



NASA/JAXA MBSE Meeting:

IT ALL STARTED WITH MODEL-BASED SYSTEMS ENGINEERING

Online Meeting via Teams

Terry R. Hill / NASA / JSC

Agenda

- Work since our last meeting.
- Efforts in 2022
 - MBSE Capability Survey
 - Orion Digital Twin via SysML model



[illegible]



Recent History for MBSE

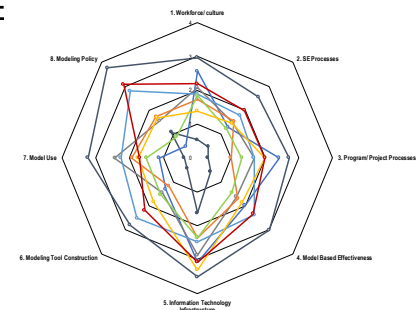
2020

- Following Feb. '20 the MBSE Leadership Team (MLT) was established to develop a MBSE implementation approach for the Agency.
- Incorporated the lessons learned from MIAMI project.
- Added the NASA MBSE Community of Practice Lead to the MLT.
- Initiated Phase I of the MBSE Capabilities Assessment along with Center Capabilities Prioritization based on tailored version of: Hale, J. and Hoheb, A., INCOSE-MBCM-2020-001.1, INCOSE Model-Based Capabilities Matrix and User's Guide, Version 1, Jan 01, 2020.

NASA											
Model-Based Capability Categories	Average	ARC	GRC	GSFC	JPL	JSC	KSC	LaRC	MSFC	SSC	
1. Workforce/ culture	0.5	0.1	1.0	1.1	0.2	0.7	0.7	0.5	0.5	0.0	
2. SE Processes	0.4	0.6	0.2	0.8	0.5	0.4	0.4	0.9	0.4	0.0	
3. Program/ Project Processes	0.3	0.4	0.4	1.1	0.0	0.0	0.3	0.7	0.0	0.0	
4. Model Based Effectiveness	0.6	0.8	0.5	0.9	0.0	0.5	0.3	1.0	0.6	0.3	
5. Information Technology Infrastructure	1.6	2.5	1.6	2.2	1.5	1.5	0.7	2.6	1.8	0.2	
6. Modeling Tool Construction	0.4	0.2	0.4	1.1	0.0	0.3	0.4	0.9	0.2	0.1	
7. Model Use	0.4	0.0	1.0	1.0	0.0	0.0	0.5	0.7	0.3	0.0	
8. Modeling Policy	0.6	0.0	0.0	2.9	2.8	1.5	0.4	0.6	1.6	0.0	

2021

- Initiated the Orion 'Digital Twin' effort to shore up needs of the NASA side of Orion and to be used to flesh out what would be needed for large Agency MBSE/Modeling efforts.
 - Modeled and demo'ed modeled Orion Power sub-system to Orion Chief Eng. and VIO in November.
- Worked with APPEL to develop Tier 4 MBSE Training requirements.
- Recorded an APPEL MBSE podcast detailing the NASA efforts to date regarding the MBSE journey and plans for the future and was distribution to the Agency and available at: <https://appel.nasa.gov/podcast/episode-56-model-based-systems-engineering>
- Completed Phase II of the MBSE Capabilities assessment, refined results and gathered Vanguard projects and organizations.
- MLT to EMB Briefing 3-25-21



MBSE Vanguard Groups/Projects Across NASA



Multi-Center Projects

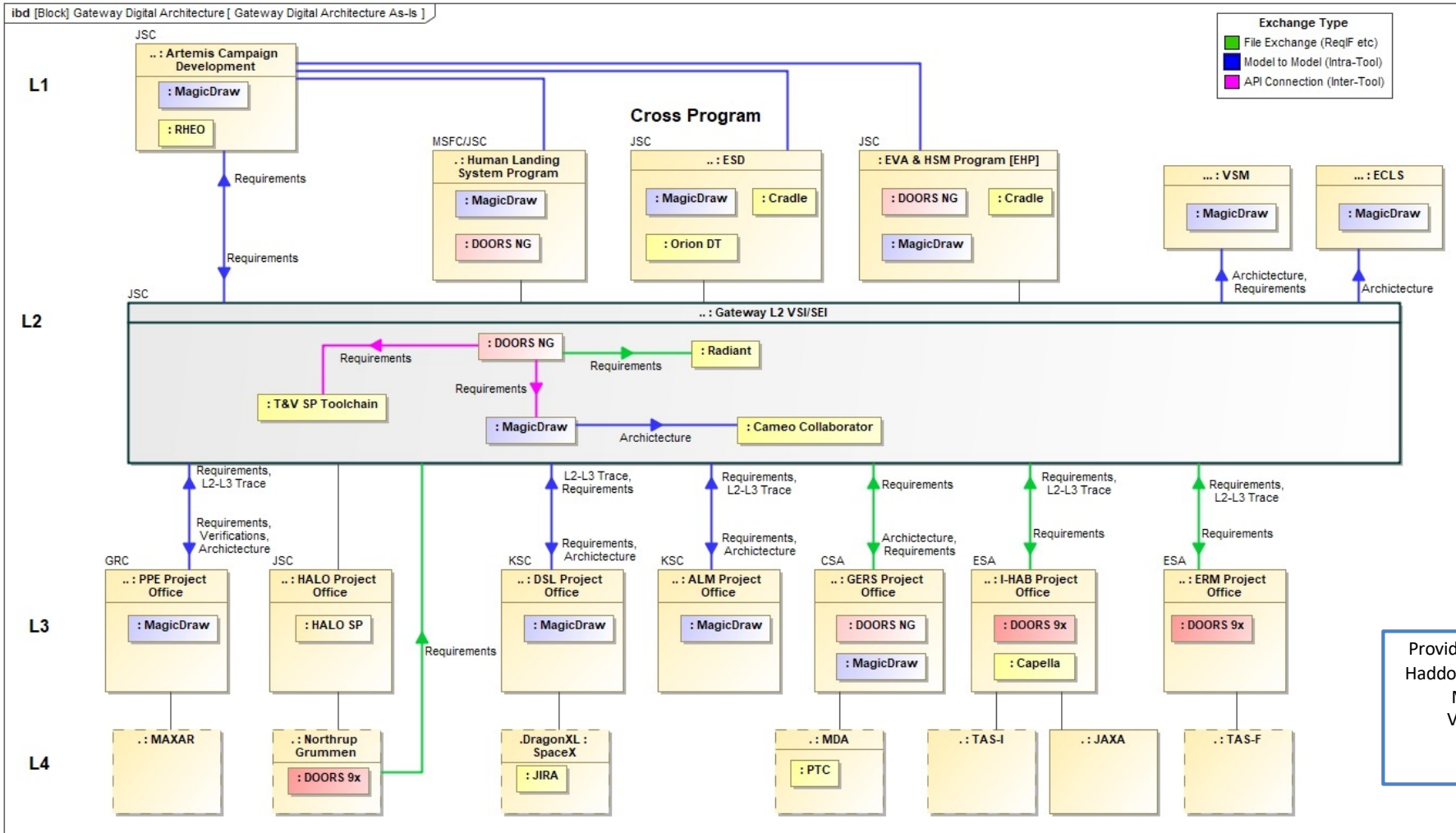
Project/Program	Centers	Project Maturation Phase	Project Status
Artemis / Gateway	GRC, JSC, GSFC, KSC, MSFC	A: Concept & Tech Dev	Active
SCaN PSE	GSFC, GRC	Pre-A: Concept Studies	Active
ExMC	JSC, LaRC, ARC	Pre-A: Concept Studies	Active
ATM-X/UAM	LaRC, ARC		Active

Center Projects

Project/Program	Center	Project Maturation Phase	Project Status
FROST	GRC	A: Concept & Tech Dev	Cancelled
JPSS Ground	GSFC	E: Ops & Sustainment	Active
SCaN NEN/NIKA		D: Integration & Test	Active
Integrated Modeling IRAD		Pre-A: Concept Studies	Active
HLS Software		B: Preliminary Design	Active
MIAMI Sounding Rockets		F: Closeout	Completed
Gateway Test & Verification		A: Concept & Tech Dev	Active
SCaN NIMO		E: Ops & Sustainment	Completed
STAR-X		Pre-A: Concept Studies	Active
Exploration Ground Systems	KSC	E: Ops & Sustainment	Active



Current Federation of MBSE in Artemis



Recent History for MBE & MBSE



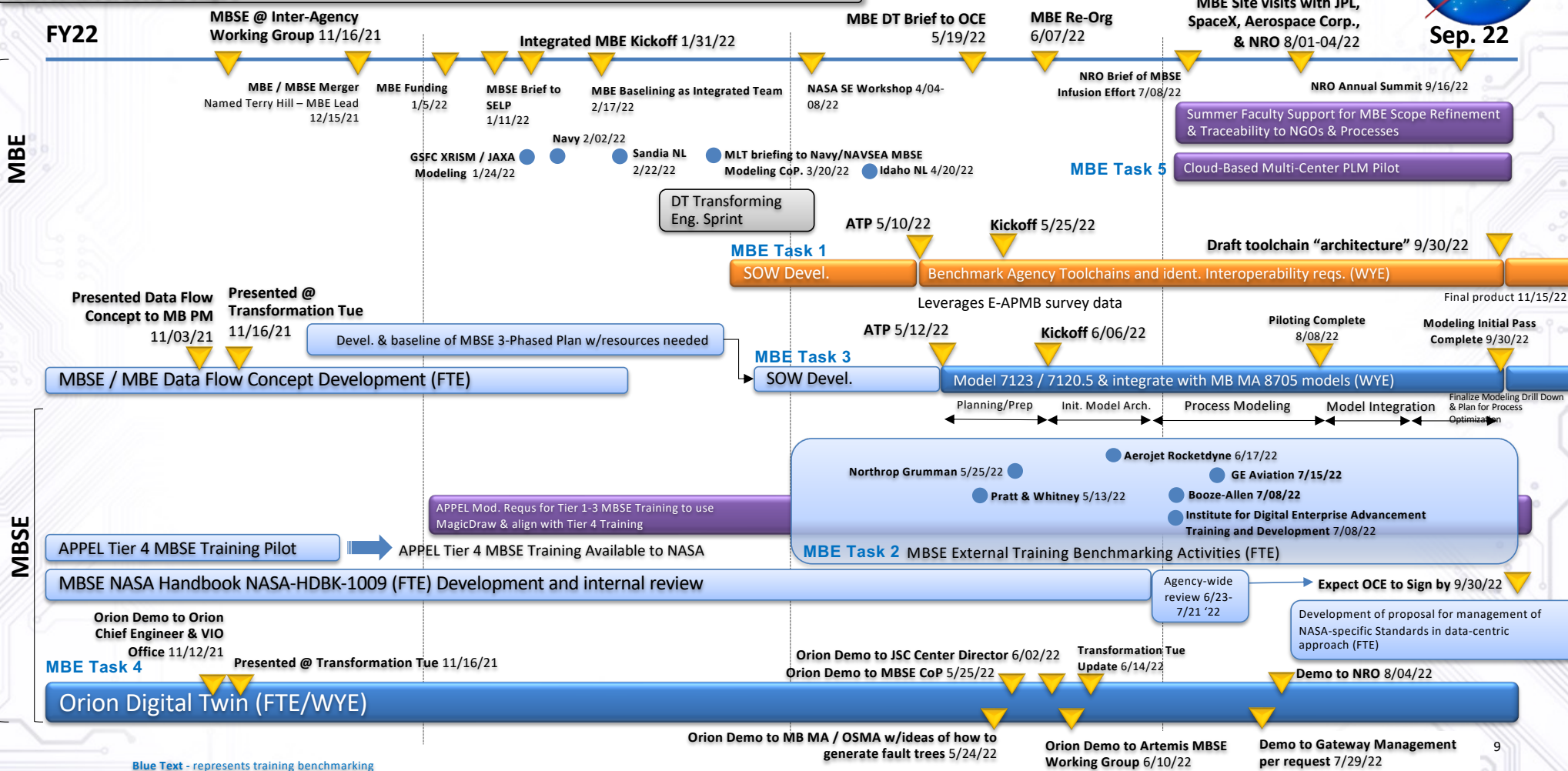
2022

- It was always intended that MBSE be expanded to Include all domains and activities associated with the Engineering Domain, eg. the formulation of the NASA Model-Based Engineering (MBE) leadership team.
 - Jan – created the integrated MBE team comprising: MBSE, Design to Manufacturing, Multi-Physics modeling.
 - Jun – re-organized the MBE to reduce scope over-lap of teams and broaden coverage over entire life-cycle of projects wrt toolchains.
 - Jun – Task 5: initiated a multi-center (JSC, KSC, GRC) AWS Gov. cloud-based PLM pilot project.
 - Orion DT – Task 4: Worked with MB MA / OSMA to explore ideas of how to generate fault trees from SysML models.
- Developed MBSE 3-Year/Phase Implementation Plan based upon INCOSE Capabilities Assessment Maturation Model.
 - Has been used to prioritize activities as funding was made available.
 - Fall '21 Piloted new APPEL Tier 4 MBSE course, and approved for Agency use. Existing training changed to use MagicDraw.
 - Task 1: Perform Agency survey of integrated toolchains and associated interoperability requirements/capabilities.
 - Task 3: Modeling of Agency Main-Three NPRs: 7123 (SE&I), 7120.5/8 (Project Management), 8705 (Mission Assurance) with the objective to:
 - Worked with other DT MBx domains to assess processes via SysML modeling and integrate to determine needed dataflow.
 - Model associated processes as is
 - Assess processes from 'data-centric' viewpoint – more on this later
 - Assess processes for efficiency opportunities
 - From data centric approach determine needed data interoperability requirements to inform infrastructure changes/adds, policy changes, toolchain selection guidelines for Agency.
 - Task 2: Continued baselining of external agencies and companies for MBSE, toolchains, and workforce training approaches.
 - Released NASA MBSE Handbook for Agency review.
 - Integrated MBE with NASA SBIR S17.02 Integrated Mission Modeling

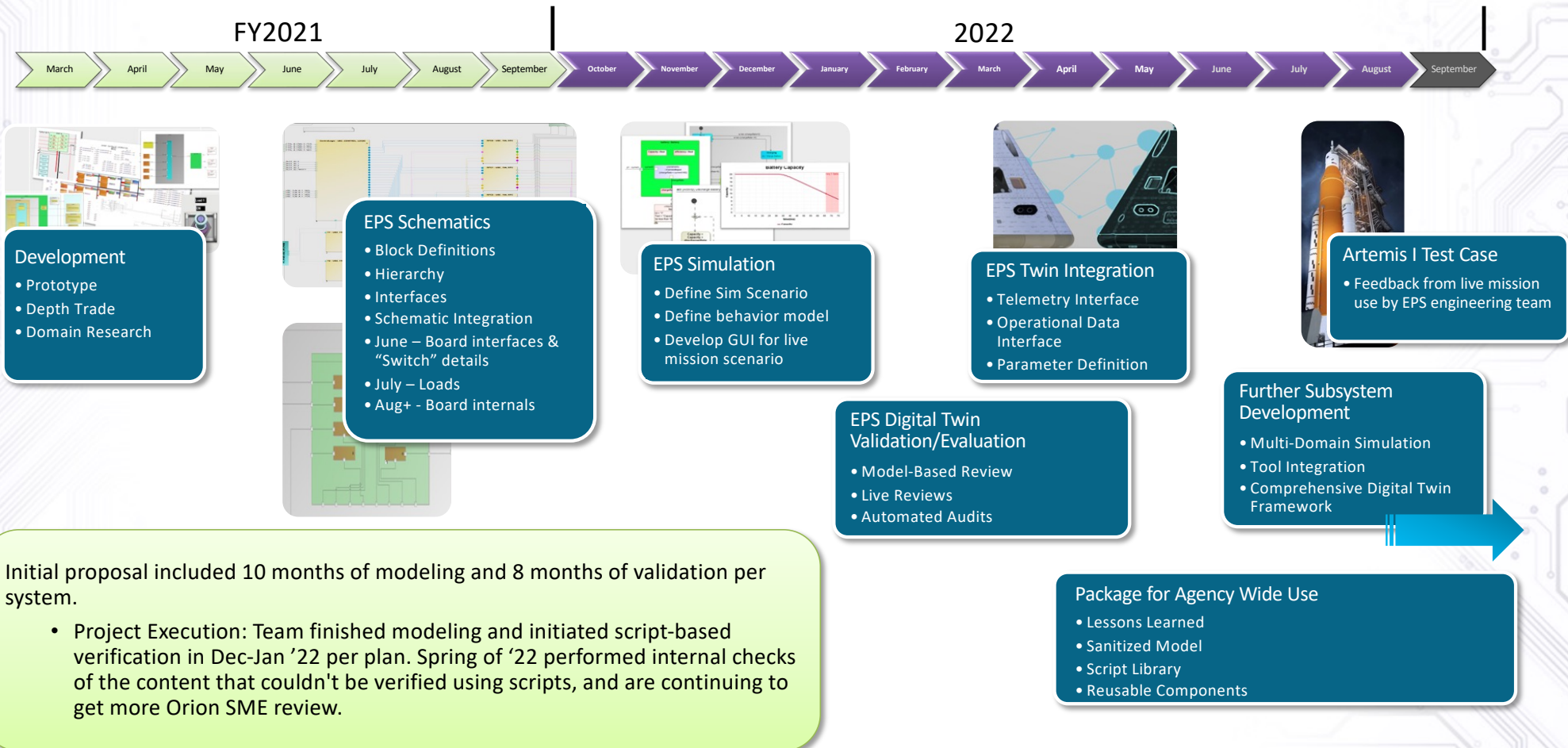
Year 1 MBE Project Schedule



NASA Centers at COVID-19 Stage 3



Orion DT Project 2021-2022 Plan & Milestones

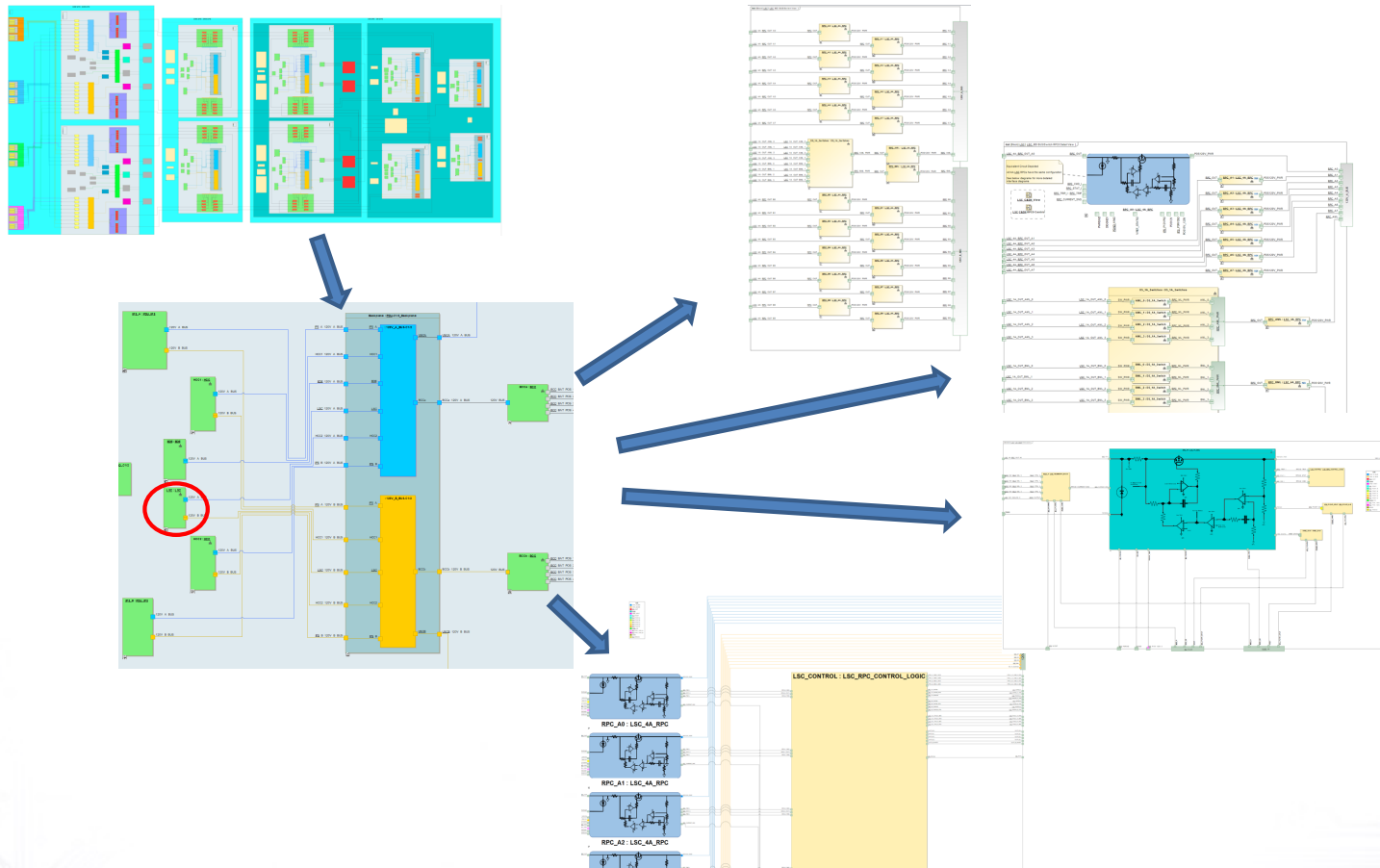


Progress on Orion Digital Twin



- Over 2,000 components represented
 - ~120 elements of definition reused
 - Over 130 hyperlinks to schematics database integrated into SysML Model
- Over 2,700 interfaces defined between components
- 2,208 ports imported ready for CD&H/Avionics/GNC subsystems
- Over 500 loads integrated into EPS architecture
 - Channelization to specific switch within PDU
 - Individual load parameters
 - “Spec Power”
 - “Actual Power”
 - Etc.
- Automated syncing and validation of data and architecture to authoritative sources
- Simulation utilizing built architecture and imported component specifications

Integrated High-level Architecture and Lower-Level Schematic Details



Data Driven Design / Automation



Legend	
Implied Relation	
02 Schematics	
Printed Wiring Assembly And Schematic - Un	
DC_DC_Power_Supply	
DC_DC_Power_Supply	
DS_1A_RPC	
DS_1A_Switch	
DS_1A_Switches	
EDE	
EMI Filter and Input Cur	
EMI_FILTER	
Feeder Switch	
Gate_Drive_Inhibit	
HCC	
HCC_AGND	

Document Revision Traceability to Model Elements

- Keep track of latest source document revisions
- Scope out necessary changes to SysML model

Name	Drawing Number	Date	Revision	Page Code
04 Electrical Check Out Diagram	948CA200012	24/11/20	-	04236
Schematic Diagram, Backplane, S1/S2	948CA171111	03/10/14	-	04236
Schematic Diagram, Battery Charge Control, Part A	948CA1712311	01/11/16	D	04236
Schematic Diagram, Battery Charge Control, Part B	948CA1712511	01/11/16	B	04236
Schematic Diagram, Backplane, C1/C2	948CA1715111	09/18/14	-	04236
Schematic Diagram, Heater Control	948CA1715311	06/24/14	-	04236
Schematic Diagram, Internal Power Supply	948CA1715511	01/22/15	-	04236
Schematic Diagram, Backplane, C3/C4	948CA1716111	01/12/14	A	04236
Schematic Diagram, Pyro Event Controller	948CA1716211	11/25/14	-	04236
Schematic Diagram, Solenoid Drive Output	948CA1716311	02/25/15	-	04236
Schematic Diagram, Crew Module Propulsion Driver	948CA1716411	01/11/14	A	04236
Schematic Diagram, Backplane, C5/C6	948CA1717111	01/12/14	A	04236
Printed Wiring Assembly And Schematic - Unlabeled Switch Card	1722585	06/17/06	C	42895
Printed Wiring Assembly And Schematic - Load Switch Card	1722595	11/25/15	A	42895
Schematic Diagram - Power Data Unit Controller	8275781	10/23/14	B	61962
006 Volume II EEL		12/11/21	J	

Notification Window

Notification Window

Project

Environment

[2021.08.15:22:12:53] The card: CLSC003 on port: LSC1_4A_RPC_OUT_B3 is missing the load. Crew Console Payload

[2021.08.15:22:12:53] The card: CLSC004 at port: LSC1_4A_RPC_OUT_A0 has a load that is missing a REFDES in the model

[2021.08.15:22:12:53] The card: SLSC001 at port: LSC1_4A_RPC_OUT_B4 has a load that is missing a REFDES in the model

[2021.08.15:22:12:53] The card: SLSC001 at port: LSC1_4A_RPC_OUT_A3 has a load that is missing a REFDES in the model

[2021.08.15:22:12:53] The card: SLSC001 at port: LSC1_4A_RPC_OUT_A4 has a load that is missing a REFDES in the model

[2021.08.15:22:12:53] The card: SLSC002 at port: LSC1_4A_RPC_OUT_A4 has a load that is missing a REFDES in the model

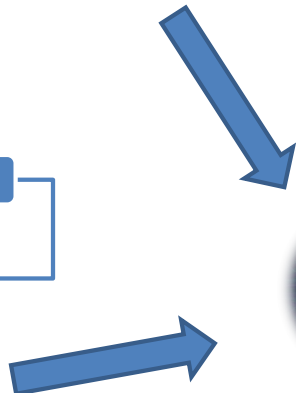
[2021.08.15:22:12:53] The card: SLSC002 at port: LSC1_4A_RPC_OUT_B4 has a load that is missing a REFDES in the model

[2021.08.15:22:12:53] 342 loads have been verified

MagicDraw API Automation

- Component channelization validation
- Component parameter value sync
- Tailorable to input format

Item	Value	Unit	Min	Max	Default	Ref
1	1.0	1.0	1.0	1.0	1.0	1.0
2	1.0	1.0	1.0	1.0	1.0	1.0
3	1.0	1.0	1.0	1.0	1.0	1.0
4	1.0	1.0	1.0	1.0	1.0	1.0
5	1.0	1.0	1.0	1.0	1.0	1.0
6	1.0	1.0	1.0	1.0	1.0	1.0
7	1.0	1.0	1.0	1.0	1.0	1.0
8	1.0	1.0	1.0	1.0	1.0	1.0
9	1.0	1.0	1.0	1.0	1.0	1.0
10	1.0	1.0	1.0	1.0	1.0	1.0
11	1.0	1.0	1.0	1.0	1.0	1.0
12	1.0	1.0	1.0	1.0	1.0	1.0
13	1.0	1.0	1.0	1.0	1.0	1.0
14	1.0	1.0	1.0	1.0	1.0	1.0
15	1.0	1.0	1.0	1.0	1.0	1.0
16	1.0	1.0	1.0	1.0	1.0	1.0
17	1.0	1.0	1.0	1.0	1.0	1.0
18	1.0	1.0	1.0	1.0	1.0	1.0
19	1.0	1.0	1.0	1.0	1.0	1.0
20	1.0	1.0	1.0	1.0	1.0	1.0
21	1.0	1.0	1.0	1.0	1.0	1.0
22	1.0	1.0	1.0	1.0	1.0	1.0
23	1.0	1.0	1.0	1.0	1.0	1.0
24	1.0	1.0	1.0	1.0	1.0	1.0
25	1.0	1.0	1.0	1.0	1.0	1.0
26	1.0	1.0	1.0	1.0	1.0	1.0
27	1.0	1.0	1.0	1.0	1.0	1.0
28	1.0	1.0	1.0	1.0	1.0	1.0
29	1.0	1.0	1.0	1.0	1.0	1.0
30	1.0	1.0	1.0	1.0	1.0	1.0
31	1.0	1.0	1.0	1.0	1.0	1.0
32	1.0	1.0	1.0	1.0	1.0	1.0
33	1.0	1.0	1.0	1.0	1.0	1.0
34	1.0	1.0	1.0	1.0	1.0	1.0
35	1.0	1.0	1.0	1.0	1.0	1.0
36	1.0	1.0	1.0	1.0	1.0	1.0
37	1.0	1.0	1.0	1.0	1.0	1.0
38	1.0	1.0	1.0	1.0	1.0	1.0
39	1.0	1.0	1.0	1.0	1.0	1.0
40	1.0	1.0	1.0	1.0	1.0	1.0
41	1.0	1.0	1.0	1.0	1.0	1.0
42	1.0	1.0	1.0	1.0	1.0	1.0
43	1.0	1.0	1.0	1.0	1.0	1.0
44	1.0	1.0	1.0	1.0	1.0	1.0
45	1.0	1.0	1.0	1.0	1.0	1.0
46	1.0	1.0	1.0	1.0	1.0	1.0
47	1.0	1.0	1.0	1.0	1.0	1.0
48	1.0	1.0	1.0	1.0	1.0	1.0
49	1.0	1.0	1.0	1.0	1.0	1.0
50	1.0	1.0	1.0	1.0	1.0	1.0
51	1.0	1.0	1.0	1.0	1.0	1.0
52	1.0	1.0	1.0	1.0	1.0	1.0
53	1.0	1.0	1.0	1.0	1.0	1.0
54	1.0	1.0	1.0	1.0	1.0	1.0
55	1.0	1.0	1.0	1.0	1.0	1.0
56	1.0	1.0	1.0	1.0	1.0	1.0
57	1.0	1.0	1.0	1.0	1.0	1.0
58	1.0	1.0	1.0	1.0	1.0	1.0
59	1.0	1.0	1.0	1.0	1.0	1.0
60	1.0	1.0	1.0	1.0	1.0	1.0
61	1.0	1.0	1.0	1.0	1.0	1.0
62	1.0	1.0	1.0	1.0	1.0	1.0
63	1.0	1.0	1.0	1.0	1.0	1.0
64	1.0	1.0	1.0	1.0	1.0	1.0
65	1.0	1.0	1.0	1.0	1.0	1.0
66	1.0	1.0	1.0	1.0	1.0	1.0
67	1.0	1.0	1.0	1.0	1.0	1.0
68	1.0	1.0	1.0	1.0	1.0	1.0
69	1.0	1.0	1.0	1.0	1.0	1.0
70	1.0	1.0	1.0	1.0	1.0	1.0
71	1.0	1.0	1.0	1.0	1.0	1.0
72	1.0	1.0	1.0	1.0	1.0	1.0
73	1.0	1.0	1.0	1.0	1.0	1.0
74	1.0	1.0	1.0	1.0	1.0	1.0
75	1.0	1.0	1.0	1.0	1.0	1.0
76	1.0	1.0	1.0	1.0	1.0	1.0
77	1.0	1.0	1.0	1.0	1.0	1.0
78	1.0	1.0	1.0	1.0	1.0	1.0
79	1.0	1.0	1.0	1.0	1.0	1.0
80	1.0	1.0	1.0	1.0	1.0	1.0
81	1.0	1.0	1.0	1.0	1.0	1.0
82	1.0	1.0	1.0	1.0	1.0	1.0
83	1.0	1.0	1.0	1.0	1.0	1.0
84	1.0	1.0	1.0	1.0	1.0	1.0
85	1.0	1.0	1.0	1.0	1.0	1.0
86	1.0	1.0	1.0	1.0	1.0	1.0
87	1.0	1.0	1.0	1.0	1.0	1.0
88	1.0	1.0	1.0	1.0	1.0	1.0
89	1.0	1.0	1.0	1.0	1.0	1.0
90	1.0	1.0	1.0	1.0	1.0	1.0
91	1.0	1.0	1.0	1.0	1.0	1.0
92	1.0	1.0	1.0	1.0	1.0	1.0
93	1.0	1.0	1.0	1.0	1.0	1.0
94	1.0	1.0	1.0	1.0	1.0	1.0
95	1.0	1.0	1.0	1.0	1.0	1.0
96	1.0	1.0	1.0	1.0	1.0	1.0
97	1.0	1.0	1.0	1.0	1.0	1.0
98	1.0	1.0	1.0	1.0	1.0	1.0
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100	1.0	1.0	1.0	1.0	1.0	1.0

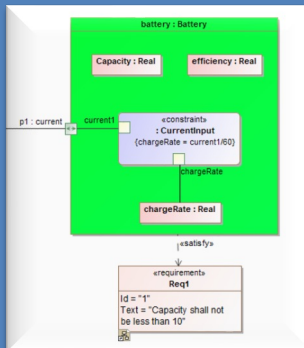


Source of Truth

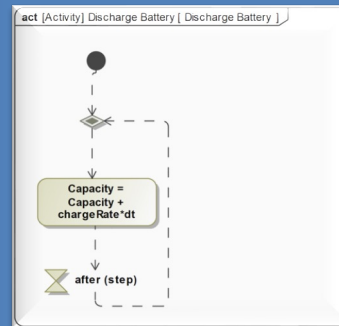
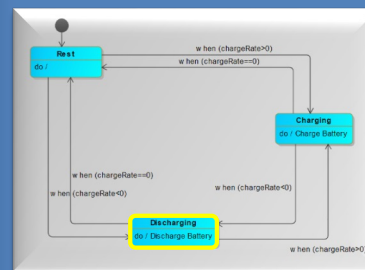
Integrated Simulation



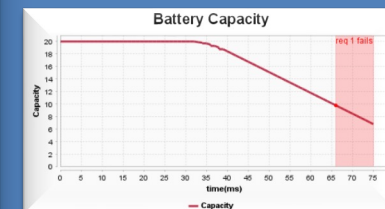
- Interfaces
- Key Parameters
- Mathematical Relationships
- Requirements



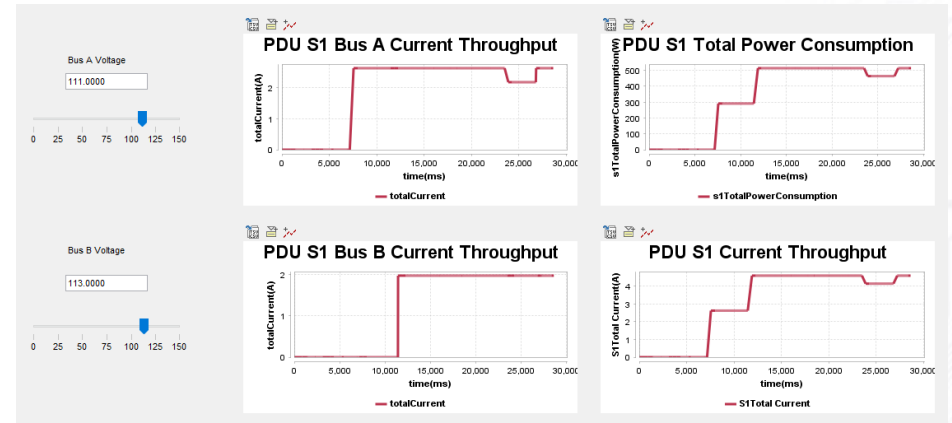
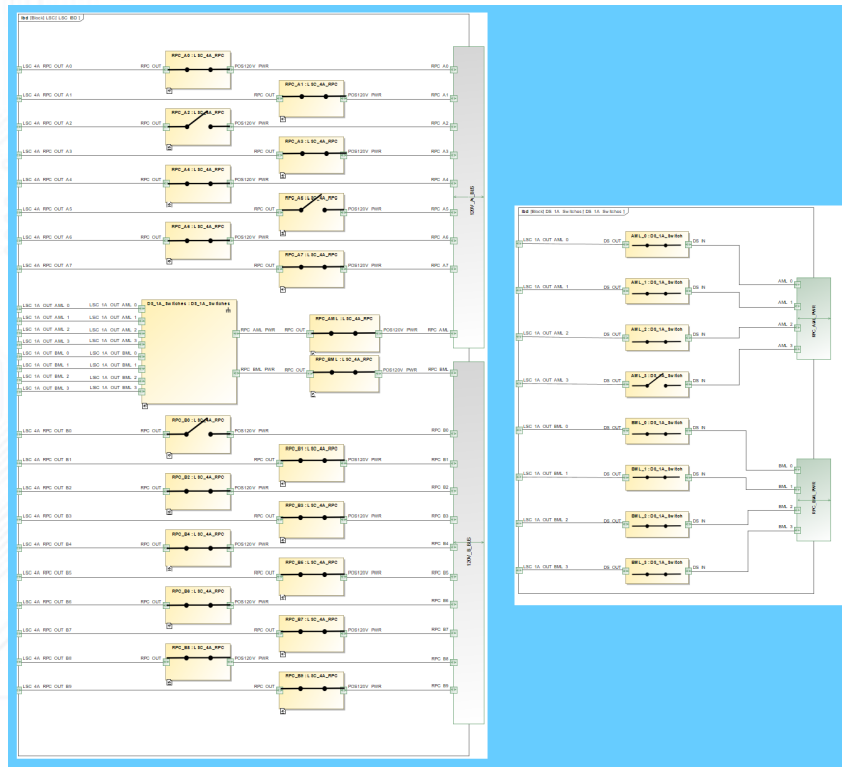
- Component Behavior



- Performance Analysis
- Verification of Requirements



Integrated Simulation





WHY MODEL PROCESSES?

Year 1 MBE Project Schedule



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 Named Terry Hill – MBE Lead 12/15/21

MBE Funding 1/5/22

MBSE Brief to SELP 1/11/22

MBE Baseline as Integrated Team 2/17/22

NASA SE Workshop 4/04-08/22

NRO Brief of MBSE Infusion Effort 7/08/22

NRO Annual Summit 9/16/22

MBE / MBSE Merger Named Terry Hill – MBE Lead 12/15/21

GSFC XRISM / JAXA Modeling 1/24/22

Navy 2/02/22

Sandia NL 2/22/22

MLT briefing to Navy/NAVSEA MBSE Modeling CoP. 3/20/22

Idaho NL 4/20/22

DT Transforming Eng. Sprint

ATP 5/10/22

Kickoff 5/25/22

MBE Task 1

SOW Devel.

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

Leverages E-APMB survey data

Draft toolchain “architecture” 9/30/22

Final product 11/15/22

Presented Data Flow Concept to MB PM 11/03/21

Presented @ Transformation Tue 11/16/21

Devel. & baseline of MBSE 3-Phased Plan w/resources needed

MBSE / MBSE Data Flow Concept Development (FTE)

MBE Task 3

SOW Devel.

ATP 5/12/22

Kickoff 6/06/22

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

Planning/Prep

Init. Model Arch.

Process Modeling

Model Integration

Finalize Modeling Drill Down & Plan for Process Optimization

Northrop Grumman 5/25/22

Pratt & Whitney 5/13/22

Aerojet Rocketdyne 6/17/22

GE Aviation 7/15/22

Booze-Allen 7/08/22

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

MBE Task 2 MBSE External Training Benchmarking Activities (FTE)

APPEL Tier 4 MBSE Training Pilot

APPEL Mod. Requs 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

MBE 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

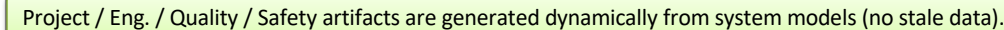
Demo to NRO 8/04/22

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

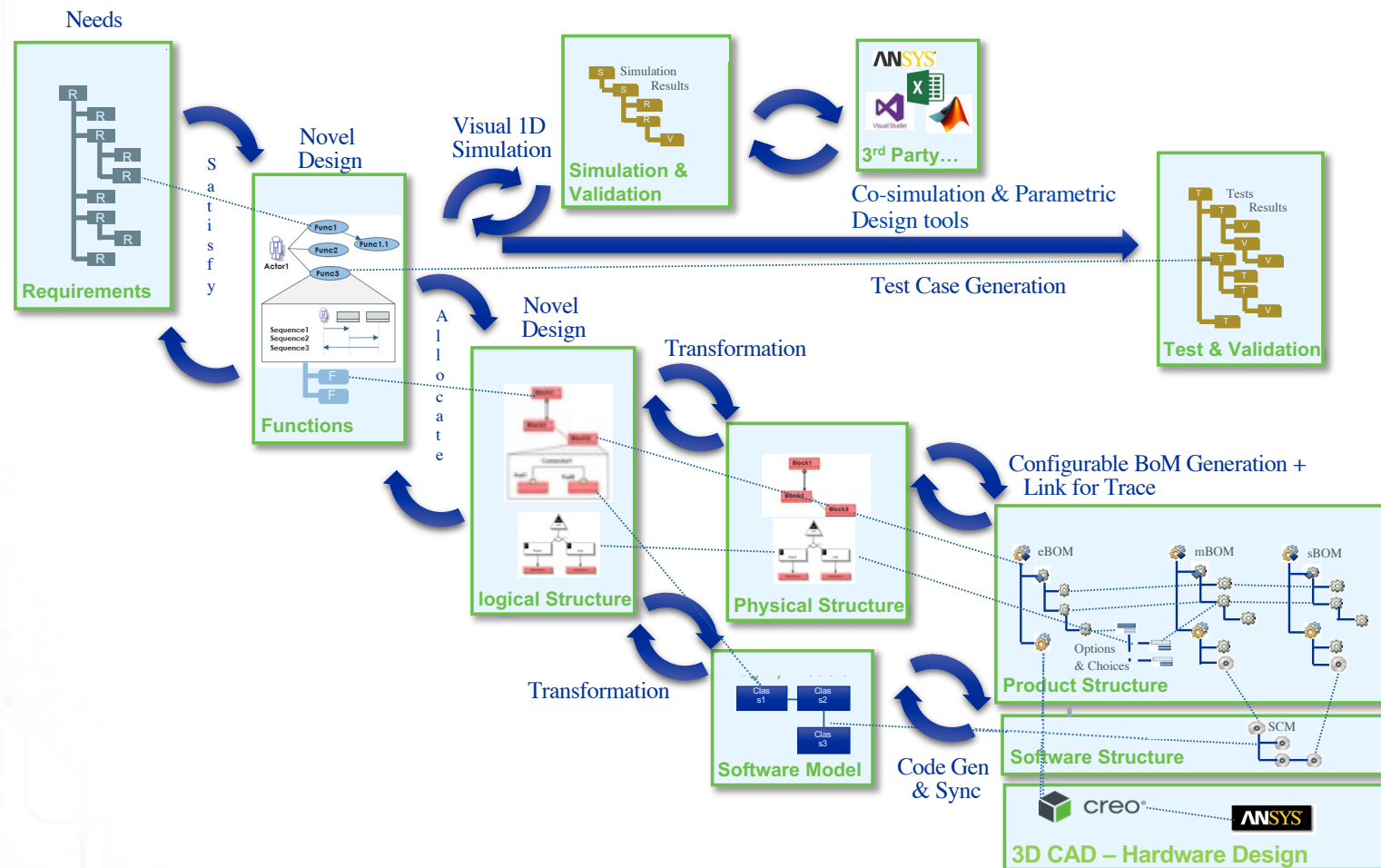




TOOLCHAINS



MBE Toolchain Supporting Parametric Design via Integrated Data Flow (The Left side of “The V”)



*PTC tool chain shown does not imply sponsorship by NASA

High-Level Path Forward



Model-Base Eng. (MBE) /
Digital Eng. (DE)

NPR Process
Modeling

Agency Integrated
Toolchain Survey

Model-Base Systems
Eng. (MBSE)

Agency MBSE
Capabilities Survey

Shift in Agency/Eng. Culture 

Toolchain
Interoperability
Requirements

Toolchain Piloting
Activities
w/Centers 

MBSE Vanguard Deep
Dive to determine
“Life & Shift” cap.

MBSE/SysML/UML
Modeling Piloting
Activities w/Centers &
Programs 

Agency
Interoperability
Standards

Agency Integrated
Toolchain
Recommendations

Agency MBSE /
Modeling
Guidelines

Agency
Recommendations for
project/design artifacts,
support for “smart
reviews”, contract
deliverables, etc.

Consistent Digital
Engineering
Across the Agency

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

Consistent MBSE
Capability Across
the Agency



GOING FORWARD

Near-Term Forward Work



FY23

Close Partnership with the Center Engineering Directorates:

- Direct involvement with the Center's Engineering directorates to better understand current capabilities, where they want to get to, and determine how MBE can help.
- 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, complete the NASA extension of BFO ontology, 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.
 - Build on existing collaboration capabilities with JAXA and use as approach to implement with other space agencies.
 - Understand how ESA has integrated across multiple companies and national space agencies within ESA.