Model-Based Systems Engineering Adoption Trends 2009-2018

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The MBSE Initiative was kicked off at the INCOSE International Workshop (IW) in 2007 at the Albuquerque, NM, USA Embassy Suites. There were approximately 45 INCOSE members for this first meeting, held during the two days preceding IW.

Surveys were conducted in 2009, 2012, 2014, 2018, and 2019 to better understand the adoption trends of model-based systems engineering.

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Introduction

Model-based systems engineering (MBSE) is not a new concept. Wymore (1993) published the seminal work on the topic. This book presents the mathematical theory behind MBSE. Since that time, engineering has made significant movement from text-based approaches using office-based tools (e.g. Harvard Graphics, Microsoft PowerPoint, Microsoft Visio, etc.) to an interconnected set of graphical diagrams. These diagrams are generally created in a tool with a specialized graphical user interface.

Today aerospace engineers no longer use drafting boards to create their drawings – they use computer aided design (CAD) tools. Likewise, software engineers seldom use EMACS or Vi (text editors), instead, they use software GUIs that allow them to code, check syntax, compile, link, and run their software all in a single environment.

Broadly speaking, a model_ can be thought of as a facsimile or abstraction of reality. To this end, even a requirements document can be considered a model – it represents what a real system should do in performing its mission or role. While systems engineering has used models for a very long time, MBSE is the systems engineering migration to computer-based graphical user interfaces to perform our analysis and design tasks just as our other engineering brethren have moved to computer-based graphical user interfaces.

A discussion of available tools is beyond the scope of this article, and it is not the practice of the SEBoK to review or promote specific tool offerings. However, it is fair to state that current MBSE tools fall into three broad categories: 1) Functional decomposition tools that use IDEF0 (also called IPO) diagrams, N2 diagrams, functional flow block diagrams, etc., 2) Object-oriented tools that implement the Object Management Group's Systems Modeling Language (SysML), and 3) Mathematical modeling tools.

This migration for systems engineering might have begun in the late 90's. The INCOSE INSIGHT publication proclaimed that MBSE was a new paradigm (INSIGHT 1998). Cloutier (2004) addressed the migration from a waterfall systems engineering approach to an object-oriented approach on the Navy Open Architecture project. At that time, SysML did not exist, and the teams were using the Unified Modeling Language (UML) that was predominately a software modeling tool. Zdanis &

Cloutier (2007a, 2007b) addressed the use of activity diagrams instead of sequence diagrams for systems engineering based on the newly released SysML. In 2009, the INCOSE INSIGHT publication proclaimed MBSE was THE new paradigm (INSIGHT 2009).

Approach

In 2009, a survey was commissioned by the Object Management Group (OMG) with the intent of informing the SysML Working Group on necessary changes to SysML since its first release (Cloutier & Bone 2010). That survey focused on process more than adoption. Beginning in 2012, INCOSE has commissioned three more surveys to understand adoption trends and obstacles. The survey instrument remained relatively unchanged for 2012, 2014, and 2018 (Cloutier 2015, Cloutier 2019a). In January of 2019, the Jet Propulsion Lab (JPL) conducted an MBSE Workshop (Cloutier 2019b). A survey of those participants was conducted, and the intent of the questions was to augment knowledge gained from the 2018 survey. The table below shows the number of respondents in each of the surveys.

Table 1. MBSE Survey Purposes and Responses (SEBoK Original)

| Year	Survey Purpose	Responses
2012	INCOSE MBSE Initiative	134
2014	INCOSE MBSE Initiative	205
2018	INCOSE MBSE Initiative	661
2019	JPL MBSE Workshop	98

Responses and Response Demographics

Each survey was sent to a diverse group of MBSE practitioners. Table 2 shows that of the 661 responses for the 2018 survey, 410 indicated their country of origin. This international representation is similar to all surveys conducted.

Table 1. MBSE Survey Purposes and Responses (Cloutier 2019, used with permission)

Country	Responses	Country	Responses
USA	197	Israel	4
United Kingdom	52	Singapore	3
France	30	China	2
Germany	28	New Zealand	2

Australia	20	Poland	2
Netherlands	19	Russia	1
Japan	8	Romania	1
Canada	6	Turkey	1
Italy	6	Columbia	1
Sweden	6	Norway	1
South Africa	5	South Korea	1
Switzerland	4	UAE	1
Brazil	4	Belarus	1
India	4		

As part of the demographics, Figure 1 shows the represented industries. Because the "Other" category was so large, the data was analyzed to better understand Figure 2.
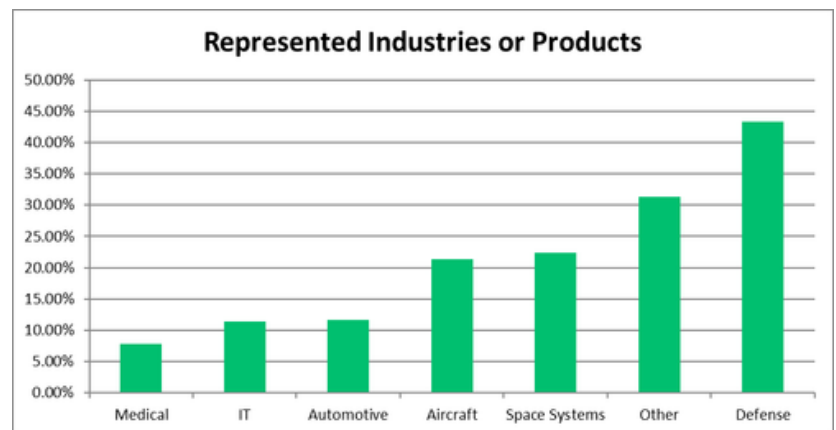

Figure 1. Industries Represented in the 2018 MBSE Survey.
(Cloutier 2019a, used with permission)
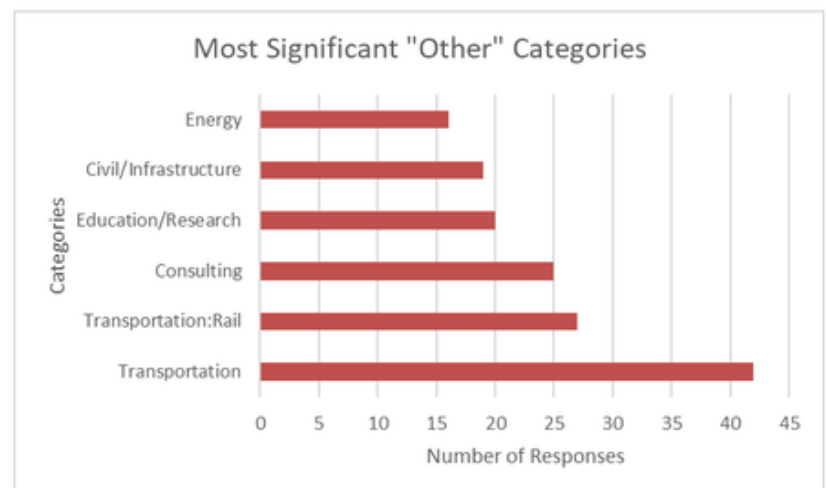
Figure 2. "Other" Industries Represented in the 2018 MBSE Survey. (Cloutier 2019a, used with permission)

The 2018 survey indicated that there seems to be an increased application of MBSE in traditionally civil engineering industries – specifically energy, infrastructure, and transportation (Figure 2) One of the most interesting aspects of the 2018 survey is the

finding that MBSE is being applied in the early phases of systems engineering, and less so in the later phases as shown in Figure 3.
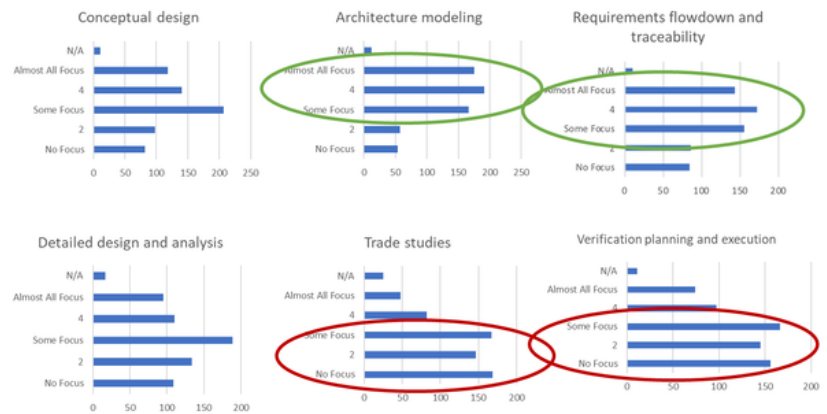

Figure 3. MBSE is More Likely to be Used in Early Stages of Systems Engineering. (Cloutier 2019a, used with permission)

This was confirmed by the JPL question "Where do we believe MBSE holds the most promise?" Figure 4 shows that 76% of the responses indicated system/subsystem architecting, 42% thought requirements analysis, and 39% believed early conceptualization (note: the question allowed for multiple answers).
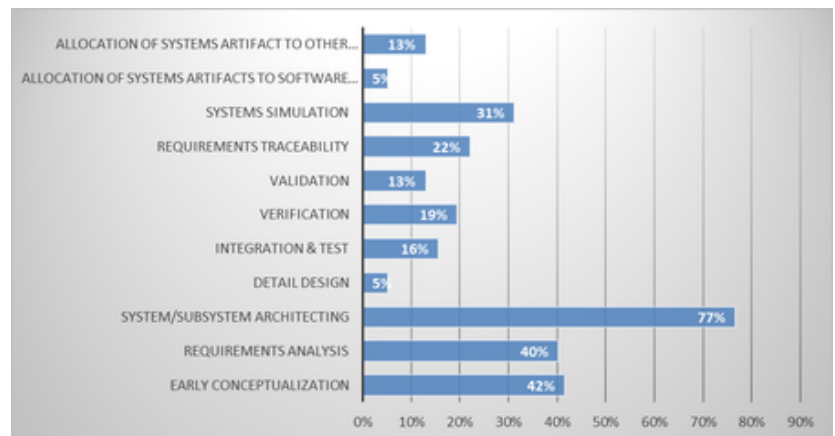
Figure 4. JPL Workshop Response Regarding "Where MBSE Holds the Most Promise." (Cloutier 2019b, used with permission)
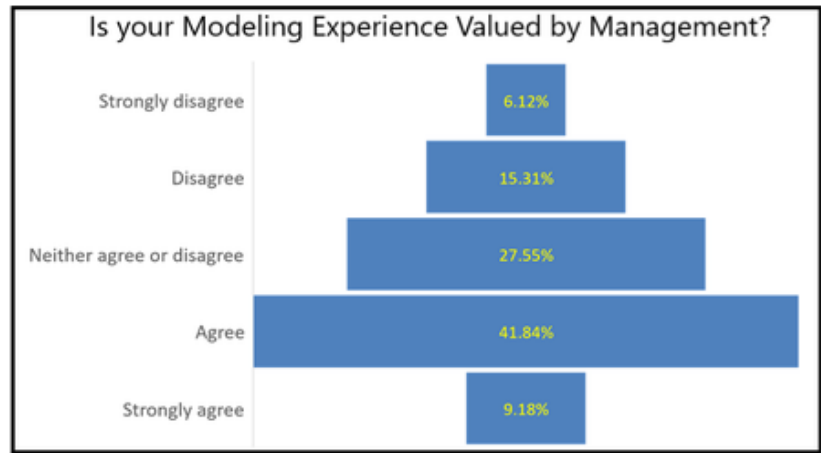
Figure 5. JPL Workshop Response Regarding "Is Your Modeling Experience Valued by Management?"(Cloutier 2019b, used with permission)

When asked whether the JPL survey respondents believed that their systems modeling experience is recognized as a valued skill supporting career growth of systems engineers in their organization, just over 50% believed management valued their experience. A smaller number, 21%, believed their modeling experience was not valued (Figure 5).

Key Adoption Trends

The remainder of this article will look at some of the trends identified across the surveys, from 2009 to 2018. Figure 6 shows that MBSE is moving from a defense and space dominated practice into other industries as discussed in Figure 4.
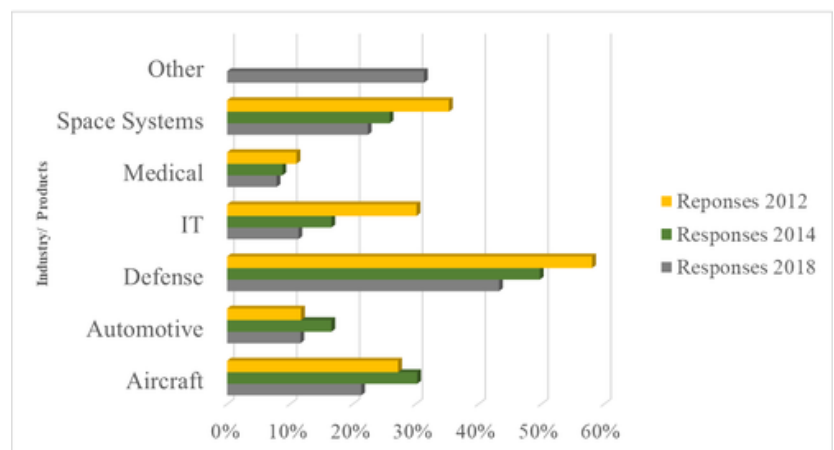

Figure 6. Shift of MBSE Adoption in New Industries. (Cloutier 2019a, used with permission)

Model-based systems engineering seems to be expanding in influence in that it is not just in the purview of systems engineers. While systems and software engineers find value in MBSE practices, Figure

6 demonstrates that the customer is finding value in MBSE practices. It is also interesting that software engineers' perceived value of MBSE is declining from survey to survey.
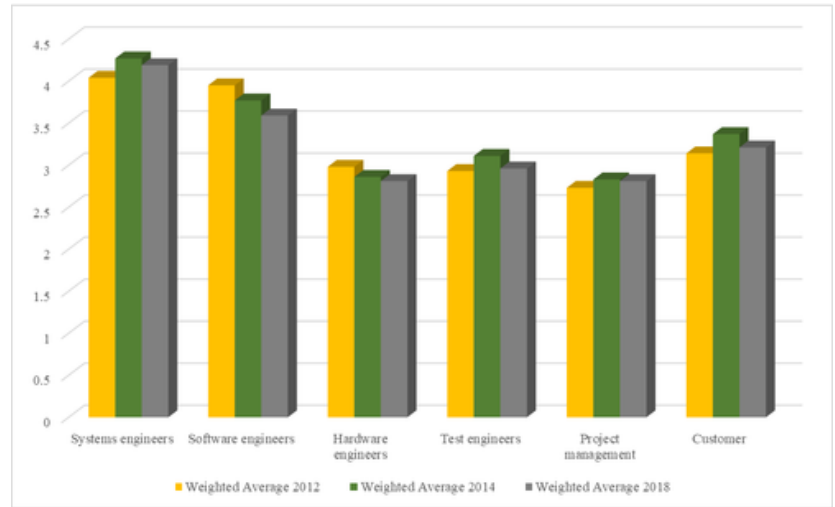
Figure 7. Perceived Value of MBSE Practices to Different Project Segments. (Cloutier 2019a, used with permission)
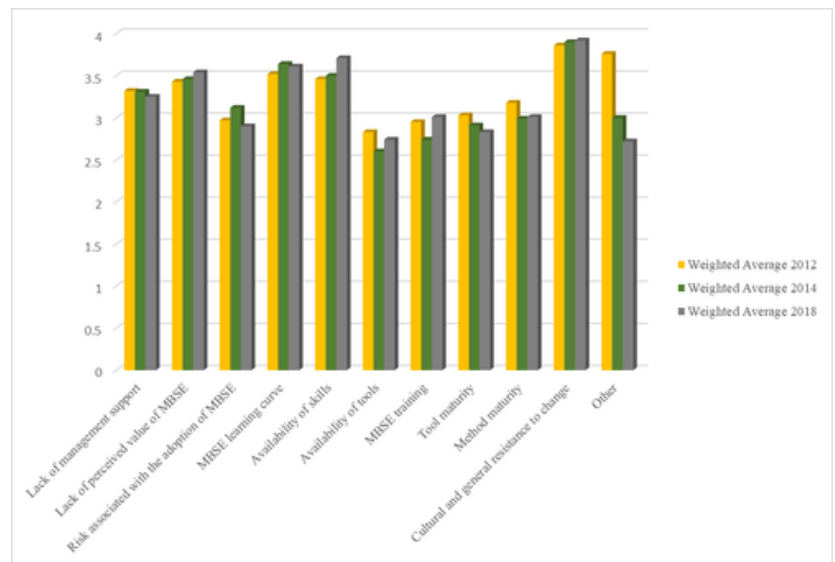
Figure 8. Inhibitors to the Successful Adoption of MBSE within an Organization/Company. (Cloutier 2019a, used with permission)

Figure 8 demonstrates that availability of MBSE skills and cultural and general resistance to change have continued to increase. Lack of perceived value reflects the findings in Figure 6 – software and hardware engineers are not seeing the value of MBSE.

Conclusions

Surveys conducted between 2012 and 2018 demonstrate that MBSE practices are spreading beyond traditional Defense and Space domains. Most MBSE practitioners are finding MBSE is most useful in the early project

phases of conceptualization, requirements analysis, and systems architecting. There continues to be a skills shortage, yet companies/organizations are providing less training to improve MBSE skills. Both systems engineers, systems engineering management, and the systems engineering customer are finding value in using models to perform systems engineering.

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