

NASA's Digital Transformation & Digital Engineering

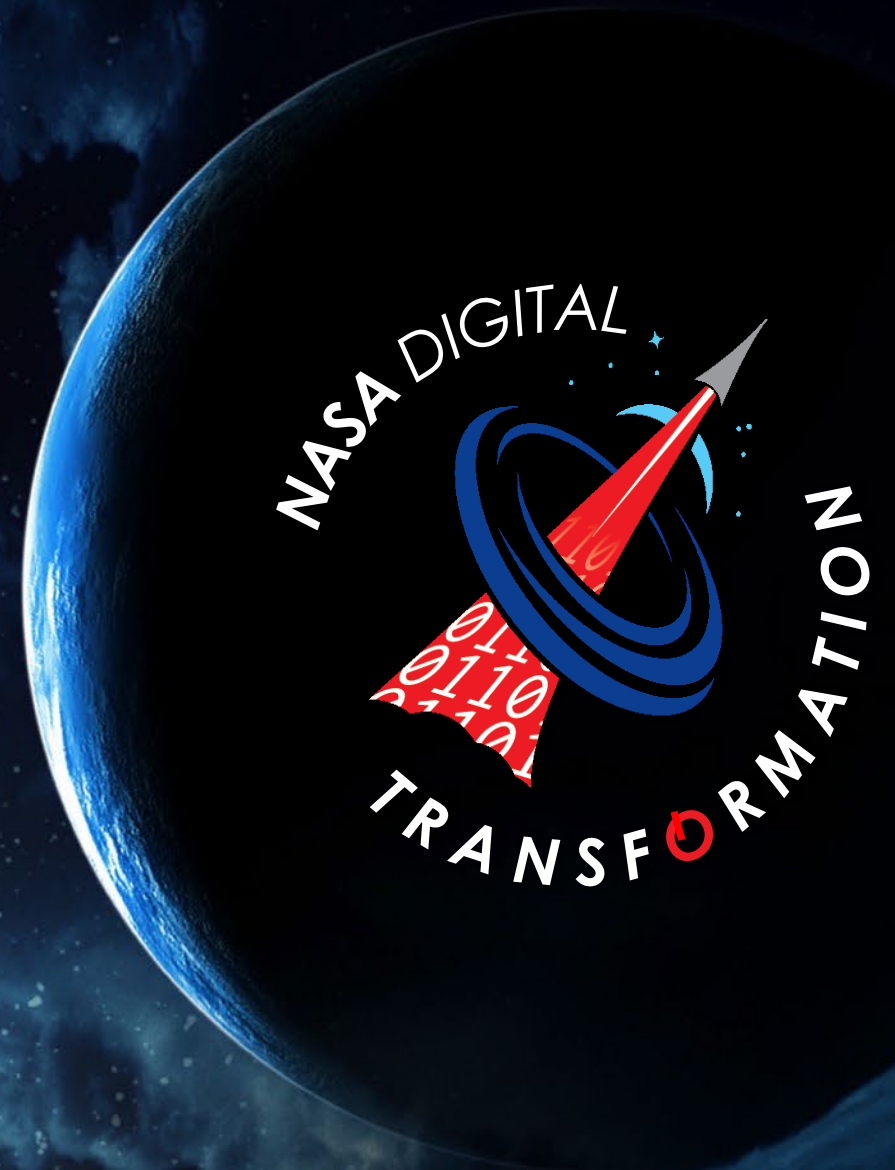


Terry R. Hill
NASA DT Digital Engineering Lead

Aug 29-31, 2023

Siemen's Aerospace & Defense Executive Council

*"It is not necessary to change. Survival is not mandatory."
(W. Edwards - Deming Institute, 2019)*



Why Digitally Transform NASA?



**ENDURING
BOLD
MISSION...**

REACH
NEW
HEIGHTS

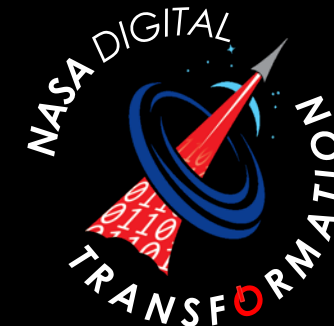
BENEFIT
ALL
HUMANKIND

REVEAL
THE
UNKNOWN



...NOW IN A CHANGING WORLD

- Increasingly bold & complex missions
- Increasingly partnered
- Increasingly fast
- Increasingly affordable
- Increasingly transparent
- Increasingly inclusive



NASA's DT Strategic Framework

3 FUTURE STATE GOALS



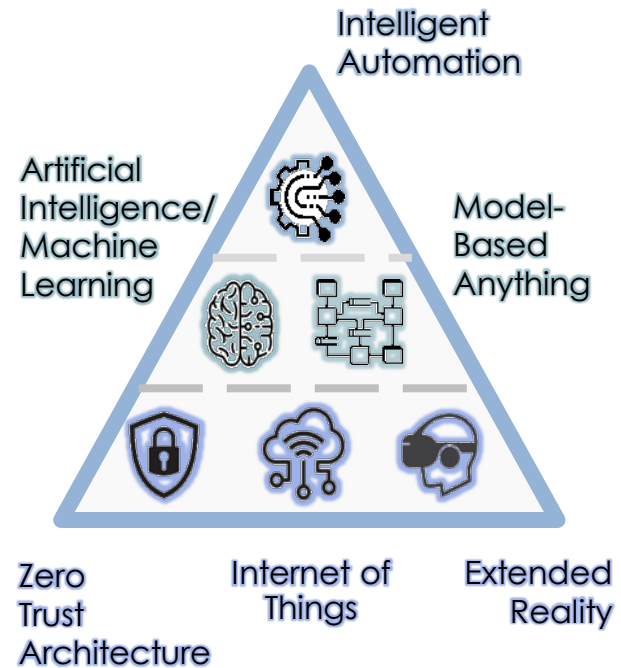
4 TRANSFORMATION TARGETS



5 DIGITAL LEVERS



6 TECHNOLOGY FOUNDATIONS



7⁺ MISSION OUTCOMES



NASA's DT Implementation Approach



Ignite Transformation

Facilitate **Tx Target Community-owned Roadmaps** & near-term priority actions to align DT intent & goals across NASA

Dec 2022

Connect Plans

Coordinate like **Organizational DT Plans** that respond to the DT Strategic Framework to synchronize DT intents

Mar 2023

Integrate Solutions

Analyze **Integrated DT Solutions Portfolio** vs. Roadmaps / priorities for redundancies & gaps to identify leveraging opportunities & inform investment decisions by OCIO, DT & other organizations

May 2023

Facilitate Adoption

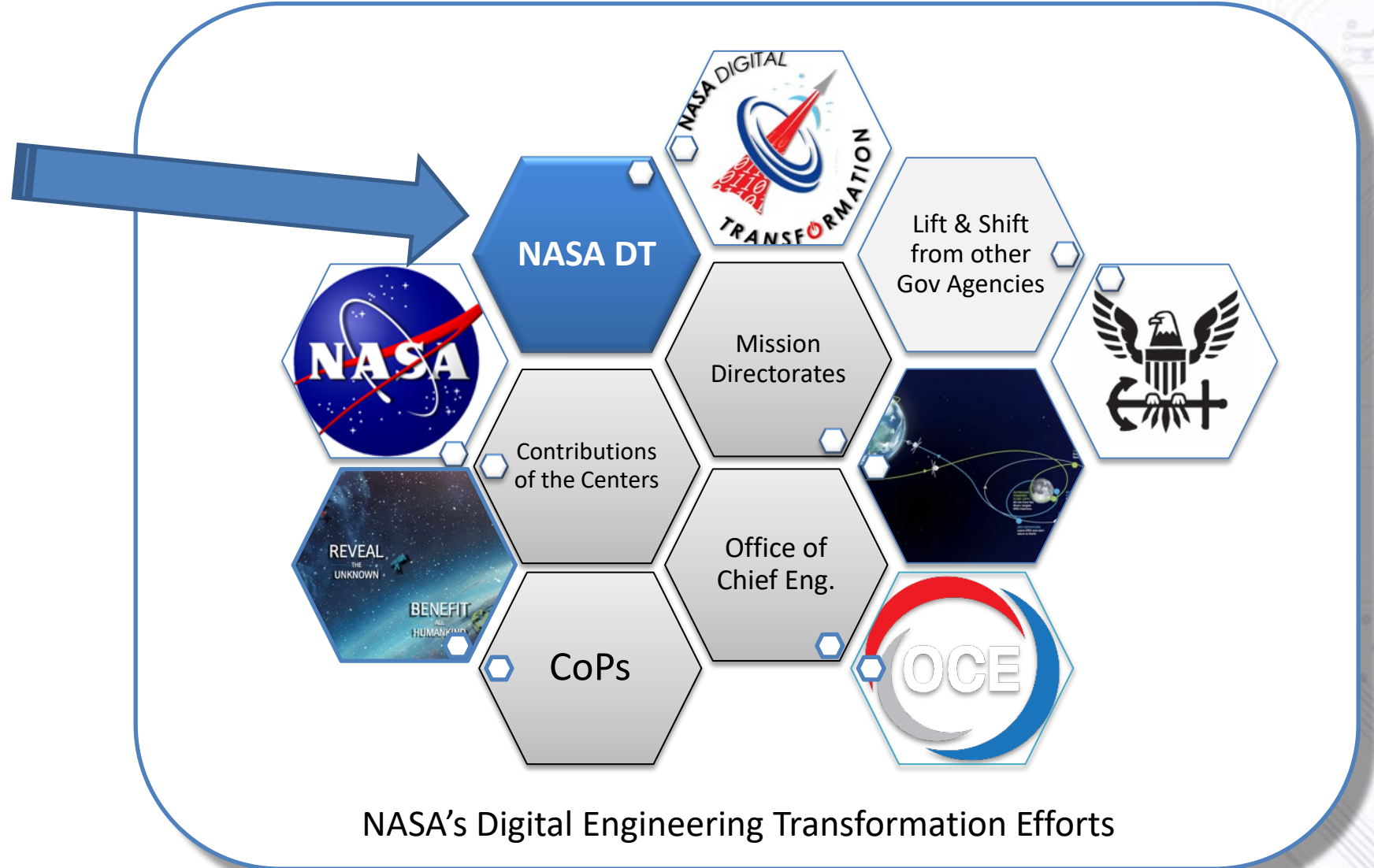
Measure **DT Progress** on funded Org DT Plans vs. Roadmaps/Priorities; elevate & address cross-cutting barriers via **DT Catalyst Projects**; celebrate & share **DT Successes & Exemplars**

Synchronize DT Plans

&

Catalyze DT Progress

Transformation of Engineering – It Takes a Village



NASA's Digital Engineering Transformation Efforts

NASA's Digital Engineering Need



...from Concept to Operations

Historically a change of Presidential administration or Congress means a change to our missions/priorities/budgets

Improve how the Agency Engineering Domain operates over the entire NASA lifecycle by effectively managing complexity, reducing cost and schedule, and improving product integrity via the integration of processes, digital tools, and techniques along with seamless flow of information throughout the engineering system development life-cycle (concept development, design, testing and validation, manufacturing and operations).

Engineering Project Lifecycle



Define the Scope and Capabilities of what Digital Engineering Means to NASA

Needs → Goals → Objectives → Capabilities

NPR's – provide Agency pro

Center's / Engineering Directorat

Digital Engineering

Model-Based Systems Engineering

Formulation and Requirement Development

Early Design & Mod/Sim

Design to Manufacturing

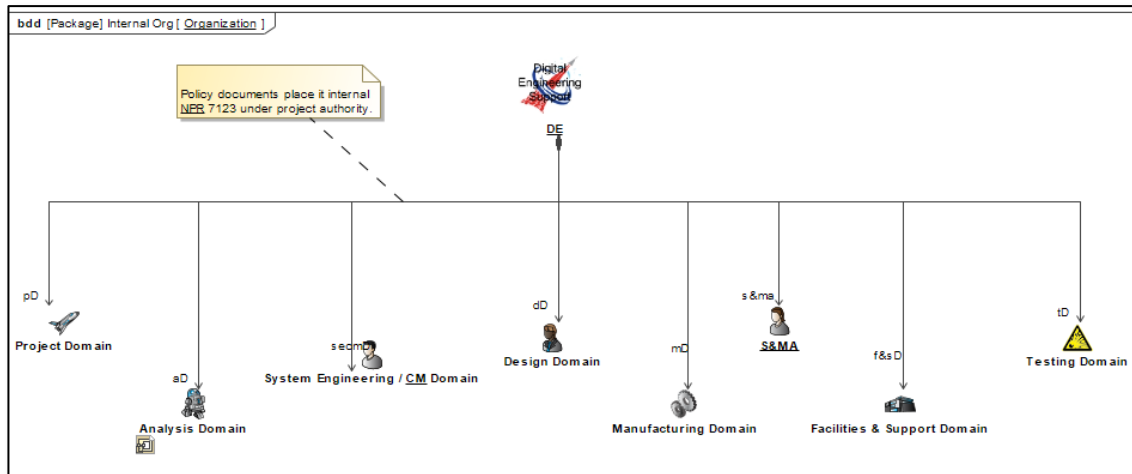
Test & Verification

Cert.

Project/Program Operations and Sustaining

Decommissioning

Produced by MBSE Leadership Team – Led by Trish Nicoli (Jan. 15 – May 30)



Digital Engineering Needs, Goals, & Objectives



Need

Improve how the Agency Engineering Domain operates over the entire NASA lifecycle by effectively managing complexity, reducing cost and schedule, and improving product integrity via the integration of processes, digital tools, and techniques along with seamless flow of information throughout the engineering system development life-cycle (concept development, design, testing and validation, manufacturing and operations).

Goals

- **G1 Lifecycle:** Establish a Digital Engineering (DE) strategy that can be integrated throughout the entire Engineering Life Cycle, aligning with NASA's mission objectives.
- **G2 Deployment:** Develop an interoperable, tailorable, and scalable deployment strategy for the Digital Engineering Ecosystem across the Centers including implementation options and methods.
- **G3 Guidance:** Establish the guidance for model development, tool integration and deployment, and formulation of data threads while ensuring alignment with the industry standards advocated by DE.
- **G4 ASoT:** Establish an approach providing stewardship, governance, security, traceability, and management of the engineering Authoritative Sources of Truth (ASoT), while ensuring the data within the ASoT are curated.
- **G5 Configuration/Change Management:** Evolve existing CM approaches for data-centric management of engineering baselines which enable teams to manage and track changes made throughout the entire product lifecycle.
- **G6 Digital Threads:** Develop strategies for Digital Threads/Ecosystem that improve collaboration, data exchange, design formulation, data-centric processes and workflows, operations, and insight, and data-informed decision making.
- **G7 Culture and Workforce:** Evolve NASA Culture and the Workforce by creating a demand for adoption of DE techniques, providing training, and cultivating a digital engineering community.

DE Environment
 Explore Design Space
 Conduct Trade Studies
 Select Architectures
 Engineering Communication
 V&V
 Improved Agility
 Improved Quality
 Improved Efficiency
 V&V Usage

Clear decision-making process - increase in decision velocity
 Method for evaluating the health & status of the Agency implementation
 Deployment strategy for DE implementation across the Agency
 Auditing method utilizing CM best practices to ensure to ensure mission objectives.

Objectives

Standardized Development
 Standardized Integration
 Standardized Usage
 Standardized Central Data
 Common Policies
 Guidelines
 Tool Standards
 Tool Interoperability Standards
 Tool Procurement/Development
 DE Terminology

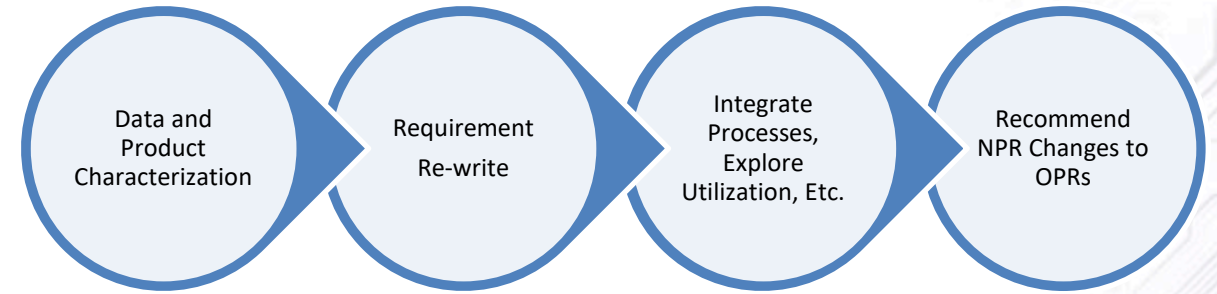
Integrate model libraries while also maintaining ASoT.
 Establish a Governance for ASoT.
 Method for integrating Engineering Data.
 Method for Configuration Management (CM) of ASoT to be shared with internal entities.
 Method for CM of ASoT to be shared with external entities.
 Process for data & IT security to be implemented across the DE domain.

CM Strategy
 Number of PLM systems
 Approval of PLM systems
 PLM for Acquisition
 PLM for Execution
 PLM for Lifecycle Development
 PLM for Workflow Management
 PLM For Inventory Management
 Maintain PLM Licensing
 PLM Sustainment
 CM Processes For systems
 CM status accounting data for systems

Integrate NPRs into processes.
 Environment for managing similar sets of data.
 Environment for integrated data.
 Strategy for toolchains.
 Protocols for IT to enable collaboration.
 Provide IT the tools to enable collaboration.
 Inform changes to the NPRs.

Establish outreach programs including training development activities
 Organize professional DE roles
 Establish outreach programs developing DE expertise
 Organize professional DE role responsibilities
 Create a policy for systematic adoption
 Establish a DE community

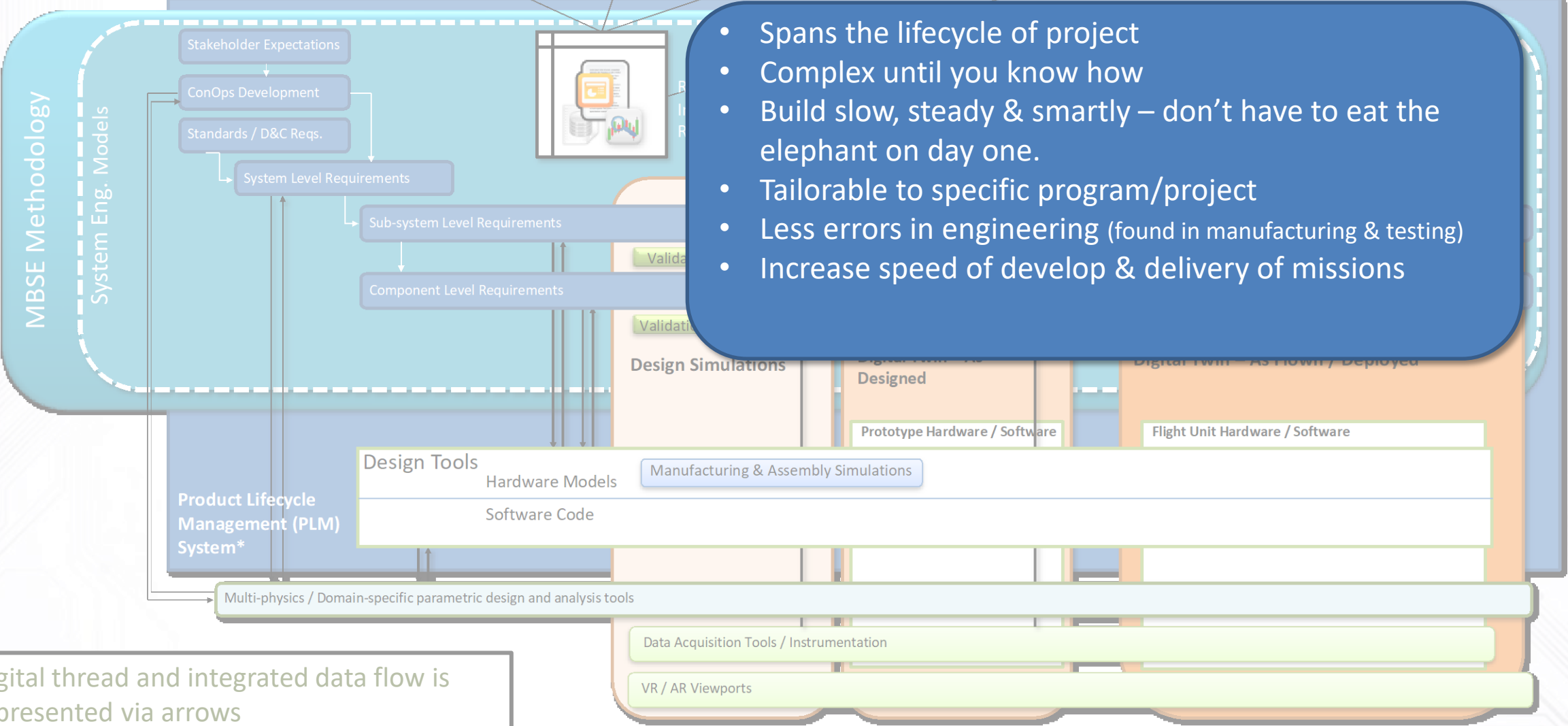
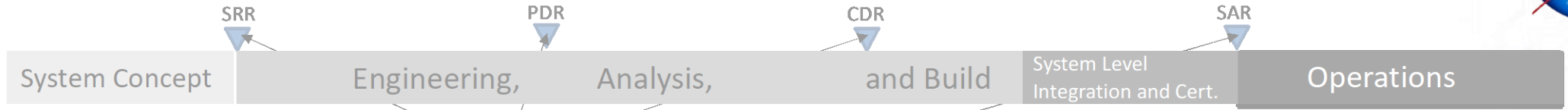
NPR Analysis Process



- Data and Product Characterization by Topic (cost/schedule, authority, etc)
 - Differentiate between data items and deliverables
 - Data Hierarchy and consolidation (preliminary, update, baseline)
- Review associated topic requirements and implement Easy Approach to Requirement Syntax (EARS) compliance
 - Remove multiple continuances, vague words, etc.
 - Re-write (possibly multiple statements)
 - Ensure roles and responsibilities are clear
- Integrate Processes
 - Ensure data item traceability into deliverables
 - Ensure activities that produce deliverables have a responsible role for execution
- Provide recommendations to OPRs
- In parallel – Model Usage and Documentation
 - Programs/projects – ease compliance burden
 - Technical Authorities – mapping into Center processes
 - Systems Engineering – Support lifecycle reviews

Legend	Lifecycle Activities [Common]																												
Type	MRP1 : Form	MRP1 : Preh	MRP1 : Preh	MRP1 : Preh	MRP1 : Preh	MRP1 : Preh	MRP1 : Preh	MRP1 : Preh	MRP1 : Preh	MRP1 : Preh	MRP1 : Preh	MRP1 : Preh	MRP1 : Preh	MRP1 : Preh	MRP1 : Preh	MRP1 : Preh	MRP1 : Preh	MRP1 : Preh	MRP1 : Preh	MRP1 : Preh	MRP1 : Preh	MRP1 : Preh	MRP1 : Preh	MRP1 : Preh	MRP1 : Preh	MRP1 : Preh	MRP1 : Preh	MRP1 : Preh	MRP1 : Preh
8705.2 Requirements ALL	1																												
Acceptance Plan																													
Baseline Acceptance Plan																													
Preliminary Acceptance Plan	1	1																											
Acquisition Strategy																													
Agency Risk Tolerance	1																												
Agency Safety Goals and Thresholds	7																												
Agency Safety Goals and Thresholds Request	1																												
Agency Strategic Priorities																													
Agency Vision																													
Alternative Concepts	1	1																											
Architecture Definition Document																													
Baseline Architecture Definition Document	2	2																											
Preliminary Architecture Definition Document																													
Basis of Estimate																													
Updated Basis of Estimate	3	3																											
Bill of Materials	1	1																											
Certification of Critical Event Readiness																													
Final Certification of Critical Event Readiness	1	1																											
Certification Package																													
Final Certification Package	1	1																											
Checkout and Activation Plan																													
Preliminary Checkout and Activation Plan	1	1																											
Command and Telemetry List	1	1																											
Communications Plan																													
Concept Definition																													
Baseline Concept Definition																													
Updated Concept Definition																													
Concept of Operations																													

Integrated Digital Engineering Framework per Lifecycle of a Project



- Spans the lifecycle of project
- Complex until you know how
- Build slow, steady & smartly – don't have to eat the elephant on day one.
- Tailorable to specific program/project
- Less errors in engineering (found in manufacturing & testing)
- Increase speed of develop & delivery of missions

Digital thread and integrated data flow is represented via arrows

* Some PLM systems may integrate with multi-physics tools and/or store analysis results.

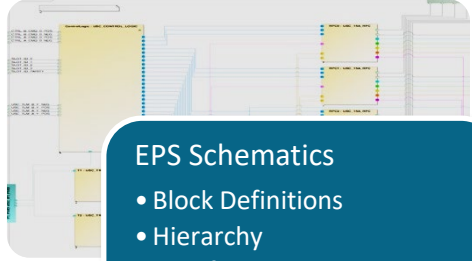


Orion Digital Twin Project 2021-2022 Activities



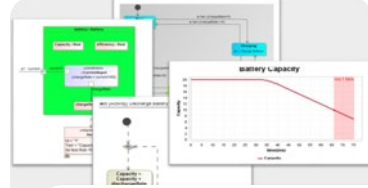
Development

- Prototype
- Depth Trade
- Domain Research



EPS Schematics

- Block Definitions
- Hierarchy
- Interfaces
- Schematic Integration
- June – Board interfaces & “Switch” details
- July – Loads
- Aug+ - Board internals



EPS Simulation

- Define Sim Scenario
- Define behavior model
- Develop GUI for live mission scenario



EPS Twin Integration

- Telemetry Interface
- Operational Data Interface
- Parameter Definition



Artemis I Test Case

- Feedback from live mission use by EPS engineering team

- 10 months of modeling and 8 months of validation.
- Over 9,000 components represented
- ~6000 elements of definition reused
- Over 130 hyperlinks to schematics database integrated into SysML Model
- Over 4,500 interfaces defined between components
- 2,208 ports imported ready for CD&H/Avionics/GNC subsystems
- Over 500 loads integrated into EPS architecture
- Automated syncing and validation of data and architecture to authoritative sources
- Simulation utilizing built architecture and imported component specifications

- ### EPS Digital Twin Validation/Evaluation
- Model-Based Review
 - Live Reviews
 - Automated Audits

- ### Further Subsystem Development
- Multi-Domain Simulation
 - Tool Integration
 - Comprehensive Digital Twin Framework

- ### Package for Agency Wide Use
- Lessons Learned
 - Sanitized Model
 - Script Library
 - Reusable Components

2023 INCOSE IS Best Paper in Mod/Sim Category

Year 1 (FY22) Digital Engineering Activities



NASA Centers at COVID-19 Stage 3

FY22

MBSE @ Inter-Agency Working Group 11/16/21

Integrated MBE Kickoff 1/31/22

MBE DT Brief to OCE 5/19/22

MBE Re-Org 6/07/22

MBE Site visits with JPL, SpaceX, Aerospace Corp., & NRO 8/01-04/22

Sep. 22

MBE / MBSE Merger MBE Funding MBSE Brief to MBE Baseline as Integrated Team

NASA SE Workshop 4/04-08/22

NRO Brief of MBSE Infusion Effort 7/08/22

NRO Annual Summit 9/16/22

Summer Faculty Support for MBE Scope Refinement & Traceability to NGOs & Processes

Cloud-Based Multi-Center PLM Pilot

- Integrated MBSE into MBE and reorganized to DE to encompass whole lifecycle of engineering.
- Multi-center PLM in NASA cloud Pilot
- Orion DT completion of EPS
- APPEL Tier 4 training available to workforce
- Modeling of NPR 7123, 7120.5/.8 & 8705
- NASA MBSE Modeling Handbook released
- Agency benchmarking of toolchain capabilities

MBE Task 1: ATP 3/20/22, Idaho NL 4/20/22

MBE Task 5

ATP 5/10/22

Kickoff 5/25/22

Draft toolchain "architecture" 9/30/22

Task 1

Devel.

Benchmark Agency Toolchains and ident. Interoperability reqs. (WYE)

Final product 11/15/22

Leverages E-APMB survey data

ATP 5/12/22

Kickoff 6/06/22

Piloting Complete 8/08/22

Modeling Initial Pass Complete 9/30/22

Task 3

W Devel.

Model 7123 / 7120.5 & integrate with MB MA 8705 models (WYE)

Finalize Modeling Drill Down & Plan for Process Optimization

Planning/Prep Init. Model Arch. Process Modeling Model Integration

Northrop Grumman 5/25/22

Aerojet Rocketdyne 6/17/22

GE Aviation 7/15/22

Pratt & Whitney 5/13/22

Booze-Allen 7/08/22

Institute for Digital Enterprise Advancement Training and Development 7/08/22

MBSE Task 2 MBSE External Training Benchmarking Activities (FTE)

APPEL Tier 4 MBSE Training Pilot

APPEL Mod. Reqs for Tier 1-3 MBSE Training to use MagicDraw & align with Tier 4 Training

APPEL Tier 4 MBSE Training Available to NASA

MBSE NASA Handbook NASA-HDBK-1009 (FTE) Development and internal review

Agency-wide review 6/23-7/21 '22

Expect OCE to Sign by 9/30/22

Development of proposal for management of NASA-specific Standards in data-centric approach (FTE)

Orion Demo to Orion Chief Engineer & VIO Office 11/12/21

Presented @ Transformation Tue 11/16/21

MBSE Task 4

Orion Digital Twin (FTE/WYE)

Orion Demo to JSC Center Director 6/02/22
Orion Demo to MBSE CoP 5/25/22

Transformation Tue Update 6/14/22

Demo to NRO 8/04/22

Orion Demo to MB MA / OSMA w/ideas of how to generate fault trees 5/24/22

Orion Demo to Artemis MBSE Working Group 6/10/22

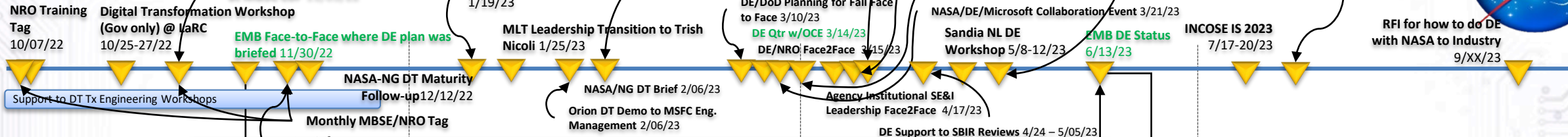
Demo to Gateway Management per request 7/29/22

Blue Text - represents training benchmarking



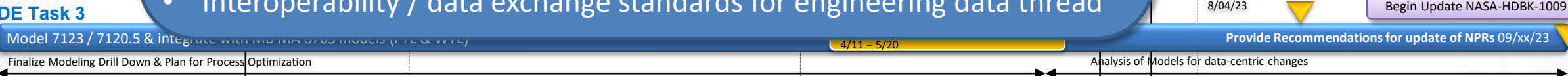
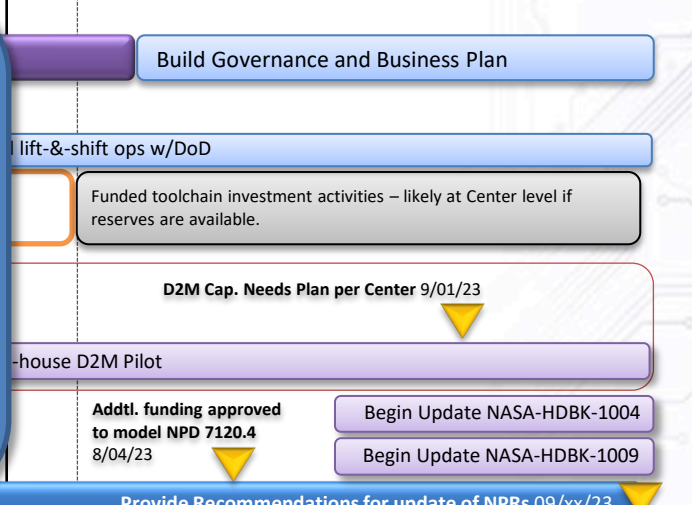
Year 2: FY23 DE Project Schedule

FY23

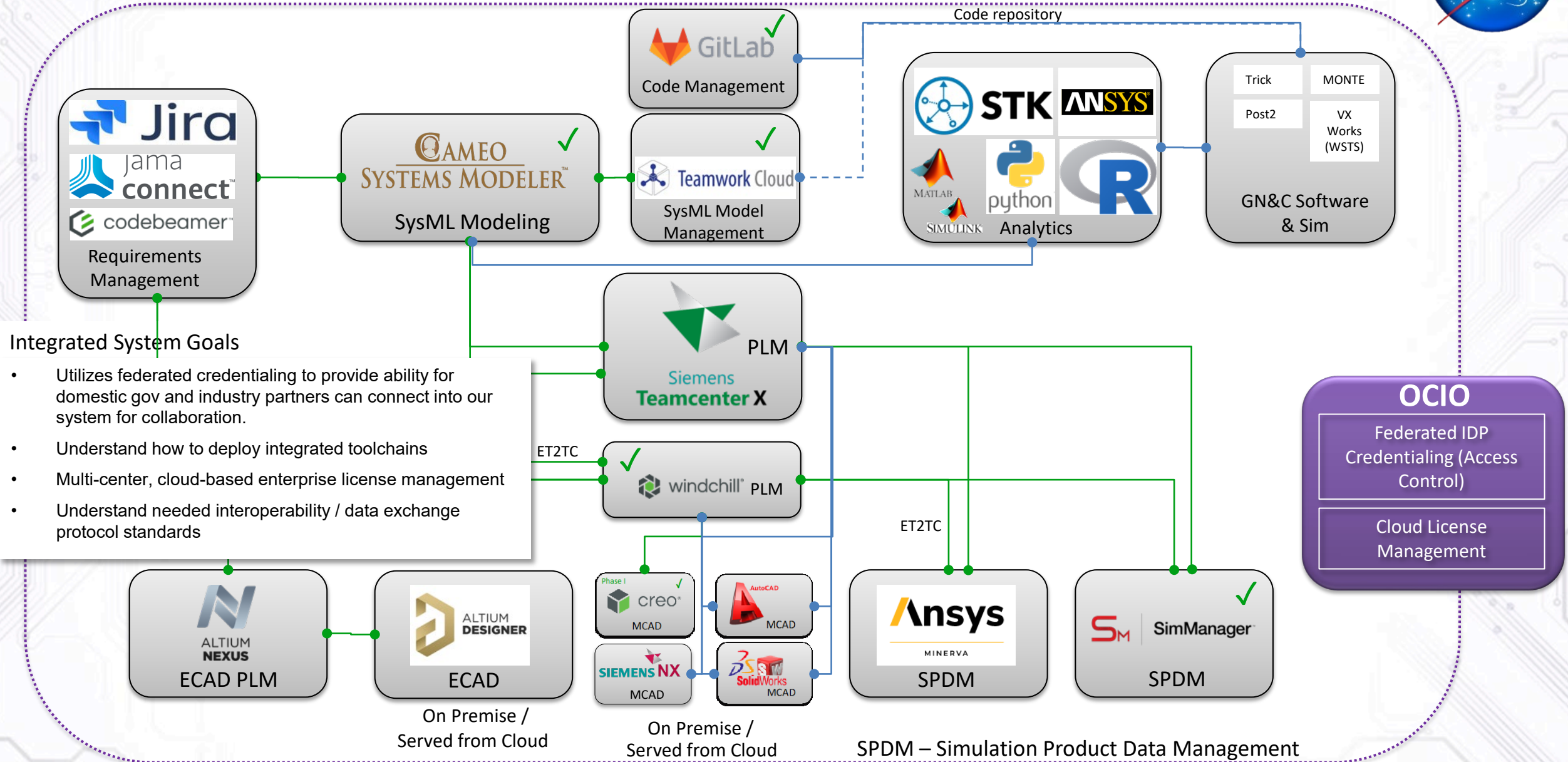


- DE Task 5**
Cloud-Based Multi-C
- DE Task 1**
Draft toolchain white
- Benchmark Agency Tool Interoperability reqs. (W
- Design to Manufacturing (D2M)

- Definition of what DE means for NASA: NGO's to Capabilities
- Engagement with DoD, DoE, Intelligence and FAA on DE
- Continued modeling & Data-centric analysis of NPR 7123, 7120.5/.8 & 8705
- Agency benchmarking of toolchain capabilities concluded
- Focus on Design to Manufacturing
- RFI to Industry
- Interoperability / data exchange for engineering data thread



Phased Integration of Commonly Used Engineering Tools w/in NASA Engineering Domain

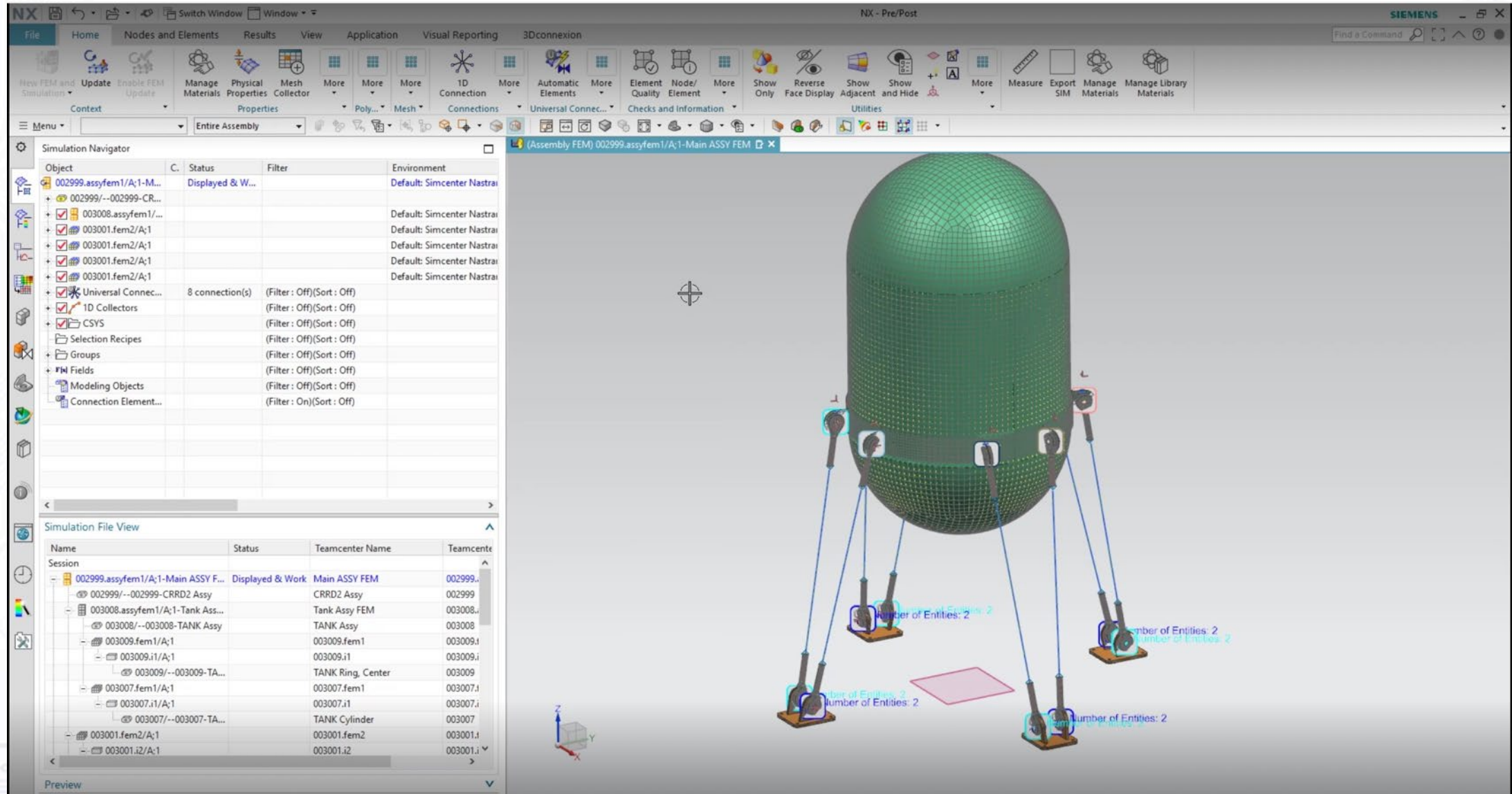


Example of Siemens tools as part of MSFC Engineering: Composite Cryo development tank



Estimated time savings for design revision:

- Siemens = 5 minutes
- Incumbent tools = 4-12 hours depending on tools

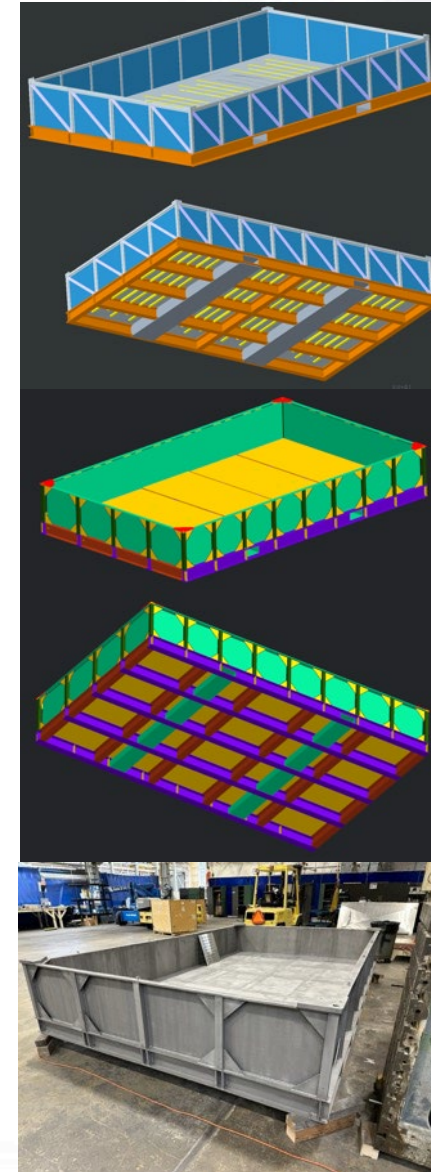


MSFC Vacuum Chamber Regolith Bed Stress Analysis Cycle Example

Time Comparison:



	<u>Traditional Approach:</u> FEMAP	<u>NX Integrated Approach:</u> Simcenter	<u>Model changes</u>
Initial Design:	12 hrs 5 min	1 hrs 45 min	-
Iteration 1:	12 hrs 5 min	20 min	Cross-section size and beam type
Iteration 2:	10 hrs 20 min	1 hrs 45 min	From fasteners to welded
Iteration 3:	11 hrs 50 min	2 hrs 15 min	AL to Steel; significant sizing changes
Iteration 4:	8 hrs 5 min	1 hrs 15 min	Added vertical stiffeners
Iteration 5:	3 hrs 45 min	55 min	Forklift tube changes
Iteration 6:	6 hrs	6 hrs	Weld changes
Total:	64 hrs 10 min	14 hrs 25 min	





GOING FORWARD

The Asks to Industry



- Software Vendors
 - Work closely with US government agencies in determining which existing industry standards are needed to support digital toolchains to form needed digital engineering threads, and/or which need to be created.
 - Be compliant with said standards asap.
- Aero/Defense Industry Partners
 - Work with/partner with US government agencies to determine the best way to collaborate (engineering and data exchange) while protecting IP so that solutions can be identified and put into place asap.
 - **Respond to NASA RFI** regarding future desired approaches to procurement and acquisitions, and paradigm shift from making money on DRDs (and associated changes) to focusing on interconnectivity and focusing efforts on accelerating project/program Concept to Operations.

REACH

NEW

HEIGHTS



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Questions?

