GLOBAL PRODUCT DATA INTEROPERABILITY SUMMIT 2019

Enabling Enterprise Systems Thinking requires an Effective SPDM Foundation

Malcolm Panthaki
VP Analysis Solutions | Aras

SPDM in the Enterprise Digital Thread

We design, build, test, simulate & maintain complex Connected Systems

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Liability from
Catastrophic failures

Intense global competition
Shorter time to market

Software as
product differentiation

Complex/changing
global supply chains

Software and electronics
determine behavior

Materials advancements
Additive manufacturing

**To understand/manage complex system behavior,
the Reductionist design approach alone is not working**

Enter, Systems Thinking…

source: national interest

Systems Thinking vs Reductionist Design?

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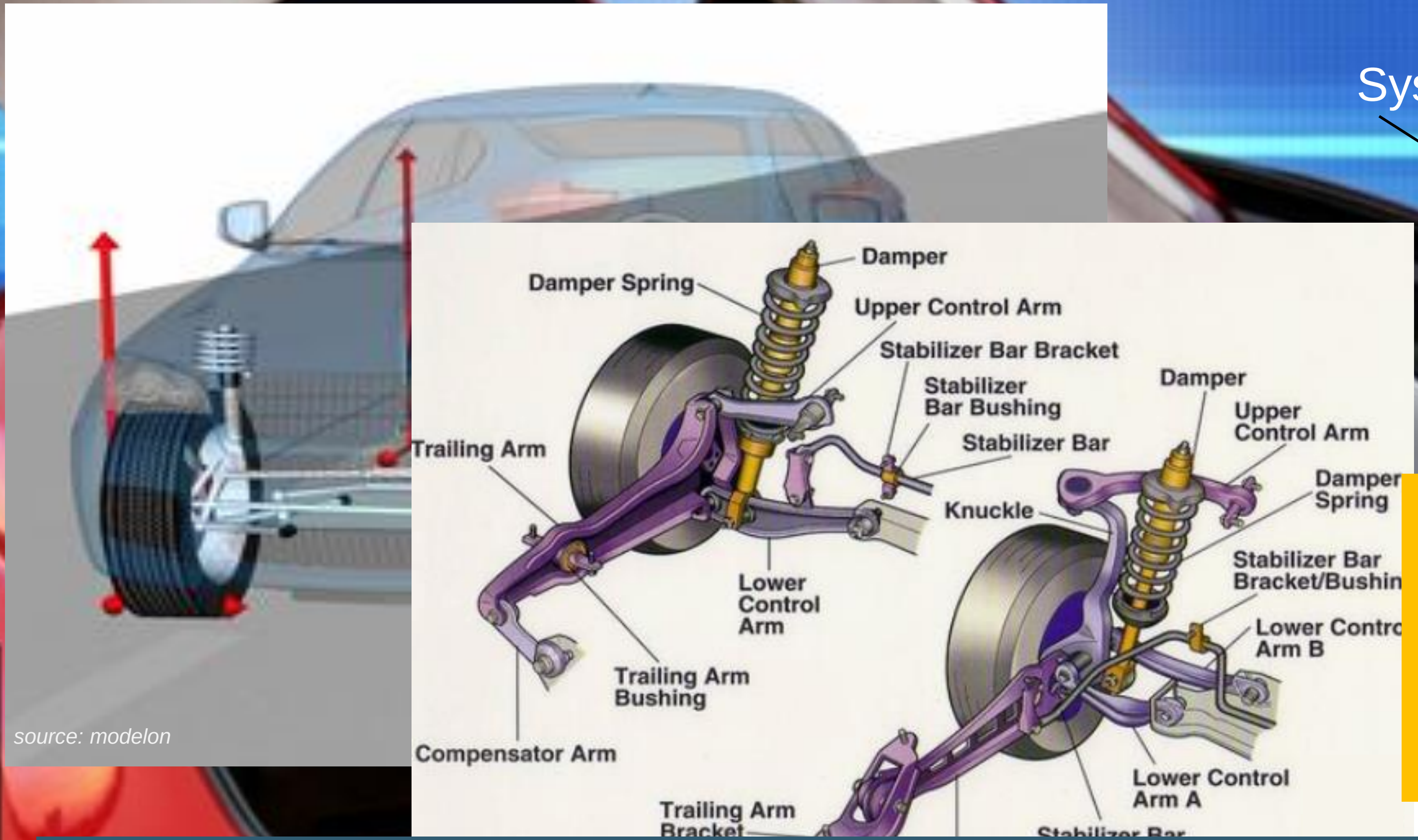

System

Requirements?

Responsibilities
Tasks

Subsystems

Blinders!

System comprehension?
System tradeoffs?
Holistic/emergent system behavior?
System optimization?

Systems Thinking & Reductionist Design

Achieving a balance between holism and reductionism

Requirements-Driven Systems and Systems Thinking

System

An arrangement of interacting parts or elements that together exhibit behavior or meaning that the individual constituents do not, *organized to achieve one or more stated purposes.*

The interaction between elements is the "key" system concept (D. Hitchins, 2009).

The focus on interactions and **holism** is a push-back against the perceived **reductionist** focus on parts and provides recognition that in **complex** systems, the interactions among parts is at least as important as the parts themselves (SEBoK, 2019).

Requirements

The stated purposes that System must achieve.

All actions must be driven Requirements

Systems Thinking

Understand and analyze system behavior and interactions holistically.

Capture and exploit Regularity/Patterns.

Capture and exploit Emergent system behavior – *the sum behaves differently than the parts.*

***…a sensibility for the subtle interconnectedness that gives systems their unique character* (Senge, 2006).**

Thinking in Systems, *Donna H. Meadows*

SEBoK: Systems Engineering Body of Knowledge (sebokwiki.org)

Systems Terms – in a Word

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Systems Thinking
understand

source: tesla

MBSE
represent

System Architecture
organize

Systems Engineering
intervene/design

Credits
Dave Long, Vitech
Pawel Chadzynski, Aras

Future Risks without enabling Pervasive Systems Thinking

Ramifications

- Non-Optimal Products
- Inaccurate Conclusions
- Wrong Design Simulated

Risks

- Loss of Life
- Catastrophic Failures
- Missed Opportunities
- Liability
- Regulatory Actions
- Operational Shutdowns
- Delays / Missed Deadlines
- Cost Overruns
- Design Quality Problems

Risks compounded by:

System Complexity & Emergent Behavior

Multiple Disciplines not in alignment

Pervasive Systems Thinking: Challenges

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- Small pool of Systems Thinkers
  - Not all systems engineers are truly systems thinkers
  - Most engineers are not trained in systems engineering
- Ingrained practices
  - Focus on reductionist organizations and practices
  - *Why should an expert finite element analyst have to worry about emergent system behavior?*
- Disconnected multidisciplinary processes
  - Disciplines handled separately; brought together in an ad hoc manner and by physical testing
- Experts and data in silos
  - Blind men and elephant analogy; understanding of holistic/emergent system behavior is lost
  - Data are not managed and accessible across the enterprise; incomplete enterprise-level data
- Multiple/Incompatible tools
  - Each tool speaks its own language; [illegible] missing standards
  - Multiple tools from multiple vendors

Challenges compounded by Multidisciplinary Products and Use of Machine Learning and AI in Design

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Requirements-Driven Everything!

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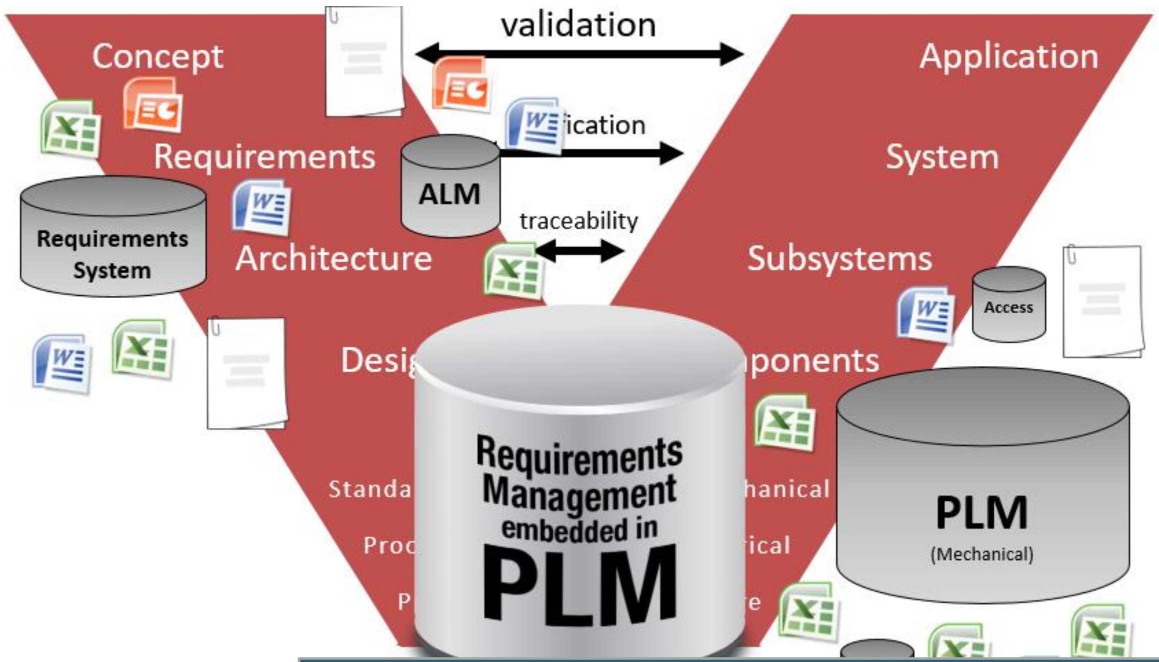
Are we designing the correct product?

Are we building the correct product?

Can we trace Requirements to all cross-discipline artifacts

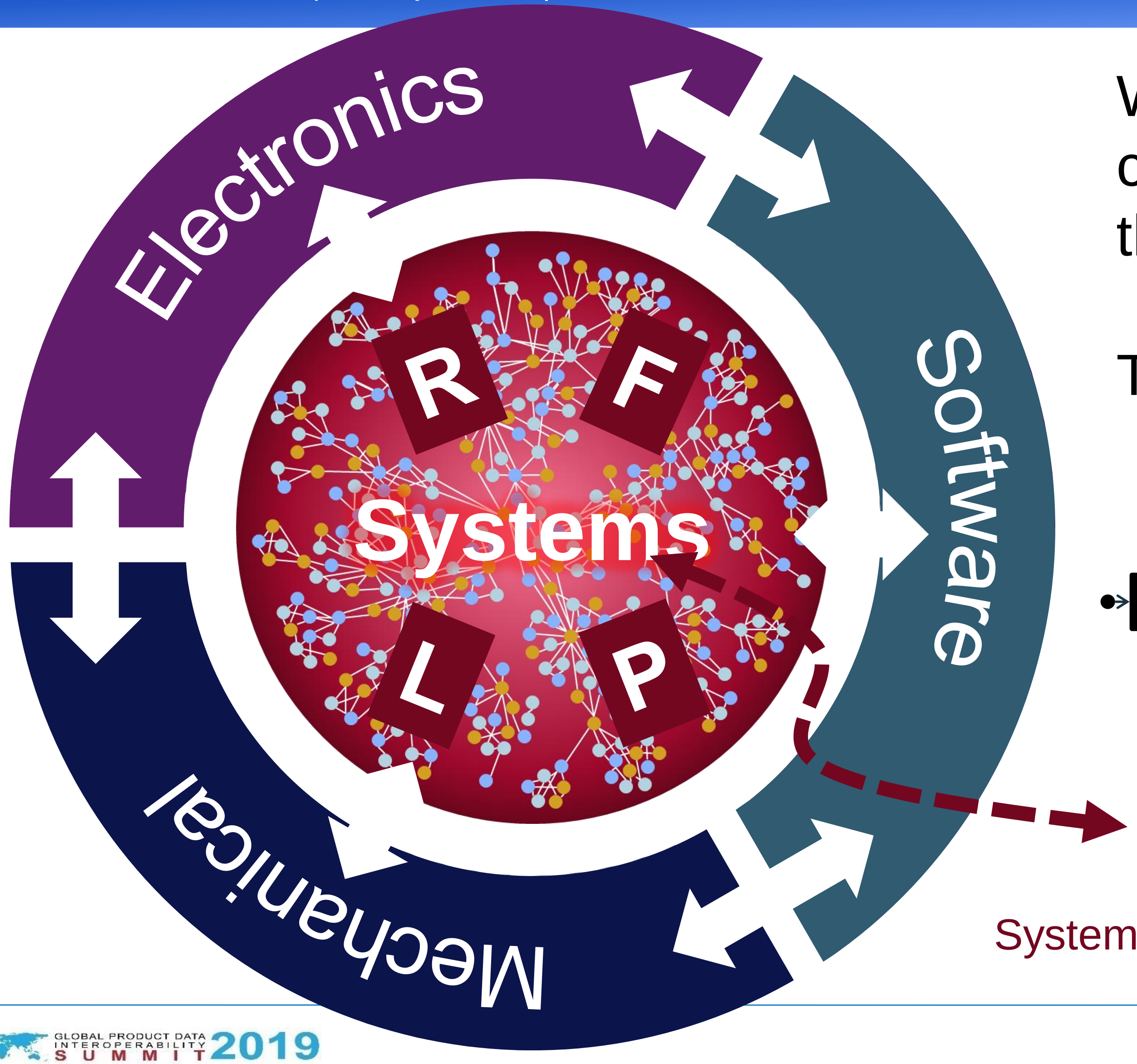


Requirements-Driven Platform Approach

- Connect all engineering data and processes using Requirements-Driven enterprise Digital Thread
- Enable change impact analysis across disciplines
- Enable closed loop V&V of Requirements

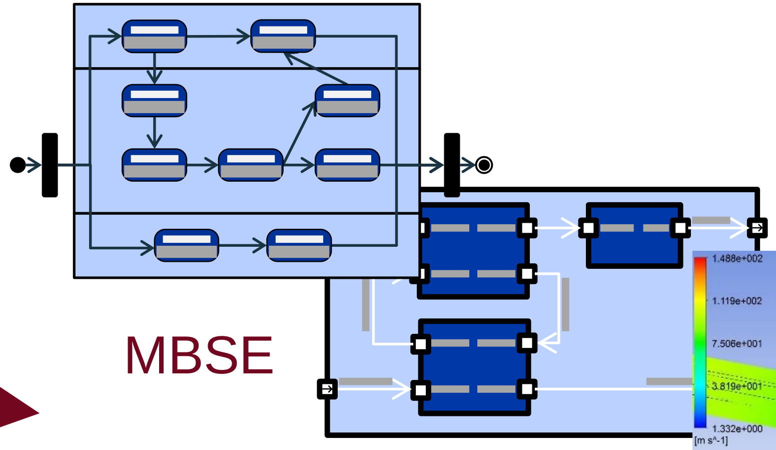
Requirements-Driven everything enables Systems Thinking

Interdisciplinary Collaboration with Systems Models

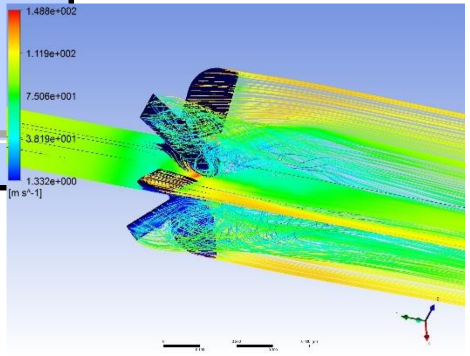


When systems models sit at the center of designs, they become the connective tissue

The Digital Thread runs through them



MBSE

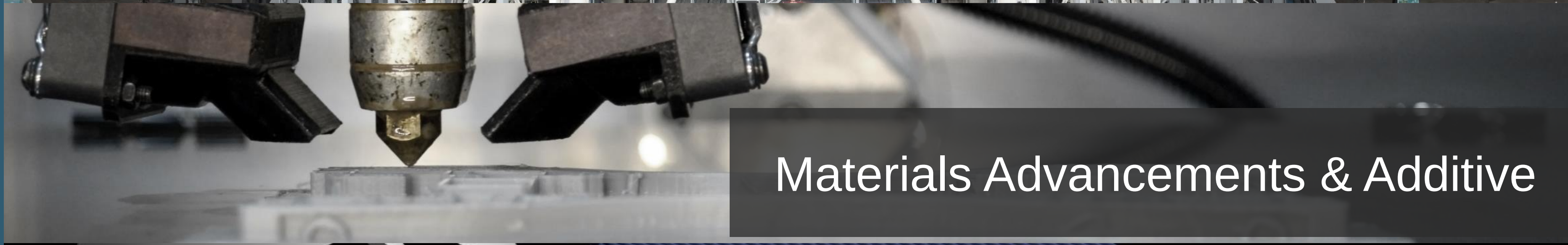


Seamless Integration
Systems Modeling to 3-D Simulation

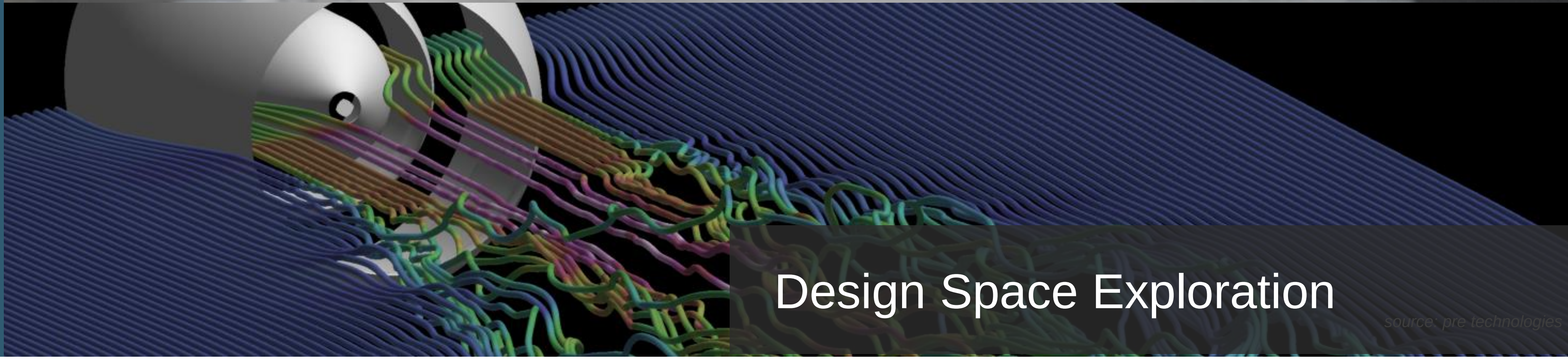
Need for Simulation Increasing Rapidly

Verification & Validation

source: airbus



Materials Advancements & Additive



Design Space Exploration

source: pre technologies

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Future:

More & More Simulations across the Lifecycle

source: modelon

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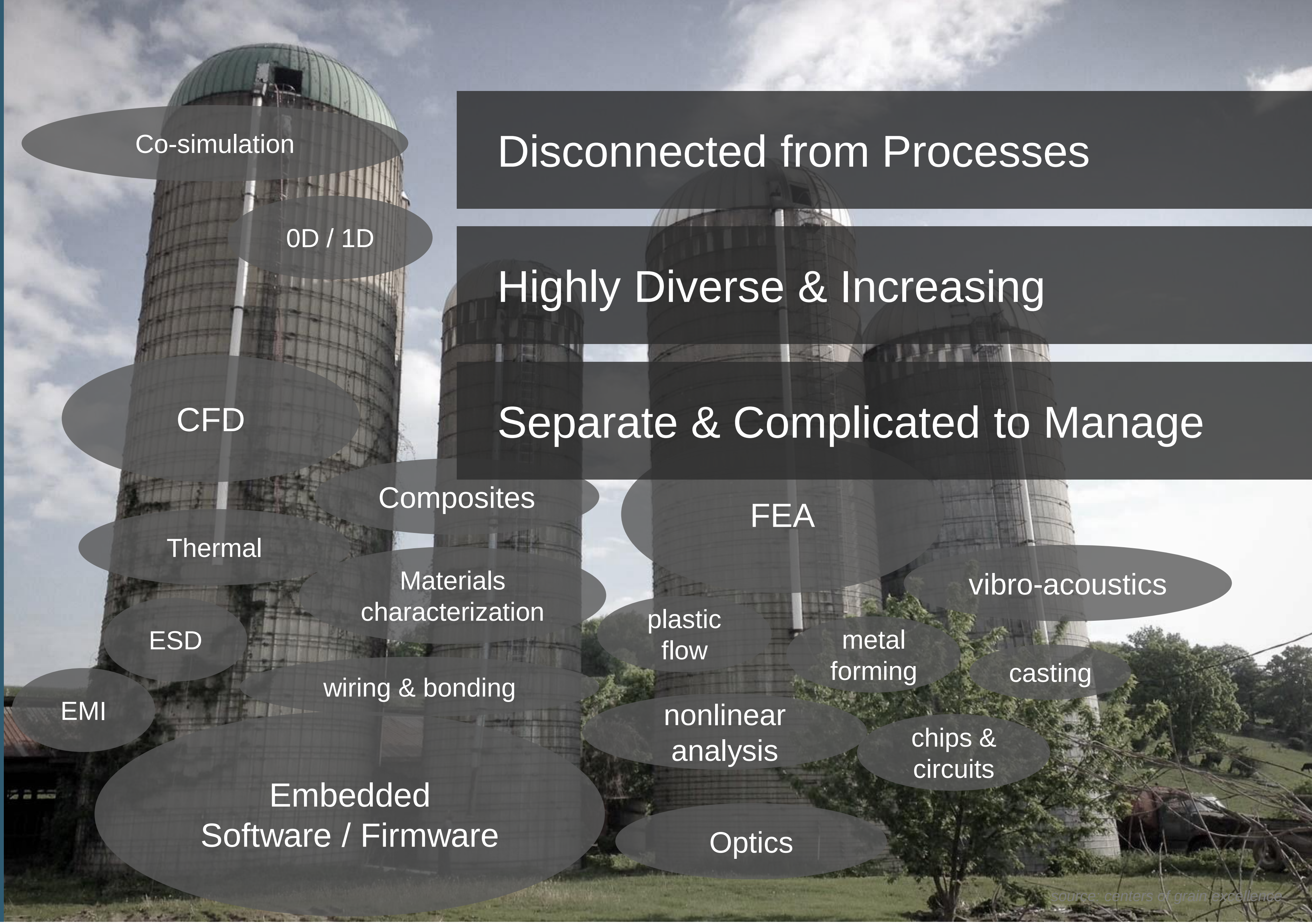
Silos: Unable to Achieve Business of Engineering Strategies

Disconnected from Processes

Highly Diverse & Increasing

Separate & Complicated to Manage



source: centers of grain excellence

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Simulation Management: Challenges

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- Large number of tools
  - Mixed-fidelity / Multi-physics modeling (from systems models to 3-D models)
  - Multi-disciplinary modeling (including mechanical, software, electronics)
  - Large number of tools from multiple vendors
- Data models (tool file formats) are all different
  - Each tool speaks its own language
  - Simulation processes usually use multiple tools
- Simulation Processes are manual and only run by experts in silos
  - Non-experts do not have access to simulation
  - Large number of product variants and autonomous testing requires full automation
- Simulation data not connected to other engineering (PLM) data
  - Tools from all vendors, all physics and all levels of fidelity must be integrated
  - Results from all tools should be available to the enterprise for decision making

Risks compounded by Multidisciplinary Products & Use of Machine Learning and AI in Design

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source: ge

Simulation On-Demand from Concept to Operation

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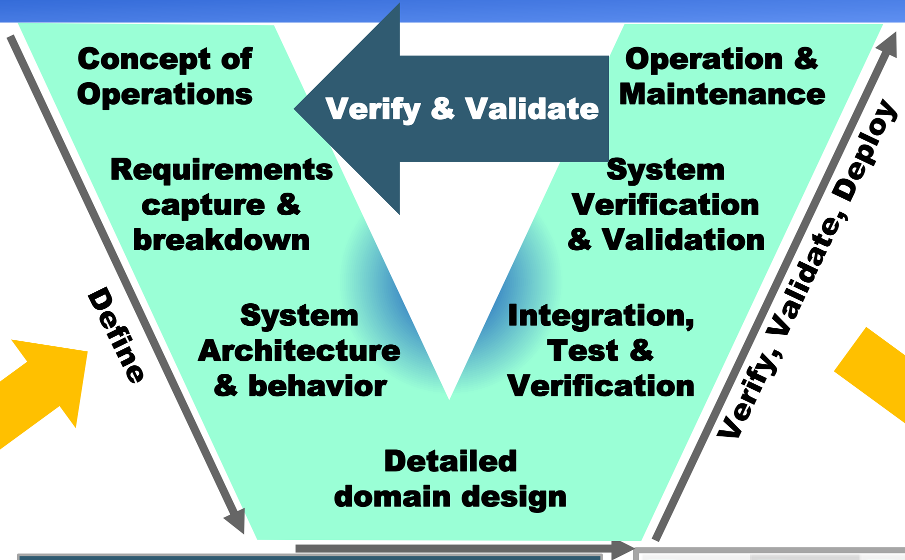
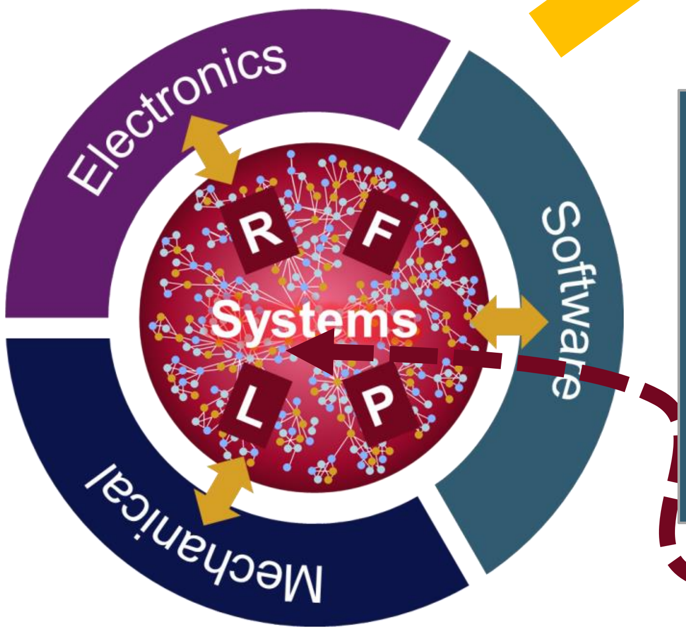


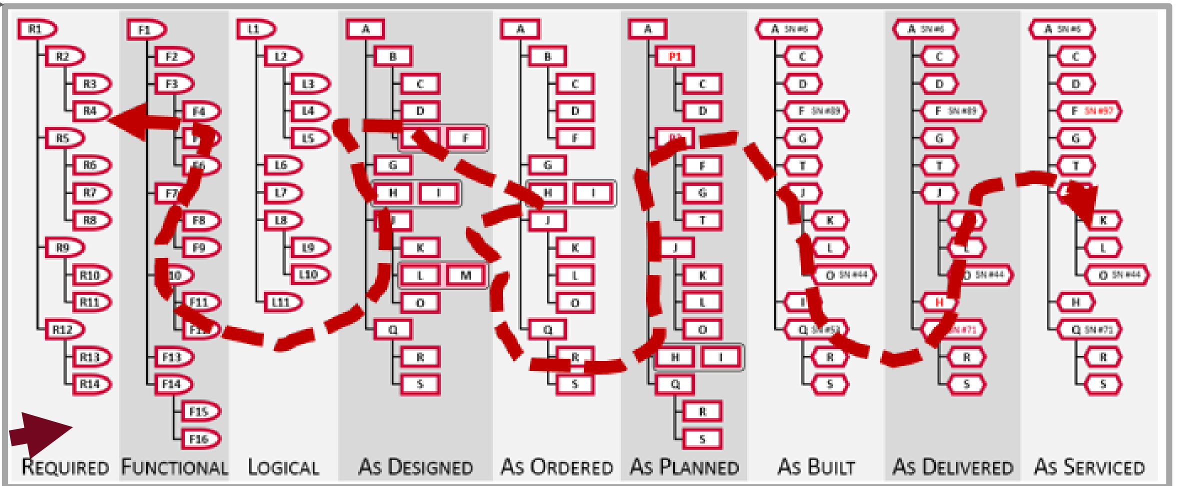
Digital Thread

- Traceability
- Support Iterative-Development Systems Models (Agile, Spiral…)



System Exploration
System Optimization
Emergent Behavior

Enable
Systems Thinking



"Right-Fidelity" simulation available on-demand

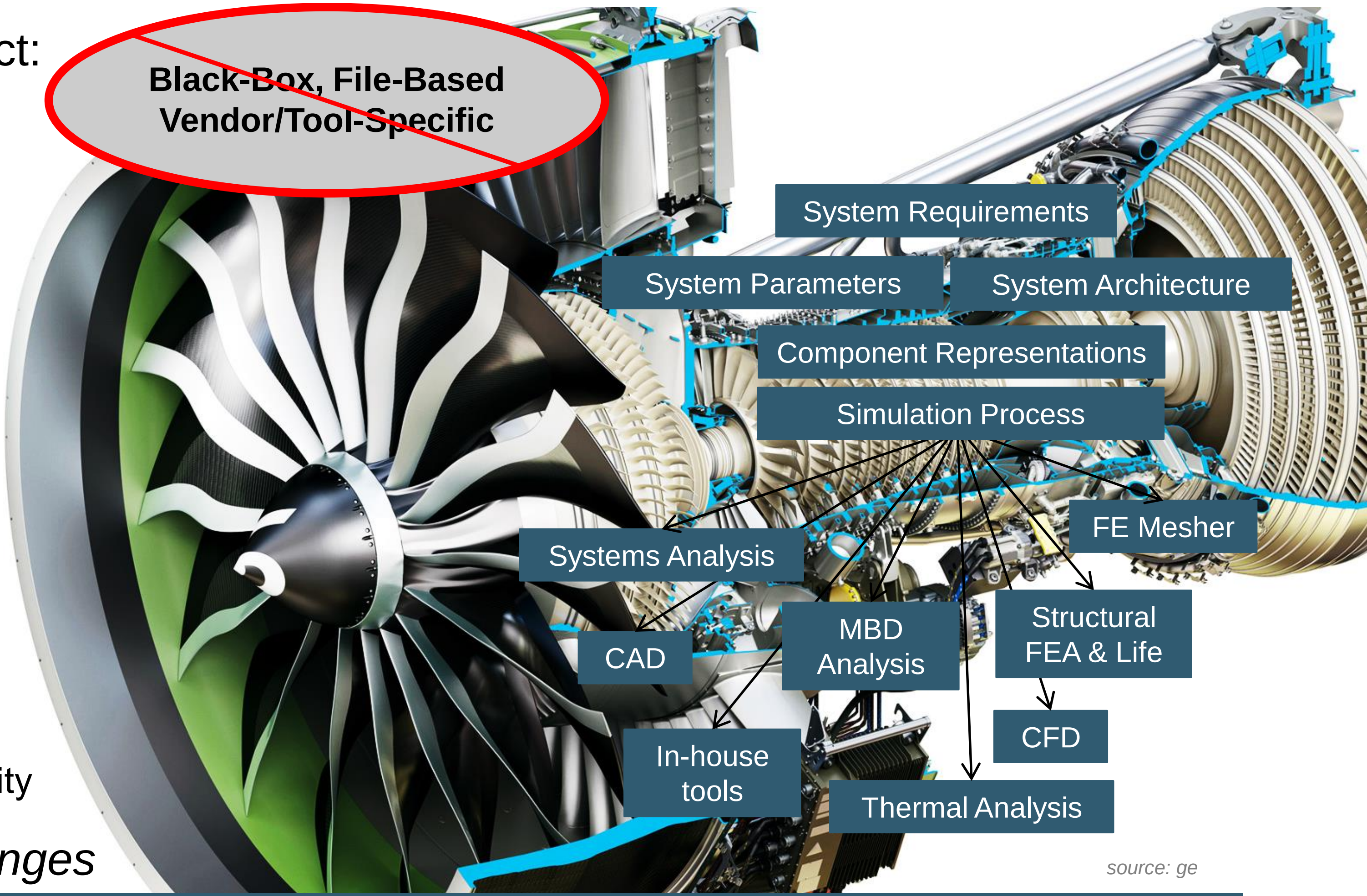
Effective SPDM Should Enable

- Experts & Engineers
  - Deliver better/timely requirements-driven simulation coverage
  - Stay in sync with design / variant changes
  - Eliminate redundant administrative tasks
- Analyze Variations Quickly and Automatically
  - Rapidly conduct analysis on product variations, options and design changes
  - Enable “right-fidelity” simulation throughout the lifecycle
  - Fully-Automate repeatable tool chain processes
- Digital Thread
  - Across Concept Engineering, Detailed Design, Simulation & Test
  - From Requirements through entire Lifecycle

source: ge

What’s Missing in SPDM – a Systems-Centric View

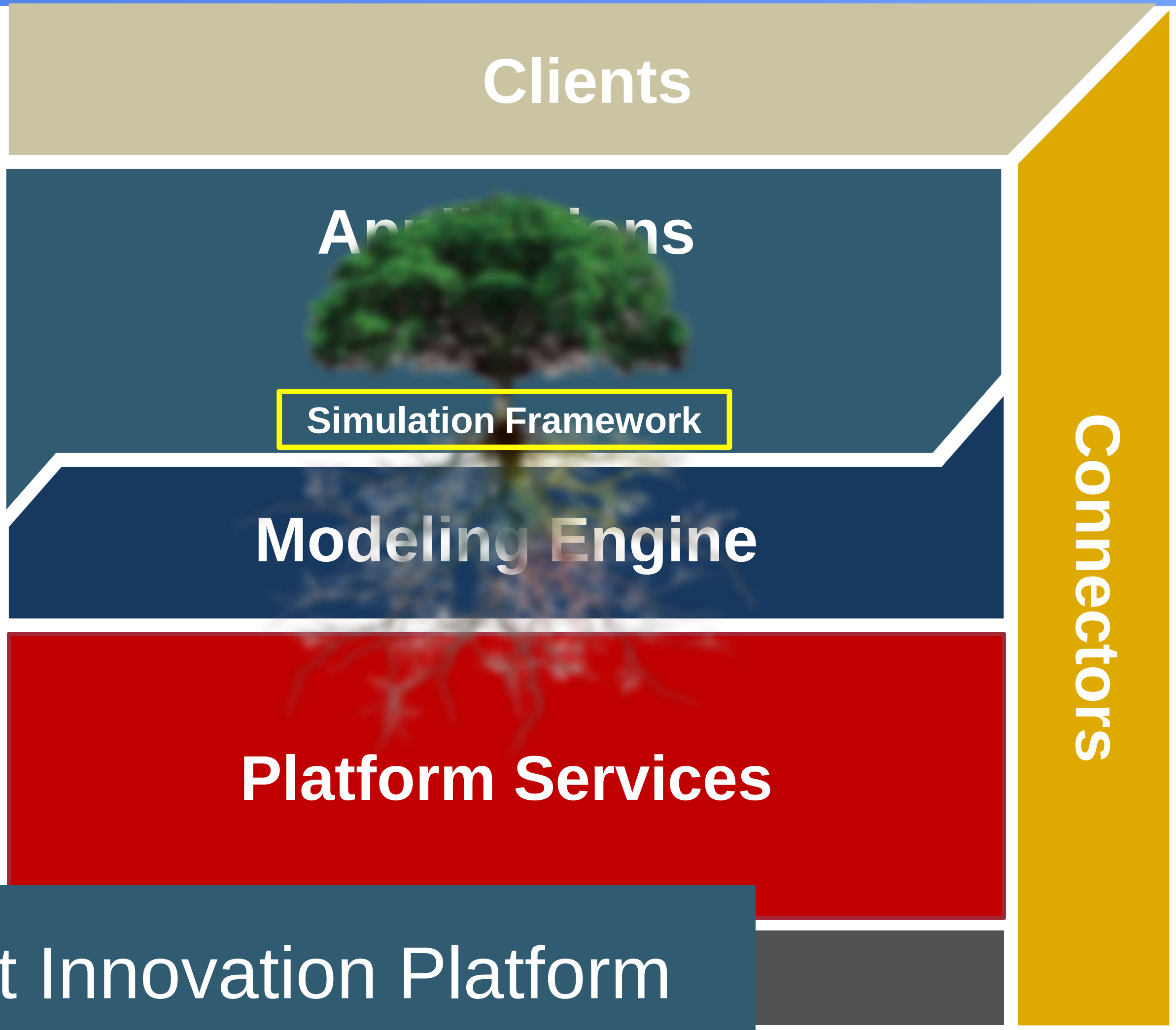
- Complete representation of the Product: A Systems-Centric view
  - System intent & System requirements
  - System Architecture & System Parameters
  - Multiple component representations
  - System constraints & Operating conditions
  - Performance metrics
  - Product variants/configurations
- Tool-agnostic data & processes
  - Commercial, in-house custom, etc.
  - “Lights-out” automation at any level of fidelity
- *Robust automation across design changes and product family variants*



Systems-Centric, Template-Driven Simulation Management

Simulation in an Integrated, Open, Extensible Platform

- Simulation integrated with all core PLM services
  - Configuration, ECO, and Lifecycle processes
  - Visual Collaboration
  - Configurator
  - Branch/Merge
  - Graph Navigation
- Open unified data model and APIs
  - Consistency for all users/implementations
  - Supports simulation data and processes
  - Custom extensions (data model, process, applications)
  - Connectors for commercial and in-house tools



Tool-Agnostic, Open Product Innovation Platform

Core Requirements That Drive Our SPDM Solution

Mach 5 Concept

1. Get the data right
   - Create and manage an engineering abstraction layer that is mostly tool-independent
2. Fully-Automate repeatable simulation processes
   - Simulation templates must be robust across significant design changes and across the entire product family, at the required level of fidelity
   - Auto-generate the simulation models
3. Connect simulation data to the product architecture
   - Simulation must be requirements-driven and systems-centric

source: boeing

Simulation Framework Architecture

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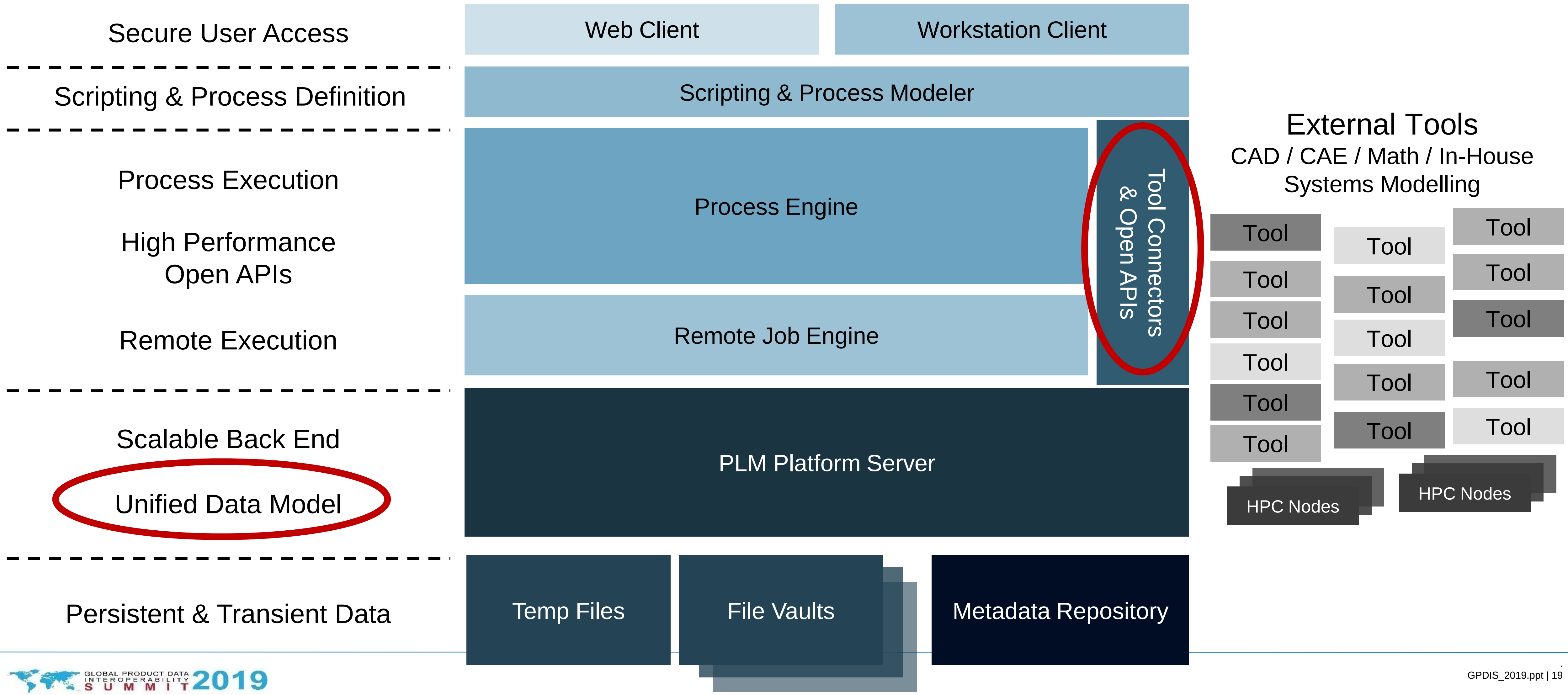

Tool-Agnostic Unified Product Data Model

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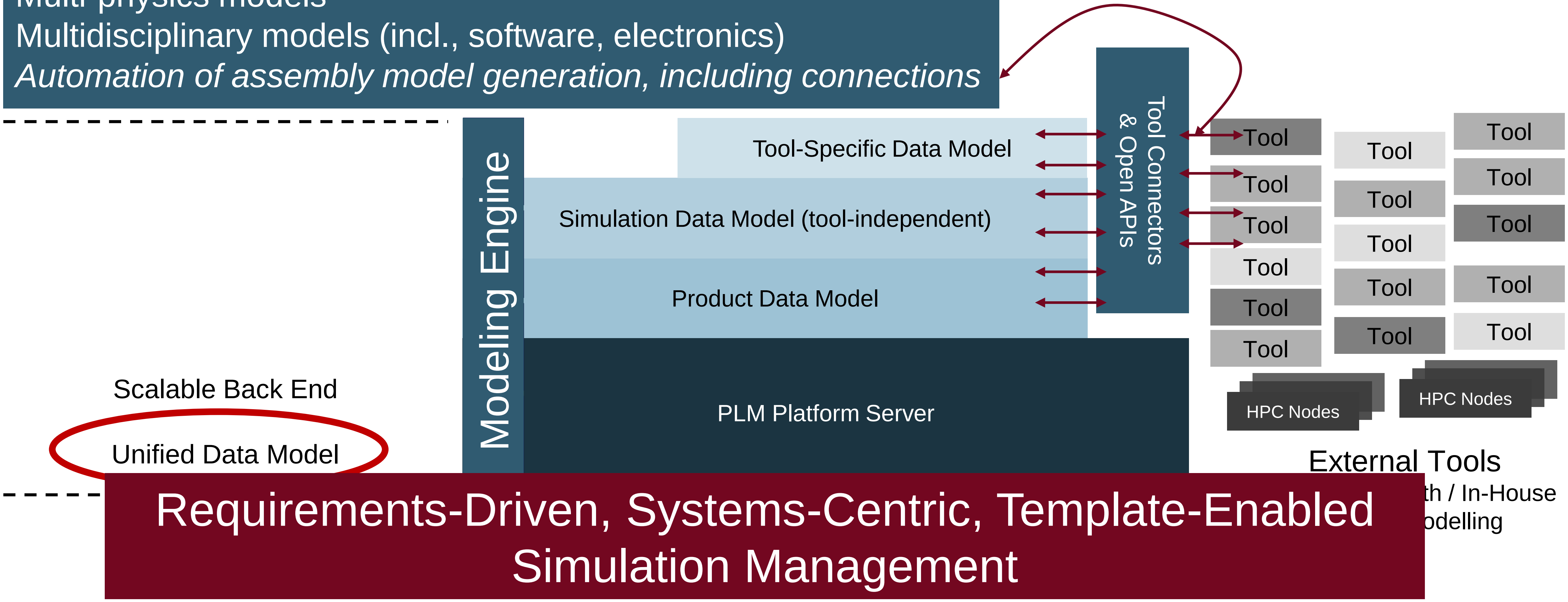
Mixed-Fidelity models (systems to 3-D)
Multi-physics models
Multidisciplinary models (incl., software, electronics)
Automation of assembly model generation, including connections



Tool-Agnostic Unified Product Data Model

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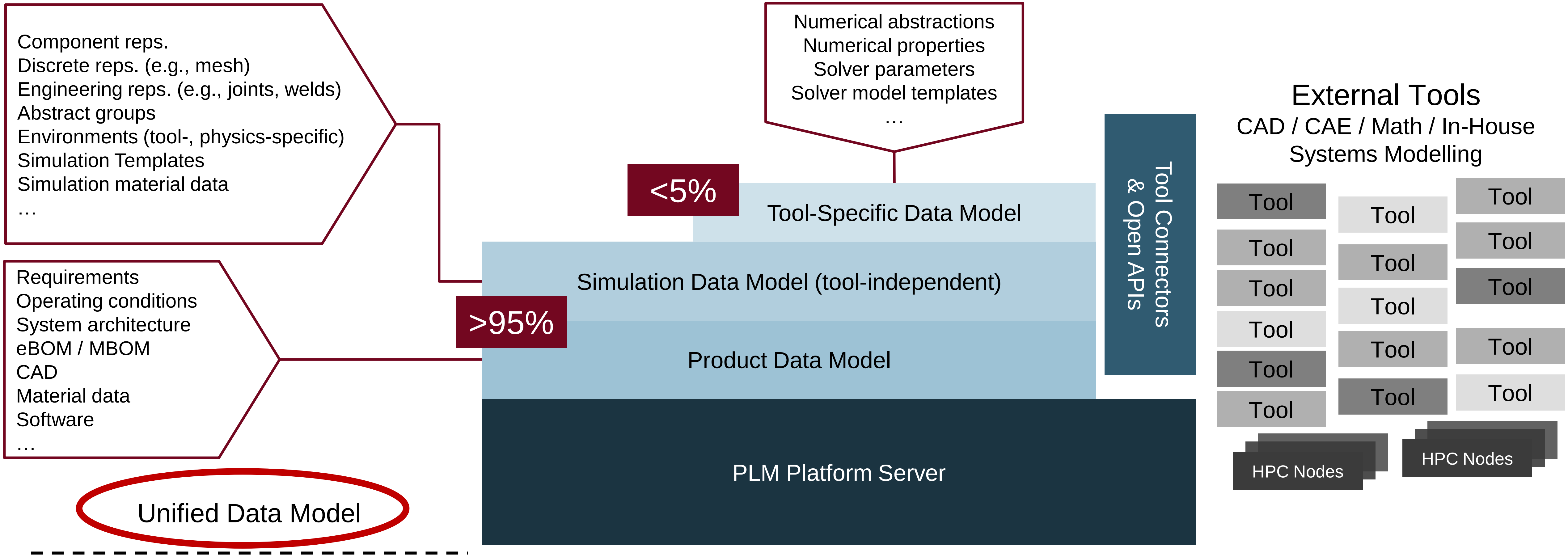

Aras Platform – Connectors

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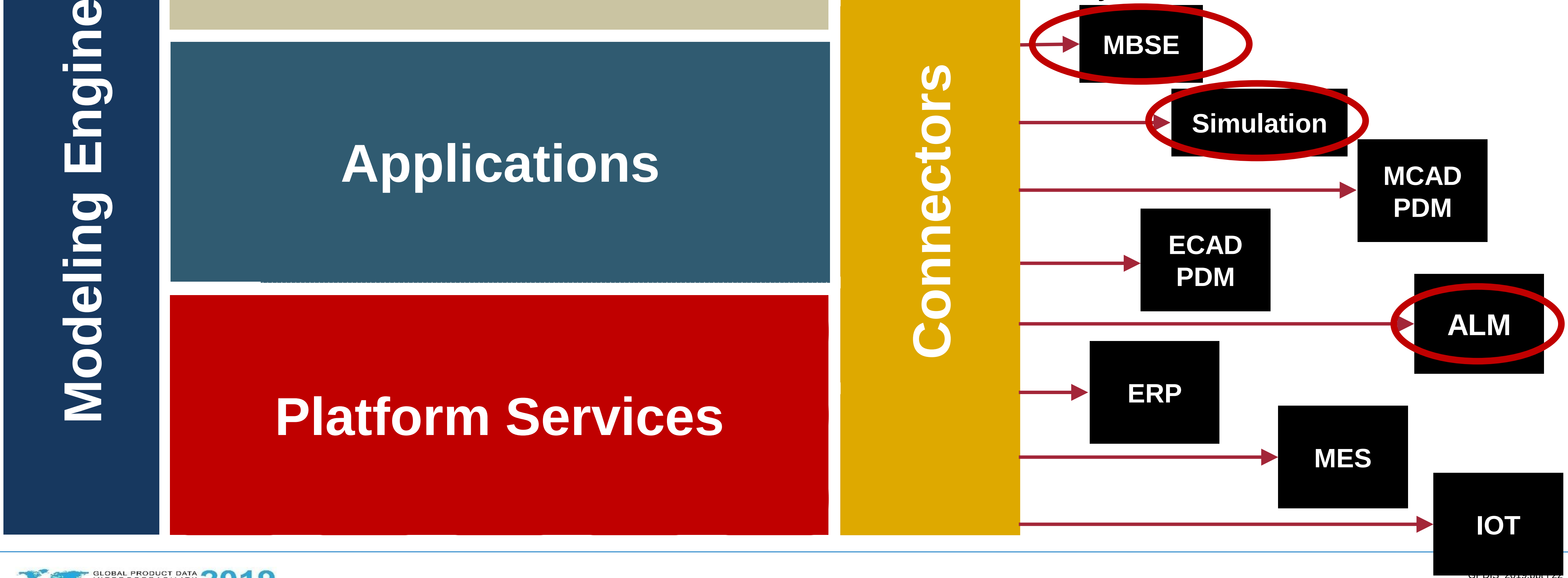
Open architecture encourages **integration** with other enterprise systems and tools



Simulation Automation – Templates & Connectors

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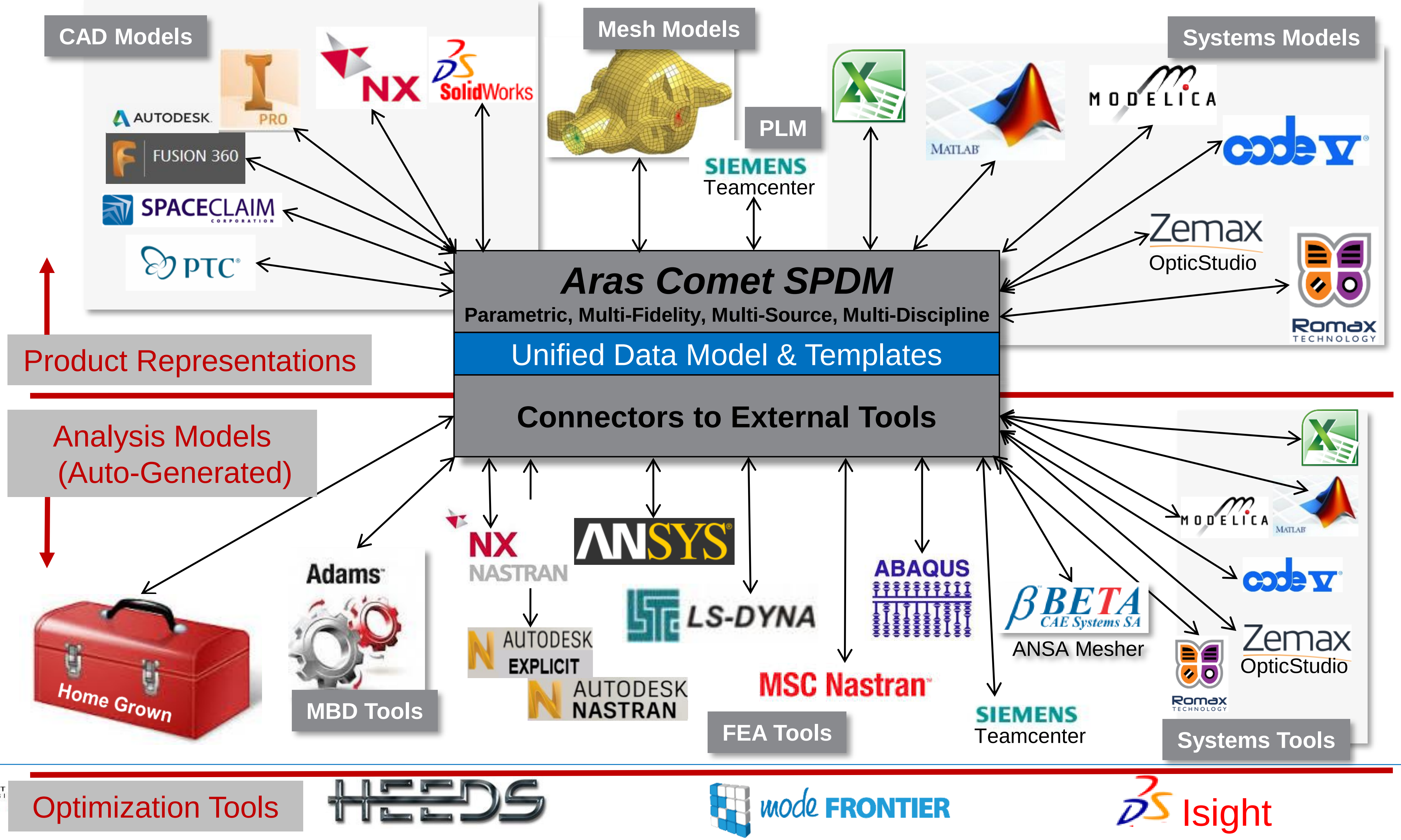

Foundations of Effective Simulation Mgmt

- Open & extensible **Unified Data Model**
  - Across all physics, levels of model fidelity and disciplines
  - Simulation data captured mostly independent of the underlying tools
  - Vendor- & tool-agnostic
  - Support for any required standards through input/output Connectors
- Open & extensible **Connector Architecture**
  - Cover in-house tools & data
  - Enable commercial tools covering all required physics and levels of fidelity
  - Tight integration between parametric CAD & parametric mixed-fidelity CAE models
- **Robust Automation** across design changes & configuration variants
  - Simulation rules not based on CAD, instead product engineering / system architecture
- Integral to mainstream processes across the lifecycle – **Digital Thread**
  - Connected to Requirements, System Architecture and variant eBOMs

Connecting the Dots…

- Systems Thinking is required, alongside the Reductionist approach
- Requirements-Driven Systems Models are the connective tissue of the enterprise Digital Thread for multidisciplinary products
- Simulation is essential and the need is growing exponentially
  - Current silo’ed & manual simulation in not adequate
- Effective SPDM within the enterprise Digital Thread is required
- Effective SPDM encourages/enables pervasive Systems Thinking

Call to Action

Aras is actively engaging in proof of concept initiatives for open reference architecture development. Please share your use cases & best practices:

MBSE / Simulation Management / Test Management

To collaborate/contribute your MBSE & Simulation Management use cases, contact:

Malcolm Panthaki | Aras

mpanthaki@aras.com

Customers who use Aras Comet SPDM…

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American Axle

Magna Cosma

AEROSPACE

Air Force Research Labs

GKN Driveline

ZHONGLI

CIOMP

SITP

JOHN DEERE

China Northern Railway

CAST

IAPCM

Superior Industries

ZPMC

XIOPM

TYUST

BIRSE

Changchun University

BCC

AVIC

CNIGC

Customer Use Case #1

Rapid, High-Fidelity, Validated Analysis of Flight Hardware

The Aerospace Corp.

Aerospace Corp: Understanding HVAC Test Data

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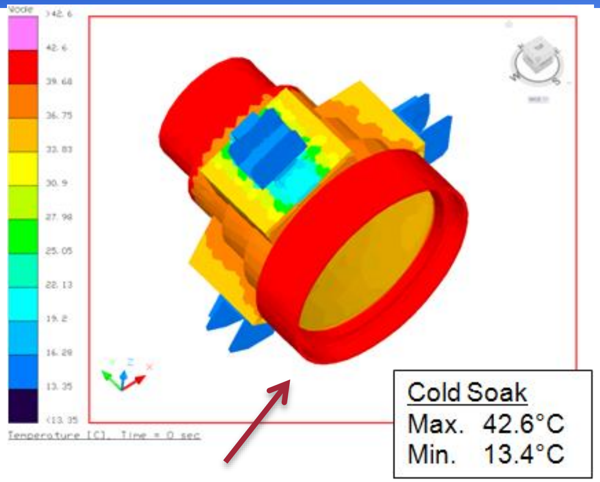
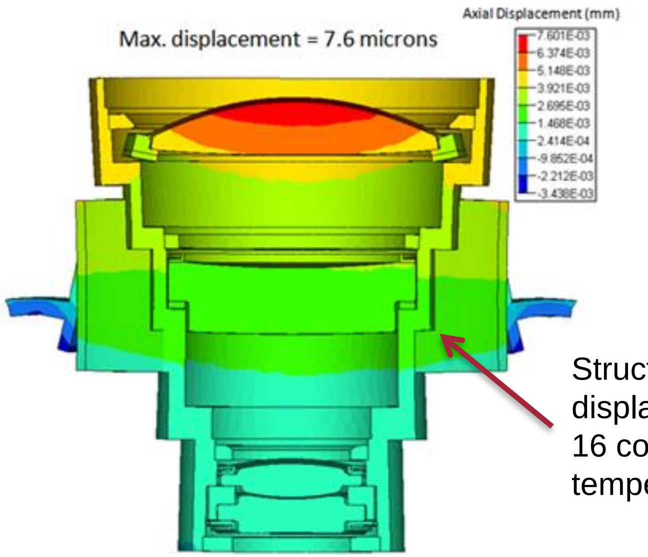
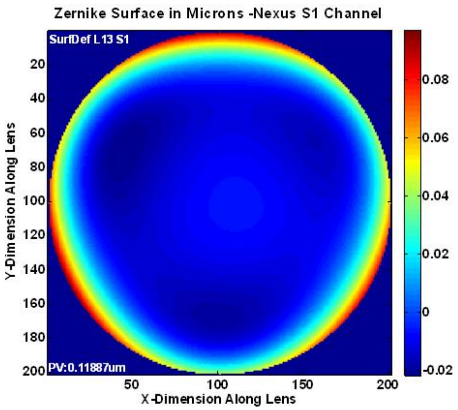


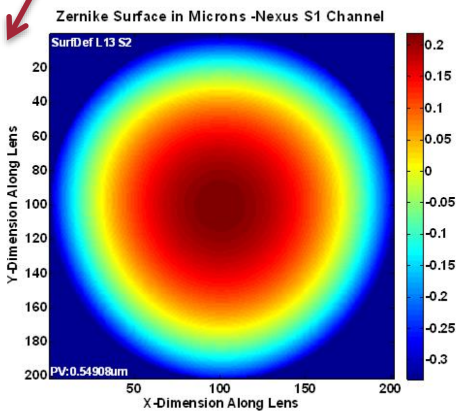
Distribution of temperatures across L13-16

Rigid body motions and wavefront errors introduced to individual lens components



Structural node displacements across L13-16 corresponding to temperature distribution

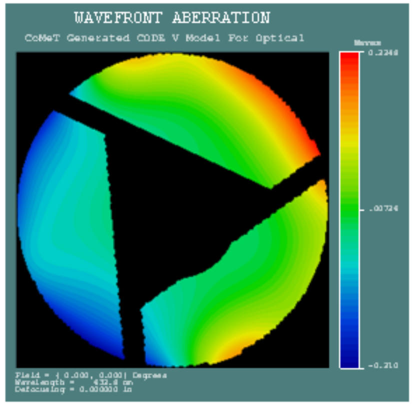




Lens 13 S1 Decenters	
X-decenter (µm)	2.44
Y-decenter (µm)	1.38
Z-decenter (µm)	5.86
α-tilt (µrad)	1.78
β-tilt (µrad)	-2.06
γ-tilt (µrad)	-17.94

L13 moves as a rigid body

Lens 13 S2 Decenters	
X-decenter (µm)	2.47
Y-decenter (µm)	1.42
Z-decenter (µm)	3.85
α-tilt (µrad)	1.52
β-tilt (µrad)	-2.28
γ-tilt (µrad)	-17.93



Best focus = -9.4mil from paraxial

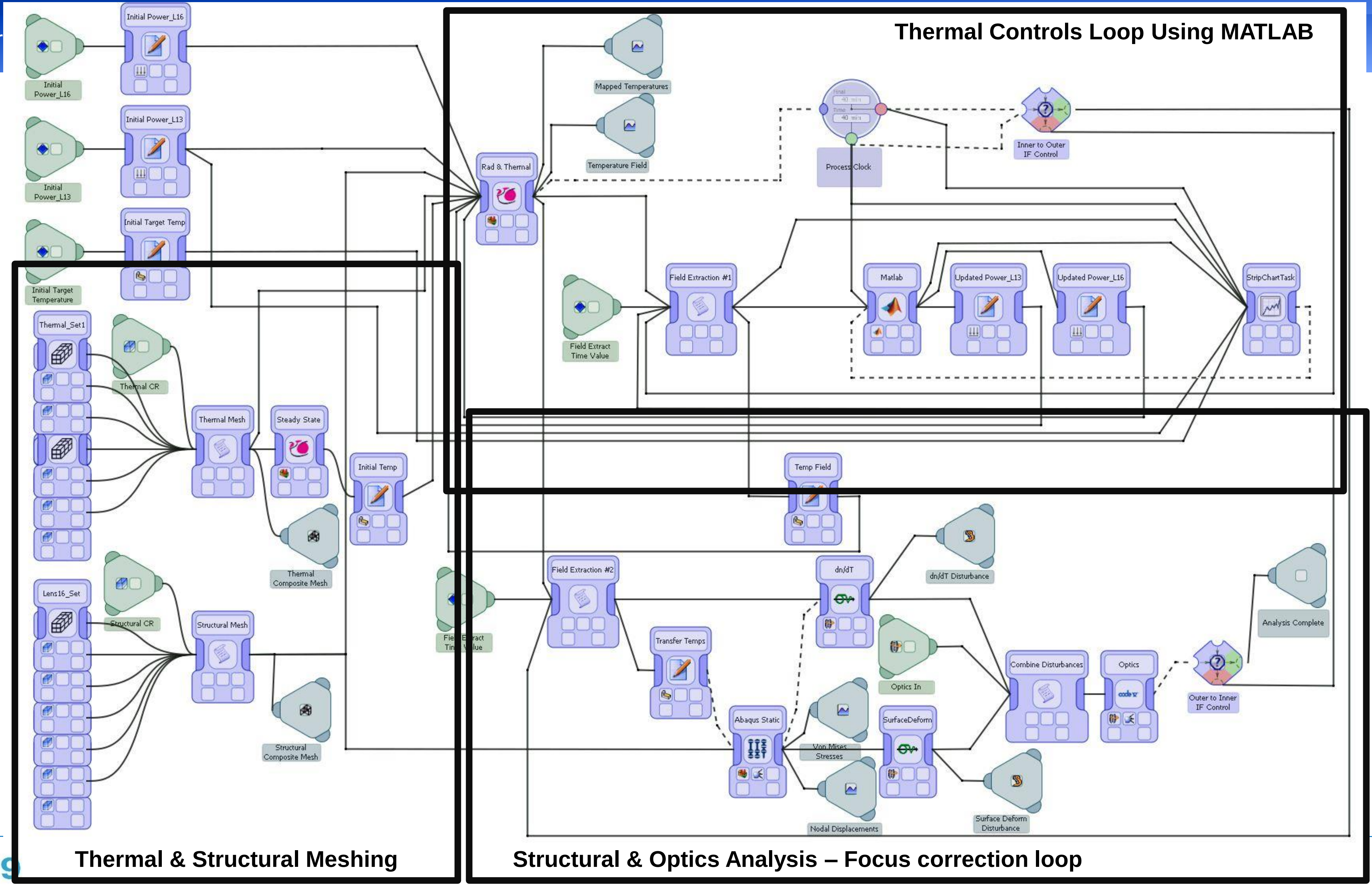
RMS Wavefront Error (λ = 630nm)	
(0°, 0°)	0.017
(0°, 0.45°)	0.103
(0°, -0.45°)	0.105
(0.45°, 0°)	0.103
(-0.45°, 0°)	0.105

Avg. RMS WFE over field = 0.087λ

Wavefront error impact to entire visible camera

Integrated Optics Process With Thermal Controls Loop

Global Product Data Inter



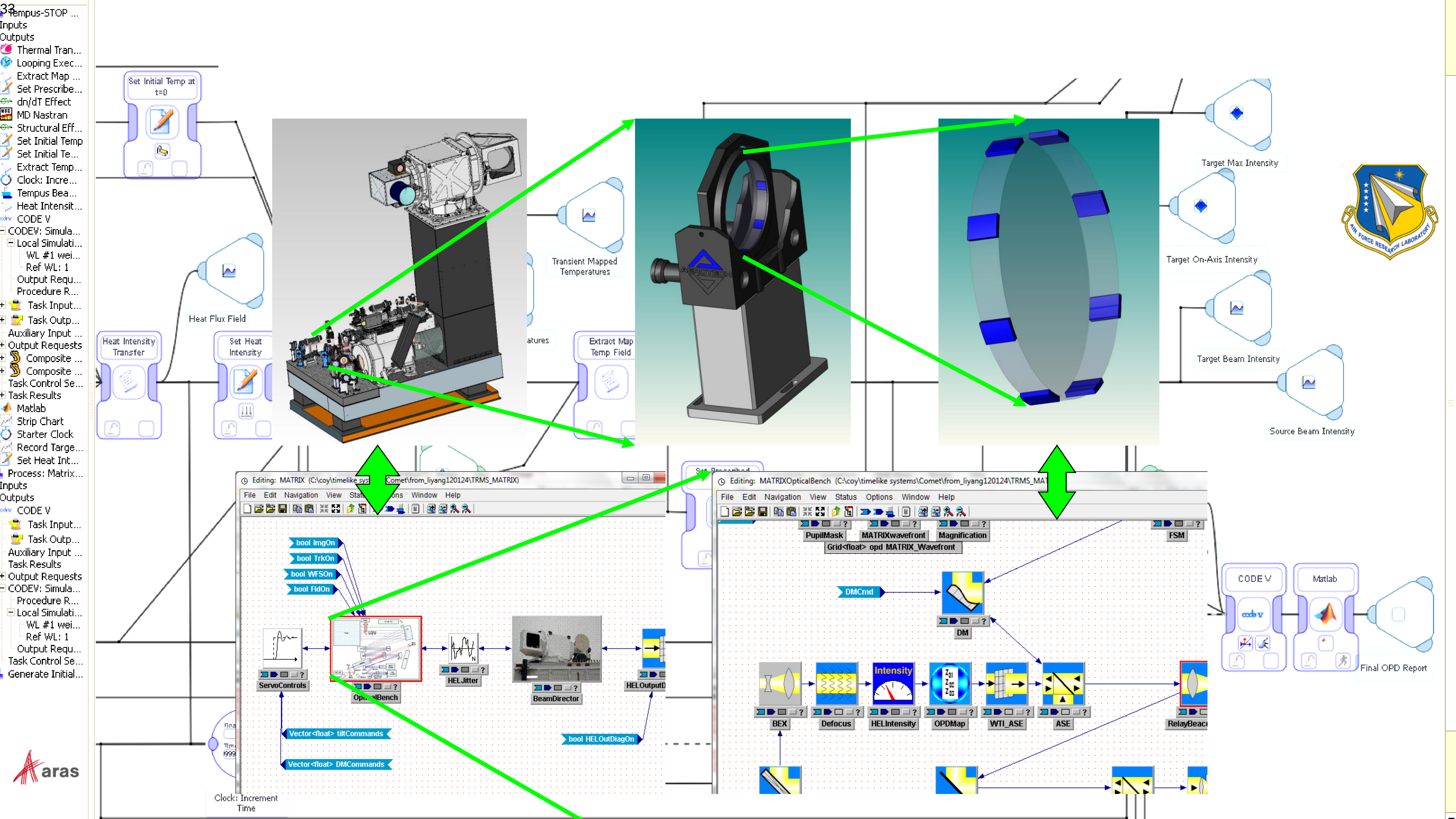
Aerospace Corp: MBSE Initiative Benefits

- MBSE is highly effective for the design of complex systems by multidisciplinary teams.
- Product quality is maintained or improved while reducing resource (cost, schedule) requirements by substantial margins (2X to 4x) by streamlining and improving the interfaces between discipline contributors.
- Additional benefits include:
  - Improved collaboration between discipline experts at Aerospace
  - Early discovery of problems/conflicts that lead to expensive rework or mission-critical failures
  - Cost-effective development of new space system concept designs
  - High fidelity system engineering of space systems early in the product development cycle
  - Excellent system engineering training vehicle for young engineers
  - Reduces overdesign of space systems with consequent cost reduction
  - Applicable throughout the product acquisition cycle
- The Aerospace Corporation is currently on the leading edge of applying MBSE methods to the design of Electro-Optical sensors due to the use of Concurrent Engineering practices and the use of the Comet automation platform.

Customer Use Case #2

Understanding a Performance Issue in a Complex Laser System using automated Mixed-Fidelity Modeling

Air Force Research Labs.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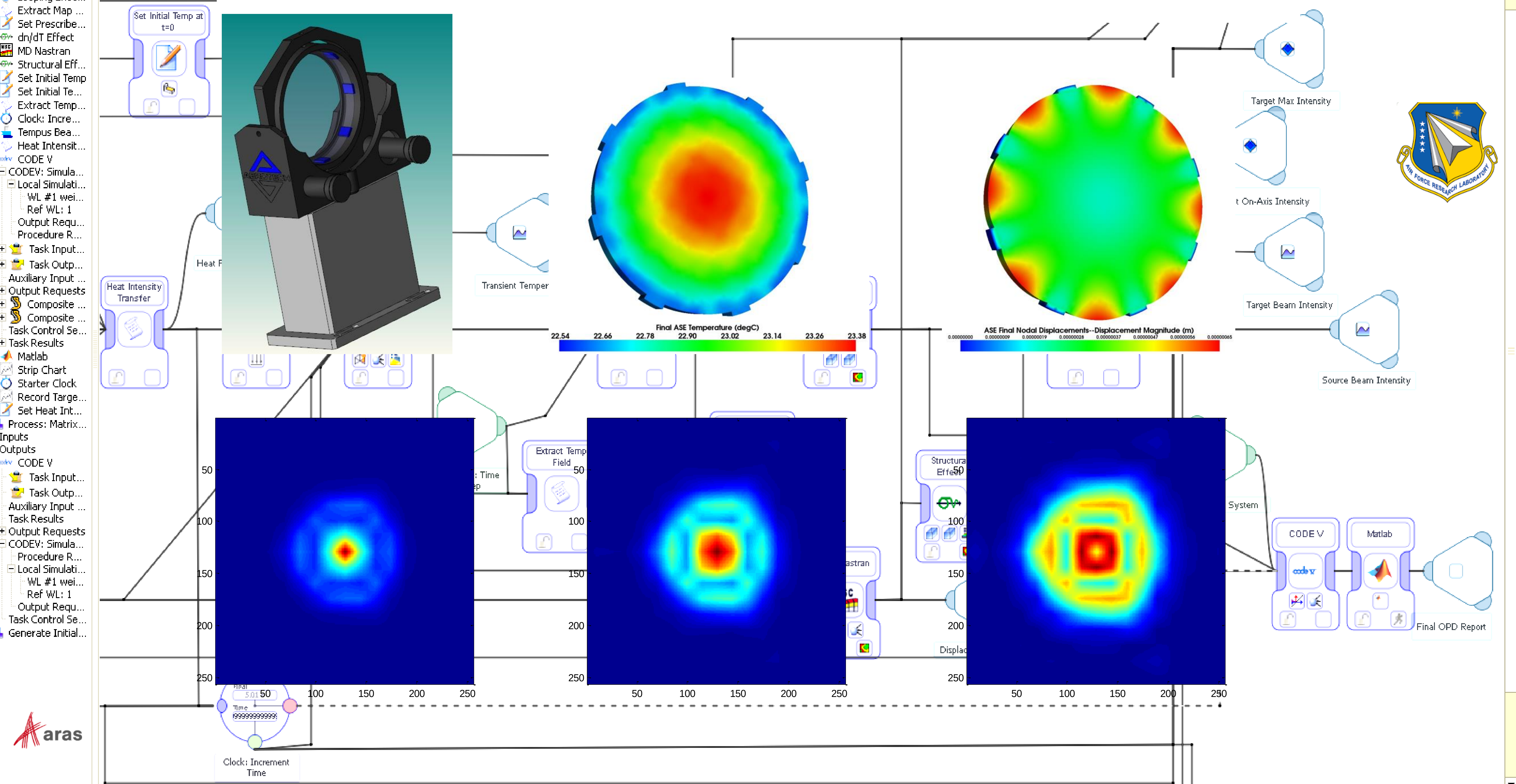
Final OPD Report

Results



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ASE Final Nodal Displacements--Displacement Magnitude (m)
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t On-Axis Intensity
Target Beam Intensity
Source Beam Intensity
Extract Temp Field
Structural Effect
System
CODE V
Matlab
Final OPD Report
Clock: Increment Time
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AFRL: Project Benefits

- Automate Mixed-Fidelity Modeling:
  Ability to perform systems level analysis using a combination of a custom systems analysis tool and 3-D FE COTS tools
- Selectively use high-fidelity models in a limited set of components – spend more computational power exactly where it is most required
- Rapidly validate complex multi-physics models against test results
- Reduce cycle time per iteration from weeks to hours while increasing accuracy and consistency
- Run large numbers of simulations automatically, looking for a better design

Tools & Solvers
NX CAD
Simulia/Abaqus
NX/Nastran
Romax
Excel
Mathematica

American Axle

- Market advantage based on engineering delivery of new technology systems at cost
- Enable consistent & accurate data for traceability
- Create repeatable processes for global scalability
- Each program: 50-100 configurations, each requiring 100’s to 1000’s of simulation runs

Solution Results

- Average 75% time reduction for analysis set up & report generation
- Improved product quality & reliability through greater simulation coverage
- Attained better reuse and repeatability of simulation processes

source: GM

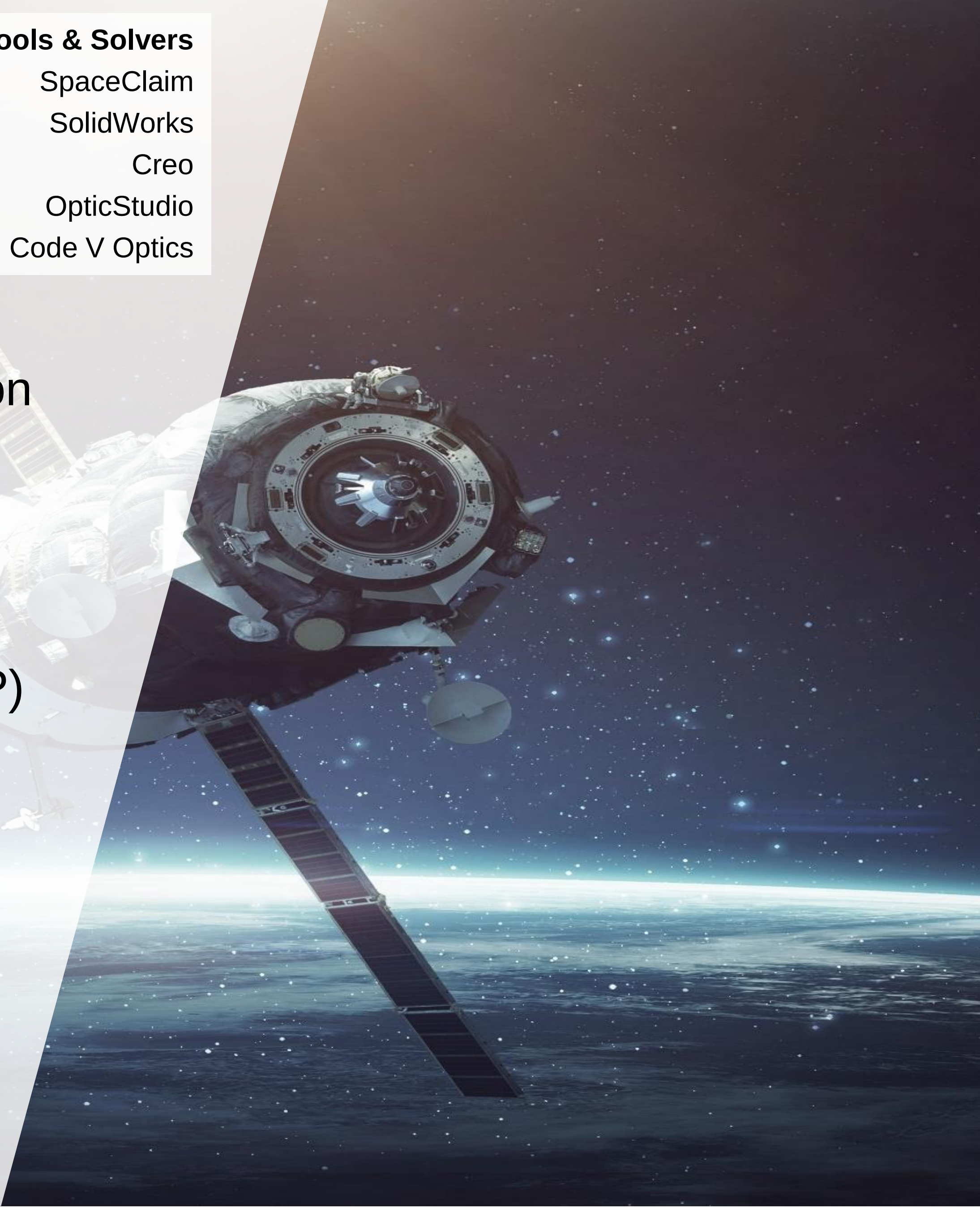
	Tools & Solvers
Simulia/Abaqus	SpaceClaim
MSC/Nastran	SolidWorks
Sigmadyne	Creo
C&R Technologies	OpticStudio
MATLAB	Code V Optics

NASA Langley Research Center

- Electro-Optical sensor systems for satellite data collection
- Instruments highly sensitive to solar thermal effects
- Previously each analysis iteration took 2-4 weeks

Solution Results

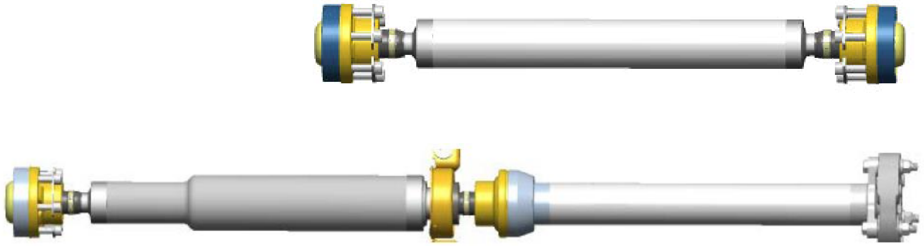
- Structural-Thermal-Optical-Performance Analysis (STOP) with single repeatable process
- Ability to quickly conduct trade studies over many concepts for high level of design confidence
- Analysis iteration now takes < 1 day
- Engineers are introduced to “Systems Thinking” when using the Concurrent Engineering development process



source: NASA

GKN DRIVELINE

Tools & Solvers
Creo
Mesher
MSC/Nastran
Excel



GKN Driveline

- Bending Frequency influenced by many design variables
- Libraries of templates and design architectures
- Create repeatable processes for global scalability across all engineering teams

Solution Results

- Democratize process for all engineers using Web GUIs
- Non-experts investigate design iterations rapidly before the experts are involved
- Automation drives process refinement/improvement, resulting in accuracy and consistency globally
- Improved product quality & reliability through greater simulation coverage

Credits: Glenn Valine

source: GKN Driveline

Tools & Solvers
NX CAD
LS-Dyna
MSC/Nastran
Excel
ANSA Meshing
VCollab

Magna Cosma

- Configuration and barrier crash analyses of bumper systems
- Manual process results in 6-8 hours per iteration
- CAD design change coordination issues resulted in errors, added costs and reliability impact

Solution Results

- Enabled repeatable parameter studies for better design decisions and traceability
- Process definition improved product quality across global organization
- Model assembly and report generation reduced from avg. 6-8 hrs to 15 minutes / iteration

source: gm

Thank You

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