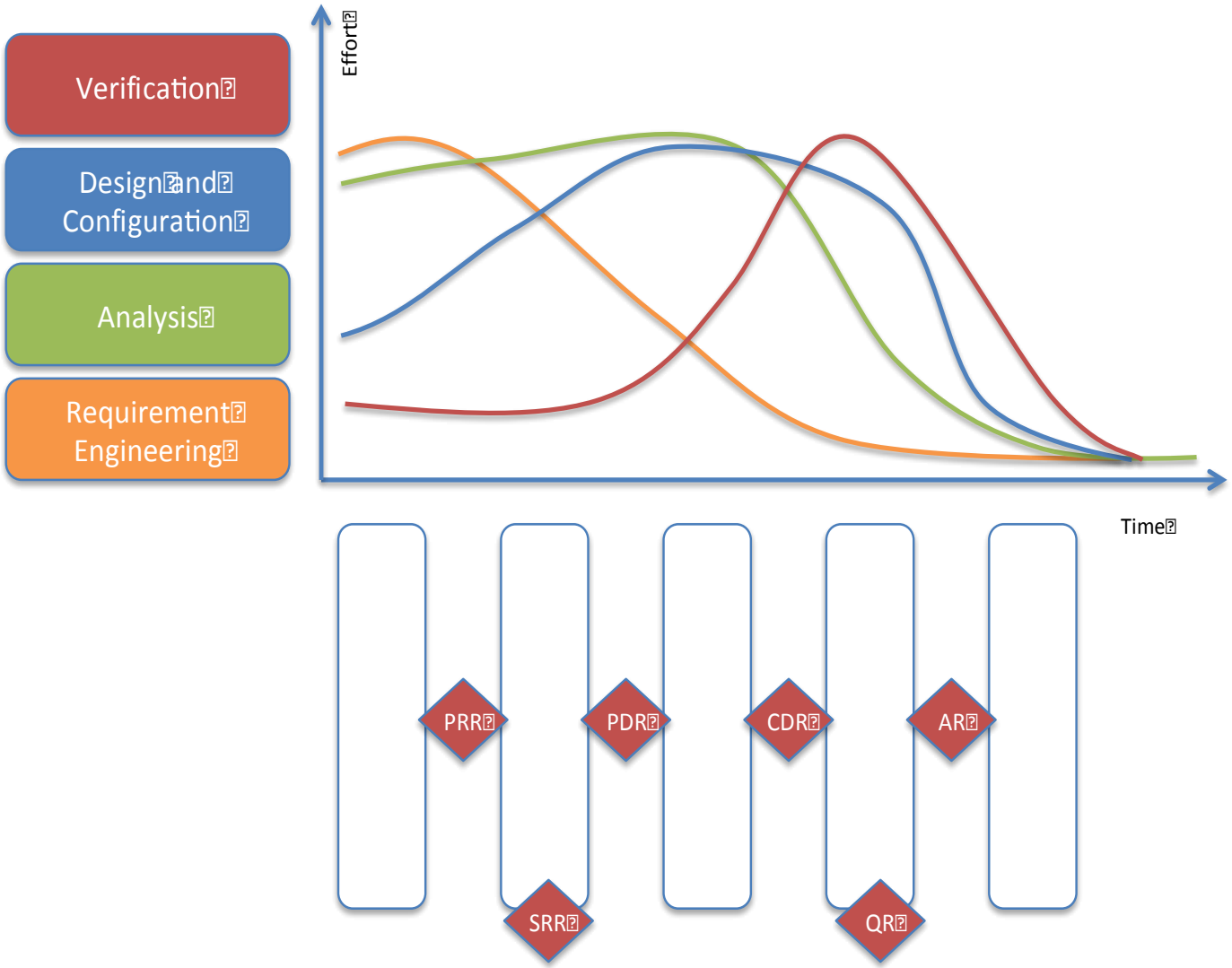
Later Phases (B, C, D, E)



- Tens of users
- One or few organisations
- Near-real-time data sharing in minutes, hours
- Trade studies / Strawman models
- Requirements in state of flux
- Support decision making / programme formulation
- Few relatively small models
- Fine-grained version control (object level)

- Hundreds of users
- Tens of organisations
- Synchronisation times in days, weeks, months
- Formal configuration/version control
- Strict requirements baseline
- Formal, detailed V&V
- Orders of magnitude more models/data
- Coarser-grained version control (“dataset” level)

SE Functions During Life-cycle



The use of Models in the engineering process

- A Model captures the characteristic of a system
- A Model is a representation of reality.
- The dynamic properties, the behavior are provided, by propagating the model as function of time, frequency, load, temperature. Sun-aspect angle,…..
- Before any modeling:
    a. Make sure the question is clear
        - "what is the objective of this model"
        - "Which answers it shall provide"
    b. The required fidelity of the model is linked to the Objective (which question are we trying to answer)

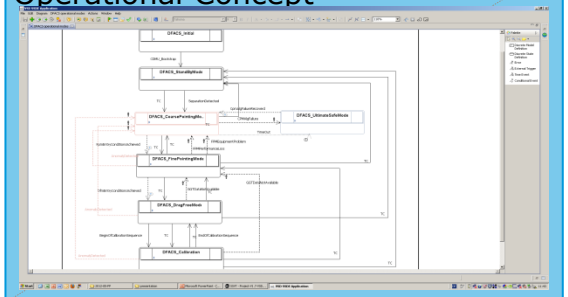
Models and their Use

1. Modeling
    a. Generation of models
    b. Closely linked to “design / architecting” activity
    c. Description as well as relations between engineering artefacts
2. Communication
    a. Exchange of data
    b. Often linked to “review” activity
3. Use / exploitation
    a. Use of model information in dedicated tools
    b. Closely linked to “analysis” or “verification” activity
    c. Reasoning on model data (design knowledge, experience, rules)

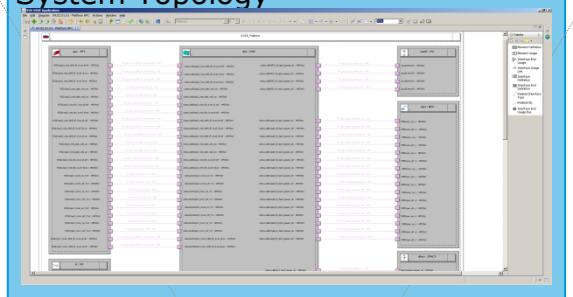
4. Formal and automatic transition between different levels (model transformation, e.g. CAD → FEM → 3D printing, SW spec → Code)

Common Representation and tailored Presentations (or Views)

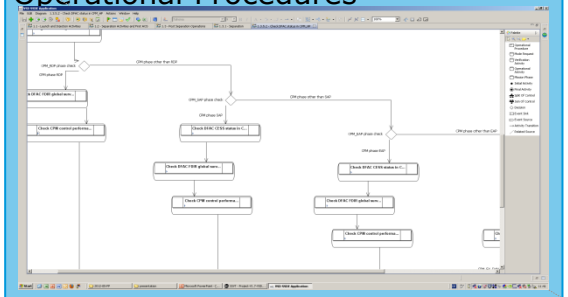
Operational Concept



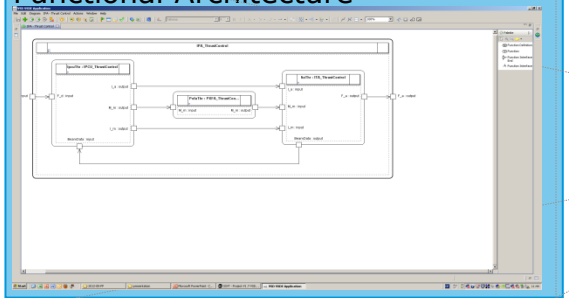
System Topology



Operational Procedures

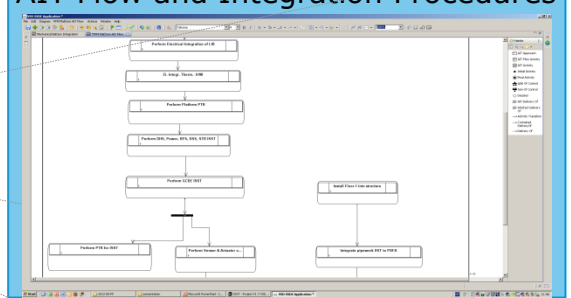


Functional Architecture

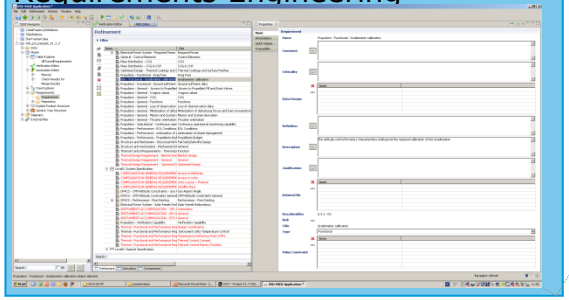


Representation

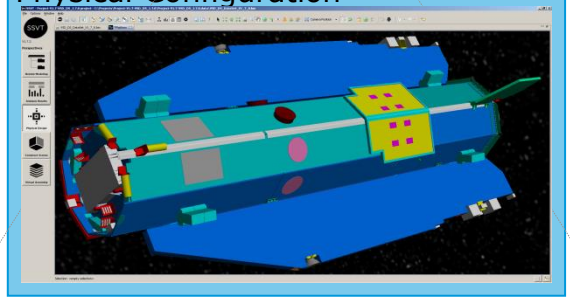
AIT Flow and Integration Procedures



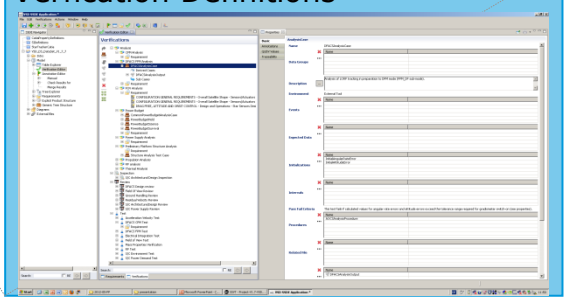
Requirements Engineering



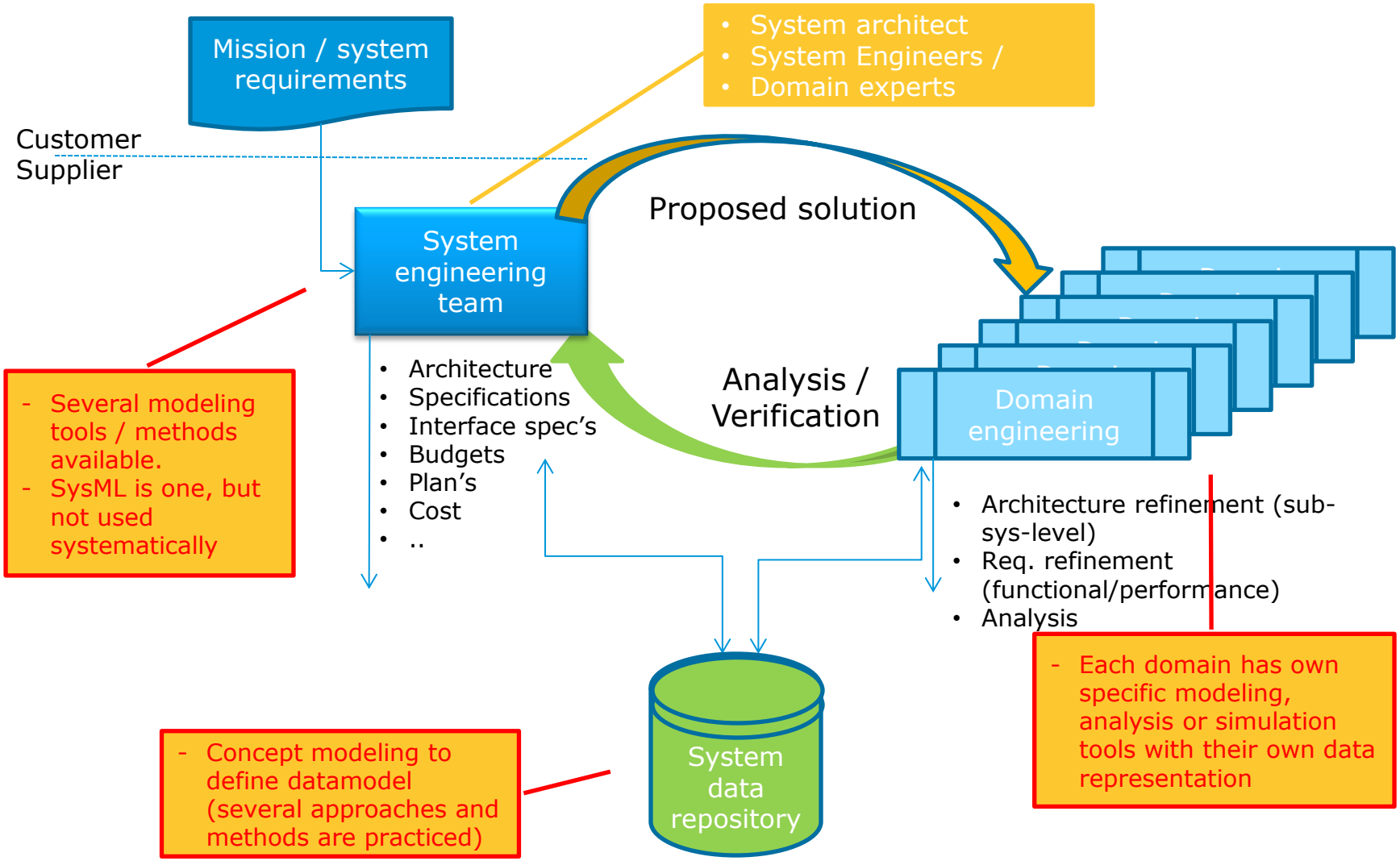
Physical Configuration



Verfication Definitions



The data challenge



Status today (ESA activities)

1. VSEE (Virtual Spacecraft Engineering Environment)
2. Data Mapping Editor
    a. FSS – link system model and verification method
3. Space System Data Repository
    a. Harmonisation exercise ongoing and roadmap defined
4. Verification over life-cycle
    a. Reviews – what do they mean
    b. Data / information – where and how does it need to be exchanged
    c. "Contracts" as means to ensure traceability also on model level
5. Standardisation / methodologies
    a. Conceptual data modelling (FBM)

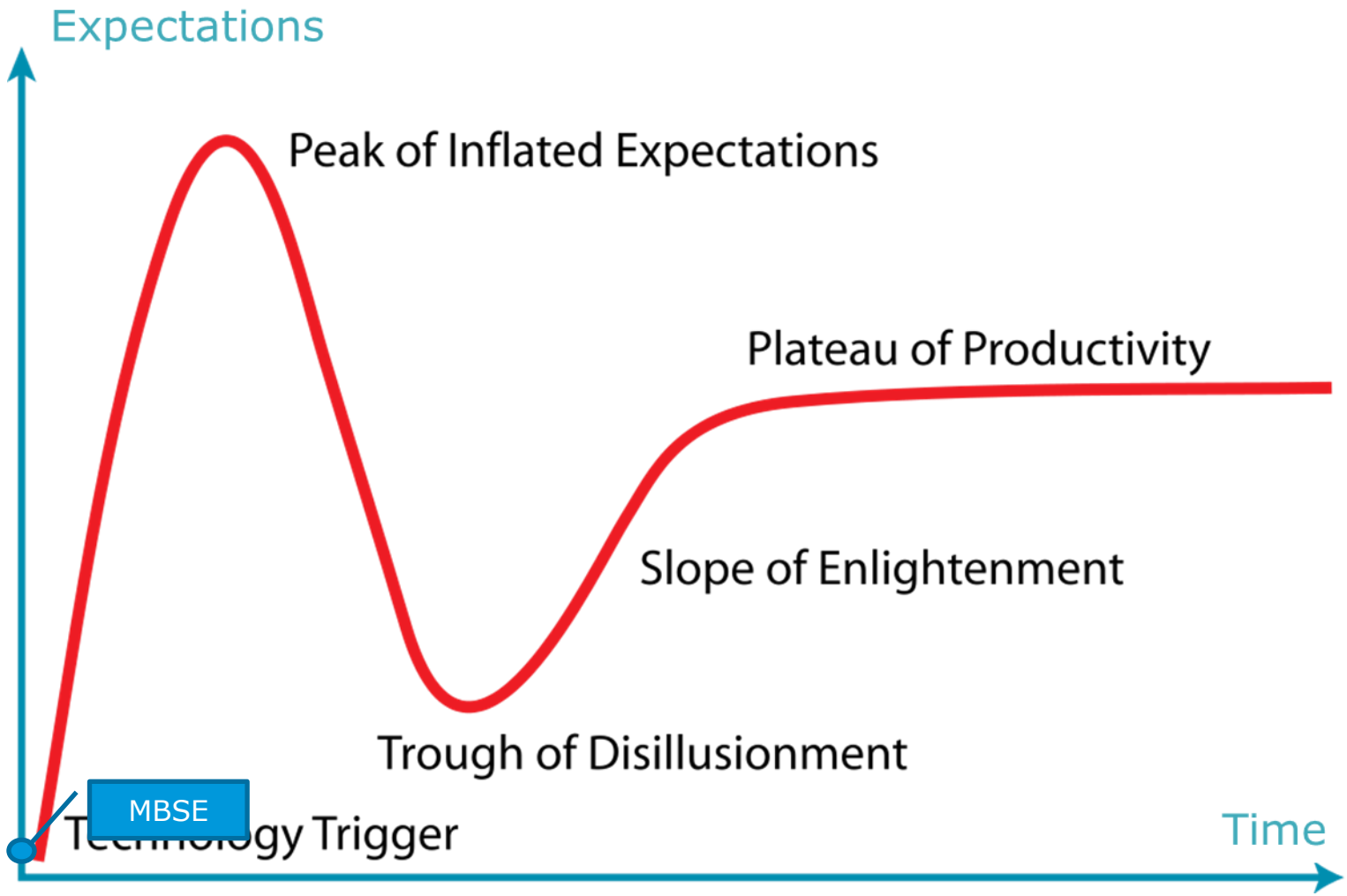
The Top-level Objectives at Engineering Level

1. Manage increasing complexity without loosing grip on cost and quality.
2. Maintain consistency between properties used by the system architect and the domain engineering experts.
3. Perform verification early in the lifecycle to ensure our spec's are feasible, complete, coherent and consistent.
4. Interchange of data between domain tools that uses own data model.
5. Ensure that all domain analysis /verification are based on the same system data-set.

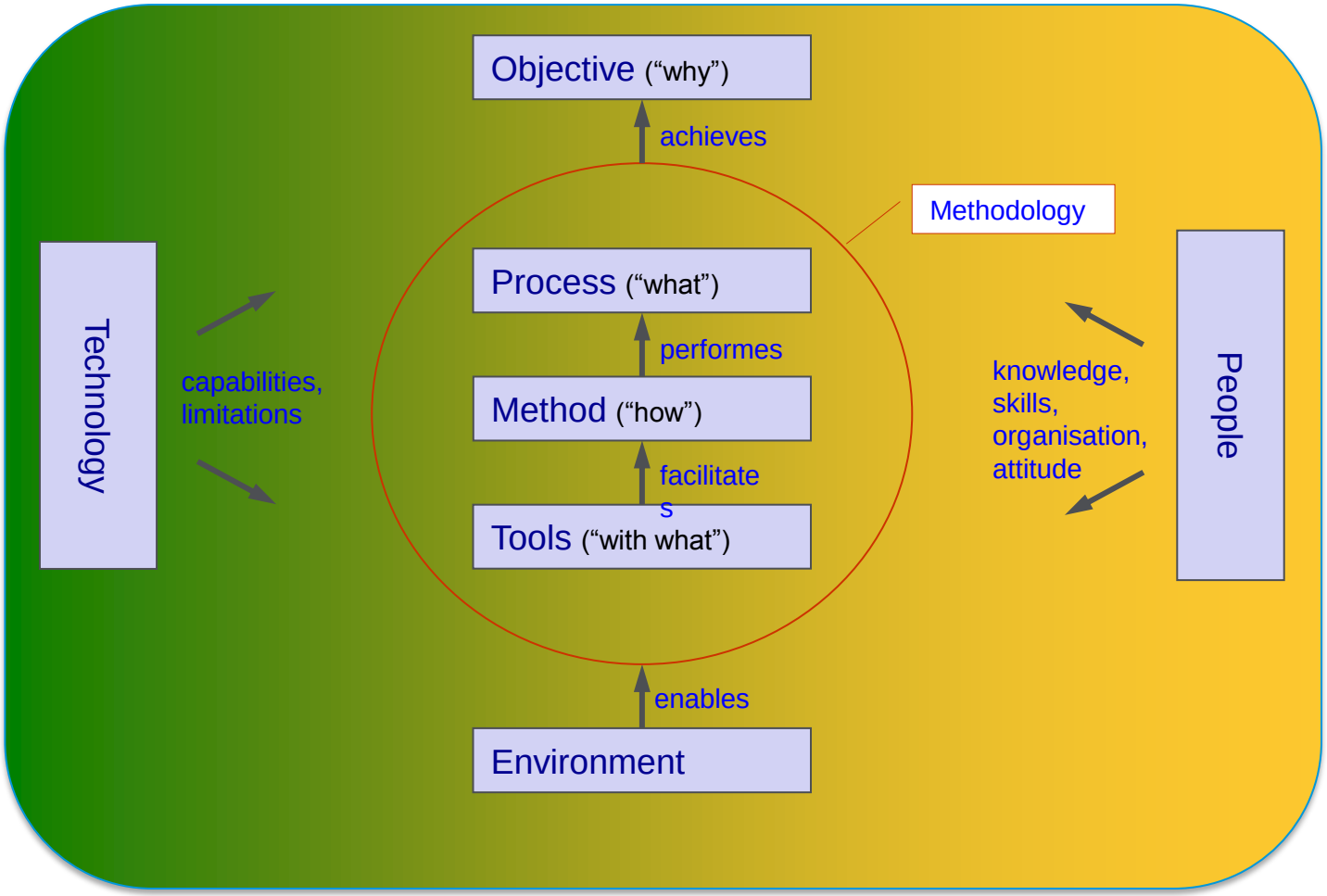
What are the challenges

1. Infusion into projects
2. Measurable advances
3. We understand
    a. Context of engineering
    b. Underlying mechanisms
    c. Domain needs and interactions
    d. Traceability
4. What we need to improve
    a. Requirements / verification logic
    b. Where is interoperability needed, where is communication, where is contractual / technical / programmatic
    c. Boundary between system and discipline level
5. Need to focus to get acceptance

Where is the MBSE in supporting this cross domain problem?



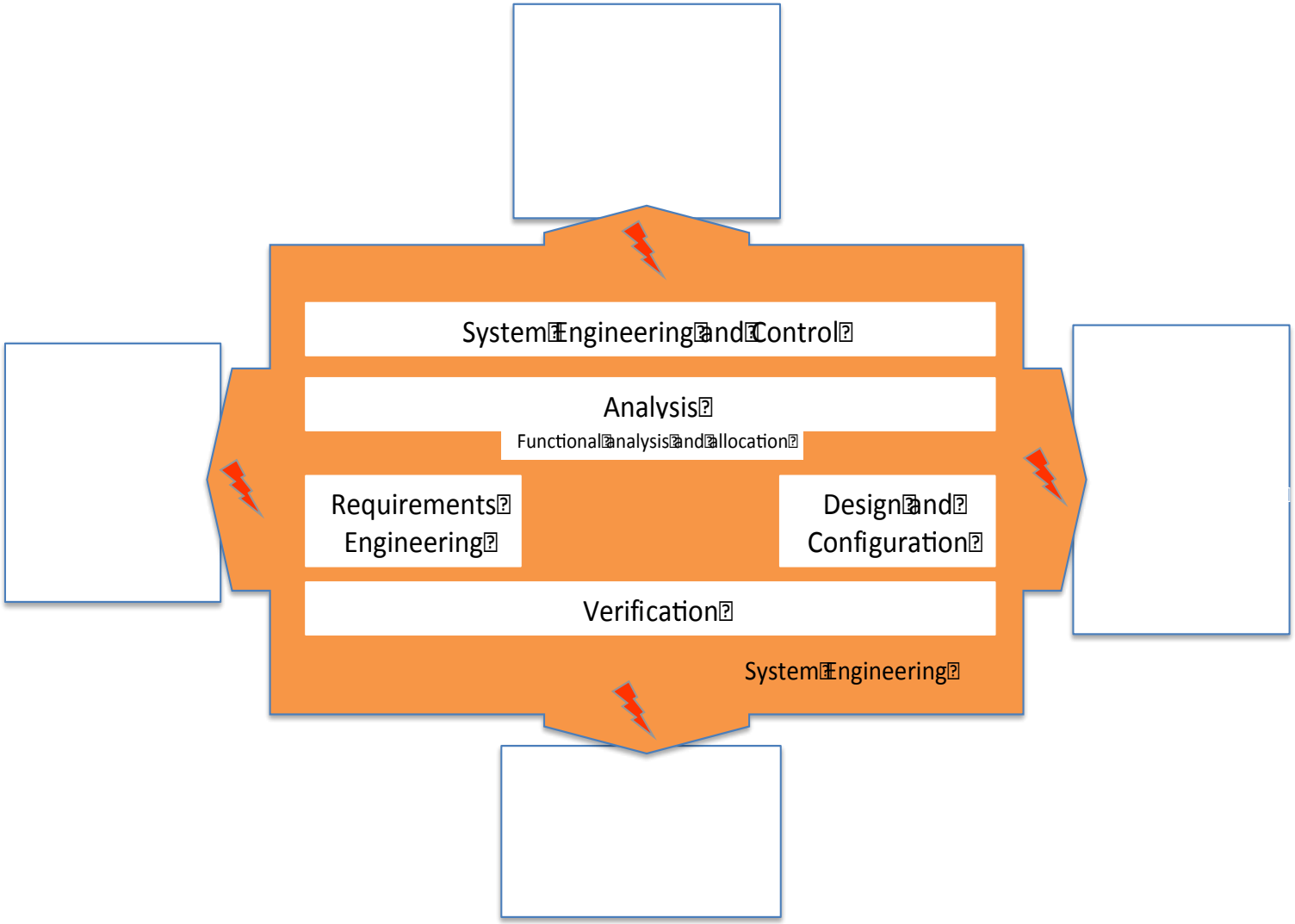
Challenges for Introduction



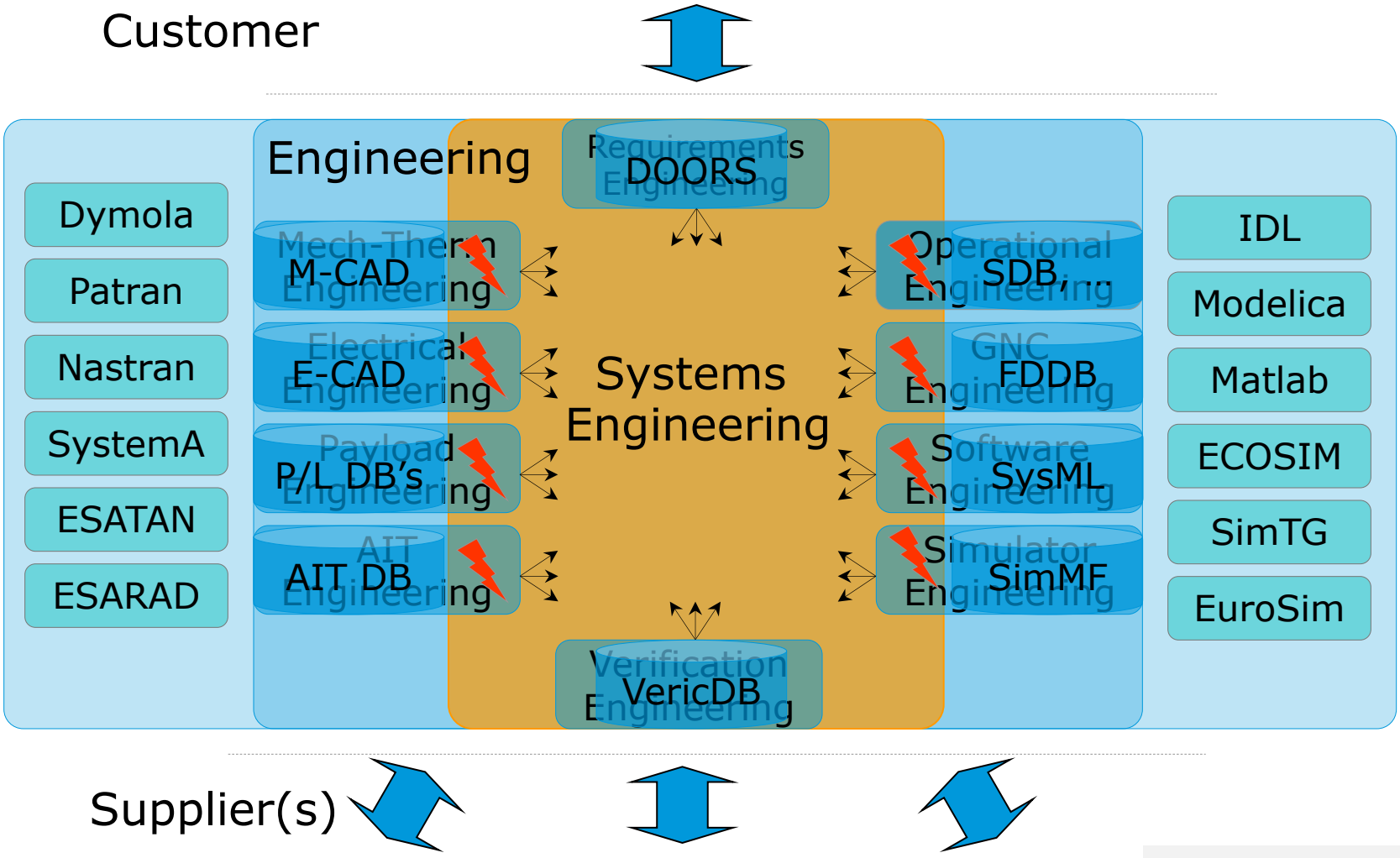
- Manage the change process
- Data and process central
- Not a technology looking for a problem

Adopted from: James Martin

System Engineering Domain and Interfaces (according to ECSS)

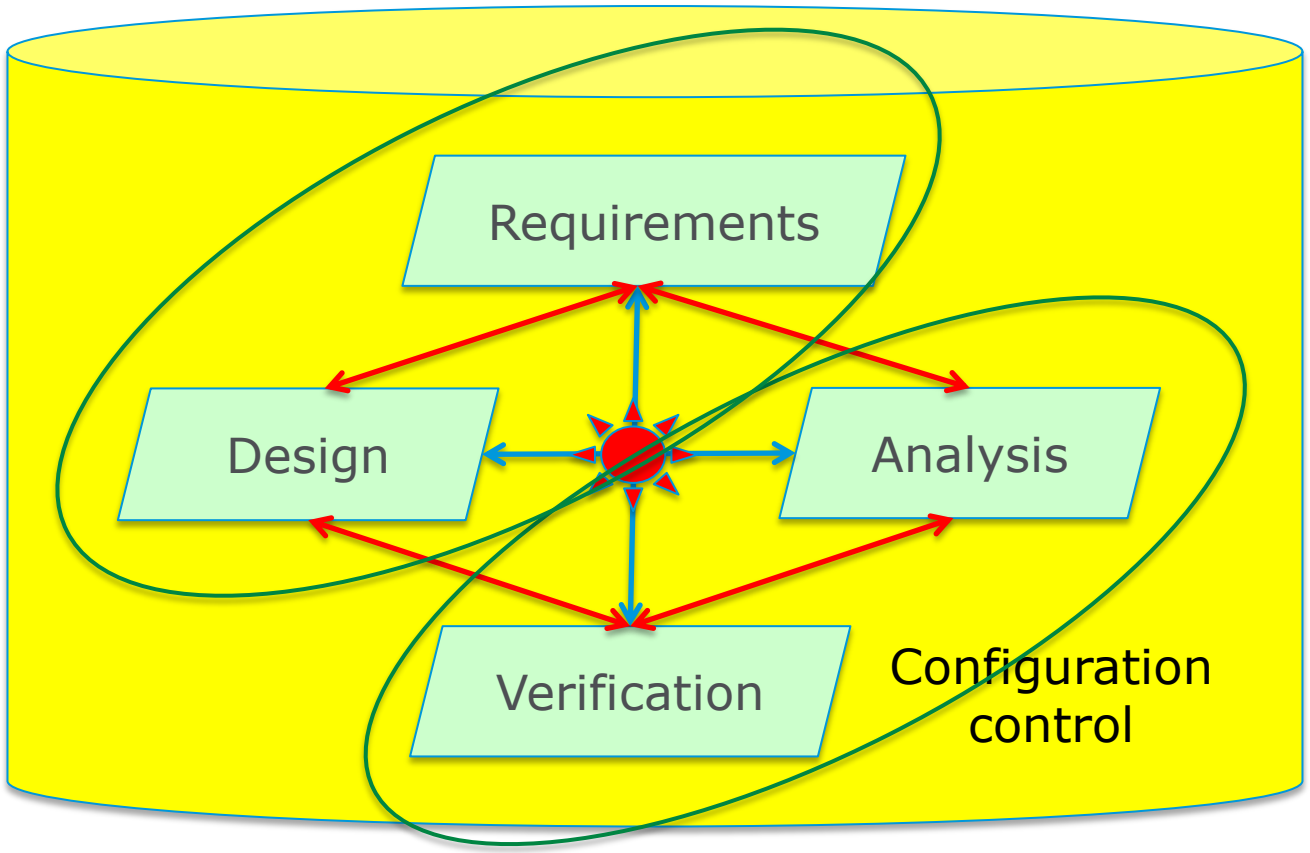


Resulting Data Challenge



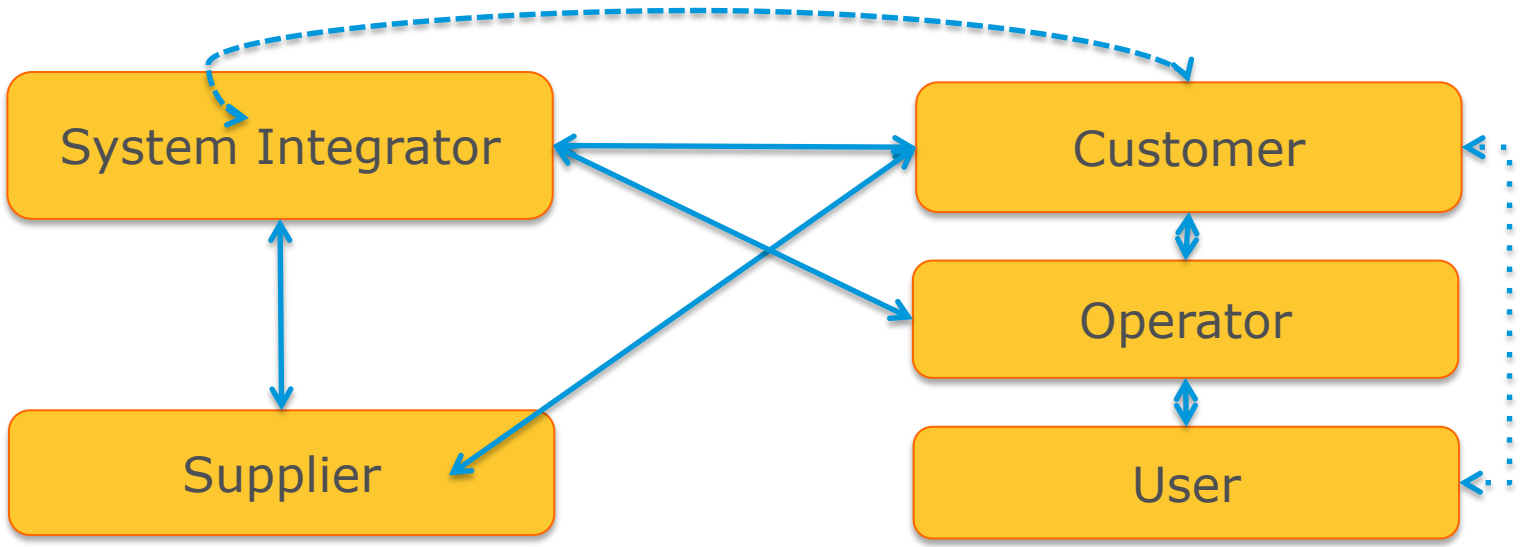
Adapted from Astrium presentation at OMG Technical Meeting Reston (03/13)

Simplified View (process)



Simplified…?

Simplified View (Stakeholders)



- Work up to now has focused much on the data and information side of things, and not yet fully understood (and modelled) the exact need for interoperability and the associated tangible elements and the users of them.
- Interactions need to be redefined, taking into account ownership and governance, design vs. process, review vs. verification, with changing roles through the life-cycle

.. a multi-dimensional problem

- System engineering propose solutions – domain engineering responds by detailed requirements and analysis/verification.
- The system engineering process has to manage many interdependencies, **'views',** across domains. (e.g. operability, power, control)
- Exchange of system data between domain tools without loosing semantic information.
- Must maintain Governance and configuration control of system design data
- The system engineering process is an end-to-end process with different phases;
    1. Conceptual design
    2. As specified
    3. As designed
    4. As built
- Address the full verification chain

Cross domain data consistency

Focus on

- Establish the agreed (standardised) information terms and definitions at system level and its mapping to the respective sub-domain.
- Establish a formalised (logic based) system data model allowing automated verification for correctness.
- Shared information management (System Data repositories)
    - securing consistency of data-sets used by domain engineers across the domains where they couple.
    - All ‘views’ shall operate on the system data repository (operability -, thermal-, power- ,GNC-, Digital Mock-up)
    - Have a clear governance of all data items (owner, user)
    - Have a strong configuration control.

Next steps

- Understanding how to model
  - Modelling guidelines / rules
- Pilot
  - Looking for suitable project (phase / complexity / context)
  - Small step: Euclid P/L Reqts engineering
- Consolidate overall objectives
  - Which questions need to be answered
  - How / where to use model data
  - From whom in which way (stakeholders)
  - How to organise (link to PLM…)
- Methodology / basis
  - Data modelling, Conceptual basis

→ Stakeholder Group on (MB)SE processes

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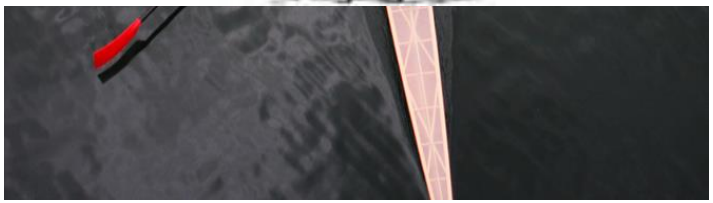
Need for Coordination and Collaboration



My Questions

1. Where is the right interface between partners – how to define these interfaces (data, information, process, function…)?
2. What are the right "deliverables" supporting the MBSE? Common infrastructure?
3. What is the role of PLM in this?
4. Where do we need further standardisation?
5. Is it right to maintain the strong link between technical and contractual milestones / gates?
6. What is the impact of reuse on the design and verification process?
7. Verification – where does it start, where does it end, how do we ensure that system verification is understood as the "sum" of many activities, from simulation and analysis to test and analysis of test results?