Aircraft System Model in SysML Multi-disciplinary Simulation and Analysis for Early Virtual Integration

Connect Systems Models in SysML
to
3DEXPERIENE Platform and other Models Using Process Composer

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3DEXPERIENCE®

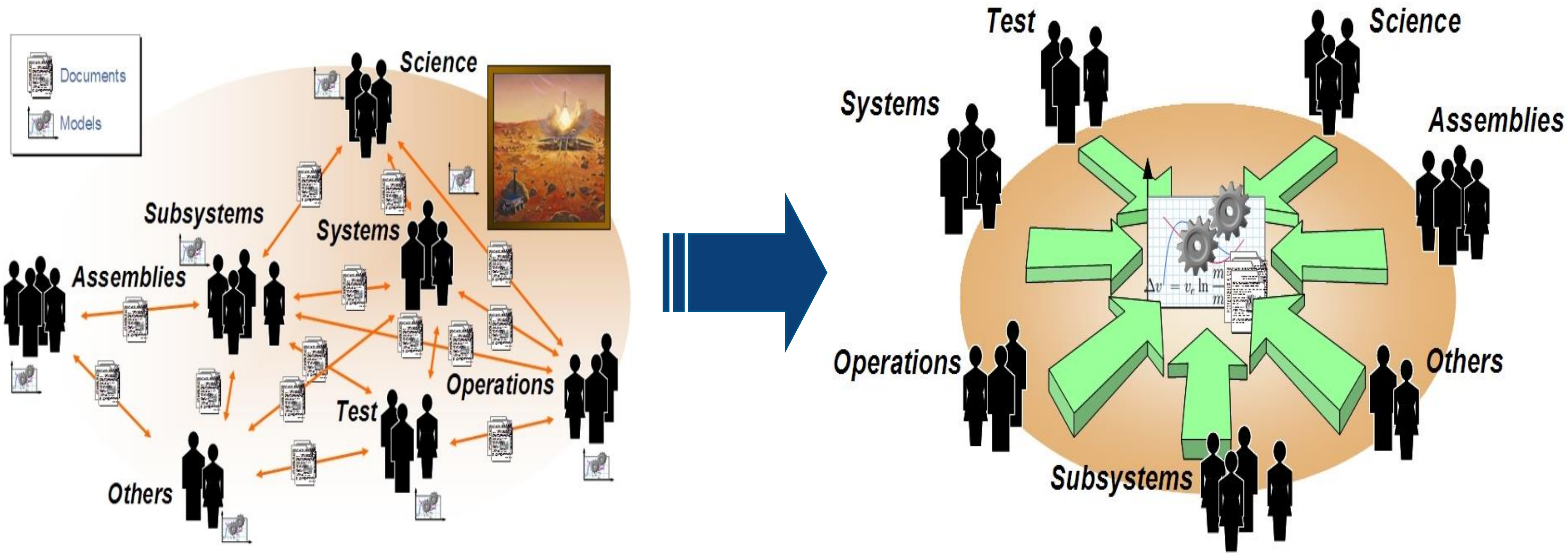
Agenda

- Introduction to MBSE with SysML and Catia Magic / Cameo Systems Modeler
- System architecture simulation and analysis in SysML
- MBSE ecosystem
- Multidisciplinary simulation orchestration and analysis - Process Composer
- Connect Cameo Models to **3DE**XPERIENCE Platform models in Process Composer
- Next steps
- Conclusions

Overview

Decreasing time-to-market phases and the increasing complexity of future systems make it difficult for engineers to test the proper performance of the systems, implement changes, and optimize system architecture. With help of system model in SysML simulation and integration with multidisciplinary engineering tools we can reach high level maturity of MBSE / digital engineering adoption. In this webinar we will present state of the art solution:

- ▷ Cameo Systems Modeler aircraft SysML project simulation.
- ▷ We will connect SysML model with Dassault Systems 3DEXPERIENCE Platform Process Composer for multidisciplinary simulation orchestration leveraging multiple models and simulations.
- ▷ We will simulate system model in context of aircraft geometry and mission parameters.
- ▷ We will perform requirement verification.



Today: Standalone models related through documents

Future: Shared system model with multiple views, and connected to discipline models

Existing Modeling Practice

Analysis Simulation and Verification

Standards Compliance

Regulatory Compliance

Management of Complexity

Requirements Traceability and Verification

Modularity and Reuse

Strong Partner with Experience

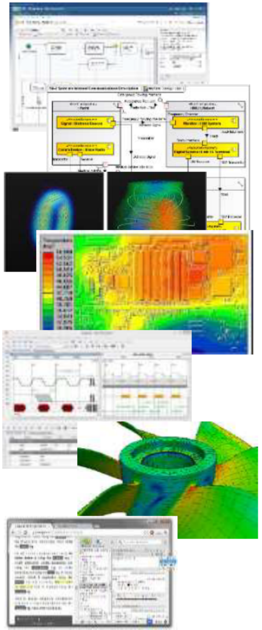
Model Based Systems Engineering provides paradigm shift

- Defects caught earlier in the process
- Less expensive to address at these stages
- Overall quality improves

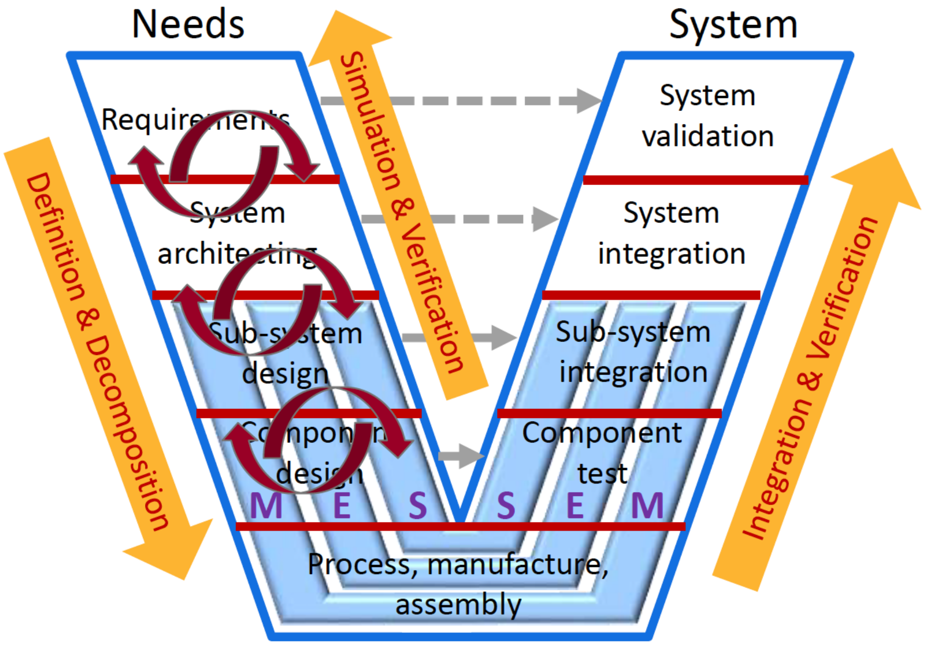
Model-Based Systems Engineering

Traditional Systems Engineering methodology

System engineering process (V process)

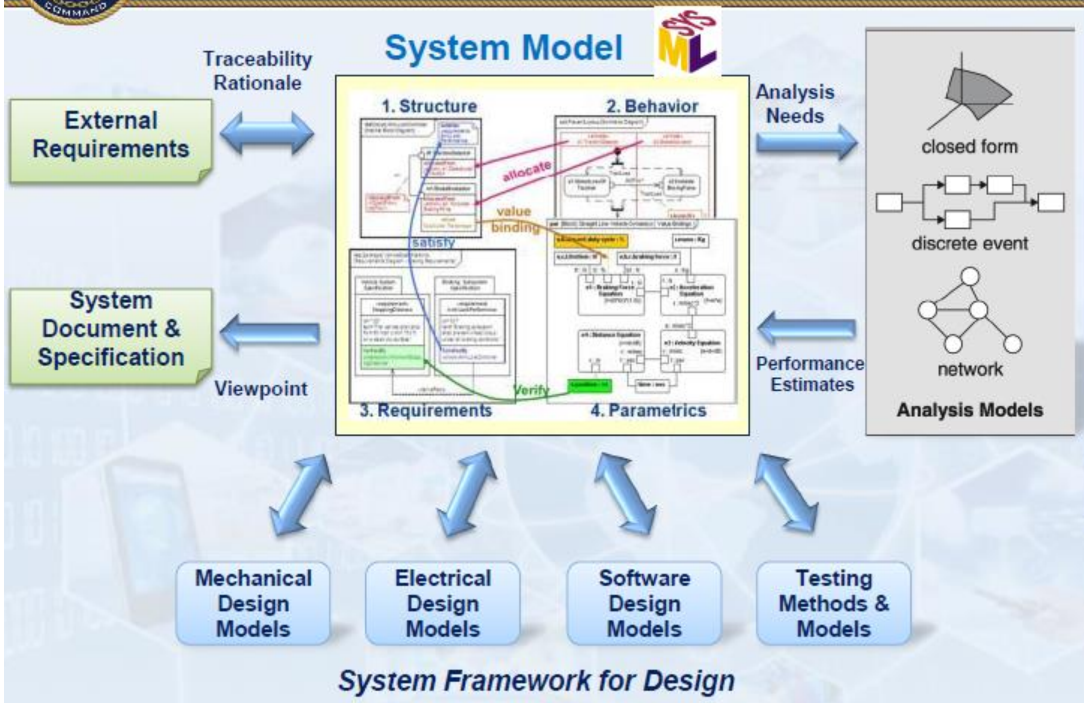


REQ model
SysML model
Simulation
AML/Software
MCAD
ECAD
Timing
Thermal
Stress
etc.



Credits: Pawel Chadzynski & Michael Pfenning - MBSE and the Business of Engineering

System Model – As An Integration Framework



The system model is linked "upstream" to mission effectiveness models and CONEMPS, and "downstream" to decomposed and allocated sub-system requirements and associated designs. It is also linked to verification tools (FEM, CFD) which validate it's fidelity and utility for intended purpose

The system model flows down, and is interconnected with the subsystem requirements and emerging designs. These design are instantiated in different models based on their governing physics (stress/strain, fluids, electro-magnetic, etc.)

Note: this diagram originated from Sandy Friedenthal, A Practical Guide to SysML. (In the third edition, it is Figure 18.1, page 507)

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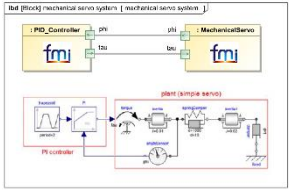
MBSE Maturity Model



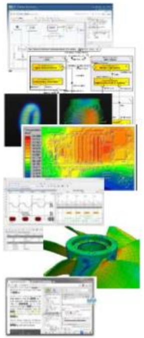
Ad Hoc

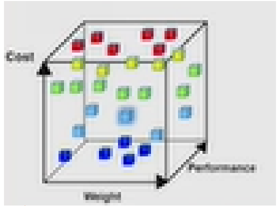
Modeling

Executing

Integrating

Optimizing





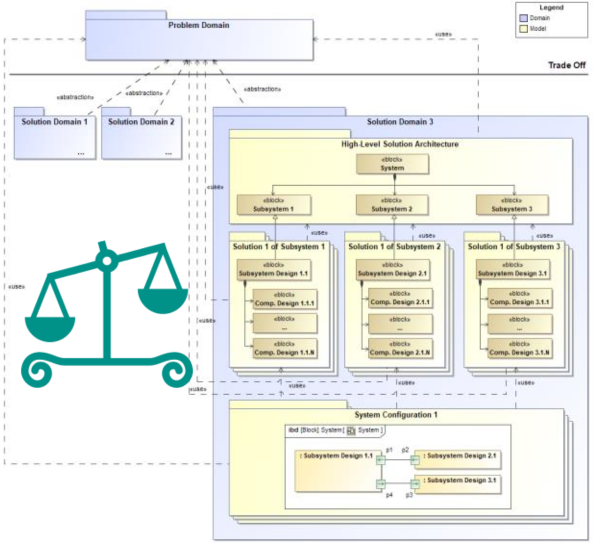
- Communicability
- Greater insight into design and intent
- Early Convergence
- Confidence
- Efficiency
- Integration with design disciplines
- Source of Truth
- Model Fidelity

Modeling a system without following a framework, without a formal language and with a tool supporting the standards ⇨ **Descriptive Modeling** with a framework, with a formal language and with a tool supporting the standards ⇨ Modeling facilitates execution, **Verification & Validation.** ⇨ **Modeling is integrated** with other downstream design disciplines ⇨ Model remains the **Single Source of Systems Truth** from the inception till the End of life of the System

Source: Chris Schreiber
Systems Engineering Senior Manager at LMCO , JPL MBSE Symposium 2019

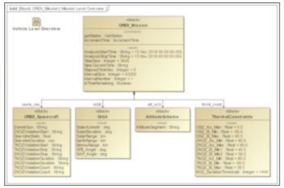
Use Cases

- System level multidisciplinary trade studies
- Parametric optimization
- Requirements V&V



System Design

Requirements & Constraints

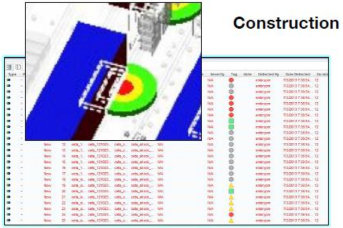


Drive analysis parameters from system definition

Via Prop. Code & API

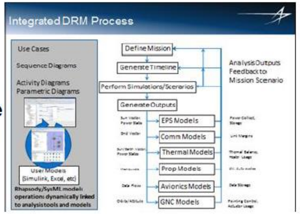
Mechanical Interface Analysis

Construction Geometry



Shock Violation Analysis

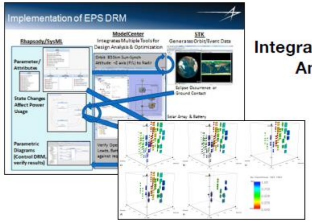
Behavior & Performance Constraints



DRM Integrated-Analysis and Optimization

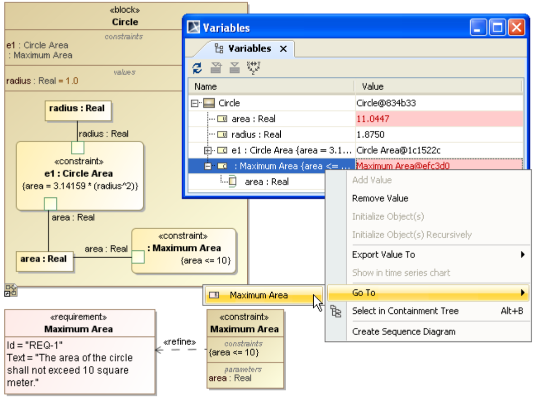
Via code & Tool API

Mission Design Optimization



Integrated System Analysis

Trade space Exploration & Optimization

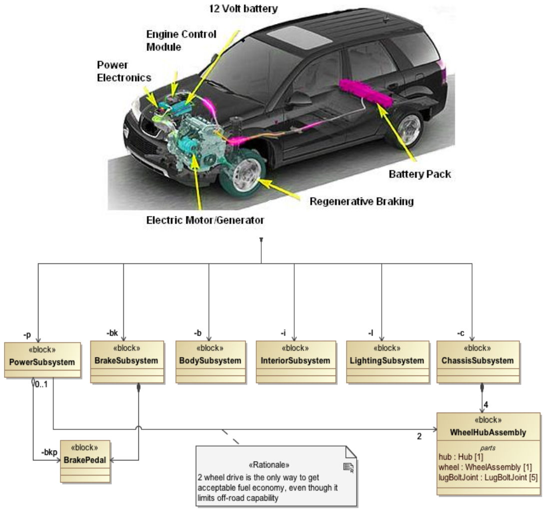


Source: Chris Schreiber
Systems Engineering Senior Manager at LMCO , JPL MBSE Symposium 2019

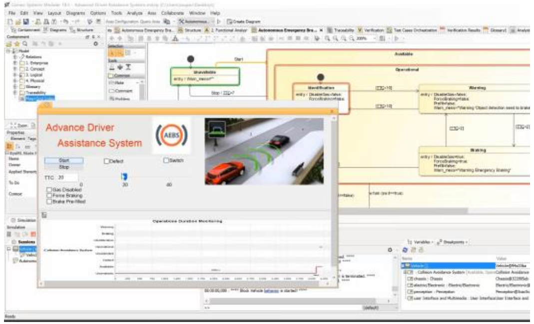
Leading Standard Based MBSE Solution by CATIA | No Magic

System Modeling

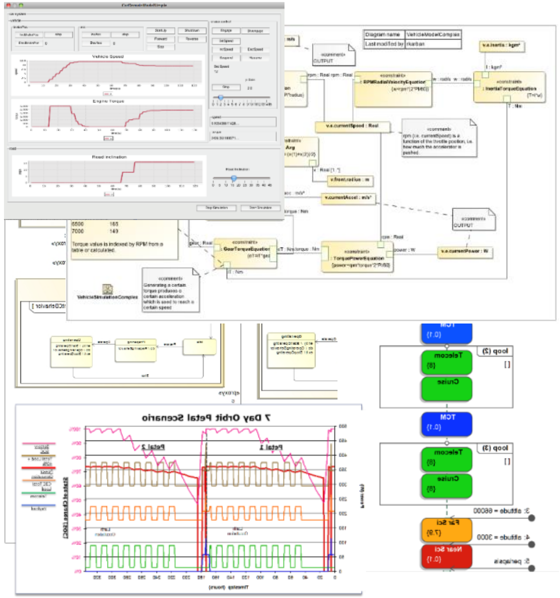
Example of a Hybrid SUV



System Simulation



System Analysis



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Cameo Simulation Toolkit

Model execution framework:

- Model debugging and animation environment
- Pluggable engines, languages and evaluators
- User Interface prototyping
- Co-simulation orchestration

The standard based model execution of:

- Activities (OMG fUML standard)
- Composite structures (OMG PSCS)
- Statemachines (W3C SCXML and OMG PSSM standards)
- Actions/scripts (OMG ALF, JSR223 scripting)
- Parametrics (OMG SysML standard)
- Sequence diagrams (OMG UML Testing Profile)

Analysis Capabilities:

- Automated Requirements Verification
- Trade studies / trade-off analysis
- Mass/cost/power rollups
- Timing and duration analysis
- Monte Carlo analysis
- Model-based testing
- Co-simulation environment

3DEXPERIENCE V+R Process Apps Overview

- Simulation Expert
- Method Developer
- Simulation User
- Decision Maker

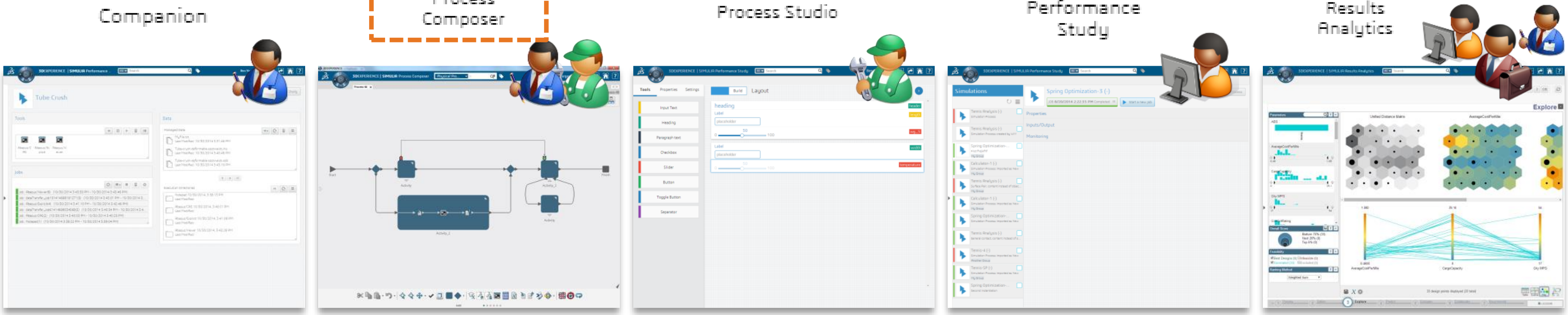
SIMULIA Simulation Companion

SIMULIA Process Composer

SIMULIA Process Studio

SIMULIA Performance Study

SIMULIA Results Analytics



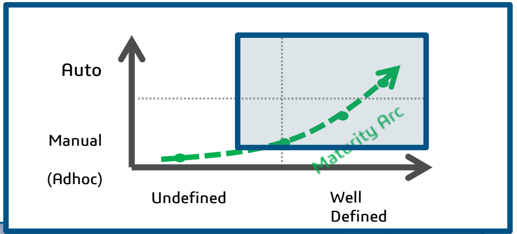
Ad-hoc Session → Simulation Process → Simulation Experience → Simulation Result

3DOrchestrate Services

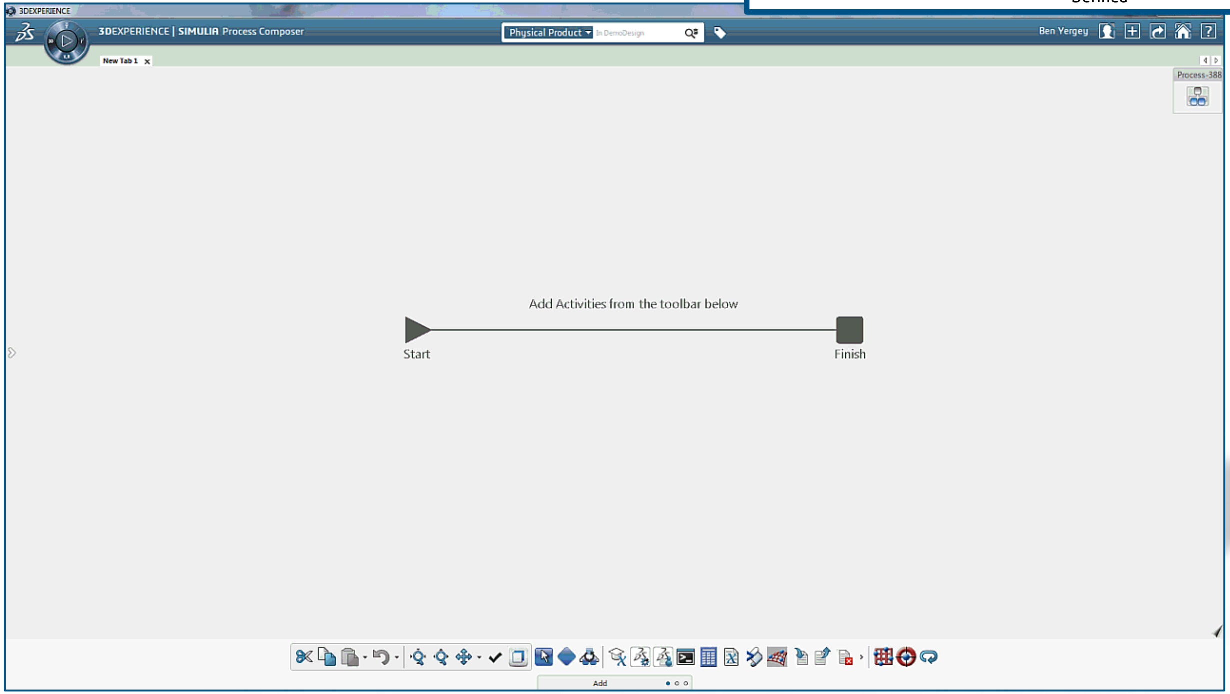
3DEXPERIENCE Platform

Process Composer App

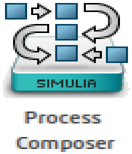
Create processes that integrate your applications, disciplines and data



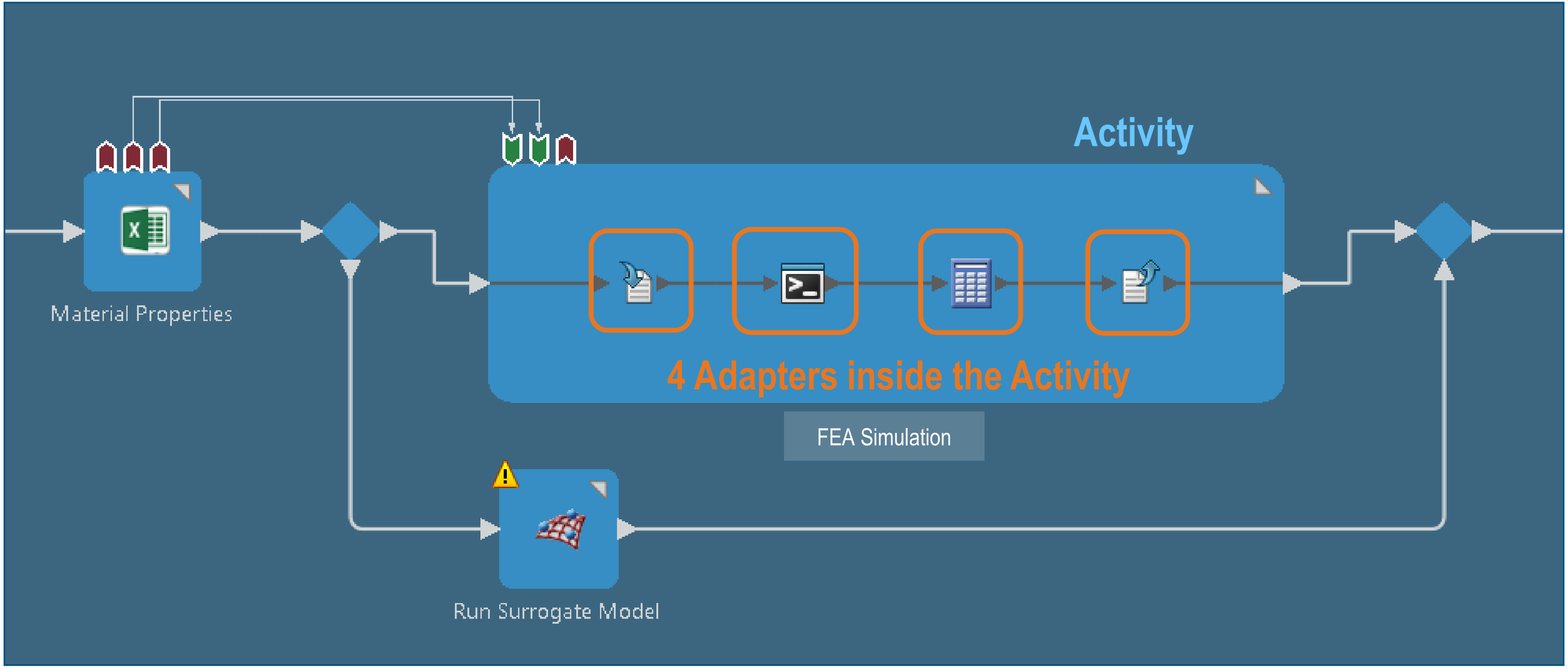
- **Capture and deploy expert methods**
- **Graphical Process Builder**
  Drag-and-drop process authoring
- **Exchange data and execute**
  - DS applications
  - External Applications
- **All processes types**
  Man-in-the-loop and/or automated



Activities



Process
Composer



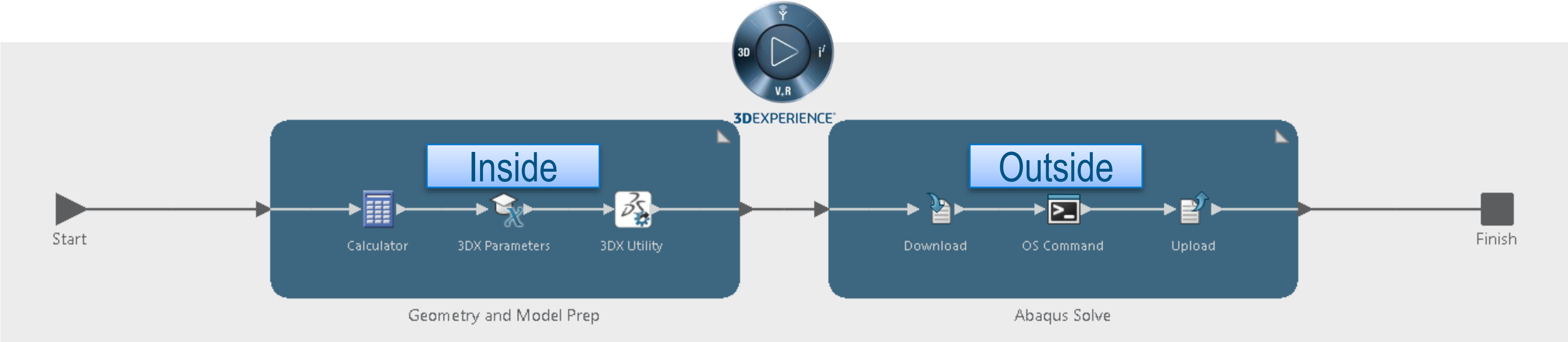
Activity
Material Properties
4 Adapters inside the Activity
FEA Simulation
Run Surrogate Model

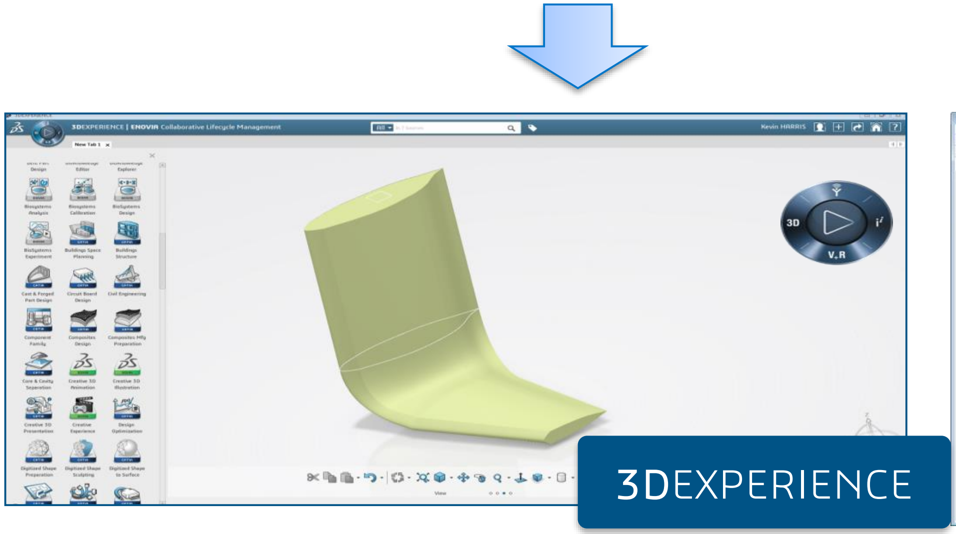
Process Composer Adapters

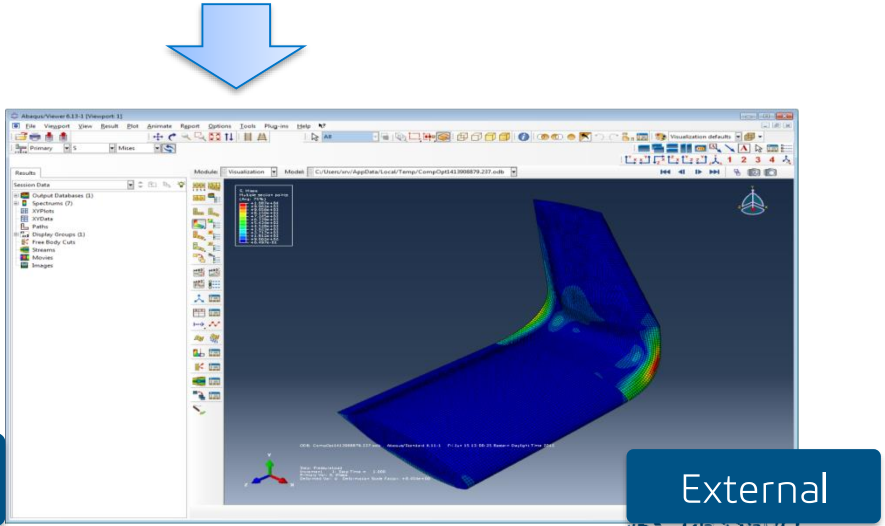
- Upload/Download Content
- OS Command
- Delete Content
- Text Parser
- Calculator
- Java Script
- 3DX Script
- Create Report
- Approximations
- Data Matching
- Co-Simulation
- Update Attributes
- Excel
- MATLAB
- Abaqus
- Isight
- DOE
- Loop
- Optimization
- Monte Carlo
- Exchange 3DX parameters
- 3DX Utility
- 3DX App
- 3DX Simulation

…Or create your own!

Use Native or External Tools

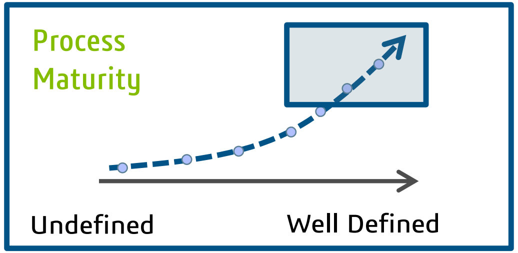


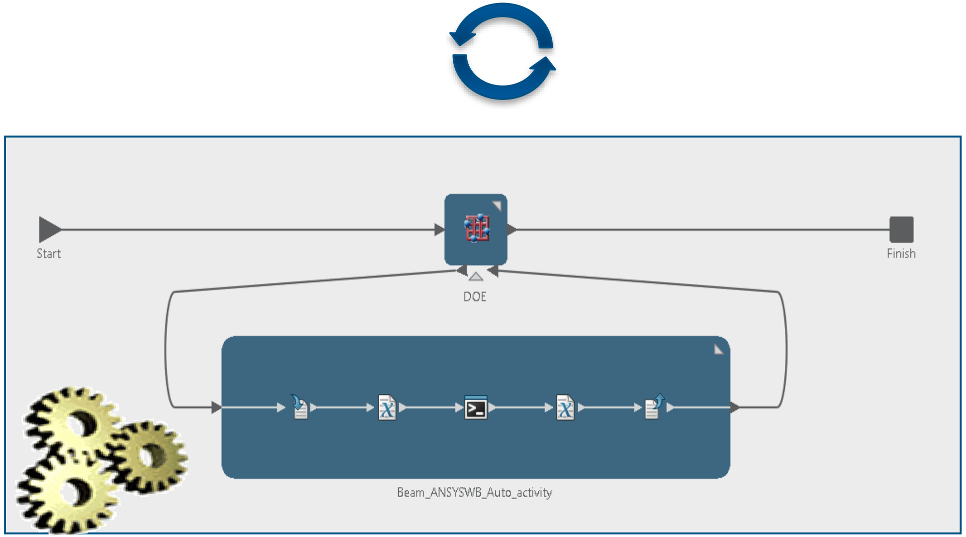


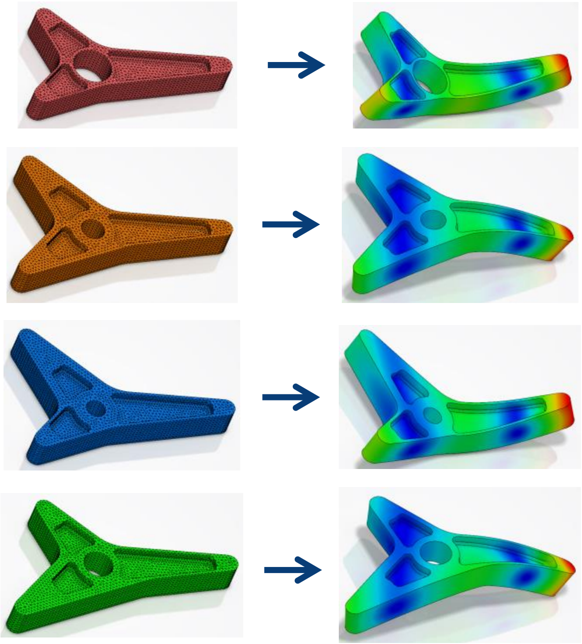


Automated, Exploratory, Hierarchical Processes

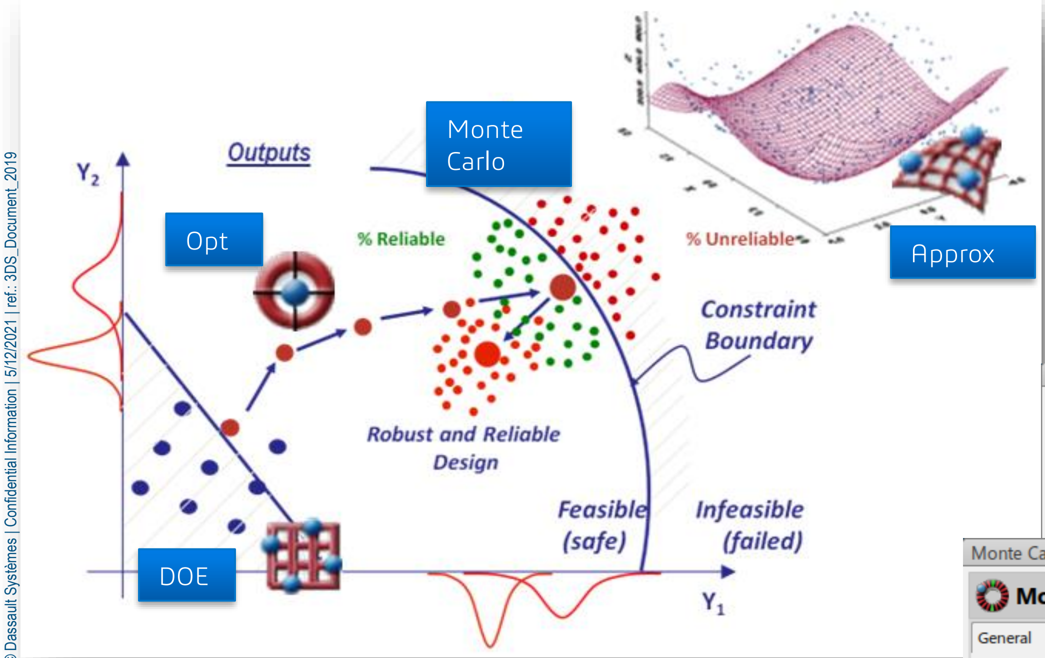
Automatically execute data movement, data exchange and application execution. Iterate execution of a sub-process using specific logic.

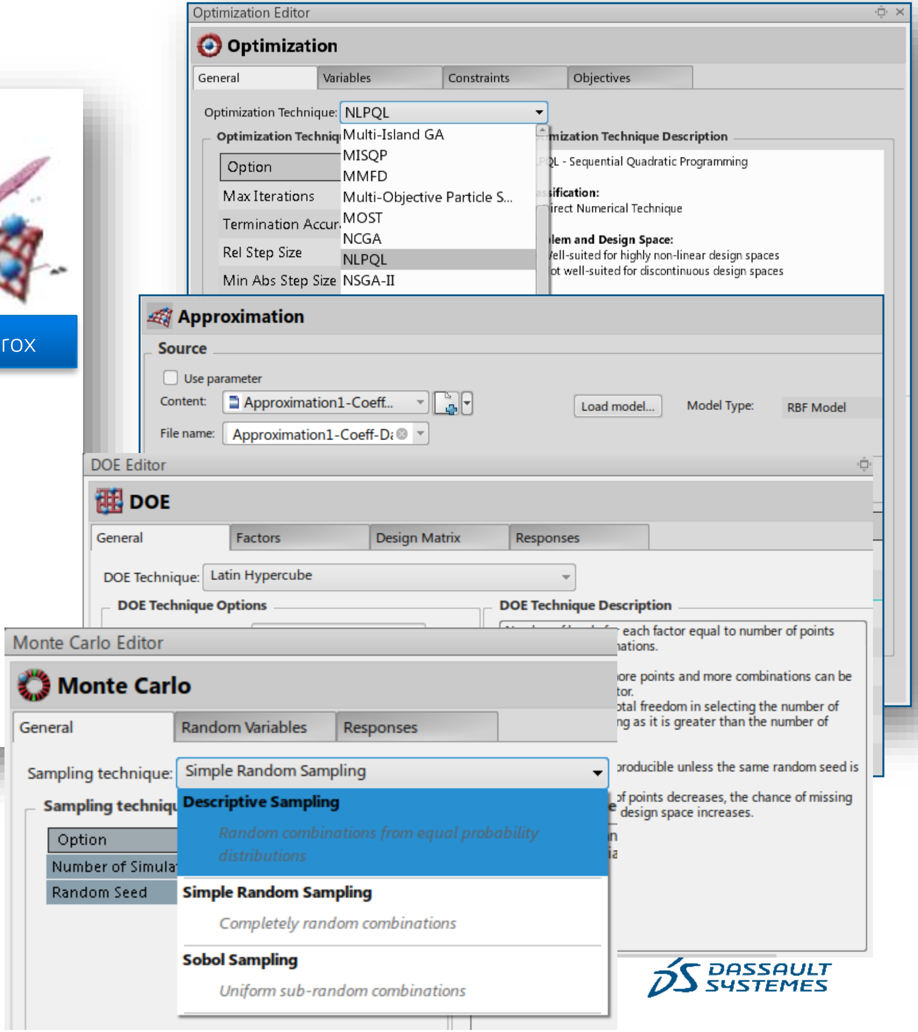






Design Exploration Techniques



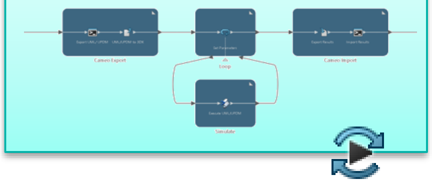


Most DOE, Opt, MCS and Approx techniques from Isight are included in Process Composer

What is a Simulation Experience?

Input Parameters
Input 1 = 2.44
Input 2 = 12
Input 3 = 0
…

Simulation Experience



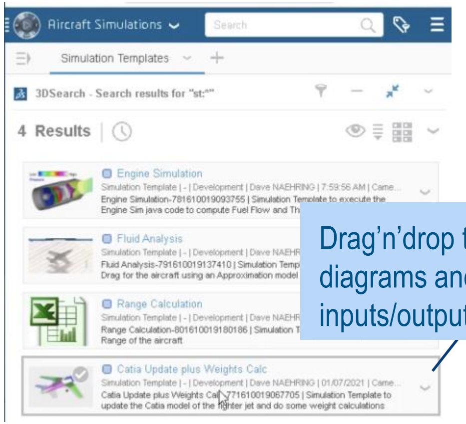
Output Parameters
Output 1 = 2.7229E7
Output 2 = 78.49
Output 3 = 2100
…

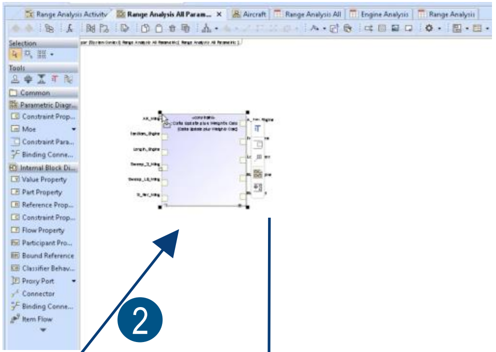
What's in the black box?

- 3rd party or custom developed tools (Excel, MATLAB, Nastran, etc.)
- **3D**EXPERIENCE data (Engineering Items, Requirements, Logical or 3D Fluid or 3D Structural Simulations, etc.)
- Combination/multiple of the above in sequence and/or with branching
- Exploration, loops, optimization, robustness

SIMULIA Process Composer integration

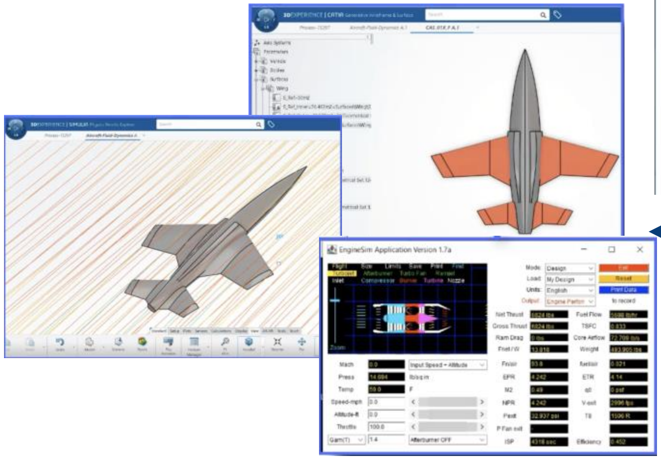
1. Create simulations in SIMULIA Process Composer and share as templates on the 3Dx platform

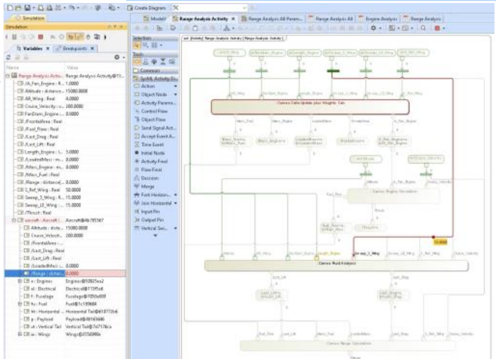




2. Drag'n'drop to CAMEO diagrams and expose inputs/outputs

3. Connect SysML parameters and launch the simulation in CAMEO Simulation Toolkit

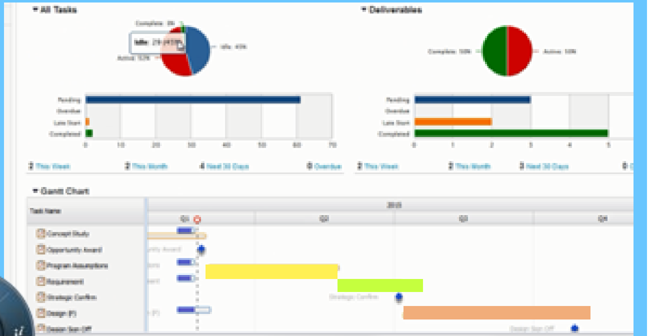




4. Executes in SIMULIA and gets results back to CAMEO to verify

Connect Cameo to Digital Thread

3DX maintains Design, Project, Reqs Traceability



Milestones

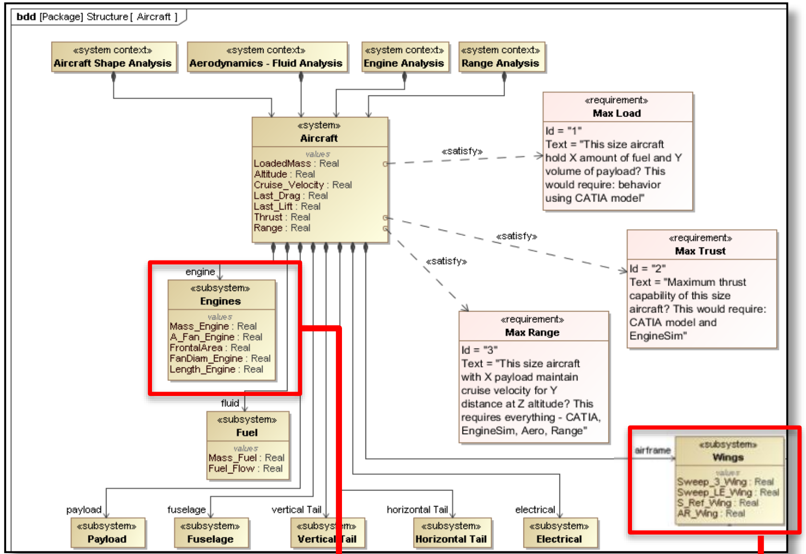
Concept

Preliminary

Detailed

Via Simulation Experiences

- ✓ Lifecycle Controlled
- ✓ Secure Access
- ✓ Single Source
- ✓ Execute Anywhere

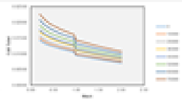


Increasing Fidelity

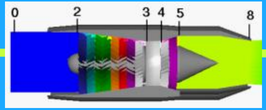
1st Principle Equations

$$F = \dot{m}_e V_e - \dot{m}_0 V_0 + (p_e - p_0) A_e$$

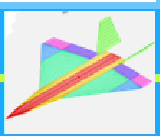
Lookup Tables



1D Thrust Analysis

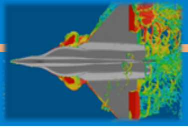


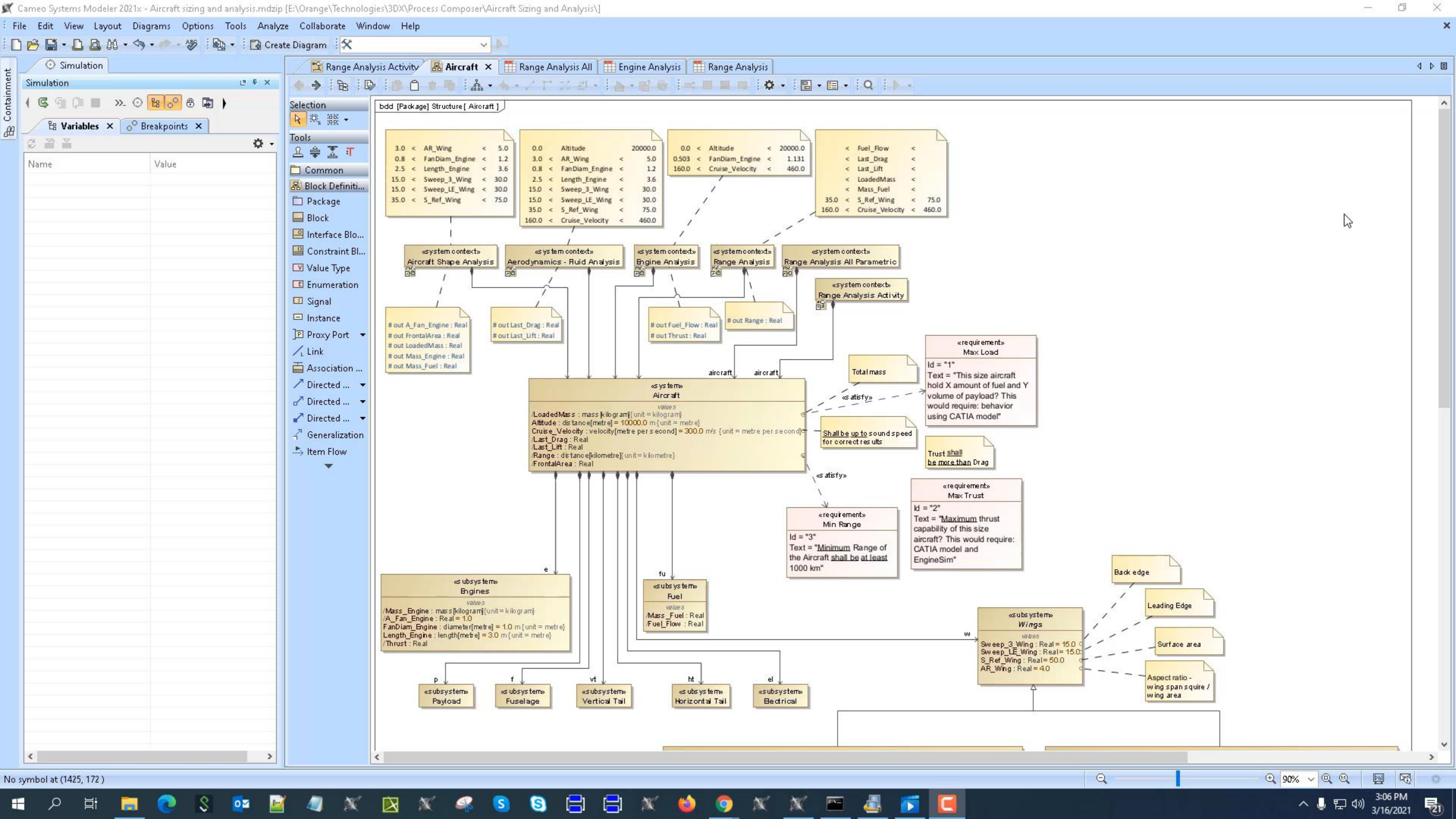
Control Surface Analysis



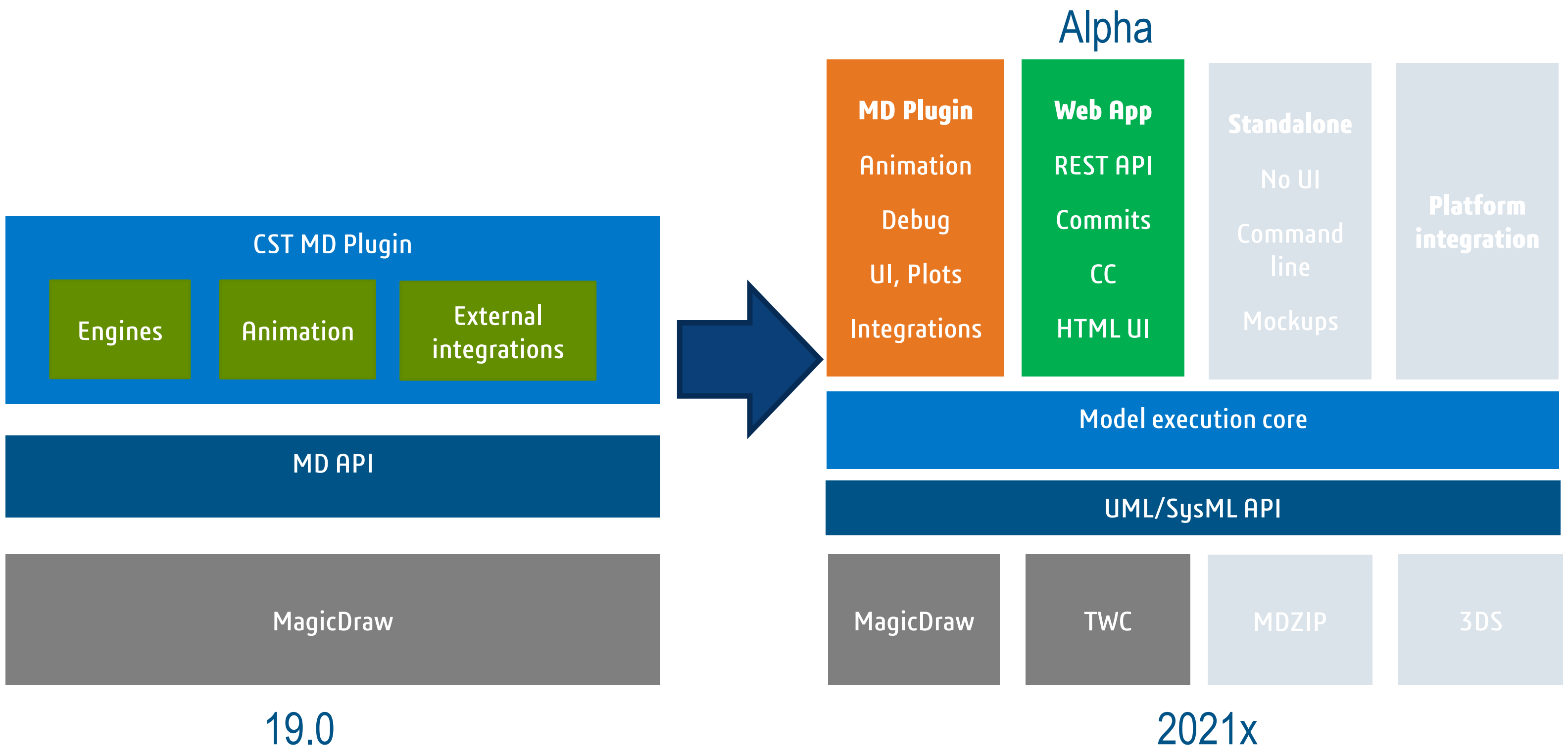
Aeroacoustic 3D Simulation

3D Fluids Simulation



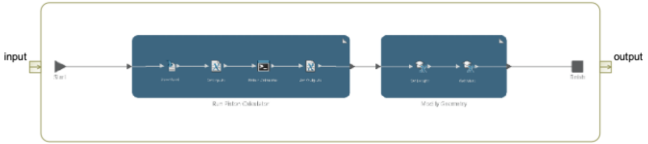

Cameo Systems Modeler 2021x - Aircraft sizing and analysis.mdzip [E:\Orange\Technologies\3DX\Process Composer\Aircraft Sizing and Analysis\]
File Edit View Layout Diagrams Options Tools Analyze Collaborate Window Help
Create Diagram
Simulation
Variables
Breakpoints
Name
Value
Range Analysis Activity
Aircraft
Range Analysis All
Engine Analysis
Range Analysis
Selection
Tools
Common
Block Definiti...
Package
Block
Interface Blo...
Constraint Bl...
Value Type
Enumeration
Signal
Instance
Proxy Port
Link
Association ...
Directed ...
Generalization
Item Flow
bdd [Package] Structure [Aircraft]
«system context» Aircraft Shape Analysis
«system context» Aerodynamics - Fluid Analysis
«system context» Engine Analysis
«system context» Range Analysis
«system context» Range Analysis All Parametric
«system context» Range Analysis Activity
«system» Aircraft
/LoadedMass : mass[kilogram]{unit = kilogram}
Altitude : distance[metre] = 10000.0 m {unit = metre}
Cruise_Velocity : velocity[metre per second] = 300.0 m/s {unit = metre per second}
/Last_Drag : Real
/Last_Lift : Real
/Range : distance[kilometre]{unit = kilometre}
/FrontalArea : Real
«requirement» Max Load
Id = "1"
Text = "This size aircraft hold X amount of fuel and Y volume of payload? This would require: behavior using CATIA model"
«requirement» Max Trust
Id = "2"
Text = "Maximum thrust capability of this size aircraft? This would require: CATIA model and EngineSim"
«requirement» Min Range
Id = "3"
Text = "Minimum Range of the Aircraft shall be at least 1000 km"
«satisfy»
Total mass
Shall be up to sound speed for correct results
Trust shall be more than Drag
«subsystem» Engines
/Mass_Engine : mass[kilogram]{unit = kilogram}
/A_Fan_Engine : Real = 1.0
FanDiam_Engine : diameter[metre] = 1.0 m {unit = metre}
Length_Engine : length[metre] = 3.0 m {unit = metre}
/Thrust : Real
«subsystem» Fuel
/Mass_Fuel : Real
/Fuel_Flow : Real
«subsystem» Wings
Sweep_3_Wing : Real = 15.0
Sweep_LE_Wing : Real = 15.0
S_Ref_Wing : Real = 50.0
AR_Wing : Real = 4.0
Back edge
Leading Edge
Surface area
Aspect ratio - wing span squire / wing area
«subsystem» Payload
«subsystem» Fuselage
«subsystem» Vertical Tail
«subsystem» Horizontal Tail
«subsystem» Electrical
No symbol at (1425, 172)
90%
3:06 PM
3/16/2021

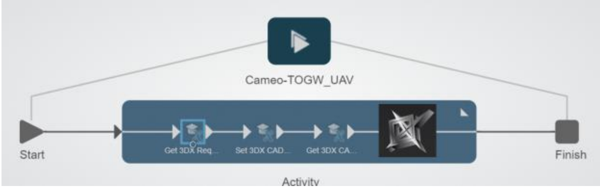
Porting simulation code to the server/platform side



SIMULIA Process Composer integration roadmap

- v2021x
  - ▷ Login to the platform
  - ▷ Simulation template drag'n'drop and invocation in Activity or Parametric diagram
- Next
  - ▷ Tool adapter interface for CAMEO in PC
  - ▷ Design Exploration and Results Analytics
  - ▷ Commercial solution





Requirements	Bracket_AM A.1	Bracket_Casting ...	Bracket_Milling A.1	Bracket_Legacy ...
	Rank: 1 Score: 100	Rank: 3 Score: 75.52	Rank: 2 Score: 79.2	Rank: 4 Score: 1
4 ↓ < 400.0e+6	387.0e+6 N_m2	-177.0e+6 N_m2	-177.0e+6 N_m2	26.00e+6 N_m2
	184.0e+6 N_m2	-80.00e+6 N_m2	-76.00e+6 N_m2	43.00e+6 N_m2
	596.0e+6 N_m2	-273.0e+6 N_m2	-274.0e+6 N_m2	27.00e+6 N_m2
3 ↓ < 350.0e-3	272.0e-3 mm	-21.00e-3 mm	-18.00e-3 mm	288.0e-3 mm
	232.0e+0 N	106.0e+0 N	128.0e+0 N	515.0e+0 N
	268.0e-3 J	-35.00e-3 J	-59.00e-3 J	187.0e-3 J
! ↓	52.20e-6 m3	16.10e-6 m3	1[illegible].90e-6 m3	41.20e-6 m3
3 ↓	227.0e+0 N	120.0e+0 N	75.00e+0 N	132.0e+0 N
	123.0e+0 N	10.00e+0 N	36.00e+0 N	42.00e+0 N

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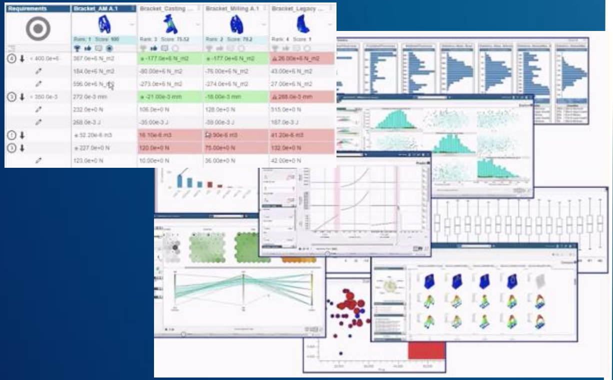
The Pinnacles of Integration

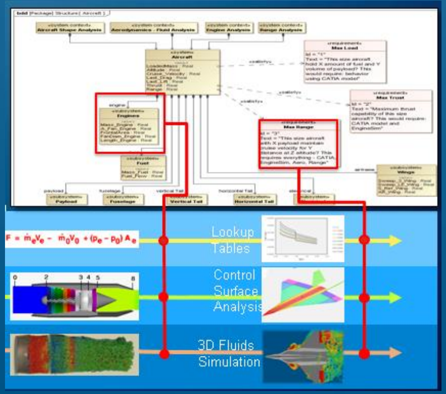
MBSE Maturity



Reach Highs MBSE with Simulation Maturity Level:

- Optimize your system with system architecture, design and analytical models in the loop.
- Integrated workflow

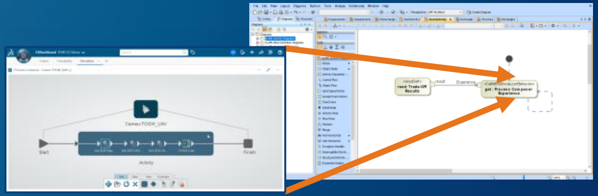
Integrated Analysis and Simulation

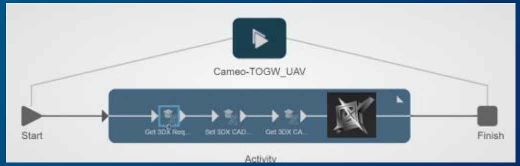


Perform Integrated Analysis:

- Integrate system model for quick V&V, change, trade study optimization, analysis

Unified Simulation Interface





Unified Interface Between System Model and Simulation:

- Brake engineering silos
- Use engineering and system engineering simulation models together easily.

Realize Model-Based Requirements Engineering to Its Fullness

DASSAULT SYSTEMES

Lets keep in touch!

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