HPS High Performance Space Structure Systems GmbH GERMANY

Validation of thermo-mechanical deformation of an in-orbit antenna

Third International Workshop on the Validation of Computational Mechanics Models

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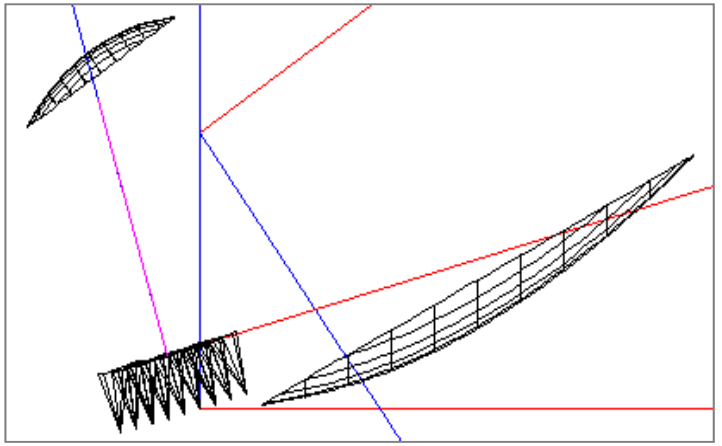
Part 1: Technical Concept

Highly Stable Antenna Technologies (STANT)

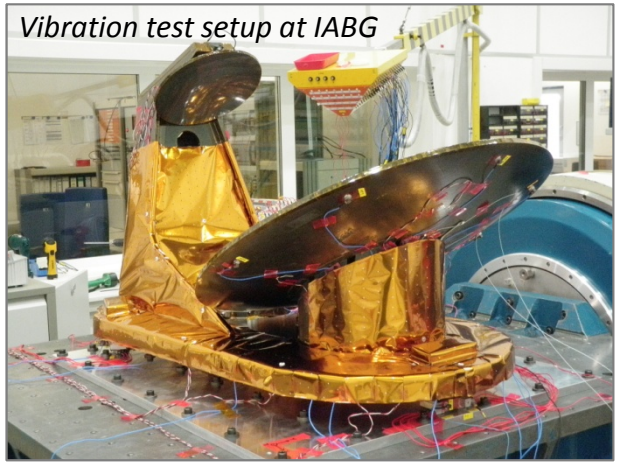
- ESA ARTES 5.2 activity
- Ka-band & Q/V-band
- 1 to 19 RF beams, European coverage
- Compact
- High thermo-elastic stability
- High stiffness to mass ratio
- Low heat transfer between S/C and antenna
- Neither reflector coating nor sunshields
- For CFRP & Alu-satellite top decks
- Mass below 10kg
- 1 eigenfrequency > 100Hz
- In-orbit deformation < 20µm RMS.



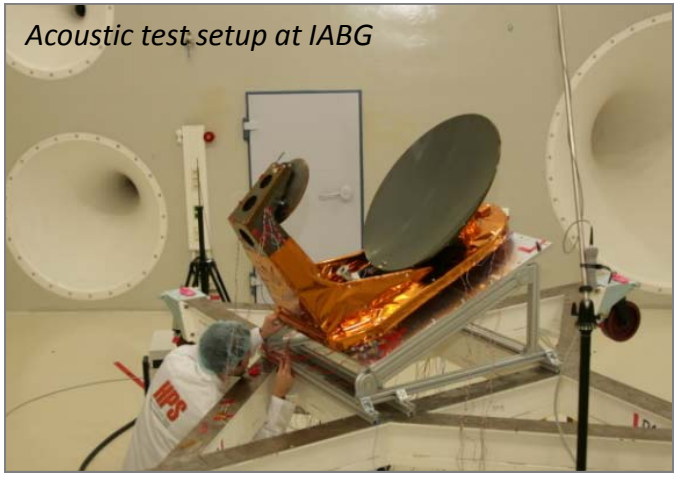
Gregorian dual reflector configuration

STANT Testing

Vibration test setup at IABG

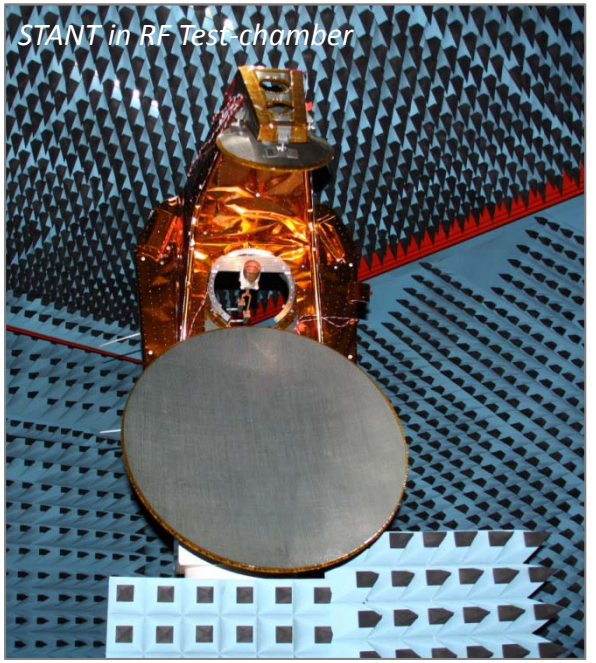


Acoustic test setup at IABG



STANT in TV-chamber

STANT in RF Test-chamber

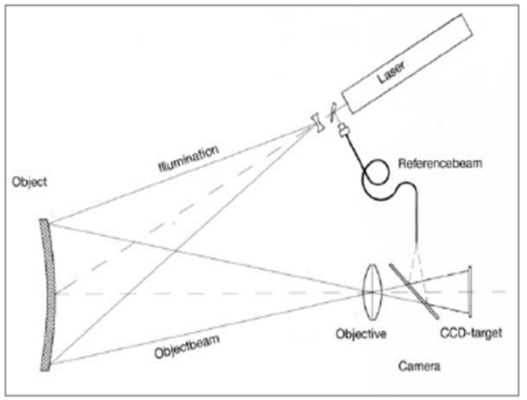


Highly Stable Antenna Technologies (STAN'D) Testing

Part 2: ESPI

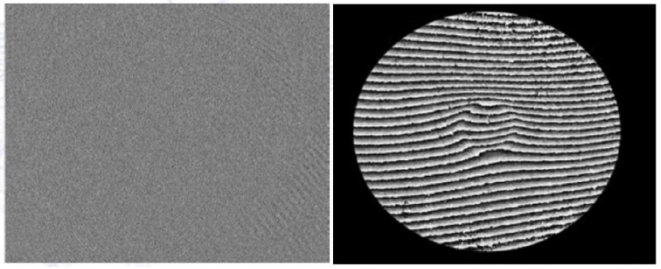
Electro Specle Pattern Interferometry

- Optical measurement:
  - Illuminate target with pulsed laser
  - Record back scattered light “Speckle Pattern”
  - Compare with reference beam “PhaseImage”
  - Phase image remains constant as long as geometry between laser, camera and object does not change



ESPI optical path

- ESPI data analysis:
  - Motion of object causes change of phase image
  - Difference of two phase images includes rigid-body and elastic displacement) information of object in terms of inter-ferometric fringes “Interferogram”
  - Unwrapping and post processing of the interferograms separates rigid-body motion from elastic deformation part by best fit calculation for rigid-body part



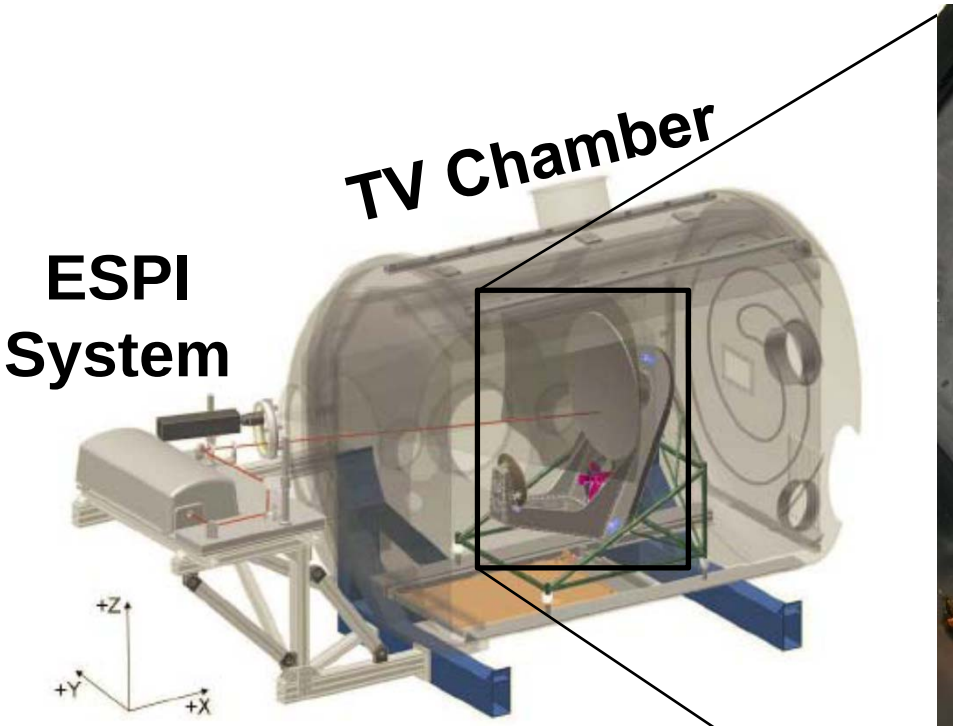
Specle pattern Interferogram

- Accumulation of many successive interferograms results in total deformation map

Highly Stable Antenna Technologies (STANT) Testing

Part 3: STANT Thermo-Mechanical Deformation Test and Modeling

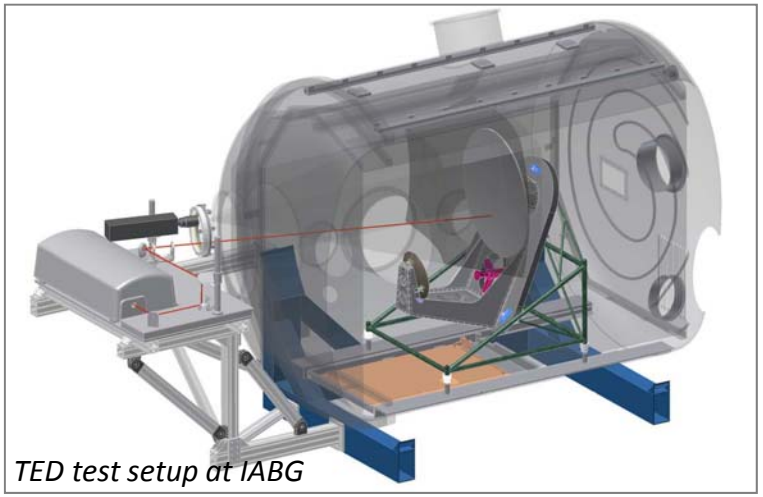
STANT TED Test Campaign



STANT Antenna Reflector

Thermal Cycling and Thermo-Elastic Test

- 3 in vacuo cycles from -120 C to +120 C
- TED-measurement of main reflector
- Challenges
  - Any rigid-body motion must be limited in magnitude
  - Vibration isolation of the chamber
  - Thermal isolation of fixture from chamber
  - Window (spectral transmissibility for external sensor)
  - Reflector surface (optical contrast at reflector level)
  - Data processing
- Measurement via ESPI
- Results
  - No failure and low TED

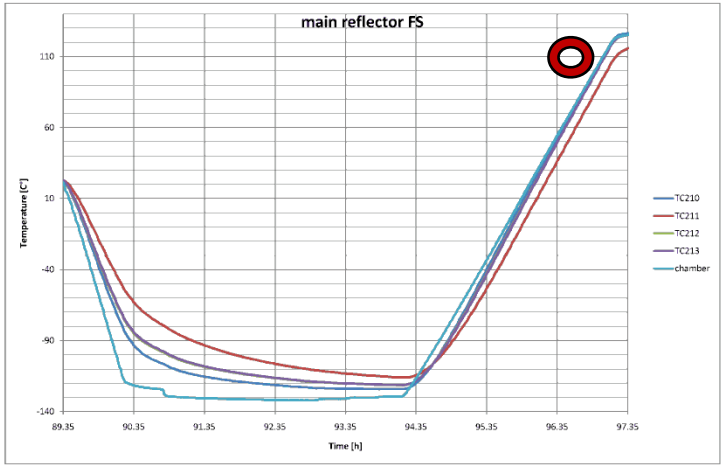


TED test setup at IABG

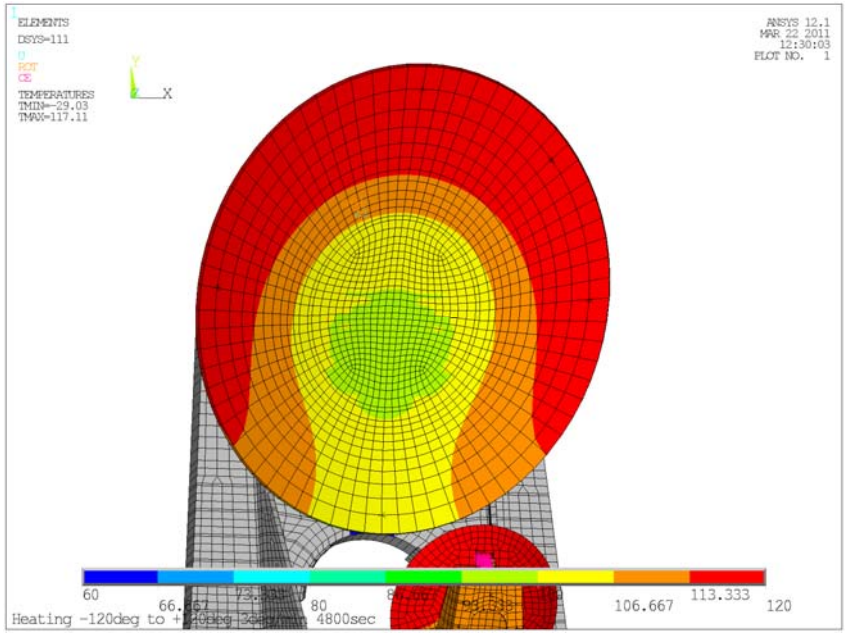
STANT in TV-chamber

Thermal Analysis

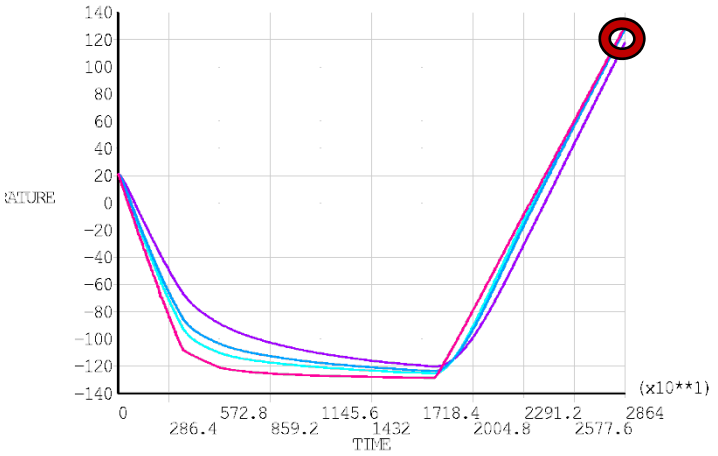
- Correlation of thermal analysis and measured temperatures of TV cycling test
- Mapping of temperature results to structural model and analysis of corresponding deformations



Measured temperatures on MR at cycle 1



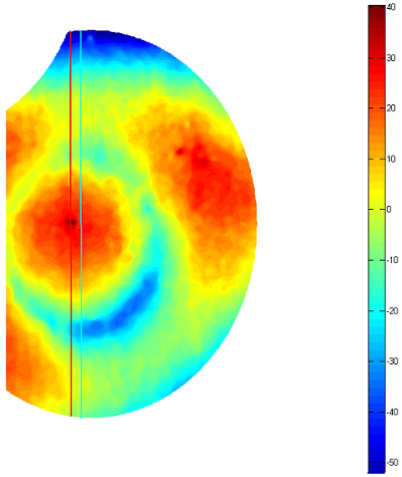
Simulated temperatures on MR at end of cycle 1



Simulated temperatures on MR at cycle 1

Initial Correlation

TED Test



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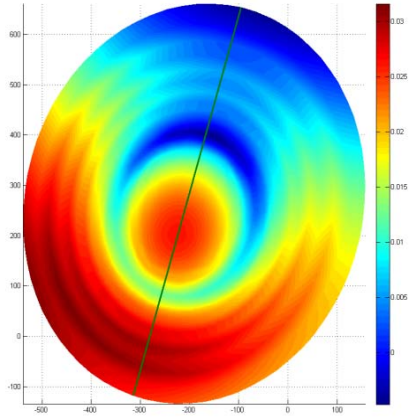
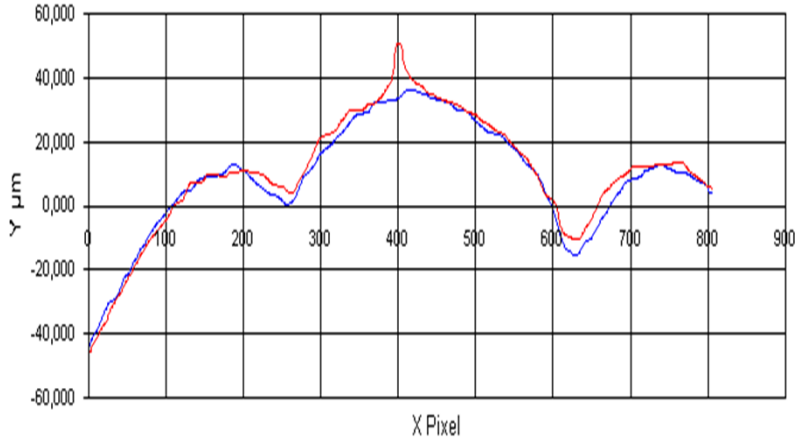
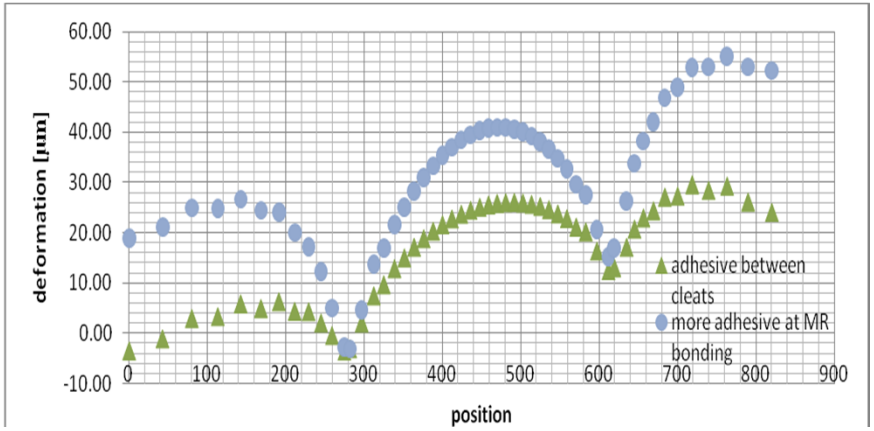


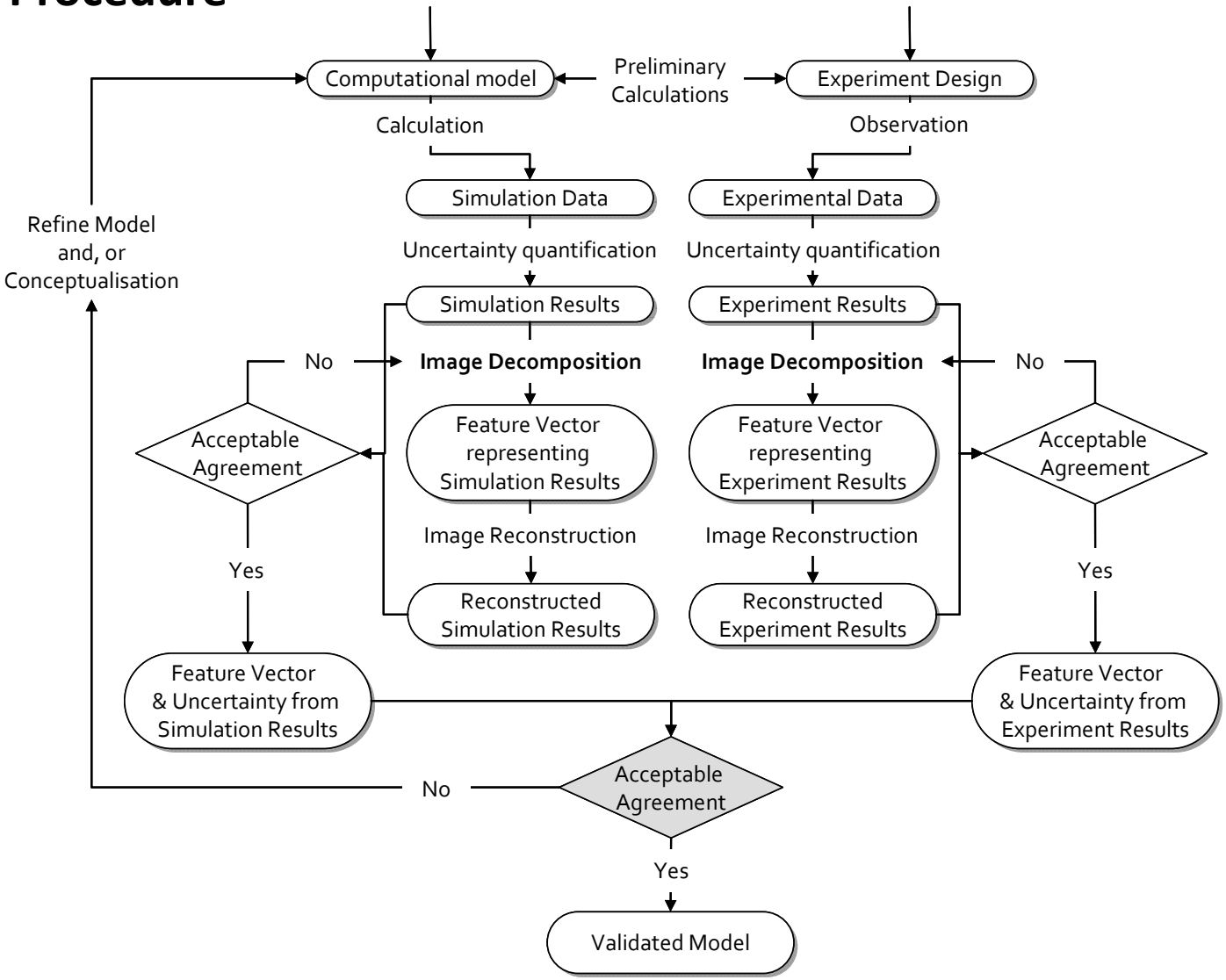
FEM





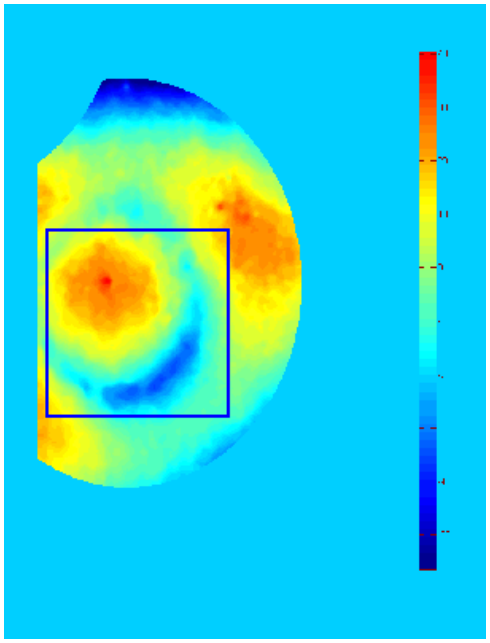
Qualitative comparison!

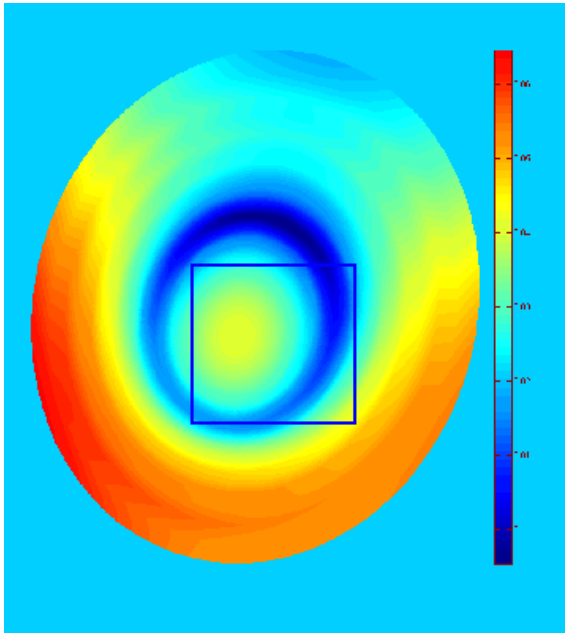
Validation Procedure



Validation Procedure (STANT)

TED Test

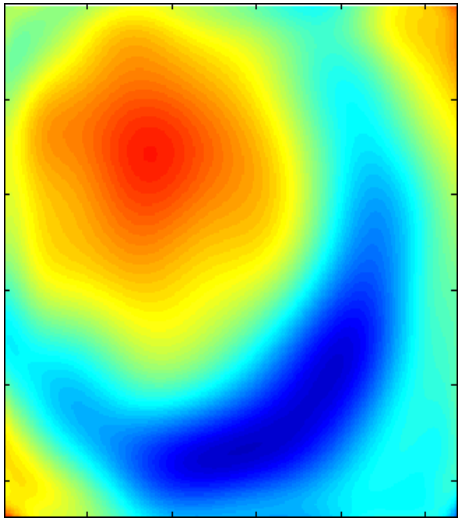




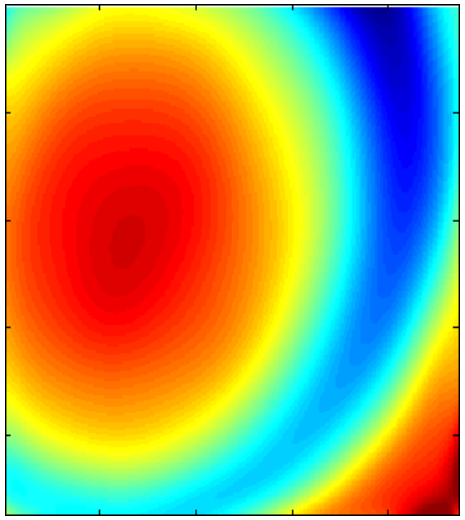
FEM

Selection of region of interest to be used for image decomposition

Validation Procedure (STANT)

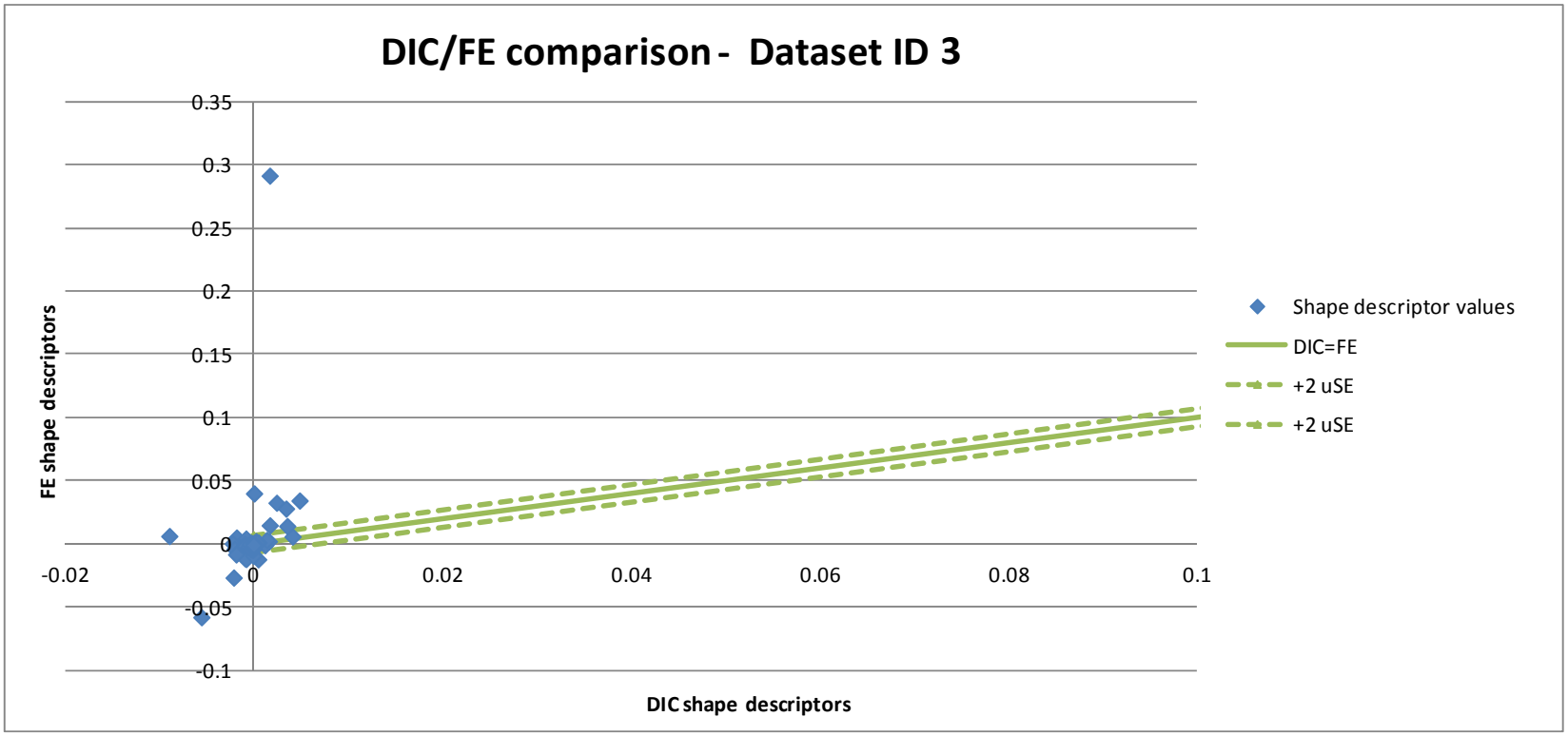


Decomposition of ESPI
UE=0.002



Decomposition of FEM
UM=0.006

Validation Procedure (STANT)



Ucal=0.003

UE=0.002

USE=0.0036

$$u(s_E) = \sqrt{u_{cal}^2(\varepsilon) + u_E^2}$$

Highly Stable Antenna Technologies (STANT) Testing

Part 4: Conclusion and Outlook

Conclusion

Model representation

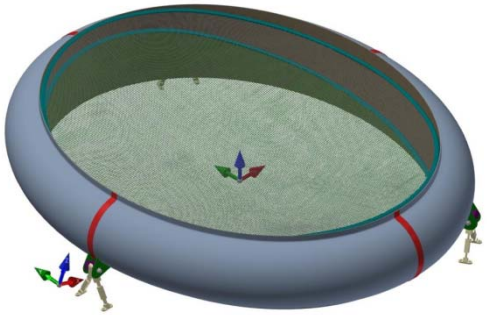
- Reflector deformation is sensitive to bonding layer
- Bonding layer varies across circumference of I/F
- Varying layer is not represented in model
- VANESSA method might help, e.g. in parametric analysis

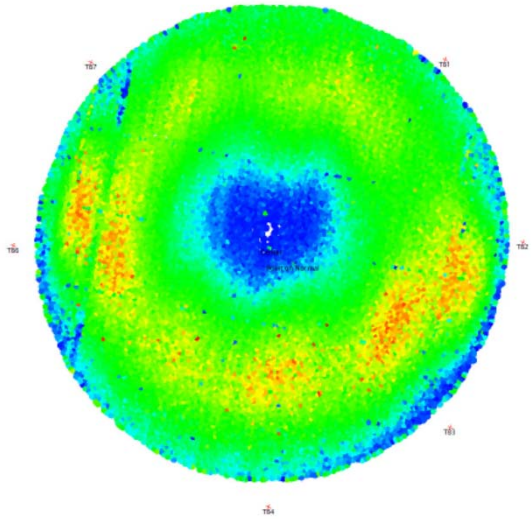
Region of interest

- Test was not intended to be used for VANESSA methodology
- No complete test data (some regions missing)
- Orientation and alignment of test data not known
- Test data and FEM data input files don’t match (size, maybe orientation, maybe alignment)
- ROI cannot be selected properly, best guess approach

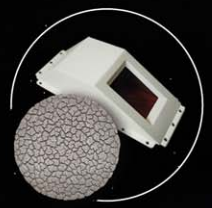
Outlook

- References on structure would help for ROI selection
- Alignment and orientation should be well known
- Representative/sufficient test data coverage
- Consider for VANESSA methodology during test planning and test activity



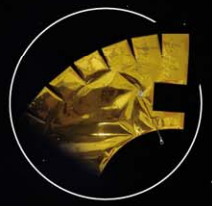


Thank you for your attention.



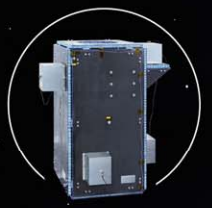
Launcher and Re-entry Components

Equipment, Instruments



MLI

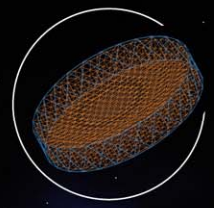
Radiators



Satellite Structures

Antennas

Reflectors



Deployable Structures

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