Passive Navigation Aids Development for EOL Management

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INTRODUCTION

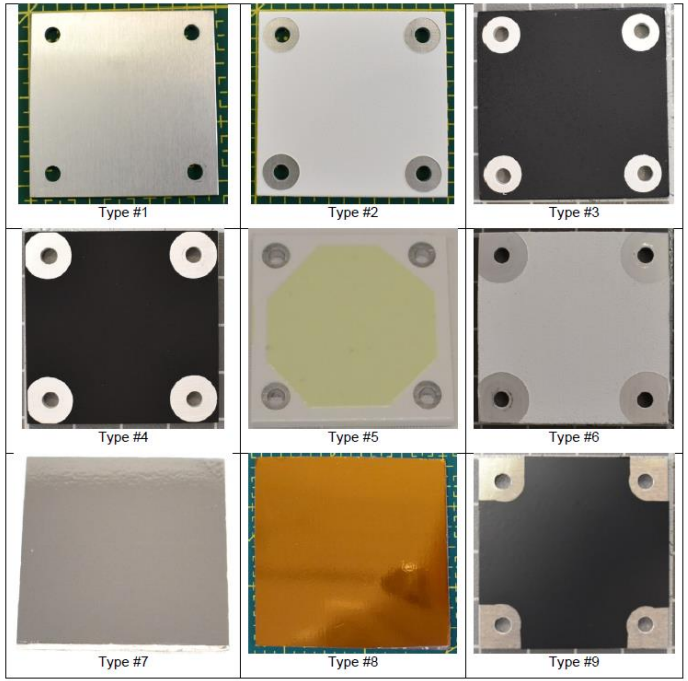
ADMATIS Ltd joined ESA Clean Space initiative through characterising the feasibility of passive marker solutions in thermal infrared and visible spectrum in the frame of PEMSUN project in 2018.

The activity focused on two types of dedicated markers:

- Adaptation of Multi Layer Insulation (MLI) to help navigation in the **TIR** spectrum
- Phosphorescent painting to help navigation in the **VNIR** spectrum

MSN INTRODUCTION Admatis

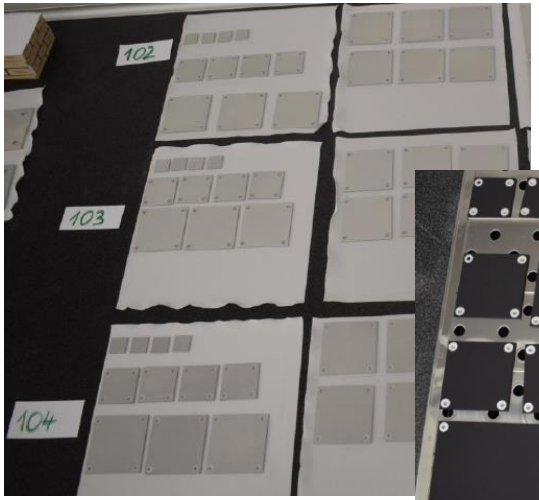
Continuation project beginning in 2020 called **M**arkers **S**upporting **N**avigation was to extend and develop marker technologies through the selection and comprehensive ageing tests on various candidate materials, including thermal control paints, phosphorescent paints, and films.



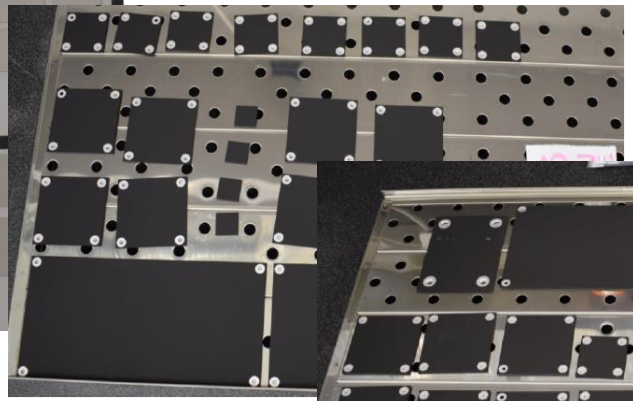
- Type #1: Trivalent Chromium Conversion Coating
- Type #2: non-conductive white
- Type #3: conductive black-1
- Type #4: conductive black-2
- Type #5: DHI Afterglo – COTS phosphorescent
- Type #6: MSN Afterglow – ADM developed ph.
- Type #7: VDA/Kapton
- Type #8: Kapton
- Type #9: Black Kapton

INTRODUCTION

MSN has been extended further to qualify organic and inorganic materials visible next to solar arrays and radiators in the VNIR and TIR spectra.

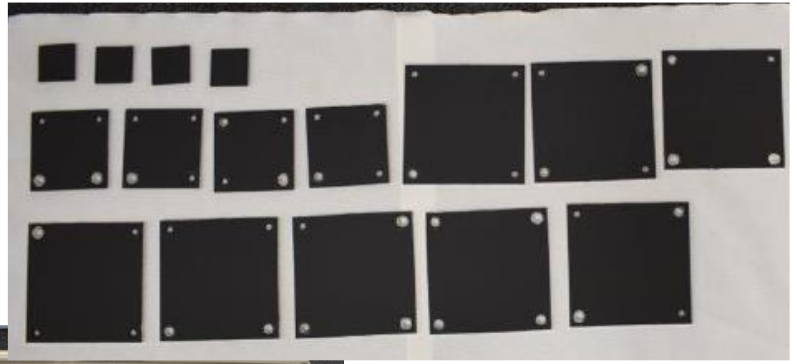


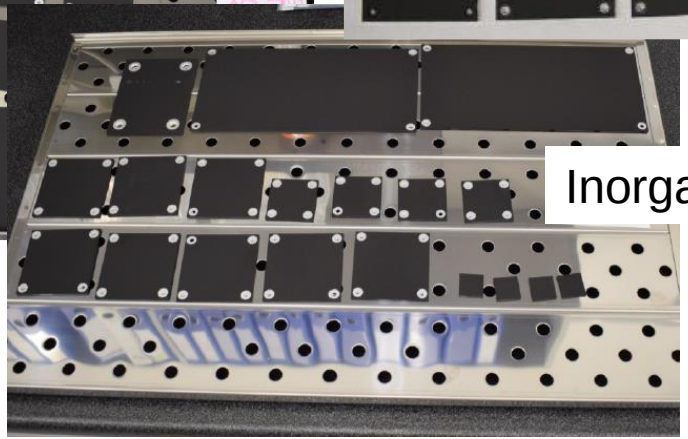
TCCC with different surface roughness



Aqueous based conductive black

Aqueous based non-conductive black

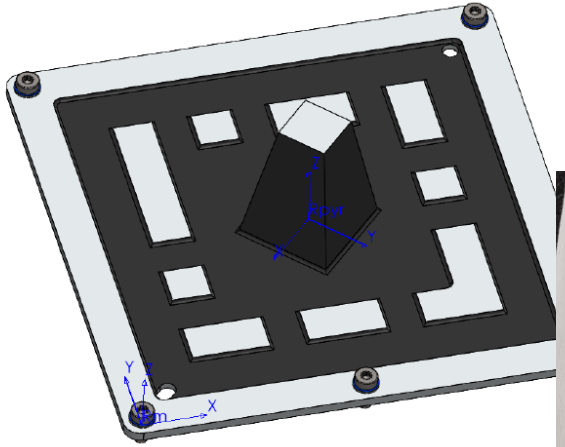




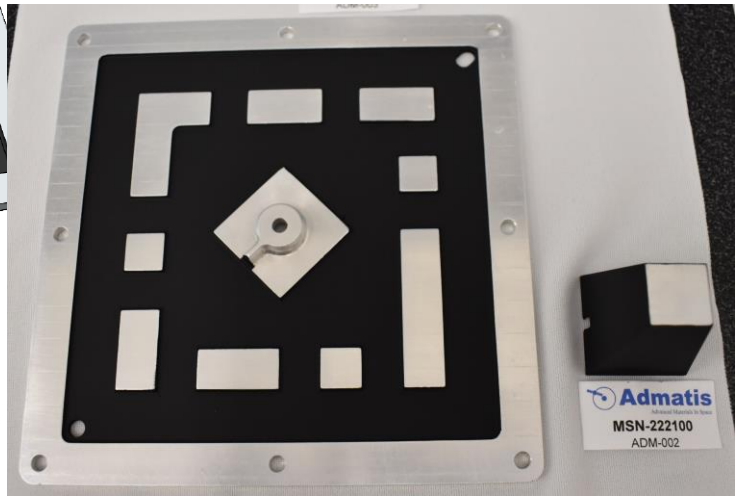
Inorganic black

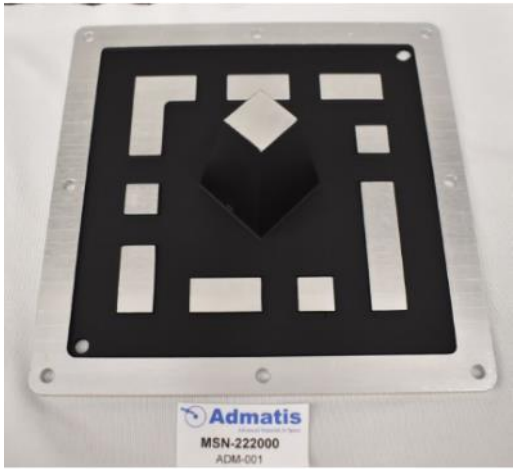
INTRODUCTION

In parallel with materials qualification, consolidation of markers design, including laser retroreflector in the 2D Marker, has been implemented. Qualification of the markers is currently implemented in the MSN-Q project.

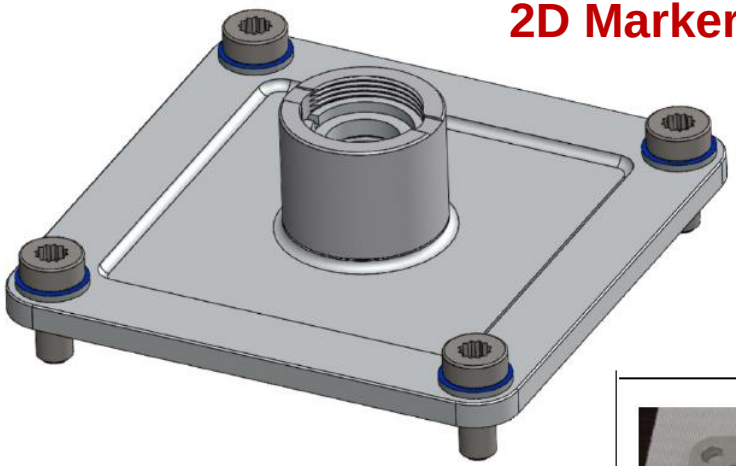


3D Marker BB design and assembly

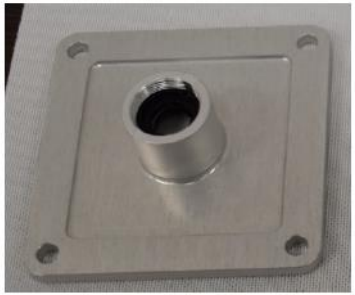
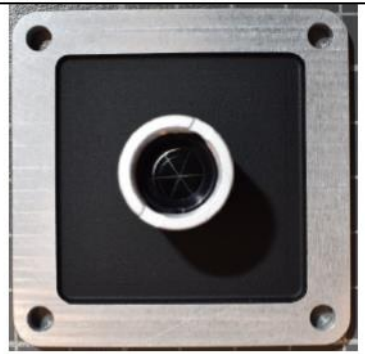
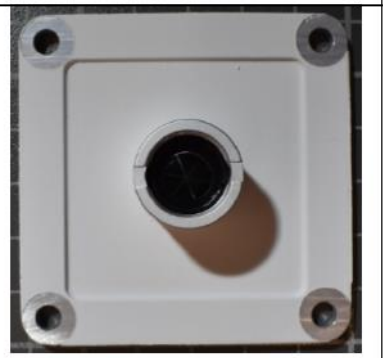




2D Marker BB design and assembly



3 different configurations in terms of coating

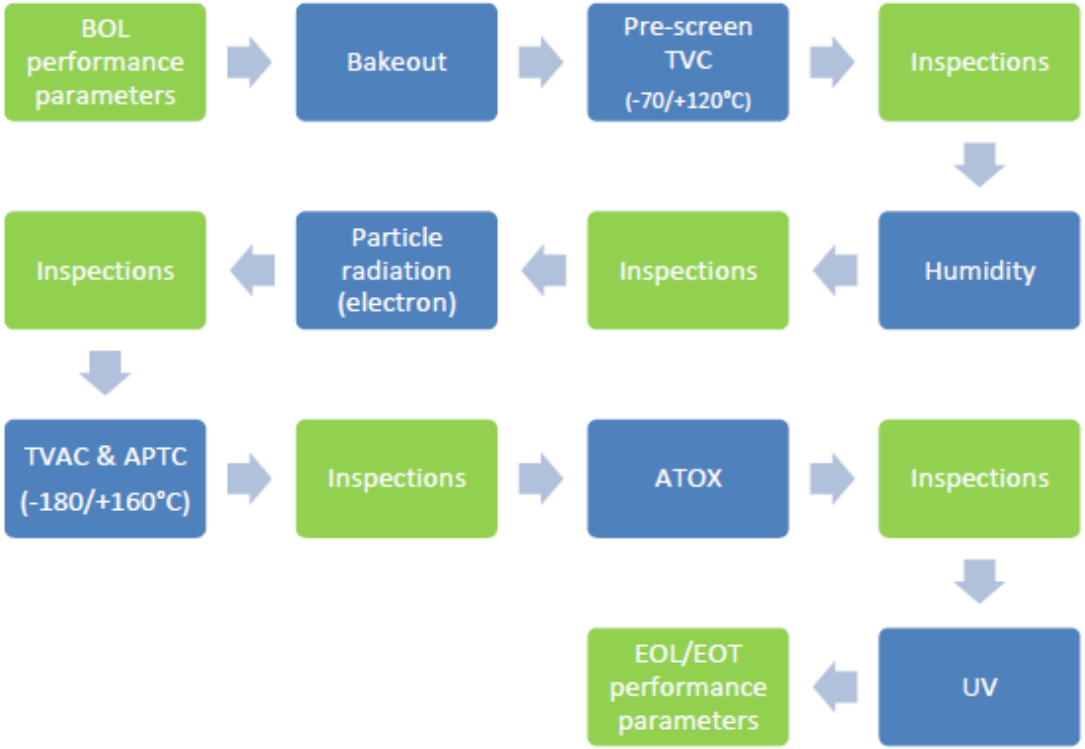
TCCC	TCCC+black	white
		

TCCC+black has been selected for further testing

MSN MATERIALS QUALIFICATION

Admatis

Coatings qualification included all relevant tests of the coatings, adhesion, thermo-optical measurements, and in addition, measuring performance parameters (i.e. contrast, visibility) of the proposed markers in thermal infrared and visible spectra.

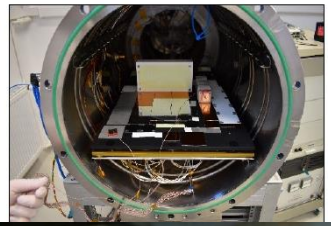


Test levels correspond to LEO environment of the 6 HPCM missions operation in sun-synchronous orbits between 630 and 820 km altitude, inclination of 98 deg.

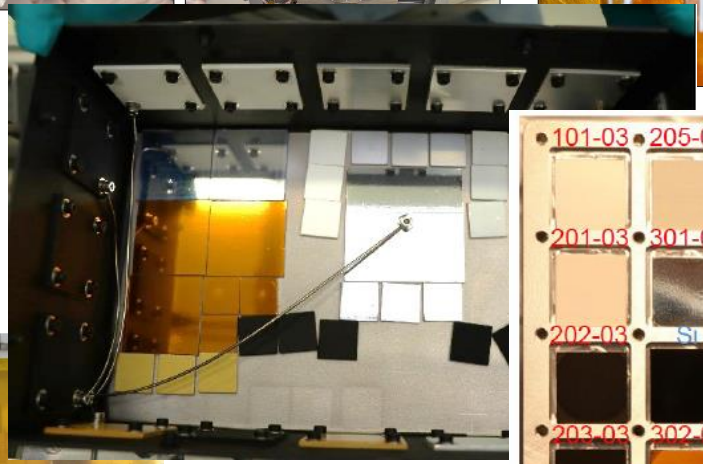
MATERIALS QUALIFICATION

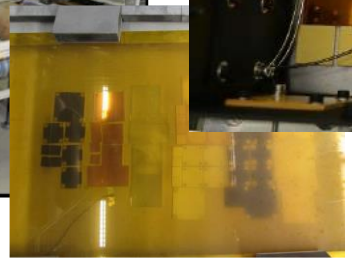
Admatis

Bakeout+pre-TVC



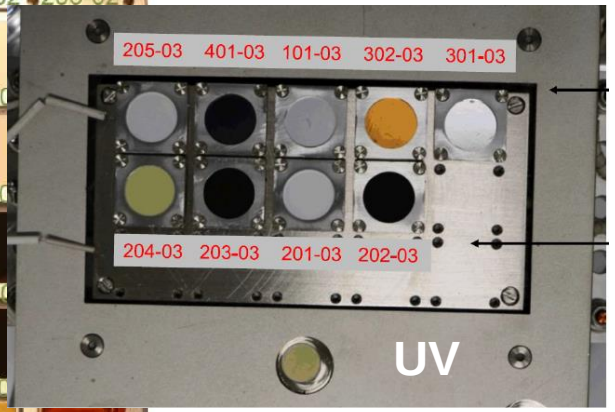
Humidity





Radiation

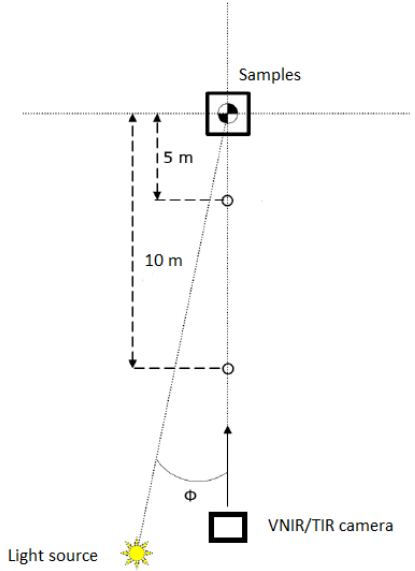
TVAC+APTC



ATOX

PERFORMANCE PARAMETERS - CONTRAST

Contrast measurement in VNIR and TIR spectrum has been implemented from 5m, 10m, 20m and 44m distances at 0°, 20°, 40°, and 60° angles and the evolution has been characterized.



For VNIR recording, the samples were illuminated by a LED reflector (Luminous flux:2700 lm, Electric power:30W, Color temperature: (6500K) placed at 10° illumination angle directly on the left side of the camera.

The evaluation was performed using the Michelson Contrast formula:

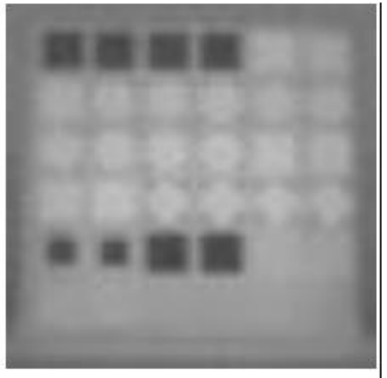
$$C = \frac{I_{max} - I_{min}}{I_{max} + I_{min}}$$

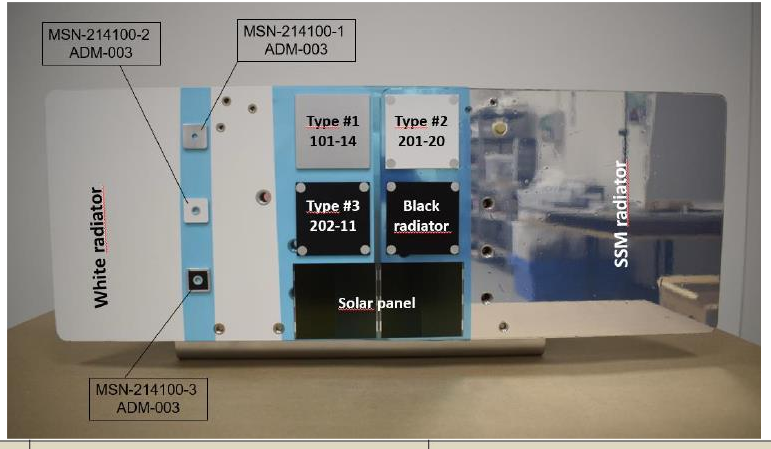
C: contrast [0<C<1]

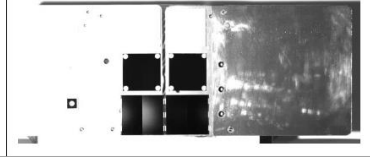
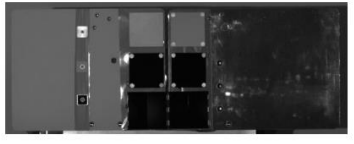
I: intensity (i.e. pixel gray value)

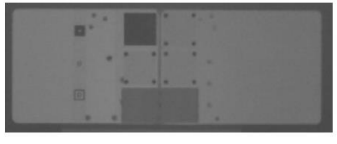
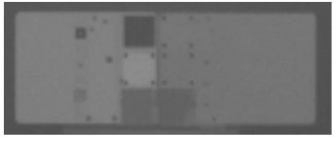
I_{max} can be considered as average intensity value of the target, while I_{min} is the average intensity of the background.

PERFORMANCE PARAMETERS - CONTRAST



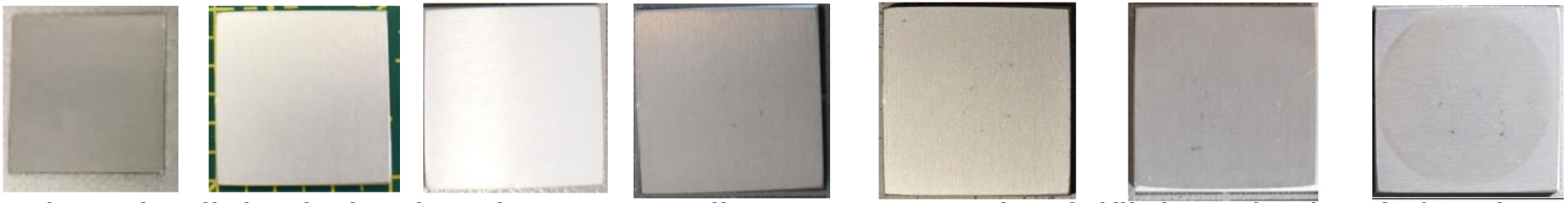


	3m	5m	10m
0°			

	3m	5m	10m
0°			

TYPE #1: TRIVALENT CHROMIUM CONVERSION COATING

BOL BO&TVC Humidity Radiation TVAC&APTC ATOX ATOX+UV



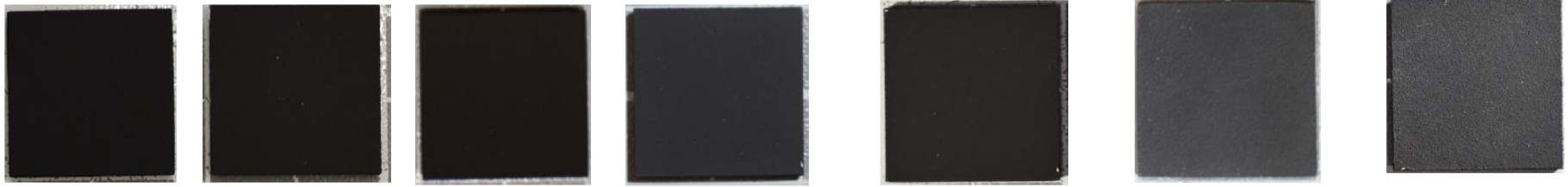
There is slight darkening due to UV. All Type #1 samples fulfil the criteria of visual appearance. All samples passed the adhesion (tape-lift) tests.

TO property	BOL	After TVAC	After ATOX	After ATOX+UV	Δ
Solar absorptance	0.29	0.33	0.32	0.32	0.03
Thermal emittance	0.03	0.05	0.04	0.04	0.01

	Δ (average)
Reflectance (<0.65)	3,5 %
Contrast (VNIR) (0.75)	16%
Contrast (TIR) (0.35)	5%

TYPE #4: CONDUCTIVE BLACK-2

BOL BO&TVC Humidity Radiation TVAC&APTC ATOX ATOX+UV



No visible change due to ATOX and UV. All Type #4 samples fulfil the criteria of visual appearance. All samples passed the cross-cut and tape-lift test.

TO property	BOL	After TVAC	After ATOX	After ATOX+UV	Δ
Solar absorptance	0.97	0.97	0.97	0.97	0.00
Thermal emittance	0.93	0.90	0.92	0.95	+0.02

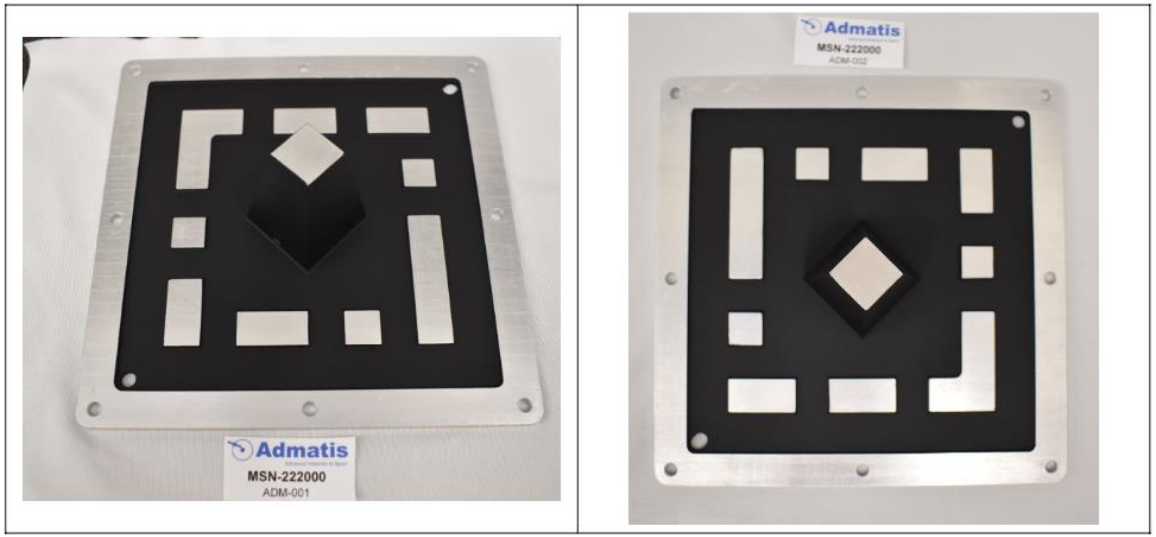
	Δ (average)
Reflectance (0.05)	0 %
Contrast (VNIR) (0.8)	12%
Contrast (TIR) (0.12)	4%

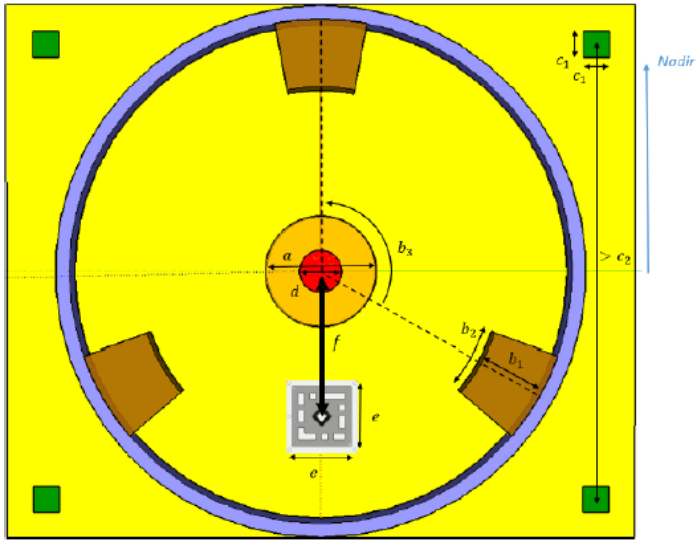
RESULTS SUMMARY

- Qualification of the coatings including all relevant tests has been performed
- There is almost no change in CONDUCTIVE BLACK-2
- TCCC showed slight visual change.
- All tested samples passed the different adhesion tests including tape-lift, cross-cut and pull-off tests.
- Reflectance, thermo-optical properties and contrast values have also been characterized.
- ADM proposal is TCCC + CONDUCTIVE BLACK-2 thermo-optical paint material pair for coating of navigations markers.

3D Marker – „MSN-150”

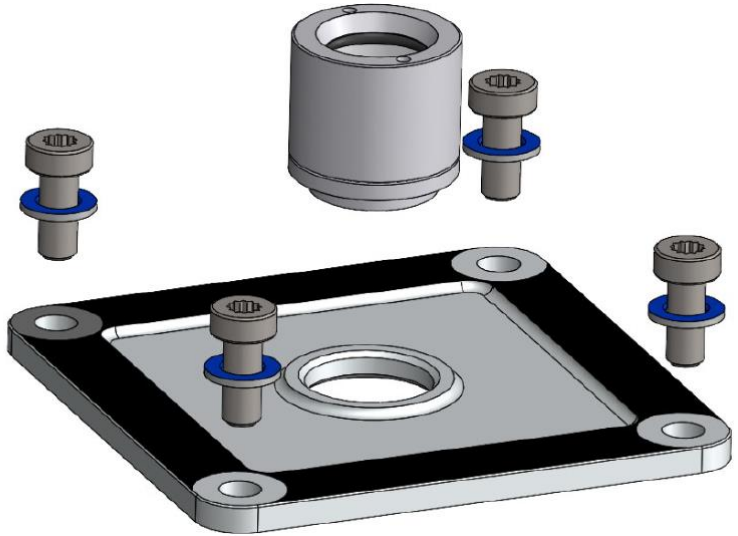
- 3D Marker QM design is equal to BB design (number of screws is 5)
- 3D Marker is located on the LAR interface of the client S/C
- 3D Marker function is to support rendezvous and tracking operations and pose estimation of the non-operational satellite from 5m to capture

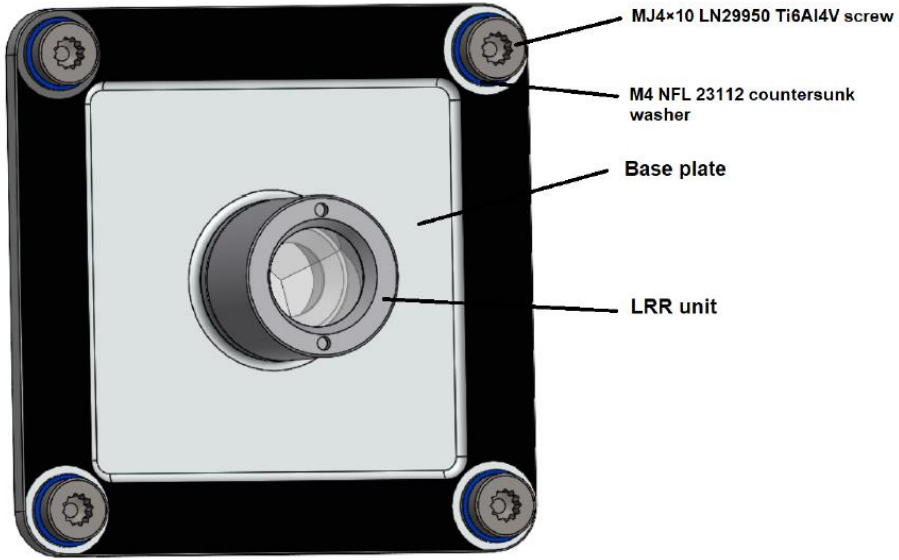




2D Marker – „MSN-60”

- 2D Marker QM design is different from BB design by swap of coatings
- 2D Markers are located on all sides of the client SC forming a unique pattern
- 2D Marker function is to support rendezvous and tracking operations and attitude determination of the non-operational satellite from 20m to 5m

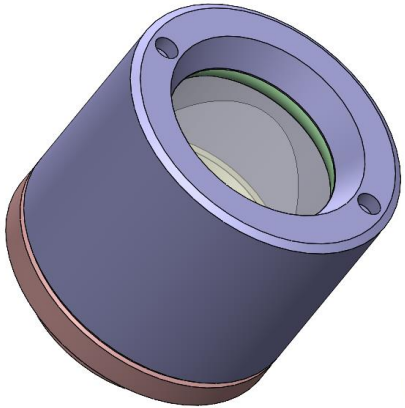


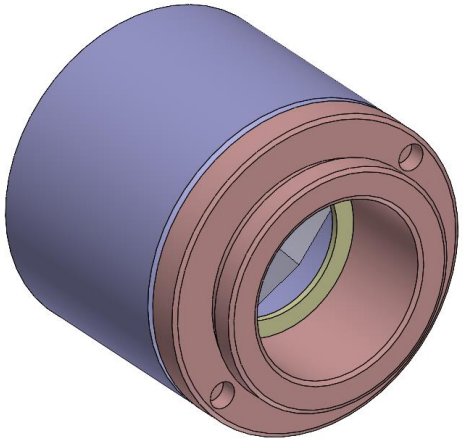


Laser Retroreflector

- LRRs are located in the middle of the 2D Marker
- LRRs to perform/support S/C standard positioning for tumbling satellite via SLR by ILRS (at 532 nm)
- LRRs perform/support S/C altitude determination for a tumbling satellite, via SLR by ILRS (at 532 nm)
- LRRs to support in space navigation to the S/C equipped with MSN by other approaching S/C

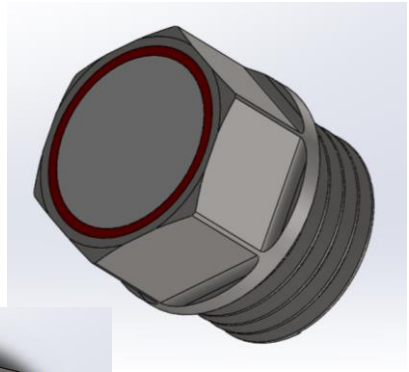
ADM

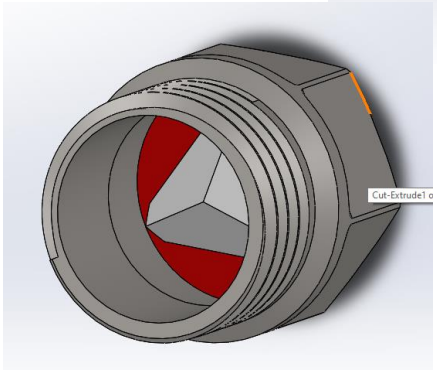




Screwed design

INFN

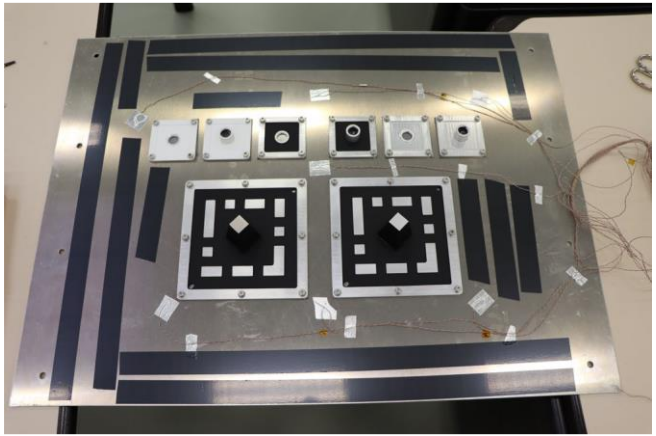


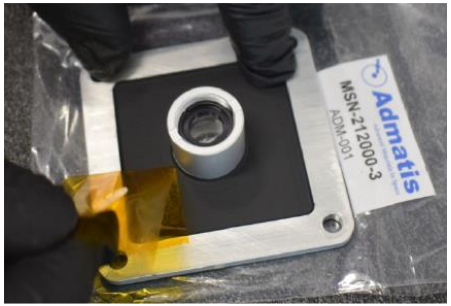


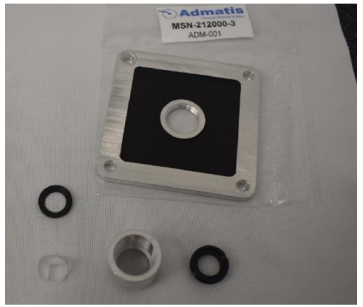
Glued design

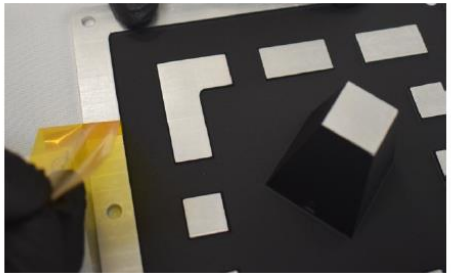
Qualification status of marker assemblies-BB

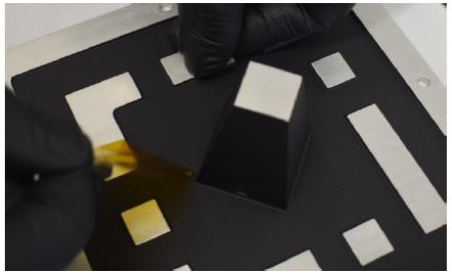
Inspections → Thermal vacuum cycling → Inspections → Vibration test → Inspections



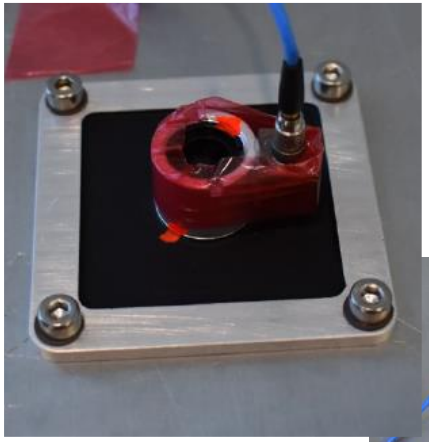


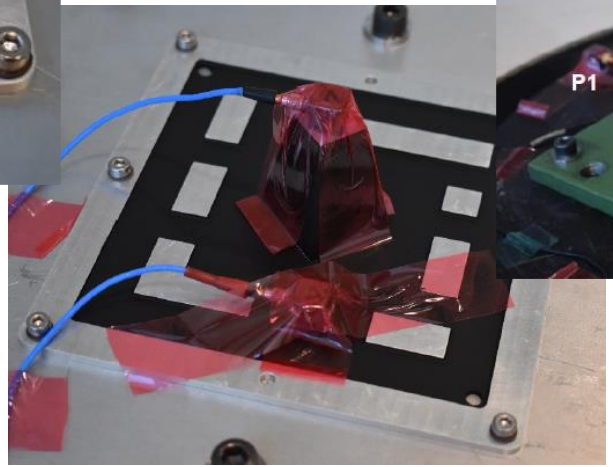


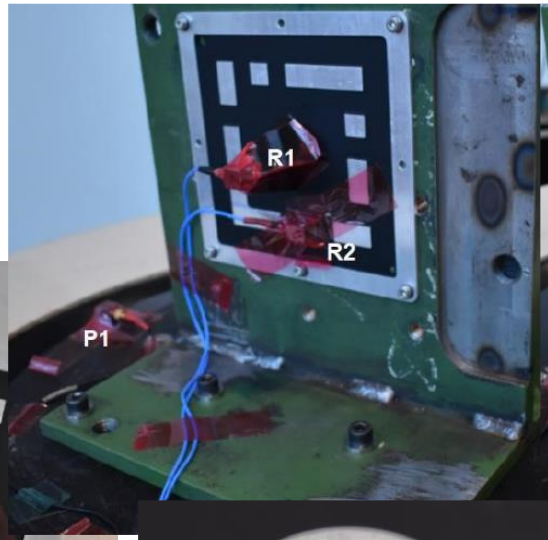


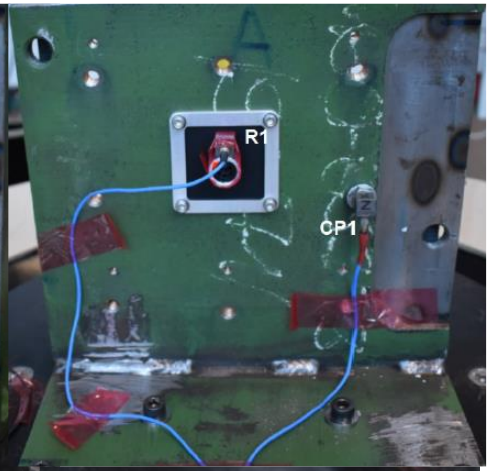


- ESTEC MEVAF -175°C/+107 °C
- 8 cycles in vacuum
- Visual inspection: PASS
- Adhesion: PASS
- Torque check: PASS







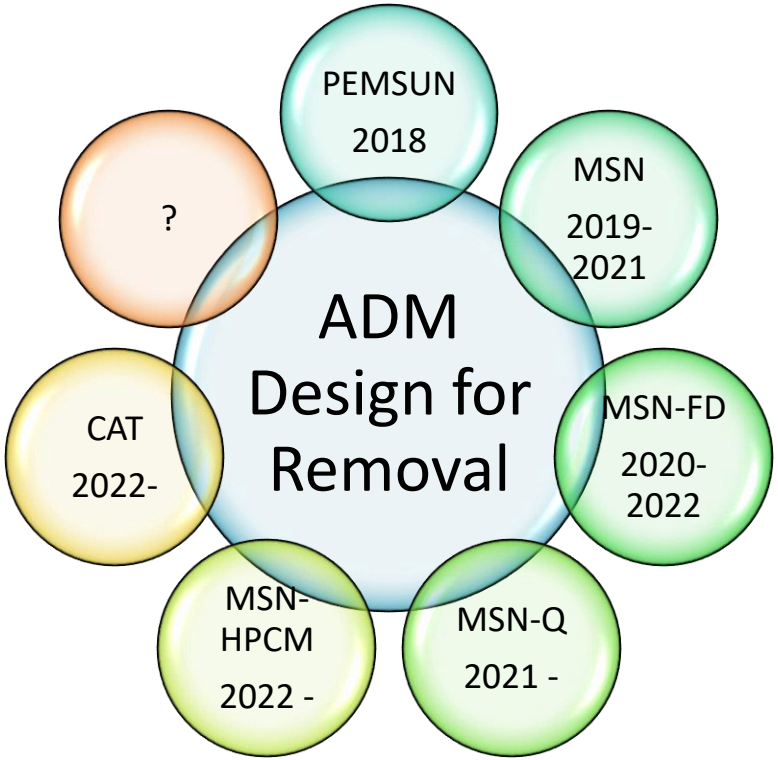


- DUE Hungary
- Sine and random against HPCM requirements
- Visual inspection: PASS. Slight rubbing marks on CCR edges
- Torque check: PASS

SUMMARY

- Materials qualification in terms of coatings of the markers has been successfully performed in the MSN project
- However, delta-qualification is necessary due to the changing requirements. It is currently running in the MSN-FD project.
- 2D and 3D Marker BBs have been manufactured and successfully tested in terms of thermal and mechanical environment
- 2D and 3D marker QM design has been consolidated based upon BB design and testing
- LRRs are designed by ADM and INFN (2 different designs). ADM design has been approved by ESA and released for manufacturing and testing.
- 2D and 3D Marker QMs manufacturing is in progress
- ADM-designed LRR qualifacation has begun in october in terms of radiation, ATOX and UV
- 2D and 3D Marker QMs assemblies qualification will be performed in Q1 2023 in terms of humidity, vibration, shock and TVAC to reach TRL7 for the assemblies

OUTLOOK



Thank you for your attention!