Building simulation models credibility: What gain can we expect from test-simulation data fusion?

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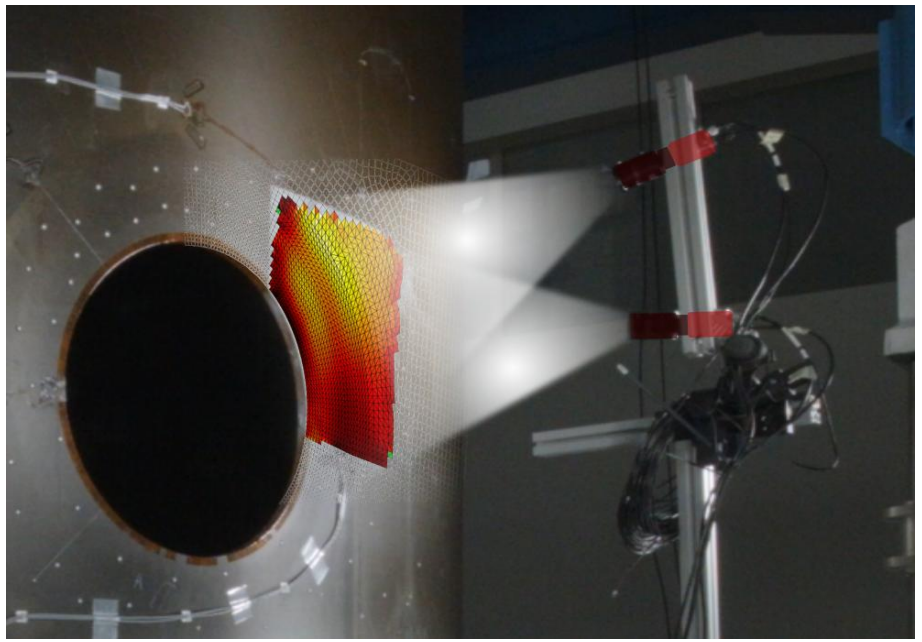
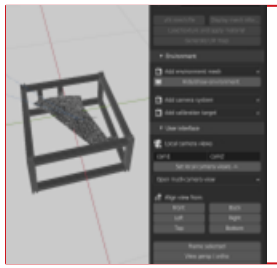
A word about EikoSim

EikoSim

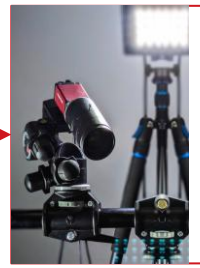
- Mission: Bridges the gap between physical testing and numerical simulation in structural mechanics.
- Technology: Utilizes Digital Image Correlation (DIC) to align simulation models with real-world experimental data.
- Value: Reduces costly physical tests and optimizes designs through accurate simulations.
- Industries: Aerospace, defense, automotive, energy, civil engineering.





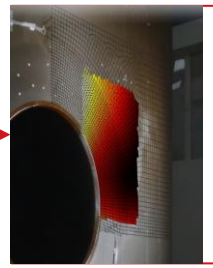
EIKOTWIN VIRTUAL

Synthetic image generation
- Planning
- Anticipating test difficulties



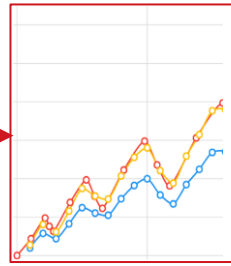
EIKOTWIN VISION

Image acquisition
- Set up cameras
- Acquire images



EIKOTWIN DIC

Image processing
- Calibration
- DIC measurement
- Test/simulation comparison



EIKOTWIN DIGITAL TWIN

Model calibration
- Boundary conditions control
- Sensitivity study
- Parameter identification

INTEGRATION PARTNERS

ALTAIR POWERED BY ALTAIR UNITS DASSAULT SYSTEMES Ansys

A few words about ArianeGroup

ARIANE 6: A VERSATILE LAUNCHER FOR ALL MISSIONS

Unprecedented mission flexibility

- 1 launcher, 2 versions: Ariane 62 and 64
- 2 types of fairings and numerous configurations
- For launching all types of payloads to all orbits

Maximum industrial efficiency

- Reduced production costs for greater competitiveness

Evolutive by design

- Designed to integrate new technologies and evolve to stay at the cutting edge of performance and versatility

13 EUROPEAN COUNTRIES INVOLVED

Austria, Belgium, Czech Rep., France, Germany, Ireland, Italy, Netherlands, Norway, Romania, Spain, Sweden, Switzerland

2 OR 4 BOOSTERS

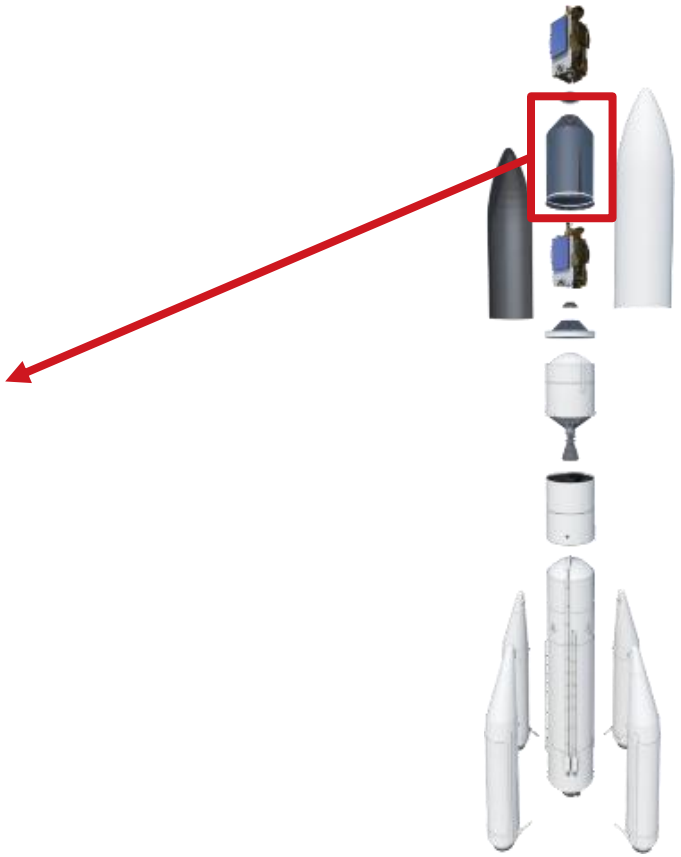
FIRST FLIGHT **2024**

UP TO **12 t** PAYLOAD TO GEOSTATIONARY TRANSFER ORBIT (GTO)

UP TO **12** LAUNCHERS PER YEAR

arianeGROUP

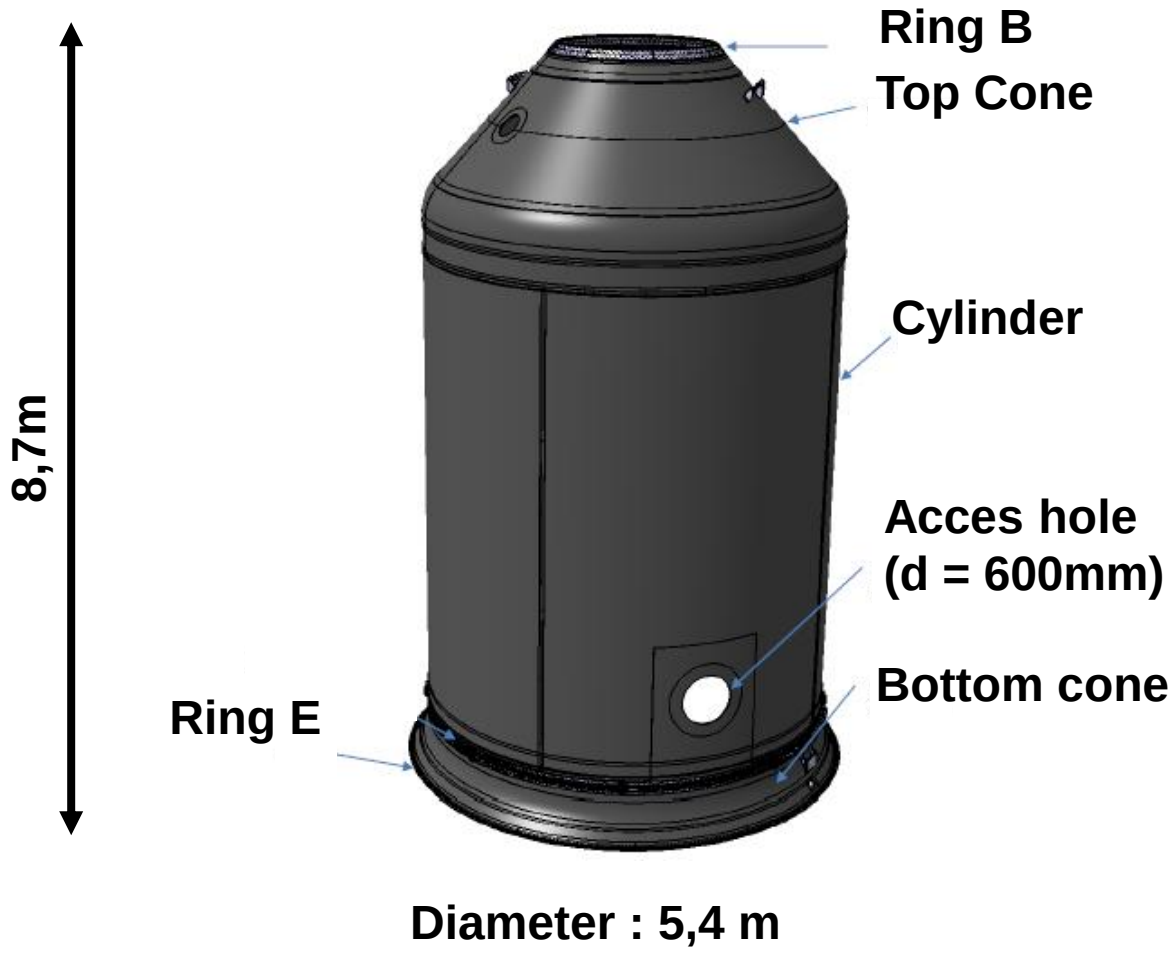
Ariane 6 Dual Launch Structure (DLS)



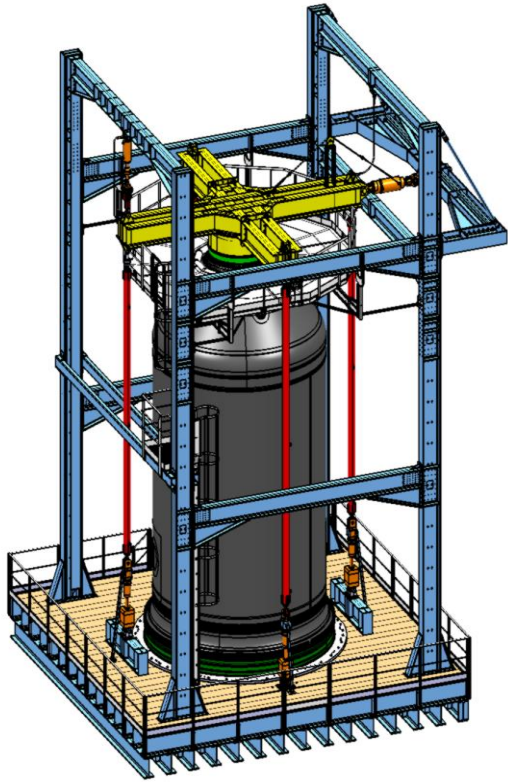
A6 Dual Launcher System

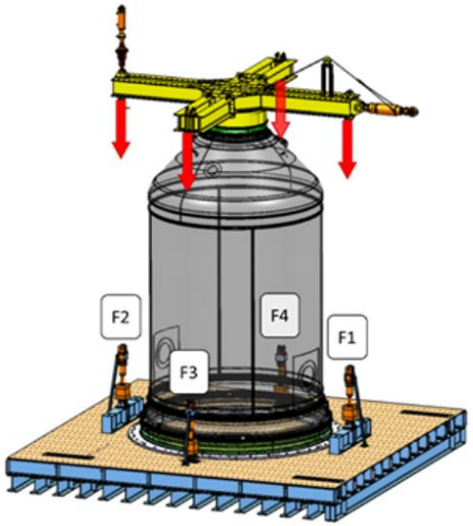
- Scale 1 static test
- Complex structure and loading paths
- Numerous measurement devices: Strain gauges, fiber optics, multi-camera optical measurements (Digital Image Correlation) for three distinct regions

Ariane 6 Dual Launch Structure (DLS)

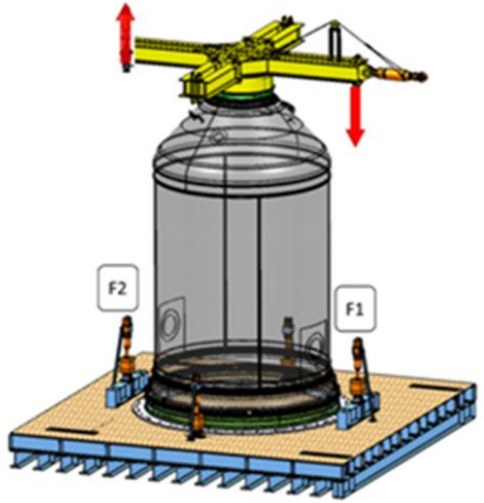


Test bench and prescribed loadings

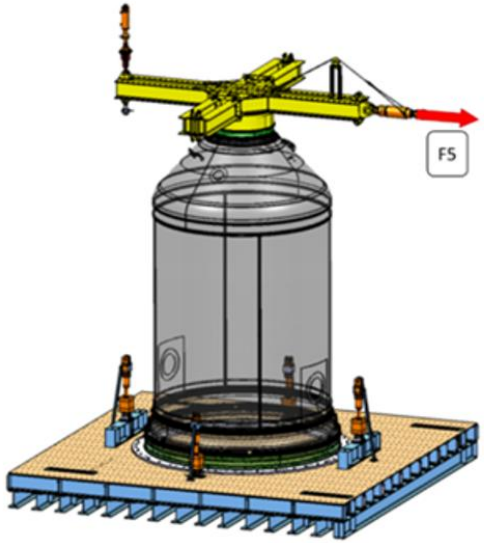




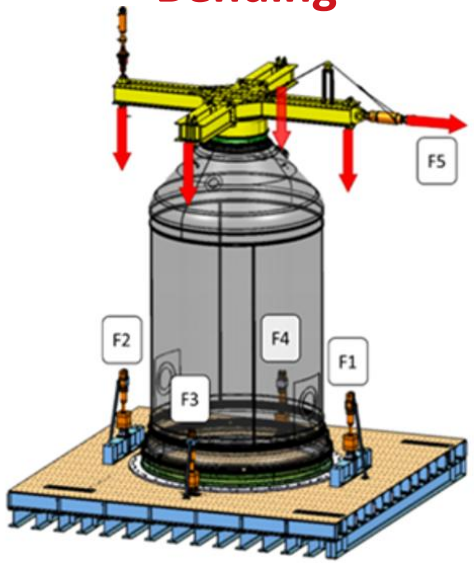
Compression



Bending



Shear

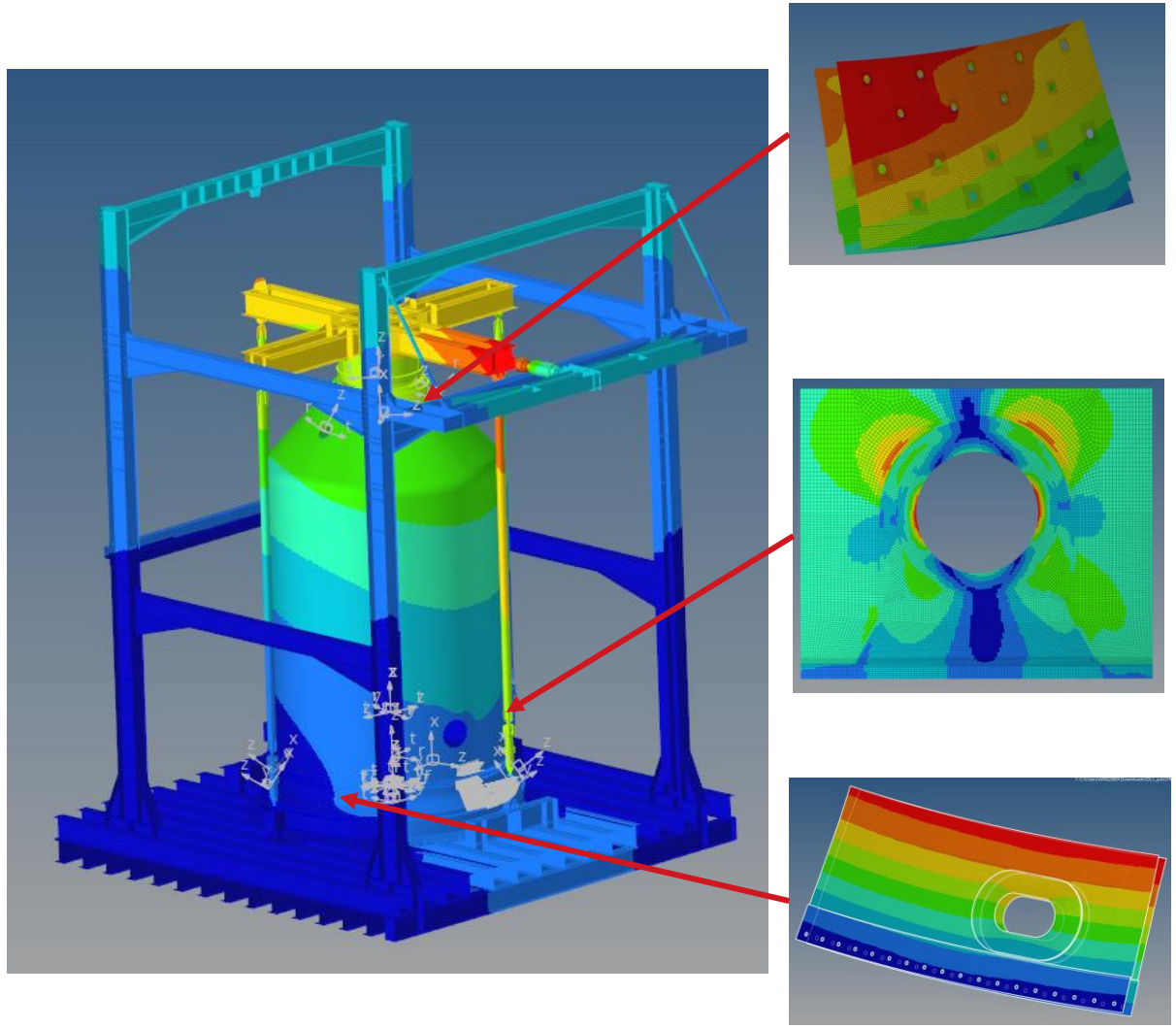


Combined

Simulation logic

Finite element models

- Shell Model with Test Bench (>1 000 000 DOF)
- 3 x 3D Patches (>> 1 000 000 DOF)
- Boundary conditions: application of loads to hydraulic jack positions
- Constitutive law :
  - nonlinear geometric
  - Hashin criteria for Composites
  - Elasto-plastic law for ring part + von mises



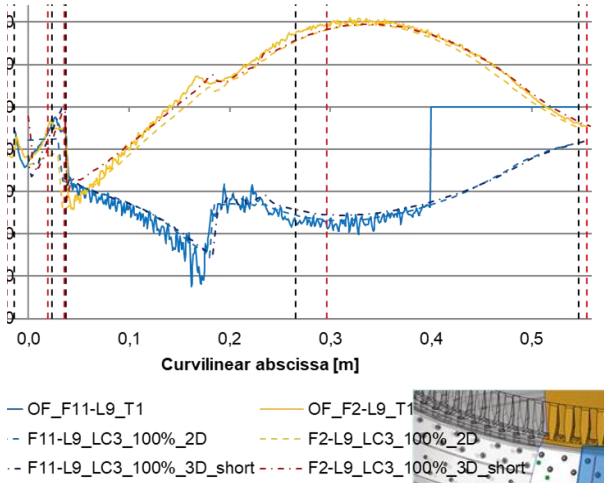
Instrumentation – local measurements

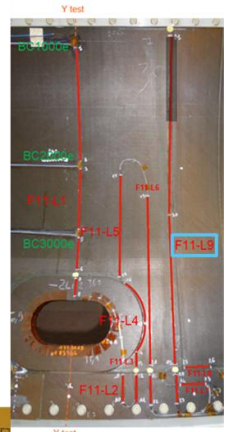
Point-wise sensors

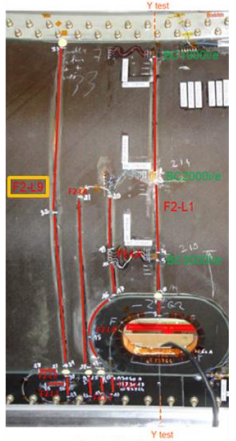
- Strain Gauges (~200 channels)
- Displacement (~30 sensors)

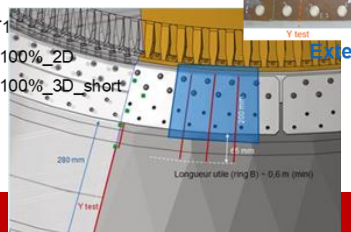
Strain by optical fiber measurement

- 2 x 10m inside and outside, on top & bottom cones
- Very satisfactory alternative to strain gauge (technically + cost)
- Post processing more critical than strain gauges
- Need for a dedicated tool





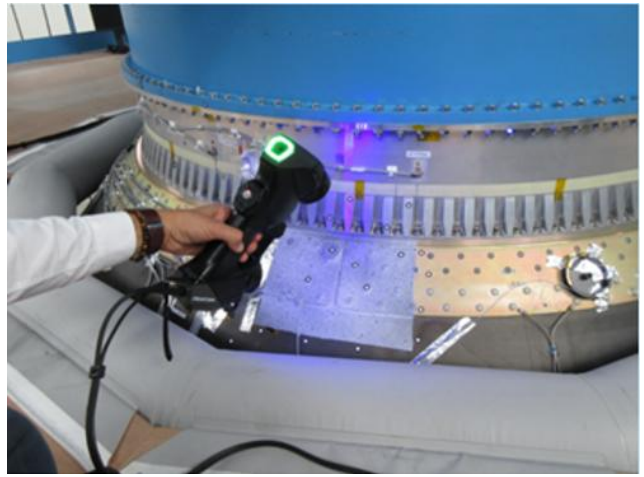


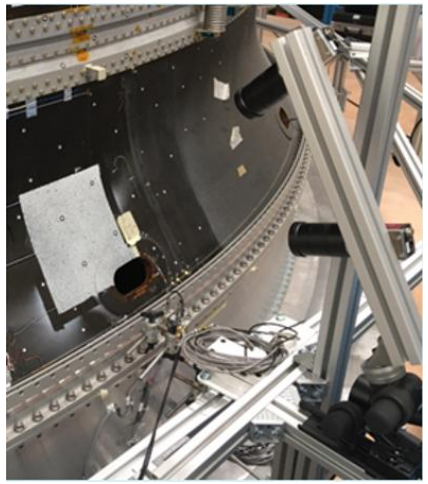


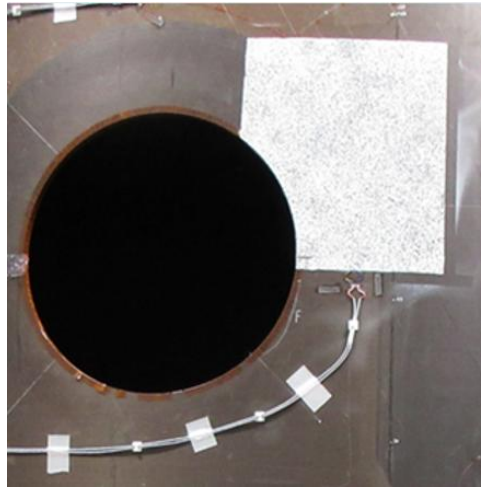
Instrumentation – full field measurements

Strain and displacement by digital image correlation (DIC)

- 3 locations

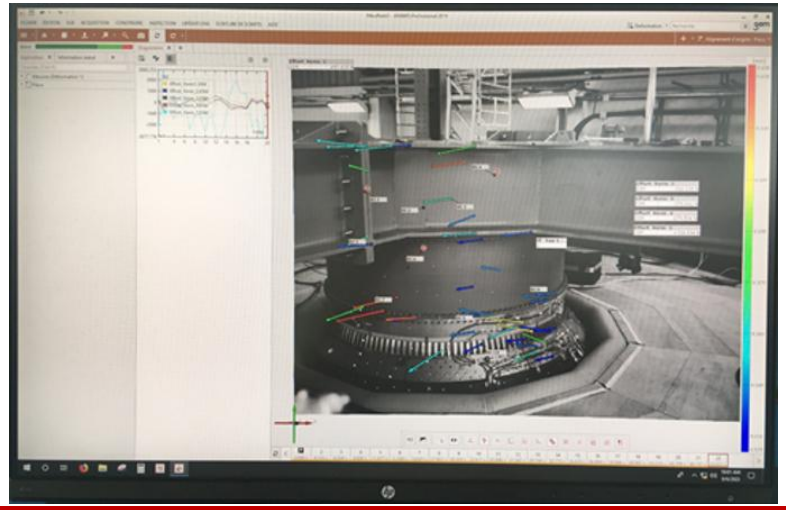




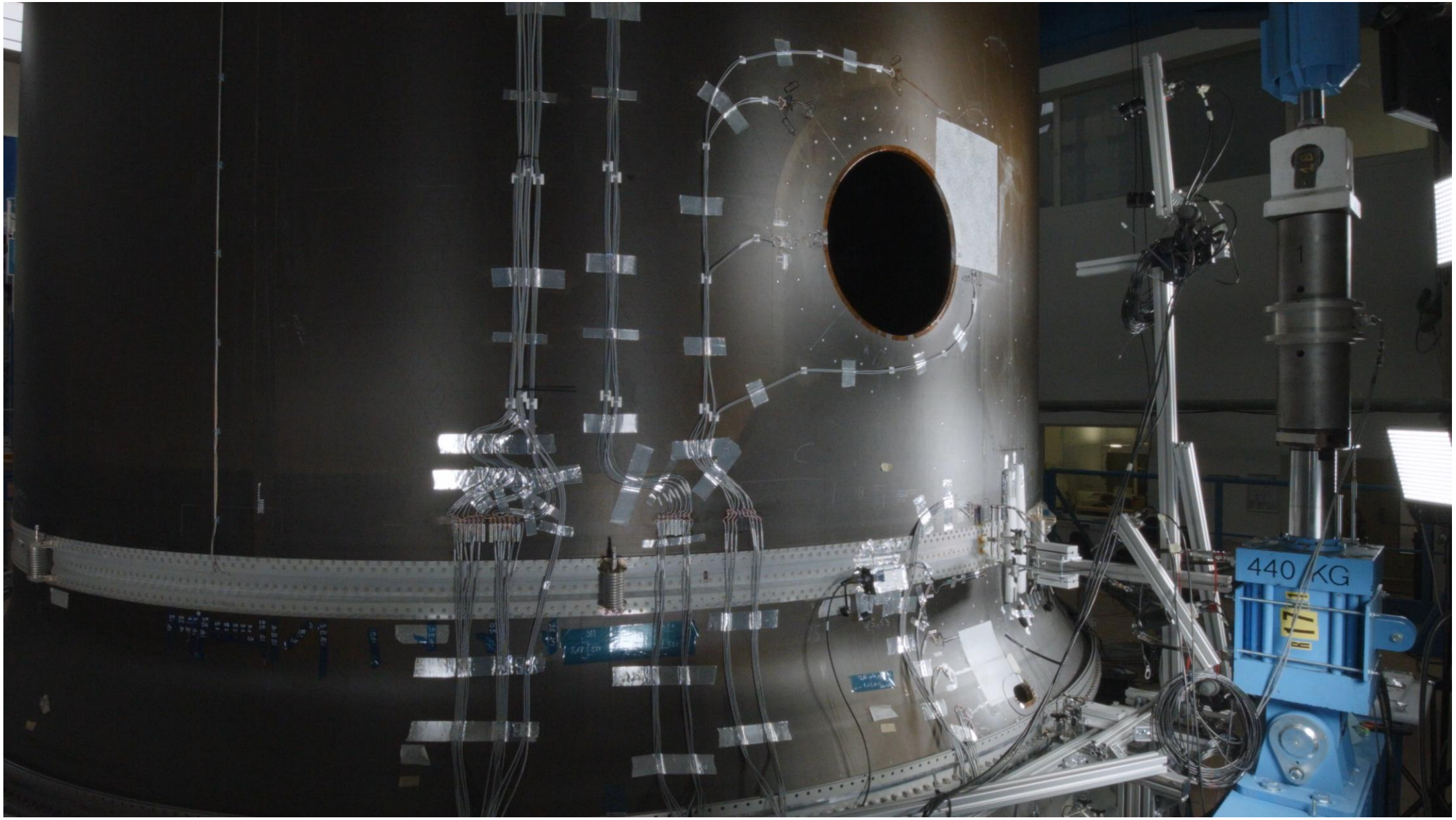


Displacement by 2 markers monitoring systems (photogrammetry)

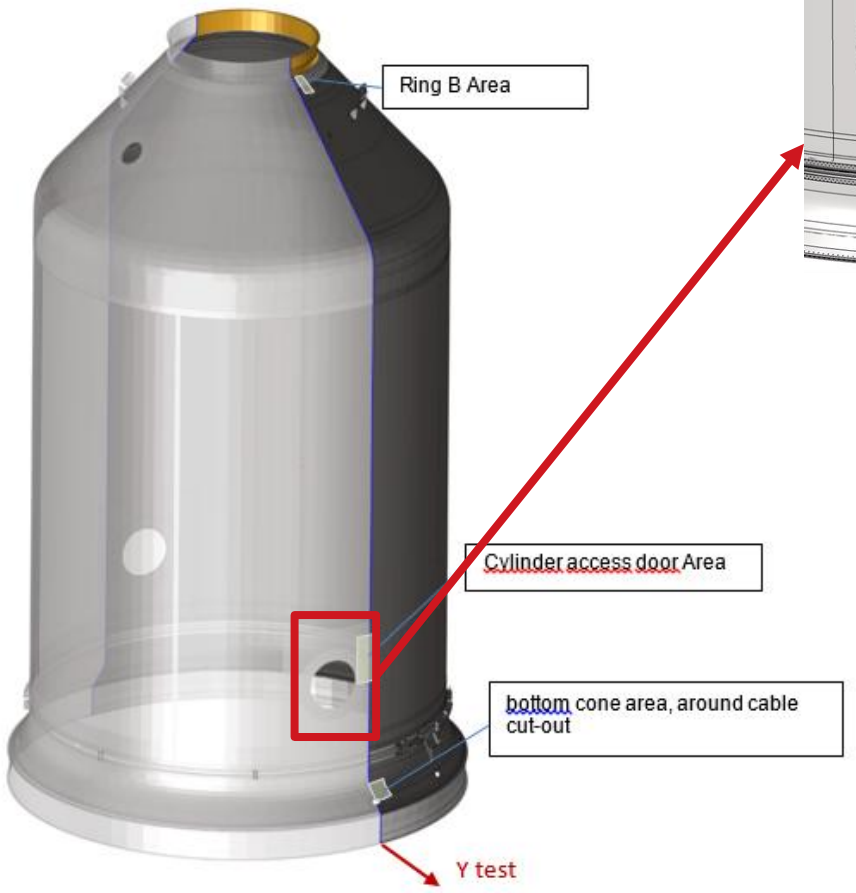
- DLS I/F sup & cross

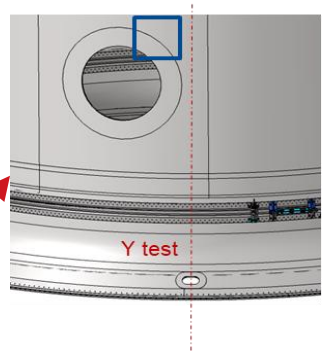


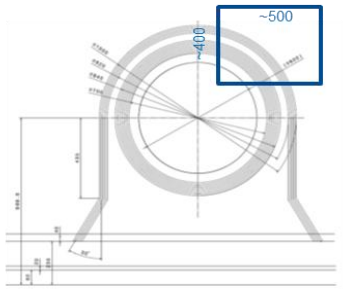
150 % load Test

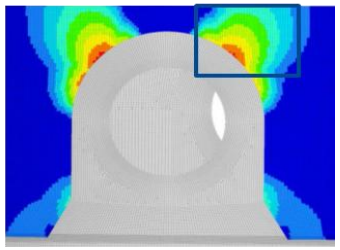


Field measurement / Digital image correlation

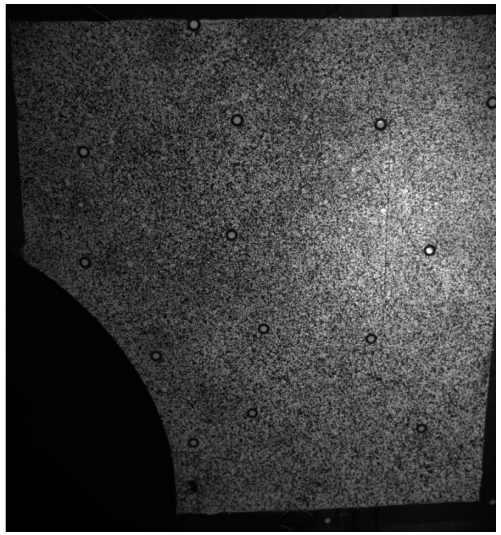








Design and initial FEM results



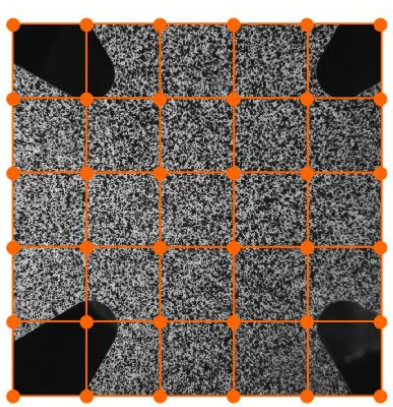
Speckle pattern (paint)

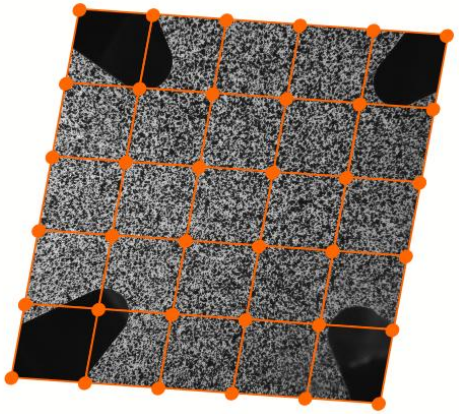
Importance of full-field measurements

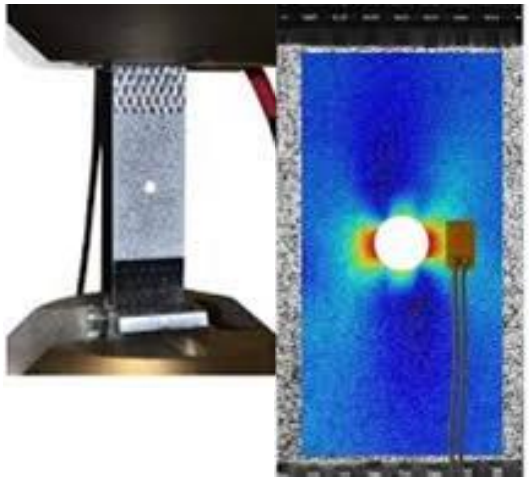
- Three DIC systems aimed at critical locations that have been identified from FEA
- Validation strain levels at critical locations aims at reinforcing trust in the simulation process

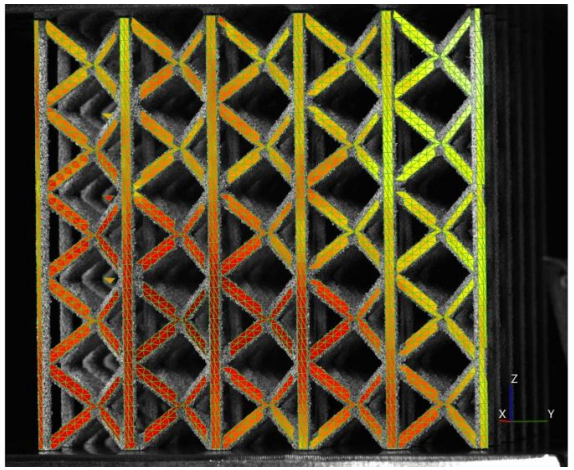
What is Digital Image Correlation?

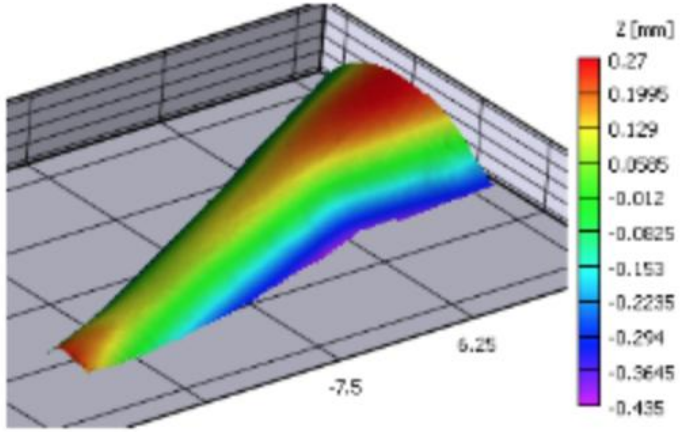
DIC is an optical measurement technique that measures displacement and strain fields by following a pattern in a series of images



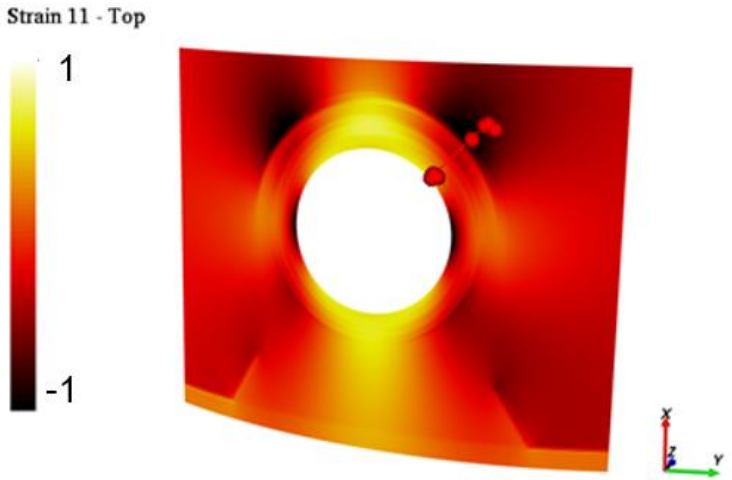






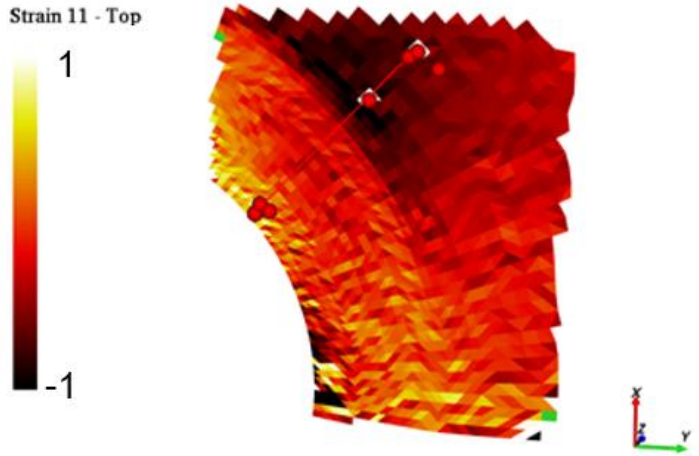


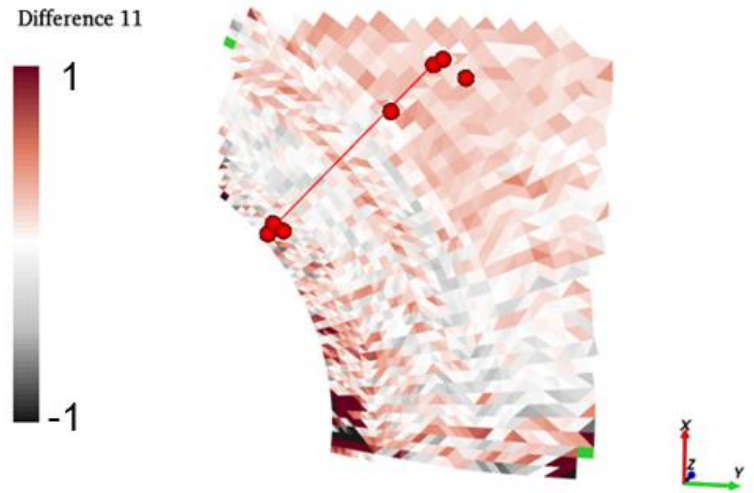
DIC comparison – strains (E11)



Comparison of measured VS predicted strains

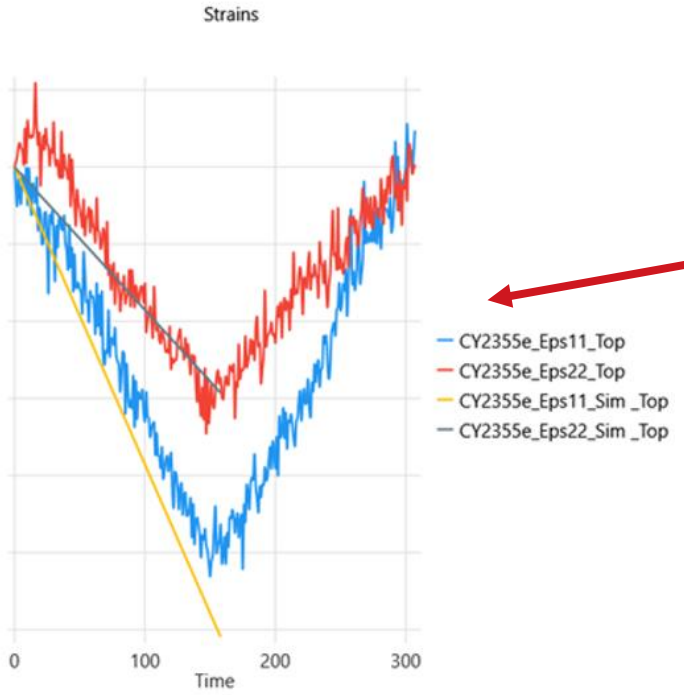
- Mesh-based DIC allows direct comparison and calculation of a difference map
- Discrepancies are acceptable and contained within the measurement uncertainties > builds model credibility
- Overall fit is satisfactory (<20%),

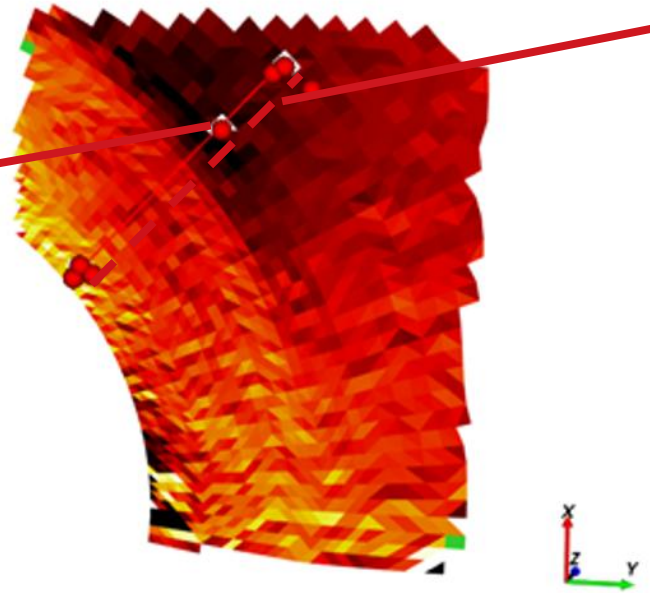


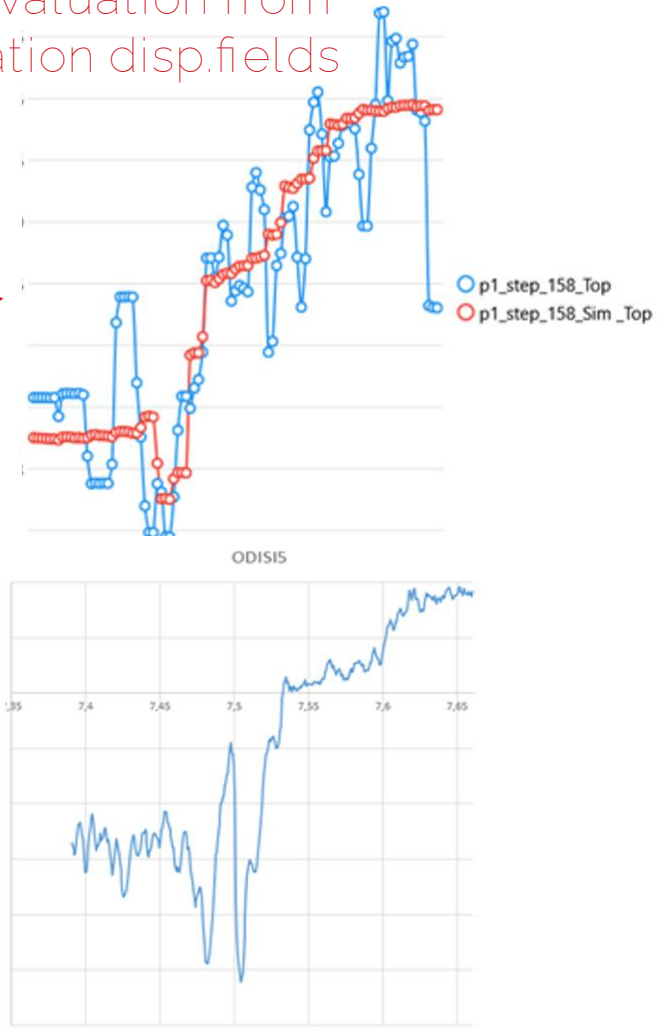


DIC processing - strains

Linear strain evaluation from DIC and simulation disp.fields







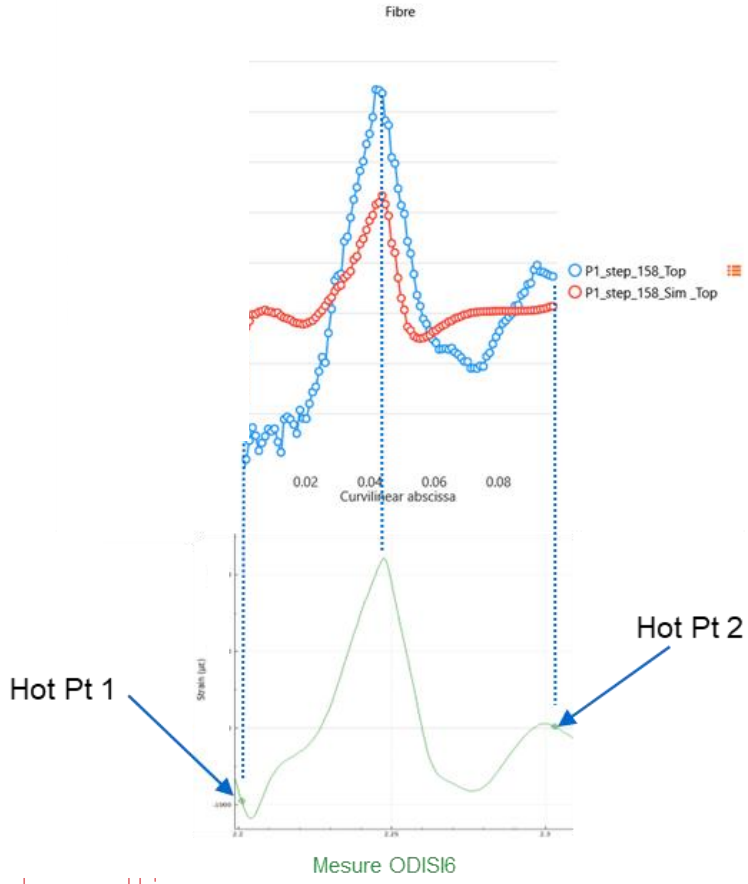
Virtual strain gauge : prediction & measurement

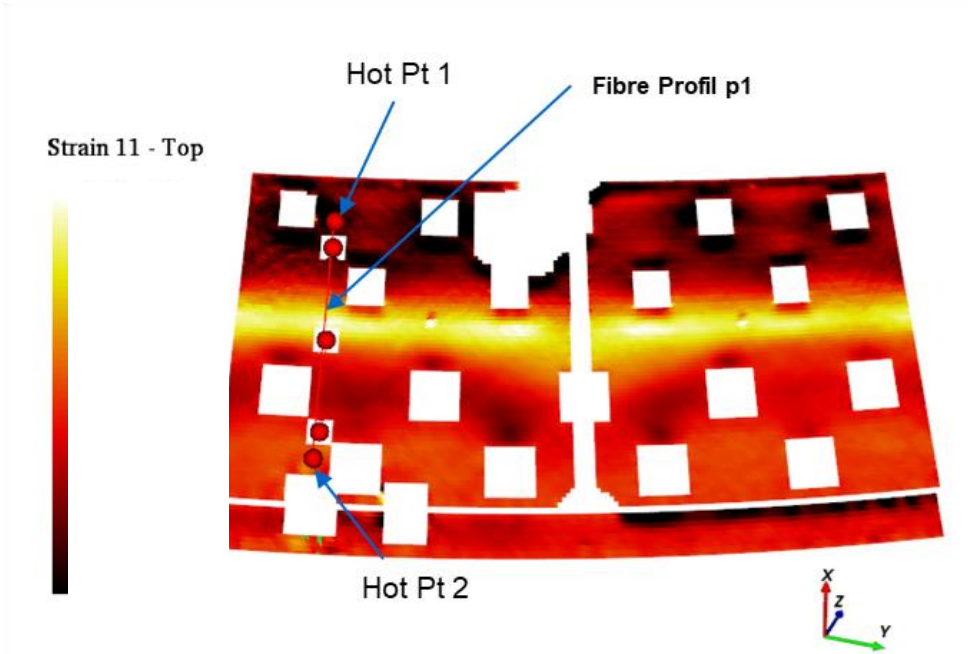
Optical fiber raw measurement

Comparison of measured VS predicted strains

- Full-field as well as point-wise and linear sensors are handled in the same software

Optical fiber comparisons





Expected savings on data manipulation: 75% / > 250 h

Data handling

- Specific tools are under development within the EikoTwin software suite
- Combined DIC & optical fiber measurement on the same areas simplifies matching simulation results to optical fiber measurement (identifying sections)

Acceptance & success criteria

Success criteria	
Linear behavior of the structure	✓
Differences between prediction and tests ❑Lateral and longitudinal displacement ≤ 20% on significant values ❑Strain in in area without singularity ≤ 20% on significant values ❑Strains in area with structural disturbance ≤ 30% on significant values	✓
No residual deformations after application of loads and return to zero load	✓
Application of the qualification loads ❑Measured displacements shall be well correlated at qualification loads (≤ 20%) to ensure a correct distribution of loads ❑Strain in the critical area shall be well correlated at qualification loads (≤ 20% on significant values)	✓

Smart testing : much more than conducting a test.

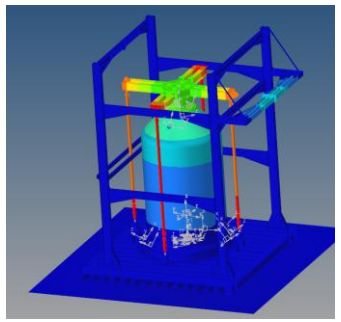
Preliminary simulation

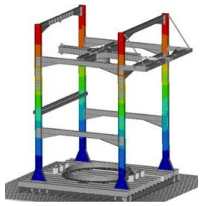
Test bench definition & optimization

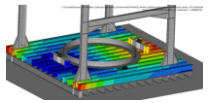
Measurement

Optimized test-simulation dialog for model validation

Qualification



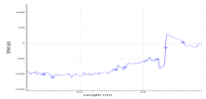




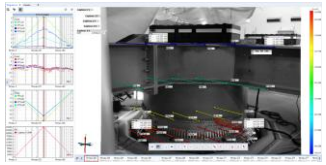
Shape measurement

Strain Gauges

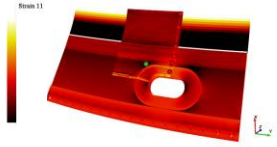
Optical Fiber



Marker Monitoring

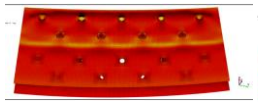


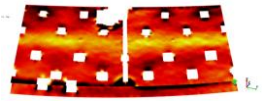
Full Field Measurement

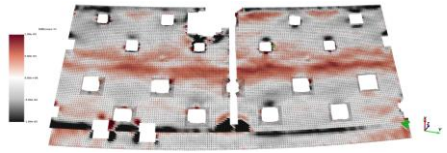


Simulation

Test







Test-simulation comparison

Smart testing

- An end-to-end integration of FEM simulation, mechanical loading and measurement for a reliable qualification

Conclusion

Main results

- Complementary measurement data have been assembled on the FE mesh to confront them to the FEA results;
- Global errors are acceptable and fit within the tolerances ; some differences (displacements amplitudes notably) can be explained;
- This validation effort reinforces model credibility and qualifies the simulation procedure: it allows for test-less future developments, thus drastically reducing the necessary time and budget for next generations of DLS.

Future works

- Development of validation metrics
- Automation
- Optimization