NASA's Digital Transformation & Digital Engineering

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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…

…now in a Changing World

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

NASA DIGITAL TRANSFORMATION

NASA's DT Strategic Framework

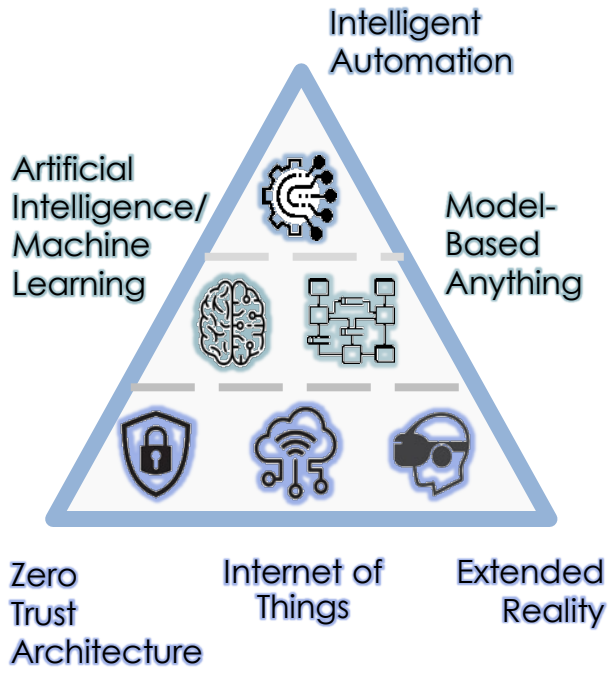
3 FUTURE STATE GOALS

4 TRANSFORMATION TARGETS

5 DIGITAL LEVERS

6 TECHNOLOGY FOUNDATIONS

7+ MISSION OUTCOMES



One Future NASA

[NASA TM 20220018538]

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

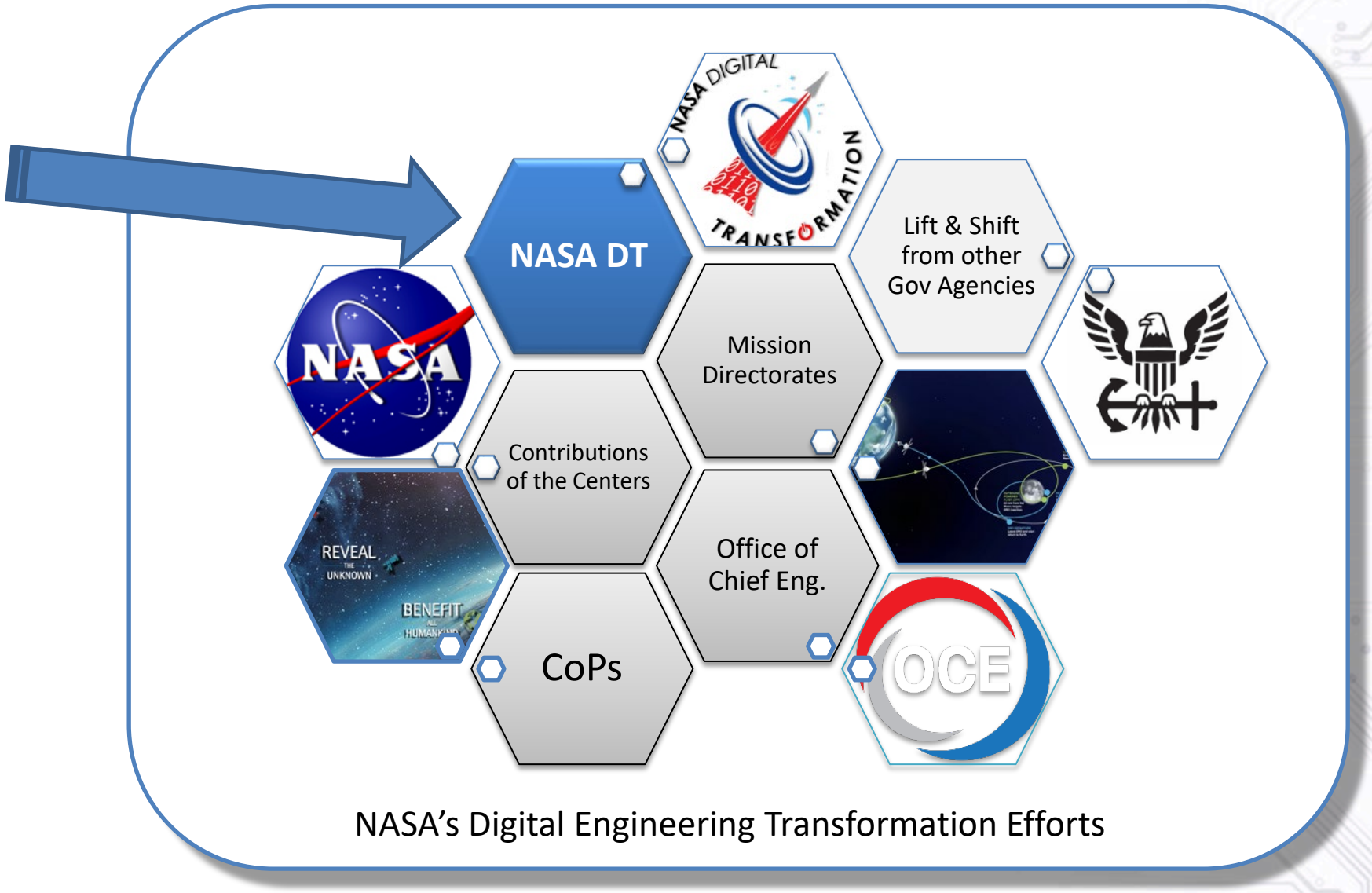
May 2023

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

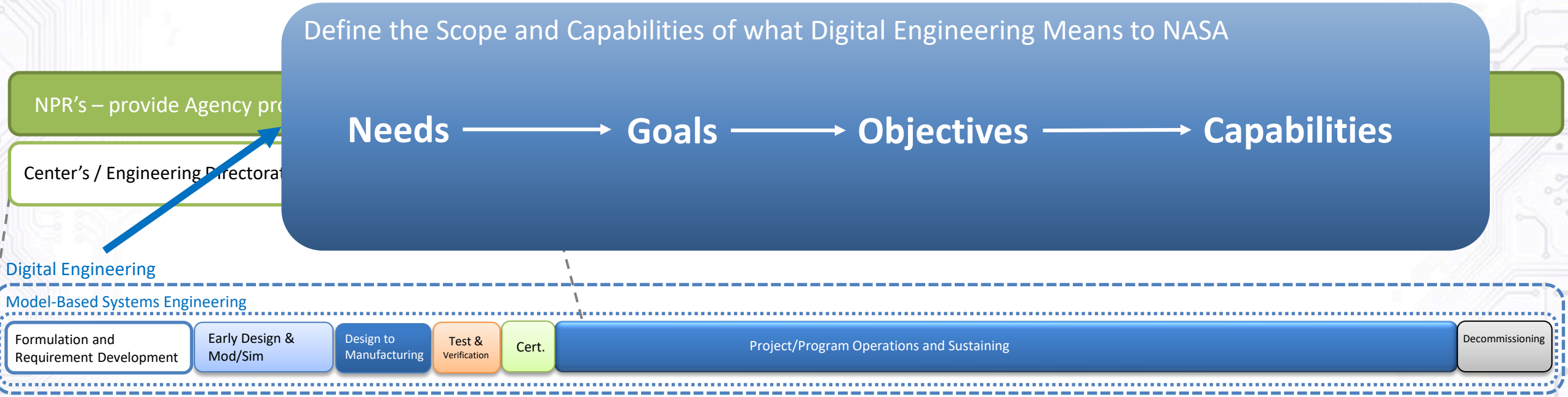
NASA's Digital Engineering Need

…from Concept to Operations

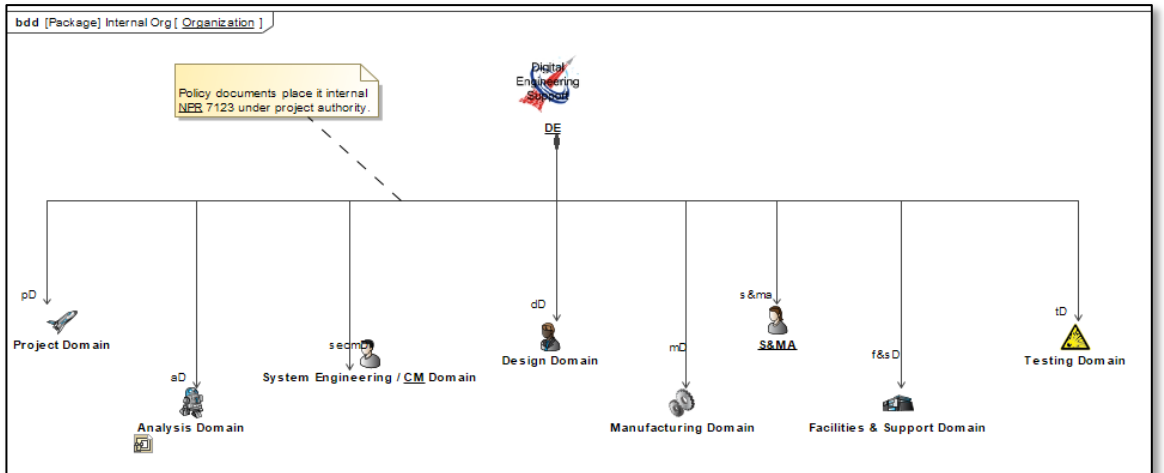
Historically a change of Presidential administration or Congress means a change to our missions/priorities/budgets

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



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.

Objectives

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.

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

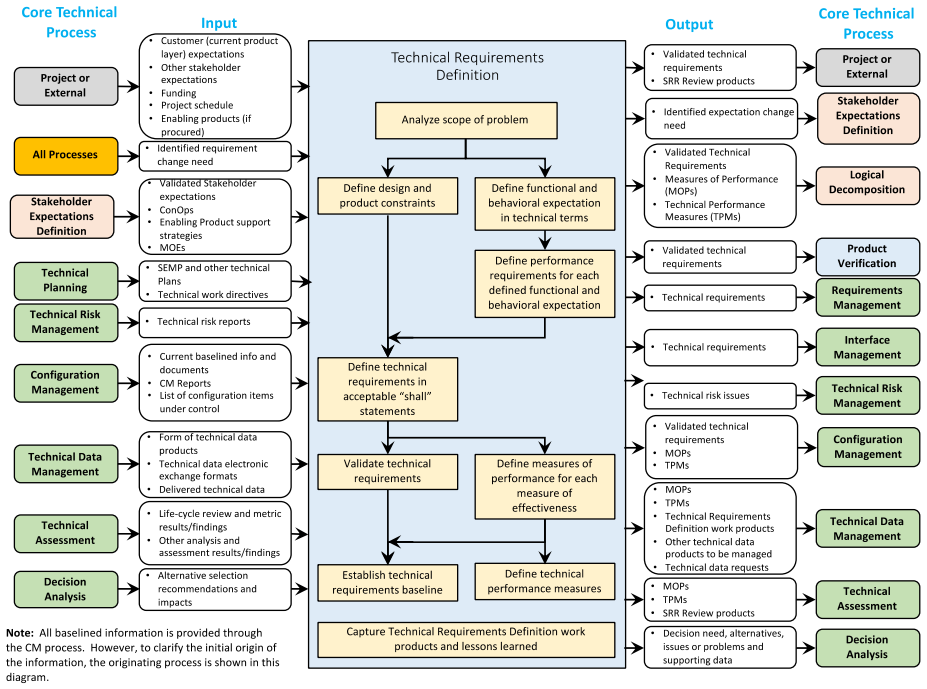
Engineering Project Lifecycle

Engineering Domain

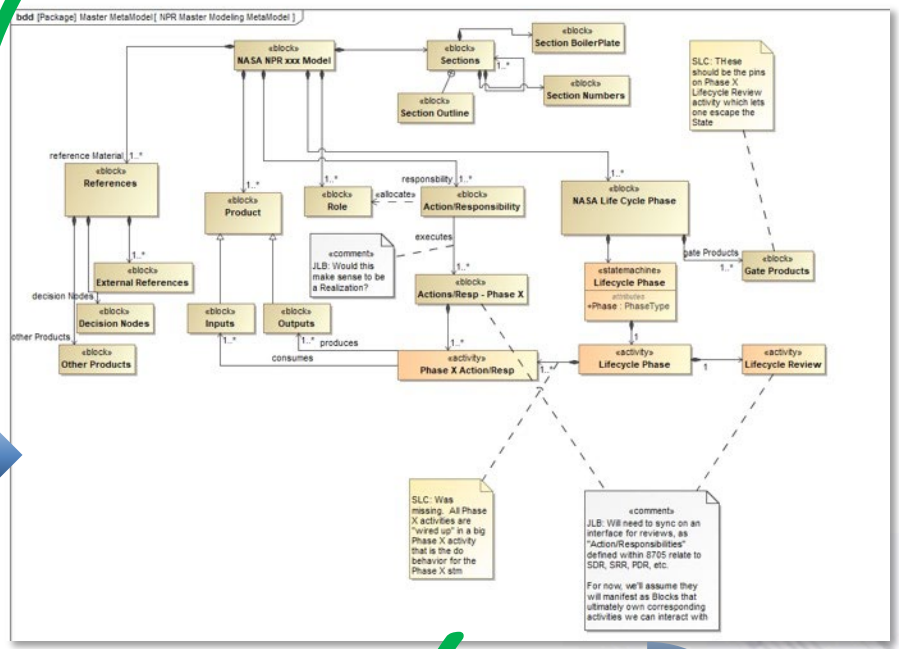
NPR's – provide Agency procedural requirements

NPR 7120.5/.8 | **NPR 7123** | **NPR 8705**

Logically decomposed current NPR document to understand the intended processed flow



Created Common Document meta-model framework so all the NPR models would be structured consistently



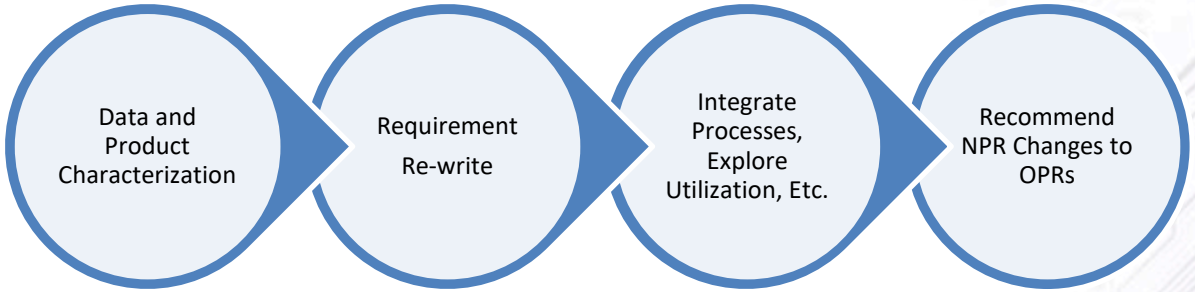
Agency-wide peer review of the As-Is NPR modeling 'trifecta'.

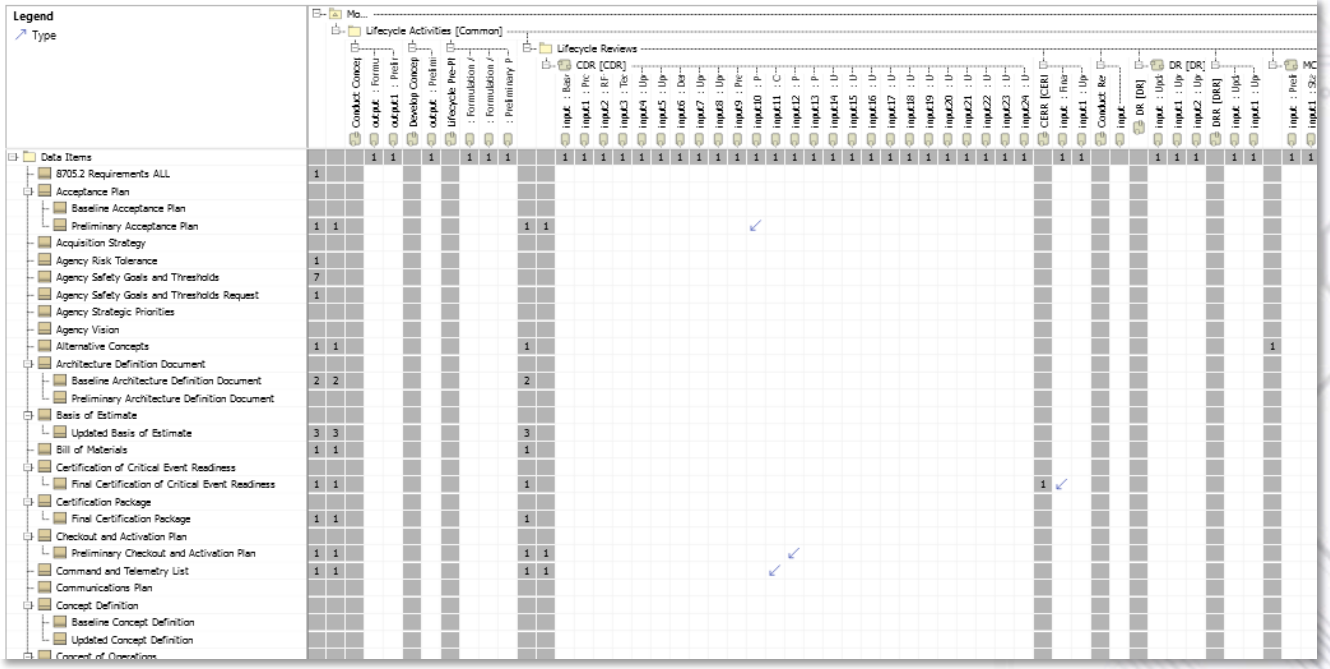
Data-Centric analysis of the process models and provide recommendations for updates to the NPRs.

Support Centers as they update their derivative processes to be more data-centric as part of their transformation.

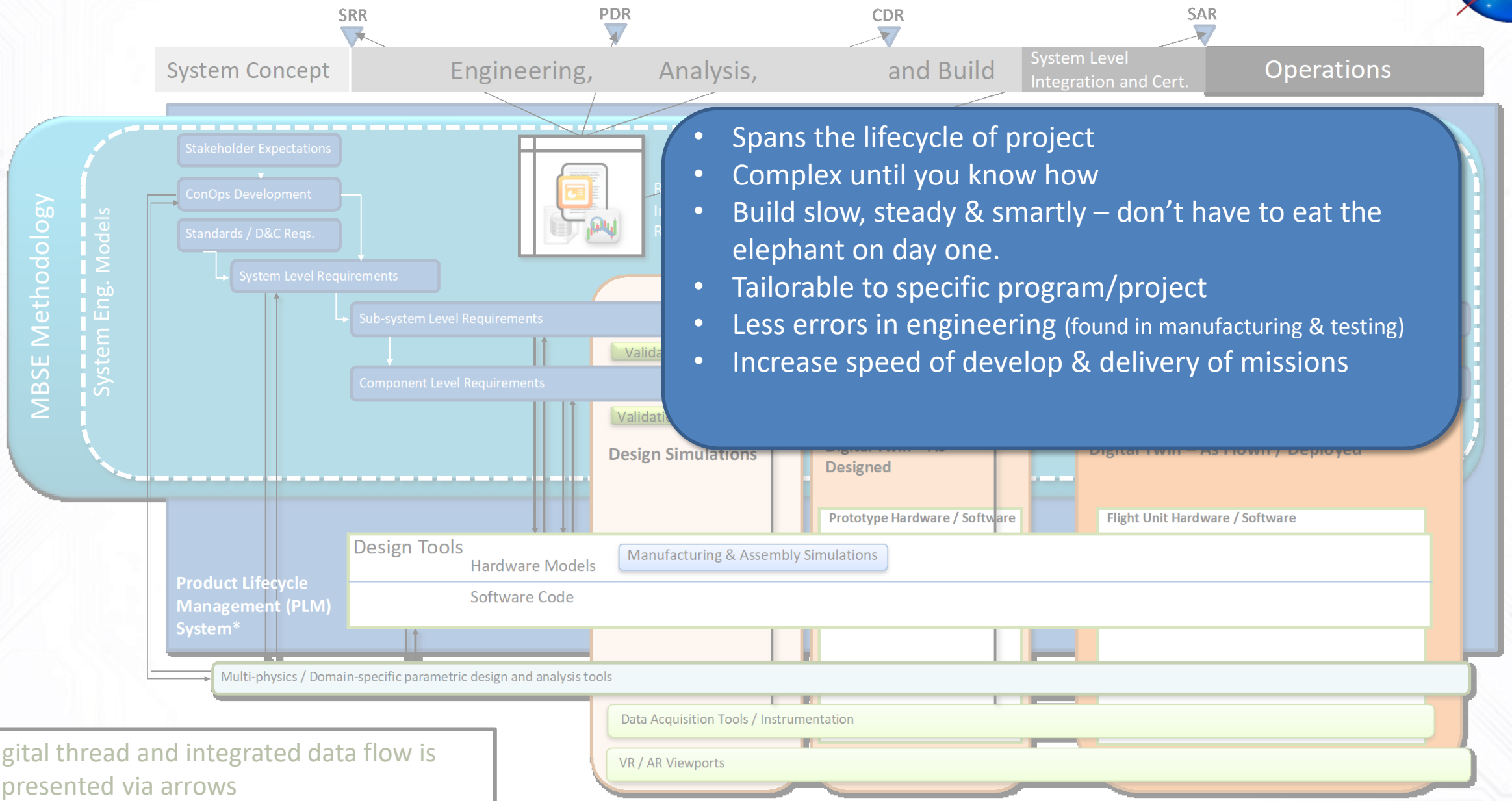
NPR Analysis Process

- 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





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

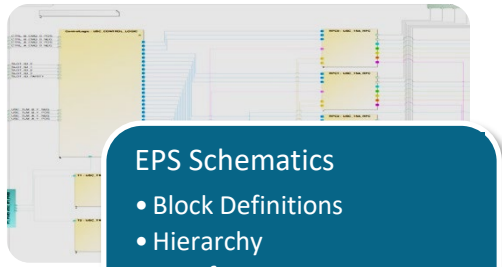
* Some PLM systems may integrate with multi-physics tools and/or store analysis results.

Orion Digital Twin Project 2021-2022 Activities

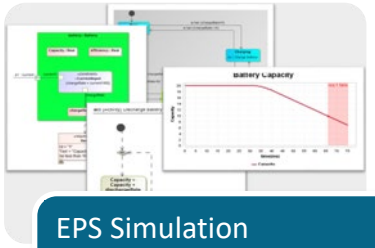
FY2021 | 2022

March | April | May | June | July | August | September | October | November | December | January | February | March | April | May | June | July | August | September

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

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

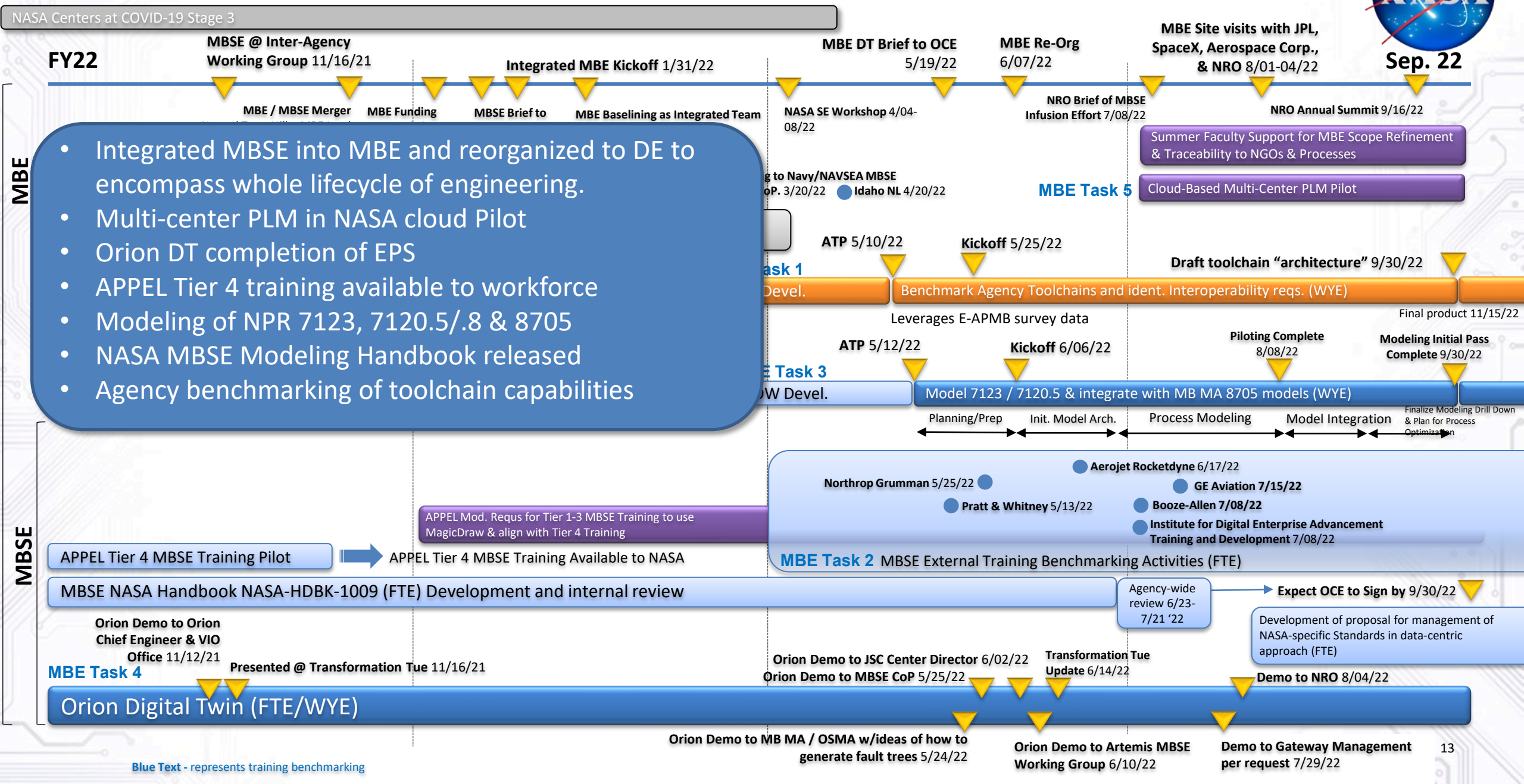
Further Subsystem Development
- Multi-Domain Simulation
- Tool Integration
- Comprehensive Digital Twin Framework

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

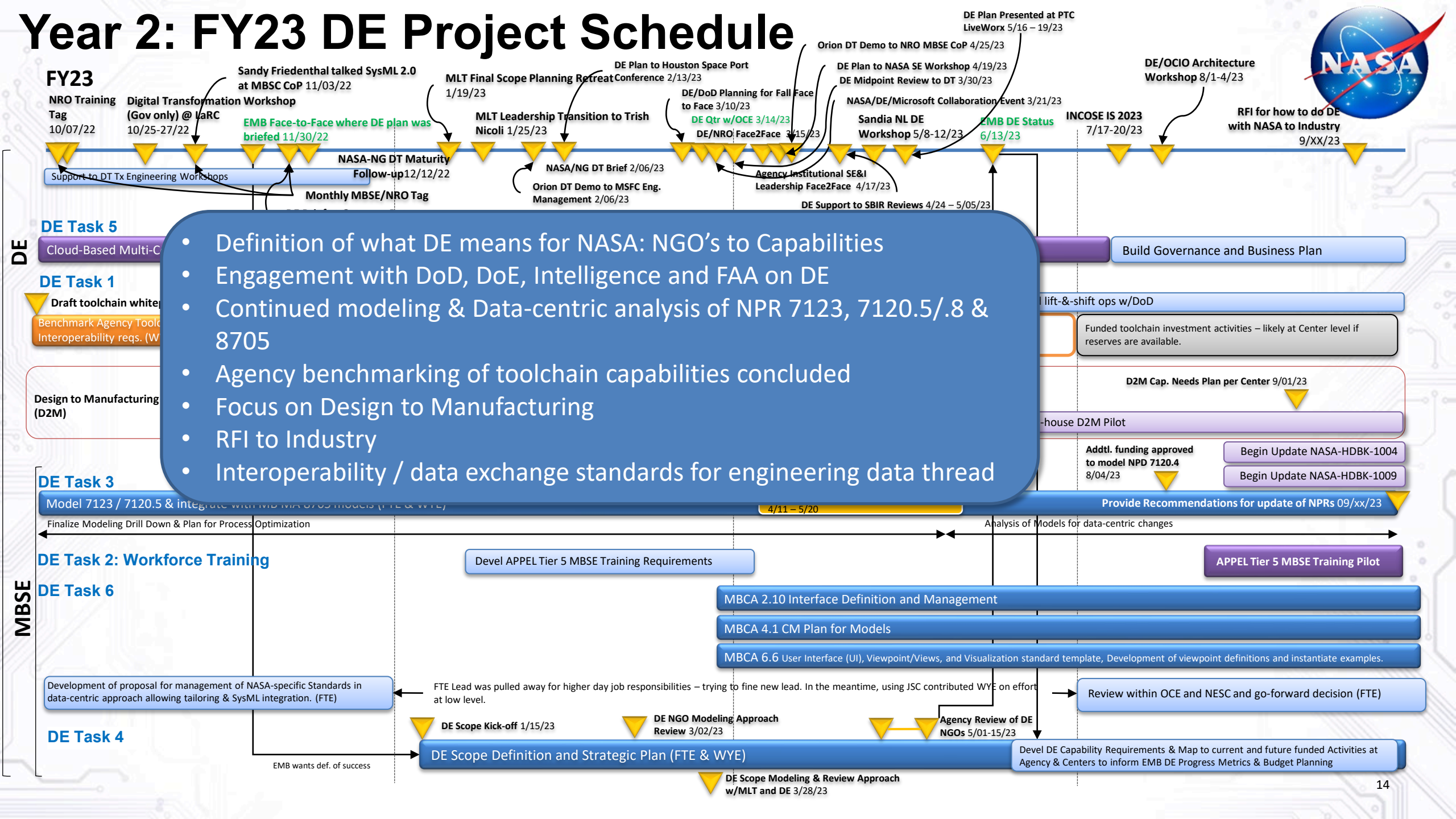
- 10 months of modeling and 8 months of validation.
- Over 9,000 components represented
- ~6000 elements of definition reused
- Over 130 hyperlinks to schematics database integrated into SysML Model
- Over 4,500 interfaces defined between components
- 2,208 ports imported ready for CD&H/Avionics/GNC 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

2023 INCOSE IS Best Paper in Mod/Sim Category

Year 1 (FY22) Digital Engineering Activities

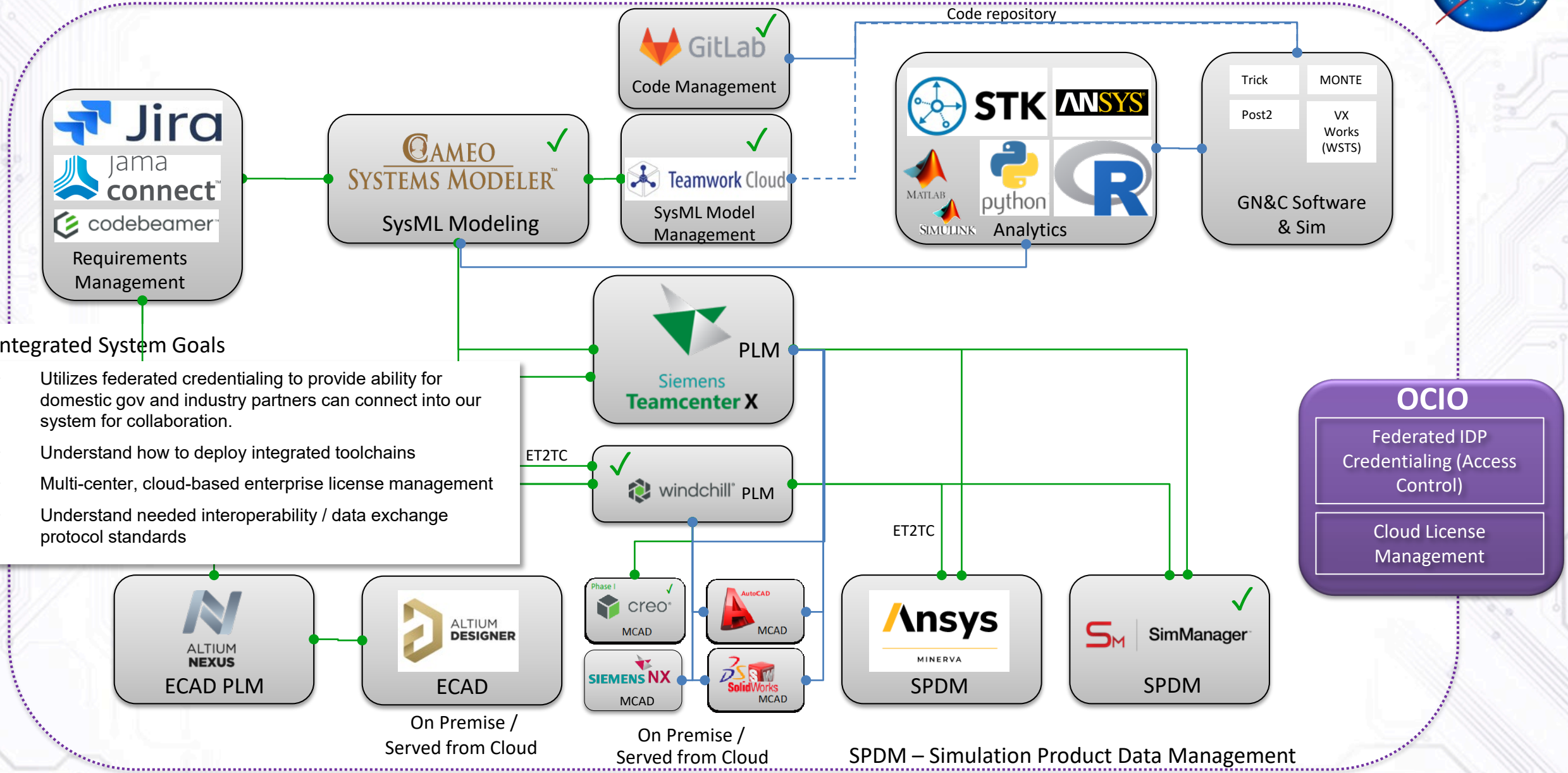


Year 2: FY23 DE Project Schedule



- 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 standards for engineering data thread

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

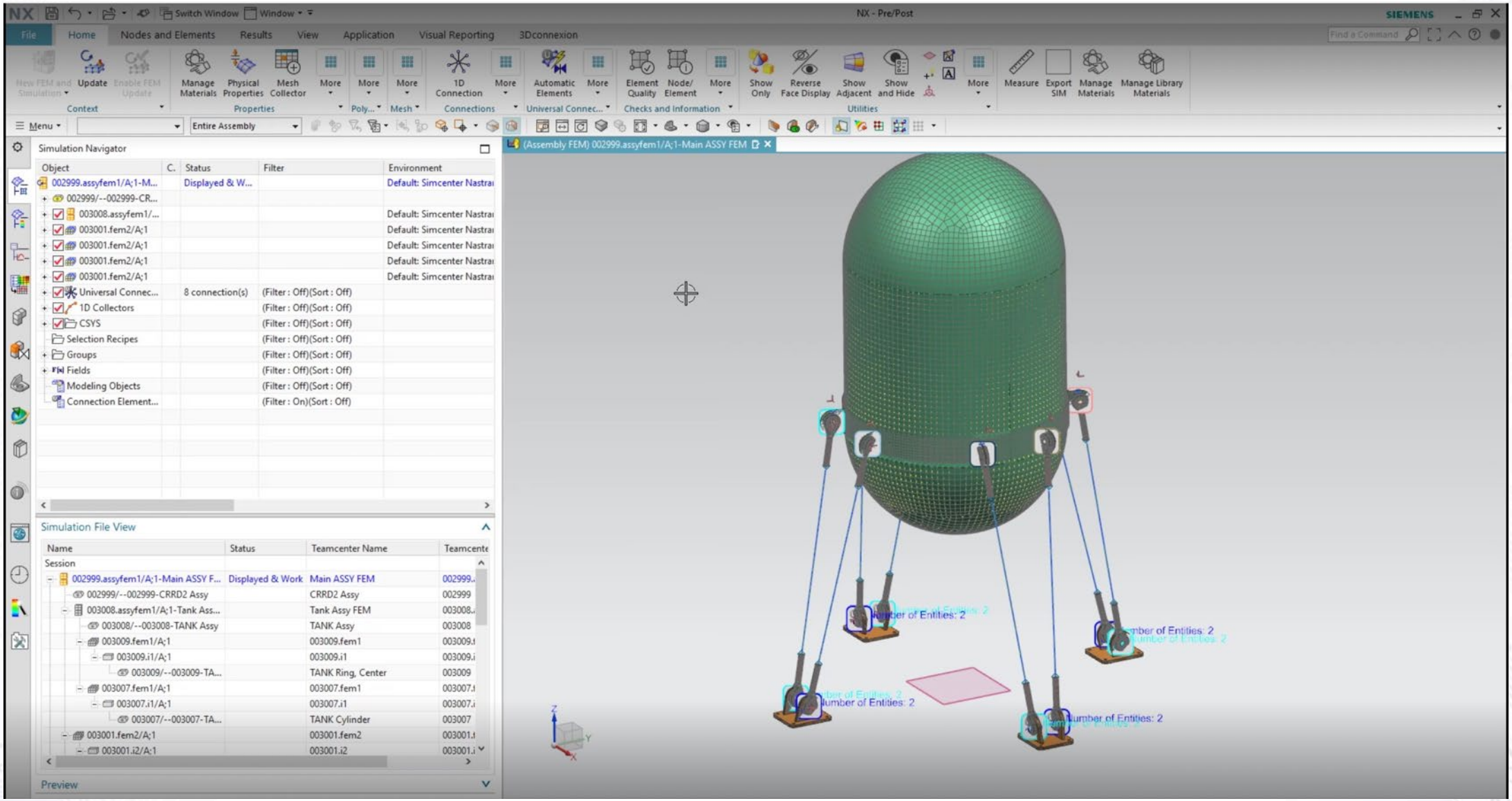


ET2TC - Exiting tool to tool connector

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

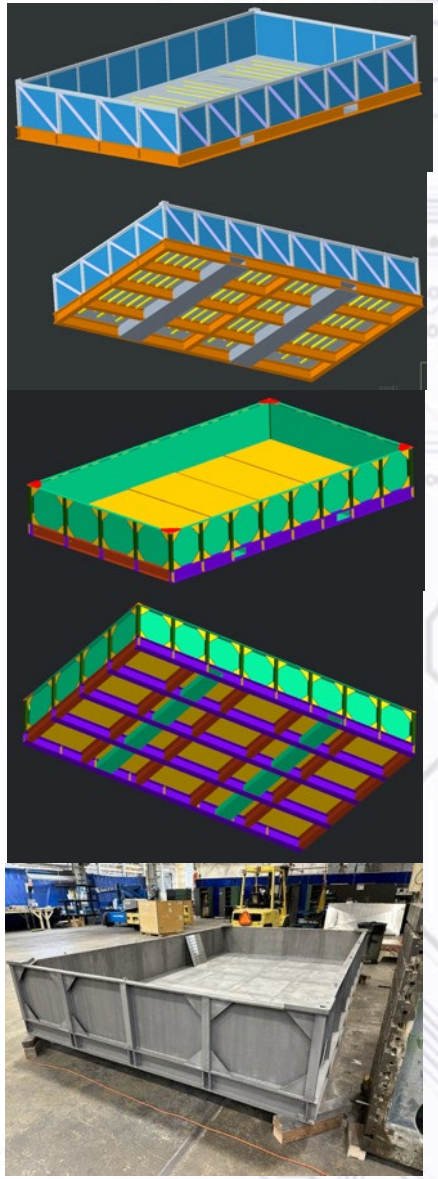
Estimated time savings for design revision:

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



MSFC Vacuum Chamber Regolith Bed Stress Analysis Cycle Example Time Comparison:

	Traditional Approach: FEMAP	NX Integrated Approach : Simcenter	Model changes
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

REVEAL
THE
UNKNOWN

BENEFIT
ALL
HUMANKIND

NASA DIGITAL TRANSFORMATION

Questions?