Uncertainty Quantification in Digital Image Correlation

An industrial perspective

Eszter Szigeti (presented by Richard Burguete, NPL)
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OUTLINE

- Introduction to Structures Test, Airbus
- DIC applications
- Workshop questions
  - → What are the sources of error in DIC measurements?
  - → How can we quantify the uncertainties reliably?
  - → Does uncertainty quantification (UQ) really matter?
  - → How do I use this uncertainty information?
  - → How does it propagate into derived data?
- The FUTURE

Introduction to Structures Test, Airbus

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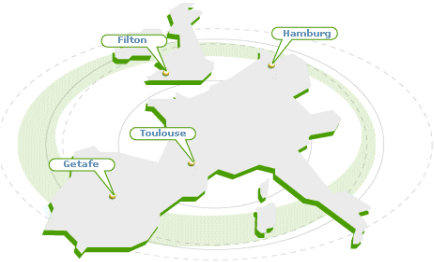
Structures Test, Airbus



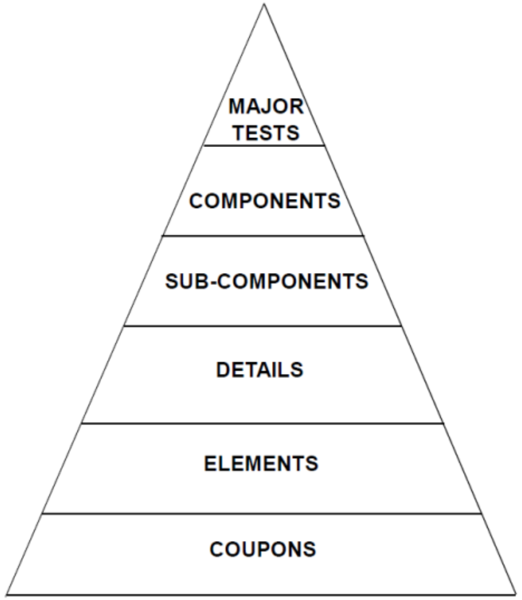
The structural integrity and safety of the airframe is typically established by analysis supported by structures tests.

<u>Certification</u>

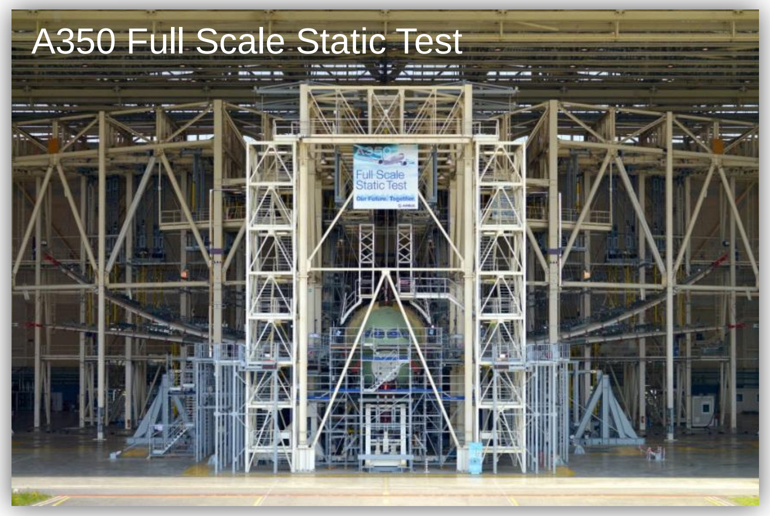
Analysis and test evidence is presented to the Airworthiness Authorities so that compliance with EASA and other certifying authority's rules, can be demonstrated, in order to achieve Type Certification. (EASA – European Aviation Safety Agency)

<u>Development / Research</u>

- Qualification of new materials and fastening systems
- Validation of new design and manufacturing methods
- Demonstration of durability and safety
- Concession support
- In-Service support and Repair scheme validation
- FTI Calibrations
- Research
- Analysis method and FEM model validation
- Validation of Virtual Testing models



Master Pyramid of Structures Tests

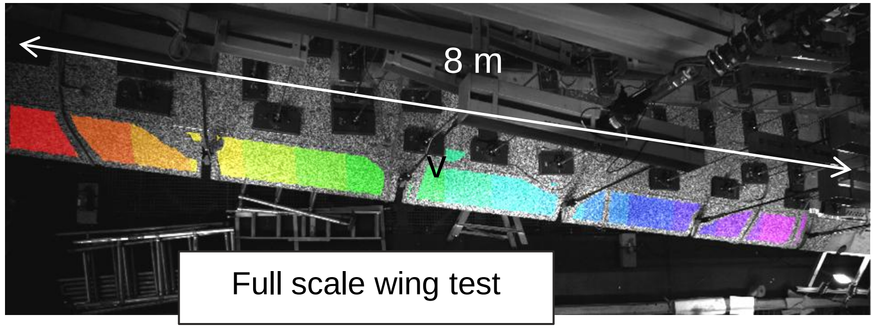


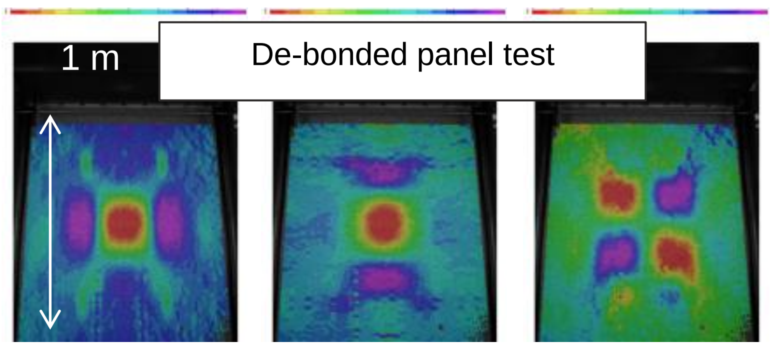
We test metallic, composite and hybrid structures

We perform Static, Fatigue, pressure and impact tests

DIC applications

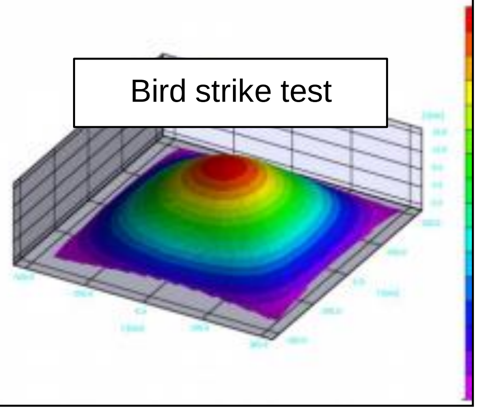
DIC applications

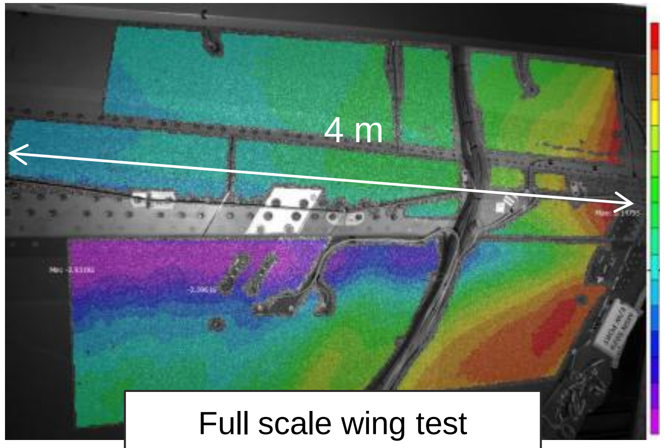


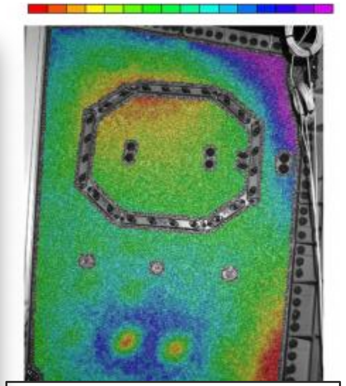


Applications:

- Large scale static tests
- Dynamic tests
- Pressure tests (static)
- Trouble shooting
- Wind tunnel support
- Etc.







Full scale wing test
– internal wing box

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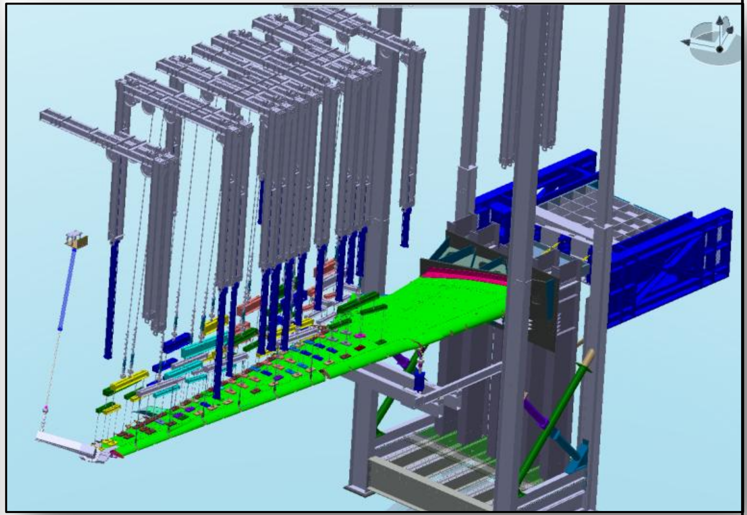
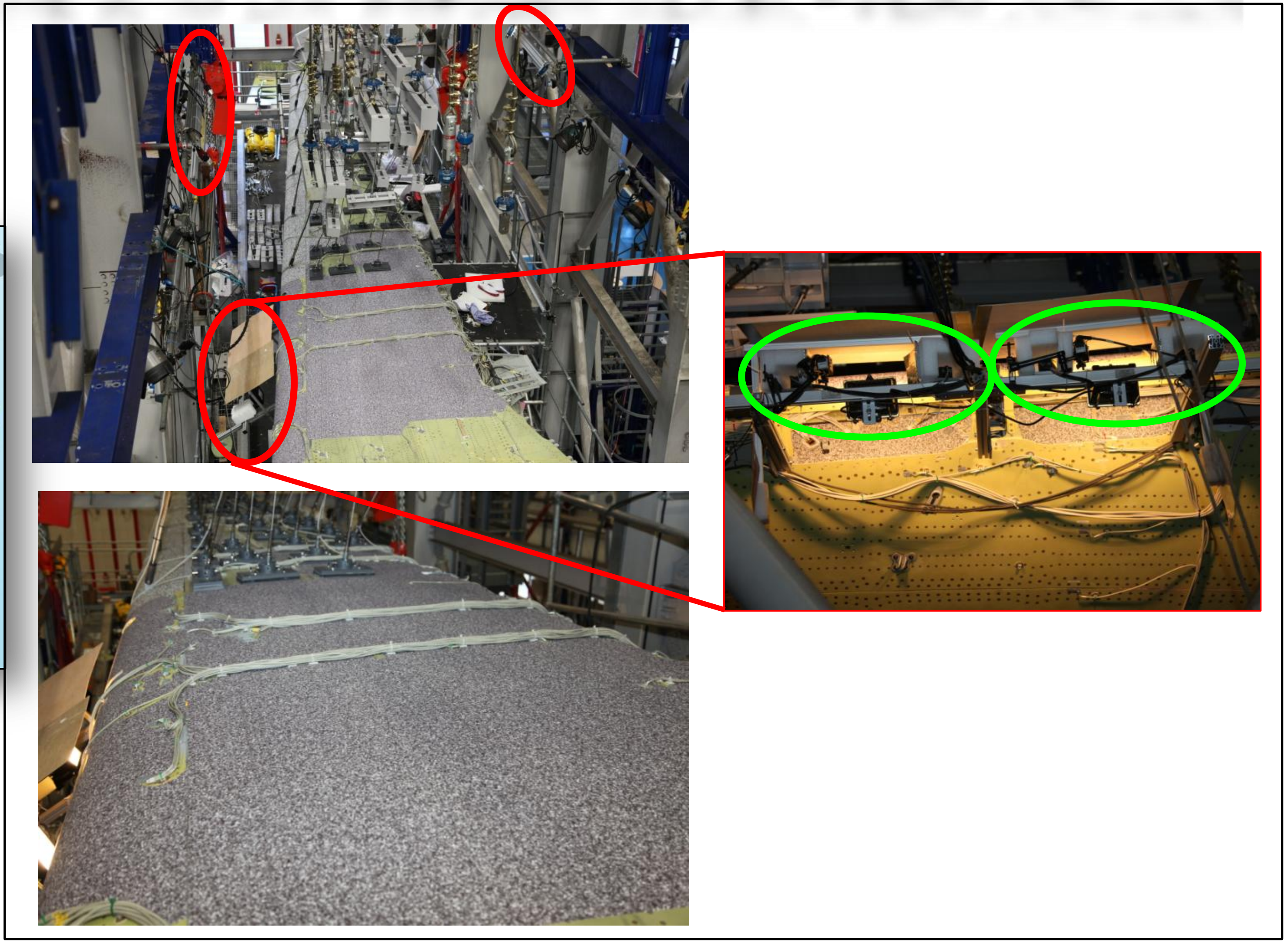
What are the sources of error in DIC measurements?

What are the sources of error in DIC measurements?

Experimental Setup
Lens distortion
Camera motion
Sample motion
Air turbulence
Image blur
Location in image
Lens focal length
Camera standoff
Stereo angle
System resolution
Calibration Parameters
Calibration target error
Calibration drift
Image quality
Image Acquisition
Noise
Contrast
Speckle size
Aliasing
Image Correlation
Interpolant
Minimization
Shape function
Subset size
Processing decisions
Filtering
Strain calculations





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Does uncertainty quantification (UQ) really matter?
How can we quantify the uncertainties reliably?

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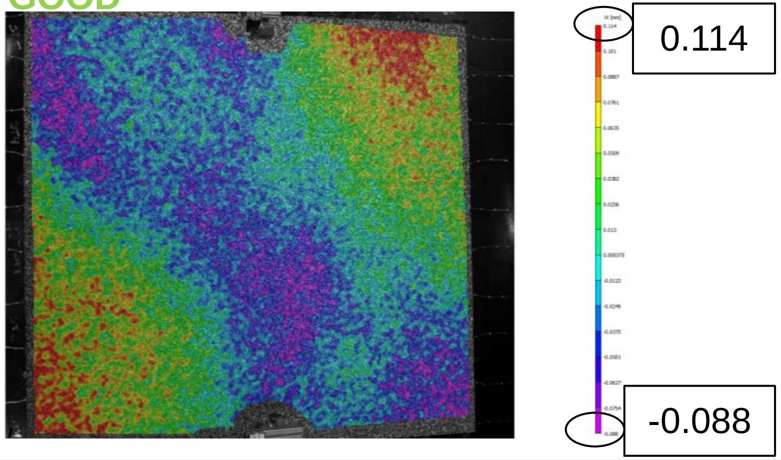
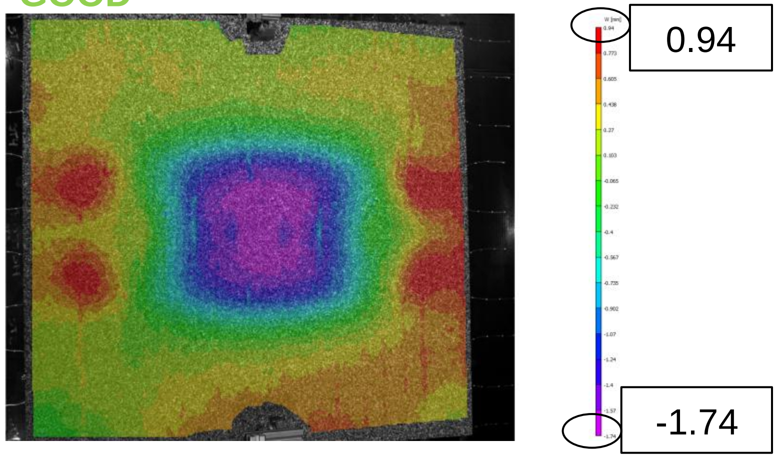
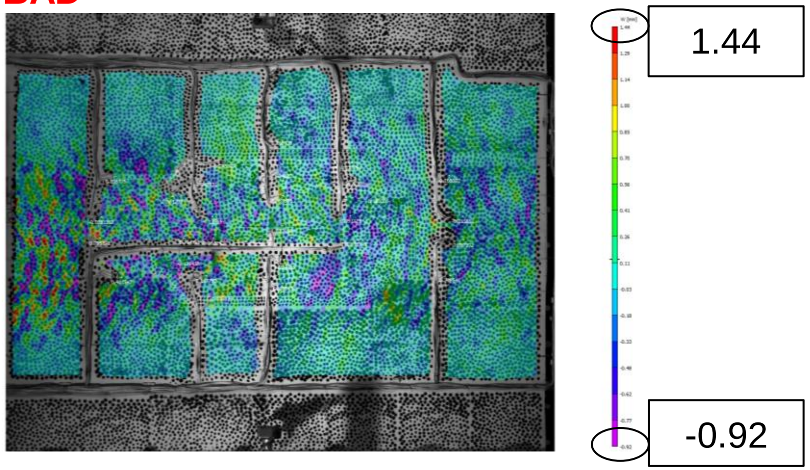
Examples of GOOD vs BAD experimental setup

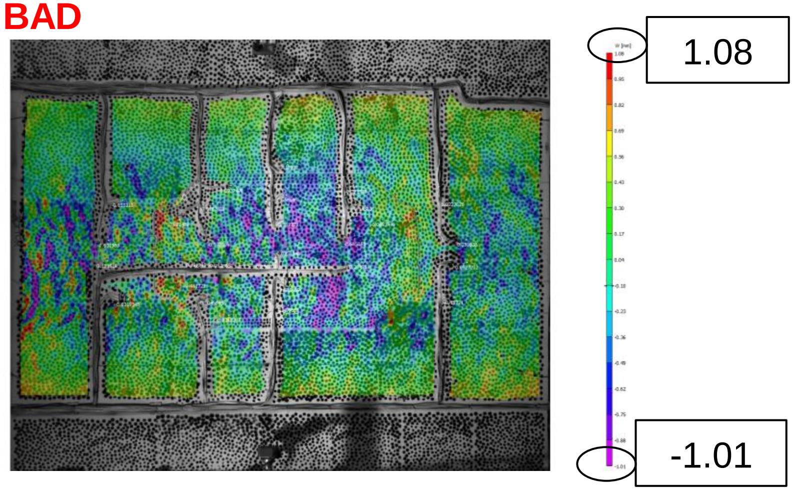
Out of plane displacement (W) at **0 kN** loading	Out of plane displacement (W) **before failure**
GOOD	GOOD





BAD	BAD





What do we do in Airbus today?

- Top-Down Evaluation – comparison with a standard e.g. strain gauges, LVDTs
- Type A simple noise floor evaluation by capturing multiple static images and analyzing displacements
- Experience based e.g. artefacts, discrepancies, sigma values, projection errors

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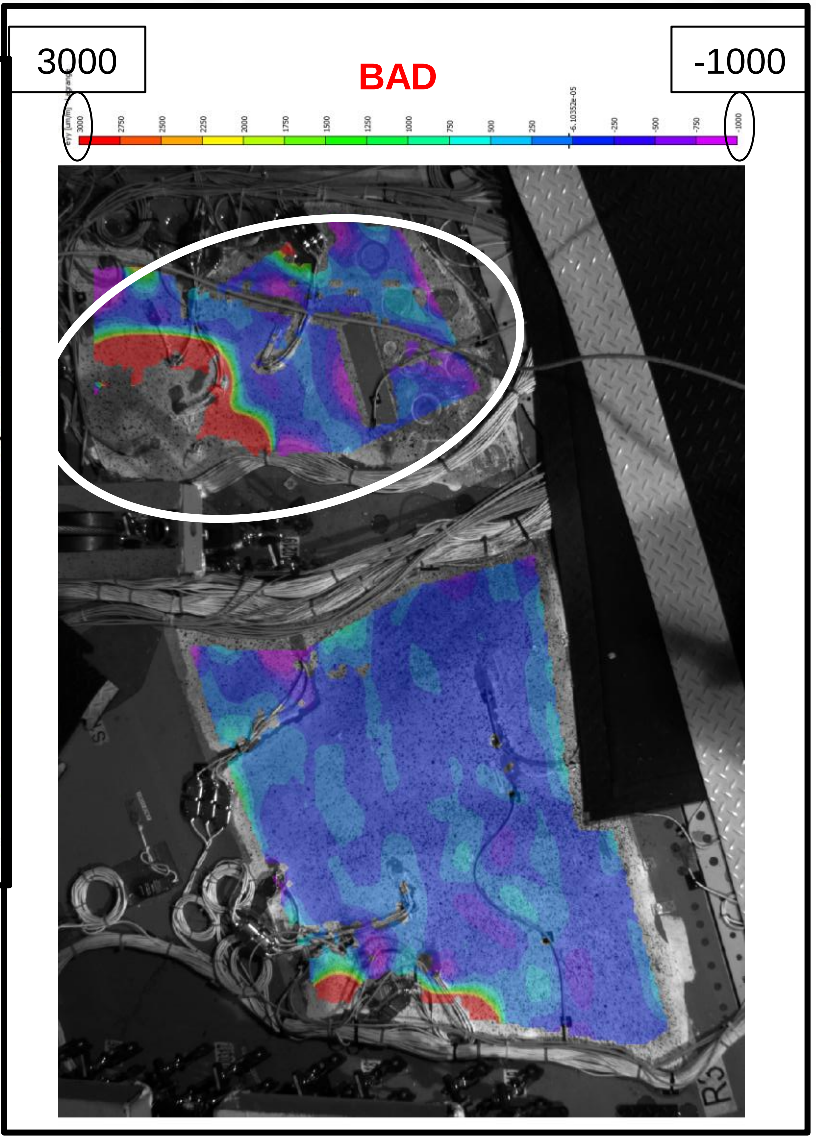
Examples of GOOD vs BAD experimental setup

Strain maps of (different) specimens at the same area



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How do I use this uncertainty information?
How does it propagate into derived data?

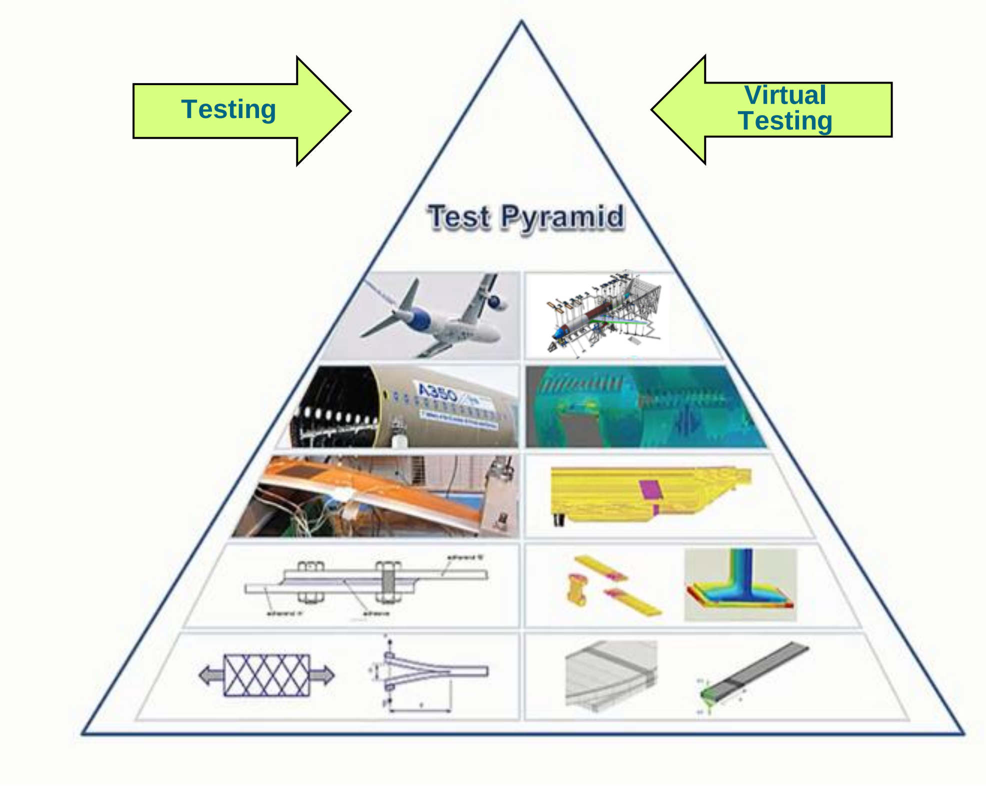
Validation of simulations

Why to use advanced measurements?

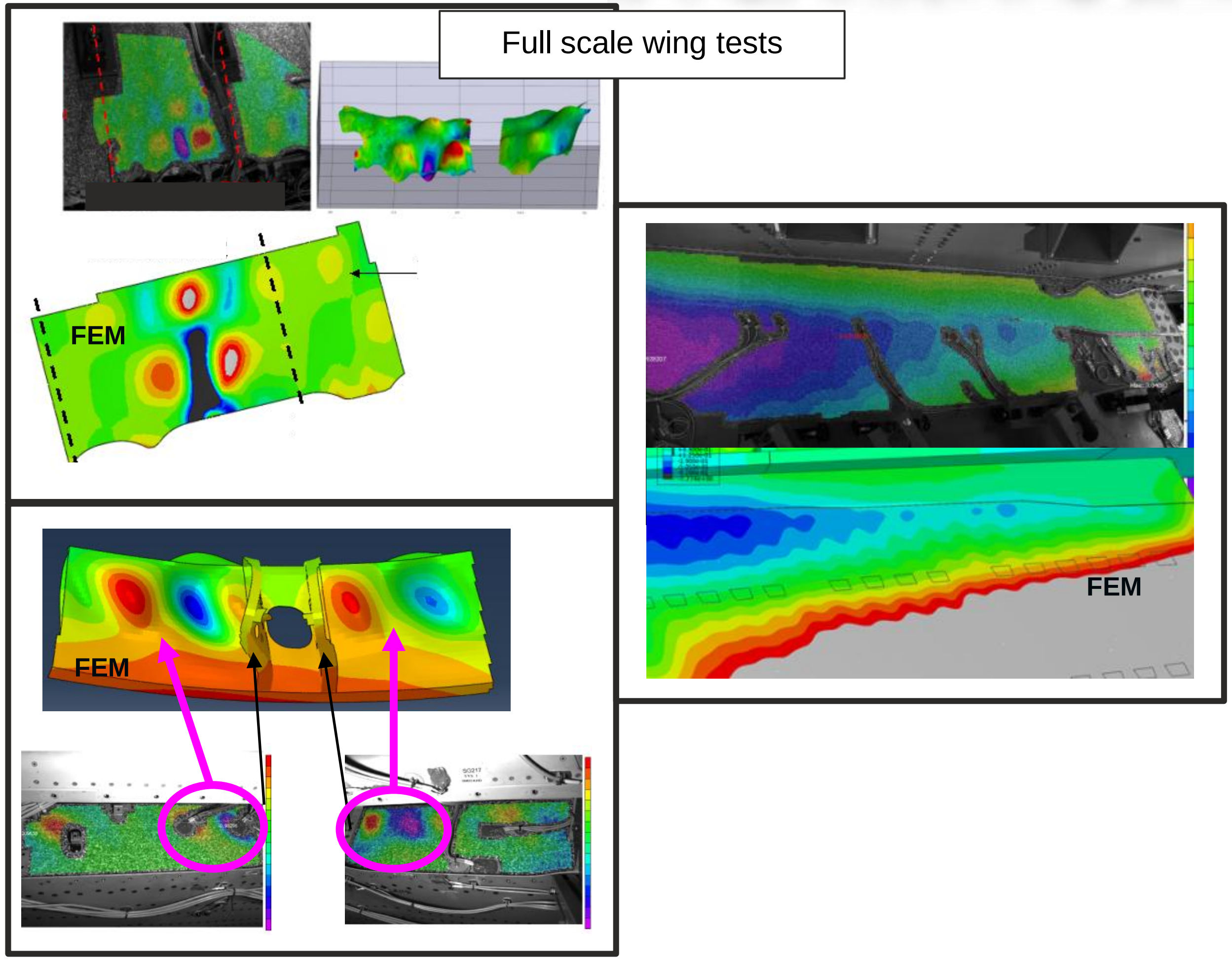
- To support the Predictive Virtual Testing philosophy
- To allow earlier use of simulation in design, in particular as a means of compliance for certification
- Validation of next generation numerical capabilities
- To enable smarter decision makings

Benefits

- Robust quantitative validation with reduced lead times in the analysis.
- Increased confidence in simulations which will result in fewer unexpected events, reduced risks and defined uncertainties
- Reduced number of test specimens
- Reduced inspection time
- Reduced lead time
- Faster and cheaper testing

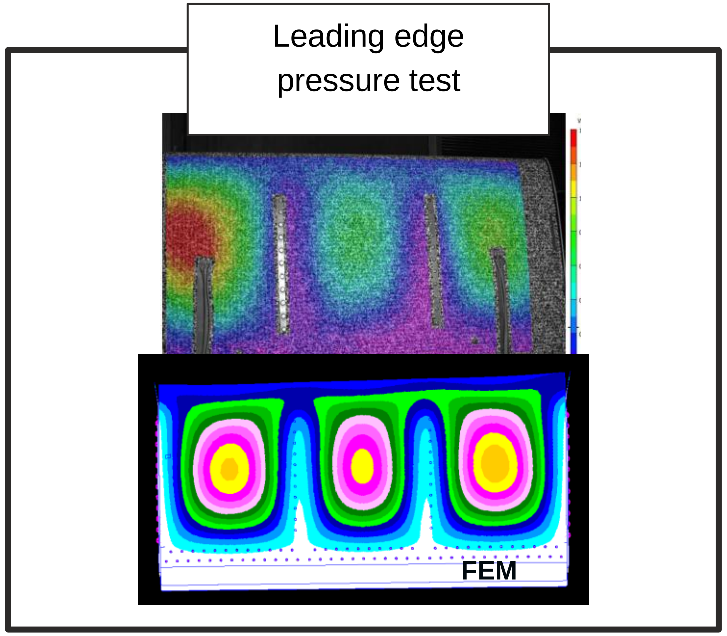


Validation of simulation using DIC QUALITATIVE!



Validation parameters:

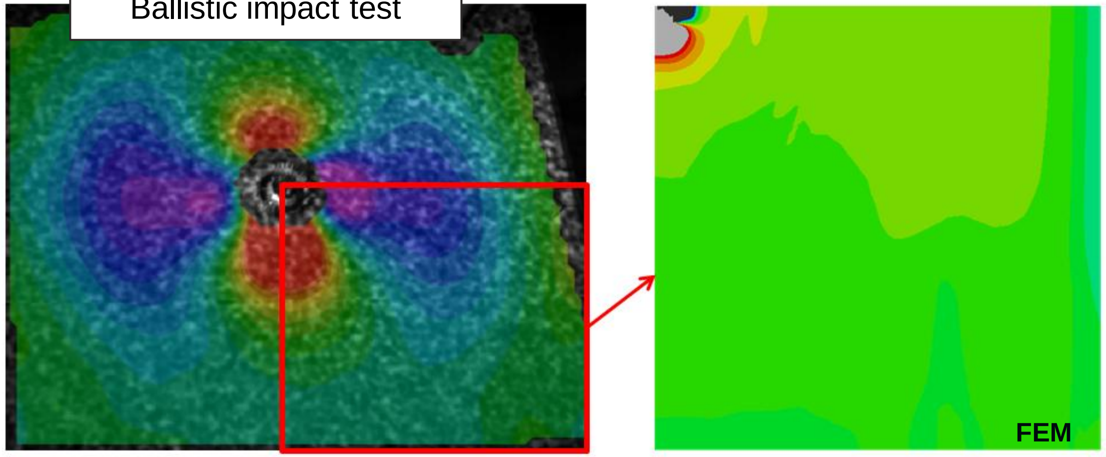
- Global displacements (behaviour) and strain distribution
- Buckling behaviour
- Onset of buckling (non-linear behaviour)
- Onset of failure
- Out of plane displacement

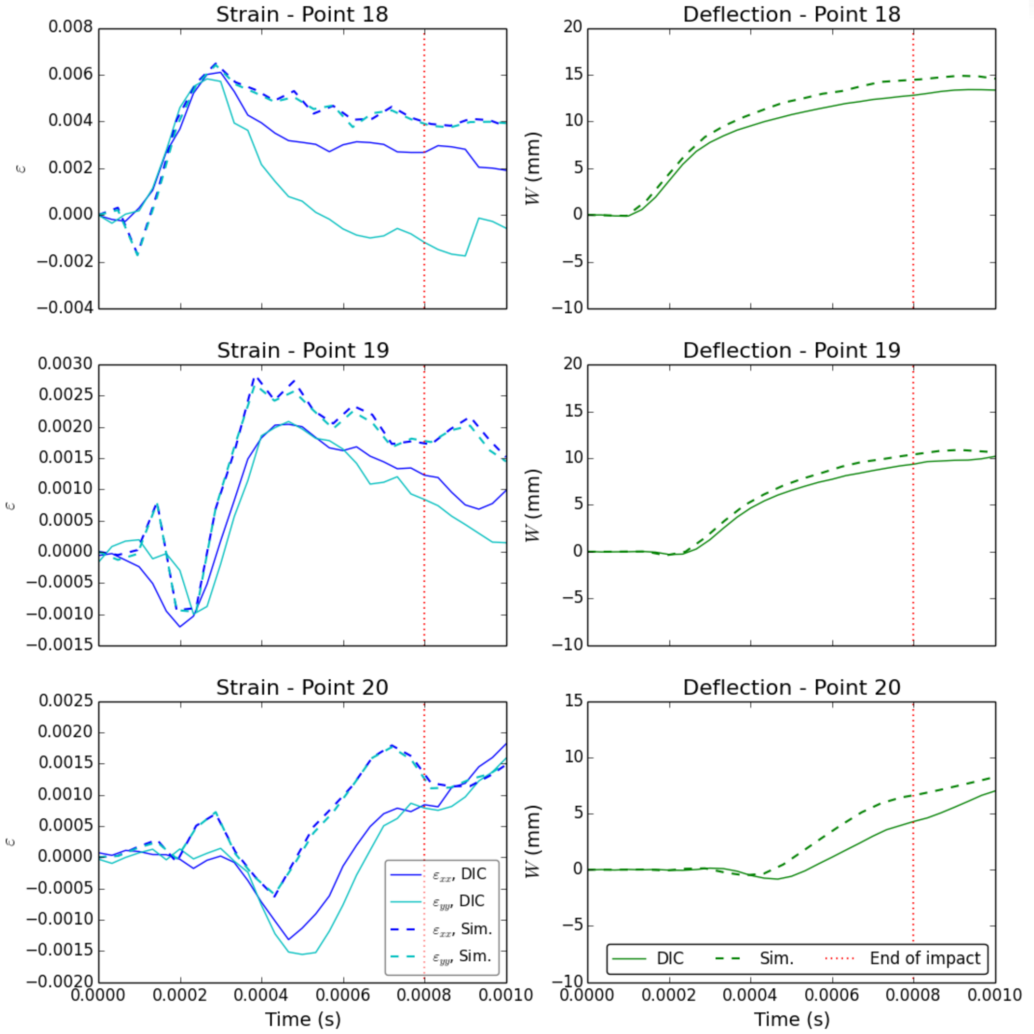


Validation of simulations using DIC

QUANTITATIVE/
QUALITATIVE

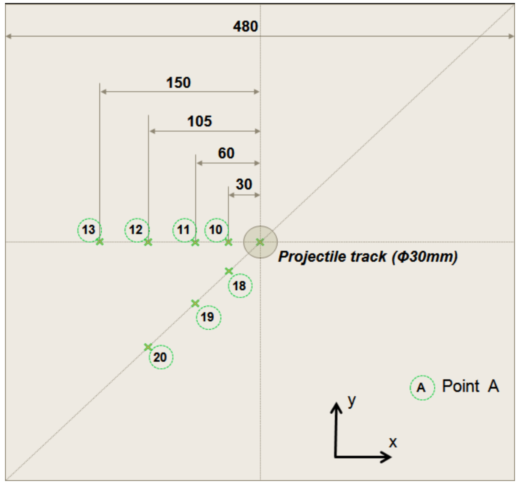
Ballistic impact test





Validation parameters:

- Out of plane displacement
- Strain values



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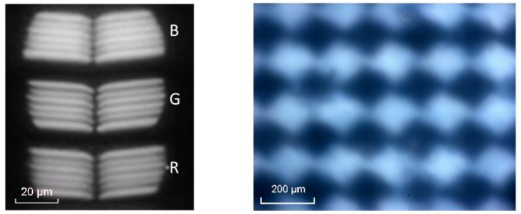
The FUTURE

How can we quantify the uncertainties reliably? Novel validation methodology for DIC

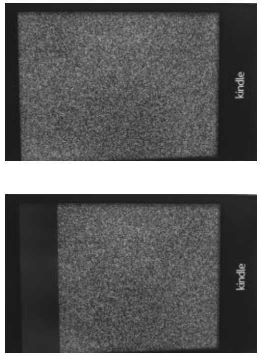
Novel validation

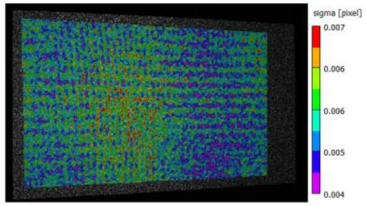
- Features
  - Traceable
  - Full-field
  - In-situ
  - In-plane
  - Scalable



(a) One LCD Pixel

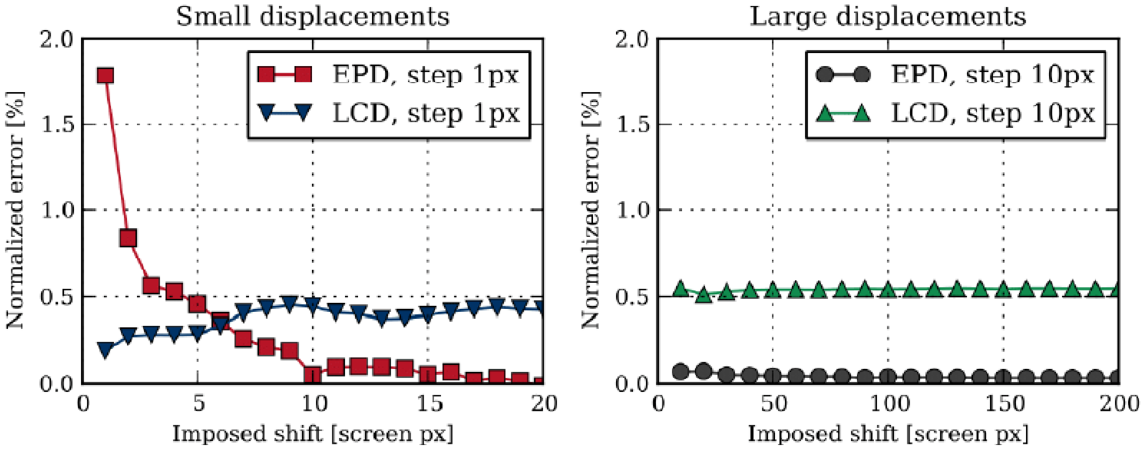
(b) EPD Pixel Array





- European patent EP3026632AP - Improvements in or Relating to Digital Image Correlation Systems

- A Traceable Technique for an In-Situ Full Field In-Plane Measurement Validation of Digital Image Correlation
  Eszter Szigeti, et al. – Optical Engineering



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The FUTURE

- Standardized and traceable DIC with defined uncertainties
- Smart data comparison (Test vs. Simulation) methodologies
- Automated decision making

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Thank you

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