An Assessment Framework for the Maturity of Simulation-Based Verification

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Problem Statement / Motivation

- Digital transformation impacts all aspects of the system development lifecycle processes
- Need to maximize the amount of simulation used to reduce the costs spent during test and evaluation
  - Objective is to use simulation as the primary iterative verification method, with live/physical tests used for validation
- Effective simulation-based verification (SBV) cannot just focus on robust simulations – it also needs consider efficient verification approaches
- MBSE allows for additional efficiency in requirements verification
- An assessment framework is needed to evaluate and motivate an organization's SBV capabilities & to demonstrate the coupling of simulation with MBSE to achieve mature SBV.

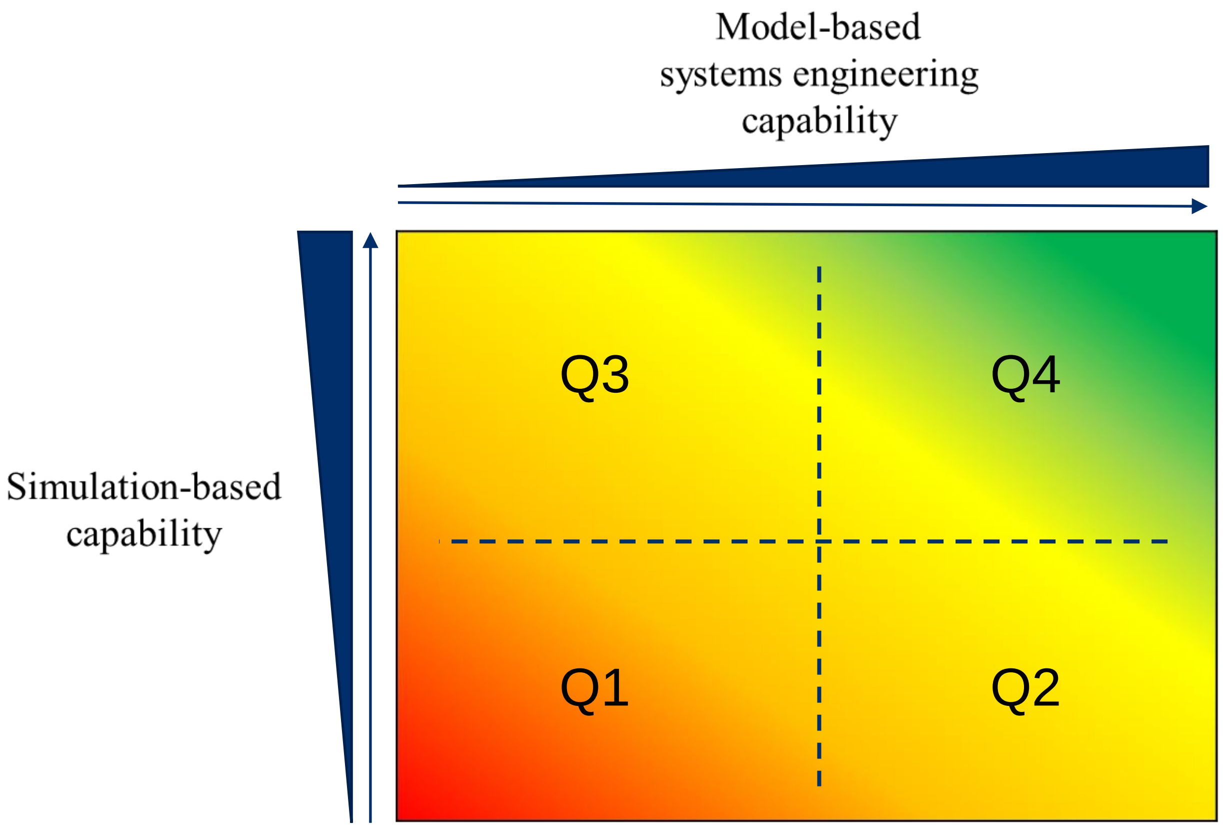
Verification Method	Description
Analysis	Technique based on analytical evidence through mathematical or probabilistic calculation, logical reasoning, modeling, and/or simulation under defined conditions to show theoretical compliance.
Analogy/ Similarity	A type of analysis technique based on prior evidence or elements similar to the subject of verification.
Simulation	A type of analysis technique performed on models or mock-ups (though not physical elements) that mimics the operation of the subject of verification in various scenarios.
Demonstration	Technique showing correct operation of the subject of verification against observable characteristics without physical measurements.
Test	Technique performed on subject of verification where functional, measurable characteristics, or performance capability is quantified.
Inspection	Technique based on visual or dimensional examination of the subject of verification, using human senses or simple methods of measurement; no stimuli are necessary.

Adapted from INCOSE SE Handbook, v4 (2015)

The focus of Simulation-Based Verification needs to include **both** Simulation & Verification

SBV Assessment Framework

- Organizations demonstrate and experience a wide range of simulation and MBSE capabilities as they mature in their capabilities over time
- Evolutionary process to transform from a traditional, physical test-based into a mature SBV organization
- Assessment framework describes spectrum of capabilities from a two-dimensional perspective, recognizing the importance of both simulation and MBSE in the assessment of the SBV capabilities of an organization
- Objective: get into Q4!



Q4 Criteria:

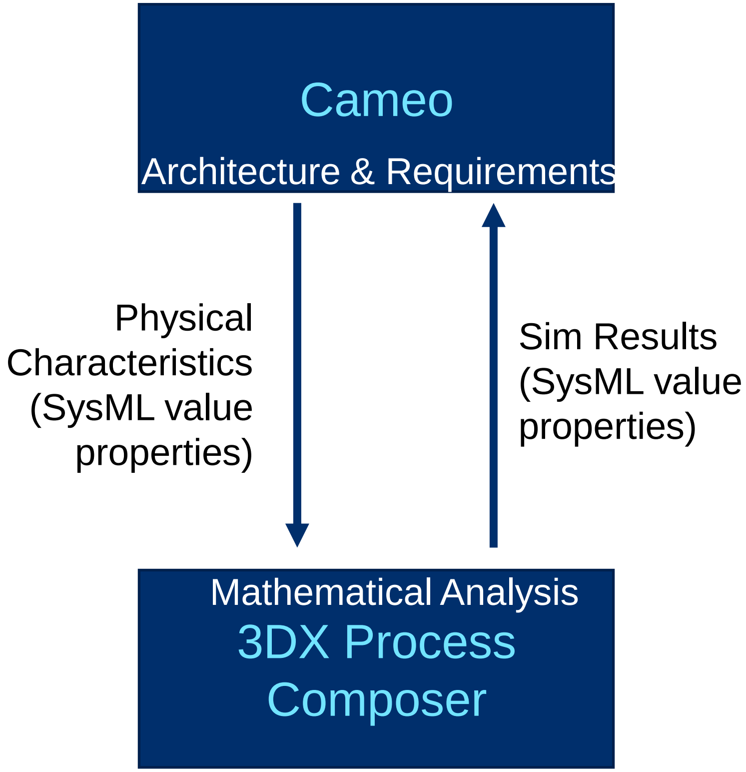
- *Simulation prioritized as a verification means for all applicable requirements*
- *SE conducted using a system architecture model as the authoritative record for the system - requirements, system elements, behaviors, etc.*
- *Verification of requirements via simulation are automatically verified by co-simulating the system architecture model and the model used for verification purposes (e.g., a physics-based model)*
- *Established interconnectivity between tools*

Example Application

- Objective: demonstrate what Q4 SBV looks like
- Test Case: Helicopter Sizing Analysis
  – System requirements for transporting a helicopter on highway, boat, or as cargo on an aircraft
- Tools selected: Dassault Systèmes tool suite
  – Tool suite readily allows for integration between system architecture model, analysis, and includes data and configuration management capabilities.

  – Cameo Systems Modeler (2021x) for system architecture + requirements.

  – 3DExperience Optimization Process Composer for simulation development and configuration management.
- Could use other tools (e.g. Ansys ModelCenter)

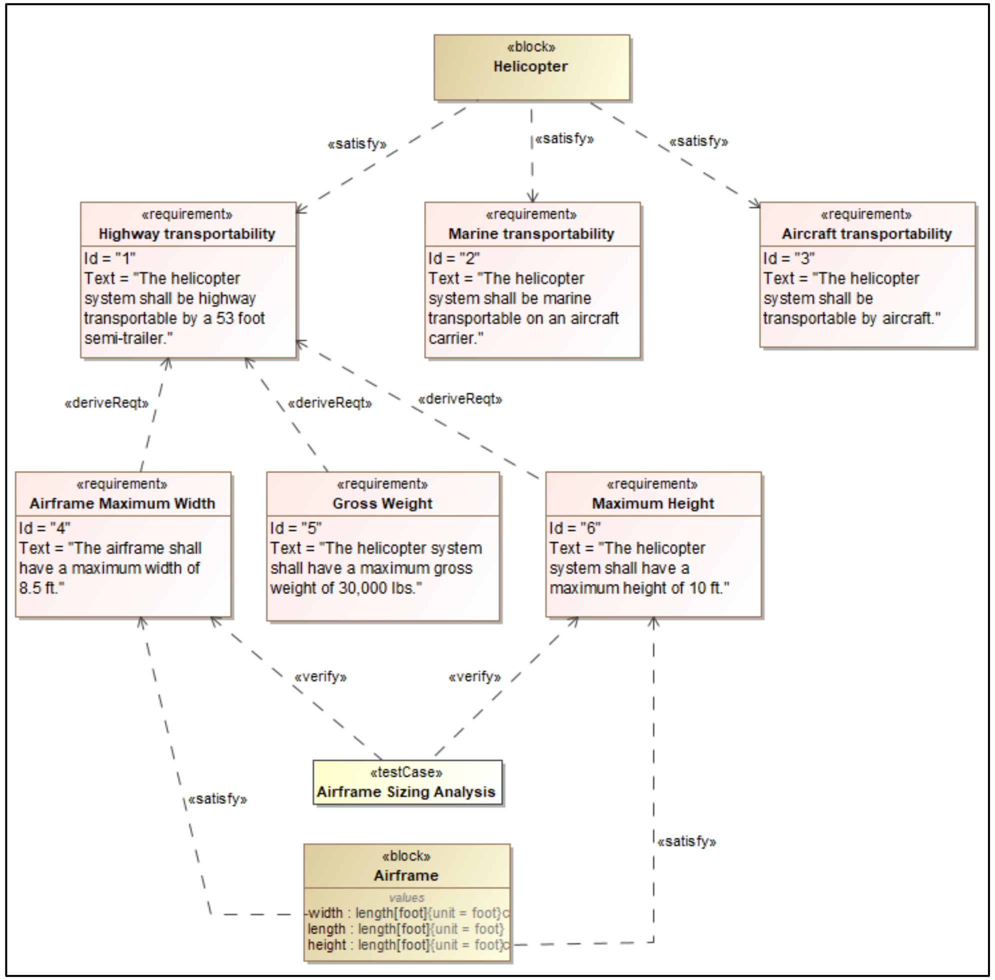


Establishing connectivity between data repositories is key to achieving the digital thread needed for SBV

Example Application – Step 1

- Develop a system architecture model, including:
  - Requirements
  - Structural elements
  - Value properties
  - Constraint properties
  - Test cases
- Need to discuss verification methods as the requirements are being developed.

From		To
How are we going to verify this requirement?	→	Can we verify this requirement by simulation?



For organizations pursuing SBV, there is a persistent shift in mindset: consistently looking for simulation opportunities.

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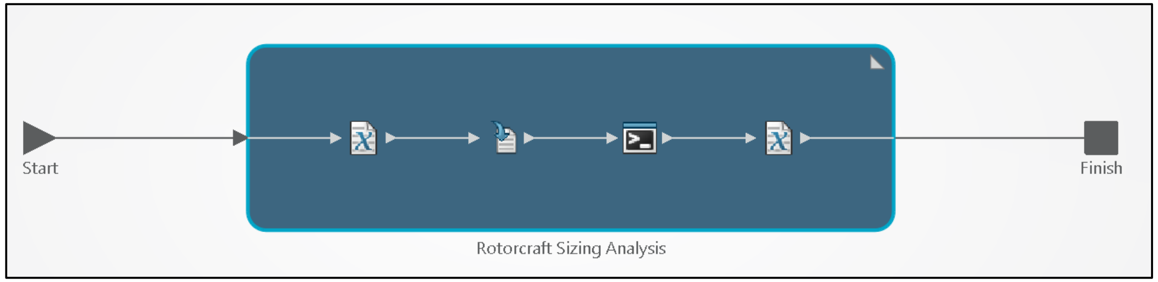
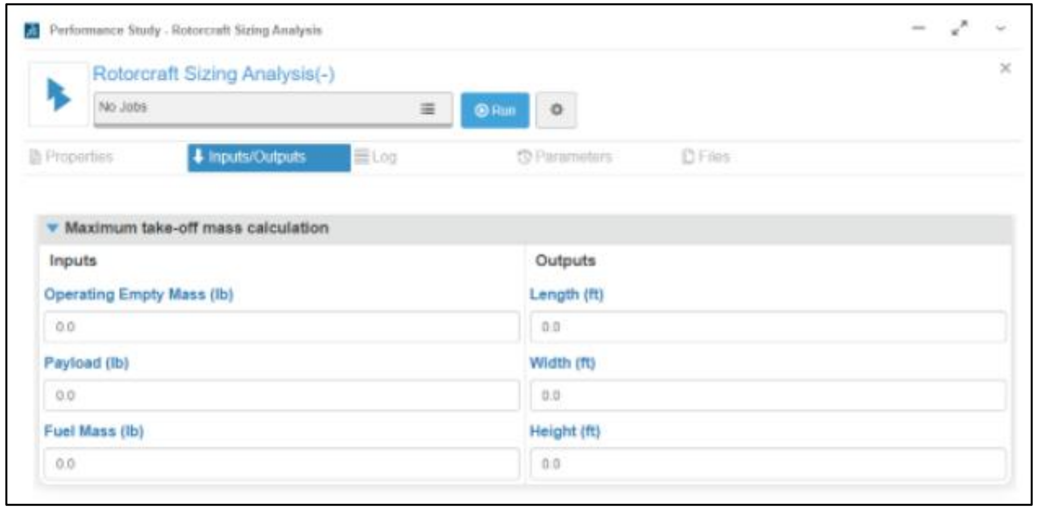
Example Application – Step 2

- For any requirement to be verified by simulation, develop the appropriate simulation
- 3DX simulation app provides means of connecting steps for performing simulation in an automated manner
  - Capable of running command scripts, upload/download off platform data, and connecting to other off-platform tools (e.g. Matlab, Excel, etc.)
- Develop rotorcraft sizing analysis simulation process
  - Parse input text files
  - Run executable that performs the sizing analysis
  - Generate results, assigned to output parameters: height, width, length
- Develop simulation template as user interface in 3DX and as object used by Cameo.



Simulation process in 3DX for rotorcraft sizing analysis



Performance study simulation template to drag and drop into Cameo

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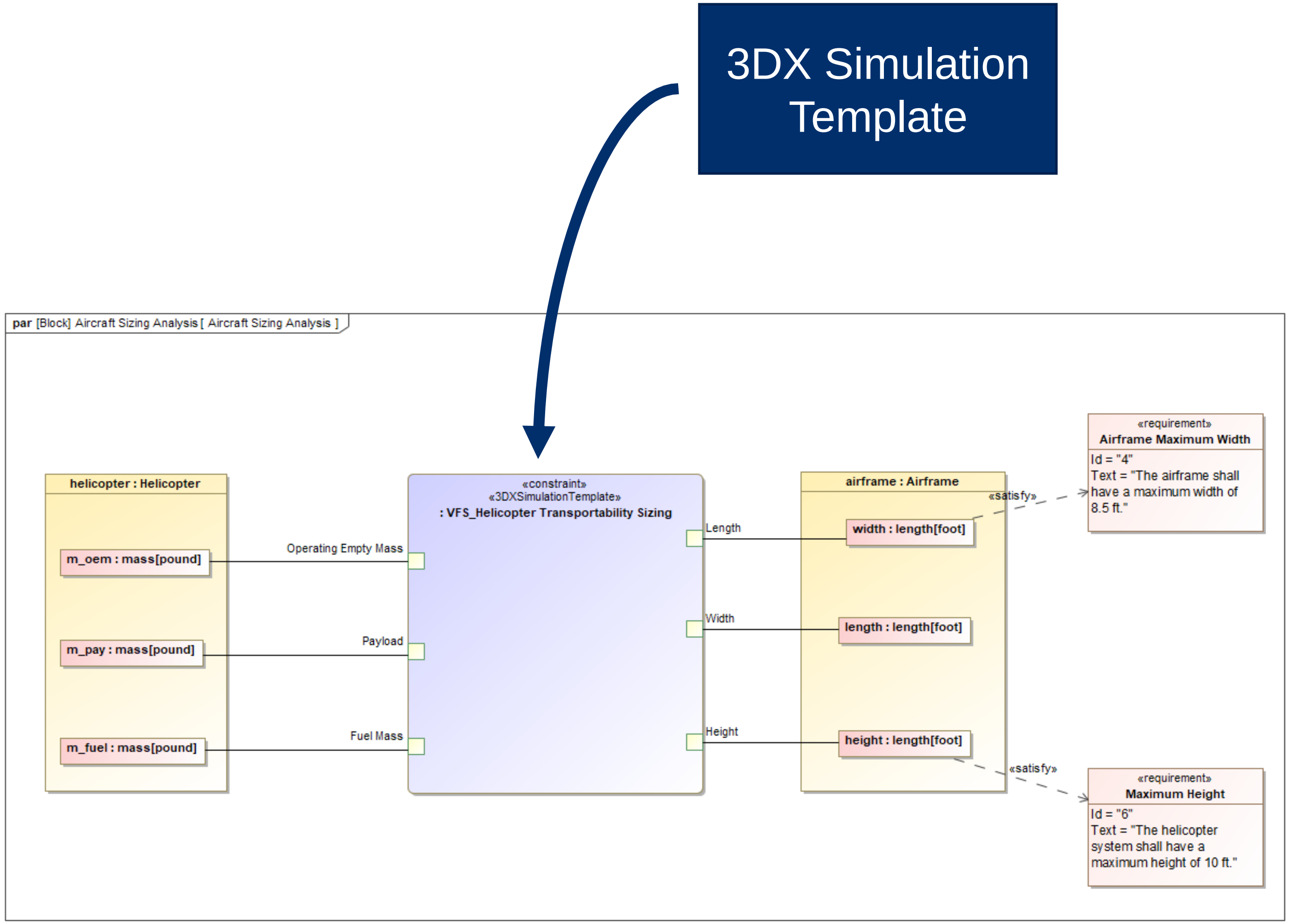
Example Application – Step 3

- Integrate the simulation into the system architecture model
  - Drag-n-drop simulation template to create SysML constraint property
- Constraint property:
  - Collects input value properties from architecture
  - Calls simulation process in 3DX
  - Returns simulation output values to architecture value properties
- Returned valued properties are connected via «satisfy» relationship to requirements.
- SysML parametric diagrams can be unwieldy – perform a complex analysis in a tool that's designed to do complex mathematical analysis.



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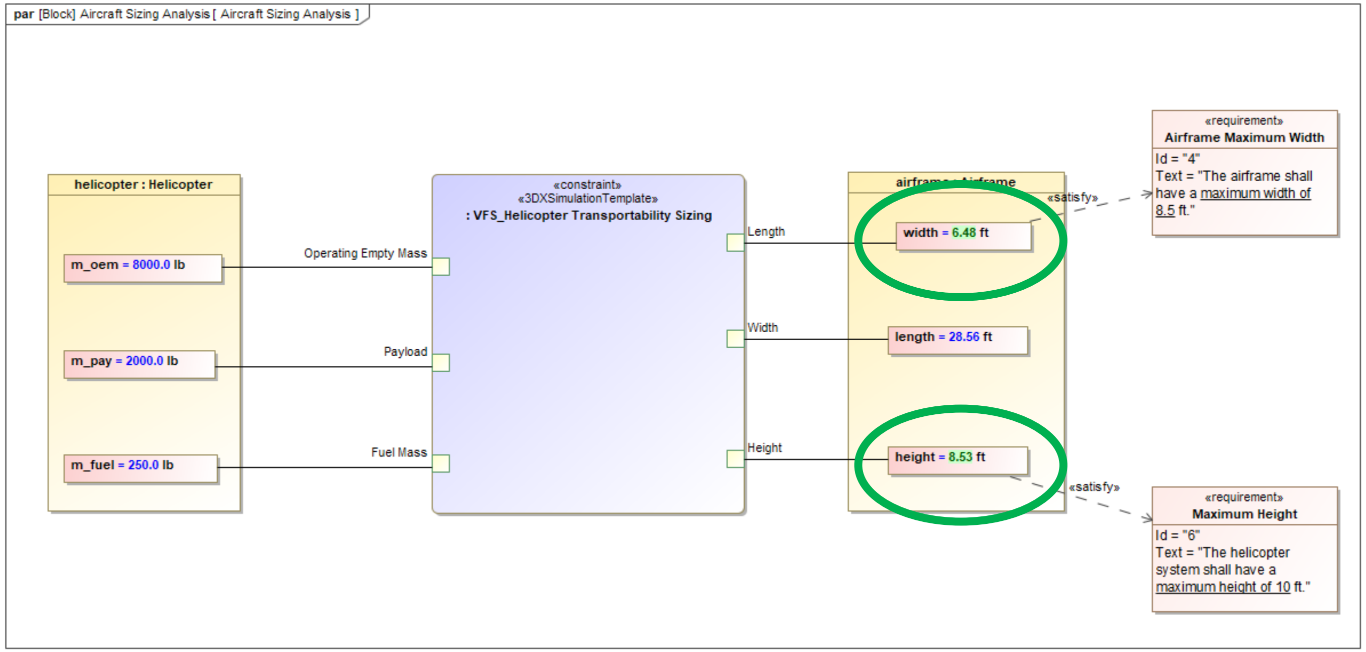
Example Application – Step 4

- Conduct a co-simulation of the system architecture model and the externally hosted simulation tool.
- Results of simulation are output as value properties of the helicopter airframe block.
- Results are compared to the parameters defined in the requirements.
  - Ex) Simulation result for width is 6.48ft, which is less than the requirement of 8.5ft.



#	Name	Text	Derived From	Satisfied By	Verified By	Verify Method	Risk	Margin	Value
1	4 Airframe Maximum Width	The airframe shall have a maximum width of 8.5 ft.	1 Highway transportability	width : length[foot] = 6.48 ft	Airframe Sizing Analysis	Analysis	Low	2.02	6.48
2	6 Maximum Height	The helicopter system shall have a maximum height of 10 ft.	1 Highway transportability	height : length[foot] = 8.53 ft	Airframe Sizing Analysis	Analysis	Low	1.47	8.53

Requirements are verified automatically (in green) in Cameo from 3DX simulation

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Conclusion

- Integrating physics-based simulations and analysis with the system architecture model allows us to:
  - Understand key system characteristics that analysis by itself cannot
  - Show traceability to authoritative source of truth
  - Automate and streamline the requirement verification process
  - Manage data and configurations more consistently
  - Demonstrate value of MBSE beyond initial architecting stages of system development
- This is only the beginning! More work to be done:
  - Refine SBV assessment framework with detailed criteria for each matrix cell
  - Communicate need for both simulation and MBSE to achieve SBV
  - Apply more complex engineering analysis to SBV model

Achieving a mature state of SBV requires a cross-disciplinary, collaborative effort

Thank you!

Questions?

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