Institute for Systems Engineering

Z9

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What is Model-Based Systems Engineering?

Systems are becoming more complex and the engineering of these systems is becoming more and more of a challenge for business to meet timescales, quality criteria and cost constraints. Model-Based Systems Engineering (MBSE) is becoming a real necessity to engineer the system complexity and to support meeting the business challenges.

The INCOSE definition of MBSE is:

The formalised application of modelling to support:

- ***System requirements***
- ***Analysis***
- ***Design***
- ***Verification & Validation***

beginning in the conceptual design phase and continuing throughout development and later lifecycle phases. (INCOSE)

It is recommended that the reader take a look at the Z0 Systems Engineering and the Z1 What is Systems Engineering? guides.

Think of Model-Based Systems Engineering 'as' Systems Engineering, it is how Systems Engineering is done!

MBSE is scalable for the engineering of a 'System-of-Systems' (SoS). This is a '*set of systems that interact to provide a unique capability that none of the constituent systems can accomplish on its own*' (definition from ISO 15288:2023 Systems and software engineering – System life cycle processes).

This guide summarises key MBSE Concepts, Benefits of using MBSE and Fundamental Enablers to introducing and using MBSE in an organisation. Further Reading provides additional insights and more detail to aid the reader deepen their understanding and appreciation of MBSE being Systems Engineering.

MBSE Concepts

Model
An abstract representation of a system, of its structure and behaviour, constructed as a set of inter-related views. The set of views being the total recorded knowledge of the system; i.e. the single point of reference. The model would ideally be in one place but in practice is likely to be distributed and managed across multiple tools and repositories.

System
A set of interacting system elements that each exhibit behaviour and which collectively deliver a whole product and/or set of services to stakeholders that the individual system elements do not.

View
A partial description of a system which may be a diagram, text, a table or other layout using a graphical language (e.g. SysML), mathematics or other notation. Even though partial, views have clear scope and purpose to be meaningful and of value to the stakeholders. A view is based on, i.e. is an instance of, its defining viewpoint.

Viewpoint
The specification of the ontology concepts and relationships that can appear on a view, along with the conventions for constructing the view. Each viewpoint is defined to address the concerns of stakeholders.

Framework
A defined set of viewpoints and associated ontology, which define the views of the system. Published frameworks are available (e.g. UAF) which should be considered and used to represent the nature of and 'frame' the modelling activities.

Ontology
A set of defined terms and relationships between those terms. An ontology provides rigour and robustness when defining the viewpoints.

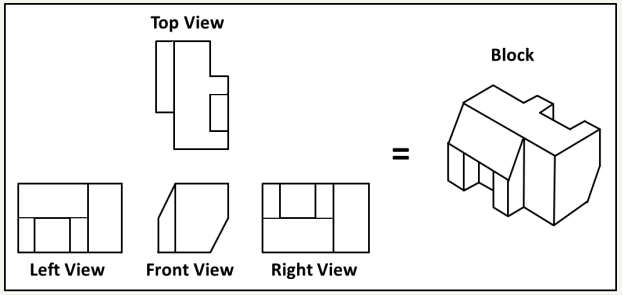
Stakeholder
A person, a group or other system that has one or more concerns with the system.

Concern
A matter of interest or importance to a stakeholder in a system, represented using viewpoints and associated views within the model of the system.

System Model Views

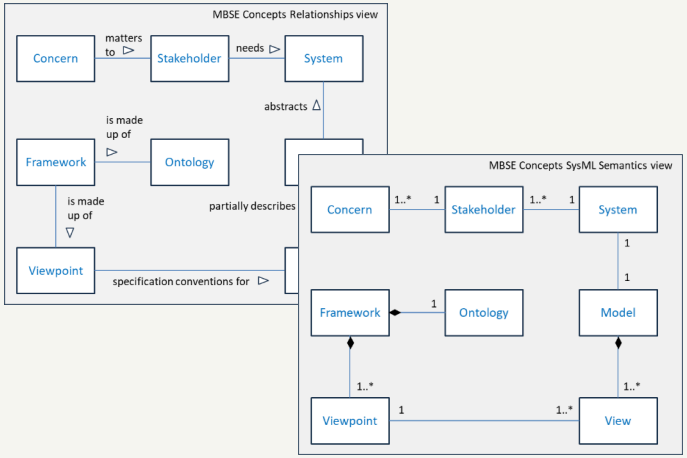
In Example 1, the collective set of views enable the shape of the Block in each dimension to be understood. Adding measurement detail to each view would enable it to be produced. It is important to consider, based on the purpose of the view, the detail to include.

Example 1 – A set of Block Orthogonal Views



In Example 2, MBSE Concepts are the System and the views 'visualise' the textual description with a Relationships view and a SysML Semantics view. In the Relationships view, Concern matters to Stakeholder. In the Semantic view, One Stakeholder has One to Many Concerns. The semantic view providing more detailed specific information.

Example 2 – MBSE Concepts View



Ideally, produce only the views required to understand, design and implement the system.

Benefits of Using MBSE

Traditional (or document-centric) Systems Engineering is heavily centred around the creation and maintenance of a set of documents. Their loosely connected nature and sometimes overlapping and conflicting content can make it difficult to assess the system of interest. They rely on the manual creation, inspection and management of the documents.

MBSE is centred around a single point of reference (the model). The connected nature of the elements and views within the model, describing the system, allows a more insightful and higher quality representation of the system of interest. Benefits include:

Improved Understanding

- Improves communication between project stakeholders and engineering disciplines, and across language barriers.
- Promotes exploring different perspectives.
- Leads to a more holistic view.

Improved Quality

- Interconnectivity of system elements and views promotes traceability, particularly between needs and requirement allocation to subsystems.
- Early identification of conflicts or issues with requirements.
- Consistent documentation, both within and across projects, generated from models.

Increased Productivity

- Improved impact analysis of requirement or design changes.
- Improved collaboration across multi-discipline and stakeholder teams.
- Common, shared, consistent information allows concurrent working.
- Automated generation of documentation.
- Reuse of existing models to support design and technology evolution and product lines.

Reduced Risk

- Early and on-going requirements validation through inspection, and design verification through the use of simulation and automatic verification.
- Improved system assurance.
- Improved cost estimates.

Fundamental Enablers

There are fundamental enablers to introducing, using, maturing and sustaining Model-Based Systems Engineering in an organisation in order to ensure that the organisation, its people and its customers achieve benefits and value that endure.

The Organisation and its People

Organisational commitment to systems engineering and to the model-based approach, with senior sponsorship and a pro-active champion is key. Including MBSE in the company strategy embeds this commitment further, and shows it.
With this commitment, the people in the organisation who will use MBSE and who will deliver the value must be supported. This includes their personal and team development with training and continual learning in the approaches, process and tooling associated with MBSE.

An Approach with Process

MBSE is best understood by being used with a clearly defined and articulated approach to follow. With the purpose and scope identified for the required systems engineering activity, the MBSE approach can be tailored to meet these needs.
Having an associated process supports this usage, facilitating repetition, consistency and improvement of the approach. The process must complement existing processes that are part of the overall systems engineering activity.
Information and guidance are generally available on-line from organisations, bodies and individuals that share their use of MBSE. In addition, standards are available to provide some foundation – particularly process. So, there is no real need to create approach and process from scratch.

Tools

A model, being a set of inter-related views of a system's set of interacting system elements, can become very complicated very quickly. Modelling, being a collaborative concurrent team activity also adds to the complexity. Using a repository-based tool, or possibly a set of tools, to facilitate creation, use, management and publication of all this is a necessity.
With a tool, an associated approach, process and some general guidance is usually provided. This may suffice for an organisation to start using MBSE and to mature their understanding and tailor the approach for their specific needs.

Common Misconceptions

It's just about SysML . . .

No - the modelling language and notation used in the model should be the most appropriate for what is being represented. SysML is a powerful modelling language which is commonly used but that doesn't mean alternatives shouldn't be considered.

It's just about drawing . . .

No - the biggest strength of an MBSE approach is that there is meaning in the connectivity and traceability between system elements represented on a diagram. This maximises benefits realising correctness, completeness, consistency, etc. Therefore, a representation should be connected to the underlying model and the tools used must have the appropriate capabilities to achieve this.

It's just about the volume of data . . .

No - as with all types of models, the quality of data is important. There needs to be enough information in the model to satisfy the role or aim that has been defined in the model scope.

It's just a tick box exercise . . .

No - MBSE is intended to be an integrated and through life approach to systems engineering which can support a project right from concept through to disposal.

Further Reading

- Don't Panic! The Absolute Beginner's Guide to Model-Based Systems Engineering - Available at www.ifse.org.uk
- Don't Panic! The Absolute Beginner's Guide to Architecture Frameworks - Available at www.ifse.org.uk
- Don't Panic! The Absolute Beginner's Guide to SysML V2 - Available at www.ifse.org.uk

For further information and help, or to download copies of this leaflet and other Systems Engineering resources online, go to:
www.ifse.org.uk

For more information about the worldwide Systems Engineering professional community, go to:
www.incose.org

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