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CleanSpace Industry Days 2022

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

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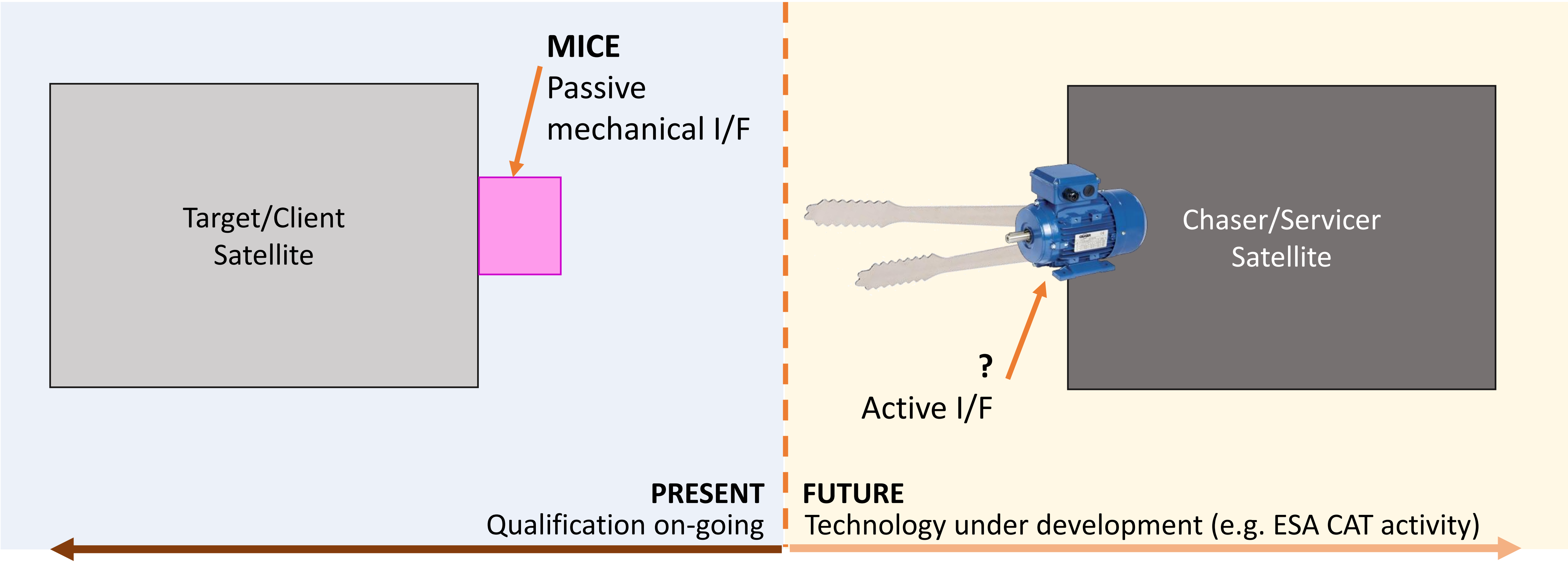
Context of the activity

MICE purpose is to enable non-cooperative capture of satellite after the end-of-life for its deorbiting.

MICE has been developed along several ESA Clean Space activities by a consortium formed by GMV and AVS.

- is the Prime, leading the requirement definition and the functional verification
- is in charge of the mechanical design, analysis, manufacturing and environmental verification.

MICE purpose is to enable non-cooperative capture of satellite after an unexpected end-of-life for its deorbiting.



MICE Functions

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

- Interface for capture
  - **Capture**
  - Integration at S/C
  - Mechanical load transfer
  - Electric charge transfer
  - Sensing /visual compatibility
  - Function at S/C EoL
  - Environmental Compatibility

- Capture before contact
  - Geometrical restriction of MICE position before contact. Drives MICE envelope
- Capture with misalignments
  - ±20mm & ±3º. Drives MICE envelope
- Capture with reduced ambiguity
  - MICE could be used in a wide set of scenarios, but it needs to achieve always the same final capture position. Drives MICE geometry

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- Accommodation
  - MICE shall be installed at the centre of the LAR at the Client satellite
- Mechanical Interface
  - MICE is attached to a CFRP panel. Assembly to be made with standard tools.
- Thermal interface
  - S/C panel temperature range: -50ºC to 60ºC. No requirements on power transfer.
- Mass budget
  - MICE mass shall be ≤1.5kg. Critical to minimise impact at Client

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- Force
  - 850 N in all directions. Driver for material selection
- Torque
  - 180 Nm around all axis. Driver for material selection

- Electric charge transfer
  - MICE will be the first point of contact between target and chaser satellites. Electro-discharge is expected. MICE function is not to stop that transference, but to avoid over-heating during the process.

MICE Functions

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

- Interface for capture
  - Capture
  - Integration at S/C
  - Mechanical load transfer
  - Electric charge transfer
  - **Sensing /visual compatibility**
  - Function at S/C EoL
  - Environmental Compatibility

– Fine sensing features
  – Since Active I/F is yet to be designed, MICE is intended to guarantee compatibility with a wide range of sensing methods, including laser scanner

– Thermo-optical surface properties
  – MICE surface properties need to be compatible with visual and sensing systems; e.g. no polished surfaces to minimise reflections.

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

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  - Capture
  - Integration at S/C
  - Mechanical load transfer
  - Electric charge transfer
  - Sensing /visual compatibility
  - **Function at S/C EoL**
  - Environmental Compatibility

- Life
  - MICE is meant to be used after EoL, which could happen potentially at any moment along the satellite life or after. 12.5 years of satellite life taken as reference.
- S/C EoL
  - EoL of satellite could potentially mean that satellite is in an inoperative status, tumbling at a high rate and with uncontrolled orientation during MICE functional operation.

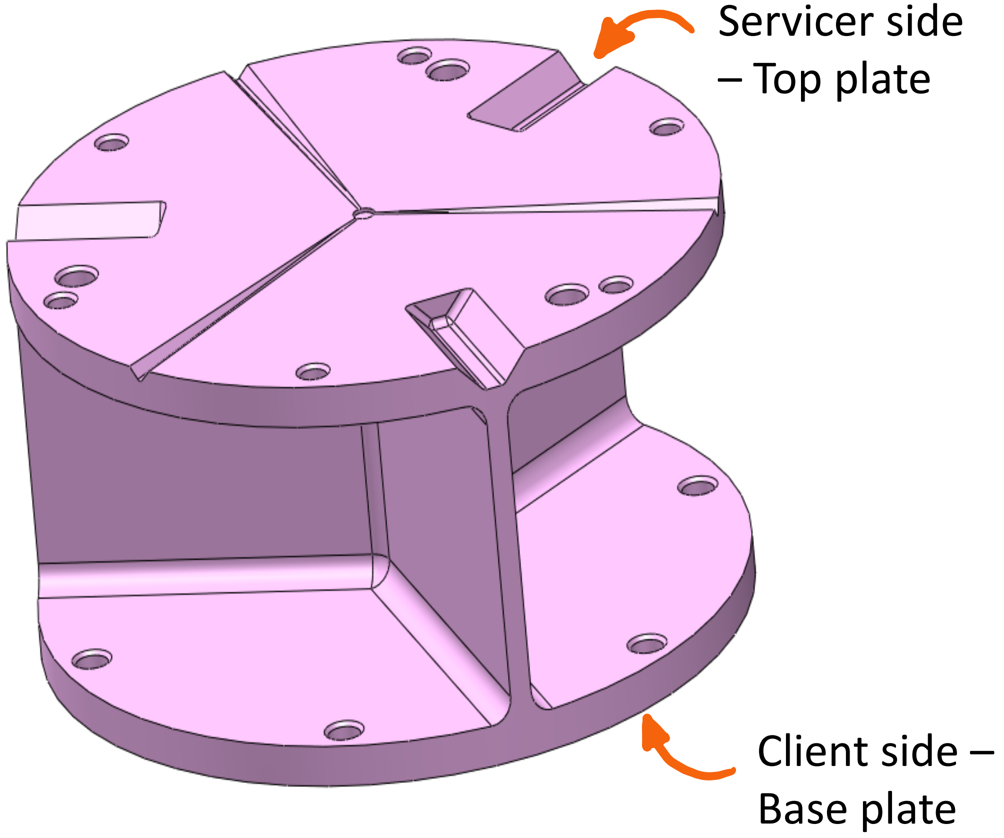
Mechanical Interface for capture at End-of-Life (MICE)

- Interface for capture
  - Capture
  - Integration at S/C
  - Mechanical load transfer
  - Electric charge transfer
  - Sensing /visual compatibility
  - Function at S/C EoL
  - **Environmental Compatibility**

- Thermal
  - -180º to 160º. Derived from worst operation conditions for inoperative satellite. Driver for material selection
- Radiation
  - LEO environment
- ATOX
  - LEO environment
- Mechanical
  - Launch with Ariane 6. Not driver as functional loads are much higher

Overview of the design

- Passive interface
  - Only 1 part, no movable components
- Material: Stainless Steel 15-5 PH H1025
  - Selected to resist loads & extreme temperatures at End-of-Life
- No tribological coating
  - Extended lifetime + minimise scratch during capture
  - All functional coatings (e.g. lubrication) to be applied on Active interface
- Several features to increase flexibility of the interface to load & potential sensing options
  - Designed in parallel to an Active interface to validate MICE capabilities

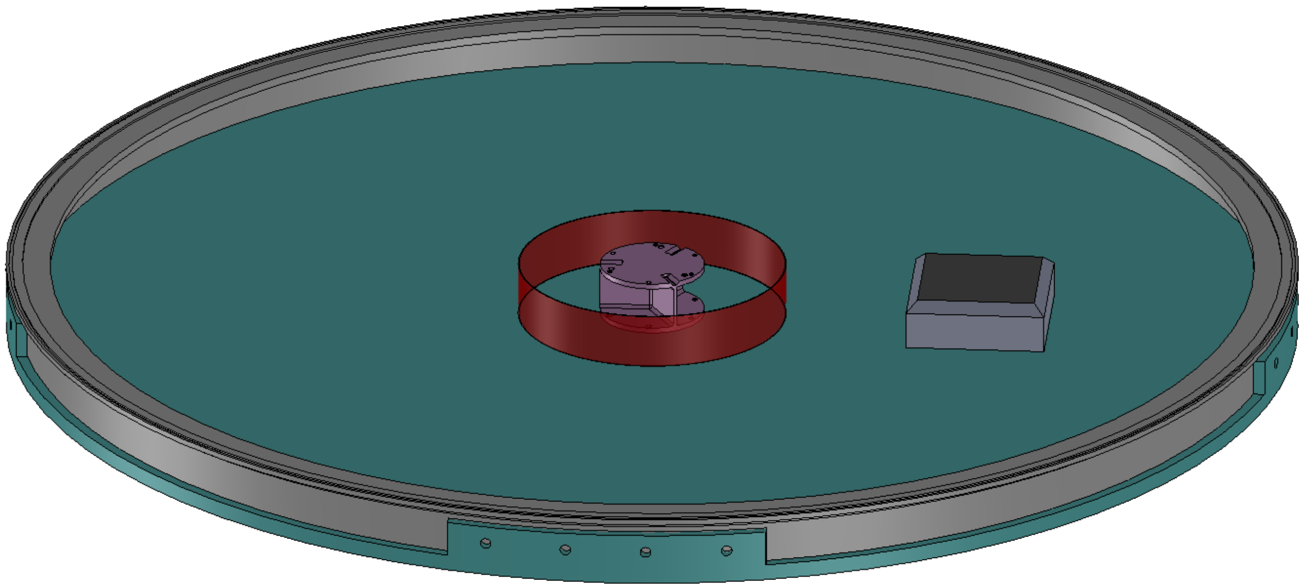


Physical properties

- Mass: 0.719 kg
- MICE outer diameter: Ø98 mm
- MICE height: 50 mm

Integration at Client satellite

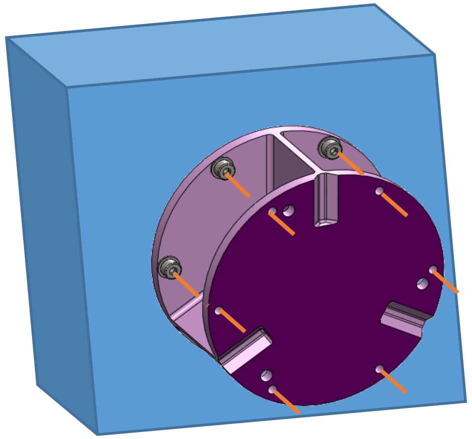
- LAR centre
- Near visual marker for navigation
- Required KOZ*: Ø250mm
- I/F: 6xM4 screws + 2 pins



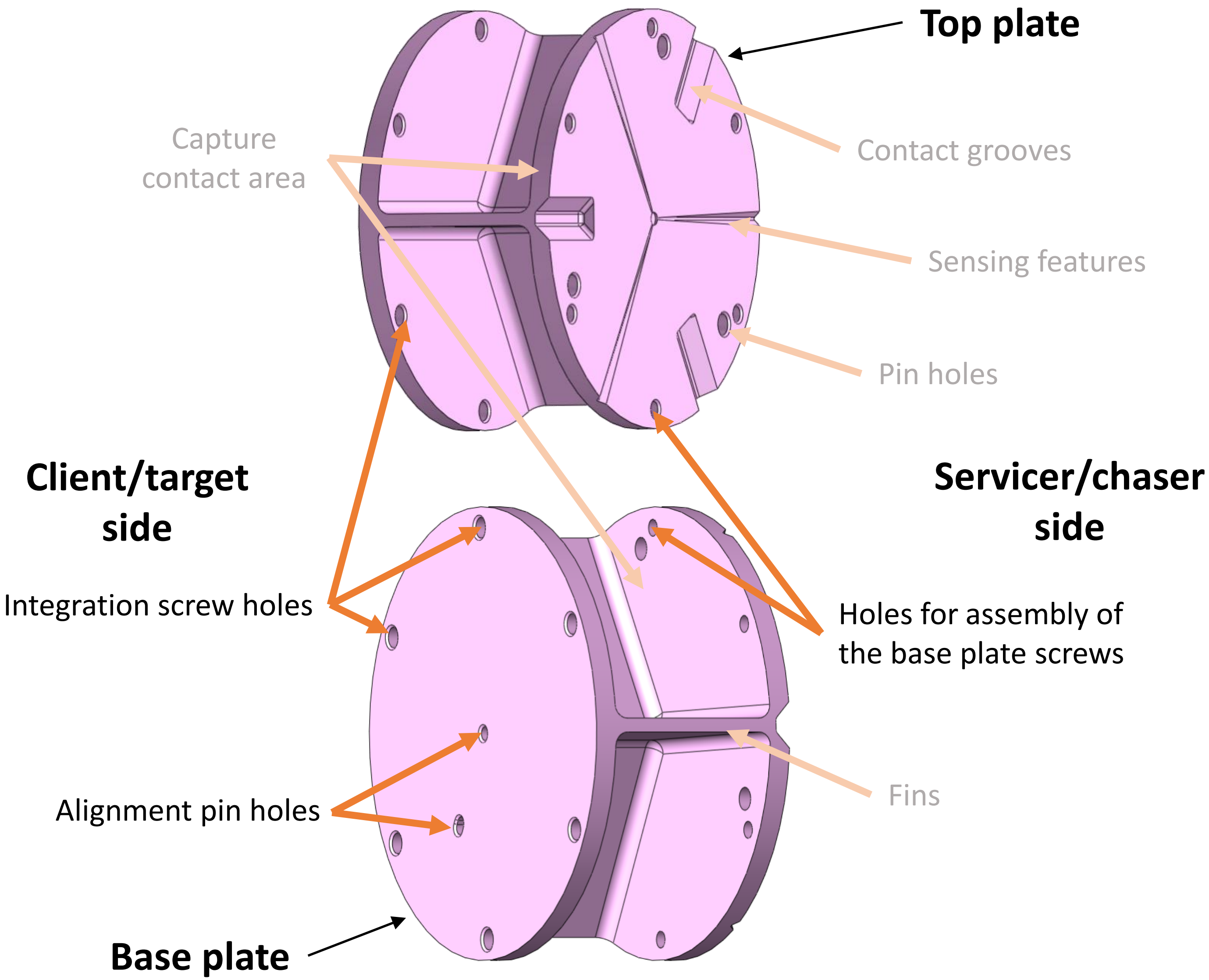
KOZ*: Keep-Out Zone for capture

MICE Features

- Features for integration
  - Guarantee repeatable mounting and limited displacement due to thermal strains
  - Detail of integration at Client satellite

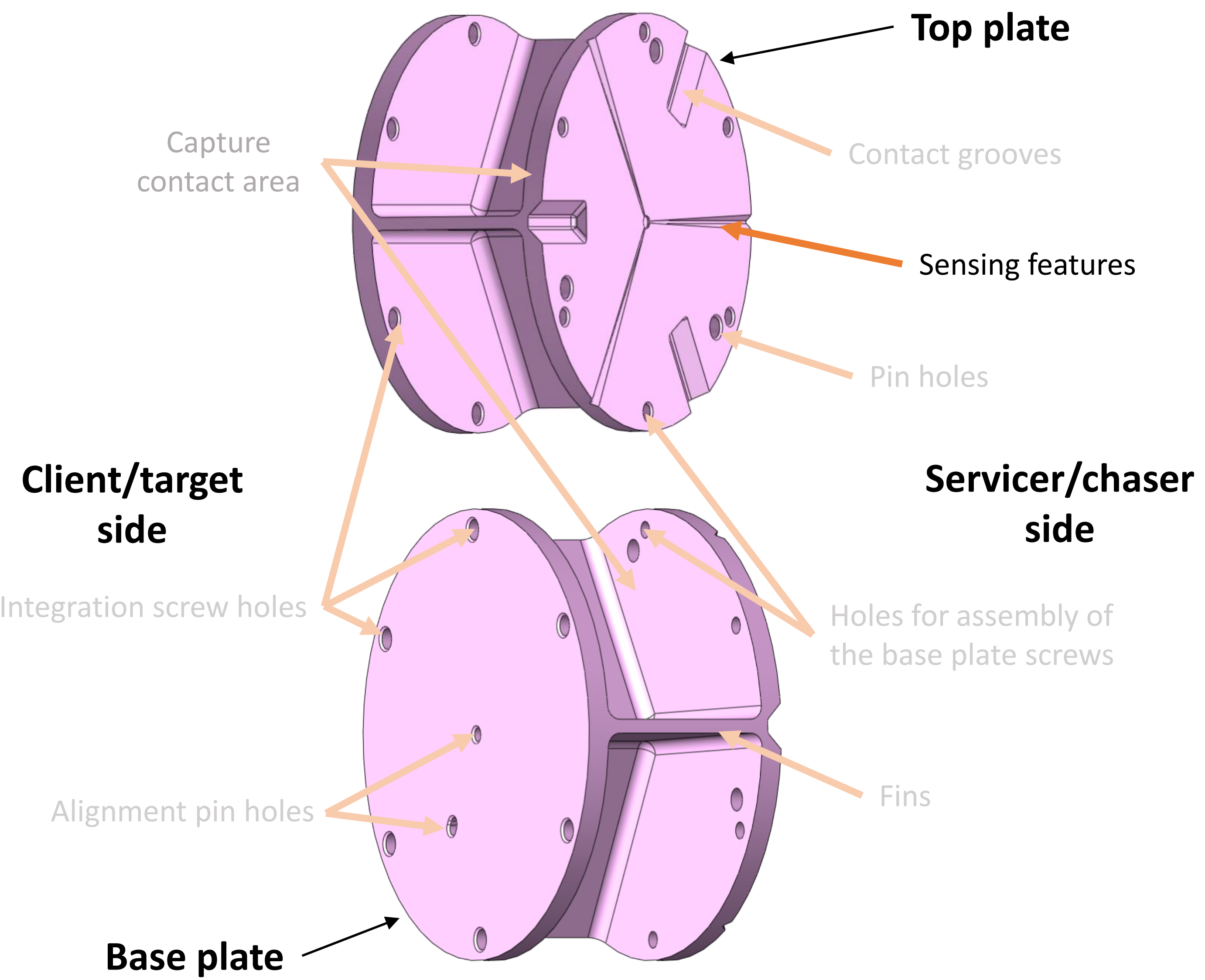


- Features for detection
- Features for capture and alignment
- Features for load transfer



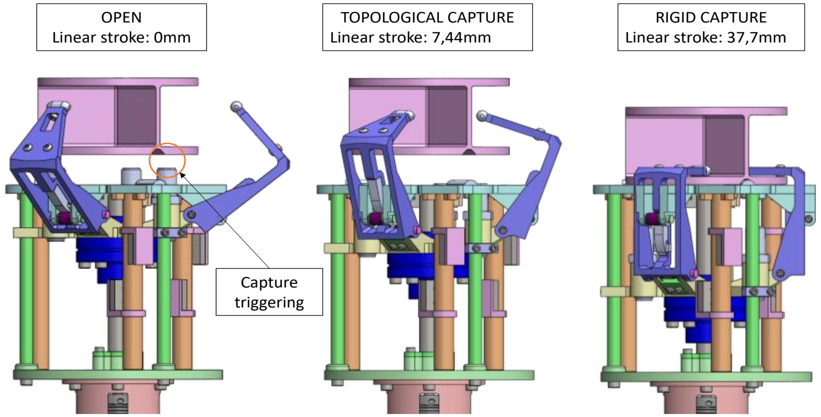
MICE Features

- Features for integration
- Features for detection
  - Enable compatibility with wide range of sensing options for Active I/F
  - Sensing required for potential Active I/F capture activation as precision of visual feedback in Z axis is limited & not compatible with Z axis position oscillation.
  - Non-contact trigger considered as baseline to avoid potential dynamic effects. Potential technologies to use: inductive sensor, laser scanner.
- Features for capture and alignment
- Features for load transfer

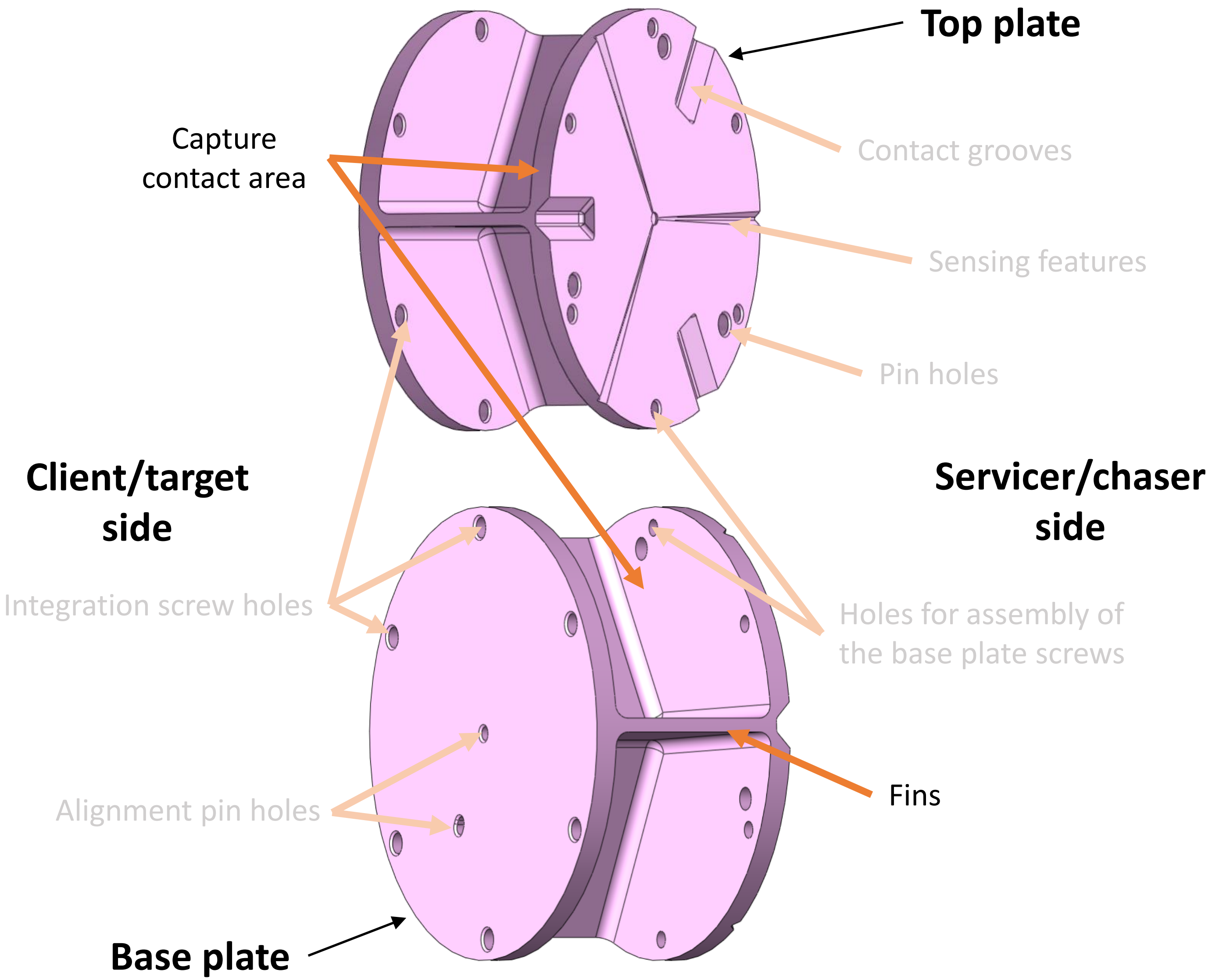


MICE Features

- Features for integration
- Features for detection
- Features for capture and alignment
  - Enable capture before contact (topological capture)
  - Enable reorientation of MICE during capture to guarantee the same final position independently from the starter relative position

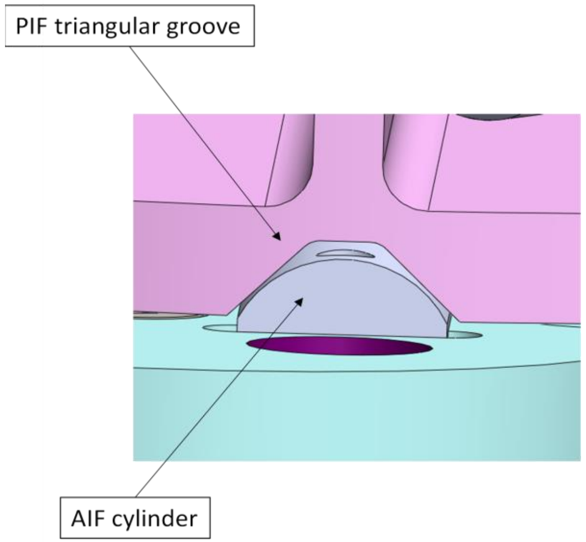


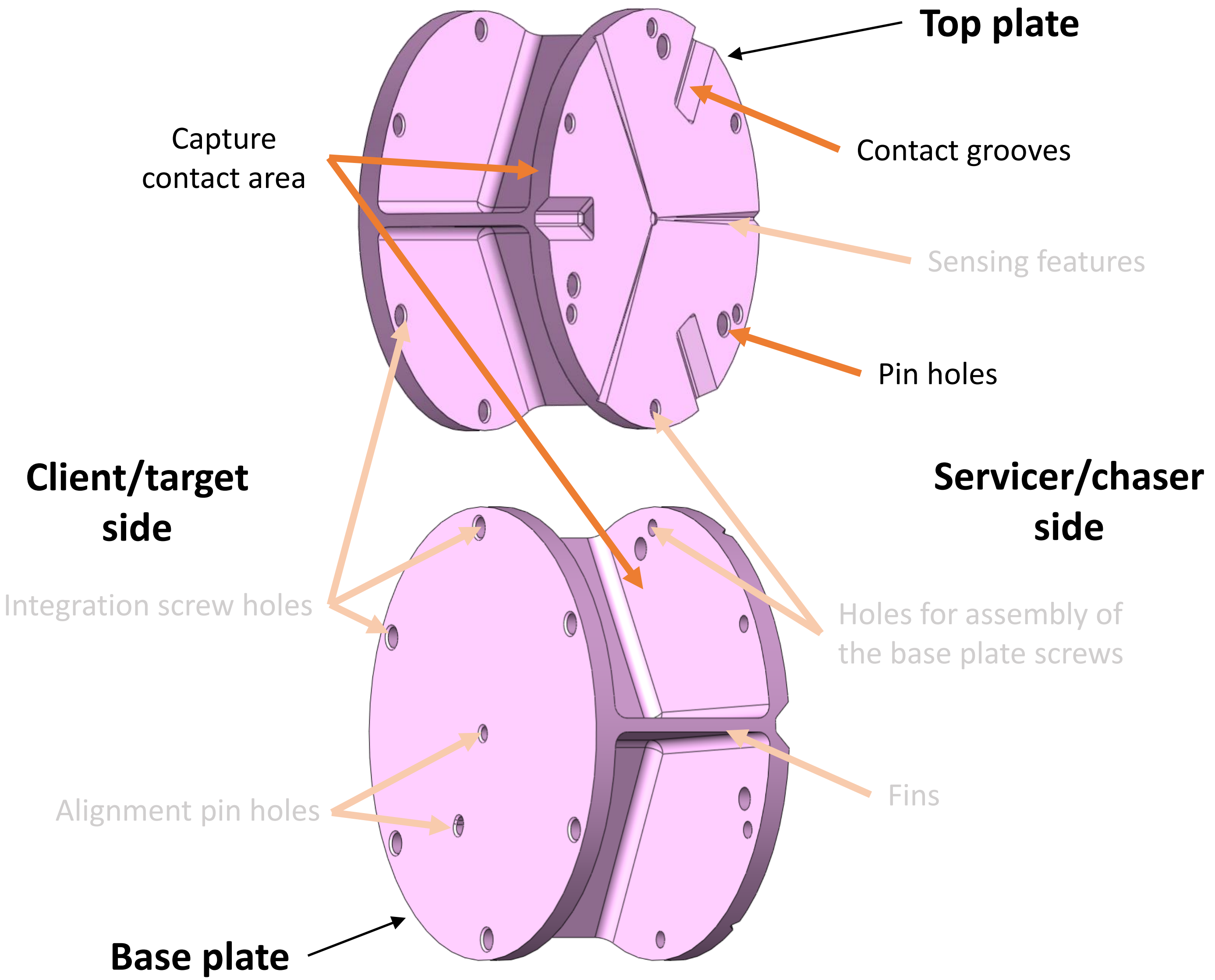
- Features for load transfer



MICE Features

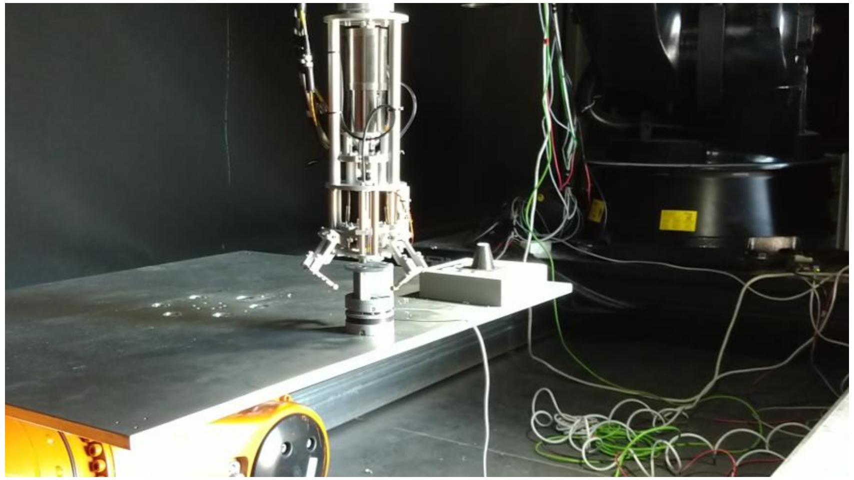
- Features for integration
- Features for detection
- Features for capture and alignment
- Features for load transfer
  - Enable force and torque transference
  - Potential implementation of anti-clocking features at Active I/F (AIF) with Contact grooves



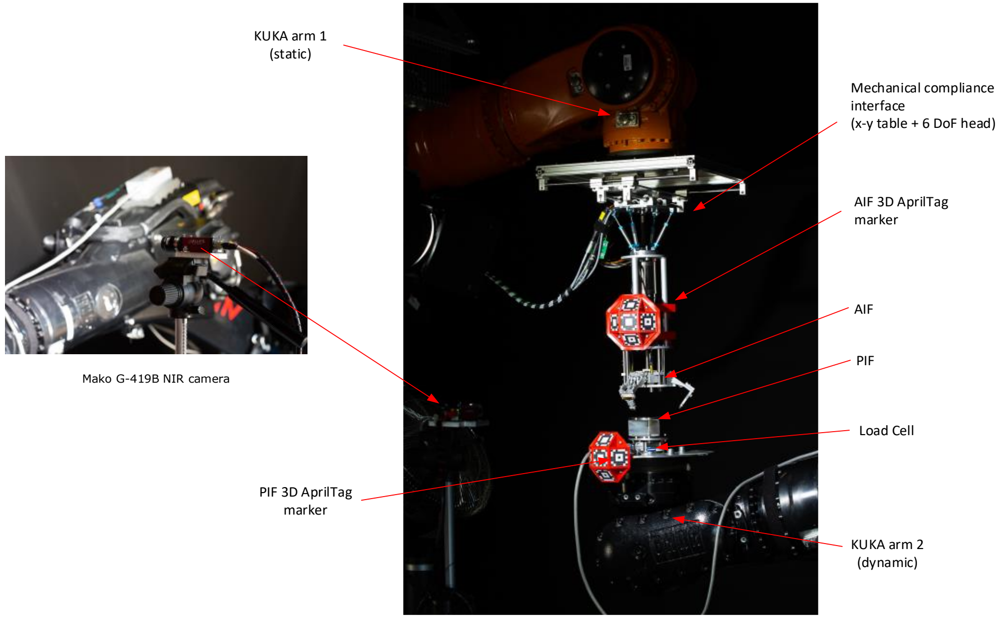


Previous activities have raised TRL:

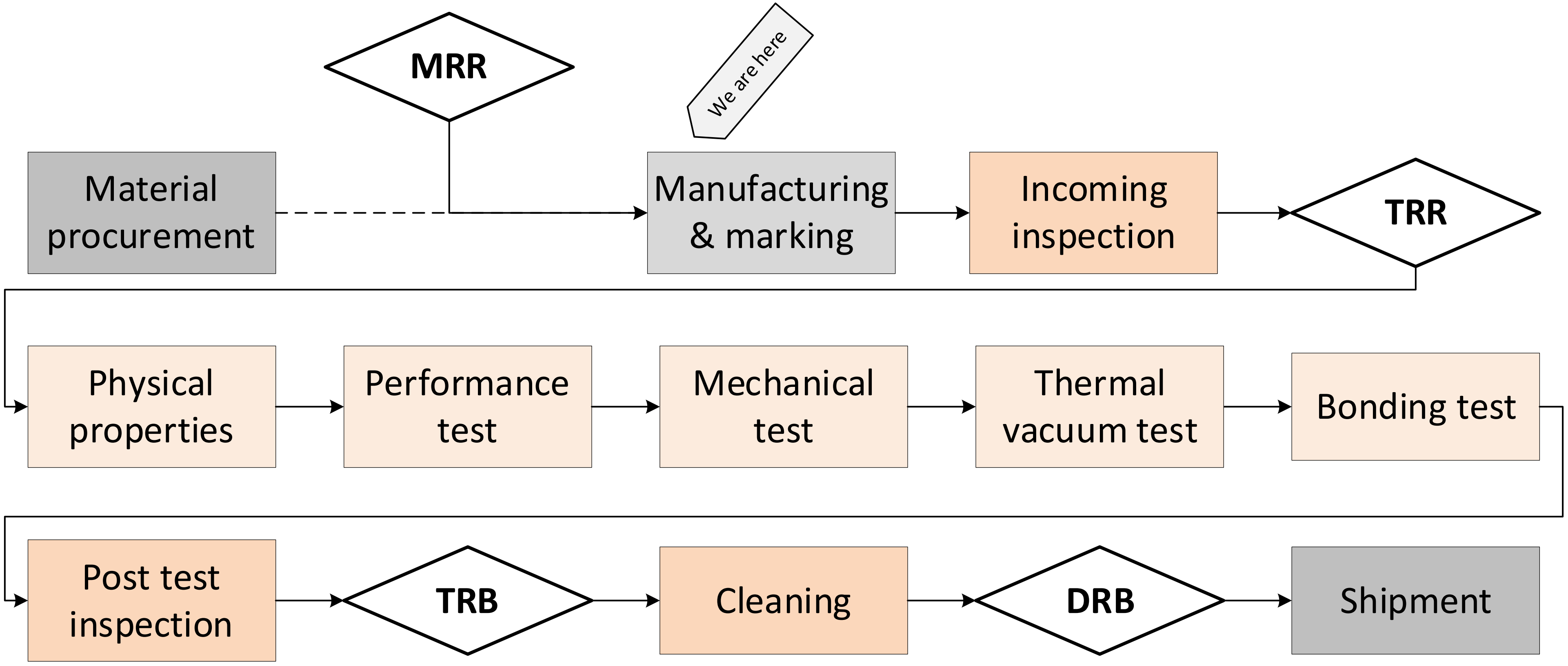
- **PRINCE** (ESA): MICE passive and active I/F breadboarding and critical functional testing (GMV's platform-art© facility) to verify concept. TRL 4



- **MICE** (ESA): MICE passive interface design iteration. Full performance and functional verification (GMV's platform-art© facility). Environmental verification descoped due to MICE characteristics. TRL 6



MICE Q is focused on qualification to reach TRL 7



MICE Q is focused on qualification to reach TRL 7

- Physical properties:
  - Measurement of mass, dimensions, roughness, thermal properties (TBC)
- Performance test:
  - Verification of MICE compliance with functional loads (850N & 180Nm)
- Mechanical test
  - Verification of MICE compliance with mechanical loads (acceleration, sinusoidal). Loads derived from Copernicus Sentinel Expansion missions
- Thermal vacuum
  - Verification of MICE compliance with thermal conditions. -180ºC to 160ºC (TBC). 10 cycles at vacuum, 90 at inert ambient.
- Bonding test
  - Verification of MICE compliance with the grounding requirements. Resistance <10^6 Ω

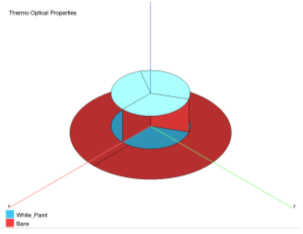
Thermal interface:

- Thermal interface not fully defined by requirements. Only panel temperatures (-50ºC to 60ºC).
- Baseline: bare material & direct contact
  - Thermo-optical 'bare' condition: ε=0.15/0.3 (hot/cold) & α=0.6
- Options for improvement: use of thermal washers/paint/surface treatments
  - Most relevant to reduce heat transfer to the Client S/C

Thermal assessment:

- Two envelope (steady state) load cases:
  - Hot case: facing Earth + direct solar irradiation
  - Cold case: facing deep space→ no direct solar irradiation
- Main results:

Surface Finishing	Contact	Load Case	Tmin (ºC)	Tmax (ºC)	Ts/c [ºC]	ΔTI/F [ºC]	Qcond [W]
Bare Finishing	**Bare Contact**	Hot Case	**110.86**	**186.79**	60	**50.86**	**23.02**
	6x Ti washers		71.04	152.59		11.04	25.07
	Bare Contact	Cold Case	**-55.87**	**-52.81**	-50	**-2.81**	**-1.27**
	6x Ti washers		-53.583	-50.554		-3.58	-8.13
White Paint Top & Bottom EoL	Bare Contact	Hot Case	93.84	144.8	60	84.80	38.38
	6x Ti washers		68.12	126.91		66.91	151.91
	Bare Contact	Cold Case	-59.309	-54.42	-50	-4.42	-2.00
	6x Ti washers		-55.84	-50.89		-0.89	-2.03



MICE has been developed to be used on the **Copernicus Sentinel Expansion missions satellites** to enable their removal in case deorbit can not be done independently.

Current MICE design is fitted to state of the art navigation and avionics capabilities and has been thoroughly verified for robustness. Other potential uses e.g. mechanical interface for on orbit servicing & on-orbit manufacturing could be achieved with little to no modification.

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Thanks!

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