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# NASA'S DIGITAL ENGINEERING TRANSFORMATION

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# NASA's Digital Engineering Transformation

Terry R. Hill

May, 2023

“It is not necessary to change. Survival is not mandatory.”

(W. Edwards - Deming Institute, 2019)

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# AGENDA

- The Big Picture: DT and The Transformation of Engineering Quadrant
- Transformation of Engineering – It takes a village ...
- Digital Engineering Framework
- Things which have been accomplished
  - Integrated Digital Engineering (DE)
  - Orion Digital Twin
  - MBSE
- The plan going forward
  - The Agency
  - Centers

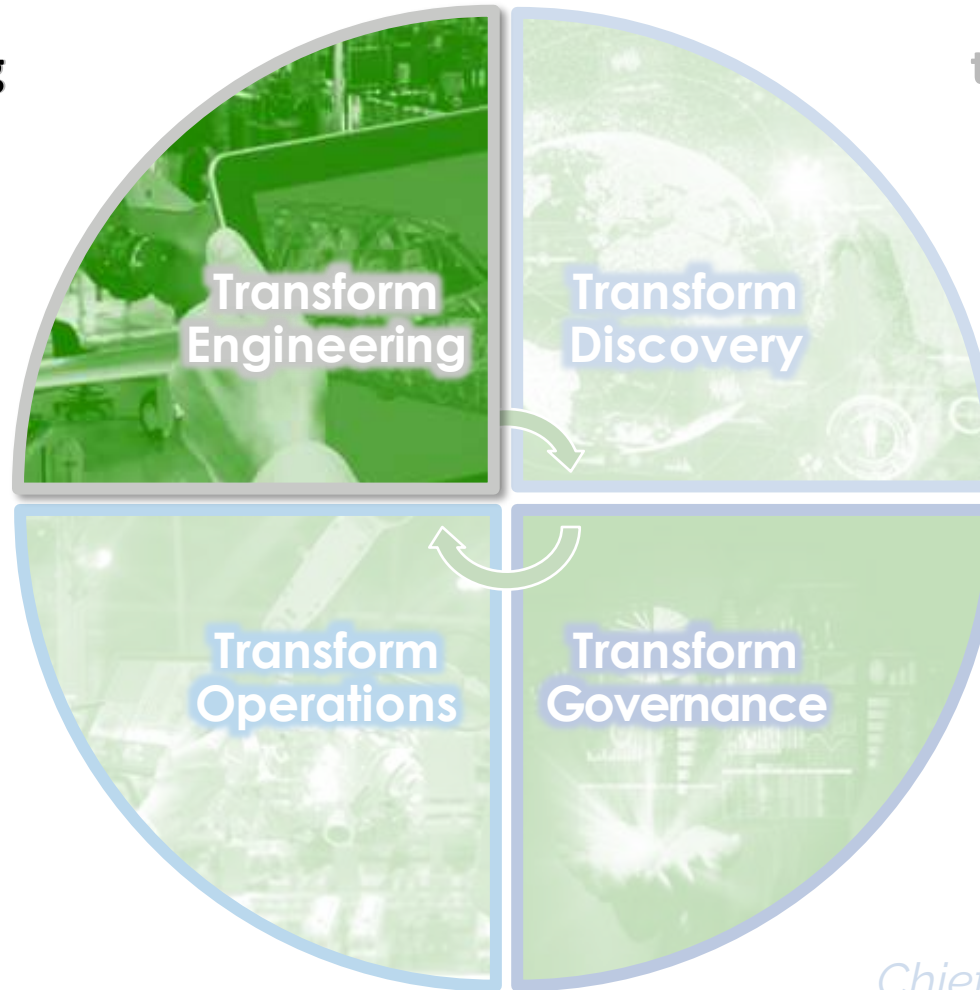
# PROPOSED TRANSFORMATION TARGETS – DIGITAL LEVEL<sup>EDCS</sup>

**Enable agile multi-center/partner engineering teams to solve frontier problems**

*Executive Sponsors:  
MDs, OCE, OSMA, Centers*

**Optimize & synchronize our work environment to increase efficiencies & effectiveness between mission & mission support**

*Executive Sponsors:  
MSD, Centers, MSEOs*



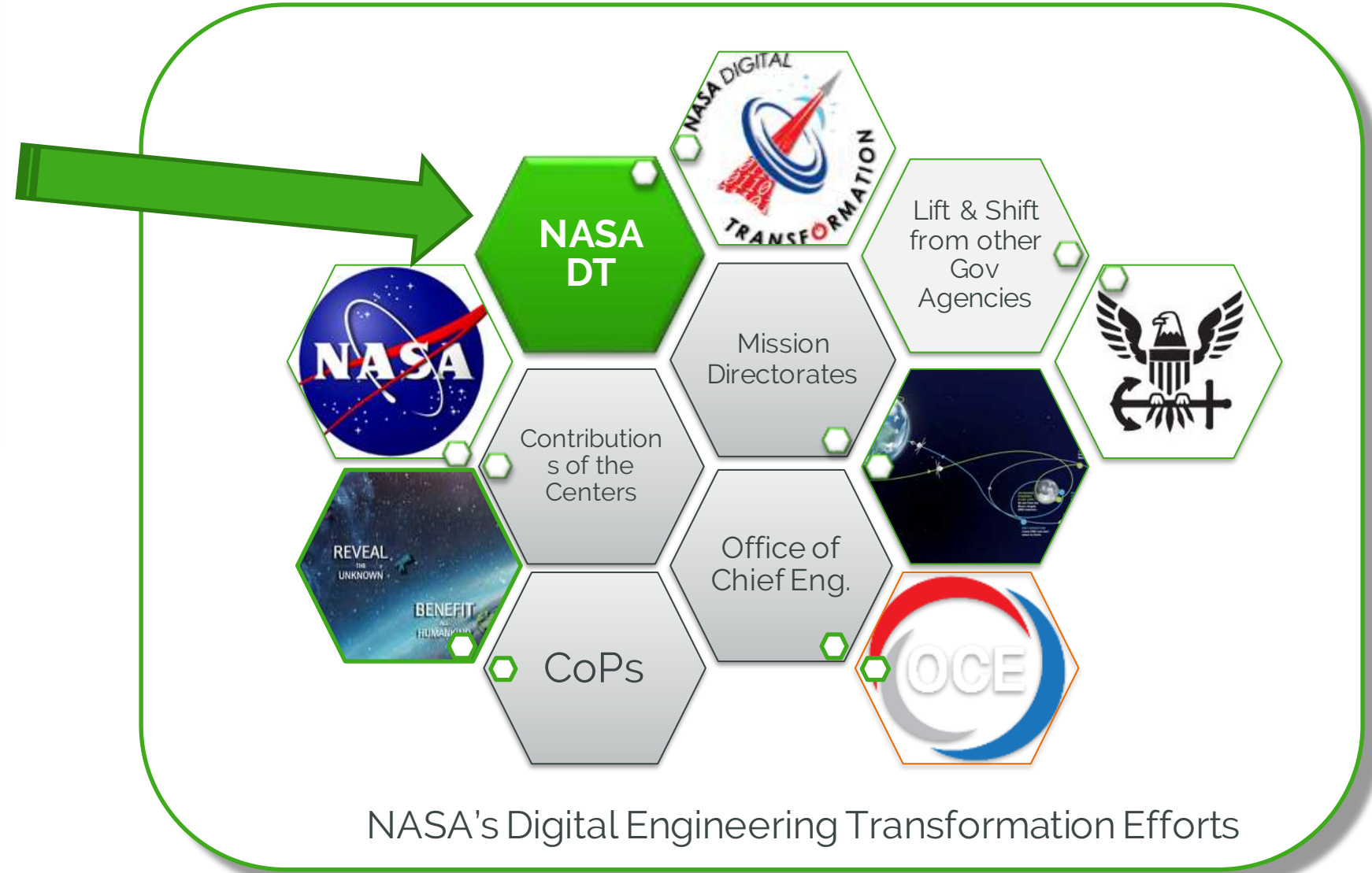
**Multiply science & technology breakthroughs by leveraging diverse global minds/advances**

*Executive Sponsors:  
OCS, OTPS, MDs,  
Centers*

**Accelerate risk-informed, self-consistent decision making**

*Executive Sponsors:  
Chief of Staff/OES, CPMO, MDs*

# TRANSFORMATION OF ENGINEERING – IT TAKES A VILLAGE



# TRANSFORM ENGINEERING – AREAS OF FOCUS

## Need:



**Enable agile multi-center/partner engineering teams to solve frontier problems via integrated digital engineering**



## Goals (agreed to by EDs @ EMB 11-04-21):

1. Establish Engineering Ecosystem Across the Engineering Life Cycle, including Best Practices
2. Formalize the Development, Integration, and Use of Models
3. Provide Integrated Engineering Data
4. Develop protocols and IT tools to enable collaboration
5. Evolve Culture and Workforce



## Approach:

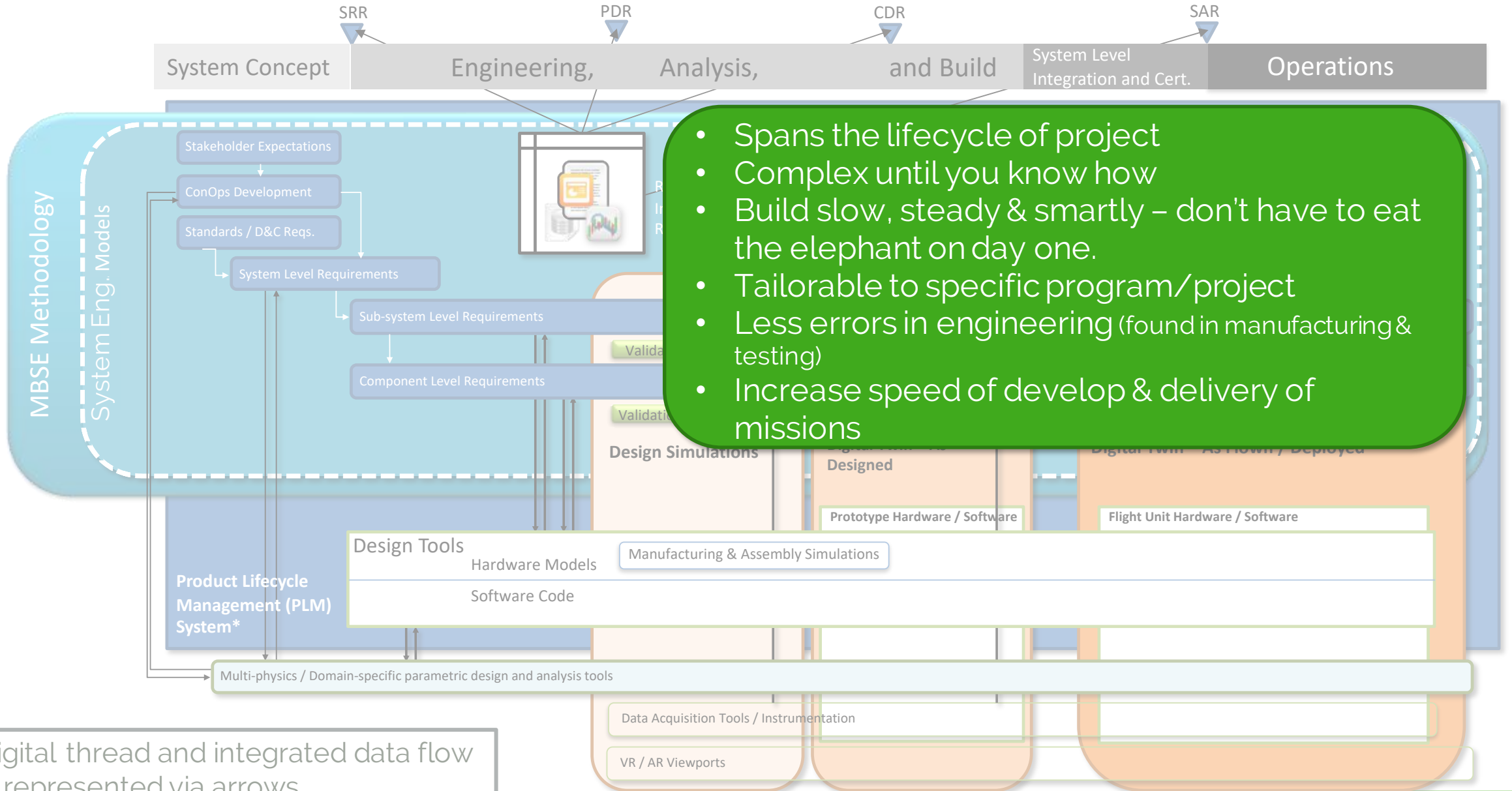
- Tailorable to programs/projects
- Address current Pain points
- Achieve needed efficiencies
- Fill capability gaps needed today and for tomorrow



## Objectives:

- Inclusive, integrated **multi-center/partner teams**
- Shared **interoperable development environment** that enables agile **interdisciplinary modsim/test, rapid learning** & diverse mission-driven approaches
- **Integrated cross-org, configuration managed, data-centric processes** to rapidly & affordably develop/evaluate options & close complex designs
- **Authoritative, discoverable design/analysis/test artifacts** with integrated **confidence measures, and common taxonomies/ontologies.**
- **Multi-fidelity digital twins** to enable rapid concept-design-develop-build-test-evaluate-operate **life-cycle engineering solutions & partner efforts**

# 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

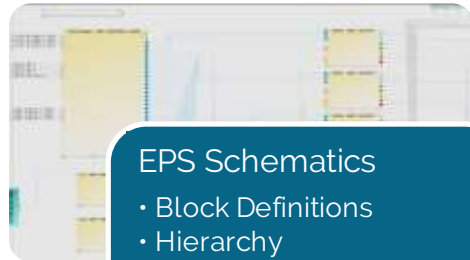
\* Some PLM systems may integrate with multi-physics tools and/or store analysis results.

# Orion DT Project 2021-2022 Plan & Milestones



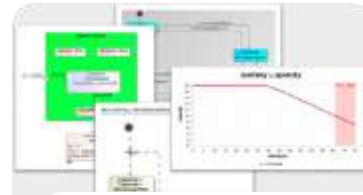
## Development

- Prototype
- Depth Trade
- Domain Research



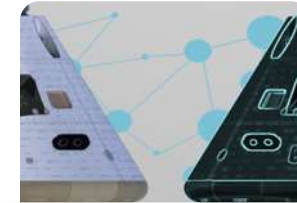
## EPS Schematics

- 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

## EPS Digital Twin Validation/Evaluation

- Model-Based Review
- Live Reviews
- Automated Audits

## Further Subsystem Development

- Multi-Domain Simulation
- Tool Integration
- Comprehensive Digital Twin Framework

## Artemis I Test Case

- Feedback from live mission use by EPS engineering team



Initial proposal included 10 months of modeling and 8 months of validation per system.

- Project Execution: Team finished modeling and initiated script-based verification in Dec-Jan '22 per plan. Spring of '22 performed internal checks of the content that couldn't be verified using scripts, and delivered models, scripts and lessons learned to the NASA CoP.

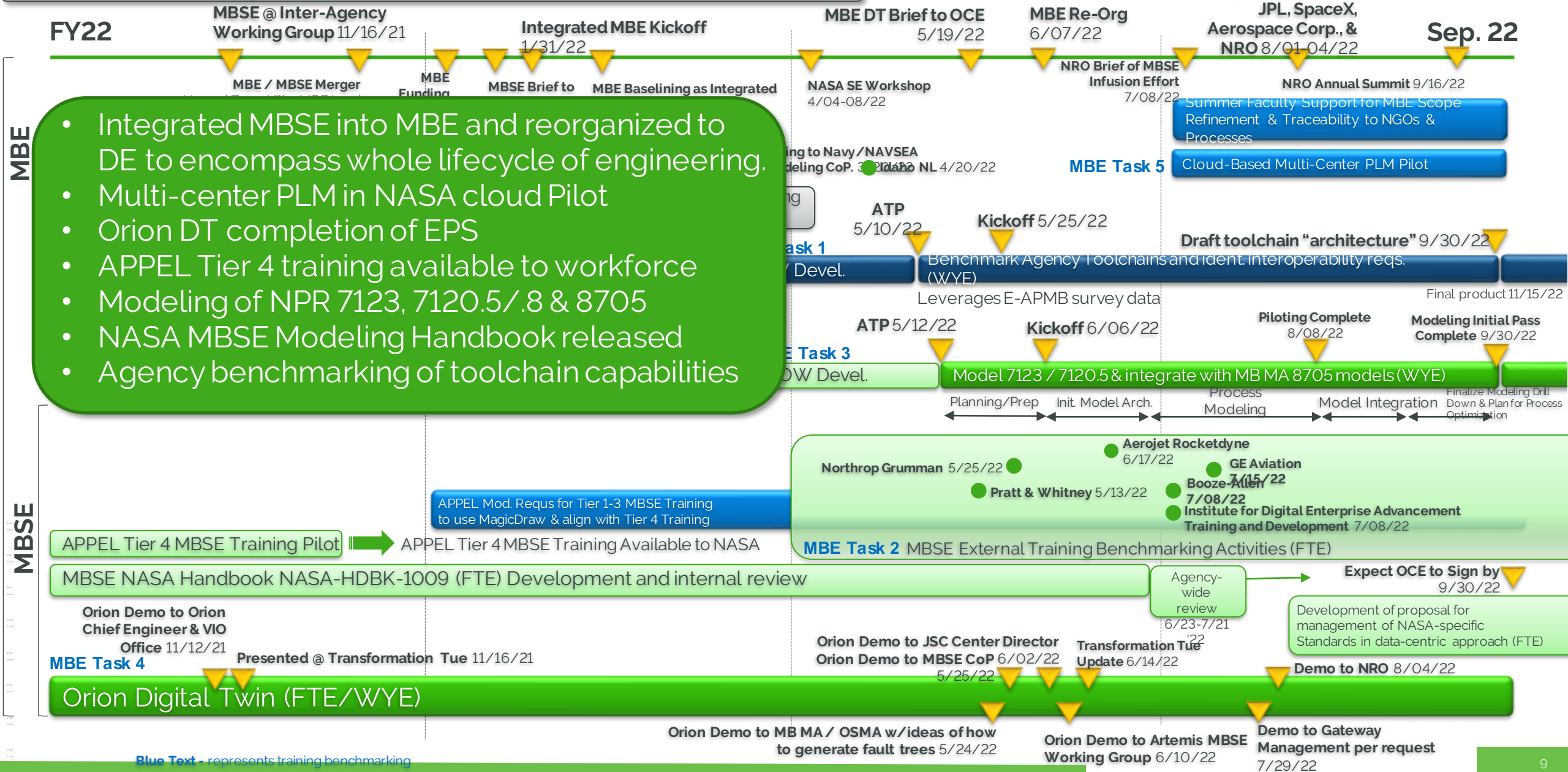
## Package for Agency Wide Use

- Lessons Learned
- Sanitized Model
- Script Library
- Reusable Components



# YEAR 1 (FY22) DIGITAL ENGINEERING ACTIVITIES

NASA Centers at COVID-19 Stage 3



- 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

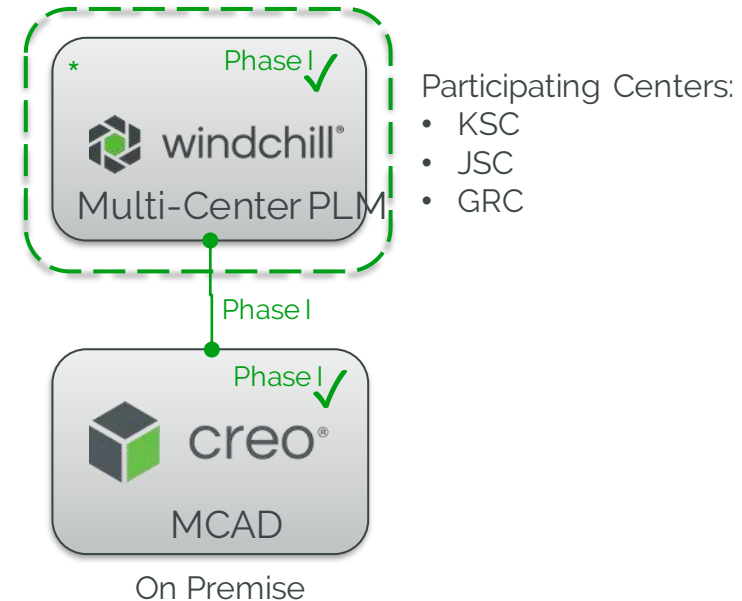
Blue Text - represents training benchmarking

# PHASED INTEGRATION PILOT OF COMMONLY USED ENGINEERING TOOLS

Phase I – FY22

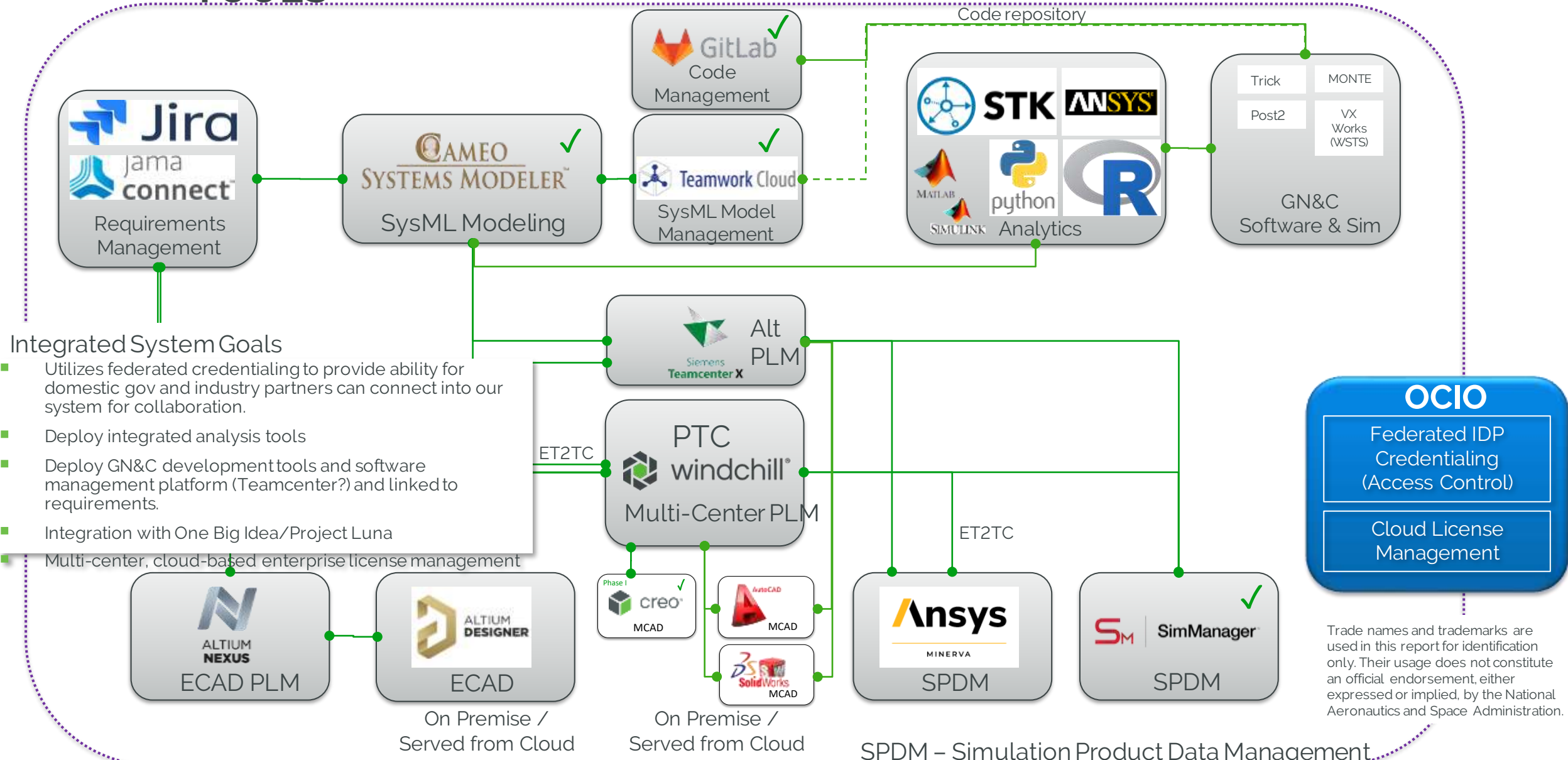
## Multi-Center PLM System Goals

- Provide cloud-based repository to manage drawings, models and all project baselined artifacts including a release process workflow
- Improve data accessibility
- Integrate with agency systems and processes
  - (Launchpad, NAMS)
- Broaden usage across centers improving system utilization
  - Manufacturing, Quality, EDCC users
- Improve system security through consolidation
  - Reduce cost by only having one security plan



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# PHASED INTEGRATION PILOT OF COMMONLY USED ENGINEERING TOOLS



## Integrated System Goals

- Utilizes federated credentialing to provide ability for domestic gov and industry partners can connect into our system for collaboration.
- Deploy integrated analysis tools
- Deploy GN&C development tools and software management platform (Teamcenter?) and linked to requirements.
- Integration with One Big Idea/Project Luna
- Multi-center, cloud-based enterprise license management

### OCIO

Federated IDP  
Credentialing  
(Access Control)

Cloud License  
Management

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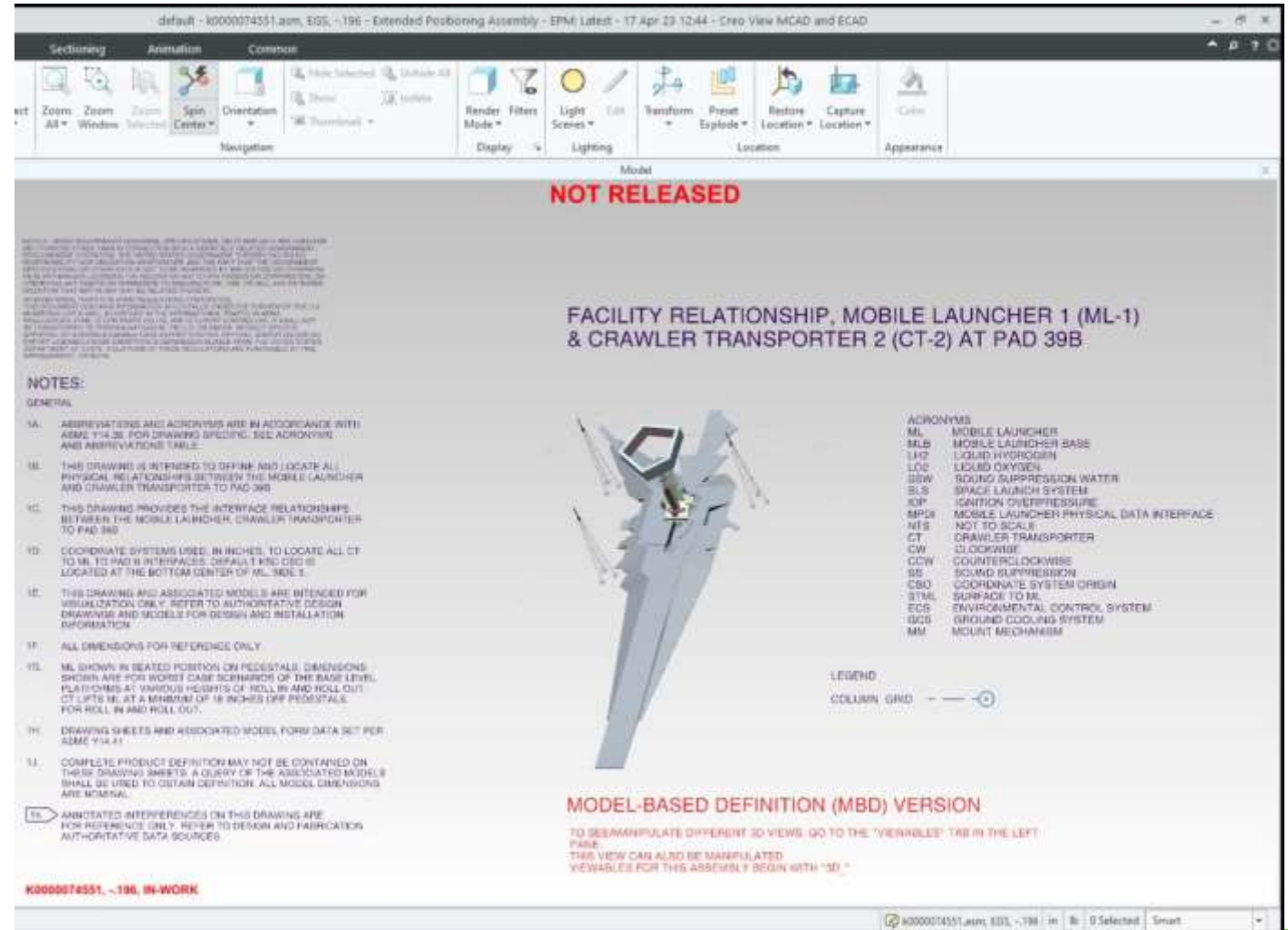
SPDM – Simulation Product Data Management

ET2TC - Exiting tool to tool connector

# VERY LARGE 3D MODEL USAGE

## Kennedy Space Center

- Launch Pad model created from scanned point-cloud
- Volumetric SLS model
- As-Designed crawler and Launch Tower



# VERY LARGE 3D MODEL USAGE

The screenshot displays the Creo CAD environment. The top ribbon includes tabs for File, Home, Markup, Tools, Sectioning, Animation, and Common. The 'Viewables' tree on the left lists various components of the assembly, such as 'OVERVIEW', 'SIDE2', 'ACCESS\_SIDE2', 'NO\_LIGHTNING', 'ACCESS\_PLATFORMS', 'LAUNCH\_CONFIG', 'ELEC\_TOWER', 'MPDI', 'NO\_LIGHTNING\_NO\_', 'PARKED\_CONFIG', 'MPDI\_FLIP\_UP', 'NO\_LIGHTNING\_NO\_', 'SLS\_UMBIL\_NO\_MCS', 'NO\_LIGHTNING\_NO\_', 'PAD\_ML\_CT\_RELATIO', 'PAD\_CT', 'ACCESS\_SIDE2\_RET', 'MPDI\_RET', 'MPDI-RET', 'PNEUMATIC-TOWER', 'PNEUMATIC-TOWER', '01-COVER-NOTES', '02-PAD-ML-CT-OVER', '03-PAD-UMBIL', '04-PAD-ML-SIDEST-2', '05-PAD-CT-ML-SIDE2', '06-PAD-ML-SIDES2-4', '07-PAD-ML-SIDE4', '08-PAD-ML-398-PLA', '09-PAD-CRAWLER', '10-PAD-ML-ELEC-INT', '11A\_PAD-ML-PNEUM', '11B\_PAD-ML-PNEUM', '12A-PAD-ML-ACCES', '12B-PAD-ML-ACCES', '13A-PAD-ML-MPDI-T', and '13B-PAD-ML-MPDI-T'. The main workspace shows a 3D model of the assembly with a large red 'NOT RELEASED' watermark. Below the watermark, the title reads 'FACILITY RELATIONSHIP, MOBILE LAUNCHER 1 (ML-1) & CRAWLER TRANSPORTER 2 (CT-2) AT PAD 39B'. A 3D model of the assembly is shown in a perspective view. To the right of the model is an 'ACRONYMS' table and a 'LEGEND' for the column grid. Below the model, the text 'MODEL-BASED DEFINITION (MBD) VERSION' is displayed, followed by instructions on how to manipulate the 3D views.

**NOT RELEASED**

**FACILITY RELATIONSHIP, MOBILE LAUNCHER 1 (ML-1) & CRAWLER TRANSPORTER 2 (CT-2) AT PAD 39B**

**ACRONYMS**

ML	MOBILE LAUNCHER
MLB	MOBILE LAUNCHER BASE
LH2	LIQUID HYDROGEN
LO2	LIQUID OXYGEN
SSW	SOUND SUPPRESSION WATER
SLS	SPACE LAUNCH SYSTEM
IOP	IGNITION OVERPRESSURE
MPDI	MOBILE LAUNCHER PHYSICAL DATA INTERFACE
NTS	NOT TO SCALE
CT	CRAWLER TRANSPORTER
CW	CLOCKWISE
CCW	COUNTERCLOCKWISE
BS	SOUND SUPPRESSION
CSO	COORDINATE SYSTEM ORIGIN
STML	SURFACE TO ML
ECS	ENVIRONMENTAL CONTROL SYSTEM
GCS	GROUND COOLING SYSTEM
MM	MOUNT MECHANISM

**LEGEND**

COLUMN GRID:

**MODEL-BASED DEFINITION (MBD) VERSION**

TO SEEMANIPULATE DIFFERENT 3D VIEWS, GO TO THE "VIEWABLES" TAB IN THE LEFT PANE. THIS VIEW CAN ALSO BE MANIPULATED VIEWABLES FOR THIS ASSEMBLY BEGIN WITH "3D."

**NOTES:**

GENERAL

1A. ABBREVIATIONS AND ACRONYMS ARE IN ACCORDANCE WITH ASME Y14.39. FOR DRAWING SPECIFIC, SEE ACRONYMS AND ABBREVIATIONS TABLE.

1B. THIS DRAWING IS INTENDED TO DEFINE AND LOCATE ALL PHYSICAL RELATIONSHIPS BETWEEN THE MOBILE LAUNCHER AND CRAWLER TRANSPORTER TO PAD 39B.

1C. THIS DRAWING PROVIDES THE INTERFACE RELATIONSHIPS BETWEEN THE MOBILE LAUNCHER, CRAWLER TRANSPORTER TO PAD 39B.

1D. COORDINATE SYSTEMS USED, IN INCHES, TO LOCATE ALL CT TO ML TO PAD B INTERFACES. DEFAULT RSC CRO IS LOCATED AT THE BOTTOM CENTER OF ML SIDE 3.

1E. THIS DRAWING AND ASSOCIATED MODELS ARE INTENDED FOR VISUALIZATION ONLY. REFER TO AUTHORITATIVE DESIGN DRAWINGS AND MODELS FOR DESIGN AND INSTALLATION INFORMATION.

1F. ALL DIMENSIONS FOR REFERENCE ONLY.

1G. ML SHOWN IN SEATED POSITION ON PEDESTALS. DIMENSIONS SHOWN ARE FOR WORST CASE SCENARIOS OF THE BASE LEVEL PLATI ORMS AT VARIOUS HEIGHTS OF ROLL IN AND ROLL OUT. CT LIFTS ML AT A MINIMUM OF 18 INCHES OFF PEDESTALS FOR ROLL IN AND ROLL OUT.

1H. DRAWING SHEETS AND ASSOCIATED MODEL FORM DATA SET PER ASME Y14.41.

1J. COMPLETE PRODUCT DEFINITION MAY NOT BE CONTAINED ON THESE DRAWING SHEETS. A QUERY OF THE ASSOCIATED MODELS SHALL BE USED TO OBTAIN DEFINITION. ALL MODEL DIMENSIONS ARE NOMINAL.

ANNOTATED INTERFERENCES ON THIS DRAWING ARE FOR REFERENCE ONLY. REFER TO DESIGN AND FABRICATION AUTHORITY DATA SOURCES.

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# GOING FORWARD

# —— FY23 DIGITAL ENGINEERING PLAN

## Close Partnership with the Center Engineering Directorates:

- Direct involvement to better understand current capabilities, where they want to get to.
- Leverage current capabilities of Centers with other Centers in need of the capability.
- Formulate a plan for pilot projects which advance a Center's needs and those of other Centers.

**Complete Agency Process Mapping** and perform Data-centric optimization, formulate interoperability requirements, and recommended toolchain with short list of tools per domain per project/program lifecycle.

## Domestic Partners:

- Release a RFI for recommendation for successful digital engineering toolchains to solution providers, to inform NASA's internal recommendations in the event there are unknown unknowns to NASA in this area.
- Release a RFI to domestic partners regarding how they would like to do business with NASA, collaborate, exchange data via contractual mechanisms to shape NASA's near-term capabilities.

## International Partners:

- Engage to develop capability to securely collaborate and exchange information seamlessly.

# FY23-25 DE TRANSFORMATION PLAN

Notional / Pre-Decisional

- Theme or Major initiative
- Agency Activity
- Agency Planning Activity
- Recommended Center Activity

Sep. 25

Digital Transformation Workshop (Gov only) @ LaRC

10/25-27/22

RFI for how to do DE with NASA to Industry

12/XX/22

DE EMB at Face 2 Face

11/30/22

DE EMB Status 11/10/22

## Eng. Digital Toolchains

Understand lift-&-shift ops w/DoD

Plan lift-&-shift w/DoD

Execute lift-&-shift w/DoD

Understand Center's capability gaps - devel. Lift-&-shift

Exp

Identifying gaps / infuse newly identified needed

Integrate digital engineering as baseline approach

Findings &

Finalize Agency Phase I toolchain baseline survey

Finalize Center agreements of their contribution to

Identify other tools which benefit multiple centers

Support planning for centers interested in migrating

### Capabilities in 3 Years:

- Cloud-based PLMs
- Broad utilization of MBSE
- Data-centric engineering workflows
- Broad utilization of integrated Eng. toolchains
- Federated Authoritative Sources of Truth

## Cloud-Centric Solution Space

Cloud-Based Multi-Center PLM Governance & Sustainable business model

## Data & Processes

Centers understand where their ASoT are & data

Centers understand core processes - map/model/analyze for data centricity

Centers integrate toolchains and structured data constructs for ASoT

Model & analyze 7123 / 7120.5 & integrate with MB MA 8705 models

Update of approved changes to NPRs

Provide Recommendations for update of NPRs 04/xx/23

Finalize interoperability and data format requirements

Explore unification of 7123, 7120.5/.8 & 8705 into centralized model flagged by discipline.

Update of approved changes to NPRs & training

Support flow down modeling of Center processes from parent NPRs

Support flow down modeling of Center processes from parent NPRs

Understand lift-&-shift ops w/INCOSE

Execute lift-&-shift w/INCOSE

Understand lift-&-shift ops w/DoD

Execute lift-&-shift w/DoD

## MBSE Capability Maturation

Perform rev 3 of MBSE Cap Asses.

Centers update local processes/documentation

Devel. Tier 5 APPEL Reqs.

Pilot Tier 5 MBSE APPEL Course

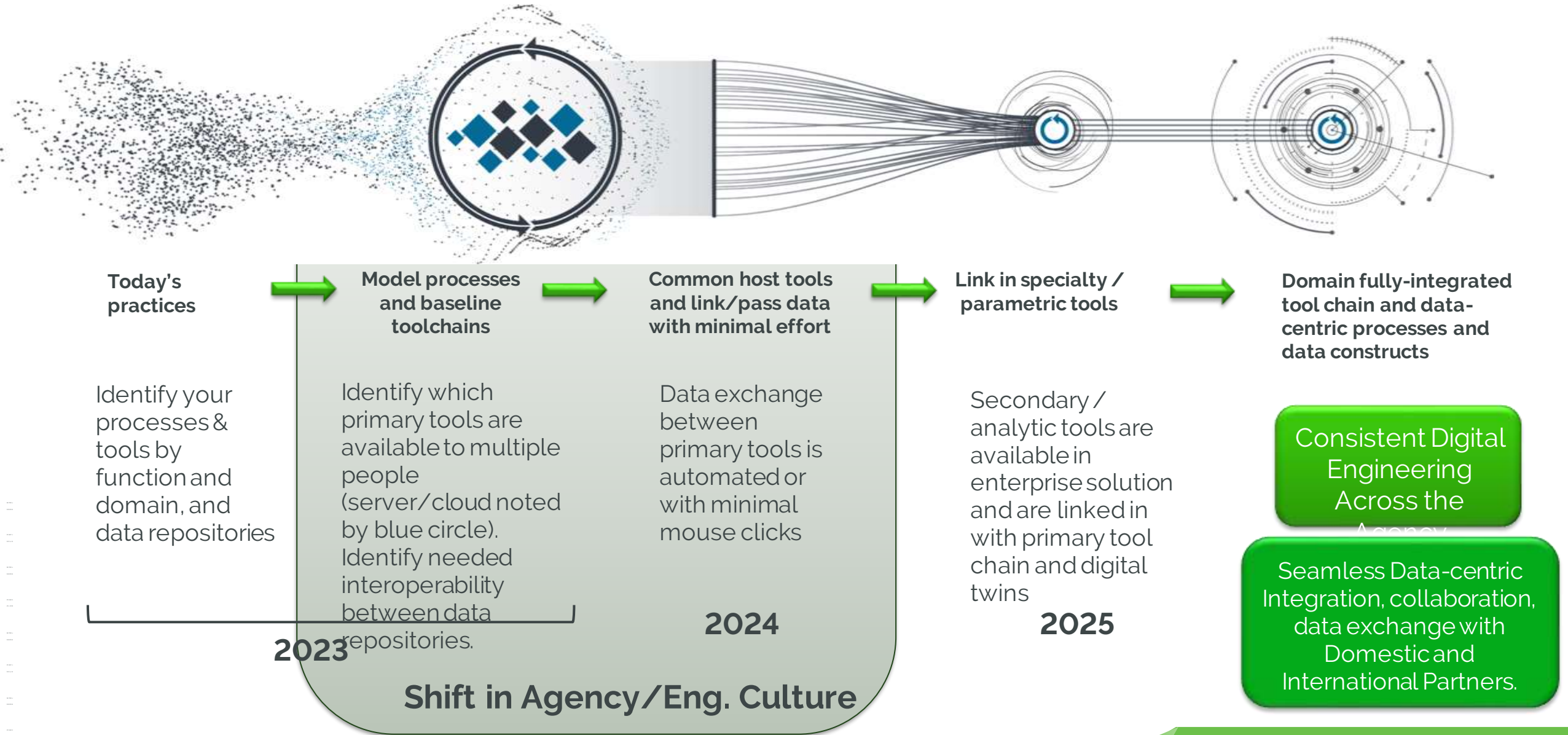
Centers implement MBSE as baseline approach on projects - hybrid approach for project reviews (models which produce trad. artifacts)

Update NASA-HDBK-1004

Update NASA-HDBK-1009



# SIMPLIFIED DIGITAL ENGINEERING IMPLEMENTATION APPROACH



REACH

NEW

HEIGHTS



REVEAL

THE

UNKNOWN



BENEFIT

ALL

HUMANKIND



Questions?





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