ESA satellites development with MBSE

Pierrik Vuilleumier (European Space Agency, ESTEC, Netherlands)

MBSE 2022

System Engineering

- System engineering principles essential to develop successful space projects
  - People went to the moon with SE

> *"Project Apollo was a triumph of management in meeting enormously difficult **systems engineering**, technological, and organizational integration requirements."* NASA

- Buzz Aldrin – 50th anniversary of Apollo XI : **"Fifty years of non progress"**

> *"Fifty years ago the Saturn V took the command module, the lunar module to the moon, three of us, to the moon. We landed, explored, got back up again rendezvoused, came back. That's fifty years of non-progress. I think we all ought to be a little ashamed that we can't do better than that".*

- MBSE shall be included in projects SE processes to deliver its promises
  - Can't be an additional discipline in isolation

"MBSE is SE"

Lloyd Pryce - https://www.optimasc.co.uk/the-apollo-project-hard-problems-need-systems-engineering/

MBSE must..

- MBSE must be multi-disciplinary (or transdisciplinary)
  - In line with INCOSE SE definition

> Systems Engineering *is a **transdisciplinary** and **integrative** approach to enable the successful realization, use, and retirement of **engineered systems**, using **systems principles and concepts**, and scientific, technological, and management methods.*

  - Space systems as “cyber-physical systems”

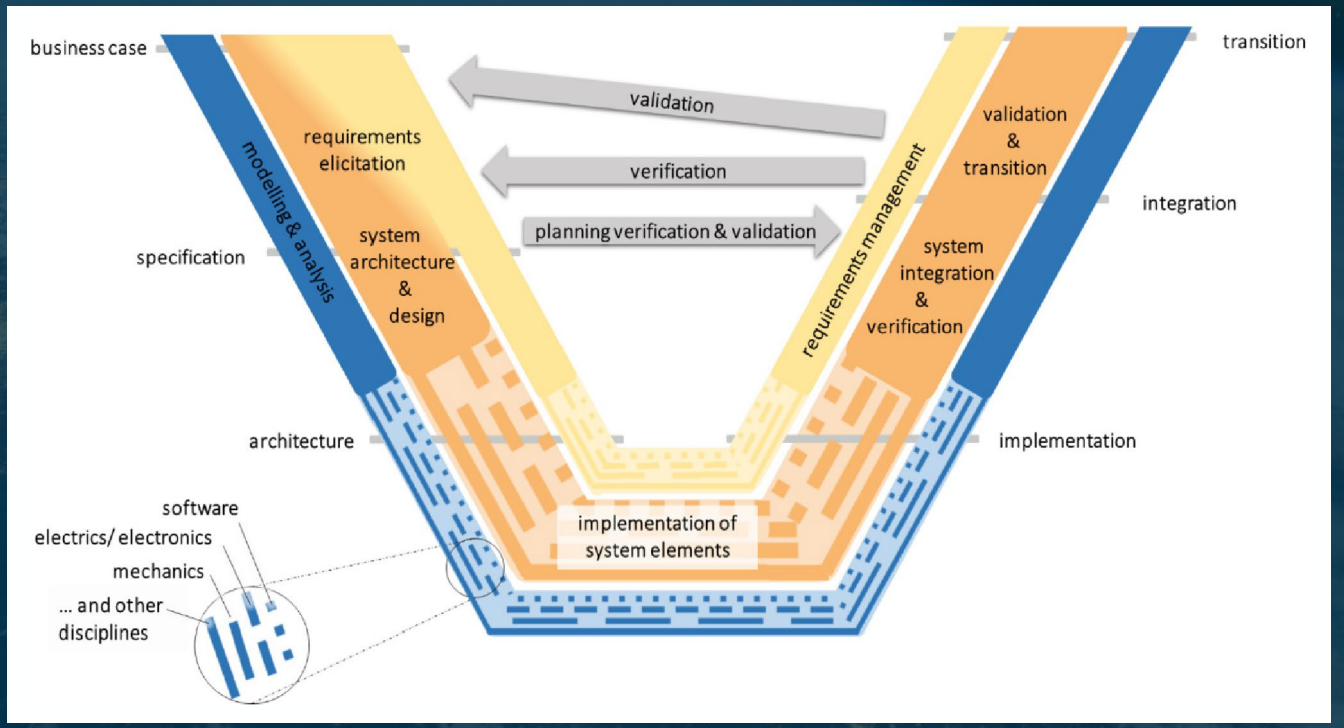
- MBSE must build the “right system”
  - Delivering performance compliant with Users/Stakeholders needs.

- MBSE must satisfy/improve SE constraints:
  - Cost
  - Schedule
  - Sustainability will become key in the future

INCOSE - https://www.incose.org/about-systems-engineering/system-and-se-definition/systems-engineering-definition

V-model in the context of MBSE

- V-model pictures the SE **transformation** processes
  - Over-arching project process
  - Document based or Model based
  - VDI account for MBSE



- **Versioning** is paramount
  - Weak point today
  - Centralised/distributed repository (aka “single source of truth”)
  - Enabler for MBSE in projects

- Complexity or volatility ?
  - Today’s systems are maybe not that much more complex
  - Digital media creates volatility

Graessler, Iris and Hentze, Julian - The new V-Model of VDI 2206 and its validation - https://doi.org/10.1515/auto-2020-0015

Single source of truth – really ?

- Single source of truth at the ideal heart of MBSE
  - But the concept does not tell how to conceive such all-encompassing “Model”.
- Many models used in projects and are not likely to change

• CAD	• Antenna models	• SW models (UML, Source)
• FEM	• Harness list	• VHDL models
• TMM	• Control loop models	• Test benches
• EMC models	• Data processing models	• EM’s
• Performance models	• System block diagram	• ..etc
• Optical models	• Simulators (SVF, Ops,…)	

- But we are not doing MBSE
  - Documents and/or “brains” still in the loop (re-capture/interpretation of information. Oversight risk)
  - Duplication or dephasing of information. Risk of incoherence.
- Actual system errors/mistakes probably often caused by in these incoherencies

”MsBSE” - modelS based system engineering

Coherence

- Coherence between models is paramount to approach the “single source of truth”

- Models partitioning seems essential to master coherence with the right granularity (“sub-models”)
  - Partition probably should match the logical model of the system (akin to product tree)
  - Partitioned entities have different **representations** in different models
    - Representations have **dependencies**

- Coherence dependencies types
  - Time based (like those handled in makefile)
  - Parametric (multi parameters constraints - bijection base on ontology as special case)
  - Derived (a representation is automatically derived from another one, e.g. FEM derived from CAD)

- System tools are needed to ensure coherence between models

MBSE in ESA institutional projects

- ESA role in projects
  - Federate users/stakeholders needs and derive mission and system requirements
  - Monitor the implementation by Industry during development
    - Ensure compliance and quality
    - Evaluate and mitigate risks (compliance, cost, schedule)
    - Dispose non-compliance, release margins and define acceptability of risks
  - Accept deliveries
- Documentation is the fundamental input to ESA - but MBSE is to replace documents by models
  - Moving towards MBSE shall not undermine the role of ESA
  - Deploying MBSE requires visibility and access to models for monitoring and reviews
    - This has been difficult until now (e.g. electrical schematics, matlab models)
  - IPR shall be safeguarded within the project consortium

Take-away messages

- MBSE is SE
- Projects SE is in fact MsBSE
- Versioning is key to manage transformation processes fundamental to (MB)SE
- System tools are needed to ensure reliable coherence between models.

Thank you for your attention !