NASA's Digital Engineering Transformation

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Audience: PTC Aero & Defense Monthly

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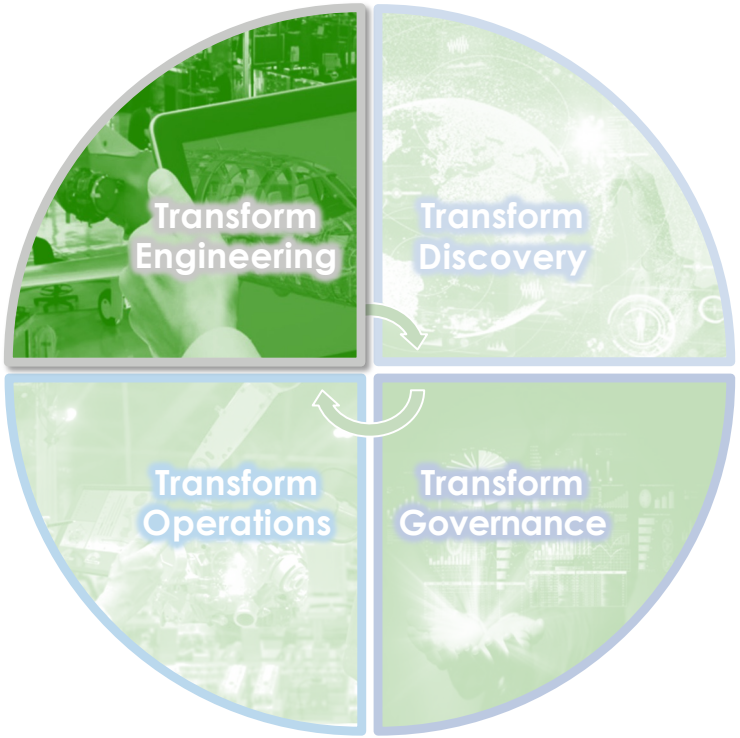
"It is not necessary to change. Survival is not mandatory."

(W. Edwards - Deming Institute, 2019)

AGENDA

- Digital Transformation (specifically Engineering) approach will be different for everyone
- NASA's approach to foundational DE change & the Four-Layered Cake
- What does DoD's Digital Engineering Instruction (2023) mean for NASA.

NASA'S DIGITAL TRANSFORMATION TARGETS



DIGITAL ENGINEERING TRANSFORMATION WILL BE DIFFERENT FOR EVERYONE

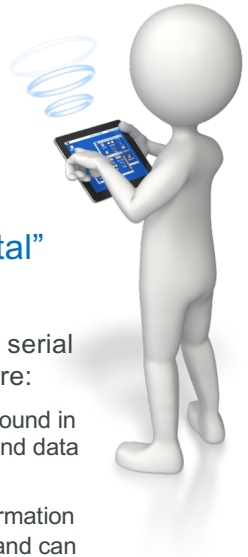
"Always remember that you are absolutely unique; just like everyone else." – Margaret Mead

If your Company / Org was born:

Each of these paths will be different…

In the last 5-8 years

You were "born digital"



Your processes are efficient & serial only when necessary. Therefore:

- Corporate information can be found in databases, data aggregators and data lakes
- Processes **create/access** information via federated sources of truth and can follow the data thread via tools which use industry standards for interoperability and data threads.

8-15 years ago

Your processes can be serial, because you learned from your predecessors, but you have moments of efficiency. Therefore:

- Your processes are serial/parallel hybrid
- Corporate information can be found in electronic documents, databases, html pages, SharePoint lists
- Processes allow the **exchange** information via links to information/data

More than ~15 years ago

iPhone - 2007

HTLM 5 – 2008

Together they culturally changed how we interact with information

Your processes are largely serial, because they are effectively the same as they were when you were founded or have changed very little since then. Therefore:

- Your processes are serial
- Corporate information is largely locked in electronic (or paper) documents still
- Processes require people to **send/received** information via electronic documents via email, share drives, & PLMs

FOR THE OLD TIMERS ORGANIZATIONS WHO WERE BORN MORE THAN 15 YEARS AGO

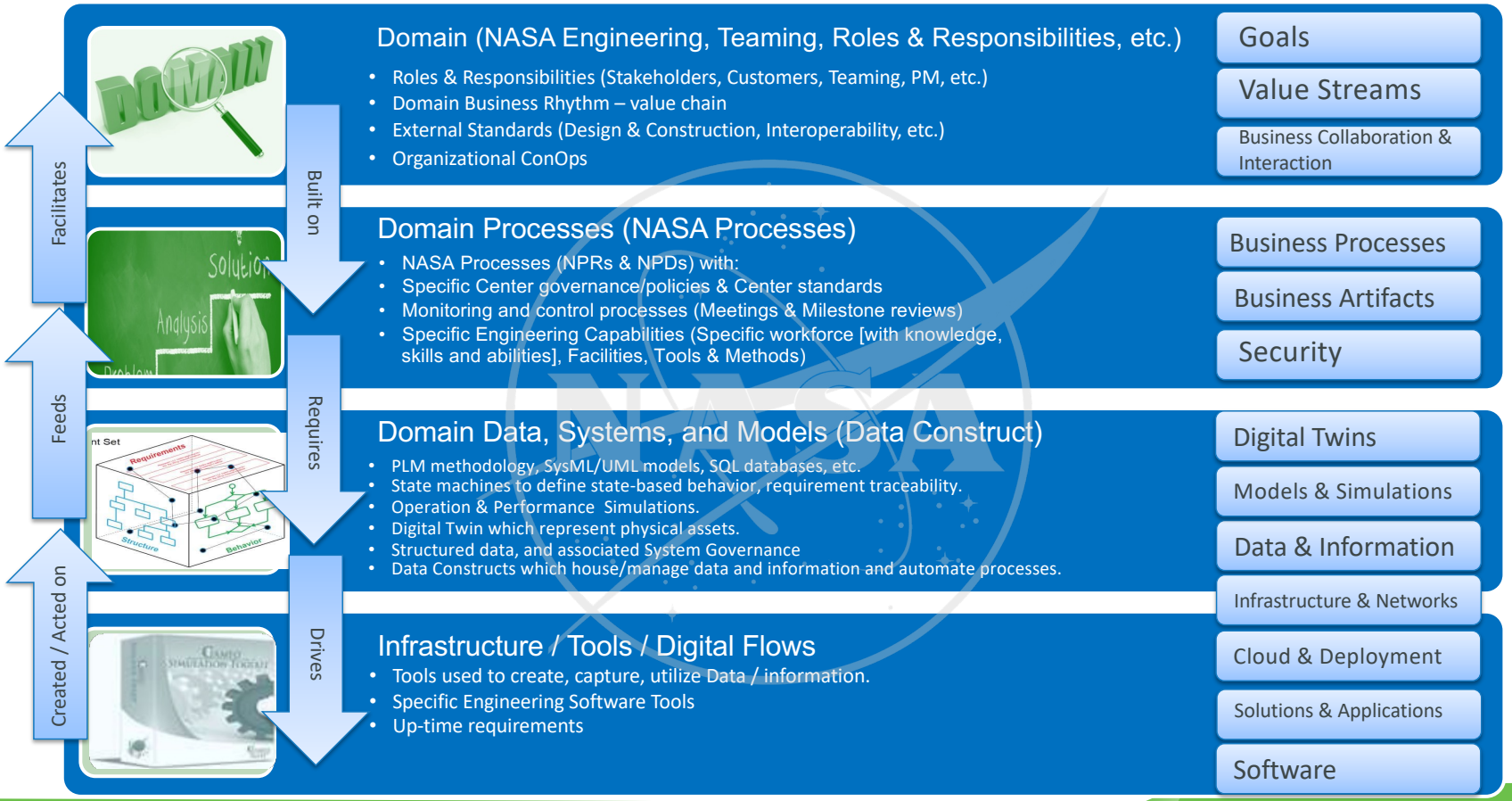
So where do we start?!?

NASA didn't invent digital engineering "sliced bread", but I'm going to tell you how we're slicing ours.

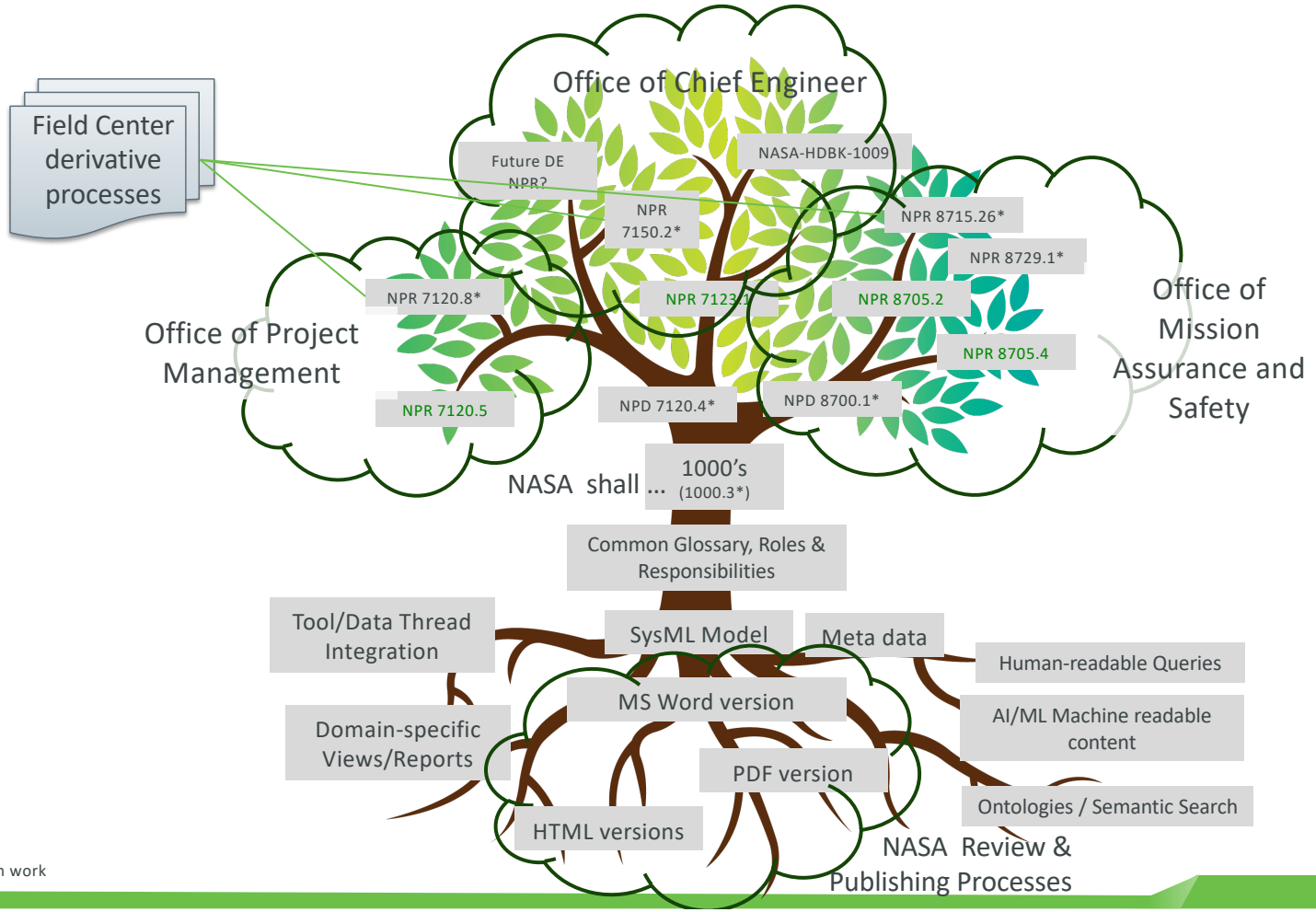
Transforming 65 Years of Engineering Legacy

THE 4-LAYER CAKE ANALYSIS FOR IDENTIFICATION OF DIGITAL TRANSFORMATION OPPORTUNITIES

Developed by NASA's Office of Chief Engineer's Digital Engineering Leadership Team



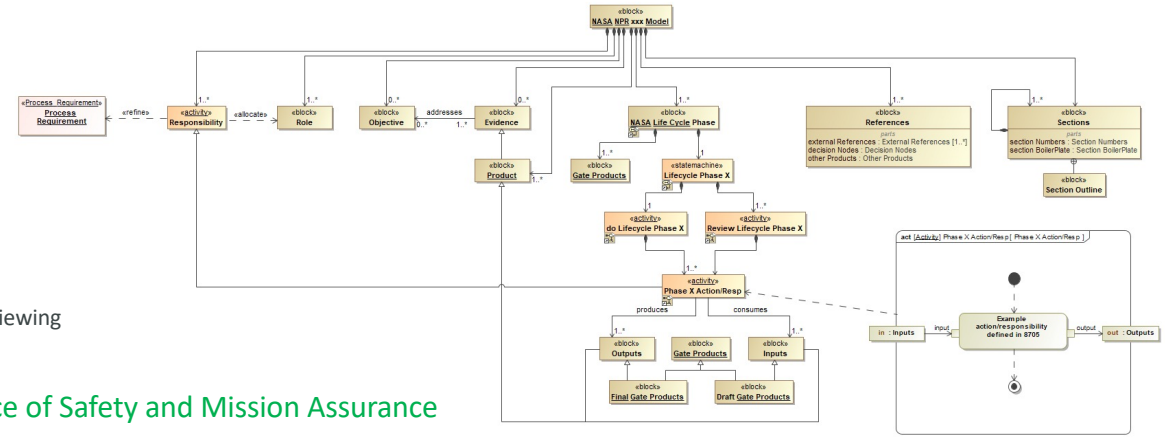
LINKED MODES, COMMON ELEMENTS, & ARTIFACTS



* Modeling in work

NPR SYSML MODELING

- Processes form the foundation of all Engineering Products and services, and for Eng Domain, NPR 7123, 7120.5 and 8705 are the core driving processes.
  - Understanding our processes from a data-centric perspective is foundational to NASA DE transformation.
- Jointly, DE modeled NPRs 7120.5/.8, 7123.1, NPD 7120.4, and Office of Safety and Mission Assurance modeled NPR 8705.2 and 8705.4
- Created common meta model so that each NPR/NPD were modeled consistently to ensure appropriate integration.
- Data-Centric Analysis Results
  - Found common elements:
    - 860 Blocks (various Data, Role, type, etc.),
    - 126 Activities (part of Lifecycle Reviews),
    - 460 Terms Terms, Roles, Data Products, Lifecycle, Organizations, Operational Areas, Program-Project Types
  - Identified discrepancies (49)
  - Classified integrated content with (25) tags (e.g., Cost, Schedule, Requirements, etc. - over 2900 elements tagged)
  - Can produce modeled documents in Word/PDF or for Web viewing

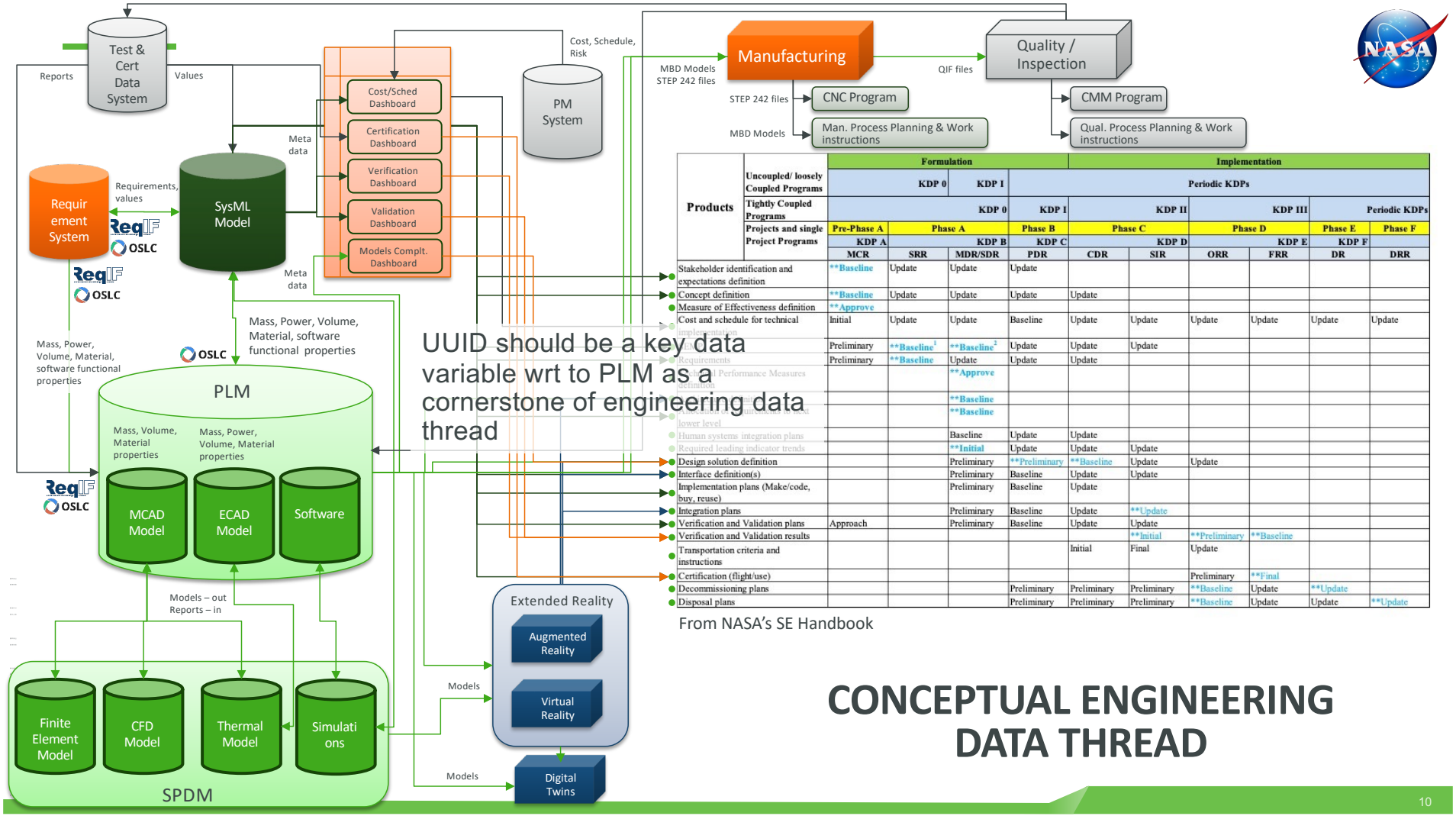


- Jan. 30 '24 – Briefed the Deputy Chief of the Office of Safety and Mission Assurance
  - Was "genuinely excited" during the subject briefing
  - Sees NPR Modeling as a way to potentially transform process updates, execution, and improvement of processes
  - Moving forward, thinks it will be useful in successfully addressing the Technical Aspects of Cross-NPR Modeling and sustainment

NPR SYSML MODELING – RESULTING RECOMMENDATIONS

1. **Common Terminology/Usages**
   - **Issue:** Discrepancies between terms and their usage in the areas of roles, lifecycle elements, products, authorities, etc.
   - **Recommendation:** Capture base definitions and the process to extend/customize as necessary. Use modern software tools to deploy a common library model.
   - **Improvement:** Streamlines comm… …ces interdisciplinary collaboration
2. **Numbering Scheme(s) for Proce…**
   - **Issue:** Procedural require…
   - **Recommendation:** Emp…
   - **Improvement:** Improve… …cross documents
3. **Clear/Current References**
   - **Issue:** Some references…
   - **Recommendation:** Nea…
   - **Improvement:** Accuracy…
4. **Clarity about Roles vs Respon…**
   - **Issue:** Implicit requirem…
   - **Recommendation:** Do n…
   - **Improvement:** Ensures … …nal priorities, increases employee sat…
5. **Improved Data Hierarchy/Vie…**
   - **Issue:** Data and product…
   - **Recommendation:** Crea…
   - **Improvement:** Easier to…
6. **Reduce Requirement Comple…**
   - **Issue:** The majority of t…
   - **Recommendation:** Perf…
   - **Improvement:** Simplify…
7. **Consolidate Default Life Cycle…**
   - **Issue:** NASA maintains t…
   - **Recommendation**: Dee…
   - **Improvement:** Simplifie…
8. **Make Policy Linkage Decision…**
   - **Issue:** NPDs/NPRs are n… …is still ongoing
   - **Recommendation:** Expl…
   - **Improvement:** NPDs an…
9. **Update Program/Project Revie…**
   - **Issue:** Every program/proj…
   - **Recommendation:** Establis…
   - **Improvement:** Reviews are fo…

- **Common Terminology/Usages** – significant inconsistent usage
- **Intelligent Numbering Scheme(s)** – requirements are difficult to reference because they can be found in pictures
- **Clear/Current References** – hard to find, refer to the wrong reference or version, or have been cancelled/obsoleted
- **Clarity about Roles vs Responsibilities** – overlap, significant inconsistent usage, etc.
- I**mproved Data Hierarchy/Views** – duplicated, re-worked, unsynchronized, lack traceability
- **Reduce Requirement Complexity** – most requirement statements have a low quality score
- **Consolidate Default Life Cycle(s)** – not apparent the flexibility outweighs addtl. complexity to maintain
- **Make Policy Linkage Decisions** – NPDs/NPRs normally maintained in silo'd org. structure where the update cycle does not align to one another
- **Update Program/Project Review(s)** – framework that allows tailoring in a model-based environment & smart reviews



UUID should be a key data variable wrt to PLM as a cornerstone of engineering data thread

Products		Formulation				Implementation					
	Uncoupled/ loosely Coupled Programs	KDP 0		KDP I	Periodic KDPs						
	Tightly Coupled Programs	KDP 0			KDP I	KDP II		KDP III		Periodic KDPs	
	Projects and single Project Programs	Pre-Phase A	Phase A		Phase B	Phase C		Phase D		Phase E	Phase F
		KDP A	KDP B		KDP C	KDP D		KDP E		KDP F	
		MCR	SRR	MDR/SDR	PDR	CDR	SIR	ORR	FRR	DR	DRR
Stakeholder identification and expectations definition		**Baseline	Update	Update	Update						
Concept definition		**Baseline	Update	Update	Update	Update					
Measure of Effectiveness definition		**Approve									
Cost and schedule for technical implementation		Initial	Update	Update	Baseline	Update	Update	Update	Update	Update	Update
Requirements		Preliminary	**Baseline[1]	**Baseline[2]	Update	Update	Update				
Technical Performance Measures definition		Preliminary	**Baseline	Update	Update	Update					
				**Approve							
				**Baseline							
lower level				**Baseline							
Human systems integration plans				Baseline	Update	Update					
Required leading indicator trends				**Initial	Update	Update	Update				
Design solution definition				Preliminary	**Preliminary	**Baseline	Update	Update			
Interface definition(s)				Preliminary	Baseline	Update	Update				
Implementation plans (Make/code, buy, reuse)				Preliminary	Baseline	Update					
Integration plans				Preliminary	Baseline	Update	**Update				
Verification and Validation plans		Approach		Preliminary	Baseline	Update	Update				
Verification and Validation results							**Initial	**Preliminary	**Baseline		
Transportation criteria and instructions						Initial	Final	Update			
Certification (flight/use)								Preliminary	**Final		
Decommissioning plans					Preliminary	Preliminary	Preliminary	**Baseline	Update	**Update	
Disposal plans					Preliminary	Preliminary	Preliminary	**Baseline	Update	Update	**Update

From NASA's SE Handbook

CONCEPTUAL ENGINEERING DATA THREAD

DE RFI TO INDUSTRY SUMMARY

RFI 1: Approach to RFPs, proposals, and contracts per traditional, or model-based acquisitions. If your preferred or recommended approach is via a model-based approaches, please provide:

- Objective measures as to the value and/or return on investment or increased capabilities the approach provides over the traditional,
- Past, sharable, examples of success stories and associated models/metamodels in native formats if applicable
- Past government customers (POCs) who can attest to the benefit and would be willing to share their perspective and lessons learned with NASA

RFI 2: Approach for future contractual engineering, quality, and safety data/informational deliverables, model assurance and assurance requirements to provide insight and inform critical decisions to support certification, operations support, operational anomalies, program, architecture, or mission integrations when elements, products, or services may be provided my numerous industry partners.

RFI 3: Approach to NASA/industry partner collaborative environments, collaborative engineering/integration/simulation/ digital twin environments. Please indicate the nature of engagement and/or lifecycle phases of a program/project you would typically value collaborating/integrating designs with NASA.

RFI 4: Approach to integration of engineering toolchain to form digital thread(s) from concept to operations. Recommendations on appropriate/recommended interfaces between models, systems, etc. when providing contract required data/information and/or collaboration with NASA.

RFI 5: Recommended commercial off-the-shelf solution(s) (COTS) for integration of your toolchain(s) with pros and cons.

RFI 6: Recommended industry data interoperability standards (or non-baselined "needed" standards) per engineering subdomain (e.g. ReqIF for requirement management software) and why.

RFI 7: Recommendations of what you would like to see common/consistent across the US government when it comes to digital engineering, procurement/acquisitions supporting engineering deliverables, and safety.

Summary:

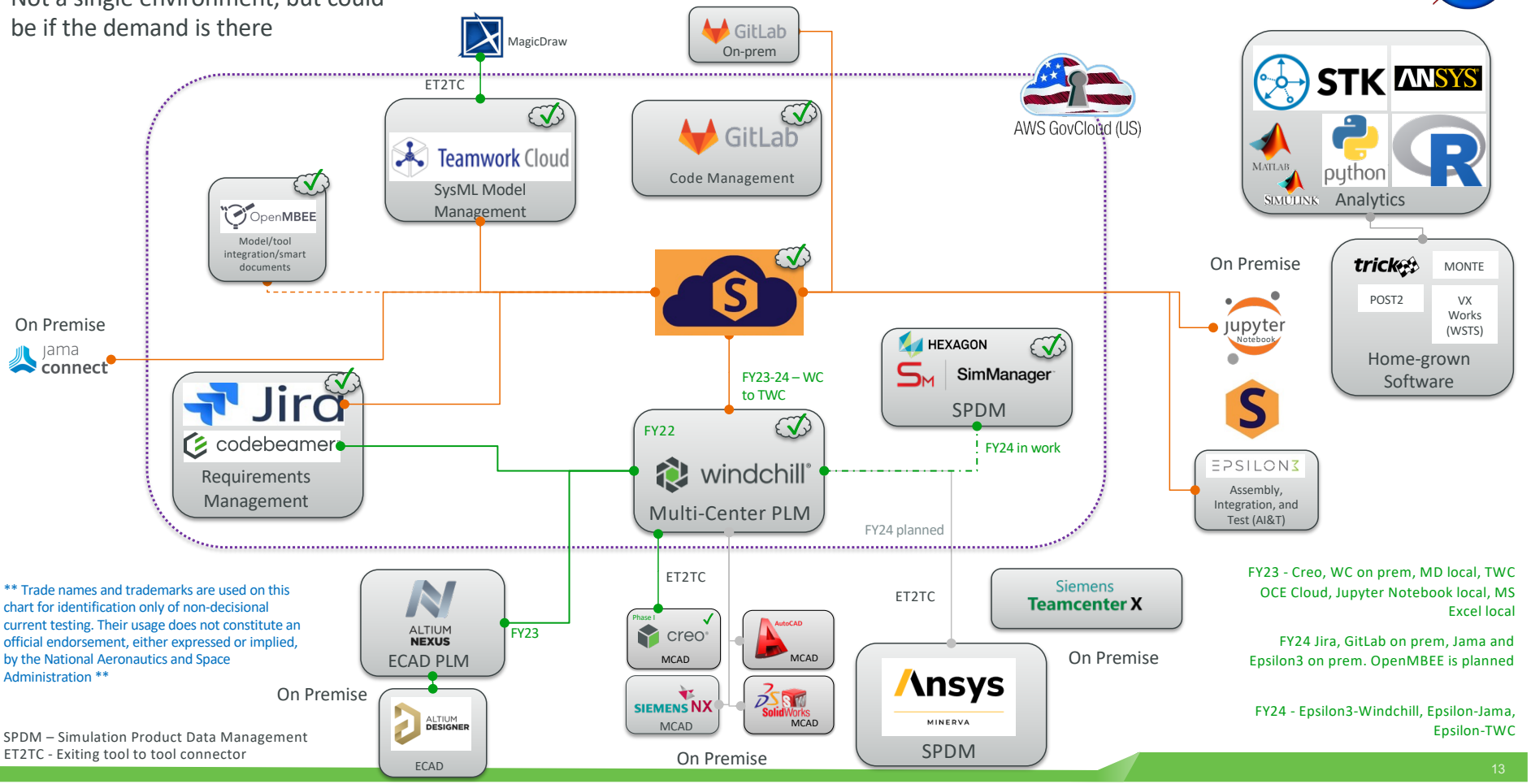
- 42 Responses – 27 met minimum expectations
- 1 company responded via SysML models
- 4-5 considered very informative

DE RFI TO INDUSTRY SUMMARY

- Majority indicate MB Acquisition saves time and increases quality of all aspects of the process.
- Significant experience with integration of tools, forming the digital thread, and needed interoperability protocol standards.
- DoD, and industry in turn, are emphasizing the use of MOSA (Modular Open Systems Approach) and it is required by United States law Title 10 U.S.C. 4401(b), states all major defense acquisition programs (MDAP) are to be designed and developed using a MOSA (https://www.dsp.dla.mil/Programs/MOSA/):
  - Employs a modular design that uses modular system interfaces between major systems, major system components and modular systems;
  - Is subjected to verification to ensure that relevant modular system interfaces comply with widely supported and consensus-based standards; or are delivered pursuant to the requirements established in FY21 National Defense Authorization Act Section 804 (a)(2)(B)
- Toolchain: proposed COTS digital backbone solutions with bidirectional interoperability, extensibility and cross-project connectivity (including non-engineering needs), and with diverse vendor toolset (avoid vendor lock) for robust and customizable COTS toolchain
- Gov. should:
  - Establish standardized digital engineering frameworks and guidelines that can be adopted across government agencies.
  - Develop a unified procurement framework for government projects that integrates digital engineering principles.
  - Promote cross-agency collaboration and information sharing to facilitate the adoption of common digital engineering standards and procurement practices.

PHASED INTEGRATION ACTIVITIES OF COMMONLY USED ENGINEERING TOOLS

Not a single environment, but could be if the demand is there



** Trade names and trademarks are used on this chart for identification only of non-decisional current testing. Their usage does not constitute an official endorsement, either expressed or implied, by the National Aeronautics and Space Administration **

SPDM – Simulation Product Data Management
ET2TC - Exiting tool to tool connector

FY23 - Creo, WC on prem, MD local, TWC OCE Cloud, Jupyter Notebook local, MS Excel local

FY24 Jira, GitLab on prem, Jama and Epsilon3 on prem. OpenMBEE is planned

FY24 - Epsilon3-Windchill, Epsilon-Jama, Epsilon-TWC

DOD'S DIGITAL ENGINEERING INSTRUCTION 5000.97 & NASA

- DEI 5000.97 is a good next logical step beyond the DoD 2018 Digital Engineering Strategy document
- Focuses on:
  - High-level definition of Digital Engineering (DE)
  - Associated DE functional capabilities and elements
  - DE Training and Guidance
  - DE Implementation high-level recommendations
  - Procedures for Maintaining Digital Models and ASoTs
- NASA currently considering created an Agency Procedural Requirement (think policy) which aligns with 5000.97 but goes into more detail in areas important to NASA

SIMPLIFIED DIGITAL ENGINEERING IMPLEMENTATION APPROACH

Today's practices

Identify your processes & tools by function and domain, and data repositories

Model processes and baseline toolchains

Identify which primary tools are available to multiple people (server/cloud noted by blue circle). Identify needed interoperability between data repositories.

Common host tools and link/pass data with minimal effort

Data exchange between primary tools is automated or with minimal mouse clicks

Shift in Organizational Eng. Culture

Link in specialty / parametric tools

Secondary / analytic tools are available in enterprise solution and are linked in with primary tool chain and digital twins

Domain fully-integrated tool chain and data-centric processes and data constructs

Consistent Digital Engineering Across the Org

Seamless Data-centric Integration, collaboration, data exchange with Domestic and International Partners.


REACH
NEW
HEIGHTS
NASA DIGITAL
TRANSFORMATION
REVEAL
THE
UNKNOWN
BENEFIT
ALL
HUMANKIND
Questions?

BACKUP CHARTS