International Council on Systems Engineering
A better world through a systems approach

Should I Use MBSE On This Project?

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Agenda

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Background for Pursuing this Effort:

- **We perform multiple, concurrent, enterprise-wide projects** to develop ground systems for space programs
- Our **projects range from very small to very large**, and anywhere in-between.
- Some of our **projects are one-off design**, build and deliver to a customer, whereas others have **extended lifecycles with continuous support** after delivery.
- We may engage with customers to **enter project lifecycles in any stage of development** or operation.
- **We currently do not use MBSE as a standardized part of our SE approach**; rather it is used by knowledgeable practitioners that make a qualitative determination to use it in their work on a project.
- **We desire to intelligently incorporate an MBSE approach when and where it adds business, technical, and organizational value**. A first principle is to perform good engineering, regardless of any method or toolset.
- We assume that the use of MBSE is capable of leading to value-added outcomes, in part or in whole. The exploration lies in the right-sizing effort; it's **finding the right tools for the job and putting them to use intelligently that matters**.

Basic Questions We Wanted To Answer:

1. Are the benefits worth the cost? How to determine if MBSE adds value, on a project-by-project basis?

   - **We may desire to use MBSE** as part of an organizational and technical strategy, **but is it actually worth it** (i.e. has tangible and/or intangible business value) for *this* project I am about to engage on?
   - **There exist many qualitative metrics*** that indicate utility and efficiency as a case for MBSE.
   - However, qualitative assessment alone makes it difficult to make a definitive determination if we actually need or want to use MBSE on a *specific* project.
   - **The project risk faced by reliance on qualitative assessment alone is using an MBSE approach that turns out to be overkill, or that consumes time and resources that would have been better spent elsewhere.**
   - Thus, are there any **quantitative metrics** to make a more definitive determination on a project-by-project basis?

*Qualitative Metric Examples:
- Architecture reusability
- Better understanding of the system
- Increased consistency/traceability
- Cost-effectiveness
- V&V enhancements

Basic Questions We Wanted To Answer:

2. Is an MBSE approach worth pursuing for **smaller / shorter duration projects**?

- Or, should we stick with our well-understood document-based SE (DBSE) approach?
  - The WG noted that using the DBSE approach is a strong function of familiarity and repetition. We already have efficiency gains built in and can tailor things quickly based on experience.
- “Smaller/Shorter” projects to us ==
  - Lower complexity one-off design/build/deliver or prototyping efforts, OR
  - Entering a project later in its development lifecycle or when in operation.
    - Corollary to this case is that documentation likely already exists in one or multiple other forms, so 'adding' MBSE creates another branch in the overall 'source of truth'.

Working Group Tenets

We initially established our WG tenets to ensure our efforts stay focused and help us resolve any conflicting priorities:

- **First, Do No Harm** – Don't add stuff we don't need. The visible/useful end-result should be simple for a third party to consume. It's ok for the complexity to be internal to the model, but not external to the customer. The end-result is of sufficient value that any perceived or real "extra work" is worthwhile.
- **Practical over Theoretical** – Make it straightforward for users. How do I best use it and when do I use it? Clear up the premise that application of MBSE is nebulous.
- **Clear Business Value** – Show this in terms of scope, schedule, cost, or staff development (or internal improvement)
- **There Is No Panacea** – MBSE should align with and enhance solid SE principles and practices; MBSE will never be a necessary condition to doing SE. *Corollary: Don't model for modeling's sake.*

Previous Research:

A research paper executed by a team at the University of Alabama Huntsville (UAH) in 2022 did a comprehensive literature survey to understand the perceived value, metrics and evidence for using MBSE. Note that this examines using MBSE in general versus our goal to determine its use specifically.

Model-based systems engineering: Evaluating perceived value, metrics, and evidence through literature, Kelly X. Campo Thomas Teper Casey E. Eaton Anna M. Shipman Garima Bhatia Bryan Mesmer, 1 January 2023; ISSN 1098-1241

https://incose.onlinelibrary.wiley.com/doi/epdf/10.1002/sys.21644

Some relevant observations and conclusions from this referenced study, and from the referenced studies within that **backed up/confirmed our own personal observations about MBSE** and the identified risks when applying to a project/organization:

- **The vast majority of stated MBSE benefits are perceived rather than observed or measured.**
- **Most metrics are qualitative (93%) rather than quantitative (7%).**
- Some of the top ten benefits are “better communication”, “better analysis capability”, “improved system understanding” and “improved consistency”.
- Some of the top ten drawbacks are “increased time”, “increased cost”, and “increased effort”.
- MBSE perception and value could benefit from side-by-side case study comparisons of DBSE to MBSE.
- **Study of the perceptions of MBSE per project type may be useful further research**.

The Approach:

- **Seek to define a concise set of quantitative and qualitative factors** that the project SE should define to determine the type of project they have, and a concise method using said factors to clearly choose/not choose to use an MBSE approach, or to employ some limited/scaled/tailored version of an MBSE approach, and/or tailor the reach of MBSE within the project team (i.e. who benefits the most from using/consuming the approach?).
- **Seek metrics that remove as much ambiguity as possible** in the result. Narrow the resultant set so that the "right answer" or at least the path ahead is more apparent versus having not done any, or only, a qualitative analysis that likely introduces inherent bias.
  - We conceded that getting to a definitive yes or no were the most welcome answers, but we observed early that in practice more likely these are the outliers. Therefore, we concluded we needed some kind of scale or band of answer results.
- **Develop a concise questionnaire** geared to the intended analyst, the SE.
- **Develop a useful quantitative scoring approach** whereby the SE can make their determinations relatively quickly.
- **Develop a visual scoring presentation** to assist the SE to educate others on the findings, namely PMs and project teams.

Quantitative Factors (1 of 6)
#1 Project Size

- **Factor #1: What is the size and scope of the project?**
  - On smaller projects, the complexity added by MBSE may surpass the complexity of the project itself (think of a Rube-Goldberg machine) and thus the value-add of MBSE must be carefully assessed. On the other hand, large projects may have too many moving parts such that keeping everything organized is challenging and therefore modeling adds more value.
  - The assumption is the SE, with PM collaboration, is in an advantaged position to assess a project's size and scope, and to **score for a relative value when compared to other projects** in which they are involved.
  - **Scoring:**
    - Small - 1
    - Medium - 2
    - Large - 3

Quantitative Factors (2 of 6)

#2 Project Definition

- **Factor #2: Does the project have well-defined needs?**
  - What is the value or need of tracking changes in the model to generate analyses or impact assessments that propagate to all aspects of the project? The value of MBSE seems to be greater in the presence of unclear or evolving needs, proportional to the SE's mastery of MBSE tools. Moreover, MBSE is great for defining and illuminating unclear or evolving needs by the visual application of SE modeling constructs such as Use Cases, and Functional Decompositions.
  - The assumption is the SE is in the best position to assess if the project's needs, goals and objectives are well-defined or not, and to what degree.
  - **Scoring:**
    - Stable - 1
    - Evolving - 2
    - Unclear - 3

Quantitative Factors (3 of 6)
#3 System Interdependency

- **Factor #3: Is there interaction with external systems (i.e., a SoS)?**
  - More interdependent systems usually have higher complexities and thus, greater risk of emergence playing a role during development. MBSE provides value by maintaining the integrity of the system interactions (internal and external). Moreover, when used correctly, MBSE can be used as an SoS modeler and assess system robustness.
  - The assumption is the SE knows this level of system interdependency given their knowledge of the system architecture and interfaces. Their past project experiences inform their understanding of the interface complexity.
  - **Scoring:**
    - Minor or No Interdependency - 1
    - Moderate System Interdependencies - 2
    - Highly Interdependent - 3

Quantitative Factors (4 of 6)

#4 Lifecycle Stage

- **Factor #4: In what lifecycle stage is the project currently?**
  - We postulate that the closer a system is to retirement, the lower the value of initiating an MBSE approach. However, MBSE can and does add value beyond project inception and development; e.g., by providing a tool to assess gaps in the system architecture such as unintended behaviors or unfulfilled needs.
  - The assertion here is that the SE can make a definitive determination on where this project currently resides in its lifecycle.
  - **Scoring:**
    - Retirement - 1
    - Production/Operations- 2
    - Conceptual/Development- 3

Quantitative Factors (5 of 6)

#5 Team Skill

- **Factor #5: What are the skill levels/backgrounds of the team members in SE and MBSE tools?**
  - This is a measure of the speed to implement as opposed to a value proposition. It is a relevant factor to consider when weighing the urgency of the project vs. the risk of MBSE slowing down the project.
  - The assumption is the SE knows the relative skill levels within the SE team and any intersecting teams to which products/artifacts of the SE process would flow. The SE can compare this project team's skill levels to other projects in which they are involved.
  - **Scoring:**
    - Low - 1
    - Medium- 2
    - High - 3

Quantitative Factors (6 of 6)

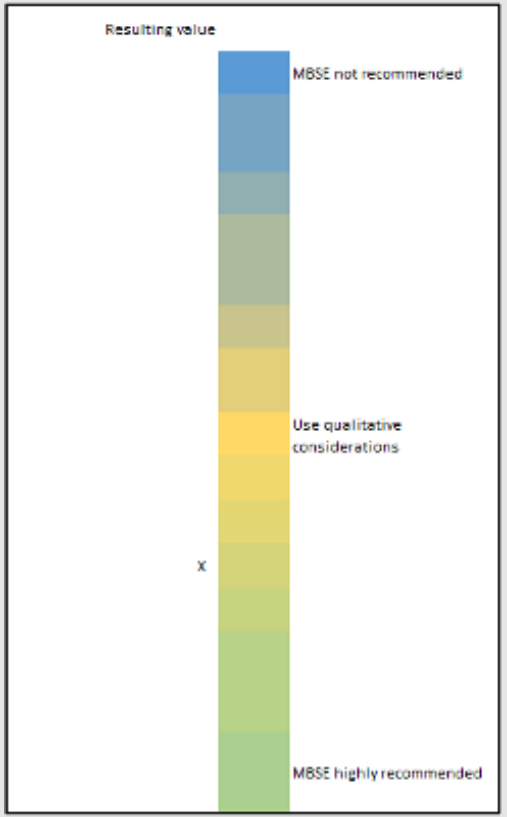
#6 Stakeholder Investment

- **Factor #6: How invested are stakeholders in the systems engineering process?**
  - The greater stakeholders' understanding is of the value of Systems Engineering itself, the more likely an MBSE approach will enhance the project. Stakeholders that understand the big picture can gain the most value from MBSE and in turn, have a rapid turn-around for SE work during the definition phases of a project (left side "V").
  - Where stakeholders do not see much value in SE or do not understand its role, it will be likewise more difficult to employ **any** SE method or approach they will buy into. There is high risk it will be seen as superfluous and of low value (i.e. costly and time-consuming).
  - The assumption is the SE has the best feel for this level of investment in systems engineering by the stakeholders.
  - **Scoring:**
    - Low - 1
    - Medium- 2
    - High - 3

Scoring

- Scoring involves totaling up the assigned values for each of the six factors – it is intentionally simplistic to lay bare any bias that could creep in to tweak scores to 'get the answer you want'.

- The scale intentionally avoids the red/green color scale which typically connotes 'green=good, red=bad'. MBSE is a tool that is neither inherently good or bad for a particular project.



Scoring

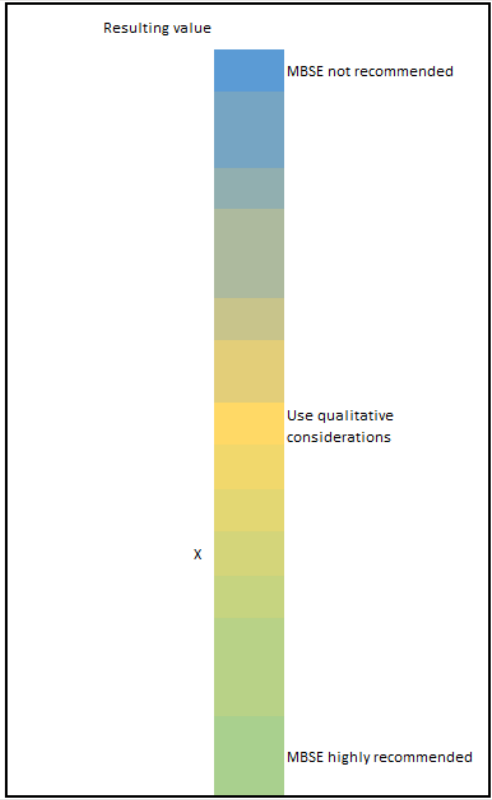
- **After initial scoring, the quantitative answer may indicate a “yes” or “no”, or something in-between**.
- **If “In-Between”**, we then consider qualitative questions to support or contradict the initial finding:
  1. Are there specific outcomes - technical, organizational, other - that MBSE is expected to improve?
     - Examples: Traceability, team communications, V&V, or SE staff retention.
  2. Are there long-term benefits anticipated from using MBSE on this project?
     - Examples might be reusability. risk mitigation, safety, or upgradeability.
  3. Some projects may be one-offs, niche or scrappy where SE principles may be dubious. MBSE can add value when it's part of a positive feedback loop on which new systems or new projects benefit from a model-based approach in addition to having other SEs benefiting from the proficiency of the broader SE team with MBSE.
     - Does the above description fit this project?
  4. The closer products are to flight hardware, the more prominent the need for traceability, standard compliance, and product change resiliency. In this case, a model-based approach provides a very strong framework for transparency when answering the "what's", "whys", and "how's" of a project.
     - Does this project fit this profile?

Scoring Example

< Project Name >

					Input Value
1	**What is the size and scope of the project?** (Small/Medium/Large) On smaller projects, the complexity added by MBSE oftentimes surpasses the complexity of the project itself (think of a Rube-Goldberg machine) and thus the value-add of MBSE must be carefully assessed. On the other hand, large projects may have too many "moving parts" such that keeping everything organized is challenging and modeling adds more value.	1- Small	2- Medium	3- Large	2
2	**Does the project have well-defined needs?** (Stable/Evolving/Unclear) What is the value or need of tracking changes in the model to generate impact assessments that propagate to all aspects of the project? The value of MBSE is greater in the presence of unclear or evolving needs, proportional to the SE's mastery of MBSE tools. Moreover, MBSE is great for defining unclear/evolving needs by the visual and coupled application of SE tools such as Use Cases, and Functional Decompositions.	1- Stable	2- Evolving	3- Unclear	2
3	**Is there interaction with external systems (i.e., SoS)?** (Minor/Moderate/Interdependent) More intertwined and interdependent systems have higher complexities and thus, greater risk of "emergence" playing a role during development. MBSE provides value by maintaining the integrity of the system interactions (internal or external). Moreover, when used correctly, MBSE can be used as an SoS modeler and assess system robustness.	1- Minor	2- Moderate	3- Interdependent	3
4	**At what lifecycle stage is the project currently in** (Retirement/Prod_Ops/Concept_Dev)? The closer a system is to closure, the lower the value-add of MBSE. However, MBSE does add value at that point by providing a tool to assess gaps in the system's architecture such as "unintended behaviors" or unfulfilled needs.	1- Retirement	2- Production/Ops	3- Concept/Dev	3
5	**What are the skill levels/backgrounds of the team members in SE and MBSE tools?** (Low/Medium/High) This is a measure of speed to implement as opposed to value proposition. It's a nuance to consider when weighing the urgency of the project vs. the risk of MBSE slowing down the project.	1- Low	2- Medium	3- High	2
6	**How invested are stakeholders in the systems engineering process?** (Low/Medium/High) The greater stakeholders' understanding of the value of Systems Engineering as a whole, the more likely an MBSE approach will enhance the development of a project. Stakeholders that understand the "big picture" will gain the most value from MBSE deliverables and in turn, have a rapid turn-around from get-to-done for SE work during the definition phases of a project (left side of the "V").	1- Low	2- Medium	3- High	3

Total Value: 15



Future Questions and Considerations:

A future step would be to collect the quantitative and qualitative data from initial Q&A surveys, plus follow-on surveys after project completion

- Build a database of metrics that can be used to then inform and improve the Q&A workbook and scoring.

The next obvious step is how to set MBSE up in the most efficient and effective/complementary way for my kinds of projects?

- We omitted this exploration in this presentation. We have been working on this to establish a tailored framework for MBSE given our specific domain and types of projects. We have observed a design pattern emerge over a few pathfinding projects that have informed our definition and rule set. For larger cross-business unit projects, there is an enterprise level MBSE team, with a well-defined framework + common libraries + on-going consulting support project teams can leverage. We observed there is future work for us in alignment and leveraging artifacts and knowledge in both directions.

The desire is for this scoring worksheet to be a stand-alone tool.

- We leverage our internal team to help ourselves and other business units make the initial assessment and to provide MBSE consulting. We help with scoring and analysis, as well as the follow-on thought processes on the what's and how's to stand up the MBSE effort. We also help with understanding the available MBSE resources within the larger enterprise, their pros and cons, versus our business unit and its specific aims for MBSE. All of the above may make the most sense in the long run for consistency in analysis and interpretation of outcomes.

Conclusions

- **What did we learn?**
  - We went into this with a principle that MBSE is not a hammer looking for a nail to use on every project. **Look at it from good engineering first, then find the best path and approach to fit the specific situation**.
  - Even with many thoughtful discussions and iterations to develop a concise set of factors to help lead to quantitative results, **we confirmed out initial intuition as true that getting to a definitive yes or no answer is more of an outlier case**, and we must use accompanying qualitative factors to support or refute the initial answer.
  - Our conclusions echo what we found in other studies on MBSE's premise of value to projects and organizations.
  - **The Q&A tool is practically useful**. It makes you think deeply about your SE strategy going into a specific project:
    - **What kind of analyses do I need out of the data for this project?** The answers to this question is probably going to lead you in a clear direction.
    - We found cases in which the Q&A tool result says not to use MBSE, but you do some or all aspects of MBSE anyway only for yourself; i.e. it makes you more efficient and effective as a SE on this project.
    - If the Q&A answer is a yes, then there is more work to begin on what and how to set up the MBSE approach in a thoughtful, efficient and effective way **for each project**.

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