Overview for the C-MAF:

A capability and maturity assessment framework for digital transformation guidance

05 July 2024

Presenter: Mike Shearin mike.shearin@gtri.gatech.edu

Co-authors: Dr. Val Sitterle, Zac Connor

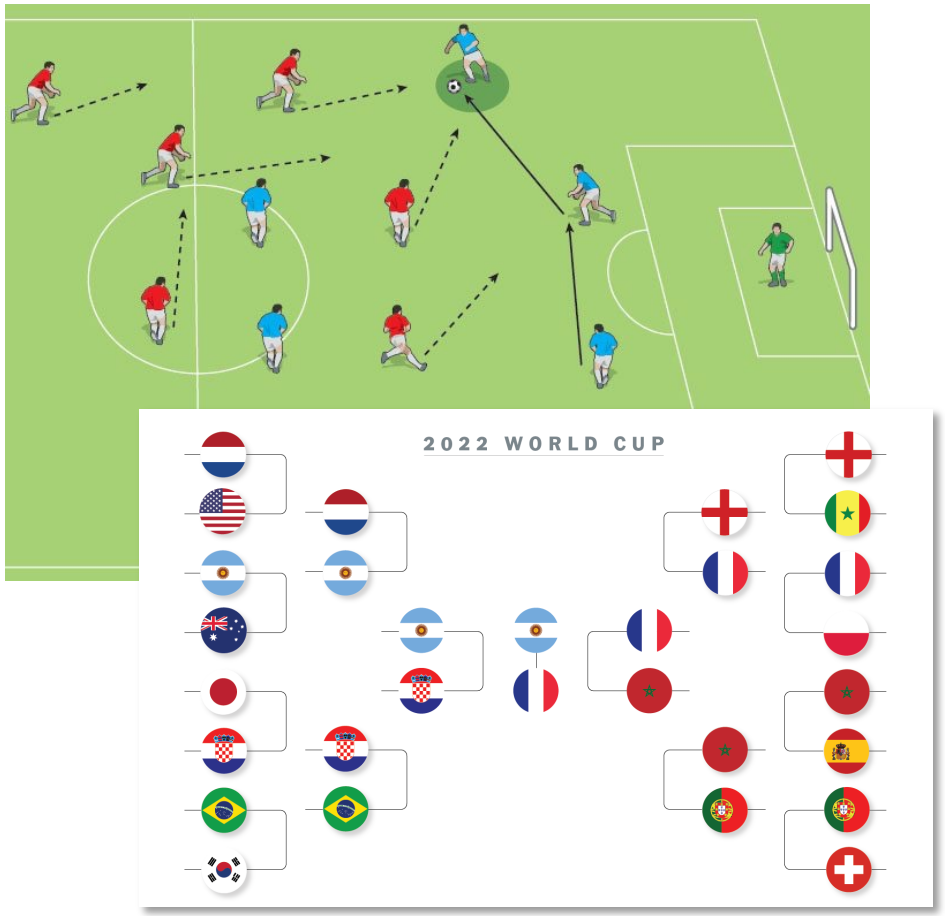
Agenda

- Introduction to the problem
- Approach and Overview of the C-MAF
- Using the C-MAF
- Conclusions/Next Steps

Problem: How do we mature our DE enterprises?

Kick the ball! Kick the ball! Kick the ball!

Set a trap! Regain the ball! Score a goal!



Win the game! Win the group! Win the cup!

Child Swarm: https://www.pomranka.net/soccertalk/004
Steer and Storm Tactic: https://www.soccercoachweekly.net/tactics/steer-and-storm
Cup Tournament: https://static01.nyt.com/images/2022/11/30/sports/world-cup/world-cup-bracket-2/world-cup-bracket-2-mediumSquareAt3X-v15.png

What do we need to do? How do we need to do it?

What: **Broadly, across industry and the US DoD, there is a push to embrace digital engineering (DE).**

This requires the transformation of engineering and systems engineering practice to a digital, model-based form that leads to more rapid and modern capability development.

This is not a binary transformation.

Organizations must determine what levels of digital maturity they exhibit currently and need in the future. This spans DE Environments and infrastructure, workforce development and skills, workflows, and practice. It also spans time.

How: **How does an organization know what to do or where to focus to begin or mature their transformation to full DE?**

That is the key question. There are already a small set of existing frameworks, requirement sets, and capability assessment methods.

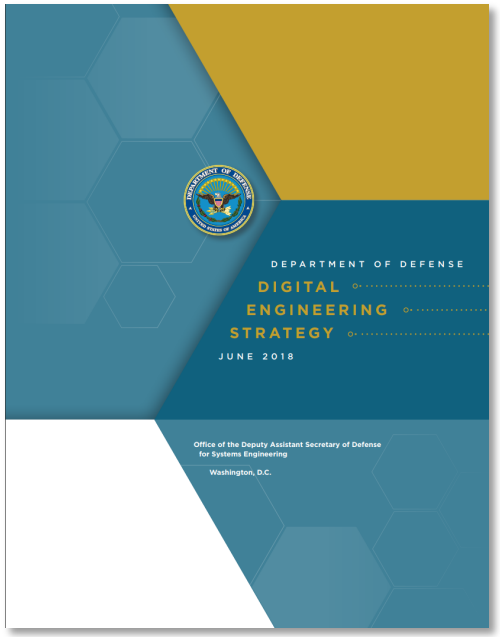
However, each focuses on limited, key areas. None are comprehensive. None articulate clear action.

How does the C-MAF help solve this problem?

The C-MAF synthesizes the information across existing guidance into an integrated capability guidance and maturity assessment framework.

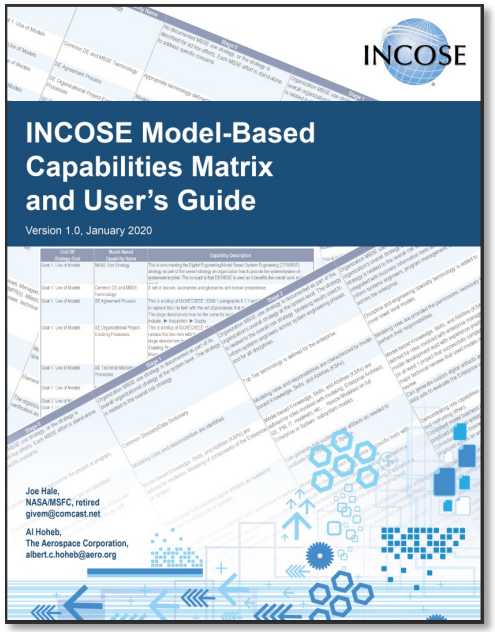
C-MAF is comprehensive. Even so, the concepts are organized in a way that allows organizations to choose – to tailor how much of the content is relevant to their needs.

Strategy



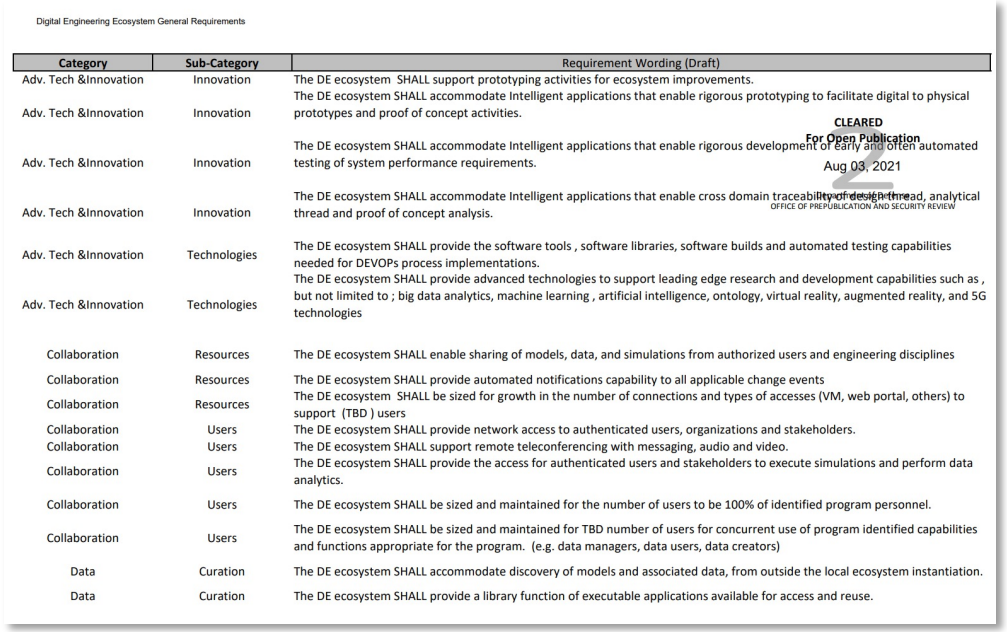
DoD DE Strategy

Processes



INCOSE MBCM

Tooling Requirements



Digital Engineering Ecosystem General Requirements

Category	Sub-Category	Requirement Wording (Draft)
Adv. Tech &Innovation	Innovation	The DE ecosystem SHALL support prototyping activities for ecosystem improvements.
Adv. Tech &Innovation	Innovation	The DE ecosystem SHALL accommodate Intelligent applications that enable rigorous prototyping to facilitate digital to physical prototypes and proof of concept activities.
Adv. Tech &Innovation	Innovation	The DE ecosystem SHALL accommodate Intelligent applications that enable rigorous development of early and often automated testing of system performance requirements.
Adv. Tech &Innovation	Innovation	The DE ecosystem SHALL accommodate Intelligent applications that enable cross domain traceability of design thread, analytical thread and proof of concept analysis.
Adv. Tech &Innovation	Technologies	The DE ecosystem SHALL provide the software tools , software libraries, software builds and automated testing capabilities needed for DEVOPs process implementations.
Adv. Tech &Innovation	Technologies	The DE ecosystem SHALL provide advanced technologies to support leading edge research and development capabilities such as , but not limited to ; big data analytics, machine learning , artificial intelligence, ontology, virtual reality, augmented reality, and 5G technologies
Collaboration	Resources	The DE ecosystem SHALL enable sharing of models, data, and simulations from authorized users and engineering disciplines
Collaboration	Resources	The DE ecosystem SHALL provide automated notifications capability to all applicable change events
Collaboration	Resources	The DE ecosystem SHALL be sized for growth in the number of connections and types of accesses (VM, web portal, others) to support (TBD) users
Collaboration	Users	The DE ecosystem SHALL provide network access to authenticated users, organizations and stakeholders.
Collaboration	Users	The DE ecosystem SHALL support remote teleconferencing with messaging, audio and video.
Collaboration	Users	The DE ecosystem SHALL provide the access for authenticated users and stakeholders to execute simulations and perform data analytics.
Collaboration	Users	The DE ecosystem SHALL be sized and maintained for the number of users to be 100% of identified program personnel.
Collaboration	Users	The DE ecosystem SHALL be sized and maintained for TBD number of users for concurrent use of program identified capabilities and functions appropriate for the program. (e.g. data managers, data users, data creators)
Data	Curation	The DE ecosystem SHALL accommodate discovery of models and associated data, from outside the local ecosystem instantiation.
Data	Curation	The DE ecosystem SHALL provide a library function of executable applications available for access and reuse.

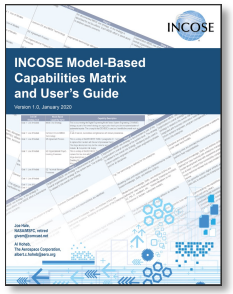
DoD DE Eco Requirements

More detail about the C-MAF sources

The 2018 DoD DE Strategy has 5 main goals that are then broken down into a total of 14 goal components.

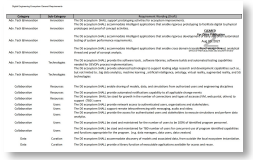
Further, sub-component focus areas are specified and bolded in the strategy. This level of detail was used as the foundation for articulating actionable DE concepts in the C-MAF.

The INCOSE MBCM was vetted by DoD and industry as it was created.



Uniquely among the source documents, it defines levels of maturity to achieve the actions. In its current format, specific action goals can be hard to discern. Discovering the actual "capability" to a meaningful level of understanding largely requires reading through all of the maturity level descriptions. It aligns only at the highest, 5 main goal level to the 2018 DoD DE Strategy.

The DE Ecosystem Requirements is the only source that gets into detail with respect to what capabilities areas are needed to implement a DE Ecosystem.



It is all about tools, networking, security, interoperability, etc.

What are the guidance sources and what do they cover?

- Individually, the guidance sources cover the ‘why’, ‘what’, and ‘how well’.
- Collectively, they cover the three most important pillars for setting, executing, and measuring maturation progress towards a strategy.

Source	Reason for use (or what question is being answered)	**Concepts of policy or guidance activities/ capabilities** that would need to exist **at an enterprise level**	**Concepts of maturity** (i.e., to what level an organization is doing things)	**Explicit DE Ecosystem requirements** from tooling and interoperability capability perspectives
2018 DoD Digital Engineering Strategy	**The “why”:** Primary source for direction and action.			
INCOSE Model-Based Capability Maturity Matrix (MBCM)	**The “what”:** Workflow and organization concept focus. Primary source for maturity concepts.			
DoD DE Ecosystem Requirements	**The “how (well)”:** Out of OUSD(R&E). Only source with solid tooling focus, but does not cover concepts outside the DE Environment.			

* NOTE: DAF does have a Digital Maturity Guide, but the guide alone lacks the comprehensiveness or detail to be directly actionable.
The source workbook may have more detail. (https://guide.dafdto.com/wp-content/uploads/2023/03/DAF-Digital-Maturity-Guide_v2.0_PA.pdf)

C-MAF organization and how it harmonizes across sources

C-MAF starts by defining a **three part organizational structure:**

1. **High-level capability category** directly aligned to the **5 main goals** of the DoD DE Strategy
2. **Focus Area** directly aligned with the **14 focus areas** in the DoD DE strategy
3. **Sub-Components** derived from the additional detail under each of the 14 focus areas in the DoD DE Strategy

Then, C-MAF defines an **Activity Description**.

This is the specific "What you need to do" description lacking in the INCOSE MBCM.
It is based on the sub-component activity description from the cited DoD Strategy portion.

Each Activity Description is then expanded with **levels of maturity 0 – 4**.

These are derived from the INCOSE MBCM to the extent possible.
If a concept is lacking in the INCOSE MBCM, they are modeled directly off of its style and intent.

The DoD Eco Requirements were used to augment the content or provide more implementation specificity where needed.*

C-MAF Example Activity Description

Capability Category	Focus Area	Sub-Component (Activity)	C-MAF Activity Description
Formalized Development, Integration, and Use of Models	Planning: Model Use and Integration	Model Use to Integrate Work and Represent System of Interest	Establish an approach that uses models to enable the orchestration of activities, the efficient management of work, and the integration of work products across enterprises and multidisciplinary teams to result in a digital representation of the system of interest.

The activity of value that the organization wants to mature:

Establish an approach that uses models to enable the orchestration of activities, the efficient management of work, and the integration of work products across enterprises and multidisciplinary teams to result in a digital representation of the system of interest.

C-MAF Maturity Levels

Maturity Stage 0	Maturity Stage 1	Maturity Stage 2	Maturity Stage 3	Maturity Stage 4
"The thing" does not exist or is ad hoc.	The organization has identified "the thing"	The organization has communicated and has started implementing "the thing"	The organization is refining and maturing "the thing"	The organization is mature in its digital practice regarding "the thing“.

- **C-MAF maturity levels are both granular to something identifiable and non-specific to how to implement it**
  - Meant to be easily understandable and applicable across multiple DE supporting disciplines
  - Does not require large investment in training for use by leaders and workforce
  - Up to the organization to decide on how to measure each stage
- **They are not quantitative in nature**
  - Facilitates strategic decision making
  - There are no ‘sub-levels’ of maturity (avoids paralysis by over analysis)
  - Measurements should be chosen based on ease of use and understanding (avoid over thinking them)

C-MAF Example Activity Maturity Levels

Maturity Stage 0	Maturity Stage 1	Maturity Stage 2	Maturity Stage 3	Maturity Stage 4
"The thing" does not exist or is ad hoc.	The organization has identified "the thing".	The organization has communicated and has started implementing "the thing".	The organization is refining and maturing "the thing".	The organization is mature in its digital practice regarding "the thing". "The thing" is standard operating procedure and has metrics that tracks and maintains consistency of its use across time.

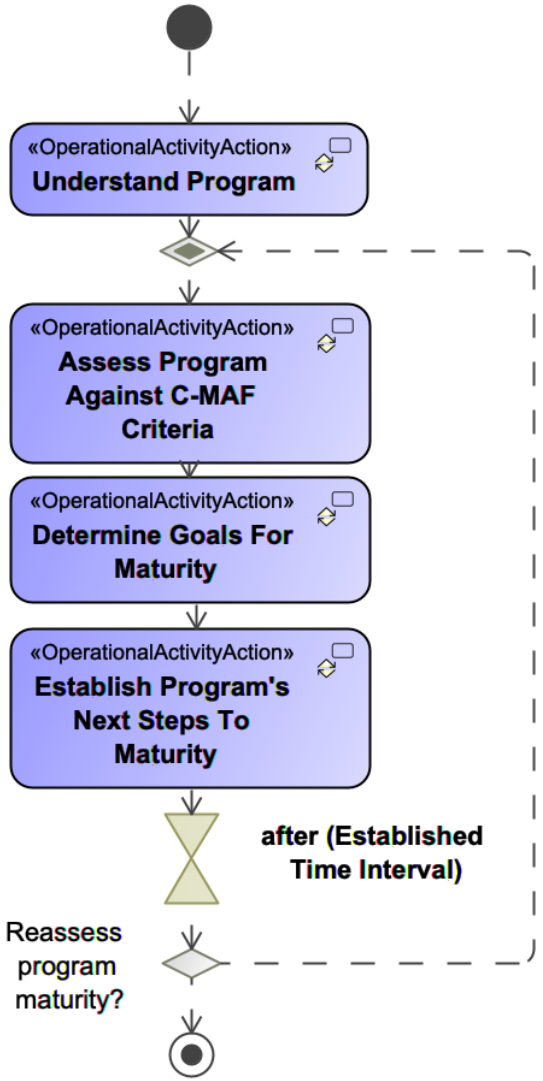
Maturity Stage 0	Maturity Stage 1	Maturity Stage 2	Maturity Stage 3	Maturity Stage 4
There are no codified plans for model use across technical engineering and systems engineering activities **relevant to the business needs of the organization**.	**The business needs of the organization are identified** as are the **types of models, simulations, and engineering activities necessary** to represent the system of interest**.**	**A formal plan and set of procedures to integrate data and models with technical and business information tools** used by the organization **are established.**	**The processes whereby data, models, and digital artifacts will be used to guide business practices and program decisions are defined**. A plan is in place to establish traceability between models and the solution components those models represent.	**All of the prior components described are implemented consistently across the organization.** Models and digital artifacts are used to guide business practices and program decisions. Metrics have been defined to guide consistent orchestration of digital engineering activities and implementation of model-based practices.

C-MAF Example Activity Description and Maturation

Capability Category	Focus Area	Sub-Component (Activity)	C-MAF Activity Description
Formalized Development, Integration, and Use of Models	Planning: Model Use and Integration	Model Use to Integrate Work and Represent System of Interest	Establish an approach that uses models to enable the orchestration of activities, the efficient management of work, and the integration of work products across enterprises and multidisciplinary teams to result in a digital representation of the system of interest.

Maturity Stage 0	Maturity Stage 1	Maturity Stage 2	Maturity Stage 3	Maturity Stage 4
There are no codified plans for model use across technical engineering and systems engineering activities **relevant to the business needs of the organization**.	**The business needs of the organization are identified** as are the **types of models, simulations, and engineering activities necessary** to represent the system of interest**.**	**A formal plan and set of procedures to integrate data and models with technical and business information tools** used by the organization **are established.**	**The processes whereby data, models, and digital artifacts will be used to guide business practices and program decisions are defined**. A plan is in place to establish traceability between models and the solution components those models represent.	**All of the prior components described are implemented consistently across the organization.** Models and digital artifacts are used to guide business practices and program decisions. Metrics have been defined to guide consistent orchestration of digital engineering activities and implementation of model-based practices.

How can my organization use the C-MAF?



The C-MAF provides a meaningful tool for assessment grounded in guidance across some specific use cases highly relevant to organizations seeking to:

i. **Begin a DE transformation**,

   i.e., needing to understand specifically what they need to consider and do in a way that allows them to prioritize in line with their unique role and objectives,

ii. **Determine where they are** in a DE transformation that is already underway, **discover** what **capability gaps** they might have, and **determine what is next**.

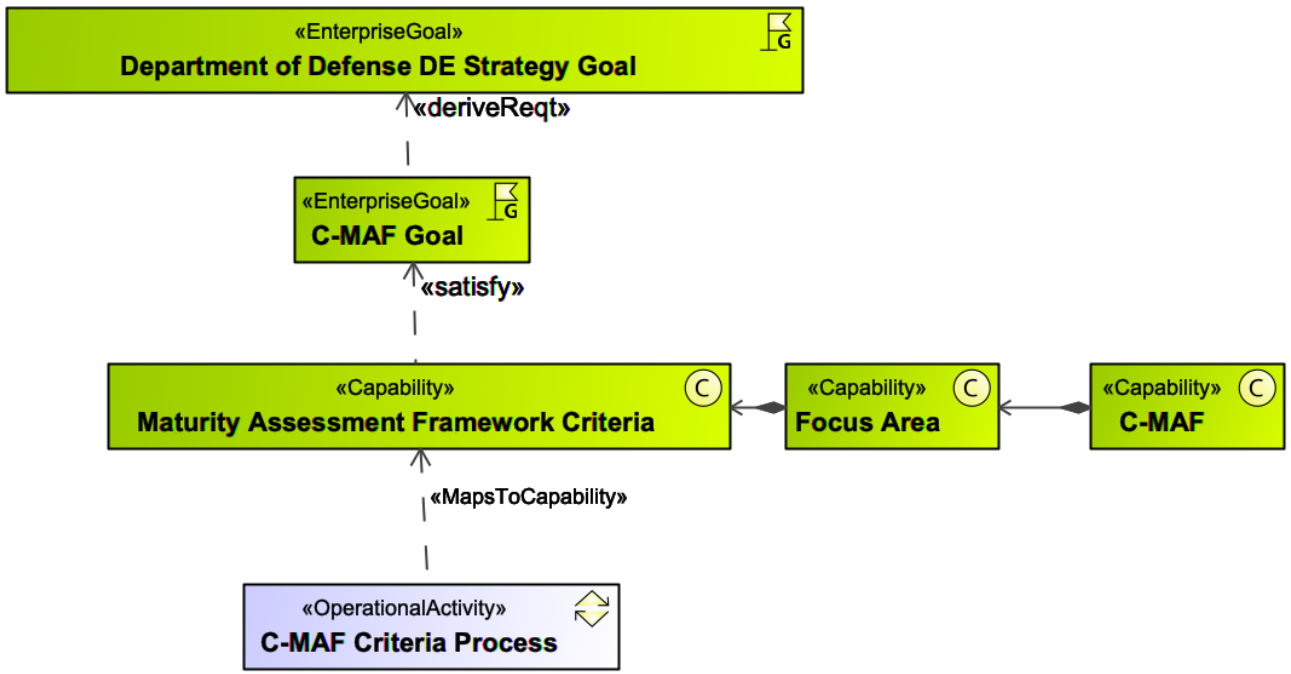
iii. **Determine their own custom profile** with respect to levels of capability maturity they need **to effectively accomplish** their **business objectives** in order to:

   a) structure and identify priorities for capture in a Request for Proposal (RFP), or

   b) evaluate profiles for vendor responses to an RFP.

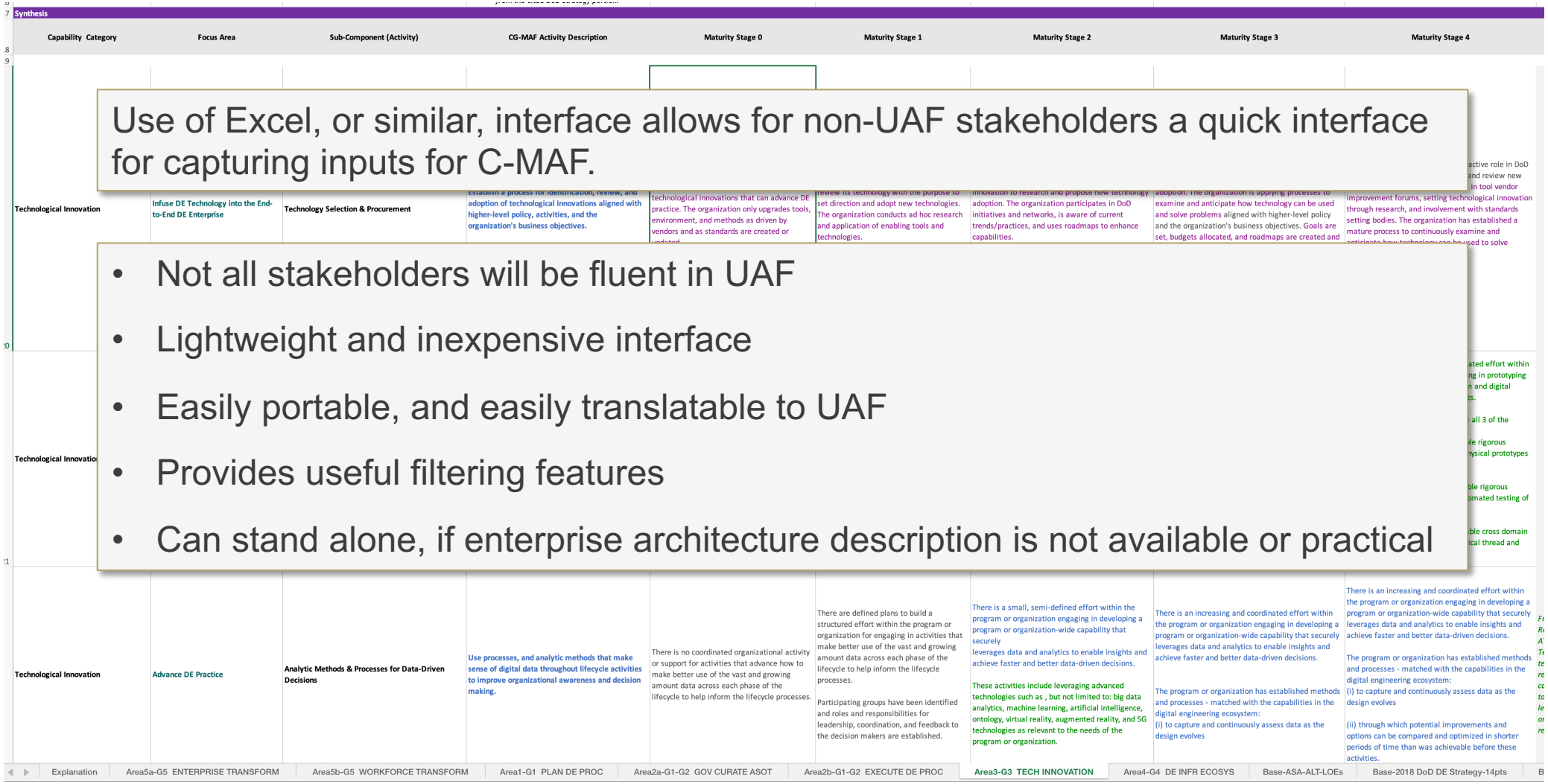
In each of these cases, the insight gleaned could be for an organization's internal continuing maturation and to communicate their status to a higher-level organization.

Tying in UAF: Tracing of C-MAF to Enterprise Goals



- Leverage the strengths of UAF to define and track enterprise-level concerns.
- Integrates with existing enterprise architecture captured in UAF.
- Designed to help expose necessary trade spaces and avoid chasing solutions (e.g. systems and tools) up front.
- Intent is to guide investments across time to help the enterprise mature towards its own goals.

Tabular Formatted Interface



Synthesis

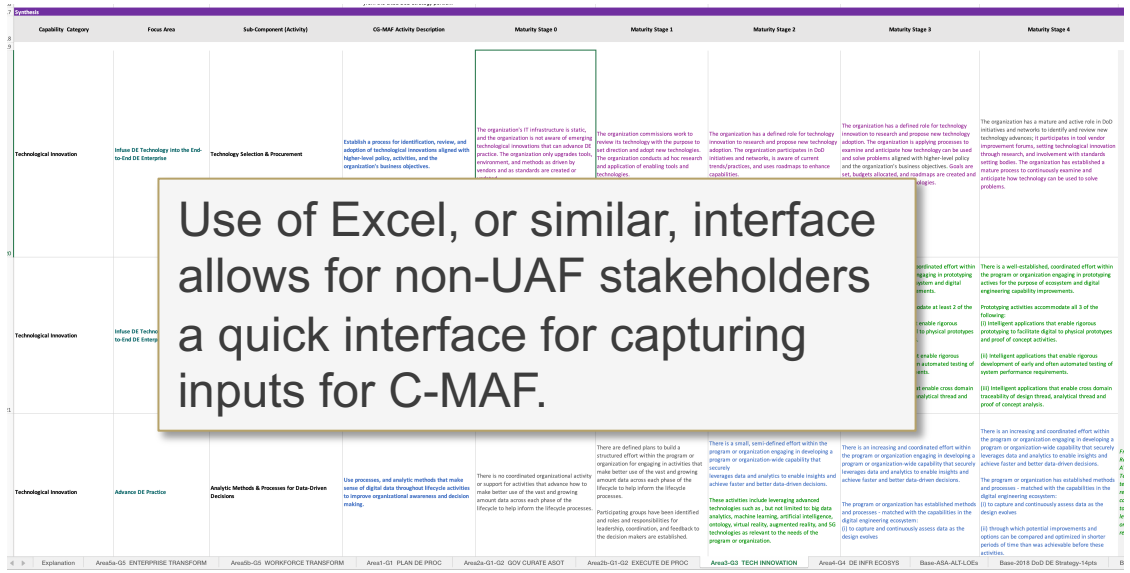
Capability Category	Focus Area	Sub-Component (Activity)	CG-MAF Activity Description	Maturity Stage 0	Maturity Stage 1	Maturity Stage 2	Maturity Stage 3	Maturity Stage 4
Technological Innovation	Infuse DE Technology into the End-to-End DE Enterprise	Technology Selection & Procurement	Establish a process for identification, review, and adoption of technological innovations aligned with higher-level policy, activities, and the organization's business objectives.	technological innovations that can advance DE practice. The organization only upgrades tools, environment, and methods as driven by vendors and as standards are created or	review its technology with the purpose to set direction and adopt new technologies. The organization conducts ad hoc research and application of enabling tools and technologies.	innovation to research and propose new technology adoption. The organization participates in DoD initiatives and networks, is aware of current trends/practices, and uses roadmaps to enhance capabilities.	adoption. The organization is applying processes to examine and anticipate how technology can be used and solve problems aligned with higher-level policy and the organization's business objectives. Goals are set, budgets allocated, and roadmaps are created and	improvement forums, setting technological innovation through research, and involvement with standards setting bodies. The organization has established a mature process to continuously examine and
Technological Innovatio								
Technological Innovation	Advance DE Practice	Analytic Methods & Processes for Data-Driven Decisions	Use processes, and analytic methods that make sense of digital data throughout lifecycle activities to improve organizational awareness and decision making.	There is no coordinated organizational activity or support for activities that advance how to make better use of the vast and growing amount data across each phase of the lifecycle to help inform the lifecycle processes.	There are defined plans to build a structured effort within the program or organization for engaging in activities that make better use of the vast and growing amount data across each phase of the lifecycle to help inform the lifecycle processes. Participating groups have been identified and roles and responsibilities for leadership, coordination, and feedback to the decision makers are established.	There is a small, semi-defined effort within the program or organization engaging in developing a program or organization-wide capability that securely leverages data and analytics to enable insights and achieve faster and better data-driven decisions. These activities include leveraging advanced technologies such as , but not limited to: big data analytics, machine learning, artificial intelligence, ontology, virtual reality, augmented reality, and 5G technologies as relevant to the needs of the program or organization.	There is an increasing and coordinated effort within the program or organization engaging in developing a program or organization-wide capability that securely leverages data and analytics to enable insights and achieve faster and better data-driven decisions. The program or organization has established methods and processes - matched with the capabilities in the digital engineering ecosystem: (i) to capture and continuously assess data as the design evolves	There is an increasing and coordinated effort within the program or organization engaging in developing a program or organization-wide capability that securely leverages data and analytics to enable insights and achieve faster and better data-driven decisions. The program or organization has established methods and processes - matched with the capabilities in the digital engineering ecosystem: (i) to capture and continuously assess data as the design evolves (ii) through which potential improvements and options can be compared and optimized in shorter periods of time than was achievable before these activities.

Explanation | Area5a-G5 ENTERPRISE TRANSFORM | Area5b-G5 WORKFORCE TRANSFORM | Area1-G1 PLAN DE PROC | Area2a-G1-G2 GOV CURATE ASOT | Area2b-G1-G2 EXECUTE DE PROC | Area3-G3 TECH INNOVATION | Area4-G4 DE INFR ECOSYS | Base-ASA-ALT-LOEs | Base-2018 DoD DE Strategy-14pts | B

Use of Excel, or similar, interface allows for non-UAF stakeholders a quick interface for capturing inputs for C-MAF.

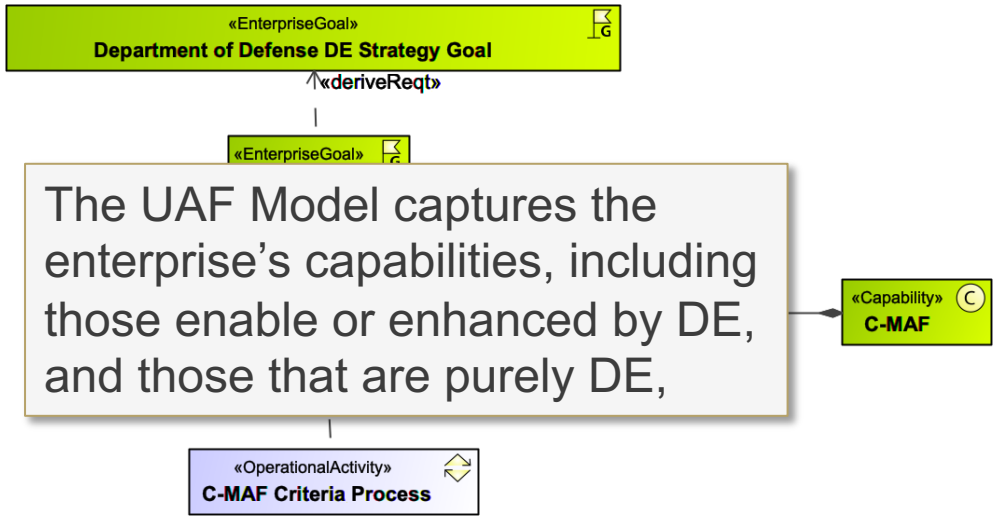
- Not all stakeholders will be fluent in UAF
- Lightweight and inexpensive interface
- Easily portable, and easily translatable to UAF
- Provides useful filtering features
- Can stand alone, if enterprise architecture description is not available or practical

Tabular Formatted Interface



Use of Excel, or similar, interface allows for non-UAF stakeholders a quick interface for capturing inputs for C-MAF.

The MBSE architecture team takes the inputs and imports them into the UAF model. They then use the inputs to capture the future "to-be" enterprise capabilities, metrics that will track progress, timelines of progress, and any new enterprise roles, operations, and resources that will be needed.



The UAF Model captures the enterprise's capabilities, including those enable or enhanced by DE, and those that are purely DE,

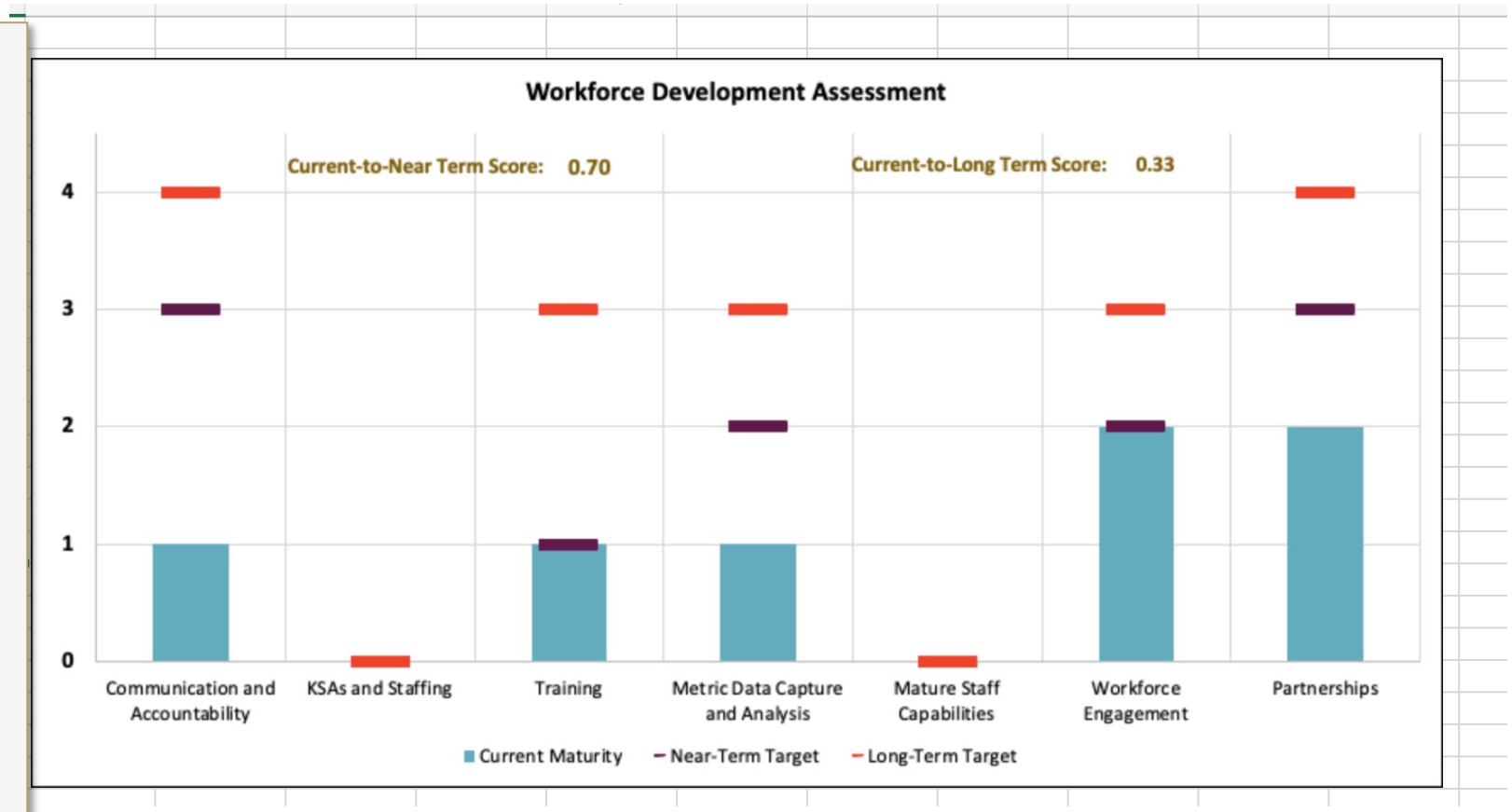
The Excel interface is populated from a UAF model that has already captured the enterprise capabilities.

Results Dashboard

- Provides a **quick overview of organization's maturity**.
- Intent is to **provide stakeholders a means to make strategic choices** (technology investments, broad stroke or large group discipline training) **and tactical choices** (small tools investments, some individual trainings).
- Intent is also to help **inform strategy shaping, technology investments, and technology obsolescence divestments**.
- Finally, this is meant to be a living, breathing assessment. **It works best when used once or twice yearly**.

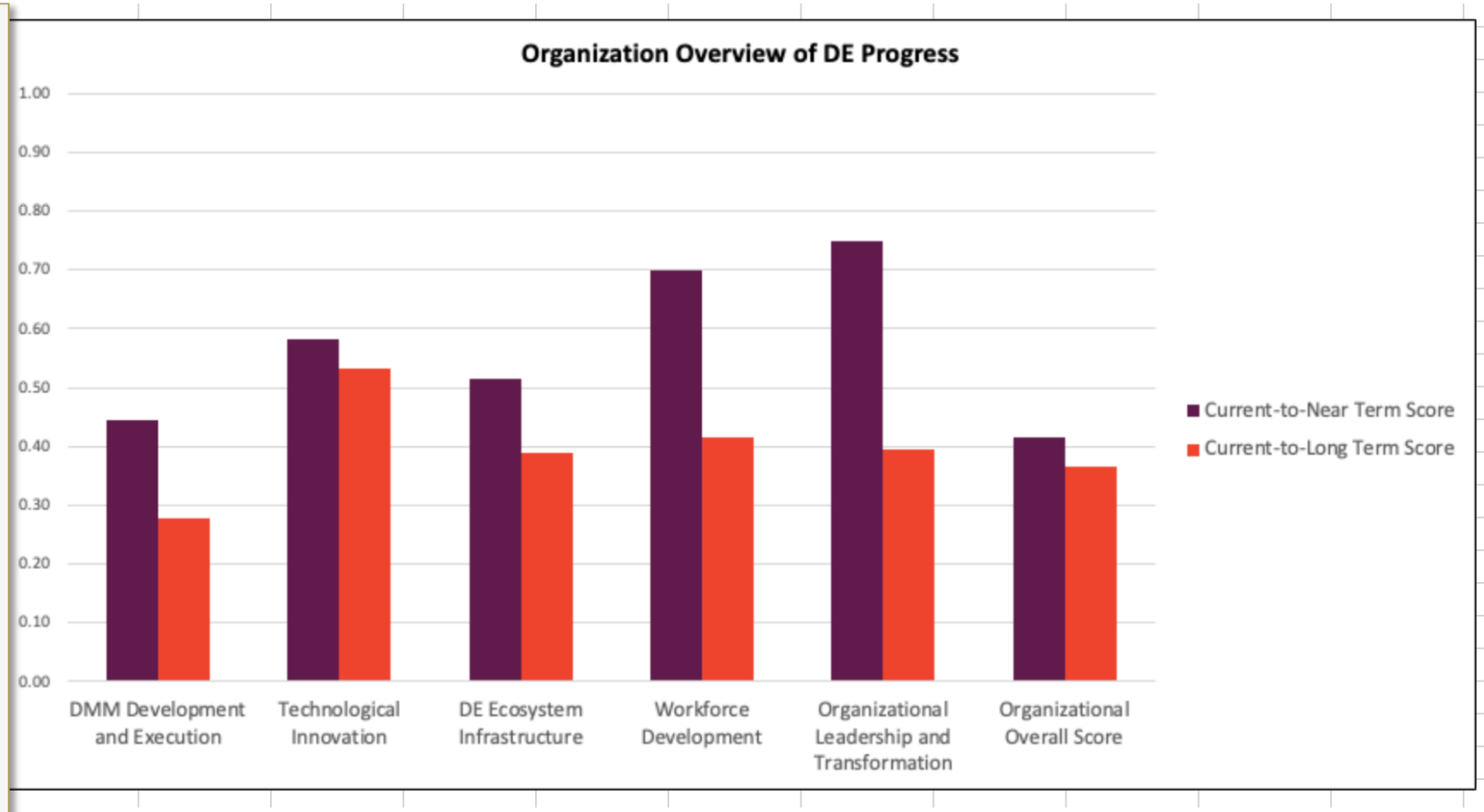
Results Dashboard – Workforce Dev Assessment

- Red lines indicate long term desired level of maturity
- Black lines indicate short term desired level of (sufficient) maturity
- Blue lines indicate current level of maturity
- ‘Empty’ areas indicate maturity areas that are not important



Results Dashboard – Overview of Progress

- Serves a quick look to assess relative progress
- Currently a basic average of each individual dashboard
- Different rollup methodology (e.g. weighted averages) can be used instead
- Again, this measures relative progress toward maturity goals; not absolute metrics.



How should my organization use the C-MAF?

- **It is not all or nothing.**
  - Your organization can use the portions of the C-MAF that you determine relevant to your organization's transformation goals.
  - C-MAF does not state how you meet your goals, only what types of things must be down to meet your maturity goals.
- **C-MAF does not have standard evaluation scales and values, only standardized definitions of maturity**
  - Your organization can define the values for measuring each maturity level criteria, and normalize across the criteria that best fits your needs.
- **I'm not a DoD or DoD-aligned organization. Will this work for me?**
  - Yes, as most of the DE Strategy and DE Ecosystem Requirements can apply to any large SE-focused enterprise.
  - C-MAF can be modified to your own organization's DE strategy and DE ecosystem requirements.
  - Do keep in mind the scope and intent of the DoD's DE Strategy and DE Ecosystem Requirements when crafting your own set.

Customizing the C-MAF – Sources

- The INCOSE MBCM forms the foundation for workflows, organizational concept, and maturity concepts
- Your organization can create your own DE strategy, and DE ecosystem or environment requirements
  - Follow the pattern of identifying goals and related focus areas in your DE strategy
  - Follow the pattern of capturing tooling, performance, standards-based interoperability needs in your DE ecosystem and/or environments requirements set

C-MAF Capability Category	Company DE Strategic Guidance Goals	Company's DE Strategy Focus Areas	INCOSE MBCM and other sources important to your organization
Organizational Leadership & Transformation	1	1.1, 1.2	INCOSE MBCM Company SEP outline v1.2

Customizing the C-MAF – Maturity Levels

- If you change the Strategic Goals, Focus Areas, and DE Ecosystem requirements, you may need to adjust the maturity stages
- Keep in mind that you should not stray too far from the MBCM guidance

CG-MAF Activity Description	Maturity Stage 0	Maturity Stage 1	Maturity Stage 2	Maturity Stage 3	Maturity Stage 4
Identify and activate leadership teams to manage and implement workforce transformation efforts that communicate and execute the vision and are held accountable for improving results.	There are no identified leadership teams (e.g., champions, sponsors, etc.) that are accountable and actively participating in managing and implementing workforce transformation efforts.	Leadership teams (e.g., champions, sponsors, etc.) accountable and actively participating in managing and implementing workforce transformation efforts are ~~identified and in place~~ are planned and budget allocated.	Leadership has ~~developed and implemented open and frequent communication strategies through multiple channels~~ funded collaboration meetings to provide awareness and a common understanding to stakeholders across disciplines and organizations related to workforce transformation.	Leadership teams have provided ~~identified barriers to workforce transformation and are removing them by providing resources,aligned with established priorities and key milestones. A~~ mechanisms for people to ask questions and provide feedback ~~has been established.~~	Accountability to measure, foster, demonstrate, and improve tangible results directly related to workforce transformation across programs and the enterprise is established via defined leadership roles and informed by metric data.

Closing thoughts: Advantages of C-MAF Approach

C-MAF Approach	Advantage
Clear C-MAF Activity Description on precisely what an organization needs to do upfront	Expressed in organizationally implementable language
Three part organizational structure	Easily identifiable guidance for traditional organizational leadership structure
5 Capability Groupings that are aligned with an organizational accountability structure	Easily identifiable areas of execution
Tailorable to organizational needs	Implementable without concern for losing the benefit of best practices of the DE community
Conceptually aligns with INCOSE MBCM	Internationally recognized process-based maturity standard

Closing thoughts: Next Steps

- Validation through use of DE C-MAF
  (started, and ongoing, completion end of Dec 24)

- Creation of dash board in descriptive modeling tools
  (targeted end of Dec 24)

- Accompanying User's Guide
  (started, completion date end of Aug 24)

  – Will include both tabular interface and UAF guidance

Closing thoughts: DE Victory through CMAF!

C-MAF provides a meaningful tool for DE assessment to organizations seeking to b**egin a DE transformation**, determine where they are, and what is next.

C-MAF is tailorable to an organization's needs to include strategy and technical requirements

C-MAF can be used as **part of** a organization's architecture roadmap to **DE adoption and execution.**

https://coloradopreps.com/broomfield-holds-off-denver-east-to-win-5a-boys-soccer-championship/

Contact Information

Mike Shearin mike.shearin@gtri.gatech.edu

Dr. Val Sitterle valerie.sitterle@gtri.gatech.edu

Zac Connor zachary.connor@gtri.gatech.edu

References

CMAF is derived directly from the following:

- United State Department of Defense Digital Engineering Strategy 2018 https://apps.dtic.mil/sti/citations/AD1068564
- DoD Digital Engineering Ecosystem General Requirements https://ac.cto.mil/wp-content/uploads/2022/12/Digital-Engineering-Ecosystem-General-Requirements.pdf
- INCOSE Model-Based Capability Matrix https://www.incose.org/docs/default-source/default-document-library/leading-mbse-transformation_v5.pdf?sfvrsn=48e59bc6_0

Other References

- Systems Engineering Research Center Report SERC-2020-TR-002 https://sercuarc.org/wp-content/uploads/2020/06/SERC-TR-2020-002-DE-Metrics-6-8-2020.pdf
- Hutchison, N. and Tao, H.Y.S. (2022), The Digital Engineering Competency Framework (DECF): Critical Skillsets to Support Digital Transformation. INSIGHT, 25: 35-39. https://doi.org/10.1002/inst.12396 Also: https://sercuarc.org/decf-review/

Other References

- Systems Engineering Research Center Report SERC-2020-TR-002 https://sercuarc.org/wp-content/uploads/2020/06/SERC-TR-2020-002-DE-Metrics-6-8-2020.pdf

C-MAF sourcing

C-MAF Capability Category	2018 DoD DE Strategy Main Goal Alignment	DoD DE Strategy Focus Area Alignment	INCOSE MBCM and other sources used for augmentation
Digital Engineering (DE) Development and Execution	1, 2	1.2, 1.3, 2.3	INCOSE MBCM
Technological Innovation	3, 4	3.1, 3.2, 4.2	INCOSE MBCM DE Ecosystem Requirements
DE Ecosystem Infrastructure	4	4.1, 4.2, 4.3	INCOSE MBCM DE Ecosystem Requirements
Organizational Leadership & Transformation	5	5.1, 5.2 INCOSE MBCM augmentation	INCOSE MBCM
Workforce Development	5	5.2, 5.3	INCOSE MBCM

DoD SEP: https://ac.cto.mil/wp-content/uploads/2023/05/SEP-Outline-4.1.pdf

(Additional sources are sometimes included for reference, e.g., the SERC's Digital Engineering Competency Framework (DECF) in Workforce Development. This level of detail is not copied for the C-MAF, however.)