EN 9100

ISO 9001

BOOSTING SCIENTIFIC KNOWLEDGE

CleanSpace Industry Days 2023

MICE Qualification Results and Future Use

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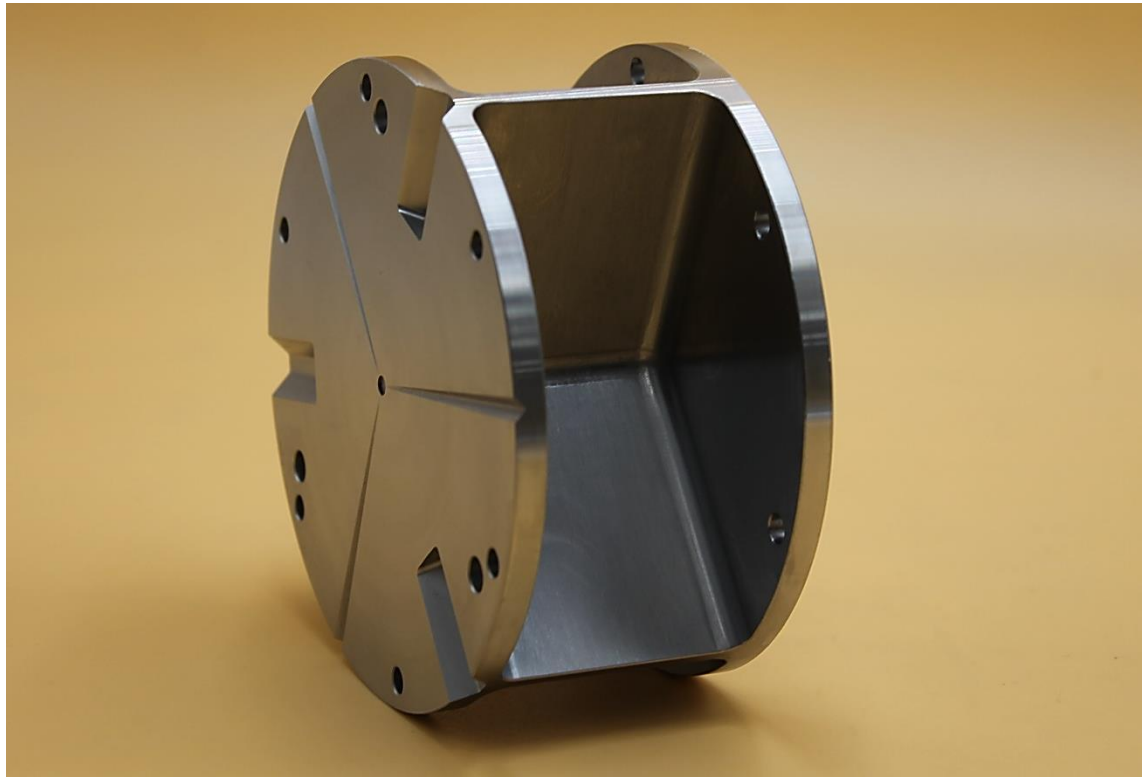
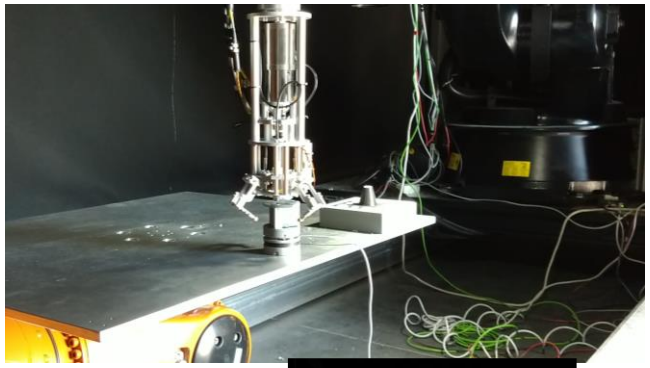
MICE (Mechanical Interface for Capture at End-of-Life)

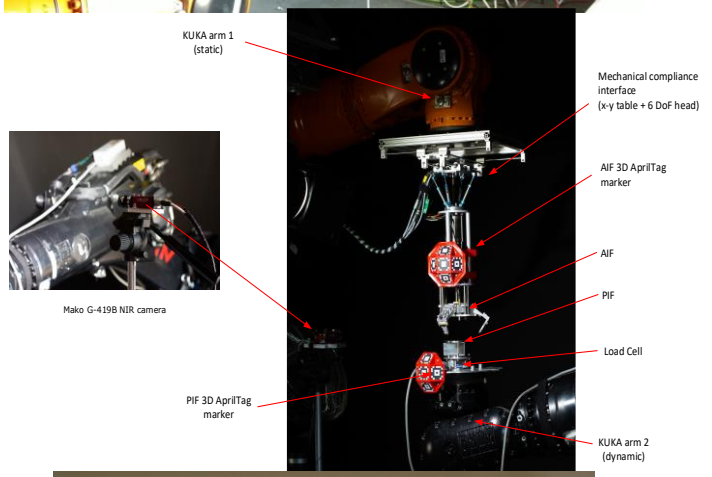
- Is a single-part interface
- objective is to enable non-cooperative capture of satellite after the end-of-life

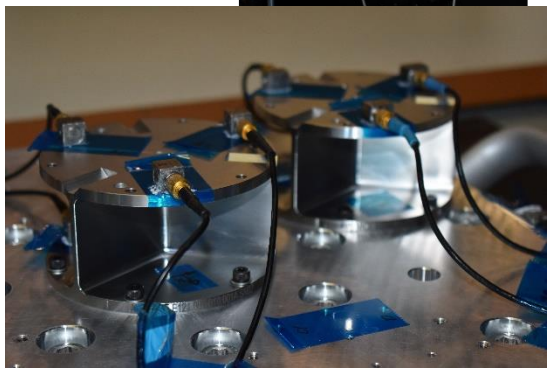


Developed under several ESA Clean Space activities by a consortium formed by GMV and AVS.

- **PRINCE** (2019): MICE passive and active I/F breadboarding and critical functional testing (GMV's platform-art© facility) to verify concept. TRL 4
- **MICE** (2021-2022): MICE passive interface design iteration. Full performance and functional verification (GMV's platform-art© facility) on EM. TRL 6
- **MICE Q** (2022-2023): Design iteration to increase compatibility with active interface solutions. Qualification Test Campaign on 2xQM. QR has been declared successful. TRL 7

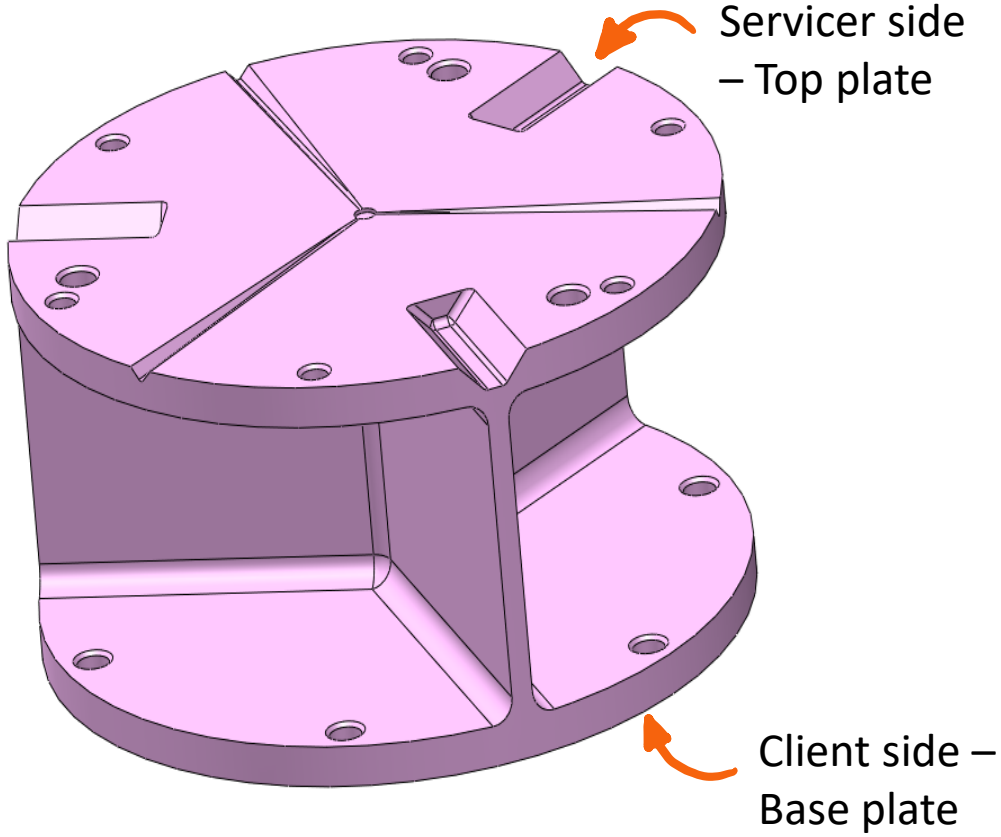




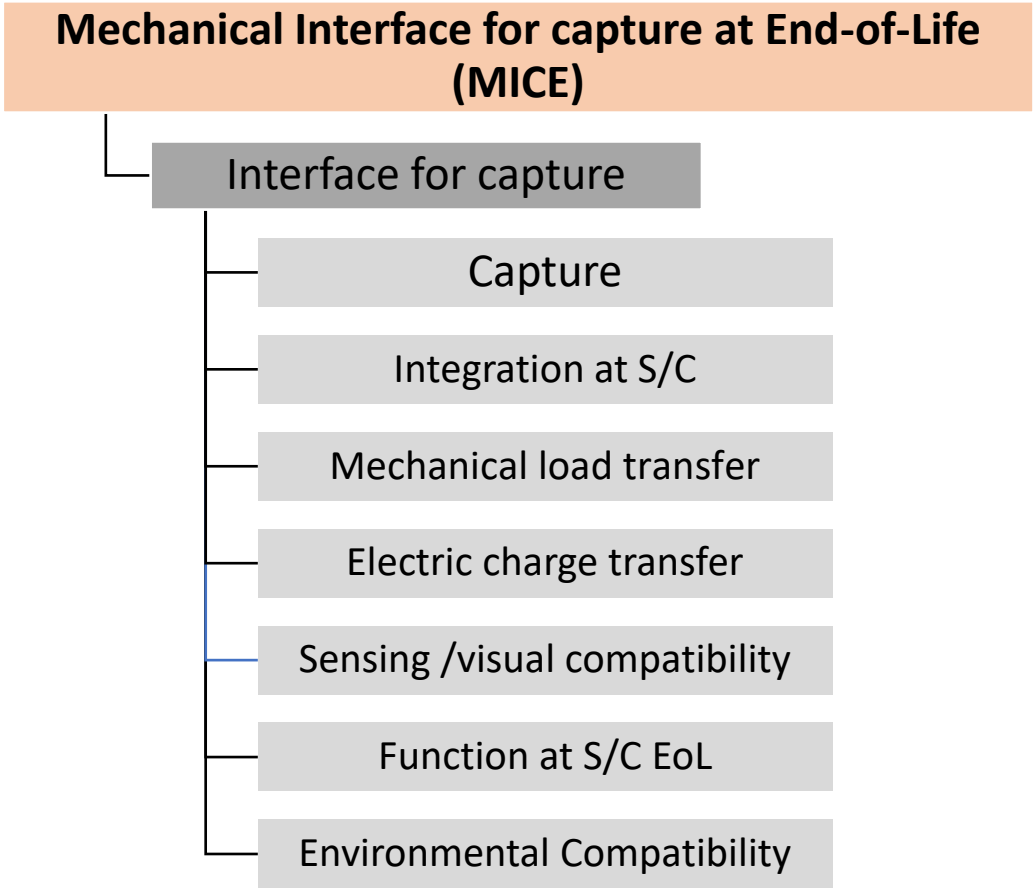


Main characteristics:

- Passive interface
  - Only 1 part, no movable components
- Mass: 0.719 kg
- MICE outer diameter: Ø98 mm
- MICE height: 50 mm
- Material: Stainless Steel 15-5 PH H1025
  - Selected to resist loads (850 N & 180 Nm) & extreme temperatures (±160°) at End-of-Life
- No tribological coating
  - Extended lifetime + minimise scratch during capture



Functions and features



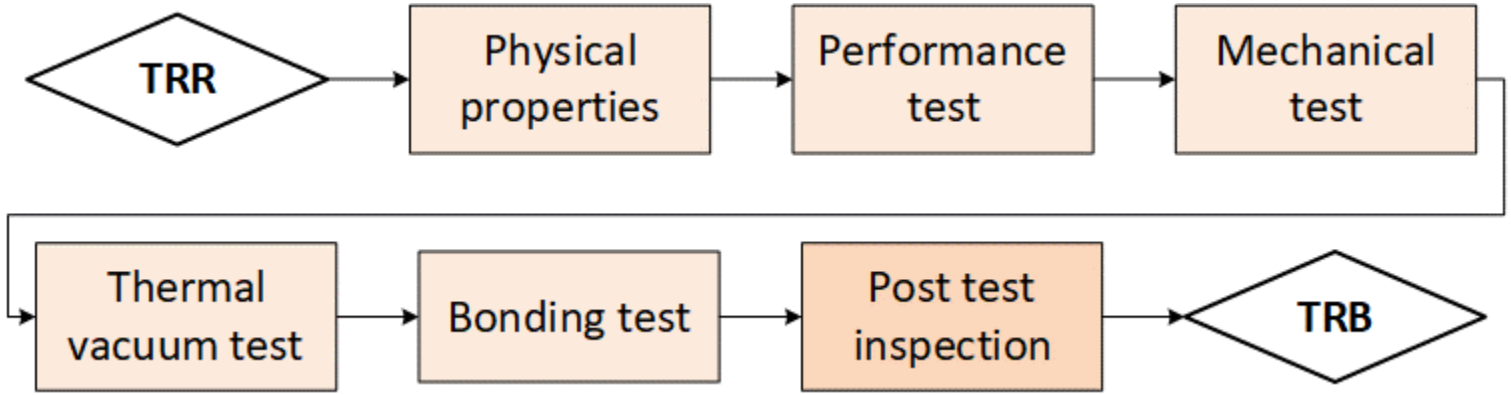
- Geometry design to facilitate geometrical **capture without contact**.
- Repeatable captured position
- Integration at S/C: **6xM4 screws + 2 pins**
- Compatible with **850 N & 180 Nm**
- Facilitate transference of **electro-discharge** at first contact
- Compatibility with wide range of Active IF **sensing methods** to enable capture
- Top surface sand-blasted to minimise reflections and increase compatibility with **visual systems**
- As a EoL assistance element, life is **>12.5 years**

Qualification test campaign objectives:

- To verify MICE against the requirements with verification method by test
- To qualify MICE design for future use in flight

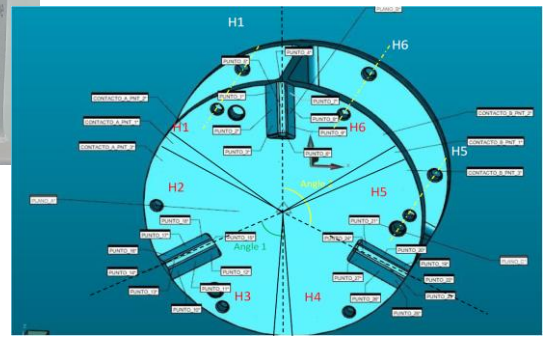
2 MICE units tested together to verify repeatability and workmanship: SN01 & SN02

Qualification test flowchart:



Objective

Verify compliance with maximum loads (850N & 180Nm) in several modes and directions

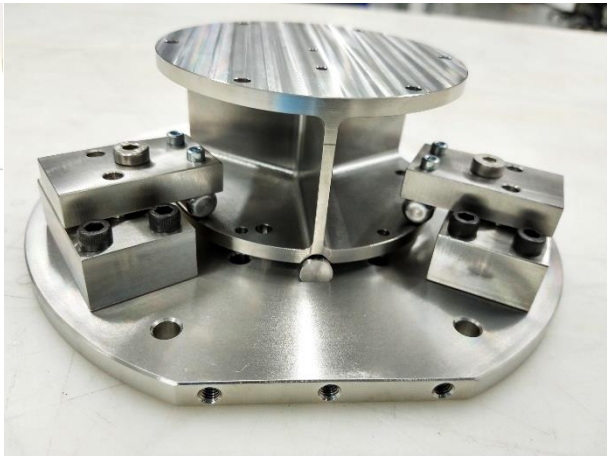


Procedure

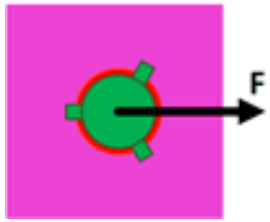
Initial dimensional measurement with CMM

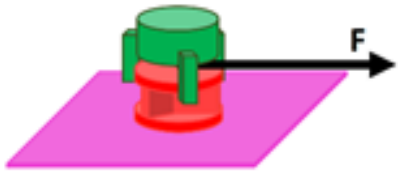
- For each load case:
    1. Quasi static application of load and torque
    2. Repetition of dimensional measurement to quantify possible plastic deformations.

GSE is used to reproduce contact between MICE and a grasping Active Interface

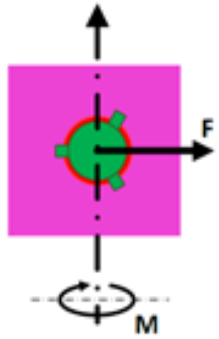


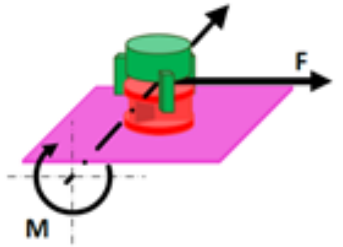
Load cases

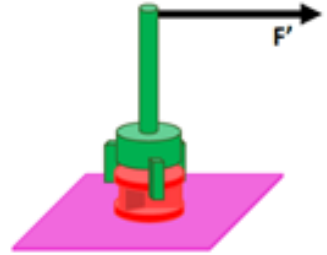




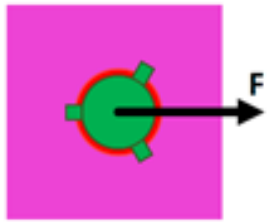
Case 1: Transversal force

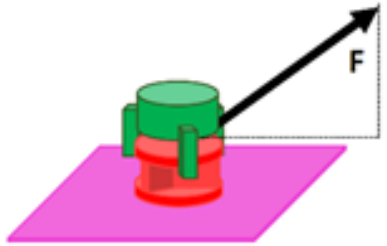




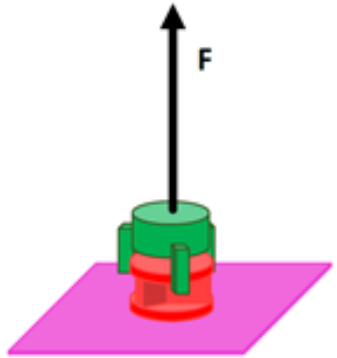


Case 2: Transversal force + momentum

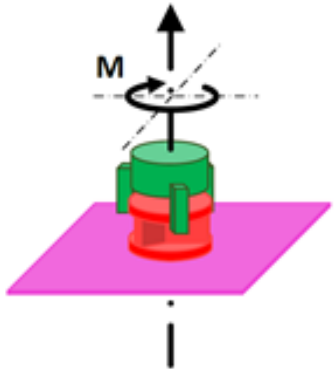




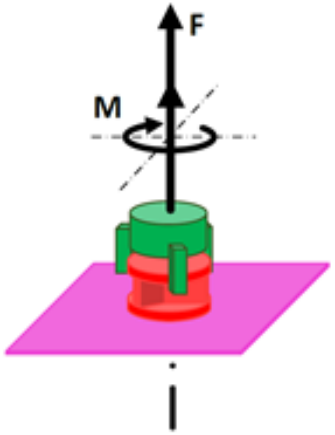
Case 3: Force at 45 deg



Case 4:
Axial force

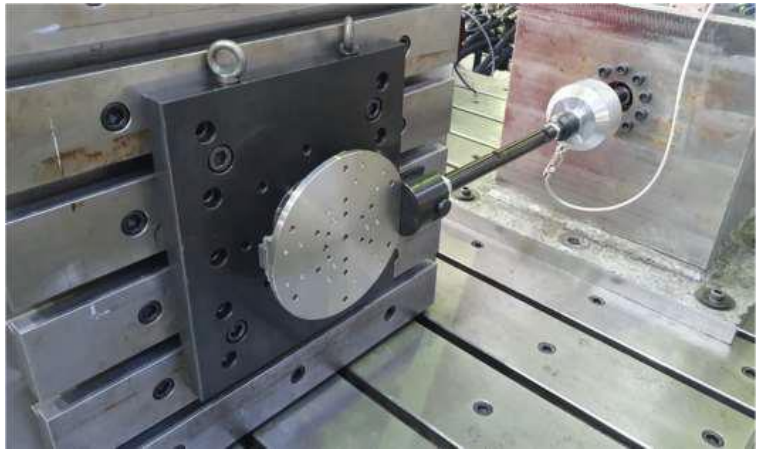


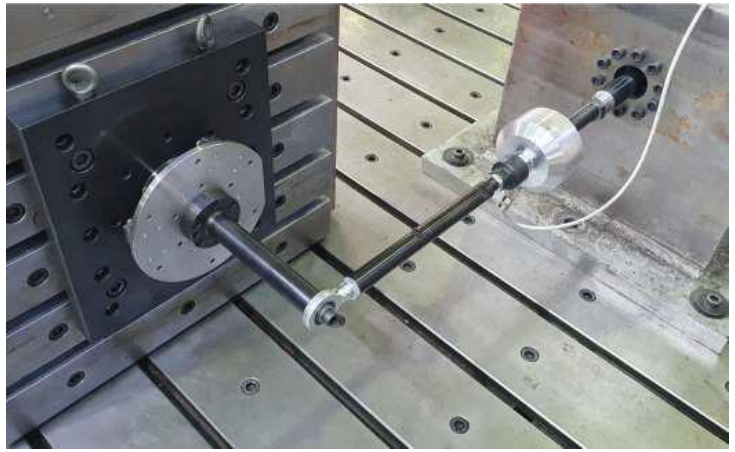
Case 5:
Pure torsion

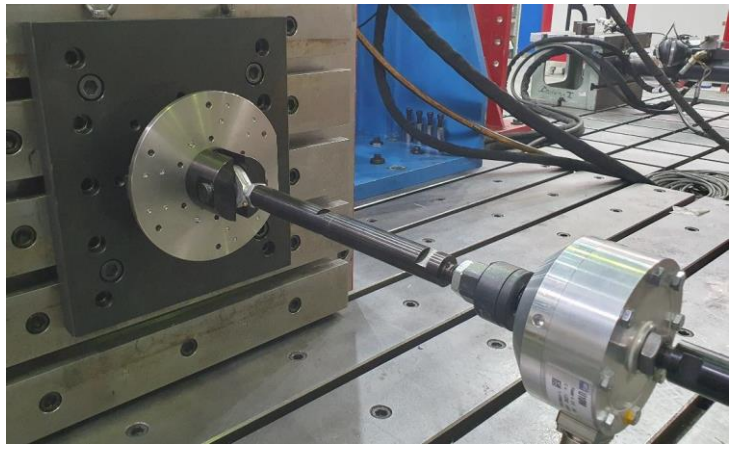


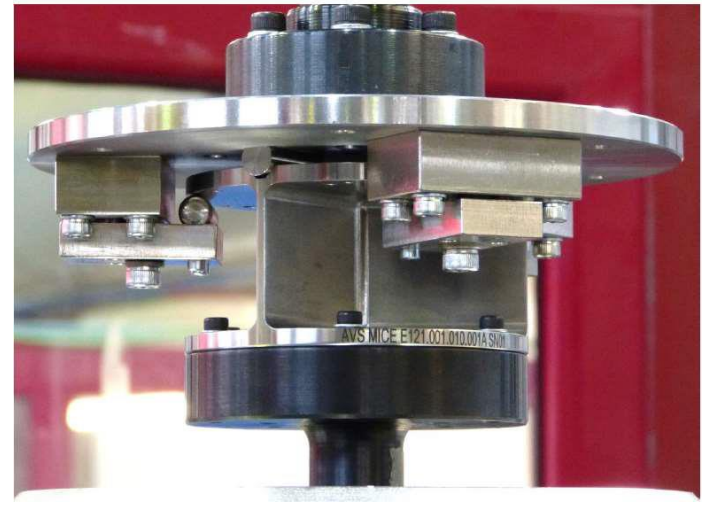
Case 6: Combination of axial force and torsion

Test Assembly









Results

Related to **stiffness curves**:

- Target values of load and torque have been reached
- Displacement & rotation measurements acceptable, considering they include not only the sample behaviour but also the full mechanical chain of load application
- Behaviour of MICE SN01 and MICE SN02 is equivalent

Related to **dimensional measurements**:

- Maximum deviation at the end of test plan vs. baseline :
  - 0.008 mm for MICE SN01
  - 0.009 mm for MICE SN02
  - Acceptance criterion: max deviations < +/-0.025 mm vs. baseline measurements before testing

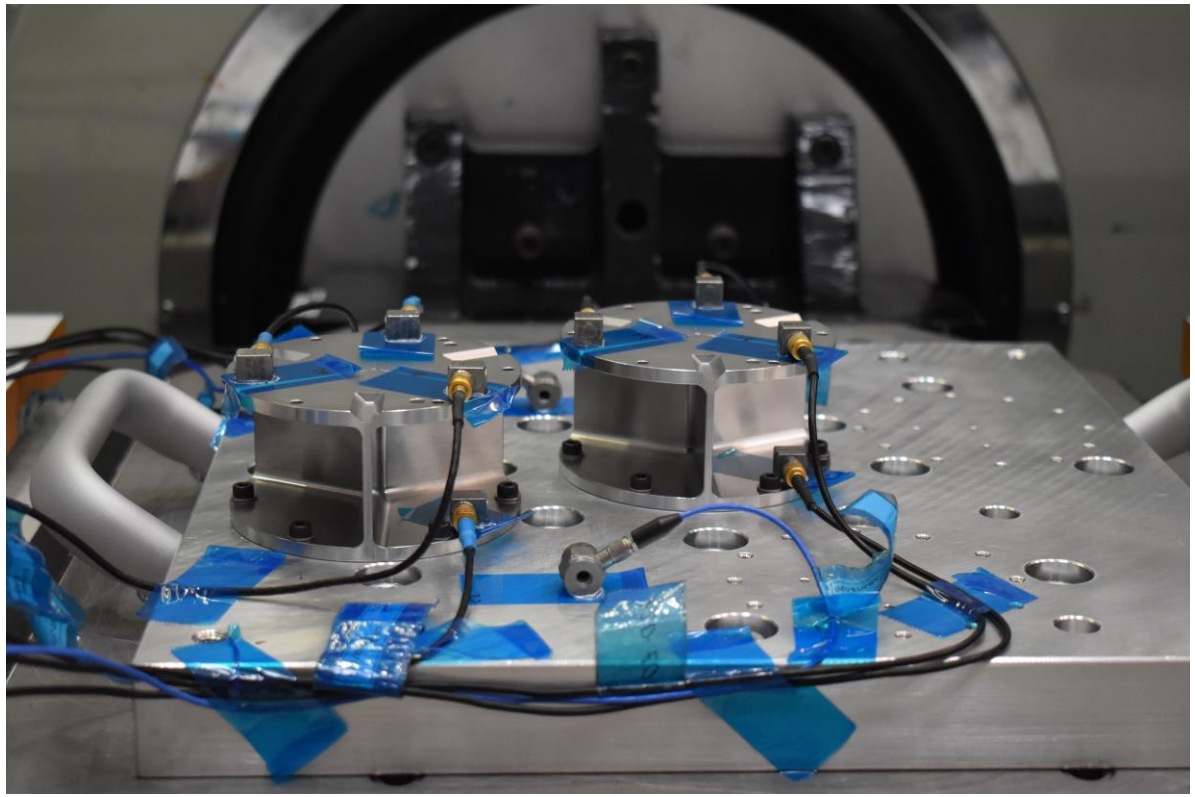
Conclusion: results are compliant with acceptance criterion fixed to evaluate permanent deformation

Objective

Expose the specimen to simulations of the dynamic response environment during handling, transportation, launch and operation.

Procedure

Test specimen	Test axis	Test Description
MICE-Q SN01 and SN02	X axis Test	Sine low
		Sine Qualification
		Sine low
		Random Qualification
		Sine low
	Z Axis Test	Sine low
		Sine Qualification
		Sine low
		Random Qualification
		Sine low
	Y Axis Test	Sine low
		Sine Qualification
		Sine low
		Random Qualification
		Sine low



Loads

Sine low level (X, Y and Z axes)

Frequency Band (Hz)	Reference level
5 - 2000	0.5 (g)
Sweep rate: 2 Oct/min	
1 sweep up	

Sine qualification level (X, Y and Z axes)

Frequency Band (Hz)	Reference level
5	20.445 (mm pk-pk)
27	30 (g)
125	30 (g)
Sweep rate: 2 Oct/min	
1 Seep Up	

Random qualification level (X and Z axes)

Frequency Band (Hz)	Reference level
20-70	+3 (dB/Oct)
70	0.362 (g^2/Hz)
100-300	1.5 (g^2/Hz)
400	0.358 (g^2/Hz)
1000	0.07815 (g^2/Hz)
1000-2000	-5 (dB/Oct)
Overall level	23.57 grms
Duration	120 s

Random qualification level (Y axis)

Frequency Band (Hz)	Reference level
20-70	+3 (dB/Oct)
100-300	1.5 (g^2/Hz)
1000	0.203 (g^2/Hz)
1000-2000	-5 (dB/Oct)
Overall level	29.3 grms
Duration	120 s

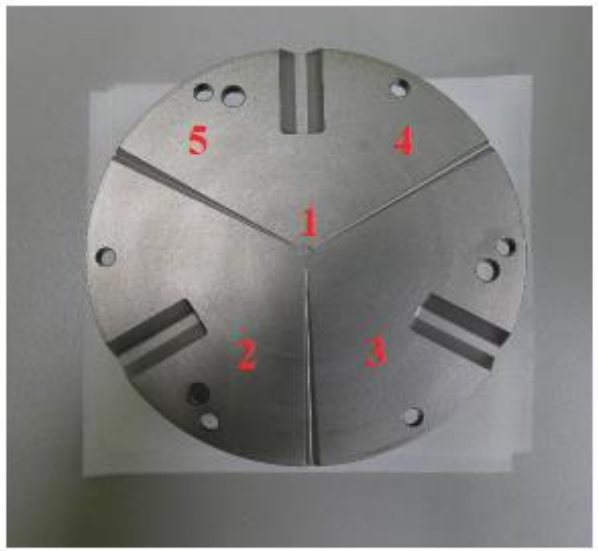
Results

- First eigenfrequency at 903.7 Hz (torsional model along the central vertical axis of the unit) → ok wrt. analyses (901 Hz)
- In vertical cases (Y axis) frequency increases 10% wrt. the previous tests (consistent along whole Y axis tests) → likely due to the cross-axes effect
- Incidence with post-random Z spectrum:
  - Shift of 12% between 1200 Hz and 1400 Hz, on both units →not likely related with local settlements
  - Low sine test repeated and values ~1220 Hz → Effect attributed to local effects at the accelerometers

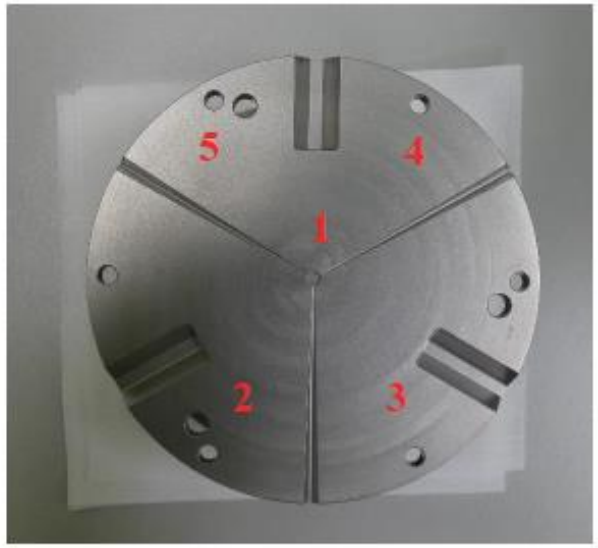
Conclusion: Test results in good agreement with analyses. No damage was detected during the overall vibration (QM levels) test sequence.

Objective

To characterize each sample of MICE (SN01 and SN02) on 5 points of the top plate in terms of: Reflectance curves in the range of UV-Vis-NIR; Solar Absorptance and Infrared Emittance.



MICE QM SN01



MICE QM SN02

Results

- Values measured are not compliant with the requirement:

	Requirement value	Test value
Emissivity at BOL	0.15	0.22
Emissivity at EOL	0.3	Not done
Absortivity	0.6	0.53/0.54

  - Values stated in the requirement are generic values for stainless steel from material database w/o surface treatment
  - MICE top surface measured is sand-blasted, and results are coherent with the expected behaviour of rough surface for metals

Conclusion: Difference wrt requirement is justified and do not affect neither the performance nor the qualification of MICE.

Objective

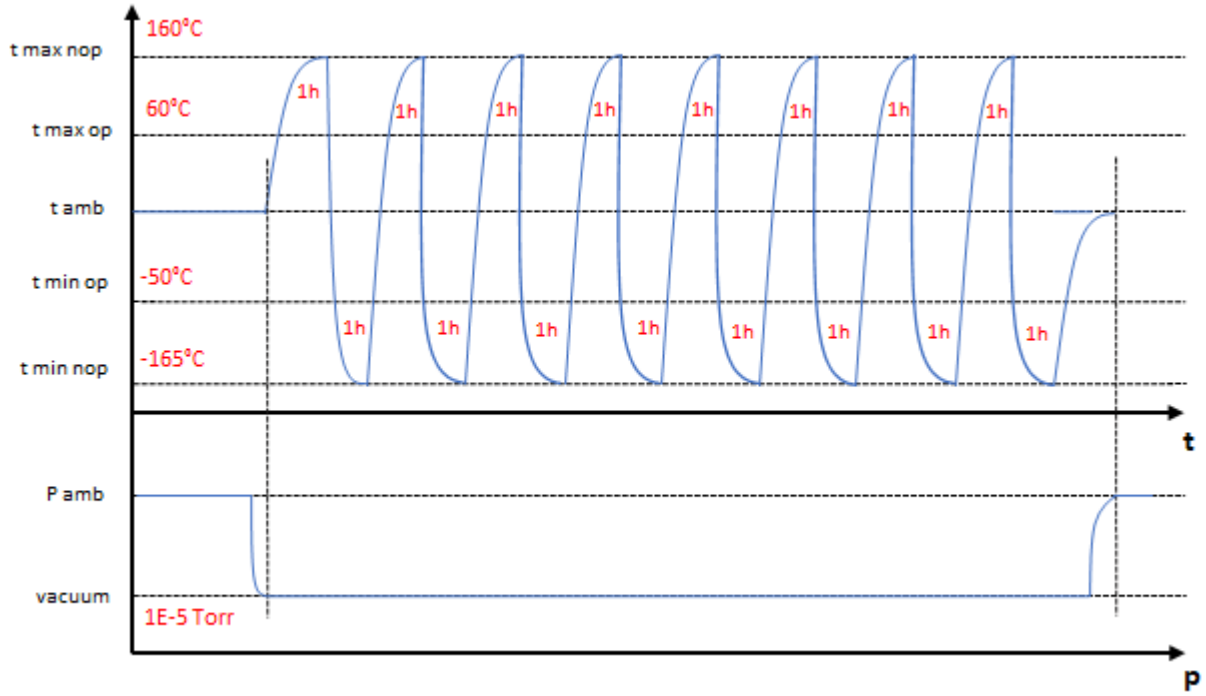
To expose the specimens to vacuum conditions in extreme temperatures, using a thermal vacuum chamber

Procedure

Thermal Vacuum Cycling Test (TVCT):

- Number of cycles: 8
- Non-operational temperature range: -165°C/+160°C
- Dwell time: 1 h

Each unit was tested separately.

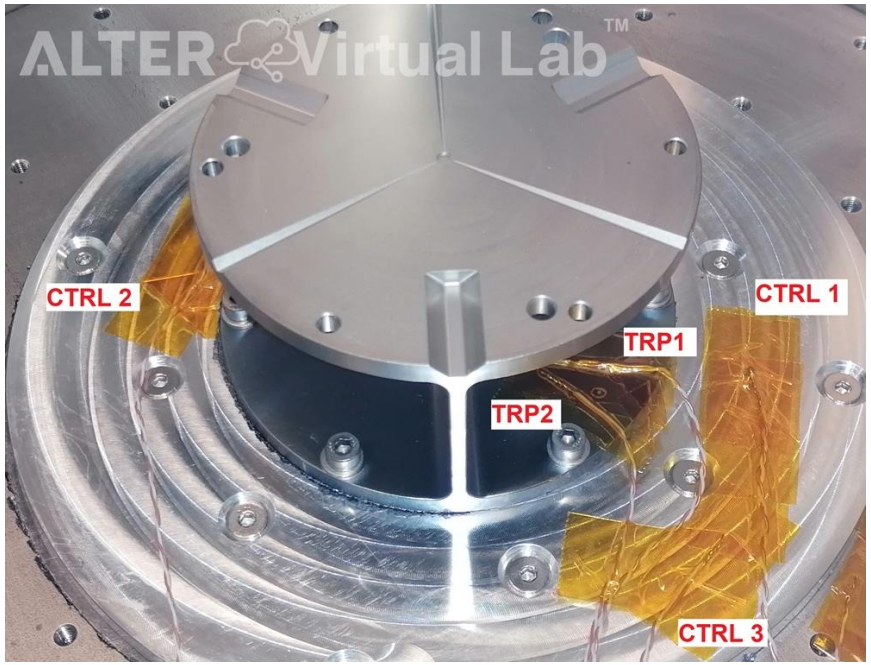


Set-up

For each unit, 5 thermocouples were used:

- 2 TRP attached to the specimen
- 3 CTRL attached to the interface plate.

SIGRAFLEX used to enhance thermal contact from chamber to interface and interface to MICE

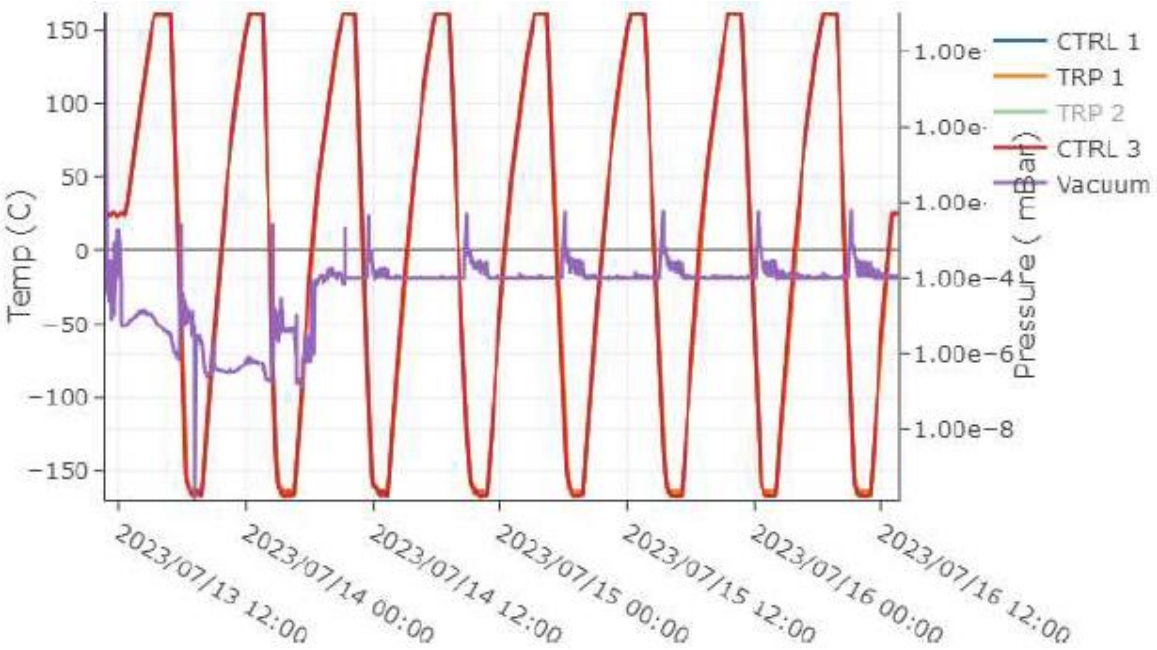


MICE-Q SN01

MICE-Q SN02

Results

MICE-Q SN01



MICE-Q SN02

Results

Both MICE units reached the target temperatures along the 8 cycles

- NC with temperature measurement: discrepancy between TRP 1 and 2 in both units → Investigated by test facility: TRP 1 and CTRL 1 sensors need an escalation factor below -80°C that was not automatically applied. After correction, the temperature obtained at TRP 1 and 2 does not show a significant difference.

Both MICE units reached the vacuum level during the test

- NC with vacuum at SN01 test was detected: pressure remained constant at approximately 1.00 × 10−4 mbar during part of the test → Investigated by test facility: wrong measurement caused by wrong operation of the sensor. Pump consumption during the test indicates that the target level of vacuum was reached in all the cycles.

Conclusion: The test is considered successful for both units.

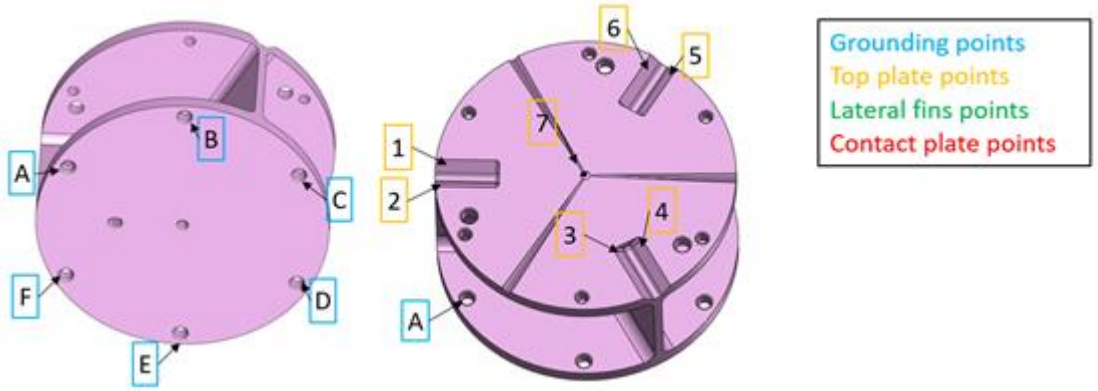
Objective

To measure the electrical resistivity between top plate and assembly screw holes on bottom plate, where the bonding strap will be placed.

Procedure

The two MICE-Q specimens, SN01 and SN02 are on a clean, flat working surface.

Points to measure have been defined based on the main contact points between MICE and Active IF. They are distributed across the top plate surface, the lateral fins and the internal top plate side.



Results

Specimen	Minimum value (μΩ)	Maximum value (μΩ)
MICE-Q SN01	218.8 (E-7)	284.6 (A-7)
MICE-Q SN02	212.7 (A-7)	260.5 (A-4)

Some values of the test were not compliant with the values specified in the requirement; a NC was raised with the following conclusions:

- The requirement values were derived from the Bonding Test performed to MICE EM in previous MICE activity and did not account for the sand-blasted surface.
- The values are in μΩ, so the difference is considered negligible.

Conclusion: The test is considered acceptable.

MICE is an optimised interface, with minimised impact and maximum performance, developed for compatibility with state of the art navigation, avionics and mechatronic capabilities and thoroughly verified for robustness.

It has the potential to become a **standard interface** for multiple applications.

First flight use will be as part of **Copernicus Sentinel Expansion missions satellites** Design for Removal package.

EN 9100

ISO 9001

BOOSTING SCIENTIFIC KNOWLEDGE

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Thanks!

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