Data Element Mapping and Analysis (DEMA): A Systematic Method to Implement a Complete Digital Thread

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Dr. Allison B. Ledford

Assistant Research Professor

Industrial and Systems Engineering

Auburn University

The Big Picture

The terms “digitization” and “digitalization” are often confused with one another. [1]

- Digitization is the computerization of manual activities.
- Digitalization is the fundamental restructuring of an existing process to improve connectivity and information flows while taking advantage of digital capabilities.

Figure 1: Picture from Open Rights Group [2]

The Goals of Digital Engineering

The Department of Defense 2018 Digital Engineering Strategy [3] defines digital engineering:

- As "an ***integrated digital approach*** that uses authoritative sources of system data and models."
- Where the "approach is to securely and safely connect ***people, processes, data, and capabilities*** across an end-to-end digital enterprise."

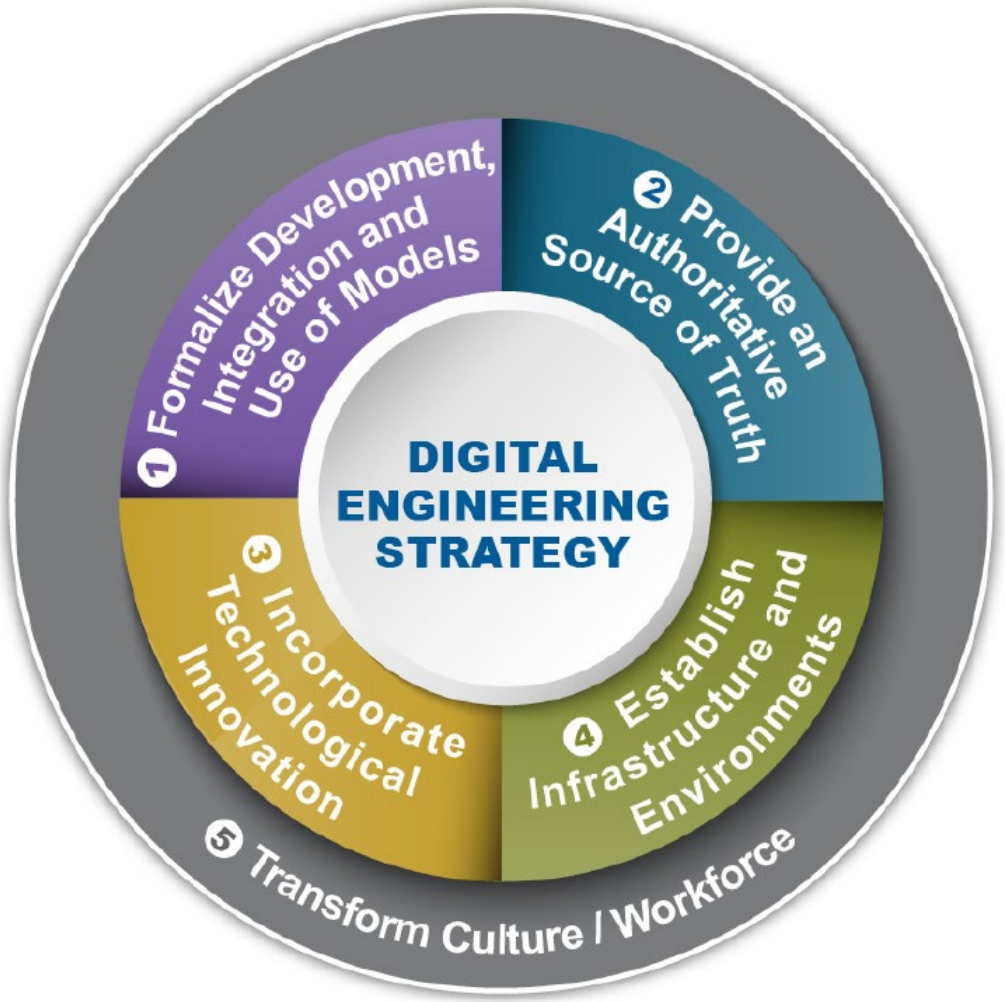


Figure 1: Digital Engineering Goals from 2018 DoD Digital Engineering Strategy [3]

Defining the Data

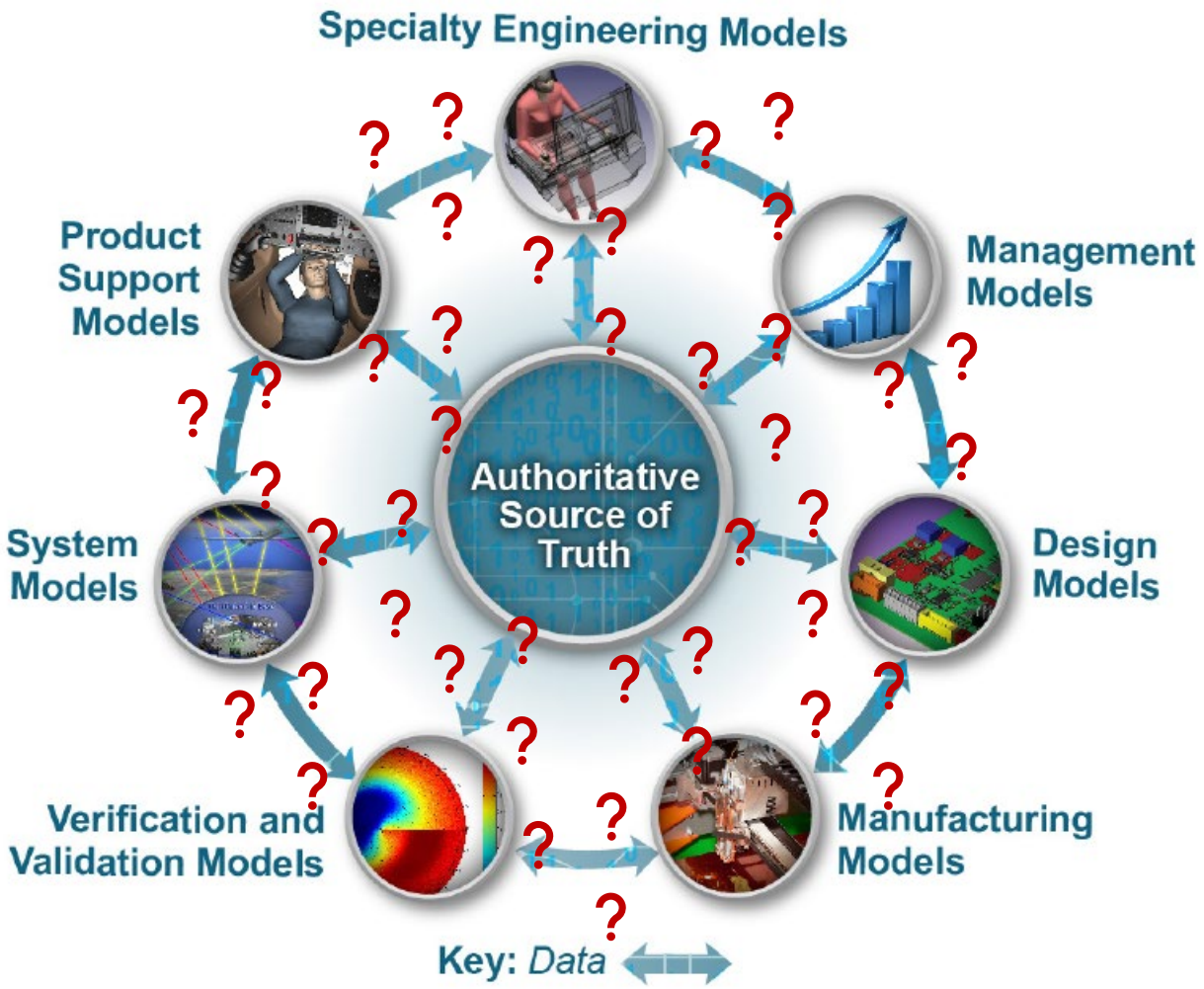


Figure 3: Adapted from Authoritative Source of Truth Figure from 2018 DoD Digital Engineering Strategy [3]

From our research [4][5]:

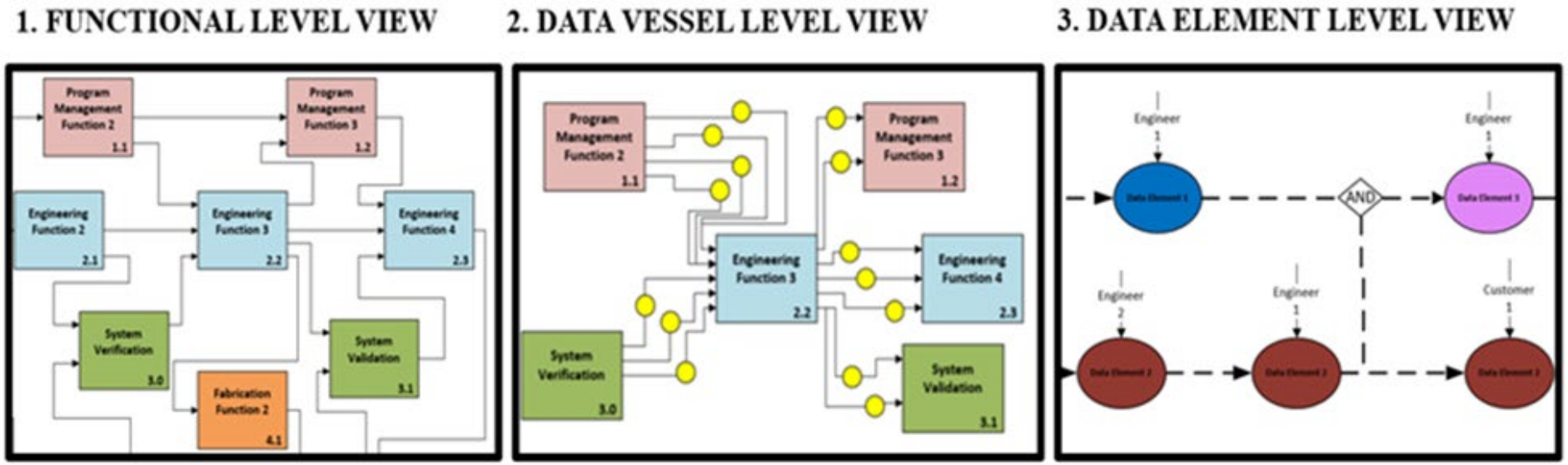
- Over 95% of data handling is unknown and nonstandard (hidden to the organization).
- Greater than 50% of data vessel inputs and outputs are unstructured.
- Greater than 90% of data element exchanges are manual.

The Need for DEMA

- Previous research concerning the Digital Thread and the Model Based Enterprise have been almost solely focused on the software, syntax, standards, and semantics necessary for data exchanges. [4]
  - While the previous work done to enable infrastructure is essential to the realization of the Digital Thread, infrastructure itself does not constitute or automatically create the Digital Thread.
- There is limited research within the field of modeling the efficiency of data and information flows quantitatively. [4]
- There are no visual mapping techniques that moves beyond a functional and document view to achieve a data element level view. [4][5]
  - As no such tool currently exist, there is also a significant gap in the research concerning the application and quantifiable proof of efficacy of such a tool.
  - Recognition that systems engineering philosophies need to be applied to enable digitalization [6][7][8].

DEMA Overview

- Therefore, a significant gap exists in providing analytical tools that can be used alongside infrastructure technologies for the realization of the Digital Thread and Model-Based Enterprise.
- Data Element Mapping and Analysis (DEMA) fills this gap by offering a systematic method for the standardized capture, mapping, and analysis of data threads for digital system understanding and architecture.
  - Combines traditional functional analysis, systems engineering elicitation, and novel data mapping techniques to provide a wholistic view of a system's data and information flows down to the data element level.
  - DEMA is currently not a software, it is an approach to be used with process mapping software and Excel.



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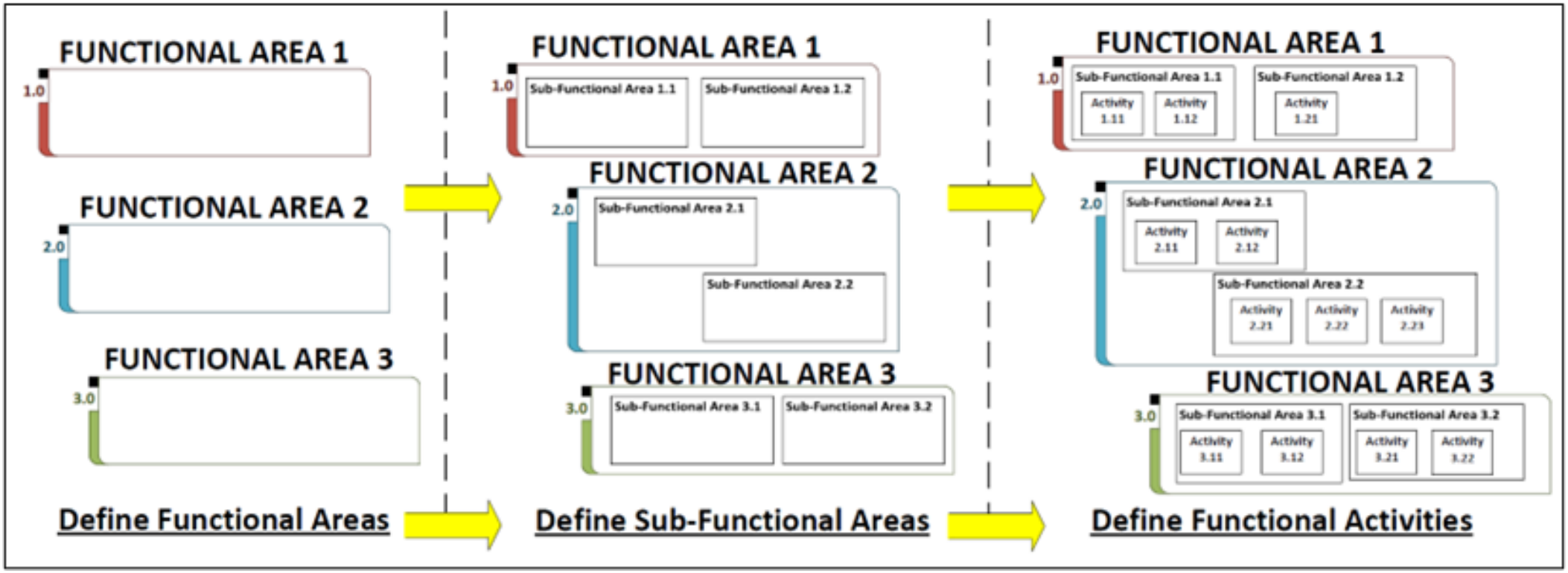
Functional Level View



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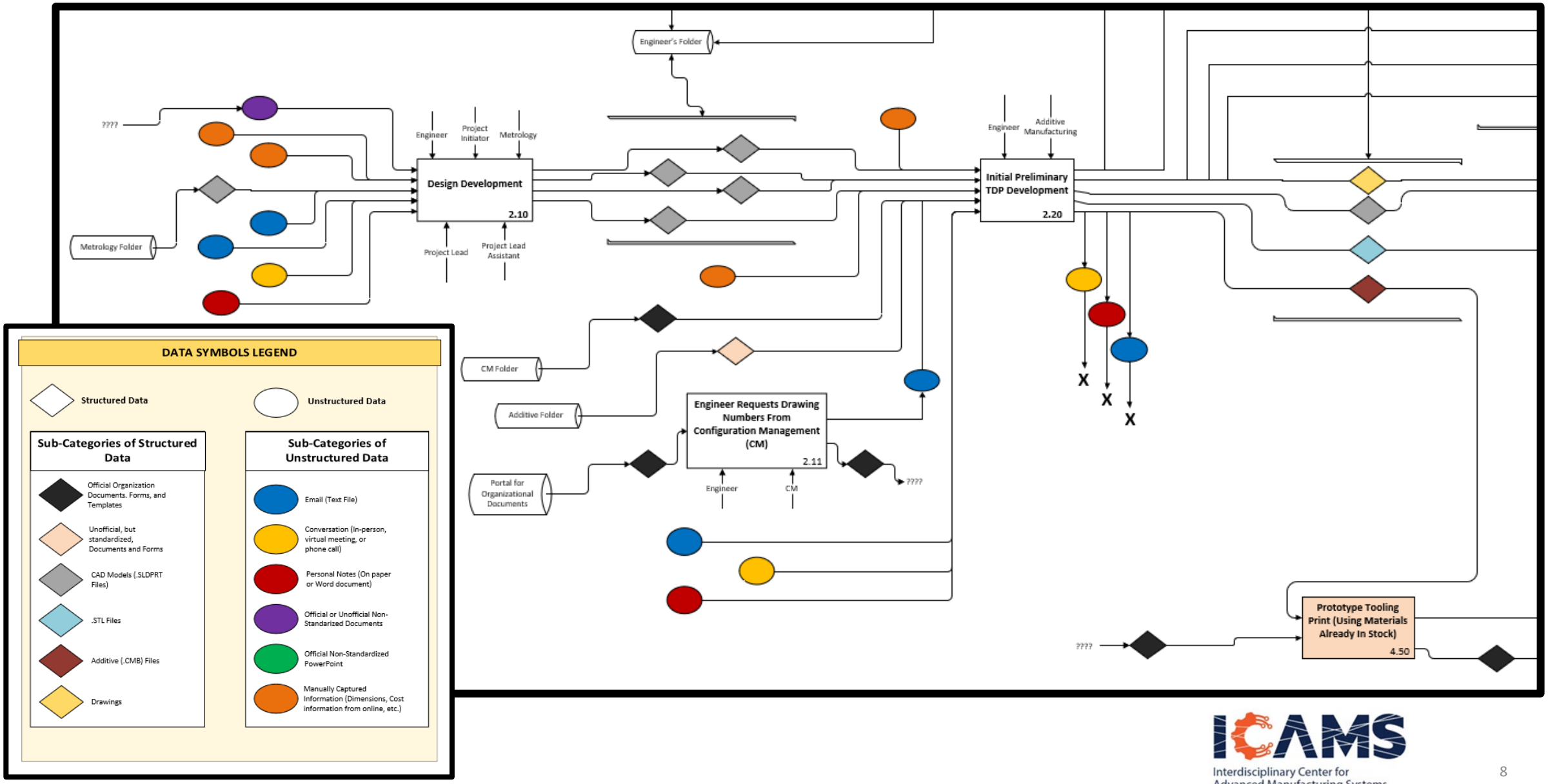
Data Vessel Level View



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Data Element Level View

	A	B	C	D	E	F	G	H	I	J	K
1	Instance ID	Data Element ID	Data Element	Functional Activity	Data Vessel Name (from Compiled Data)	Linked to Instance ID	Data Vessel Type	Data Vessel Form	Place Where Vessel Resid	Actor 1	Actor 2
12	11	E7	Dimensions of Component 2	Design Development 2.10	None	10	None	Observation	Internet	Engineer 1	N/A
13	12	E7	Dimensions of Component 2	Design Development 2.10	Personal Notes takens by Engineer 1 of Components	11	Non-Digital	Paper	Physical Storage	Engineer 1	N/A
16	15	E7	Dimensions of Component 2	Initial Preliminary TDP Development 2.20	Initital CAD Model of Component 2	12	CAD Model	Native CAD	Engineer 1's Personal Repository	Engineer 1	N/A
17	16	E7	Dimensions of Component 2	Initial Preliminary TDP Development 2.20	Initital CAD Model of Component 2	15	CAD Model	Native CAD	Engineer 1's Personal Email Directory and Engineer 2's Personal Email Directory	Engineer 1	Engineer 2
18	17	E7	Dimensions of Component 2	Initial Preliminary TDP Development 2.20	Initital CAD Model of Component 2	16	CAD Model	Native CAD	Engineer 2's Personal Repository	Engineer 2	N/A
19	18	E7	Dimensions of Component 2	Initial Preliminary TDP Development 2.20	Editited CAD Model of Component 2	17	CAD Model	Native CAD	Engineer 2's Personal Repository	Engineer 2	N/A
20	19	E7	Dimensions of Component 2	Initial Preliminary TDP Development 2.20	Editited CAD Model of Component 2	18	CAD Model	Native CAD	Engineer 1's Personal Email Directory and Engineer 2's Personal Email Directory	Engineer 2	Engineer 1
21	20	E7	Dimensions of Component 2	Initial Preliminary TDP Development 2.20	Editited CAD Model of Component 2	19	CAD Model	Native CAD	Engineer 1's Personal Repository	Engineer 1	N/A
22	21	E7	Dimensions of Component 2	Initial Preliminary TDP Development 2.20	.STL File of CAD Model of Component 2	18	.STL File	.stl	Engineer 2's Personal Repository	Engineer 2	N/A
23	22	E7	Dimensions of Component 2	Initial Preliminary TDP Development 2.20	.CMB Additive File of Componenet 2	21	Additive Print File	.CMB	Engineer 2's Personal Repository	Engineer 2	N/A

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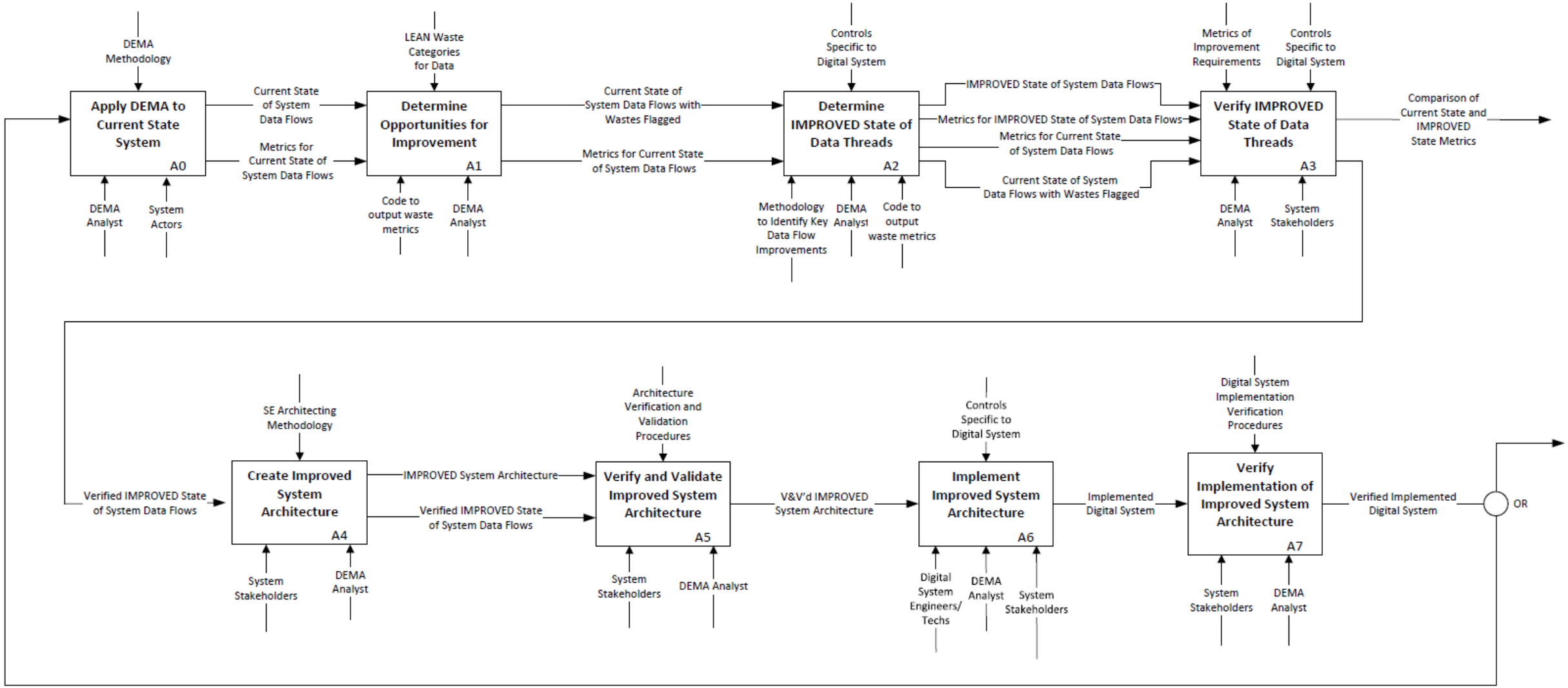
Continuous Improvement Methodology for Digital Transformation



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Waste Related Metrics Used to Determine Key Data Threads

Key Metric	Definition
Excess	A greater amount or volume of data or information than needed (minimum is ideal).
Estimated Labor Hours	The estimated labor hours for the total system and individual data elements (minimum is ideal).
Level of Automation	The level of automation (non-manual transfers) for the system and individual data elements (maximum is ideal).
Actor Access Needs	The number of times that a data element or vessel needs to change actor access (minimum is ideal).

DEMA In Real Life

- DEMA Applied to Prototyping System:
  - Step 1: Six functional areas and 67 functional activities
  - Step 2: Around 1000 data vessel inputs and outputs
  - Step 3: Around 2,500 unique data elements and around 25,000 data element instances
- These results were used to begin connecting the Digital Thread in one of the six functional areas of the system.
- Key data threads were identified and an improved data architecture for the engineering functional area was created.
  - 25% of the data operations were moved from manual to automated, beginning the connection of the Digital Thread.
  - Data element handling reduced by 22%, reducing workload and opportunities for quality errors.
  - A conservative estimate of the labor associated with data handling was reduced 888 hrs. to 661 hrs.
    - With a fully loaded rate of $100 an hr., this would result in $2,227 savings for the effort, with 227 manpower hrs. freed to be applied to other efforts.

***If the organization does 100 efforts a year, this will equate to more than $2 million in savings and the elimination of 11-man years of effort.**

Ongoing and Future Work

- Manufacturing Model-Based Systems Engineering (M-MBSE) $9.2 million DoD Project
  - Creation of DEMA Software
  - The utilization of AI to create improved state mappings and data architectures from DEMA results
- DEMA data licenses to use the approach (with training videos and workbook)
- Integrating DEMA into a Digital Twin Toolbox Framework.
  - White paper accepted by MxD as part of Digital Twin for X RFP
  - Working on full proposal with University of Alabama in Huntsville (UAH)
- Continuing applications of DEMA within the Army
- Creation of DEMA to SysML Framework for Model-Based Systems Engineering (MBSE)
  - Cameo Plug-in part to integrate with DEMA software
- More research being conducted into how DEMA plays a part in continuous improvement programs
- Partnering with other universities to integrate DEMA into safety and model-based definition frameworks

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