Simulation Driven Product Development (SDPD) – *Paradigm shift in product certification*

DEFENCE AND SPACE

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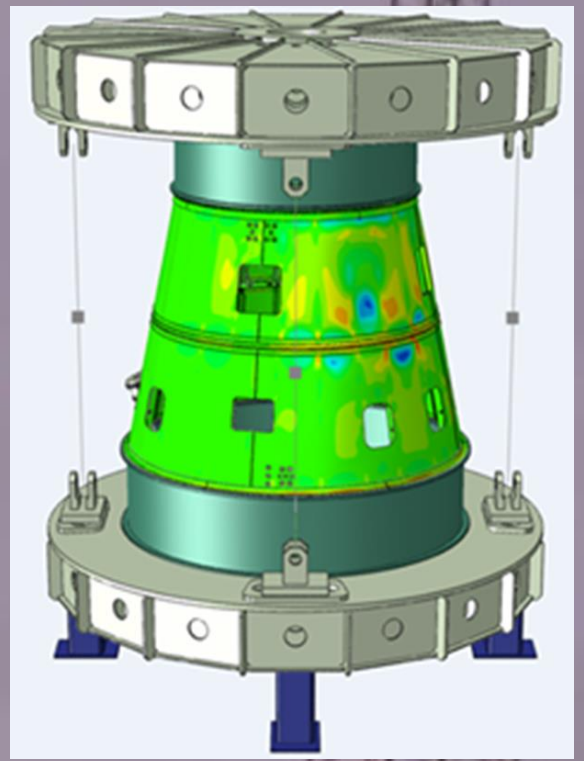
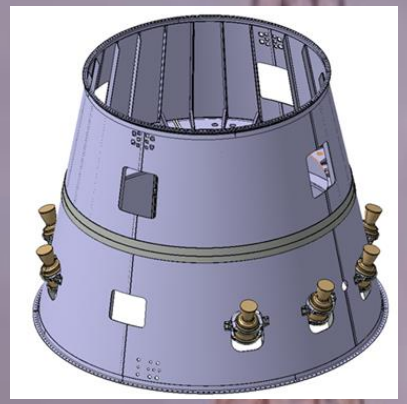
Everybody believes in test results except for the test engineer,

and

nobody believes in analysis results except for the analyst.

Can we bring these two worlds closer to accelerate the development and certification of our products with lower price and risk?





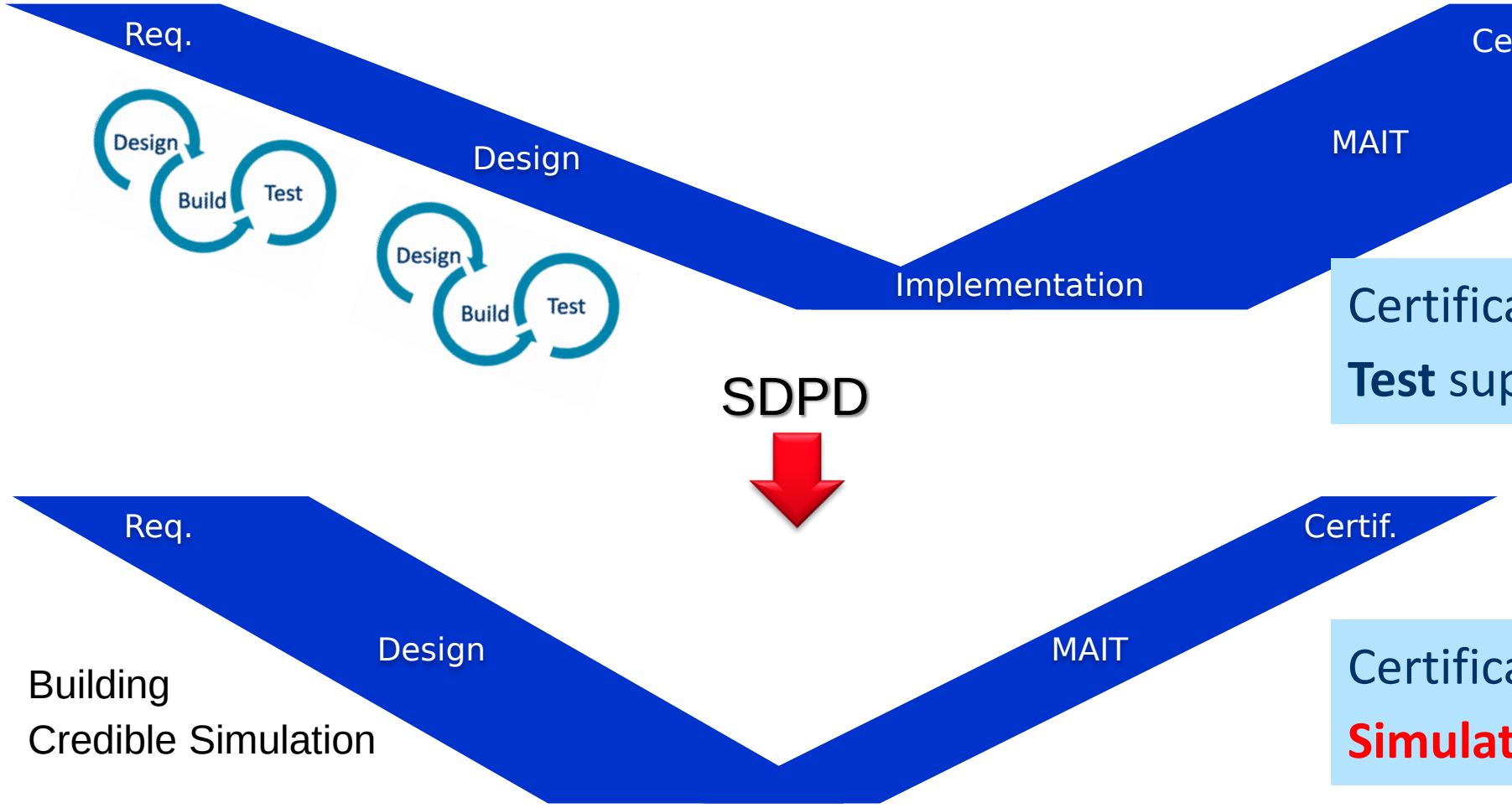
Development Cost

-35%

Development Time

Recurring Cost

Paradigm shift in product certification



Certification by
Test supported by **Simulation**

Certification by
Simulation supported by **Test**

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Importance of Simulation in product development & certification

- Level 1 – Some simulation impact (design or test support)
- Level 2 – High simulation impact (design & certification decision support)
- Level 3 – Decision making based on simulation (design & certification)

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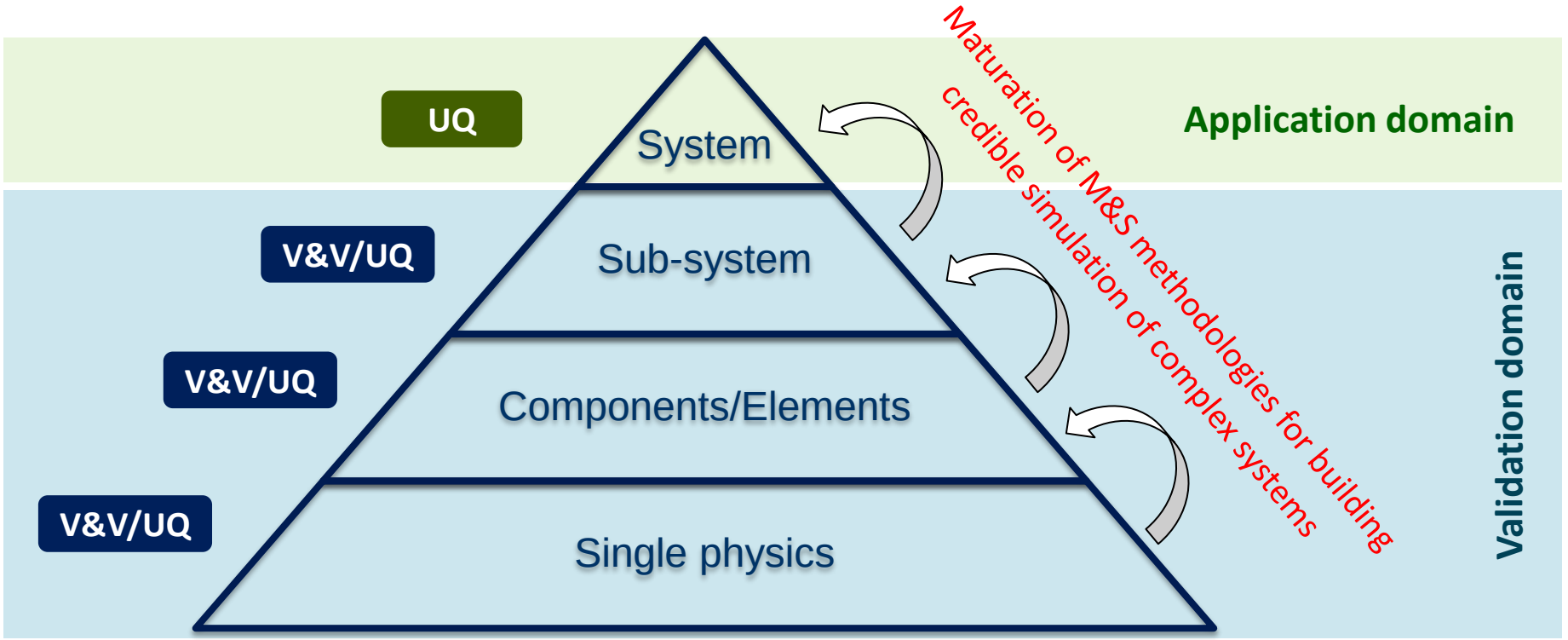
Building credible simulation following systematic V&V/UQ approach

V&V: Simulation Verification & Validation
UQ: Uncertainty Quantification



Simulation/Test pyramid is mainly defined for the purpose of Simulation V&V/UQ, and not for the verification of requirements

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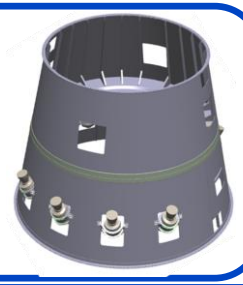
Vega-C Inter-stage 1/2 – Simulation VV&UQ

L4: Inter-stage 1/2 1

System qualification by Simulation

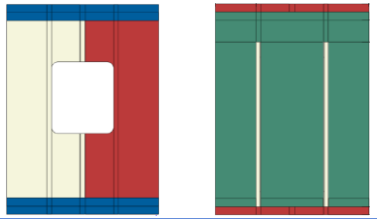
UQ
- Young's modulus
- Parts production tolerances
- Fasteners non-linear constitutive model



L3: Panels 5

Sub-system simulation validation

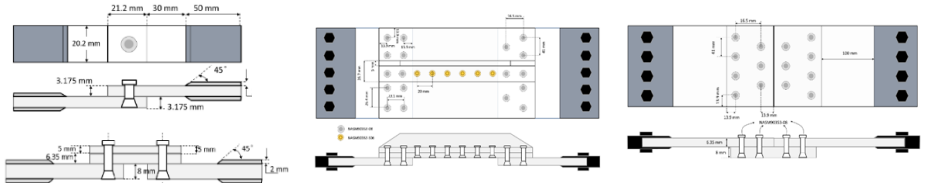
UQ
- Young's modulus
- Parts production tolerances
- Fasteners non-linear constitutive model



L2: Lap-joints 106

Mechanical joining calibration / validation

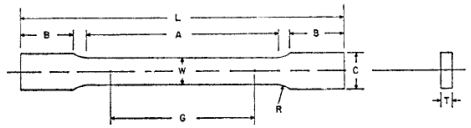
UQ
- Young's modulus
- Parts production tolerances
- Fastener non-linear constitutive model



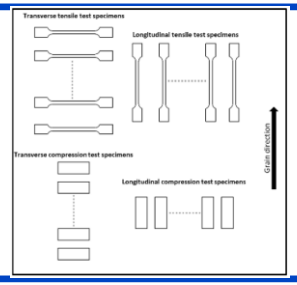
L1: Material 80

Material model calibration

UQ
- Young's modulus
  - Grain direction
  - Tensile and compressive stiffness



Tensile samples ASTM E8



Application

Validation

Calibration

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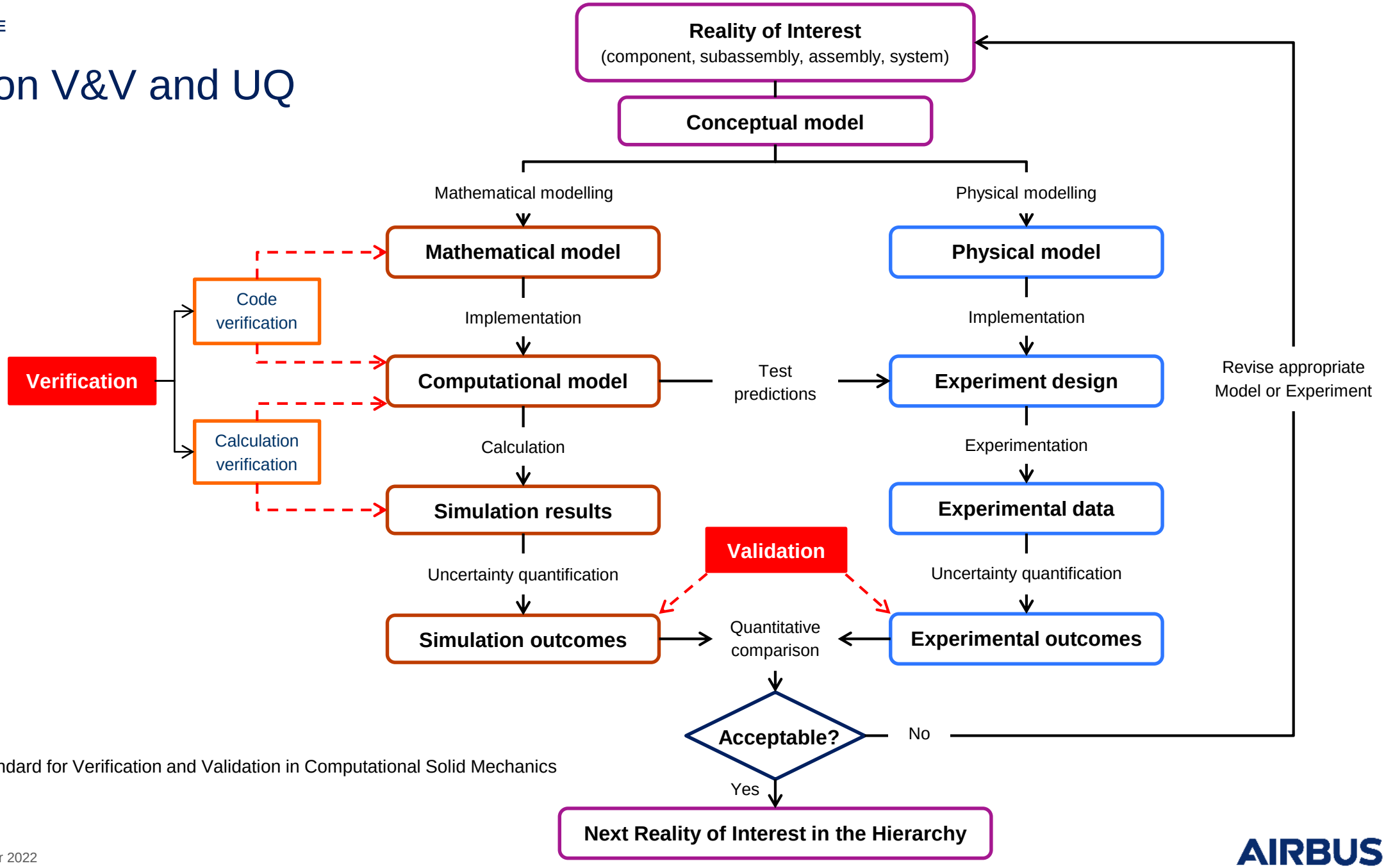
Simulation V&V and UQ



Source: ASME Standard for Verification and Validation in Computational Solid Mechanics

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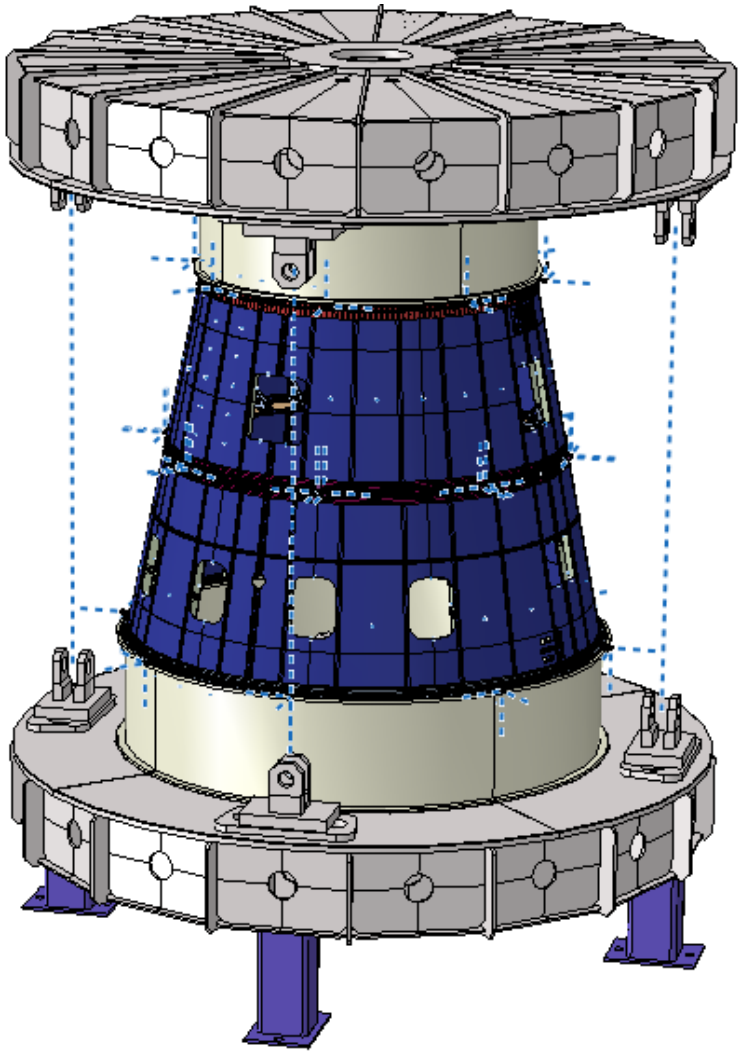
Test



Simulation

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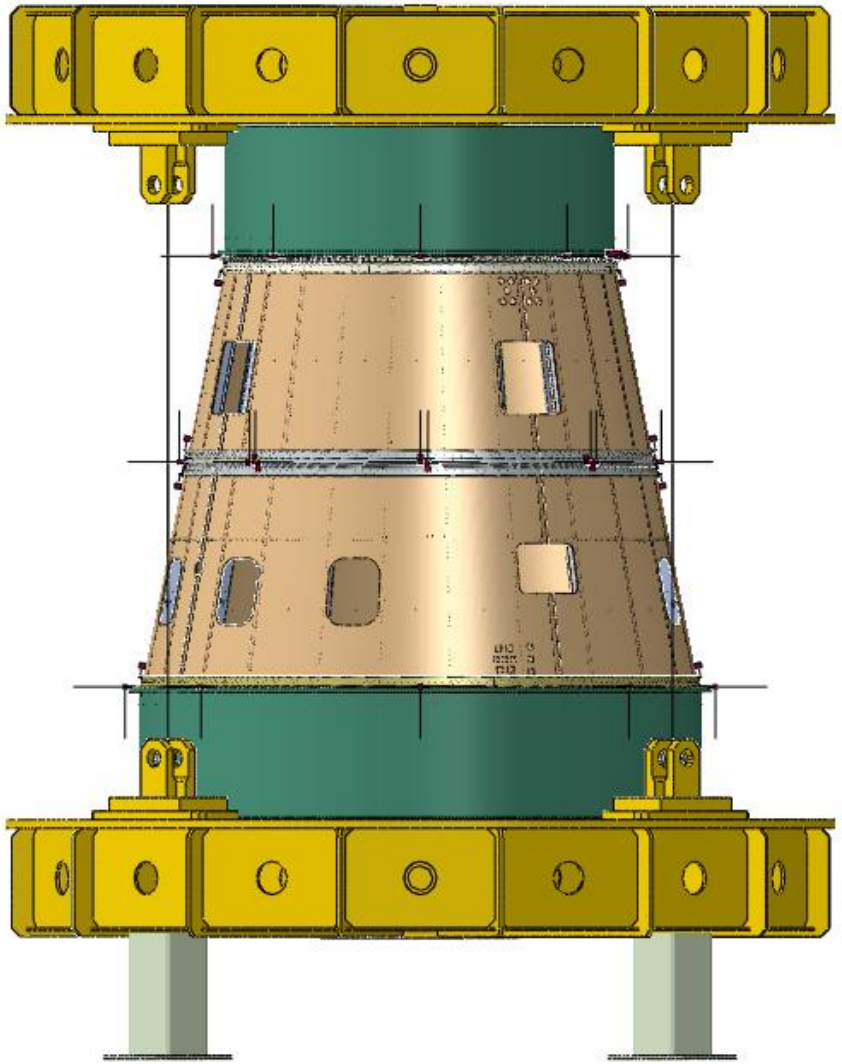

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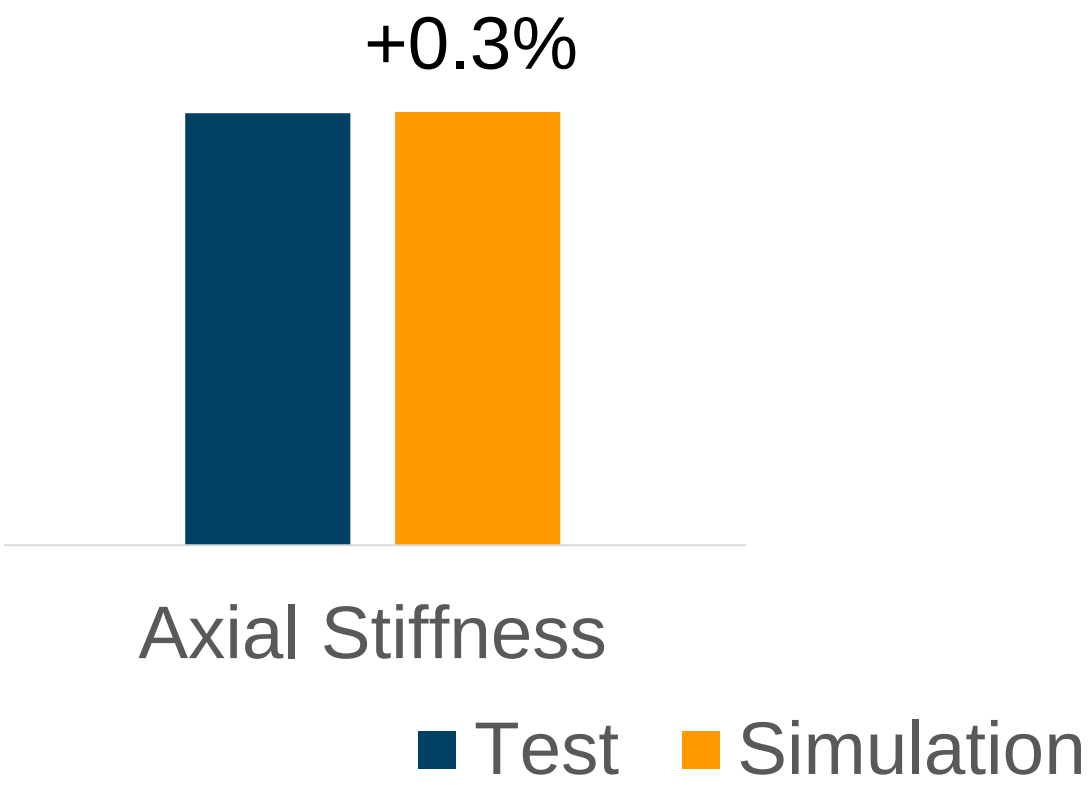
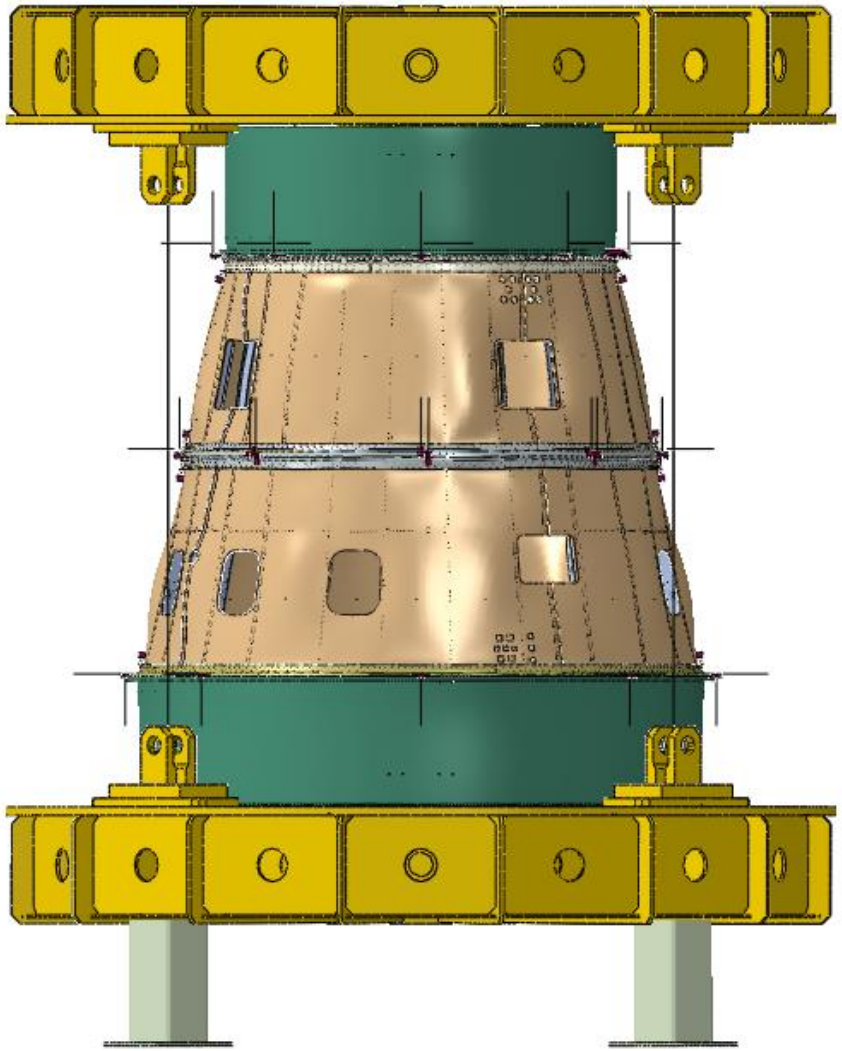
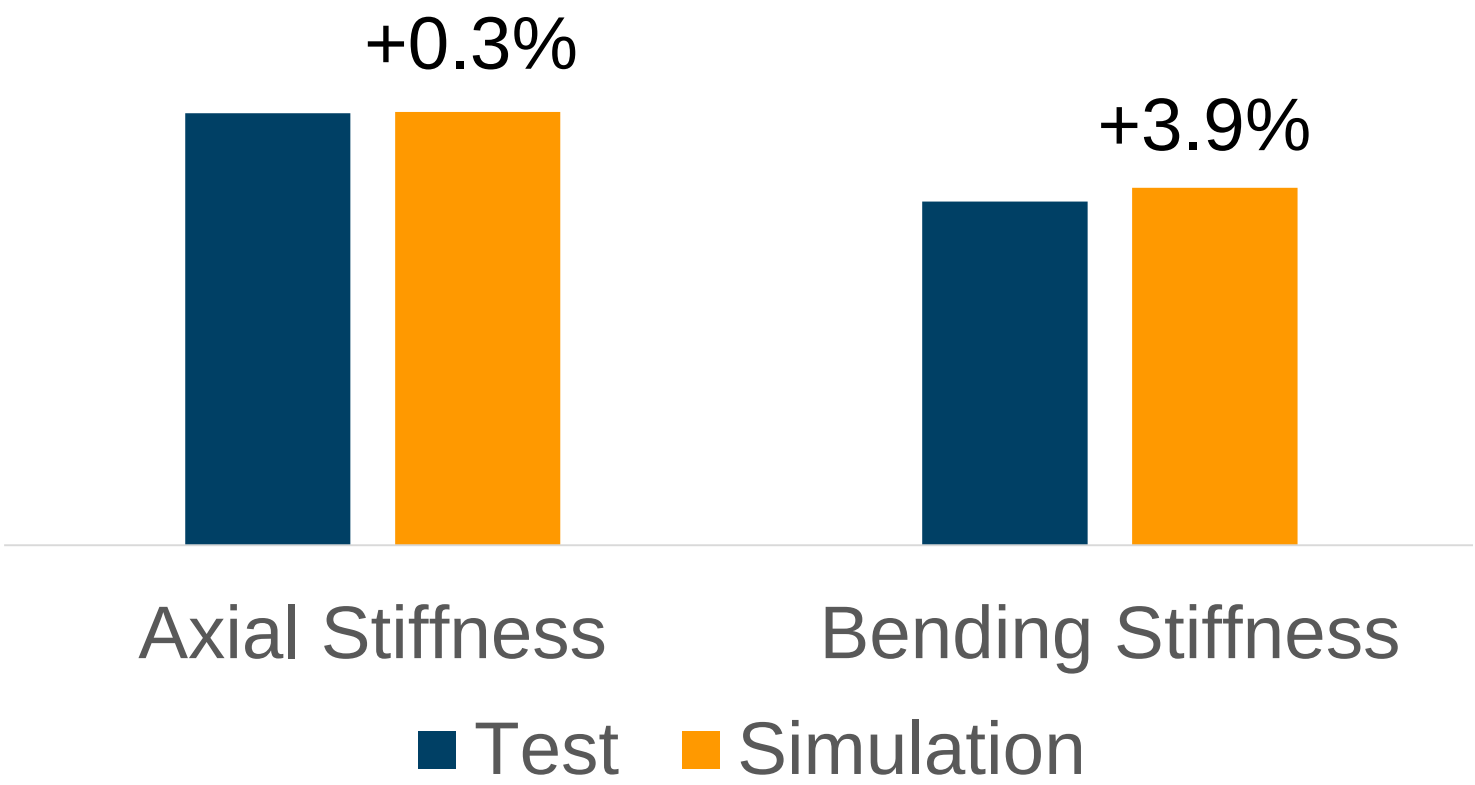
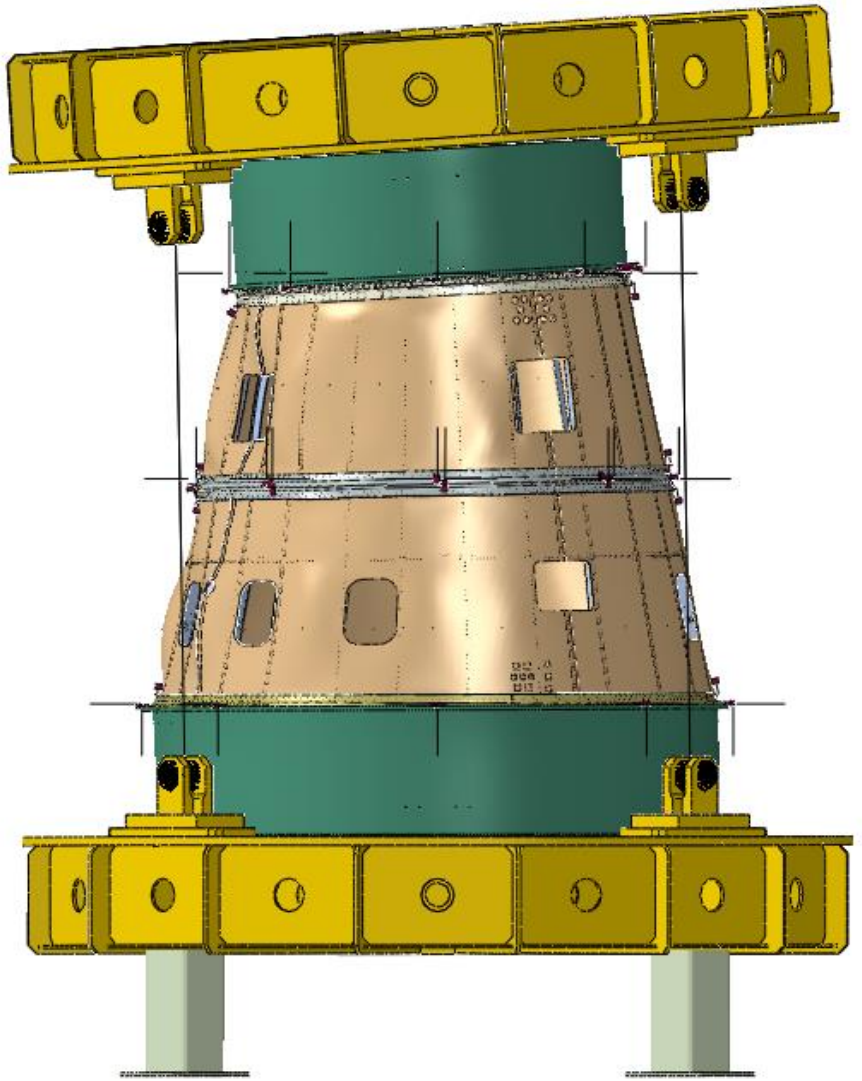
Accuracy of deterministic simulation





Accuracy of deterministic simulation





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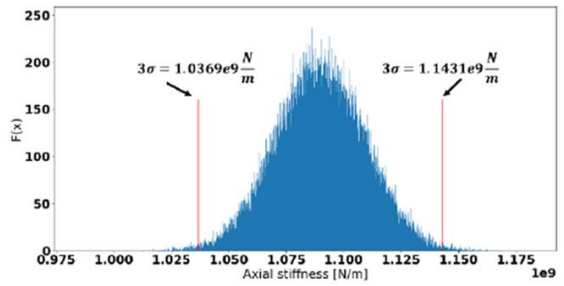
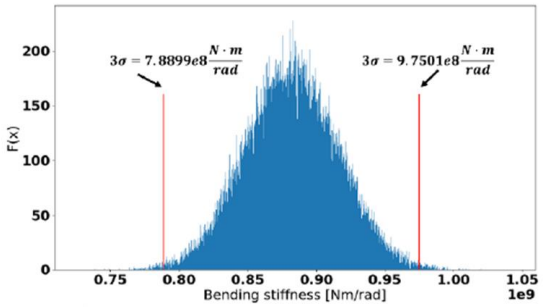
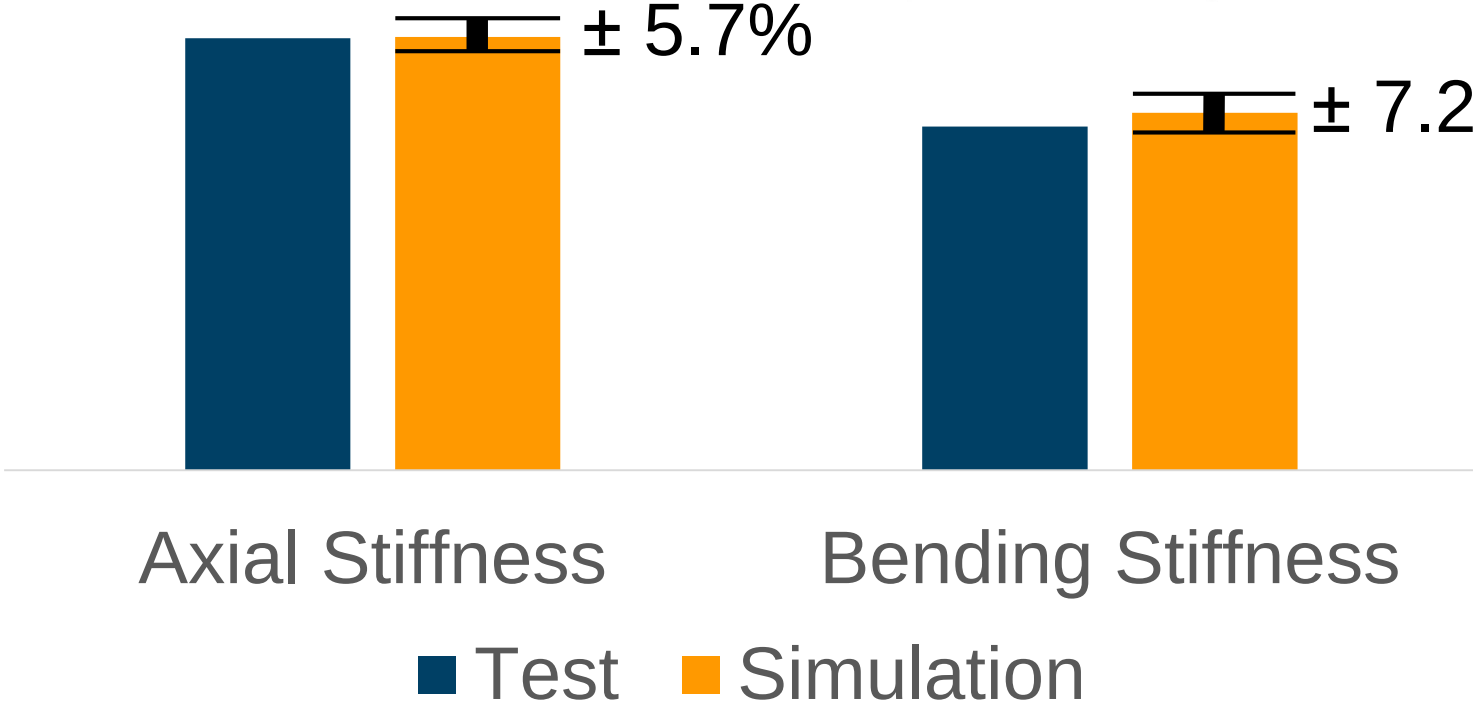
Stiffness predictions with 3σ reliability (99.7%)

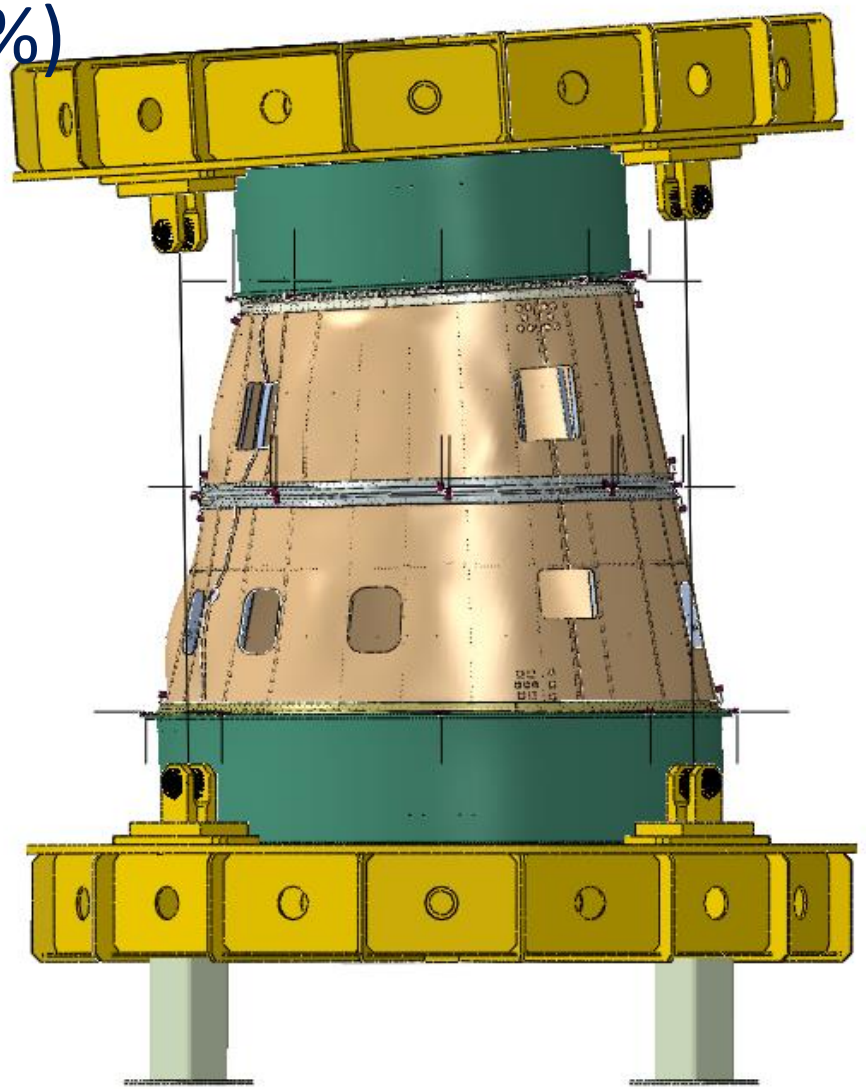


Distribution of the axial stiffness



Distribution of the bending stiffness





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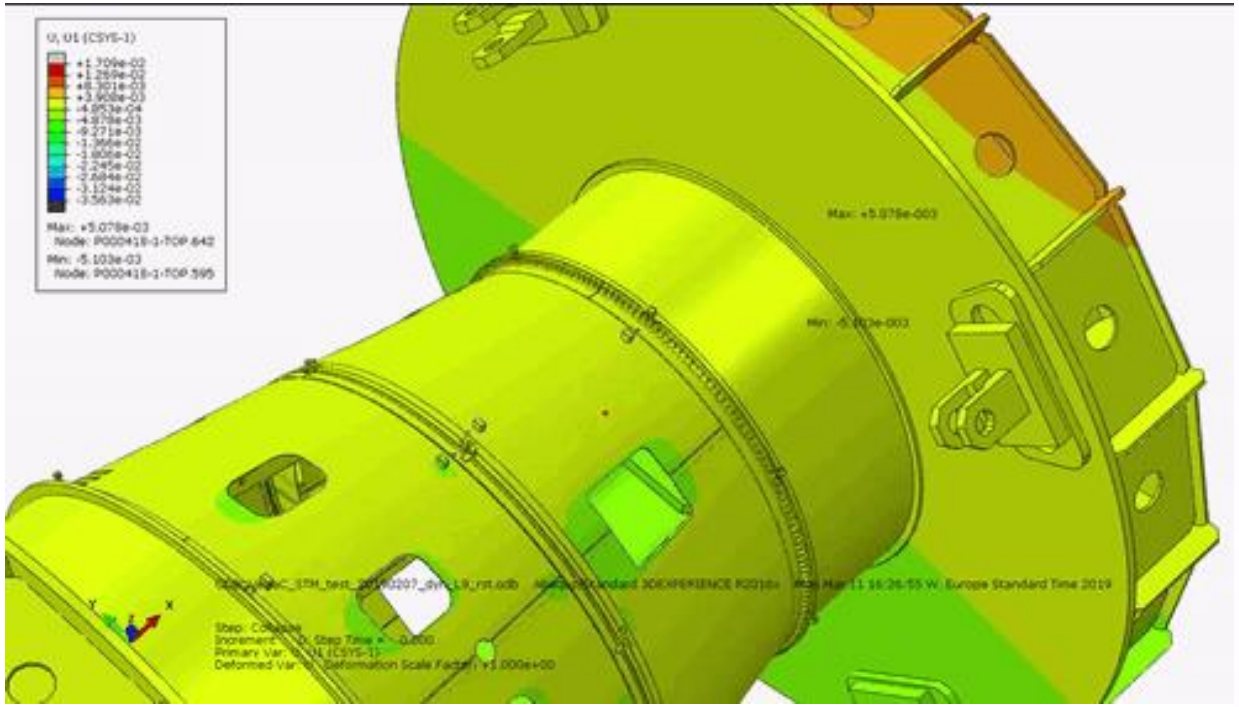
Failure mode and failure load

Failure load = **206%** of flight load



204% < Failure load < **206%** of flight load

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Challenges for building credible simulation

- Integration of “physics-based simulation” in the product development cycle
- Simulation verification and validation
- Uncertainties quantification in simulation and tests (e.g. material properties, manufacturing tolerances)
  - Probabilistic validation of simulation
  - Estimate the reliability of the product
- Simulation–Test collaboration
  - Smart testing
  - Test-simulation dialog

References

1. J. Fatemi and G. Poort: **Re-engineering the Engineering Processes for Space Product Development**, *16th European Conference on Spacecraft Structures, Materials and Environmental Testing (ECSSMET2020)* in March 2021

2. G. Poort and J. Fatemi: **Qualification of the Vega-C Inter-Stage 1/2 Structure by Simulation**, *16th European Conference on Spacecraft Structures, Materials and Environmental Testing (ECSSMET2020)* in March 2021

Thank you

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