MBSE Applicability Analysis

Bita Motamedian

Abstract— "Model Based Software/Systems Engineering - MBSE" is growing rapidly in the systems engineering (SE) domain for large complex projects to minimize risks and avoid late stage changes (in Renewable energy, Solar & Space power, Aviation, Defense, and Ship industries) as digital product models help companies and manufacturers to integrate engineering processes across production networks. Although model based development is well established in specific engineering fields like software, electronics, and mechanics, its role in SE to improve manufacturing productivity by enabling efficient integration engineering and manufacturing applications is still evolving. I was seeking voluntary information from industries that have applied Systems Engineering Techniques in their projects. My purpose for doing this survey is to highlight the position of MBSE in our real projects in addition to clarifying roughly the popularity rate of MBSE concept among engineers especially system engineers, and the usage besides the advantages, barriers and concerns of using "modeling languages" and "modeling tools" in MBSE efforts among various industries.

Index Terms— MBSE, Model Based Software Engineering, Model Based System Engineering, Model Based Development, Modeling Language, Modeling Tool

———————————————— ◆ ————————————————

1 INTRODUCTION

THE purpose of this survey is a review of the usage of Model-Based Software/System Engineering in various industries among different types of engineering-groups and the related obstacles and concerns in using MBSE. It should be mentioned that I have done this survey for the sake of introducing MBSE to those engineers who are not familiar with this concept. A further objective is an update, for those who are using it, about the current status and popularity of using modeling methods in various industries.

A study by the "Aberdeen Group" demonstrates significant time and cost savings in using model-based techniques in comparison with conventional engineering practices.[1]

While the literature on model based development and modeling techniques is extensive in its technical and structural sections, much work remains to be done on revealing the MBSE benefits and the difficulties of adopting MBSE as a mandatory fundamental phase of production lanes, which can smooth the use of it in the near future.

This study might be found interesting and might contain useful information about the applicability of MBSE, but it has a number of limitations. As a case in point, my survey was conducted in just some specific regions and focused on specific job positions. Although, I already have covered a relatively broad range of countries, further researches on other job positions should be done to

verify the result(s) of this study on a broader scale.

2 SURVEY METHODOLOGY

I distributed my online questionnaire[2], which includes 11 questions [see Appendix A] among different groups of engineers via the following social networks: LinkedIn, Xing, IBM Rhapsody Forum, SysML forum and Facebook.

The survey was a set of questions administered through a *Google Docs Form*, consisting of multiple-choices, checkboxes and grid questions.
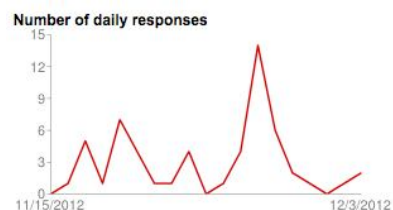
This survey was performed over a period of 17 days from 15th November to 3rd December 2012. In all, 55 people responded anonymously to the survey. The 55 responses came from various industries and from the following regions: Europe, North America, Middle East-Non Arab Countries, Africa, Asia, and Oceania Countries. I did not receive any response from South America, Caribbean Countries, and Middle East-Arab Countries.

Roughly 60% of the responses were from European countries that show the usage of MBSE is rapidly growing in Europe Continent.

———————————————

• **Bita Motamedian** *is a Software engineer and working as an IT consultant in Aerospace industry. Her focus is on new technologies especially in IT industry.*

E-mail: bita.motamedian@gmail.com
Twitter: BitaMotamedian

[1] "The Transition from 2D Drafting to 3D Modeling Benchmark Report – Improving Engineering Efficiency", Aberdeen Group, September 2006.

[2] I prepared this questionnaire based on my studies of some "MBSE" articles, which I have mentioned in the References part.

3 SURVEY RESULTS

In this part I summarize my study and analysis on the received responses.
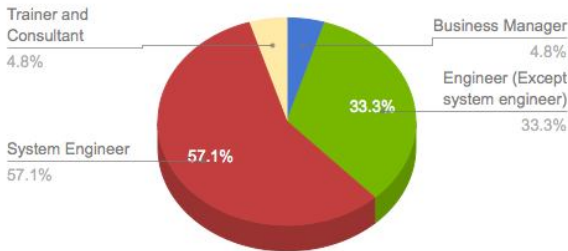
3.1 Respondents

In order to segment the respondents' answers and to understand what type of engineers and which positions are the most common users of MBSE, two questions of my questionnaire were about the respondents' job position and the industry in which they were working. The sample is heavily biased towards my social networks.

Amazingly only 38% of respondents (21 out of 55) are using MBSE in their current position.
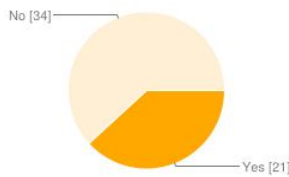
Among the users of MBSE, 57.1% were System Engineers and 33.3% were in the other fields of engineering.

Job Position of MBSE Users

Moreover, among the respondents' job positions there were many management positions, around 31% who had not heard about MBSE. This shows that we should do more feasible studies to highlight the advantageous of MBSE among managers who have the power of controlling projects.

3.2 Active Industries

Based on the received responses, "Aircraft industry" is standing in the first position of the MBSE user's list, "Defense industry" is in the second position and "Banking/Payment and IT industries" are in the third position of using MBSE in their projects.

I should add here that according to my researches, "Automotive and Shipping industries" have high potentials to use MBSE techniques in their processes, although I did not receive any response from Shipping industry.

Active Industries in MBSE Usage
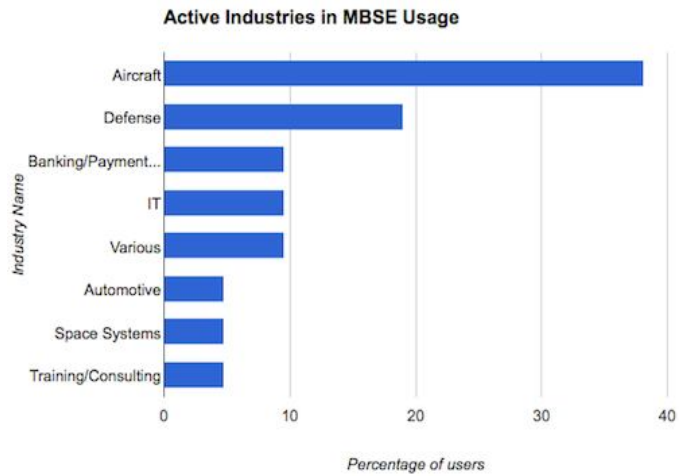
3.3 Know-how Level of MBSE Users

To be able to analyze the degree of know-how among the MBSE users, I defined 4 different levels of technical knowledge attached to the MBSE practical experiences as below:

- Basic → Just started
- Intermediate → Between 1 and 2 years of experiences
- Advance → Between 2 and 5 years of experiences
- Expert → More than 5 years of experiences

As you can see in the following pie chart, almost 43% of MBSE users who participated in my survey have more than 5 years of practical experiences in their jobs. Amazingly, all respondents from "Defense industry" were in the expert category of users. It illustrates that MBSE is being seriously used in "Defense systems" by experts. "Aircraft industry" seems to be more dynamic in this regard by having all levels of MBSE users from beginners to experts. It can be concluded that Aircraft industry is trying to benefit from MBSE experts while giving the chance to newbies of MBSE.

MBSE Know-how Level
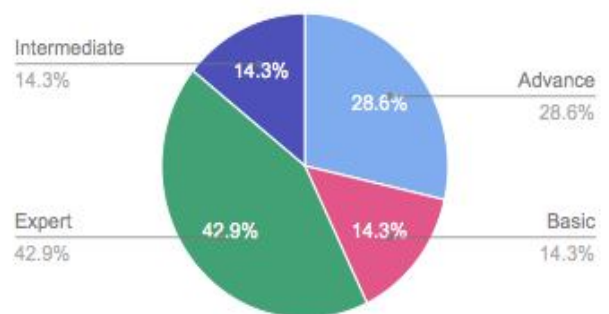
3.4 The extent of MBSE usage

To measure the popularity of using MBSE in practice, I differentiated the answer options of my questionnaire in 4 categories:

- Awareness by training courses, workshops, seminars
- Applying MBSE on Pilot projects
- Applying MBSE on R&D projects
- Adopting MBSE in real programs/projects

Based on the received responses, "Defense and Aircraft industries" seem actively using MBSE in practice in their real projects more than the other industries; but "Aircraft industry" is not as active as "Defense industry" in increasing the know-how of MBSE by training, R&D and pilot projects.

From my working experience in Aerospace and my researches I can add here that the next generation Requirements Engineering projects try to improve the requirements engineering process in connection with MBSE.

Amazingly the "Banking/Payment industry" seems to be very active in awareness part of MBSE activity due to the fact that online global financial transactions are becoming more and more complex by considering the variety range of regulations and rules in different countries and estates which needs deeper analysis both in software (security data transactions) and in hardware (payment devices, embedded card readers).

I summarized the responses based on the highest and the lowest MBSE focus among active industries in using MBSE in table below:
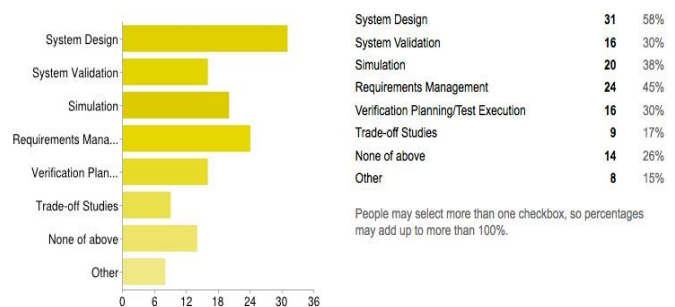
The Extent of MBSE Usage		
	Highest	**Lowest**
Awareness	Defense, Banking/Payment Industries More than 81%	Aircraft Industry Around 10%
Pilot projects	Defense Industry More than 81%	Aircraft Industry Around 10%
R&D projects	Various Industries 51% - 80%	Aircraft Industry Around 10%
Real programs/projects	Defense & Aircraft Industries 51% - 80%	Automotive Around 10%

3.5 The Organizations' Focus on MBSE

To be able to investigate which part of MBSE is more favorable in practice, I asked this question "On which part of the MBSE does your organization focus?" and I gave the possibility of multiple choices to the respondents. The result states that 56% of users are applying the MBSE on "System Design". "Requirement Management" and "Simulation" have the second and third position in practice respectively.

This result illustrates that most of the organizations or companies that are using MBSE have focused on the "System Designing" features of MBSE more than on other aspects; hence, it can be highlighted that the use of MBSE implies valuable benefit in the beginning phase of production lanes, as it creates the ideal product development architecture to design, calibrate and test the different parts of a system both individually and in relation with other elements in a simulation environment.

System Design	31	58%
System Validation	16	30%
Simulation	20	38%
Requirements Management	24	45%
Verification Planning/Test Execution	16	30%
Trade-off Studies	9	17%
None of above	14	26%
Other	8	15%

People may select more than one checkbox, so percentages may add up to more than 100%.

3.6 Modeling Language & Modeling Tool

To clarify the most popular and the most favorite modeling languages and modeling tools, I asked a question with the possibility of multiple choices answer; here is my analysis on the received responses:

"Rhapsody" and "SysML" both were selected as the most usable modeling tools and modeling languages with 15% selected "always" option and "UML" and "MATLAB" with the 15% and 13% respectively were selected as the languages and tools that are being used "often".

I should mention that based on the received responses, "Rhapsody" and "SysML" seem to be the experts' first choices in practical use of MBSE. It might be concluded that these two tools are growing rapidly in MBSE life cycle of real projects. On the other hand UML as the base of modeling languages can still be the first step of starting model-based engineering.

I would like to point out here that distribution of my questionnaire in Rhapsody and SysML forums could be suspected as a biased way of collecting data for this survey, however, according to my experience, these two tools are widely applied in practice, why such biasing effect can be regarded as rather limited in the overall picture. Further, the possible biasing seems justified when comparing with the current survey's benefit of finding more experts in real projects, disclosing the advantageous of MBSE. All in all, however, these arguments are not disguise the fact that, for a more complete picture, more reliable results should be obtained in similar future researches including other tools'/languages'/techniques' forums.

3.7 MBSE related training

To recognize how many efforts are being done officially by the organizations and companies to improve the theoretical part of MBSE among their technical teams via offering related trainings and workshops, I asked a question and the responses depict that incredibly 62% of MBSE active users never received any official training from their organization and only 2% received a complete technical course that financially was covered by their companies.
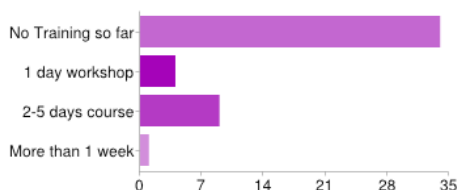
In more details, around 43% of respondents among the MBSE users never had any training in "Modeling Languages", and around 43% of respondents among the MBSE users had 2-5 days courses in modeling languages.

52% of respondents among the MBSE users never received any training in "MBSE Method", and only 29% of respondents among the MBSE users had 2-5 days courses in the "MBSE Method".

43% of respondent among the MBSE users had 2-5 days courses in "MBSE Tools"; but 38% of respondents among the MBSE users never had any training in "MBSE Tools".

This finding can be a reason that MBSE is not highly popular in general, despite being able to provide benefits to all manufacturing production lanes and to almost all industries. It can be considered as an investment on know-how in organizations, companies and manufactures by managers who are seeking for a better solution to minimize the risk and costs and maximize the reliable outputs, besides keeping the technical experts motivated by supporting them to improve their skills in their professional path.

3.8 The Value of Modeling Effort

To give the MBSE experts and users the opportunity to share their opinions about the value of modeling efforts based on their experiences in practice and real projects, I asked for the field(s) in which they believe that MBSE can be highly beneficial.

The answers show that "System Engineering" with 89% is the first field that obviously can benefit using MBSE. "Software Engineering" and "Hardware Engineering" with 85% and 74%, respectively reached the second and third positions. This result clarifies the importance of not only familiarity with MBSE by system and software engineers but also the ability of using its techniques in real, complex projects. It should be noted that the knowledge improvement of technical teams in the men-

tioned fields needs strong support of managements.
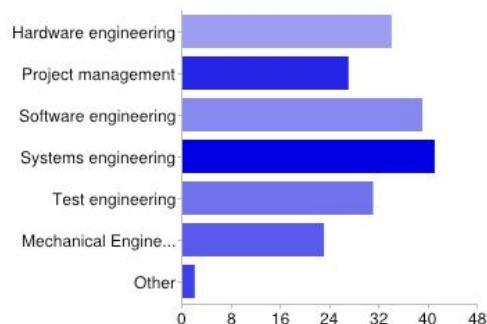
3.9 The Barriers in using MBSE

The most important technical barrier in using MBSE is the "lack of related knowledge and skills" in practice and not easy access to the experts. This reason is around 57% of the received responses to my question about the MBSE preventions. The second reason with 48% of the received answers is the "lack of perceived value of MBSE" and also the same 48% rate for "resistance to change".

It shows that each of us should be more active to make this valuable concept more transparent. We can introduce the benefits of MBSE not only by presentations but also by introducing the successful projects that used MBSE in their lifecycle. Universities and the Modeling forums can play vital roles in this regard.

The most managerial barrier in using MBSE -*in case the management teams support the efforts of modeling*- is the "inability to sufficiently merge and integrate multiple engineering applications involved in the design, production, and inspection of products across the production network". In the contrast case, the "lack of managerial support" in my survey received 43% as one of the main prevention of using MBSE.

In this regard, we might need to consider some impressive presentations with successful outputs of real projects to the top managers of organizations, companies and manufacturers to highlight the benefits of using MBSE in reducing the risks of failure, especially, in production processes by using the simulation feature of MBSE.

4 CONCLUSION

Model-Based Engineering applies modeling methods and simulation technologies to integrate and manage not only the requirements but also all processes and functions related to the product design, development, test and production. The aim of Model-Based Engineering (MBE) is minimizing risks and avoiding late stage changes, and, therefore, the related costs, which might be very critical to

managers while planning the project budget.

MBSE helps engineers and managers in more precisely controlling and better handling a project in early design phases by using simulation features, which can bring out the virtual result of the design before a costly production phase starts. In this case, any amendment and correction or even change in design, can be done much easier and at lower cost than after start of the production lane. Moreover, in some industries, like Space and Aircraft, testing the final produced version is impossible without using the simulation capabilities. Even testing some parts of these huge systems in practice is impossible due to various reasons. MBSE is the only solution in this regard.

In conclusion, a model is an ideal representation of various characteristics of a real-world system, such as, its structure, requirements' relation, behavior, function, and operation. It simulates functionality or behavior and can merge design and development information in a virtual world with cheaper budget. It should be noted that for having a high quality and reliable model-based approach, additional detailed data is vital for downstream analysis, design & development, manufacturing and control/monitoring processes. For example in manufacturing context, a product model is a container not only of the nominal CAD[3] geometry, but also process specifications, GD&T[4], material specifications, and many more.

At the end, the analysis I have done can be useful for MBSE providers, marketers and analysts to understand the position of MBE, and for technical managers to understand that their industries' need to benefited by the advantageous of MBSE, and for manufacturers to figure out the risk minimization and cost savings by using MBSE in their design and production lanes.

The small sample of my survey implies that the highly segmented data should not be relied on without further verification and a more controlled selection process. However, it yields a first valid indication for trends in the field and gives a guideline for how to conduct further research in this field, aiming towards an adoption of on-demand MBSE technologies.

Based on my analysis, in order to be able to use MBSE seriously, it is vital to invest more on identifying MBSE concept and its benefits by training and workshops. Advertising about this technology is crucial in order to reduce doubts and ambiguities about it and increase both the usage and support of it.

5 END SECTIONS

5.1 Appendix: "MBSE Applicability Analysis" Questionnaire

1. In which industry are you working? If your industry is not in the list, please enter it in the "Other" field.

[3] Computer-Aided Design
[4] Geometric Dimensions and Tolerances

○ Aircraft
○ Automotive
○ Banking / Payment Solutions
○ Defense
○ IT
○ Marine / Shipping
○ Medical
○ Renewable Energy (Solar, Wind, etc.)
○ Space Systems
○ Telecommunication
○ Other:

2. Are you using MBSE?
○ Yes
○ No

3. What is your job position? If your job position is not in the list, please enter it in the "Other" field.
○ Business Manager
○ Engineer (Except system engineer)
○ Executive Manager
○ Project Manager
○ System Engineer
○ Other:

4. In which country you are working now?
○ Europe - Schengen Countries
○ Europe - Non Schengen Countries
○ North America
○ South America
○ Middle East - Arab countries
○ Middle East - Non Arab countries
○ Africa
○ Asia
○ Oceania Countries (Austrailia, New Zealand, ...)
○ Caribbean Countries (Bermuda, Haiti, ...)

5. How knowledgeable are you in MBSE?
○ I have no idea about MBSE.
○ Basic (Just started)
○ Intermediate (between 1 and 2 years of experiences)
○ Advance (between 2 and 5 years of experiences)
○ Expert (More than 5 years of experiences)

6. To what extent has your company/organization done the following activities?

	0%	Around 10%	11% - 50%	51% - 80%	More than 81%
Applying MBSE on Pilot projects	○	○	○	○	○
Applying MBSE on R&D projects	○	○	○	○	○
Adopting MBSE on programs/projects	○	○	○	○	○
Increasing MBSE awareness (e.g. by	○	○	○	○	○

	0 %	Arou nd 10%	1 1% - 50%	5 1% - 80%	M ore than 81%

training)

7. On which part of the MBSE does your organization focus? (Multiple choices are acceptable) If your focus of using MBSE is not listed below, please enter it in the "Other" field.

- ☐ System Design
- ☐ System Validation
- ☐ Simulation
- ☐ Requirements Management
- ☐ Verification Planning/Test Execution
- ☐ Trade-off Studies
- ☐ None of above
- ☐ Other:

8. To what extent are you using the following "modeling languages" and/or "modeling tools" in your MBSE effort? If you are not using MBSE at all, please choose the last row(None of Above) and first column(Never)

	Ne ver	Some- times	Of- ten	Al- ways
AADL	○	○	○	○
Enter- prise Archi- tect	○	○	○	○
FFBD	○	○	○	○
IDEF0	○	○	○	○
MATLAB	○	○	○	○
OPM	○	○	○	○
Rhapsody	○	○	○	○
Simulink	○	○	○	○
Statemate	○	○	○	○
SysML	○	○	○	○
UPDM	○	○	○	○
UML	○	○	○	○
Visio	○	○	○	○
XWiki Eclipse	○	○	○	○
Other COTS mod-	○	○	○	○

	Ne ver	Some- times	Of- ten	Al- ways
eling tools				
Home grown mod- eling tools	○	○	○	○
None of Above	○	○	○	○

9. Is any of the following trainings offered by your company/organization officially to the team members involved in the modeling effort?

	No Training so far	1 day workshop	2-5 days course	M ore than 1 week
Modeling Language	○	○	○	○
MBSE Method	○	○	○	○
MBSE Tools	○	○	○	○

10. Do you believe that there is any value of the MODELING effort in the following fields? (Multiple choices are acceptable) Please add any other field that you think the modeling effort can be beneficial.

- ☐ Hardware engineering
- ☐ Project management
- ☐ Software engineering
- ☐ Systems engineering
- ☐ Test engineering
- ☐ Mechanical Engineering
- ☐ Other:

11. Which of the following issues are/were preventing your company/organization from using MBSE? (Multiple choices are acceptable) If you encounter other obstacles that are not in the list, please enter them in the "Other" field.

- ☐ Concerns about MBSE learning curve
- ☐ Lack of management support
- ☐ Lack of perceived value of MBSE
- ☐ Lack of related knowledge and skills
- ☐ Lack of related tools accessibility
- ☐ Resistance to change
- ☐ Risk associated with the adoption of MBSE
- ☐ Other:

5.2 References

5.2.1 Articles, Presentations, Thesis:

[1]   INCOSE, MBSE International Workshop PowerPoint docu-
      ments, Jacksonville-Florida, 21-24 January, 2012
      (http://www.incose.org/newsevents/events/details.aspx?id=
      140)

[2]   Jeff A. Estefan, "Survey of Model-Based Systems Engineering (MBSE)
      Methodologies",
      http://pdf.aminer.org/000/260/416/towards_a_unified_paradigm_fo
      r_verification_and_validation_of_systems.pdf,   INCOSE MBSE Initia-
      tive, May 23, 2008

[3]   Mary Bone, Dr. Robert Cloutier, "The Current State of Model Based
      Systems Engineering: Results from the OMG™ SysML Request for In-
      formation 2009", 8th conference of Systems Engineering Research
      (CSER), March 17-19 ,2010, Hoboken, NJ, Paper #1569270919

[4]   Silvia Mazzini & John Favaro (INTECS), Rudolf Schreiner &
      Ulrich Lang (ObjectSecurity Ltd.), Hans-Peter de Koning (Eu-
      ropean Space Agency), "Improving Requirements Engineering
      within the European Space Industry", 2011

[5]   Joe Wolfrom, "Model Based Systems Engineering (MBSE) using the
      Object Oriented Systems Engineering Methods (OOSEM)", The
      John   Hopkins   University-Applied   Physics   Laboratory
      (JHU/APL), 2011

[6]   Robert Karban, Tim Weilkiens, R. Hauber, R. Diekmann,
      "MBSE Practices in Telescope Modeling", with the collabora-
      tion of ESO org., OOSE de, Hood-Group, and Hamburg de,
      2010

[7]   Aberdeen Group, "The Transition From 2D Drafting to 3D
      Modeling Benchmark Report-Improving Engineering Efficien-
      cy", September 2006

[8]   Christopher L. Delp, "FireSat: Model vs Documents Alone",
      Space Systems Working Group-INCOSE MBSE Challenge
      Team, 2010

[9]   Joshua Lubell, "Systems Integration for Manufacturing Con-
      struction Applications" [2012 EL project MBE], Prepared on
      September 02, 2011

[10] C.E.Dickerson, "Model Driven Architecture for Model Based
      Systems Engineering", Published on September 28, 2007

[11] Özlem Demirci, "Development Of Mbse/Uml Maturity Mod-
      el", Tekniska Jönköping School of Engineering, Master Thesis
      2010

5.2.2 URLs:

[12] http://www.incose.org/

[13] http://mbse.gfse.de/

[14] http://www.omgwiki.org/MBSE/doku.php?id=mbse:method
      ology

[15] http://www.lmsintl.com

[16] http://www.omgsysml.org/