# INCOSE Model-Based Capabilities Matrix User's Guide version 5.2d

Joe Hale,

NASA/MSFC,

joe.hale@nasa.gov

Al Hoheb,

The Aerospace Corporation,

albert.c.hoheb@aero.org

# Table of Contents

SECTION PAGE

TABLES



FIGURES

***Forward***

This User's Guide for the INCOSE Model-Based Capabilities Matrix is the first MS Word based guide produced. When the concept for an INCOSE "Matrix" was spawned at the INCOSE International Workshop January 2018 the effort revolved around determining if a Matrix product would be useful and its scope. During a workshop to develop the matrix it was suggested that a User's Guide would be very helpful. Initial User's Guides were produced in PowerPoint so they could be briefed and refined. User's Guide versions 1 through 4 were in PowerPoint. Feedback on the PowerPoint User's Guides was positive in that the team was encouraged to continue its development and consider more use cases that allow tailoring and greater application.This version is the first MS Word version that has captured a great many of the user comments recorded during on-line INCOSE Challenge Team Meetings and also from real-time workshops. The authors are grateful for the interest and passion of the Matrix users, Challenge Team members, and workshop participants and welcome comments.

# 1 Overview

The INCOSE Model-Based Capabilities Matrix is intended to be a tool to help organizations that have already made the decision to implement digital engineering or Model-Based capabilities, assess, and then plan the development of these capabilities in a comprehensive and coherent manner. It is meant to be a tool for organizational transformation and development, providing a set of capabilities and organizational implementation stages that are used for the conversation, planning and resulting assessment of capabilities. This document uses the terms Digital Engineering (DE) and Model-Based system engineering (MBSE).

While the pedigree of the matrix is from the US government and commercial space organizations, the intent of the matrix is to be applicable to non-space related organizations both in the government and commercial sectors. The authors urge users to become familiar with the terms uses but to also tailor the matrix to use terms familiar to the target organization.

The scope of the organization under regard may be the entire enterprise or a subordinate organization (e.g., project, department, division, etc., hereafter generically refered to as "department") within an enterprise. The Models being discussed are also those at the enterprise or department level. Alternatively, or additionally, the role-based view of the Model-Based capabilities may be suitable for specific roles to take-action; enterprise manager, system engineer, program manager, Modelers, information technology representative, training, and even human resources.

The Matrix is intended to serve as a starting point for the various uses. In most cases, the wording and level of detail will be tailored for specific applications and organizations. A section on tailoring is provided.

The purpose of this Guide is to provide approaches on how to use the Matrix for the following purposes:

- Organizational self-assessment
- Enterprise-wide assessment of a portfolio of projects/program organizations
- Role-based capabilities assessment for those that are stakeholders in the organizational development
- Providing the strategic basis for qualifying bidders and/or planning for the acquirer's pre-award process leading to a source selection and contract award.

Matrix assessment results typically identify the current Model-Based capability that an organization has and the targeted capability stage. This "need" or "gap" provides the starting point to create plans to transform the organizations involved. The assessment grading approach and report formats are left to the matrix user to define.

The authors intend that the assessment itself being a quick half-day activity where the goal is to get a "good enough" assessment to begin planning the organizational transformation. Pre-work is recommended to ensure the right assessors, the matrix is tailored to the needs, and that the enterprise/department purpose is defined, the organizational transformational objectives are

considered, and that Modeling objectives are initially established. Sample enterprise and department purposes are provided as an appendix as are a set of Modeling objectives.

The authors intention is that the matrix grading be generous when applied, meaning that if in doubt allow the capability assessment to be a higher stage. The goal for matrix application is to serve as a starting point for organizational transformation and development to the stage that the organization has determined it would like to be competent in.

The Guide begins with an abbreviated developmental history and an explanation of the Matrix structure.

## 2 Developmental History (abbreviated)

The matrix begins with two independent efforts to provide a reference for enterprise and program/project organizations to assess their current and desired implementation of Modeling

- The Aerospace Corporation MBSE Community Roadmap
- NASA MSFC MBSE Maturity Matrix

Following a presentation of both at the Office of the Secretary of Defense (OSD) Digital Engineering Working Group in 2017, it was decided to combine these efforts to bring the work to the January 2018 INCOSE International Workshop to determine if there was a valid community need and to design a matrix combining elements of both efforts and supplementing them to address the IEEE 15288.1 and 15288.2 as well as the emerging OSD Digital Engineering Strategy, June 2018[1]. Two four-hour workshops with 67 participants ratified the need and developed the framework for the INCOSE Model-Based Capability Matrix. INCOSE then raised the bar by commissioning a Challenge Team to continue development.

Early drafts of the Matrix were created and refined over a series of workshops at various System Engineering fora and on-line INCOSE Challenge Team meetings:

- INCOSE International Workshop (Jan 2018) where an INCOSE Challenge Team was formed to produce a candidate INCOSE product
- Aerospace System Engineering Forum (May 2018)
- INCOSE International Symposium (July 2018)
- NDIA SE Conference workshop (Oct 2018)
- INCOSE International Workshop (Jan 2019)

About the Challenge Team: The Challenge Team was commissioned by Mark Sampson and Troy Peterson, INCOSE leads for the System Engineering Transformation/MBSE Initiative efforts.

The **Challenge Team** is co-Led by

- Al Hoheb – The Aerospace Corporation
- Joe Hale – NASA/MSFC

**INCOSE Challenge Team** includes Reps from numerous Governemt, Industry, and Academic organizations and continues to grow. Challenge team members are volunteers that would like to be informed of the efforts, contribute as they can to develop the products, and as they are able, promote and use the products providing feedback.

**INCOSE Challenge Team resources.**

- OMG Wiki: http://www.omgwiki.org/MBSE/ The OMG wiki entry discusses the effort.

[1] https://www.acq.osd.mil/se/docs/2018-DES.pdf

- http://www.omgwiki.org/MBSE/doku.php?id=mbse:mbecm
- INCOSE Connect, workgroups, Model-BasedCapabilities Matrix (INCOSE Members only). This is the INCOSE member download area for the matrix and User's Guide.

## 3 Model-Based Capability Matrix Structure

### 3.1 Capability Rows

The matrix is arranged as a table with rows identifying Model-Based capabilities for an organization and columns identifying the stage of that capability. See Table 1. The capabilities are meant to be unique and necessary capabilities for an organization to have a Model-Based approach.

Table I. Matrix Structure

| Capabilities/Stages | Stage 0 | Stage 1 | Stage 2 | Stage 3 | Stage 4 |
|---|---|---|---|---|---|
| Capability 1 | | | | | |
| Capability 2 | | | | | |
| Capability 3 | | | | | |
| Capability N | | | | | |

### 3.2 Stage Columns

Columns: Increasing Stages of Capability generally defined as:

*Stage 0: No MBSE capability or MBSE applied ad hoc to gain experience*
*Stage 1: Modeling efforts are used to address specific objectives and questions*
*Stage 2: Modeling standards are applied; ontology, languages, tools,*
*Stage 3: Program/project wide capabilities; Model integrated with other functional disciplines, digital threads defined and digital twin*
*Stage 4: Enterprise wide capabilities: contributing to the enterprise, programs/projects use enterprise defined ontologies libraries, standards*

## 4 MBCM Views

The Matrix has three tabs: 1) provides the Role-Based View of Model-Based capabilities, with 2) an accompanying tab for Role-Based View of Model-Based Capablities Descriptions, and 3) provides the capabilities allocated to the United States Office of the Secretary of Defense (OSD) Digital Engineering (DE) Strategy document. The virtue of the Role-Based allocation is that it conforms with the matrix versions 1.0 – 1.7a. It provides a fairly straight-forward mapping to roles that are performed in an organization. It is the basis for the "Model-Based Stakeholder Roles Assessment" to allocated capability transformations to specific roles (and thus specific people) in an organization.

The role-based areas are:

1. Workforce/Culture
2. System Engineering Processes/Methodology
3. Project/Program Process/Methodology
4. Model Based Effectiveness
5. Modeling Tool Construction
6. Information Technology Infrastructure
7. Policy

Another matrix view of capabilities is the allocation of capabilities to the five goals listed in the United States Office of the Secretary of Defense (OSD) Digital Engineering (DE) Strategy document. The virtue of assessing organizational capabilities against these goals is that the order of goals provides a more logical flow; an example being that the capabilities under "User of Models" need to be established before the capabilities allocated to the "Authoritative Source of Truth." Assessors may find it easier to use this allocation than the Role-Based allocation because it leaves workforce and culture assessments to the end after the precursor capability needs have been assessed. U.S. Government organizations familiar with the OSD DE Strategy may also want to use this matrix capability view to maintain or demonstrate traceability among their organization's capabilities, the OSD DE Strategy, and transformation plans.

1. Use of Models
2. Authoritative Source of Truth (ASOT)
3. Innovation
4. Establish Environments
5. Workforce Transformation

## 5 Other Model-Based Assessment Matrices

There are other Model-Based assessment matrices available. The Aerospace Corporation and NASA/MSFC center started this effort with their own until they collaborated. Major corporations such as Siemens, Lockheed Martin, and Boeing have at various times shown elements of their corporate defined matrices at INCOSE events. Similarly, the NIST/ASME manufacturing matrix has been in use to focus on Modeling for manufacturing. This INCOSE Challenge team effort has benefitted from presentations and enriched by those efforts as they joined and strengthened the over 160 INCOSE Challenge Team members.

This INCOSE MBCM has been used in many INCOSE, NDIA, and corporately-sponsored workshops, during which proposed concepts along with a breadth of ideas were culled and incorporated. Not all ideas can be incorporated: some ideas contradict, some are beyond the state of the current Modeling practice, some will come as users apply the matrix (such as standard scoring and reports), others are currently beyond the reach of efforts the leads and teammembers can achieve as volunteers.

If users discover a move valuable matrix – use it! It may fit a specific need such as Modeling for manufacturing or a matrix of Model-Based personal competencies needed to satisfy Model-related leadership or staff roles.

## 6 Matrix Concepts of Operations (CONOPs)

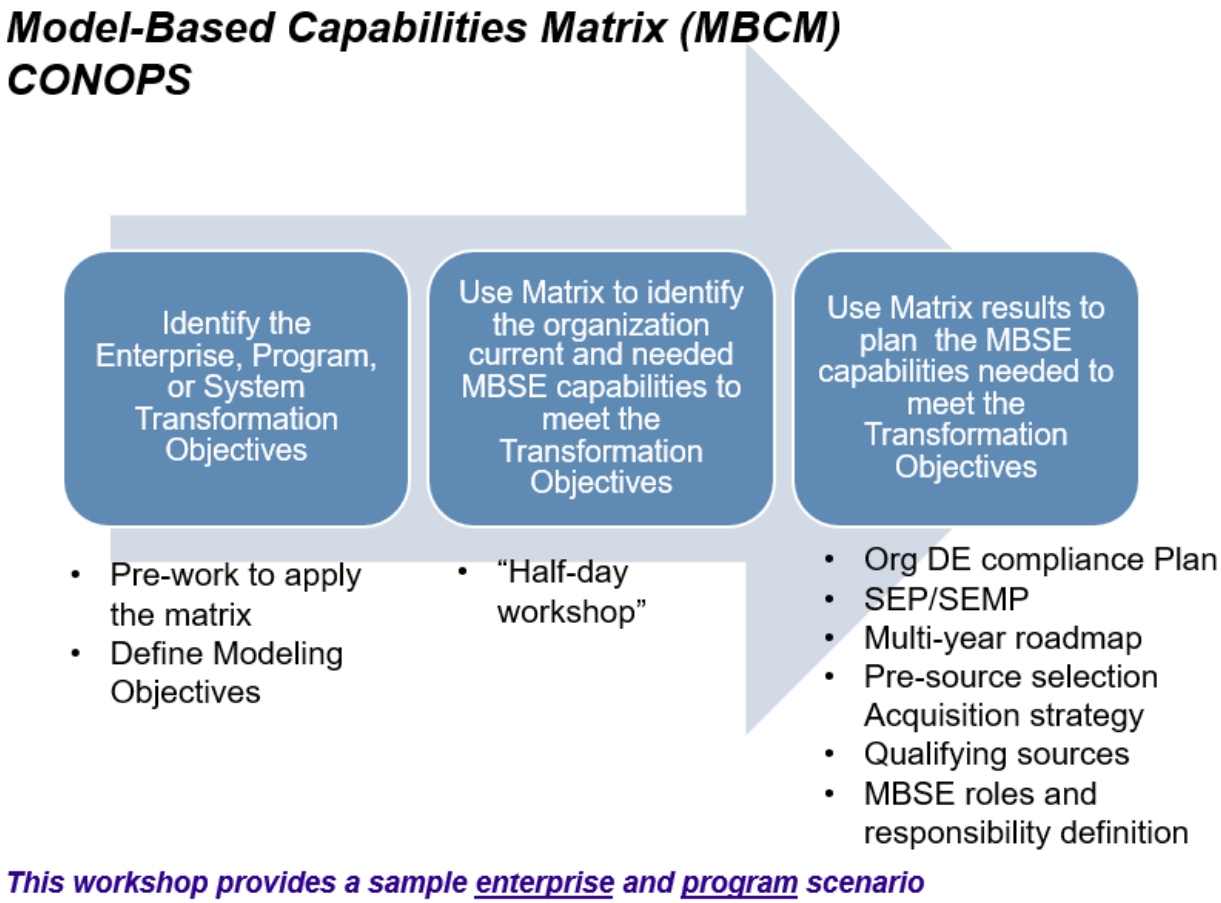


Figure 1. Model-Based Capabilities Matrix (MBCM) CONOPs

The purpose of the matrix is to provide organizations an assessment of the capabilities needed to transform to improved and purposeful model use. Figure 1 illusstrates how an organization applies the matrix by first doing necessary pre-work. Necessary pre-work includes: defining organizational transformation objectives, defining the organizatoin's enterprise or program objectives, and tailoring the matrix. This is the step that includes organizing the assessment team, understanding what how the assessment results will be characterized and how the assessment results will be used.

The last step, illustrated by the right-most box of Figure one, provides a list of products that an organization may develop and that the matrix assessment results may contribute to. For example, a DoD organization may want to see what capabilities it has and what additional capabilities need to be developed if they are concerned with complying with the DoD Digital Engineering Strategy document. An organization may want to write/update their System Engineering Plan (SEP) or System Engineering Management Plan (SEMP) to more fully utilize modeling as part of their system engineering approach and the capabilities assessment results could contribute to that

understanding and plan. Organizations may want to use the assessment as part of their acquisition strategy to characterize what capabilities the acquirer and suppliers may need to ensure successful modeling efforts. Lastly, the organization may want to review key roles and assess what modeling capabilities the key roles must satisfy or lead. Their may be other applications for the results of the INCOSE Model Based Capabilities Matrix assessment and Figure 1 may not capture those.

The middle block of Figure 1 covered the activity of using the matrix to assess organizational capabilities. A "Half Day" workshop is noted because workshops have been run in as little as 2 hours, run for 4 hours, or run as a fully day workshop. This depends on the quality of the pre-work, the size of the assessment group, and workshop leadership's direction and workshop management. A key concept to consider is that moving quickly, without a lot of debate on the assessment, may speed results, help to assess those capabilities that are most important and yield a quick starting point for the organizational planning. The Challenge Team leaders for the development of the matrix have envisioned that it be used to quickly assess an organization's capability and urge generous scoring because it's really not the scoring that is the result but rather the plans that result from the scoring.

Here are some recommended actions to run the Matrix Assessment:

1) Provide an overview brief to the sponsor and key advisors/stakeholder to
   a) *Identifies what the matrix is, how it can be useful, how long it takes (4 hours), and resource commitment*
   b) *Agree on the output product; an assessment used to begin planning*
   c) *Identify key people; Enterprise manager (EM), Project/program Manager (PM), System Engineer (SE), Information Technology (IT), Modeler, Contracts, Training, etc..*
2) Develop a short project plan
   a) *Tasks, timeline, stakeholders, and have it signed off by the sponsor*
3) Identify/develop a customer scenarios (e.g., enterprise, program – new or existing) and identify their overall enterprise or program objectives
   a) *Create the objectives if they aren't available*
4) A-priori matrix tailoring
   a) *Use customer language if needed*
   b) *Emphasize the right capability rows; tailor-out or create new row*
   c) *Agree on scoring method and being generous (benefit of the doubt)*
5) Run the assessment in a half day
   a) *Using the enterprise or program objectives as a basis, review the row and stage for current capabilities and those needed to meet customer objectives.*
   b) *Group the gaps and begin development of an organizational development plan. It could be a multi-year roadmap.*

## 7 Tailoring

Organizations should choose which view of the capabilities it would like to use. Matrix version 2.0b and beyond provide either a role-based view (legacy version refined between matrix versions 1.0 – 1.7a) or a Digital Engineering view aligned to the United States, Office of the Secretary of Defense (OSD)' Digital Engineering (DE) Strategy document found at:
***https://www.acq.osd.mil/se/docs/2018-DES.pdf***

The DE view may be important to any organization that would like to show traceability of their capabilities and plans against the DE Strategy goals and focus areas. It is arranged in a logical fashion where the earlier goals enable the completion of the later goals. Hence the associated capabilities may enable the later capabilities in the Matrix.

Tailoring of the matrix by organization is not only allowable but encouraged. Organizational language should be used to enhance the organization's understanding and use. The capabilities are not of equal value and users may want to eliminate rows, combine rows, add rows to tailor the matrix to their needs. Tailoring may reduce direct benchmarking with other users but may be an appropriate approach based on need.

Use language that is important to the organization – tailor before use.

- E.g., government organizations may use the terms "center" while commercial organizations may use terms such as "business unit" or "profit center"
- E.g., NASA uses "project," DoD uses "Program"
- "Enterprise," "system-of-system," and even "system" may have specific organization definitions to be used.

Identification of SE areas and individual processes to be addressed are critical to successful matrix-based assessment and the following capability planning step. Choosing the right level of SE areas/processes is a bit of an art; too many will complicate and bog down the assessment, too few may omit key concepts that are essential to success. The Matrix has gone through many debates and iterations. While it was at first desirable to have each system engineering process and subprocess as a unique row and capability it was found that some SE areas/processes were necessary to Model-Based applications. For those such as configuration management, data management, Model management, Model metrics were retained as their own capability rows. Patterns emerged from looking at the SE areas/processes candidate stage descriptions and the INCOSE Challenge Team leads made the editorial decision to not repeat those patterns.

Addition/deletion of capability rows to focus on organization perspective or to focus stakeholder roles: If the organization is more concerned about architecting or system engineering across the life-cycle then the matrix may be used as is. If the organization is concerned about manufacturing readiness, then additional rows may be added to cover this and/or adoption of the NIST/NDIA/ASME Model Based Enterprise matrix for manufacturing readiness would apply. Similarly, some organizations have a focus on workforce development and would like to use elements of the INCOSE matrix to assess organization development capabilities and enhance those.

Establishing capability relative weighting: The INCOSE Matrix doesn't provide capability weighting although some users would like to add it. In the spirit of making the matrix suitable for the SE community and to promote user acceptance, users may want to add their own weighting.

# 8 Matrix Uses

## 8.1 Overview

This User's Guide has identified specific use-cases:

1. Organizational self-assessment
    a. DoD org DE implementation plan, SEP/SEMP, Acq strategy and pre-RFP/source selection, Bidder qualification
2. Enterprise-wide assessment of a portfolio of projects/program organizations
3. Model-Based Stakeholder Roles Assessment
4. Qualifying bidders and/or planning for the acquirer's pre-award process

## 8.2 Organizational Self-Assessment

Organizations may want to define the capabilities and stages they would like to demonstrate once their goals are fully realized or to define roadmaps to achieve that goal. To apply the matrix, organizations may want to:

1. Determine the stakeholders involved with the assessment and ensure they identify and accept the responsibilities for matrix tailoring, matrix capabilities assessment, putting together the resulting transformational plan to improve the organizations capabilities, and then be responsible for the organizational developmental activities and organizational performance.
2. Determine the assessment approach. It can be done in one workshop or it can be split into separate, but related, tasks. Determine the assessment scoring approach.
3. Tailor the matrix via stakeholders.
4. Define the enterprise or department engineering goals for the deployment of Model-Based capabilities
5. From the enterprise or department goals identify Modeling objectives.
6. Use the tailored matrix to perform the capabilities assessment. Establish the scoring approach first. Will scoring identify current and desired stages for each capability? Weight the capabilities? Other approaches?
7. Discuss the results and create the transformation plan(s)

Identification of the organizational Model-Based capabilities may start with identification of the enterprise or SE goals to address a need. Common needs may be:

1. Needing to minimize enterprise or system configurations where applied Model-Based can be used to achieve this for fielded and planned capabilities.
2. Minimize requirement-design errors to meet cost/schedule goals and field capabilities quicker than with non-Model-Based development.

3. Minimizing development time to get to production via paperless review activity and acceptance – e.g., replacing paper-based SE reviews and audits.
4. Ensure the enterprise or system meets strict surety, safety, security, or effectiveness requirements.
5. Minimize test time using MBE/MBSE.
6. Create the Authoritative Source of Truth (ASOT) data, information, knowledge, wisdom needed to either re-compete work or product development.
7. Enhanced standardization and common interfaces across the enterprise or system to enhance its open nature, enable alternate solutions, minimize development and enhance manufacturing flexibility.
8. Need Model-Based to enhance logistics and maintenance of fielded capabilities.
9. Need to capture existing fielded system ASOT for service life extensions.
10. Need to optimize acquisition, program/project management and system engineering processes by using MBSE

Once the organizational Model-Based needs are established they may then review the capability rows and identify the needed capabilities and the needed stage to address their needs (initial matrix tailoring may be required at this point). This will result in the strategic vision.

After the strategic vision is established the organization may put together the stakeholder team to perform the assessment (tailoring may be required) of the current state of the organization's capability. Once the current state and desired state (strategic vision) are identified, the gap between the two forms the basis of capability transformational need.

The organization may want to review all the transformational capability needs together to start the organizational transformation development strategy and plan. The strategy may include incremental transformation over a number of years/fiscal years, include pathfinder project efforts to inform others, or adopt other strategies. The organizational transformation development strategy may use a yardstick approach where the available time or investment money for enhancing capabilities are fixed and then the set of capability enhancements would be aggregated to fit within the schedule or dollar constraint.

Defining a roadmap. If the capability gap is more than one cell (e.g., stage 2 ->stage 5) then the organizational may want to define a roadmap and tie the incremental capability improvements to developmental activities.

See Appendix A.2 for examples of Matrix Uses:

A.2.1 Strategic Vision
A.2.2 Roadmap
A.2.3 Yardstick
A.2.4 Tactical Planning

### 8.3 Enterprise-wide assessment of a portfolio of projects/program organizations

An organization that manages a collection of programs, projects, or systems may want to characterize each part of its portfolio to identify those organizations with higher capabilities to leverage and learn from and characterize those organizations lagging and perhaps needing resources. A suggested approach to conducting an enterprise assessment includes:

1. Establishing POCs for the enterprise components included in the assessment
2. Tailoring the matrix for the enterprise (capabilities, language, etc.) that can be done by the enterprise manager and/or with the component POCs
3. Having the components do a component self-assessment (with the enterprise manager is context or help is needed)
4. Visualize results as an enterprise to see where there are the lowest/highest stage ratings for a capability and assess widest, most occurring, gaps.

Creating an enterprise transformation development plan would follow the same general approach as the self-assessment.

### 8.4 Model-Based Stakeholder Roles Assessment

It may be worthwhile to put together a team of transformation stakeholders – those that would affect the change in Model-Based capabilities. The role assessment would be to define what capabilities each of the stakeholder roles will transform/develop. This team may include the Enterprise Manager, Project/Program Manager(s), System Engineer(s), IT lead, Enterprise and System level Modelers, Model managers, and perhaps even representatives from human resources, training, or other departments. A suggested approach to conducting a Model-Based Stakeholder Role assessment includes:

- Identifying the role POCs and having them commit to the assessment and potential transformation
- Have the role POCs take responsibility for specific capabilities listed in the matrix. This could be a self-allocation or a coordinated allocation. See the example below

Table II. POC's Responsibilities

| User Roles | Workforce and Culture | SE Process Methodology | PM Process Methodology | Tools and IT Infrastructure | Model Based Effectiveness | Project Use | Policy |
|---|---|---|---|---|---|---|---|
| Enterprise manager | x | x | x | x | x | x | x |
| Project/Program manager | x | | x | | | x | x |
| System Engineer | x | x | | | x | x | x |
| Tool curator | | x | x | | x | | |
| IT representative | x | | | x | | x | x |
| Functional specialist | | x | | | x | | |
| HR | x | | | | | x | x |
| Training | x | x | x | x | x | x | x |

- Based on the organizational goals and target capabilities, the role POCs, for their allocated capabilities would assess the current stage and compare them to the desired organizational stage that creates the transformational developmental need.
- From the transformational developmental need, the role POC would develop plans to improve the capabilities.

## 8.5 Qualifying bidders and/or planning for the acquirer's pre-award process

### 8.5.1 Matrix Uses: Qualifying Bidders

Objective: Define how the Model Based Capabilities Matrix may be used to qualify bidders to be allowed to provide proposals

General Approach: The purpose of qualifying bidders it to create an acceptable pool of sources to provide contracted services. This is to reduce acquirer effort, not waste the time of unqualified bidders and to reduce source selection risk of selecting an unqualified bidder.

One acquirer strategy to qualify bidders using the matrix is to provide the Matrix capability areas and capabilities along with the request for input from the potential bidders on how they'd go about providing those capabilities. The acquirer would then "score" potential bidder responses against the matrix.

Acquirer pre-work includes (a) tailoring the matrix to focus on those critical elements and potentially those that would be discriminators (b) creating the capability definitions or a reference glossary of terms.

### 8.5.2 Matrix Uses: Source Selection

Objective: Define how the Model Based Enterprise Capabilities Matrix may be used to support source selection

General Approach: The purpose of source selection is to (a) ensure the acquirer has defined their Model-Based capabilities requirements and (b) select the appropriate source to meet those requirements.

To define the acquirer Model based capabilities requirements the Matrix may be used to characterize the current state and the desired state. The desired state then is parsed and processed to form requirements for the supplier to perform to.

The desired capabilities can be communicated early in the first notices of the intent to acquire the supplier services. It next can be discussed at bidder's conferences and in communication. Then reflected in the draft request for proposal/source selection plan

To select the appropriate source using the Matrix.

If the Matrix is part of the RFP/source selection plan and part of the evaluation criteria then the evaluation proceeds with assessment of offeror capabilities.

Several different methods may be used to score; a) use the complete matrix and score the proposal for each capability to identify the stage, b) use the matrix rows and stages that are the most important to the acquirer, c) use the capabilities and maximal useful stage

If the Matrix is not part of the RFP/source selection documents then, if allowed by the source selection team, it may be used as a reference to assign strengths to evaluation worksheets, findings and ratings. If the Matrix is not part of the RFP/Source selection documents it should not be used as a basis for technical assessment (e.g., doesn't not meet requirements), nor weaknesses for the risk rating, since it was not part of the evaluation criteria

# 9 Report Generation Concepts

## 9.1 Heat Map

The general notion of "Heat Maps" is to color code rows and/or cells in meaningful ways to the Stakeholders and other users. Tables V and VI in Appendices A.2.3 and A.2.4, respectively, offer a couple of examples of color coding. Table V codes Green for current Stage for that particular attribute. It codes Yellow for the Cell currently "in work." Table VI uses the resultant current organization capabilities from Table V to plan for next step(s) in further capability development for the next budget cycle. One could, then, color code the cell(s) another color for those cell(s) included in the next cycle. Further, one could color code the cell(s) yet, another color for those cell(s) included in the subsequent cycle(s).

## 9.2 Assessments Coding

In larger organizations, one might find various levels of capabilities among the various levels of the Organization (e.g., Departments, Divisions, etc.). Assesors might discover, for example,that potential users might have access to a capability, but don't use it, or that another "department" has and uses a capability that it is not available to other "departments." In these cases, one can still capture and report the information for the Attributes under consideration by recording that "departments" full response. For example, *Access: Stage 3; Use Stage 1; Existing, but Unavailable Stage 4*. This approach may more completely capture the current state-of-affairs within an Organization AND suggest some easy wins through training or removing barriers.

## 9.3 Numerical ratings

Some matrix users have noted that not all capabilities are equally important and different strategies can be adopted to handle this. One strategy is to first tailor the matrix by either combing capabilities or further splitting them to finer granularity. Another strategy is to weight the capabilities by adding a numerical weighting. In the spirit of user tailoring, this is encouraged for those that ind the concept useful.

Another concept of numerical rating is to use the stage number of a capability as a rating and to character each capabilities spread of current capability to desired capability. For most users this is a level of detail that detracts, rather than adds, to their goals of using results to build and conduct organizational transformation plans.

## 9.4 Rollups based on numerical ratings and importance weight

Some users have found that its easiest to explain results to management by rolling up the capabilities under their areas title (that differ depending on the view; role-based view or digital engineering strategy goal view). For example a portfolio manager of several/many programs may want to characterize both the individual program capabilities but also provide a sense of the state of all programs within the enterprise.

Several strategies to perform rollups have been discussed at workshops; one is to use a numerical rating to weight the capabilities and to characterize the stages. A numerical rating, either sums or averages can be used to characterize the capabilities under and area. Another is to borrow from the heat map approach where colors are coded and then some user defined algorithm is defined

to combine the capability ratings to provide a composite color under and area. As a note, one Matrix user created a set of Excel macros to do a summary rollup and presentated it to the workshop. This provided a visual rating that would be helpful to enterprise/portfolio/program managers.

## 10 Organization Transformation Plans

The purpose-for and results-from the INCOSE Model-Based Capabilities Matrix are to provide information that feeds directly into transformation plans. Taking the Matrix results to plans usually requires an executive champion and budget for the efforts that are described in the plan. In addition, its is usually helpful to create a communication plan that explains the effort motivation and plans to all stakeholders. The resultant communication is best if it uses reliable communication channels (corporate announcements, mailing lists, executive meetings, weekly/monthly reports, etc.).

Transformation plans may take many forms; organizational strategy, acquisition strategy, system engineering plans, system engineering management plans, Modeling and information technology plans or roadmaps, community of interest roadmaps, etc.). Identifying leads for these plans and associated projects provides them the opportunity to use the established communication channels to explain when the capabilities are ready. This also creates effort “ambassadors” that are the project leaders that can be used as leaders that can articulate the range of roadblocks, commitments, and steps necessary to accomplish the capabilities goals.

The steps and effort necessary for an organization to move a capability to more advanced stages will vary greatly by organization and how capabilities are grouped or decomposed. As the Matrix user community grows and shares experiences, ideas for best practices may evolve.

# APPENDIX A

## A.1 Sample enterprise and system goals and Modeling objectives

### A.1.1 Sample Enterprise Transformational Objectives: *Making more-with-less, more-with-existing, more-with-more, or preserving what is possible under stressors*

- Enhance integrating systems into an Enterprise
- Enhance enterprise resilience
- Enhance enterprise technical performance
- Technology injection
- Re-allocation of existing assets
- Enhance enterprise sustainment
- Enhance enterprise flexibility to use assets for new missions or changing mission priorities
- Move to an intelligent enterprise
    - *Reducing manpower or level of expertise*

### A.1.2 Sample System Transformational Objectives:

- Needing to minimize enterprise or system configurations where applied Model-Based can be used to achieve this for fielded and planned capabilities.
- Minimize requirement-design errors to meet cost/schedule goals and field capabilities quicker than with non-Model-Based development.
- Minimizing development time to get to production via paperless review activity and acceptance – e.g., replacing paper-based SE reviews and audits.
- Ensure the enterprise or system meets strict surety, safety, security, or effectiveness requirements.
- Minimize test time using MBE/MBSE.
- Create the Authoritative Source of Truth (ASOT) data, information, knowledge, wisdom needed to either re-compete work or product development.
- Enhanced standardization and common interfaces across the enterprise or system to enhance its open nature, enable alternate solutions, minimize development and enhance manufacturing flexibility.
- Need Model-Based to enhance logistics and maintenance of fielded capabilities.
- Need to capture existing fielded system ASOT for service life extensions.
- Need to optimize acquisition, program/project management and system engineering processes by using MBSE

### A.1.3 Sample Modeling Objectives:

- Modeling use cases for CONOPs validation
- Modeling operational functionality to generate/verify operational requirements
- Modeling a new concept (e.g., Universal command and control)
- Modeling enterprise, system and subsystem performance
- *Ensure requirements traceability*
- *Assess design maturity*

- *Assess integration*
- Modeling specialty engineering threads to verify performance
- *Reliability, security features, safety, surety, or effectiveness*
- Modeling interfaces
- Modeling a complex algorithm
- Model for manufacturing
- Model system V&V processes to verify by analysis
- Model test and/or maintenance suite compatibility
- Model baseline for alternative sourcing

## A.2 Example Matrix Uses include:

A.2.1 Strategic Vision
A.2.2 Roadmap
A.2.3 Yardstick
A.2.4 Tactical Planning

### A.2.1 Matrix Use: Strategic Vision

- Objective: Define a future state description of one or more domains/attributes of a mature Model-Based Enterprise
- General Approach: Derive a tailored vision based on the most relevant mature attribute descriptions in the left-most column.
- Example: Selected a subset of attributes from the **Role-Based Matrix Area 5. *(Information Technology Infrastructure)* & Area 6. *(Modeling Tool Construction)*** and the **DoD DE Strategy *Goal 1. (Use of Models)* and Goal 4. *(Establish Environments)*** as the relevant attributes for this example

Table III. Example for Strategic Vision

| Role Based Matrix Area | DoD DE Strategy Goal | Model-Based Capability Name and Stages | Stage 0 | Stage 1 | Stage 2 | Stage 3 | Stage 4 |
|---|---|---|---|---|---|---|---|
| 5. Information Technology Infastructure | Goal 4. Establish Environments | Collaboration cap | Collaboration by business tool applications (e.g., E-mail, telecom.) | System Model File Exchange is identified and used.. | Various organizations working on different parts of model. Models are integrated by a single organizations. | On-line, real-time collaboration amongst distributed project/program teams | On-line, real-time collaboration amongst distributed teams for am enterprise |
| 6. Modeling Tool Construction | Goal 1. Use of Models | Distributed Database/Tool interoperability | No interoperability between model based tools | Model Based Tool-to-Tool has ad hoc interoperability | Partial Federated Database Management System (FDBMS) | Main tools interoperable. Supporting tools interact through file transfer. | Fully Federated w/ standard "plug-and-play" interfaces. Data is interchanged among tools |
| 6. Modeling Tool Construction | Goal 1. Use of Models | Inter-Database/Tool Data Item Associations | Databases/tools are independent | Inter-Database/Tool Data Item associations defined | Inter-Database/Tool Data Item associations defined, captured, managed | Inter-Database/Tool Data Item associations among a data items defined, captured, managed, and traceable | Inter-Database/Tool Data Item associations among all data items defined, captured, managed, and traceable where changes in one data source alerts owners of other data sources of intended updates |
| 6. Modeling Tool Construction | Goal 1. Use of Models | User Interface (UI), Viewpoint/Views, and visualization | Model are not used to identify or define the user interface or view/viewpoints | Models allow document generation, generation of views/viewpoints | Models allow document generation, generation of views/viewpoints and custom visualization | UI supports Interrogation across the federated systems Authoritative source of truth and provides visualizations for decision making | UI supports Interrogation across the federated enterprise Authoritative source of truth and provides visualizations for decision making |

- The Stage 4 column gives the mature attribute descriptions for the relevant attributes
- A Vision statement might be:
  - We aim to provide a fully Federated IT architecture with:
    - On-line, real-time collaboration amongst distributed teams
    - Standard "plug-and-play" interfaces
    - Managed data item relationships across heterogenous, disparate data sources
    - **User Interfaces that enable navigation and interrogation across heterogenous, disparate data sources, and**
    - **On-line, real-time collaboration amongst distributed teams**

- Potential Purposes/Uses for Strategic Visions
  [Source: National Defense University]
    - Help to describe an organization's purpose; a declaration of an organization’s objectives; can help guide its internal decision-making
    - Provides a picture of the future. It bridges the present and the future. The right vision takes the organization out of the present, and focuses it on the future.
    - It attracts commitment and energizes people. This is one of the primary reasons for having a vision for an organization: its motivational effect.
    - Serve as foundations for a broader strategic plan.

### A.2.2 Matrix Use: Roadmap

- Objective: Define a Roadmap of increasing capability of one or more domains/attributes towards a mature Model-Based Enterprise
- General Approach: Derive a tailored roadmap based on one or more relevant attribute rows.
- Example: Selected a subset of attributes from the **Role-Based Matrix Area 5. *(Information Technology Infrastructure)* & Area 6. *(Modeling Tool Construction)*** and the **DoD DE Strategy *Goal 1. (Use of Models)* and Goal 4. *(Establish Environments)*** as the relevant attributes for this example

Table IV. Example for Roadmap

| Role Based Matrix Area | DoD DE Strategy Goal | Model-Based Capability Name and Stages | Stage 0 | Stage 1 | Stage 2 | Stage 3 | Stage 4 |
|---|---|---|---|---|---|---|---|
| 5. Information Technology Infastructure | Goal 4. Establish Environments | Collaboration cap mail, telecom ) | Collaboration by business tool applications (e.g., E- | System Model File Exchange is identified and used | Various organizations working on different parts of model. Models are integrated by a single organizations | On-line, real-time collaboration amongst distributed project/program teams | On-line, real-time collaboration amongst distributed teams for an enterprise |
| 6. Modeling Tool Construction | Goal 1. Use of Models | Distributed Database/Tool interoperability | No interoperability between model based tools | Model Based Tool-to-Tool has ad hoc interoperability | Partial Federated Database Management System (FDBMS) | Main tools interoperable. Supporting tools interact through file transfer. | Fully Federated w/ standard "plug-and-play" interfaces. Data is interchanged among tools |
| 6. Modeling Tool Construction | Goal 1. Use of Models | Inter-Database/Tool Data Item Associations | Databases/tools are independent | Inter-Database/Tool Data Item associations defined | Inter-Database/Tool Data Item associations defined, captured, managed | Inter-Database/Tool Data Item associations among all data items defined, captured, managed, and traceable | Inter-Database/Tool Data Item associations among all data items defined, captured, managed, and traceable where changes in one data source alerts owners of other data sources of intended updates |
| 6. Modeling Tool Construction | Goal 1. Use of Models | User Interface (UI), Viewpoint/Views, and visualization | Model are not used to identify or define the user interface or view/viewpoints | Models allow document generation, generation of views/viewpoints | Models allow document generation, generation of views/viewpoints and custom visualization | UI supports Interrogation across the federated systems Authoritative source of truth and provides visualizations for decision making | UI supports Interrogation across the federated enterprise Authoritative source of truth and provides visualizations for decision making |

- Roadmap for tool interoperability and traceability:
  - Milestone 1: Some tool-to-tool integration; cross-tool data associations defined
  - Milestone 2: Demonstration of selected tools in a Federated Architecture; cross-tool data associations defined, captured, managed
  - Milestone 3: Main tools interoperable in a Federated Architecture; cross-tool data associations defined, captured, managed, and traceable
  - Milestone 4: All tools interoperable in a fully Federated Architecture; cross-tool data associations defined, captured, managed, and traceable
- Potential Uses of a Roadmap
  [source: Wikipedia]
  - Provides a flexible planning technique to support strategic and long-range planning, by matching short-term and long-term goals with specific technology solutions

- Has three major uses:
    - It helps reach a consensus about a set of needs and the technologies required to satisfy those needs,
    - It provides a mechanism to help forecast technology developments, and
    - It provides a framework to help plan and coordinate technology developments.

### A.2.3 Matrix Use: Yardstick

- Objective: Define a method of characterizing the current capability of one or more domains/attributes for a Model-Based Enterprise
- General Approach: Assess the current Stage of Implementation by the Organization for one or more relevant attributes. Highlight the attained Stage of Implementation cell and all calls to the left of the attained Stage for all assessed relevant attributes.
- Example: Selected a subset of attributes from the **Role-Based Matrix Area 5.** ***(Information Technology Infrastructure)*** **& Area 6.** ***(Modeling Tool Construction)*** and the **DoD DE Strategy** ***Goal 1. (Use of Models)*** **and Goal 4.** ***(Establish Environments)*** as the relevant attributes for this example

Table V. Example for Yardstick

| Role Based Matrix Area | DoD DE Strategy Goal | Model-Based Capability Name and Stages | Stage 0 | Stage 1 | Stage 2 | Stage 3 | Stage 4 |
|---|---|---|---|---|---|---|---|
| 5. Information Technology Infastructure | Goal 4. Establish Environments | Collaboration cap | Collaboration by business tool applications (e.g., E-mail, telecom.) | System Model File Exchange is identified and used.. | Various organizations working on different parts of model. Models are integrated by a single organizations. | On-line, real-time collaboration amongst distributed project/program teams | On-line, real-time collaboration amongst distributed teams for am enterprise |
| 6. Modeling Tool Construction | Goal 1. Use of Models | Distributed Database/Tool interoperability | No interoperability between model based tools | Model Based Tool-to-Tool has ad hoc interoperability | Partial Federated Database Management System (FDBMS) | Main tools interoperable. Supporting tools interact through file transfer. | Fully Federated w/ standard "plug-and-play" interfaces. Data is interchanged among tools |
| 6. Modeling Tool Construction | Goal 1. Use of Models | Inter-Database/Tool Data Item Associations | Databases/tools are independent | Inter-Database/Tool Data Item associations defined | Inter-Database/Tool Data Item associations defined, captured, managed | Inter-Database/Tool Data Item associations among all data items defined, captured, managed, and traceable | Inter-Database/Tool Data Item associations among all data items defined, captured, managed, and traceable where changes in one data source alerts owners of other data sources of intended updates |
| 6. Modeling Tool Construction | Goal 1. Use of Models | User Interface (UI), Viewpoint/Views, and visualization | Model are not used to identify or define the user interface or view/viewpoints | Models allow document generation, generation of views/viewpoints | Models allow document generation, generation of views/viewpoints and custom visualization | UI supports Interrogation across the federated systems Authoritative source of truth and provides visualizations for decision making | UI supports Interrogation across the federated enterprise Authoritative source of truth and provides visualizations for decision making |

- Color coding can be used to provide additional status, e.g.,
  - Green indicates attribute capability is operational
  - Yellow indicates attribute capability in active development
- Potential Uses of a Yardstick
- Provides a easily understandable, graphical method to present:
  - The current Stage of Implementation across a variety of attributes
  - Using different color-coding, the state of activity to advance the Stage of Implementation of an attribute, e.g., *Planned Activities* and *Activities Underway* (may include different color-coding to reflect status of the activity w.r.t. schedule, budget, &c.)

### A.2.4 Matrix Use: Tactical Planning

- Objective: Given the current capability of one or more domains/attributes of a Model-Based Enterprise, determine on which domain(s)/attribute(s) to apply effort/resources to advance in the near-term

- General Approach: Starting with the attained "Yardstick" assessment of one or more relevant attributes, determine which attribute capabilities to be advanced in the budget cycle of interest. A factor to consider, in addition to resources constraints, might include possible dependencies between attributes. For example, allocating resources to advance Attribute A may not make sense without first advancing an enabling or precursor attribute.

- Example: Selected a subset of attributes from the **Role-Based Matrix Area 5. *(Information Technology Infrastructure)* & Area 6. *(Modeling Tool Construction)*** and the **DoD DE Strategy *Goal 1. (Use of Models)* and Goal 4. *(Establish Environments)*** as the relevant attributes for this example

Table VI. Example for Tactical Planning

| Role Based Matrix Area | DoD DE Strategy Goal | Model-Based Capability Name and Stages | Stage 0 | Stage 1 | Stage 2 | Stage 3 | Stage 4 |
|---|---|---|---|---|---|---|---|
| 5. Information Technology Infastructure | Goal 4. Establish Environments | Collaboration cap | Collaboration by business tool applications (e.g., E-mail, telecom.) | System Model File Exchange is identified and used.. | Various organizations working on different parts of model. Models are integrated by a single organizations. | On-line, real-time collaboration amongst distributed project/program teams | On-line, real-time collaboration amongst distributed teams for am enterprise |
| 6. Modeling Tool Construction | Goal 1. Use of Models | Distributed Database/Tool interoperability | No interoperability between model based tools | Model Based Tool-to-Tool has ad hoc interoperability | Partial Federated Database Management System (FDBMS) | Main tools interoperable. Supporting tools interact through file transfer. | Fully Federated w/ standard "plug-and-play" interfaces. Data is interchanged among tools |
| 6. Modeling Tool Construction | Goal 1. Use of Models | Inter-Database/Tool Data Item Associations | Databases/tools are independent | Inter-Database/Tool Data Item associations defined | Inter-Database/Tool Data Item associations defined, captured, managed | Inter-Database/Tool Data Item associations among all data items defined, captured, managed, and traceable | Inter-Database/Tool Data Item associations among all data items defined, captured, managed, and traceable where changes in one data source alerts owners of other data sources of intended updates |
| 6. Modeling Tool Construction | Goal 1. Use of Models | User Interface (UI), Viewpoint/Views, and visualization | Model are not used to identify or define the user interface or view/viewpoints | Models allow document generation, generation of views/viewpoints | Models allow document generation, generation of views/viewpoints and custom visualization | UI supports Interrogation across the federated systems Authoritative source of truth and provides visualizations for decision making | UI supports Interrogation across the federated enterprise Authoritative source of truth and provides visualizations for decision making |

- Beginning with the "Yardstick" example, one might next work on the "Partial Federated Database Management System (FDBMS)" before the "UI draws from multiple Models/DBs," if, as in this example, one assumes that some Federation needs to be in place before the UI can draw from multiple databases.

- Potential Uses for Tactical Planning

    - Can be partitioned allow different User Roles to focus on their relevant attribute scope and domains

- Helps support rational, practical, defensible decisions regarding where to applied (often limited) resources towards advancing the Stage of Implementation of an attribute(s), e.g.,
    - Further advancement of Attribute A may not be of value or even possible, until Attribute B is first advanced
    - Provides the “Big Picture” to consider a balanced portfolio of advancement activities

# APPENDIX B Glossary

Currently there are conflicting terms defined for modeling and as they converge they may be identified for this User's Guide.

There is no definitive source however here are the thought leaders:

Glossary of terms (sources to be integrated)

1. Digital Engineering Information Exchange Working Group (DEIXWG) – NDIA, INCOSE, and OSD joint sponsorship. 31 May 2019 e-mail notification of terms

http://www.omgwiki.org/MBSE/doku.php?id=mbse:topical_encyclopedia_for_digital_engineering_information_exchange_deixpedia

2. NAVAIR System Engineering Transformation (SET)

Model-related Lexicon per Dr. Mark Blackburn, Principal Investigator for the SET project. Excel of terms that have been sourced and assembled by a team

Please contact Dr. Blackburn for access to the list: Mark Blackburn <mblackbu@stevens.edu>

3. Office of the Secretary of Defense (OSD) Digital Engineering. OSD has issued the Digital Engineering Strategy and has an out-of-date set of definitions.

https://www.acq.osd.mil/se/initiatives/init_de_def.html