PLOT Showcase 2019

Virtual Testing to increase competitiveness within Space industry

DEFENCE AND SPACE

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21st November 2019

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Agenda

I. Virtual testing as key innovation enabler

1. Rationale
2. Definitions
3. From virtual testing to traditional testing

II. Qualification of Vega-C Interstage 1-2 by virtual testing

1. Building-block approach
2. Strong correlation between test and simulation
3. Quantification of measurement uncertainties
4. Low level tests
5. Full scale test: stiffness, strength and failure tests
6. Results and uncertainties measurement

Key takeaways

I. Virtual testing as key innovation enabler

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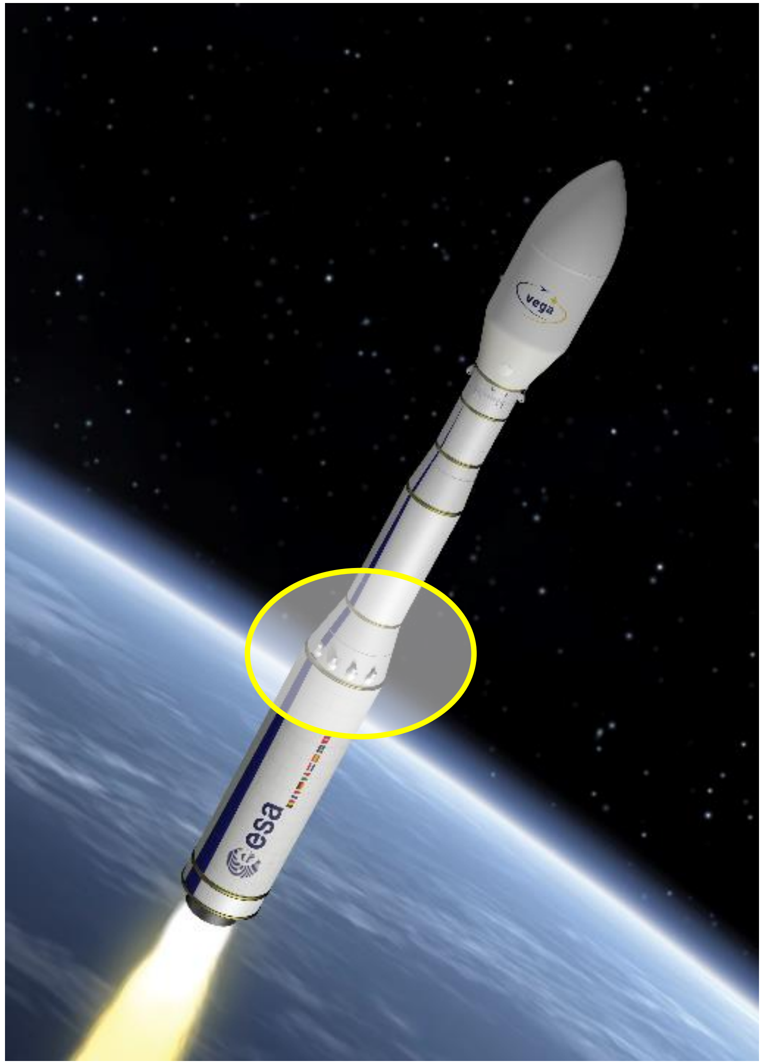
I. Virtual testing as key innovation enabler

1. Rationale

I. Virtual testing as key innovation enabler

1. Rationale

- Development of the VEGA-C interstage 1-2 based on qualification by **virtual testing**.
- Opportunities for **cost saving and time saving up** to 25% of development cycle.
- **Key innovation enabler** and a way to the future.



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I. Virtual testing as key innovation enabler

2. Definitions

Virtual testing

Virtual testing consists in **virtually testing the behaviour of a product under various operating and environmental conditions** with the use of an enhanced realistic simulation. It allows the performance of several **design iterations** early in the development process.

Verification & Validation (V&V)

- Verification: ensures the model is built according to specification (Mathematics)
- Validation: ensures the model represents the real world situation (Physics)

*« **Virtual tests will replace** physical tests*
No more physical tests...»

?

*« Unless I see...a **test result** ...I will not **believe** »*
***…** your simulation prediction.*

?

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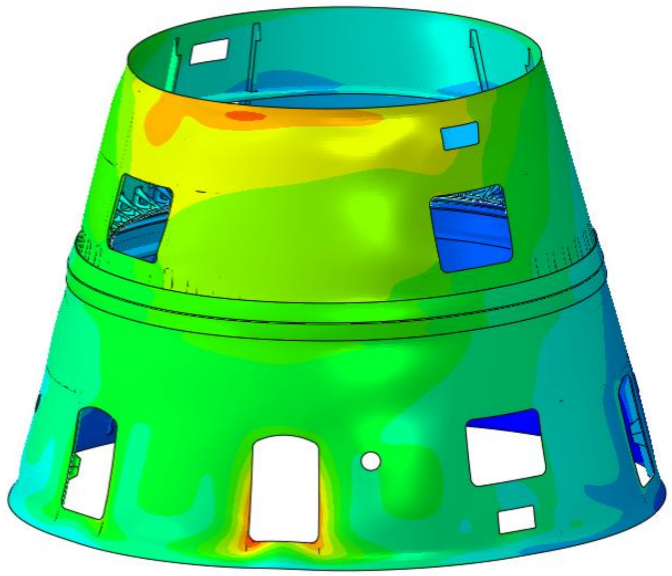
I. Virtual testing as key innovation enabler

2. From traditional testing to virtual testing

Traditional testing

❖ Physical testing is used for requirements verification and product qualification

Virtual Testing



❖ Physical testing is used for validation of simulation
❖ Test-validated simulation is used for requirements verification and product qualification (Virtual Testing)

II. Qualification of Vega-C interstage 1-2 by virtual testing

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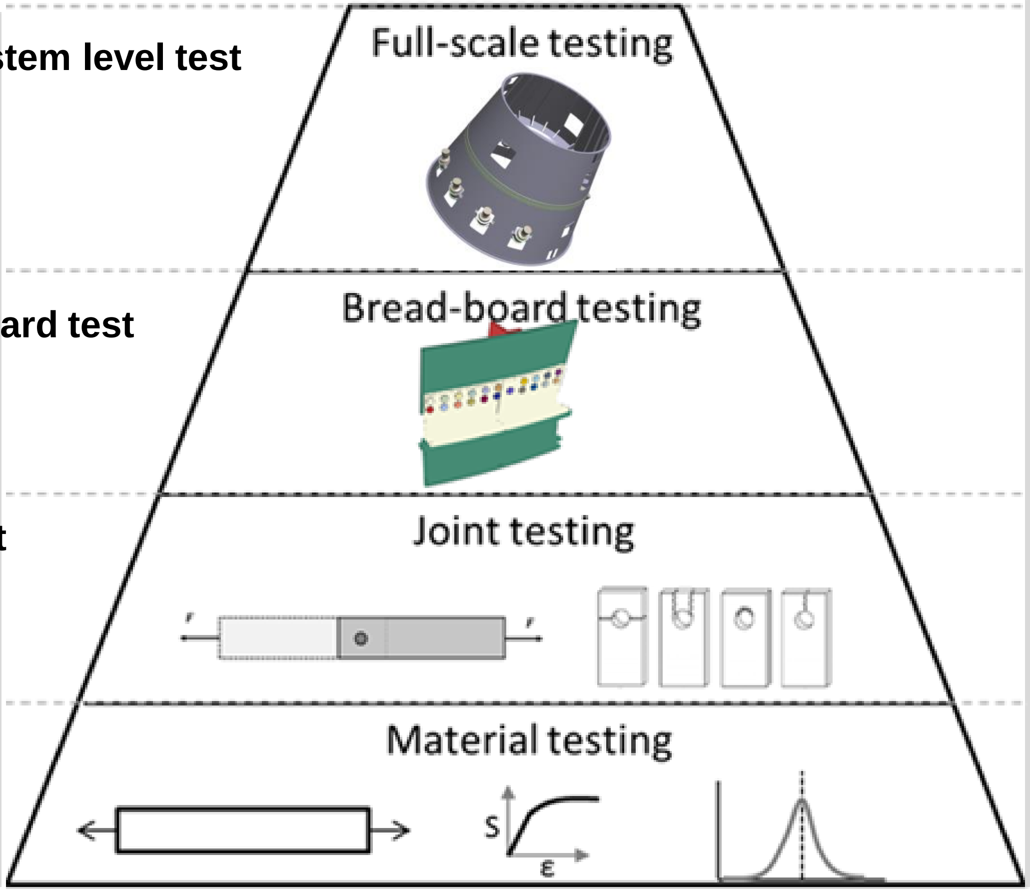
II. Qualification of Vega-C interstage 1-2 by virtual testing

1. Building-block approach



System level test
1

Breadboard test
5

Lap-joint test
106

Material test
80

Amount of experimental tests

Simulations validation
at system level

Simulations validation
at component level

Mechancical joining calibration/
validation at element level

Material model calibration/validation
at coupon level

Amount of numerical simulations

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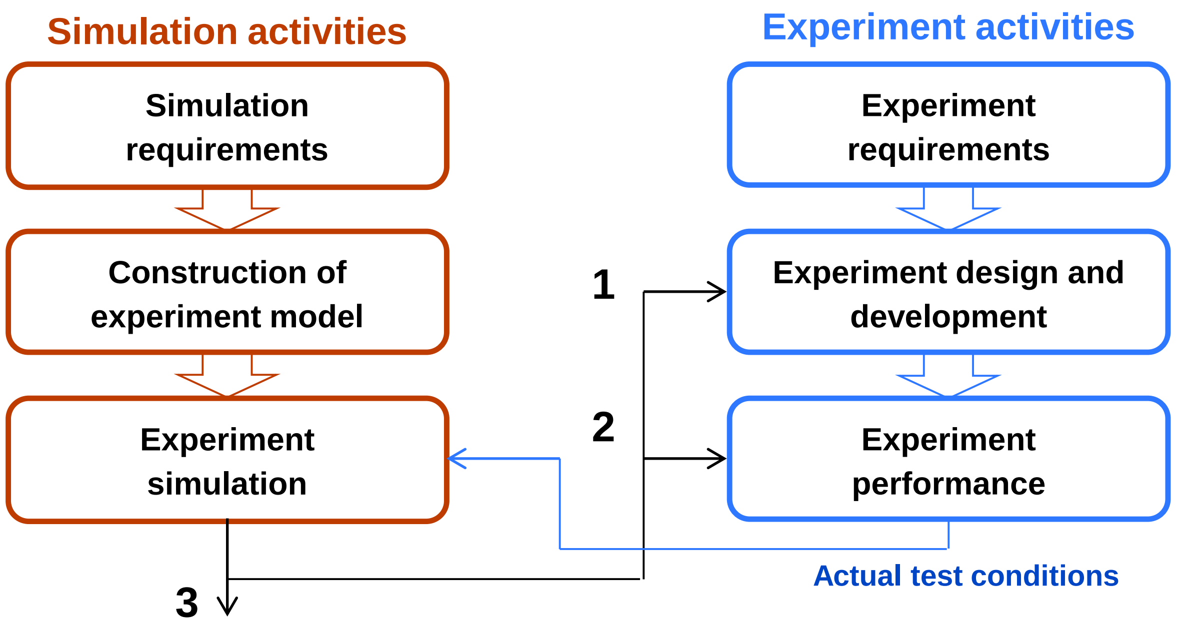
2. Strong correlation between test and simulation



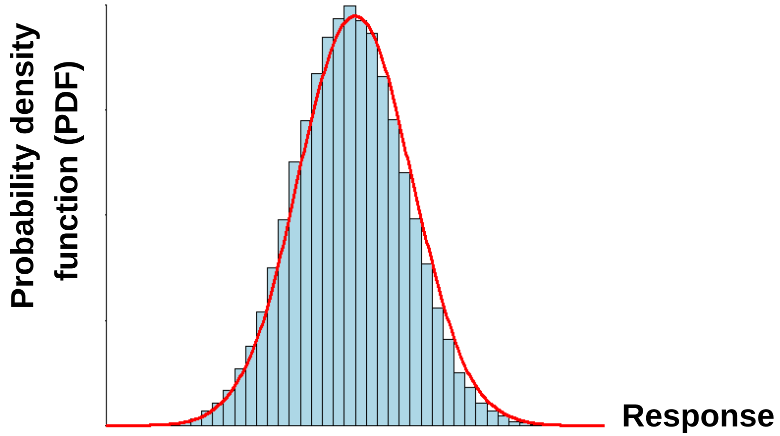
1. **Preliminary pre-test simulation** to support test design
2. **Final pre-test simulation** (with geometrical statistical distribution)
3. **Post-test simulation** (with test results statistical distribution)

"As-manufactured" test samples

Statistical distribution of key geometrical parameters, in particular samples cross-section (sample mean and standard deviation)

"As-tested" test samples

Statistical distribution of test results, such as stiffness or strength outputs (sample mean and standard deviation)



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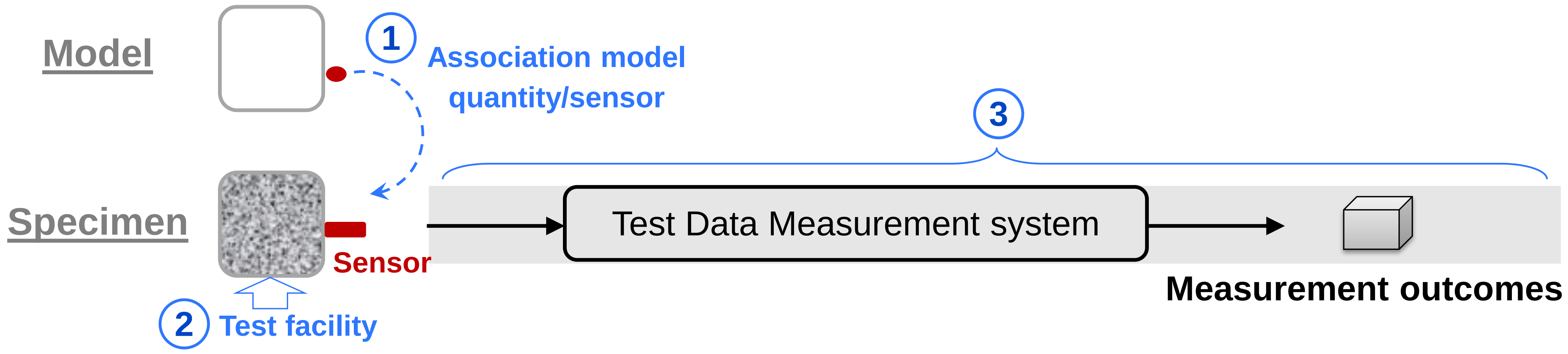
3. Quantification of measurement uncertainties

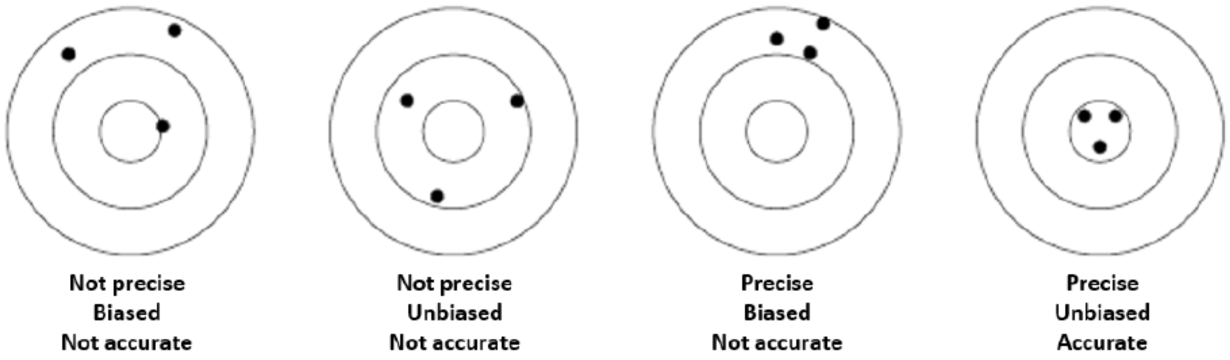


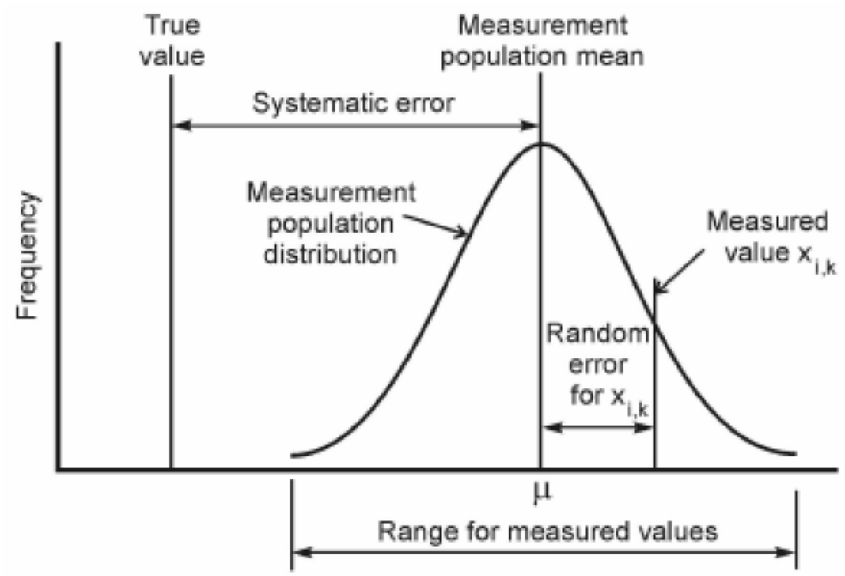
- Three uncertainty types:

1. Uncertainty from the association between sensor and model quantity
2. Test facility uncertainty including test level control
3. **Measurement uncertainty** for measurement chain components and data processing

II. Qualification of Vega-C interstage 1-2 by virtual testing

3. Quantification of measurement uncertainties





Uncertainty quantification and propagation approach

Step 1

Identify the test procedure and quantities for which uncertainties are to be estimated.

Step 2

Identify all relevant sources of uncertainties in the test

Step 3

Classify the uncertainty according to Type A or B

Step 4

Estimating the standard uncertainty for each source of uncertainty
Type A analysis – use statistical methods
Type B analysis – use other means than statistics

Step 5

Compute the combined uncertainty u_c

Step 6

Compute the expanded uncertainty U (at 95% confidence level and at 99% confidence level)

Step 7

Report results

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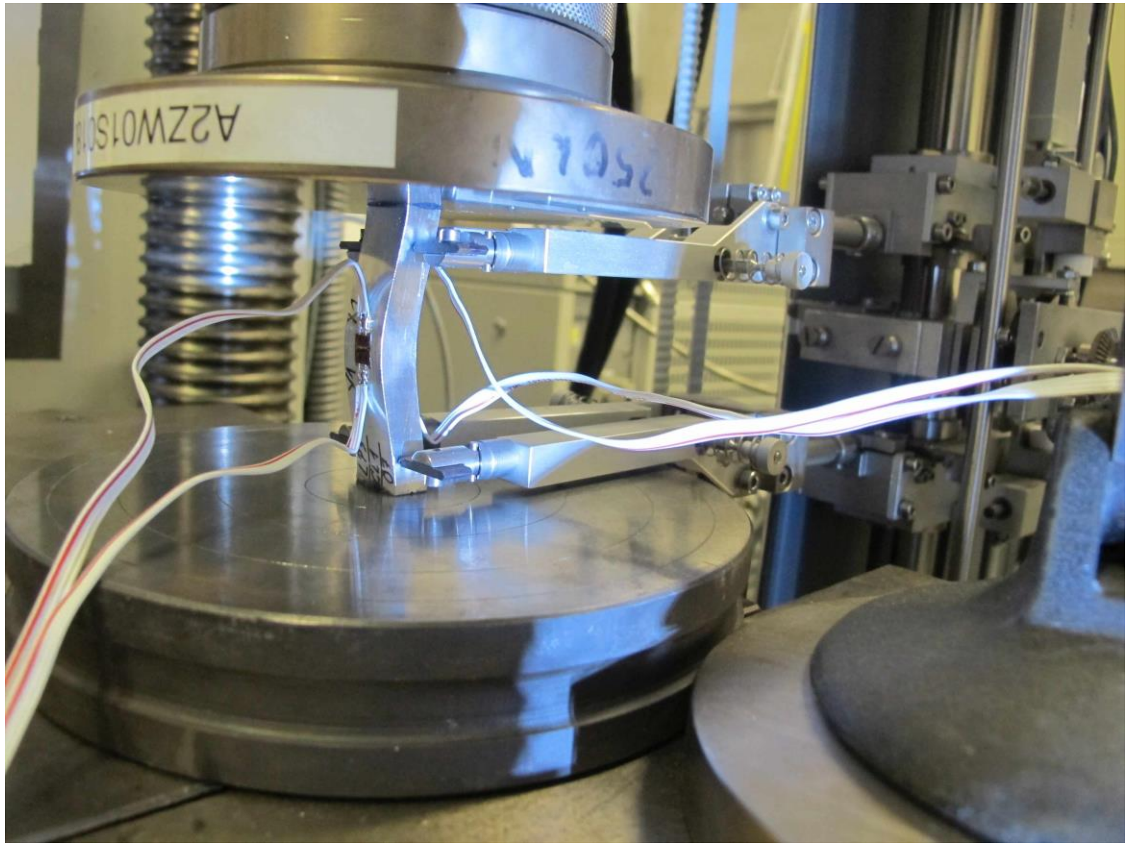
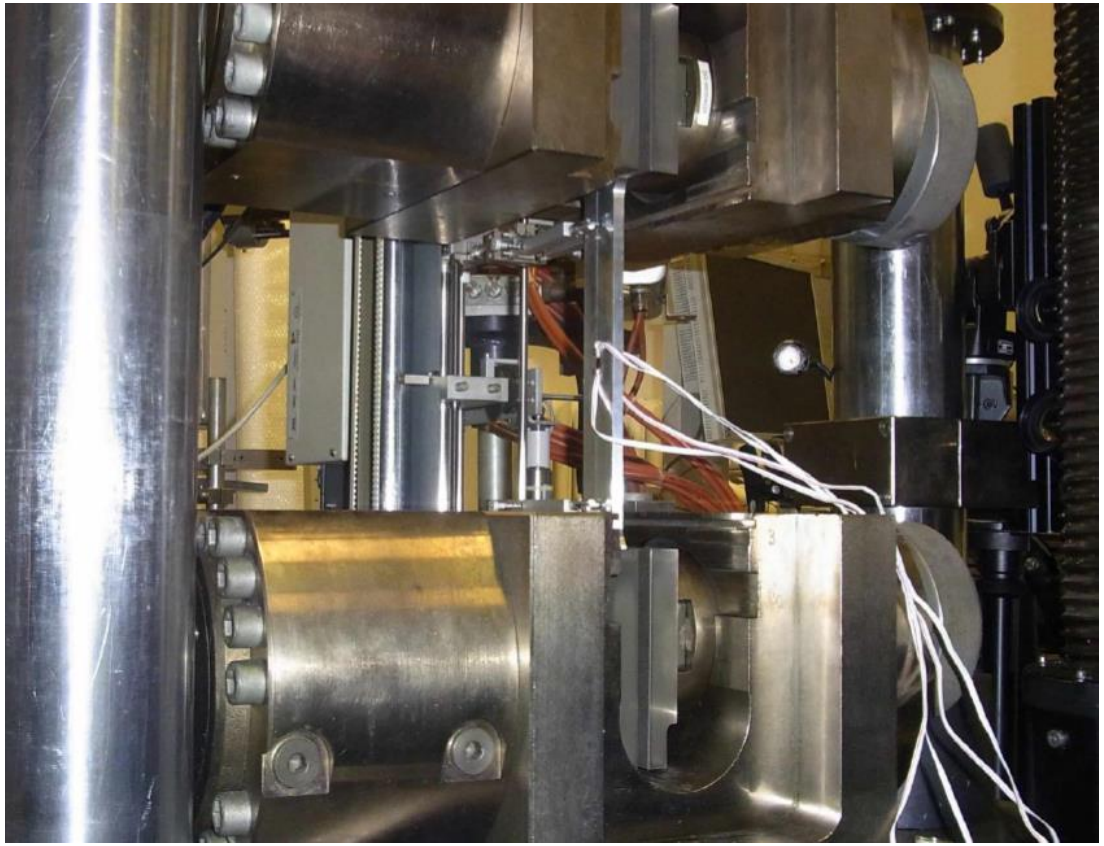
4. Low level tests





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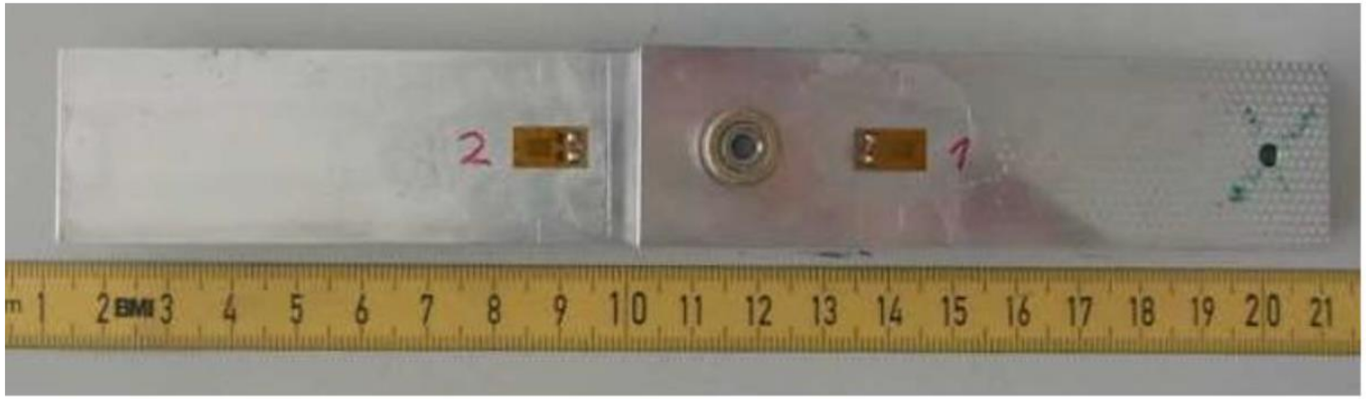
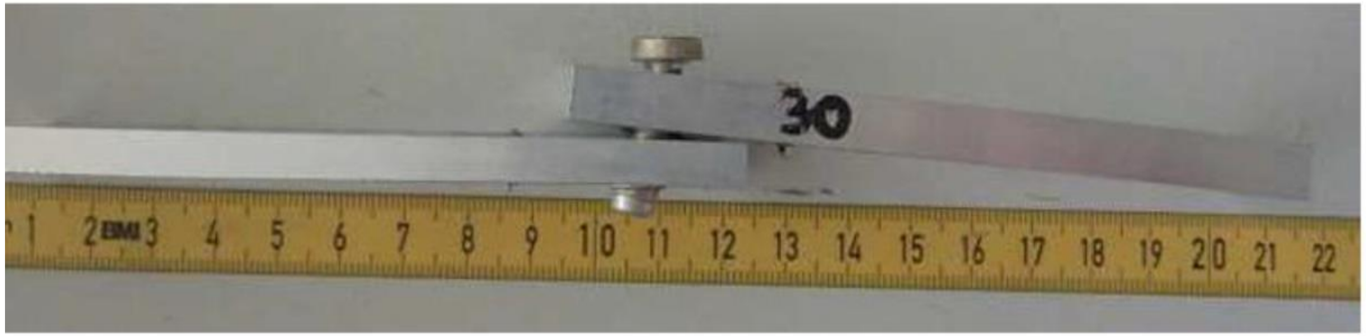
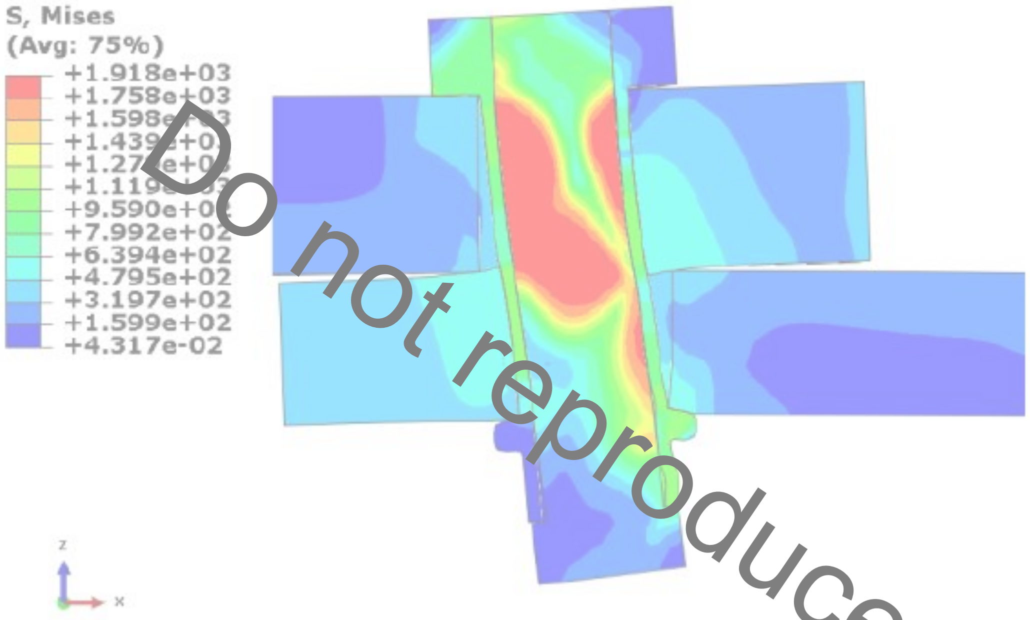
4. Low level tests







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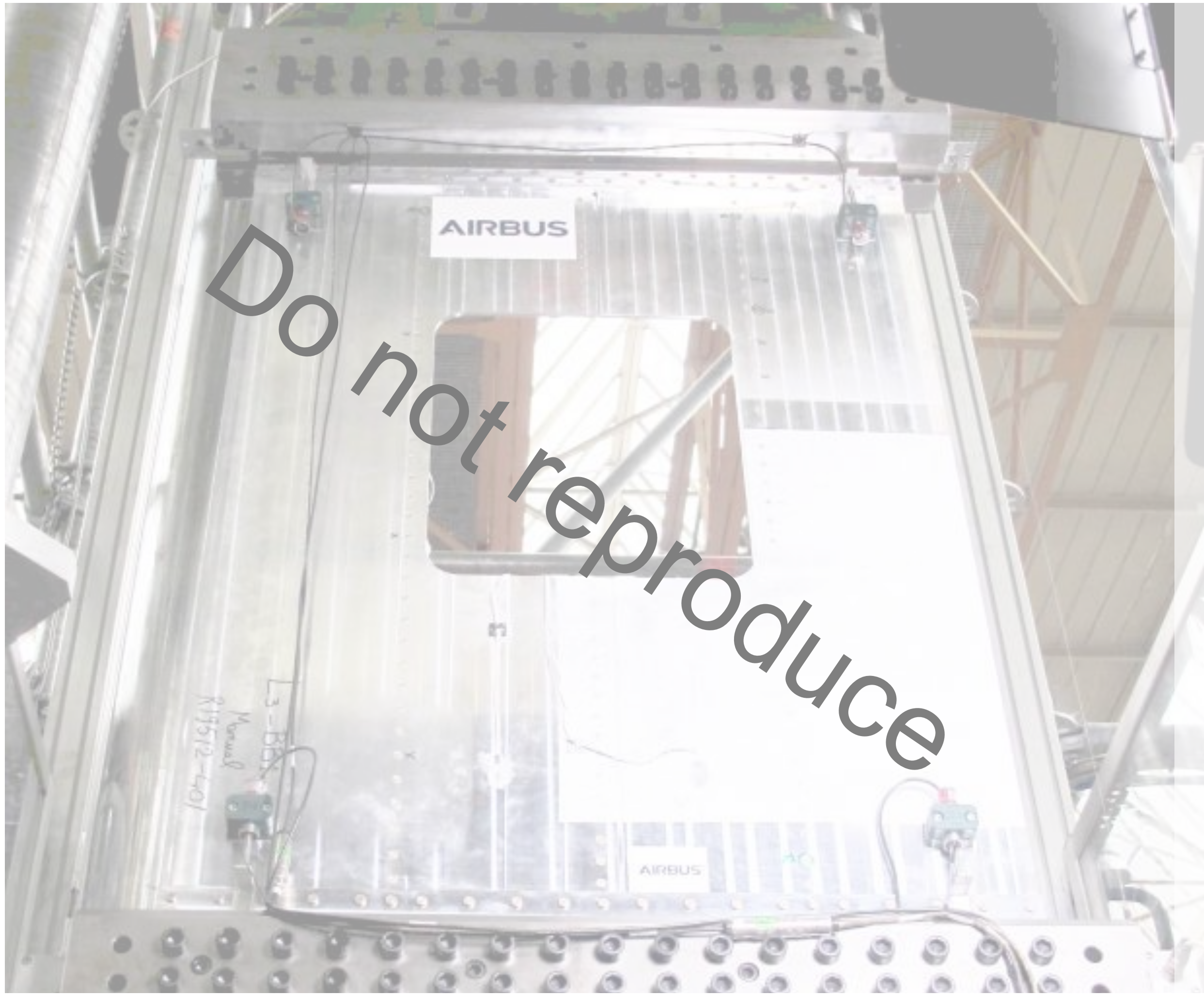
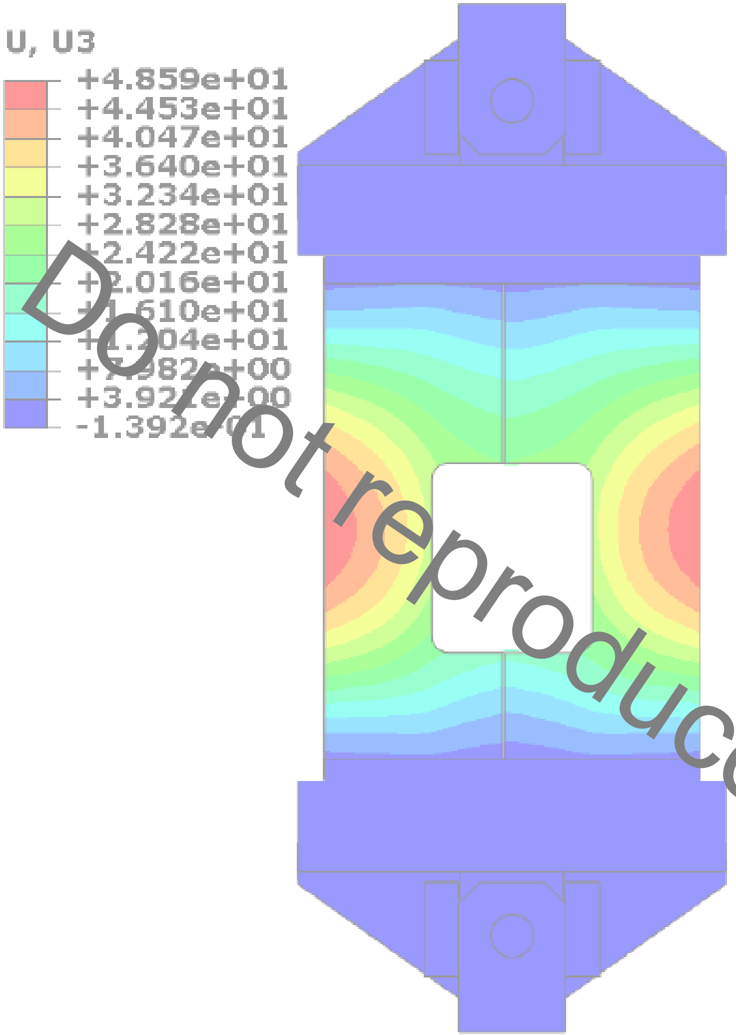
4. Low level tests

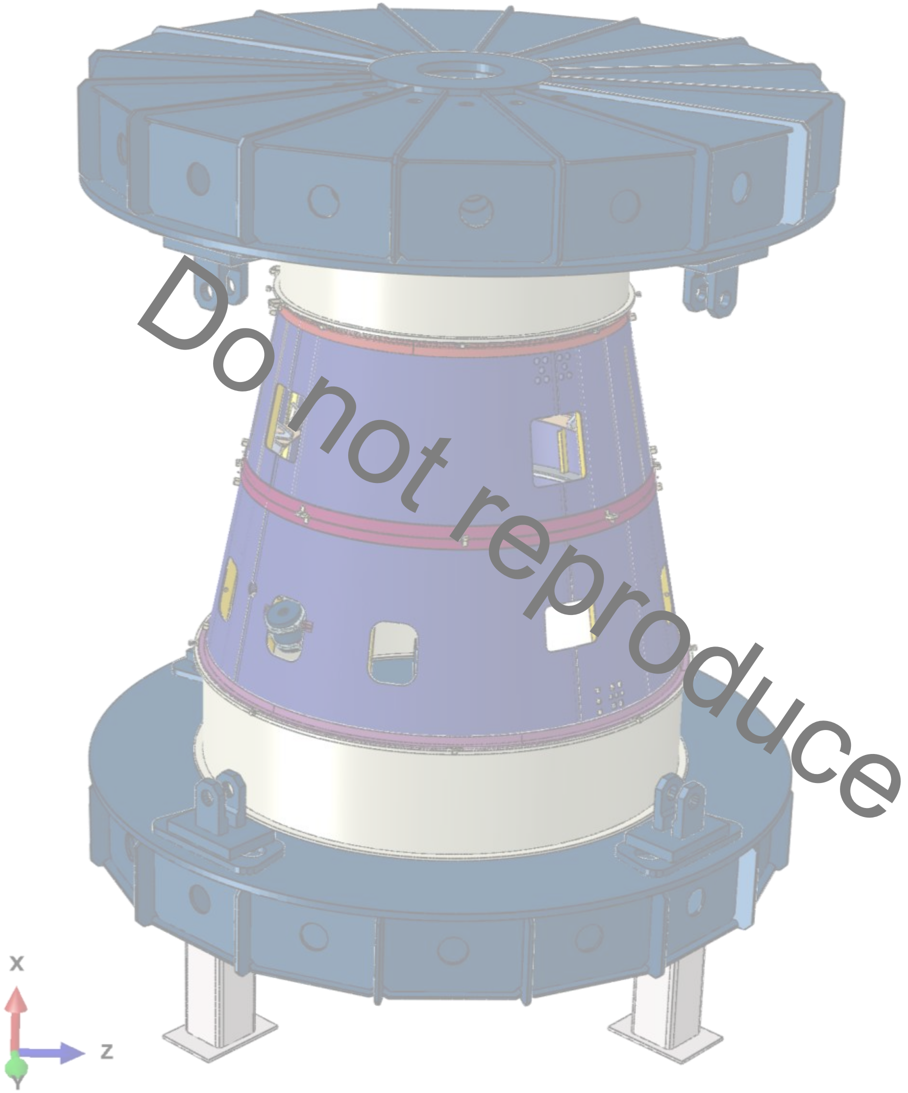




II. Qualification of Vega-C interstage 1-2 by virtual testing

5. Full scale test: stiffness, strength and failure tests

~6.5 m



II. Qualification of Vega-C interstage 1-2 by virtual testing

5. Full scale test: stiffness, strength and failure tests

Load cell
Accuracy of max **1%** of nominal load and pressure.

Displacement sensors
117 displacement sensors (LVDTs) applied to the test article and test jig. Accuracy of max **1%** of nominal measuring range.

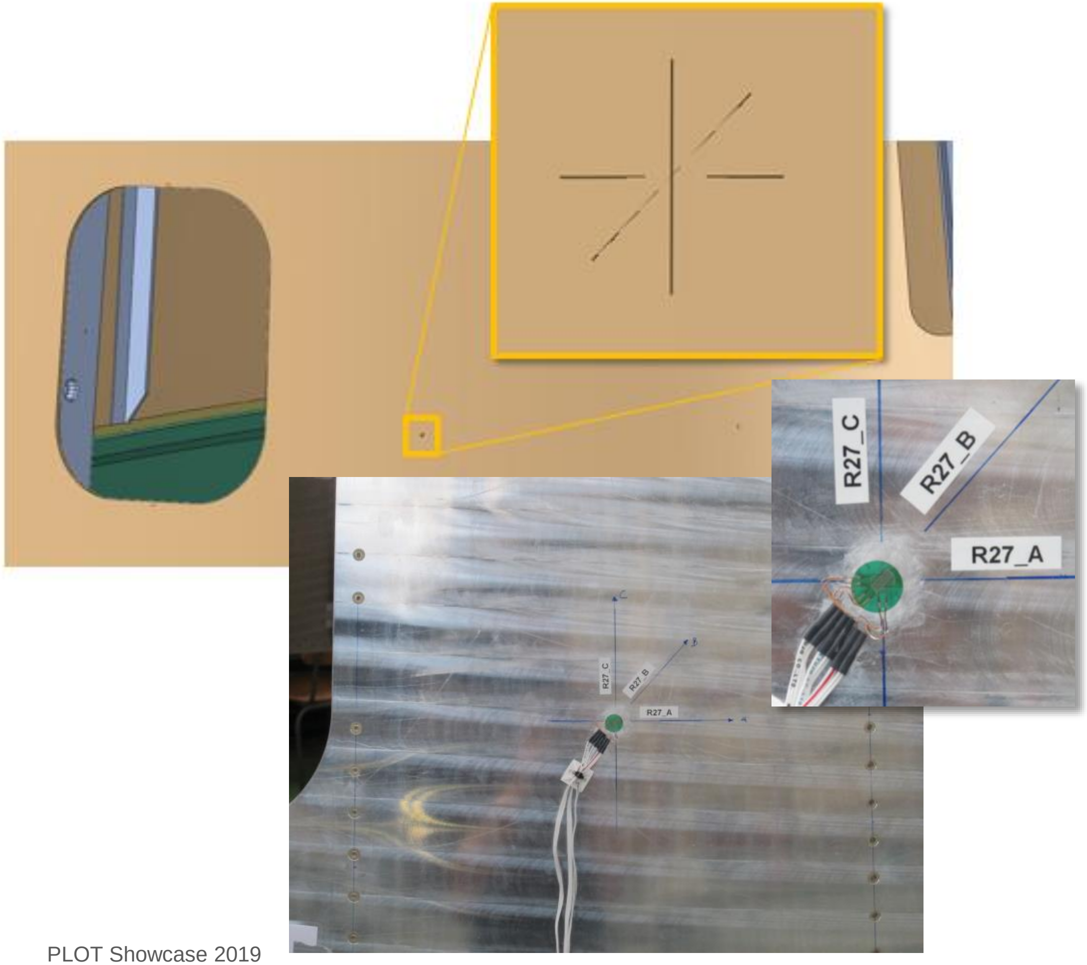
Stain gauges
458 temperature compensated strain gauges channels installed on the test article. Accuracy of strain measurement better than **±20µm/m.**

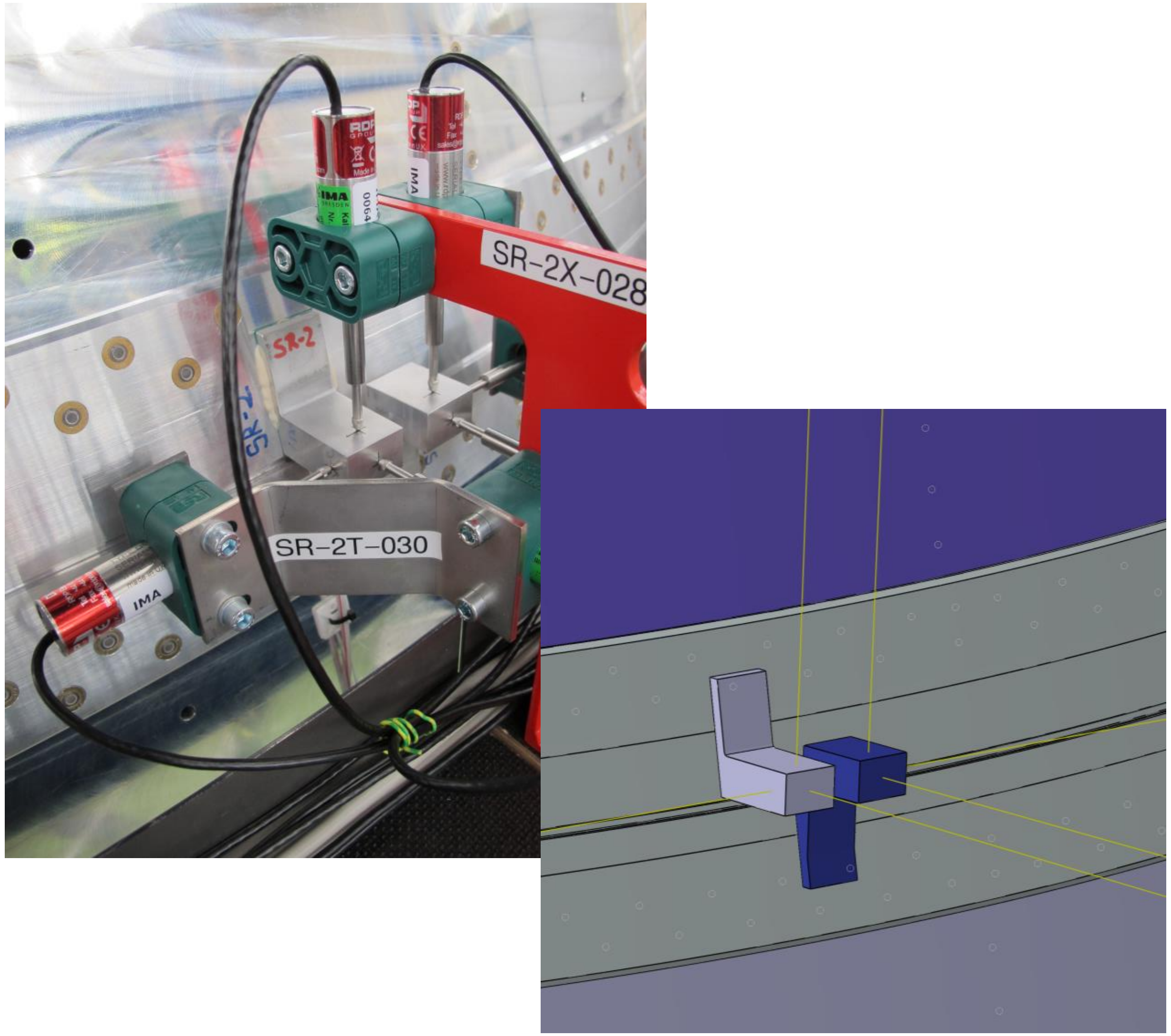
Optical measurements
DIC (Digital Image Correlation – ARAMIS). Displacement and strain can be calculated and reported. Accuracy approximately **0.2mm.**

Inspection
Visual inspection, pictures, NDI.

II. Qualification of Vega-C interstage 1-2 by virtual testing

5. Full scale test: stiffness, strength and failure tests





II. Qualification of Vega-C interstage 1-2 by virtual testing

6. Results and uncertainties measurement

- Spot-on prediction of load at which structural instability occurs

II. Qualification of Vega-C interstage 1-2 by virtual testing

6. Results and uncertainties measurement

The following input uncertainties are considered:

- Measurement error on **displacement sensors** (LVDTs)
    - extracted from individual sensor calibration sheets and ranging from **0,17% to 0,37%** of measured value
- Measurement error on **load cells**
    - extracted from individual sensor calibration sheets and ranging from **0,19% to 0,39%** of measured value
- **Positioning error** of main actuators (error of ±1mm).

The output standard deviation of axial stiffness results (caused by measurement UQ) are summarized below:

- Output standard deviation on **axial stiffness** is **1.01% (1 sigma, 67% confidence interval)**
- Output standard deviation on **axial stiffness** is **3.04% (3 sigma, 99% confidence interval)**

Key takeaways

Virtual testing shortens development time and reduce development costs

Strong collaboration is required between test and simulation teams

Virtual testing does not replace traditional testing

Thank you

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