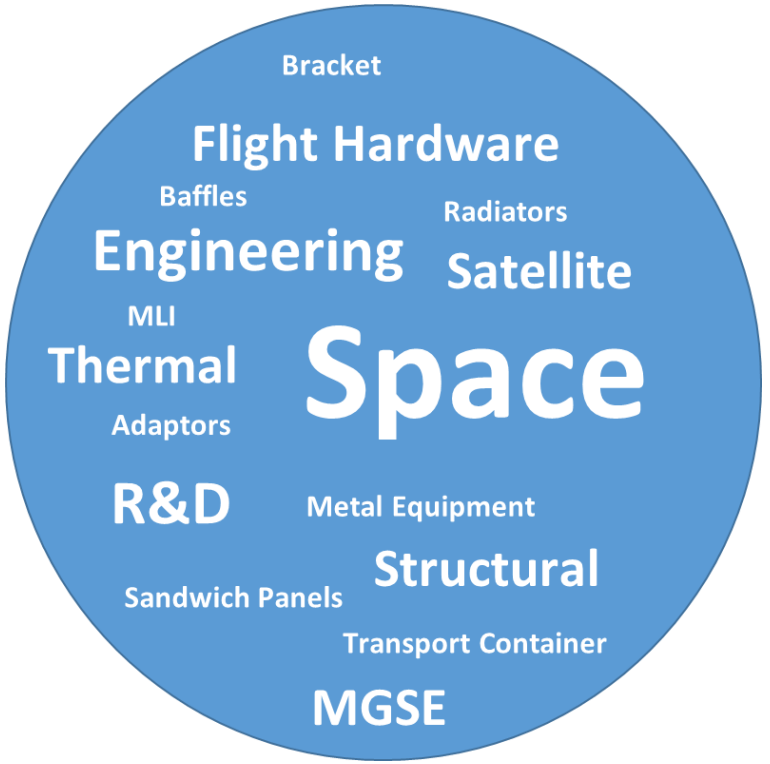
Navigation Markers Development
Clean Space Days 2024

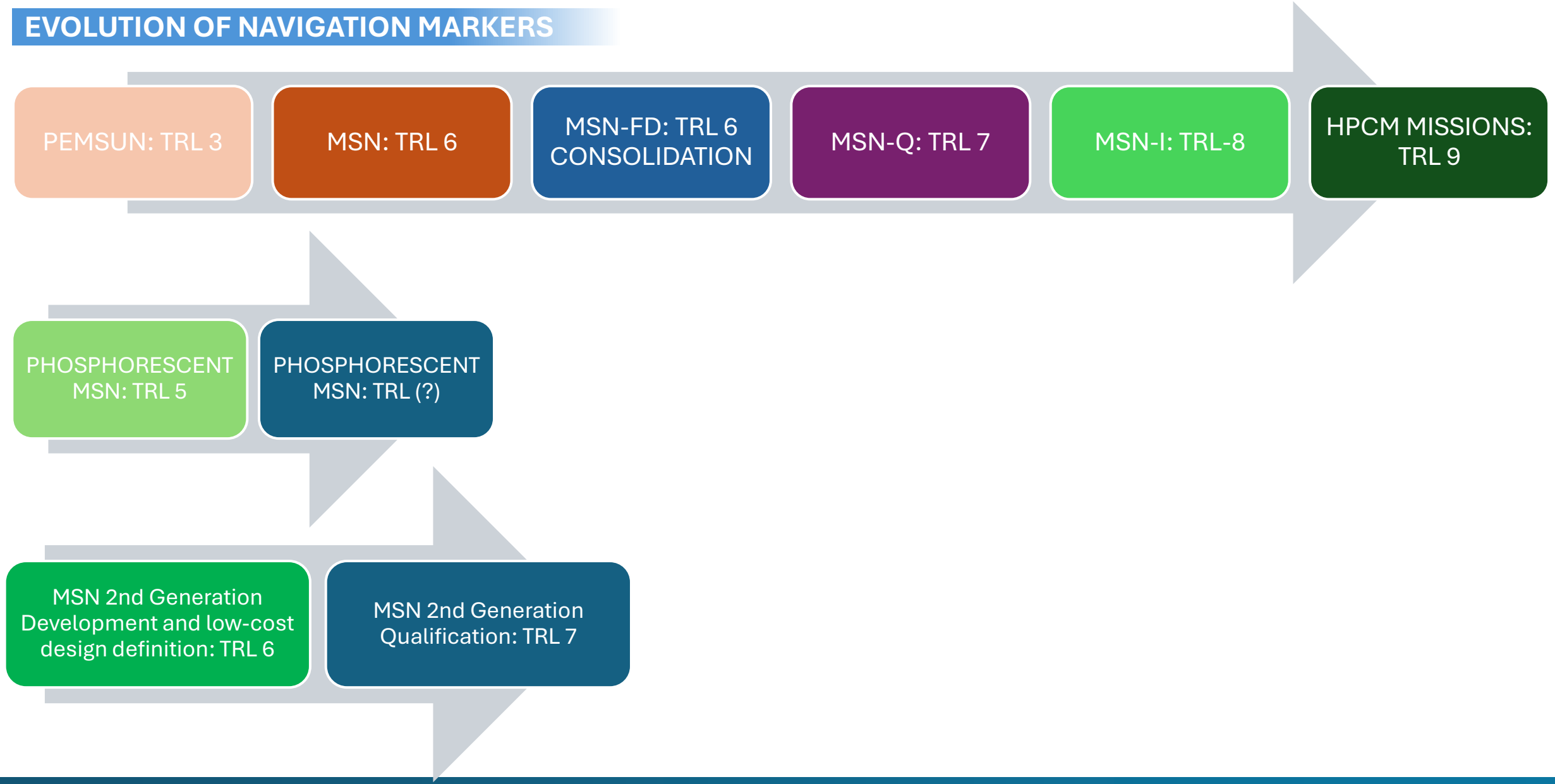
Admatis

Advanced Materials In Space



László SZEGEDI

EVOLUTION OF NAVIGATION MARKERS



PEMSUN: TRL 3

PROJECT OVERVIEW

ADMATIS Ltd joined the activity of ESA Clean Space initiative back in 2018 in the frame of **PEMSUN** (Passive Emitting Material Supporting Navigation for Close Proximity Operations project.

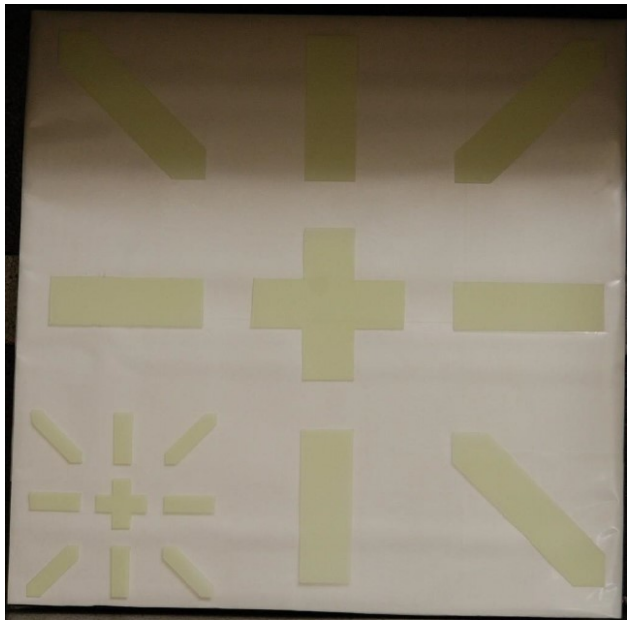
- characterize the feasibility of passive marker solutions in the infrared (**IR**) and in the visible (**VNIR**) spectrum
- trade-off different technical solutions in terms of image contrast, cost, system impact and effectiveness
- basic tests regarding marker visibility and estimations on EOL performance

CONCEPTUAL DESIGN

- Dimensions: 400×400m

IR

- Thermal control films with high (~ 0.7) and low (~ 0.05) emissivity

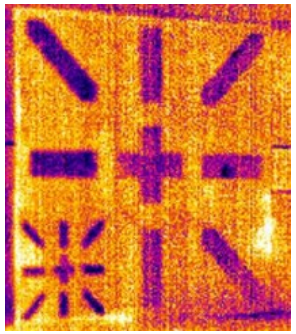
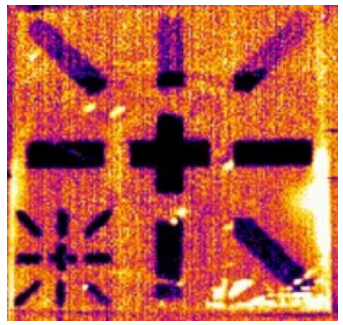
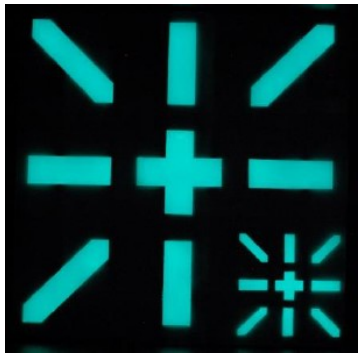
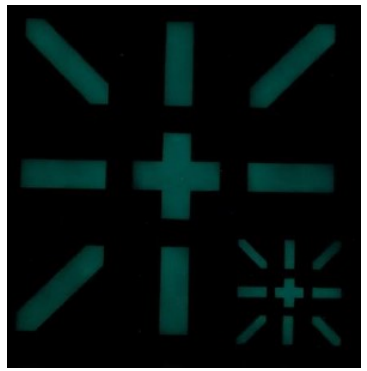
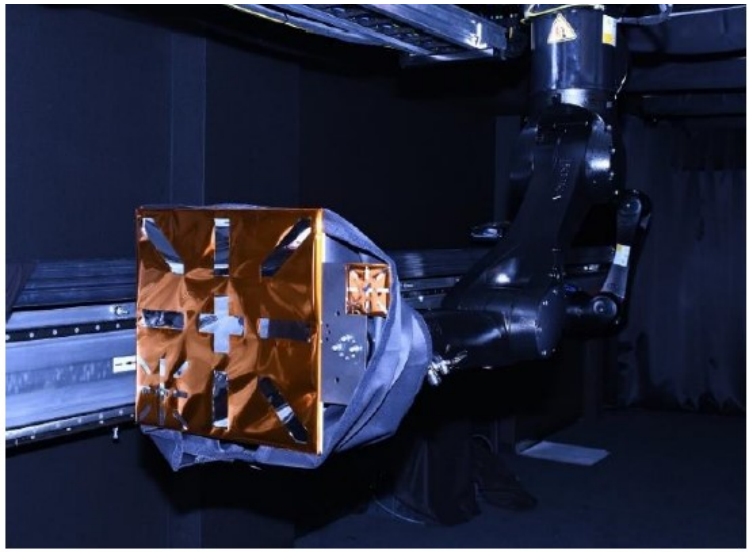
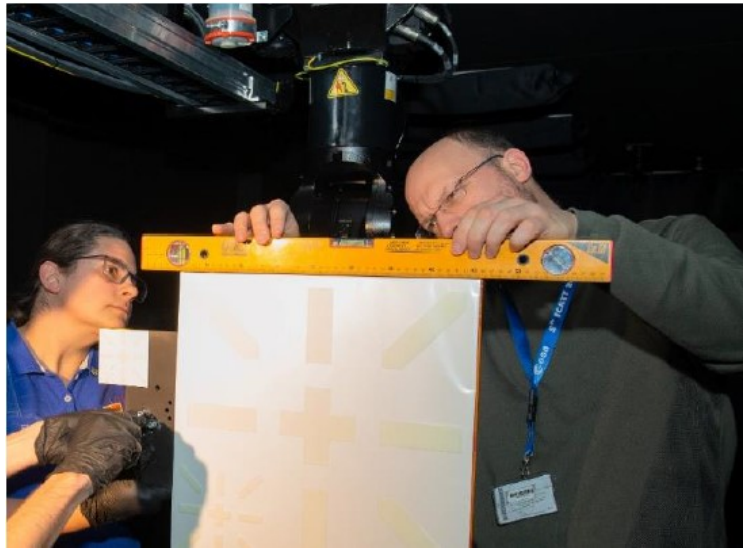


VNIR

- COTS phosphorescent paint

PEMSUN: TRL 3

TEST RESULTS-CONCLUSIONS

- Selected pattern is able to help image processing and can be used for navigation and pose estimation purposes
- good candidate for further development in case of both IR and visual markers
- space environment leads to changes of optical properties, that results to loss of contrast, but it remains detectable after the operational period of the spacecraft and will be able to use for positioning

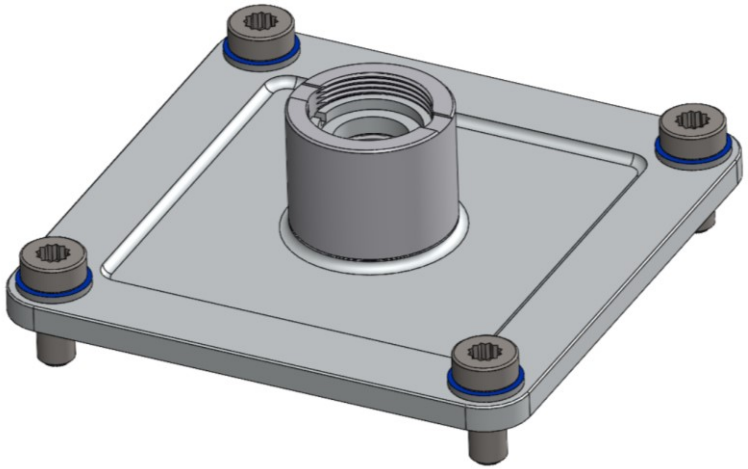
PROJECT OVERVIEW

Markers Supporting Navigation

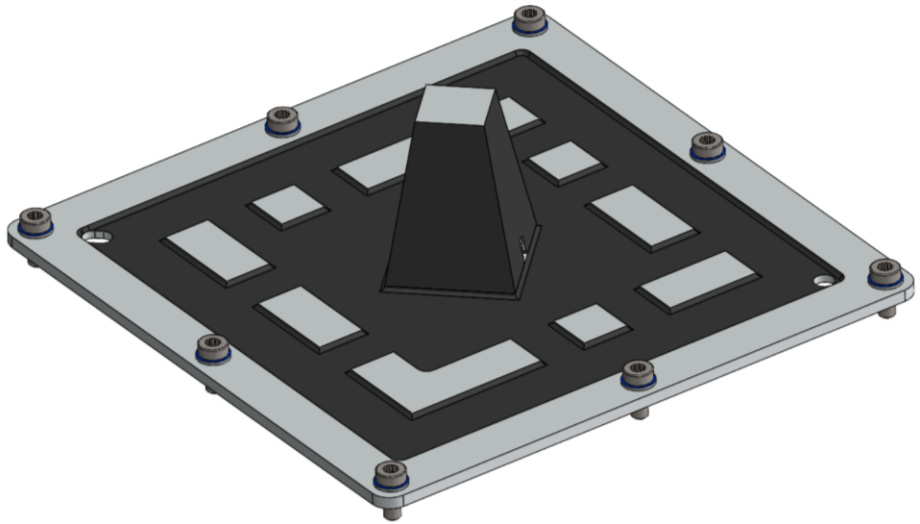
- started in 2020 to extend and further develop results achieved in PEMSUN
- to select most promising materials for IR/visual satellite markers with lowest degradation during ageing tests,
- to select processes for manufacturing,
- to design and build representative markers (BB) to be used as support GNC equipment in ESA Design for
- Removal (D4R) project.

CONCEPTUAL DESIGN – SIGNIFICANT CHANGES

- 2 kind of markers
  - 3D Marker (150×150mm) for close range (below 5m)
  - 2D Markers (60×60mm) for long range (50-5m)
- Implementation of LRR units in the 2D Markers



3D Marker BB

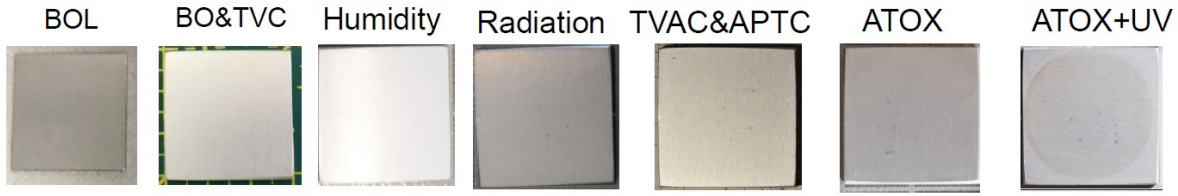


2D Marker BBs with COTS LRR unit

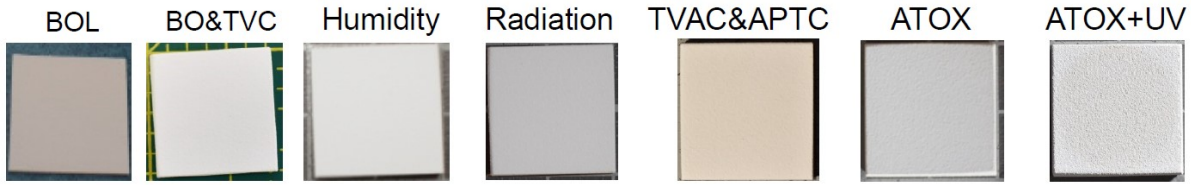
MSN: TRL 6

MATERIALS-COATINGS QUALIFICATION TESTS

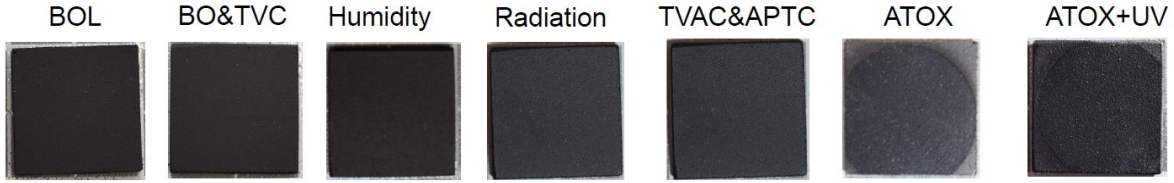
Trivalent Chromium Conversion Coating-Surtec



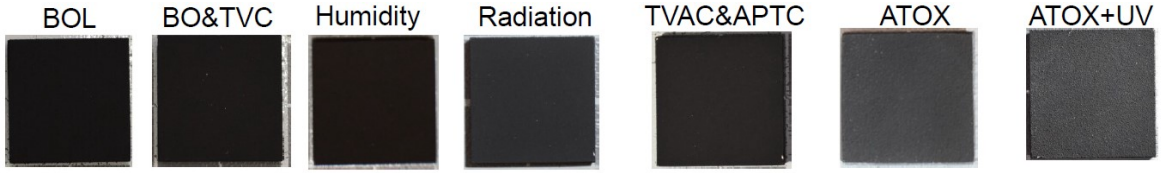
Silicone Based White-SG121FD



Polyurethane Based Black-PUK

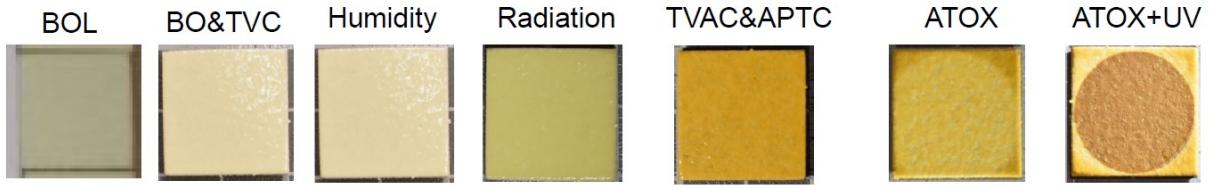


Silicone Based Black-PNC

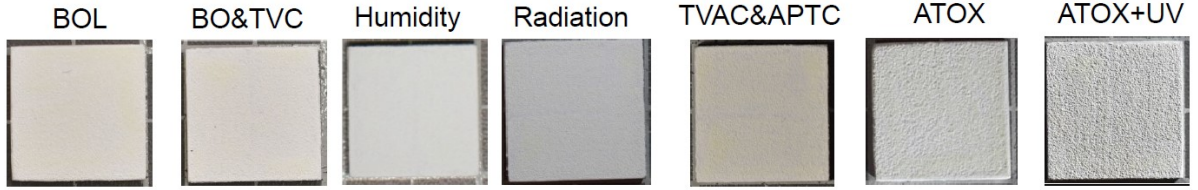


- 5 materials are recommended for further use as marker coating materials based on Q tests

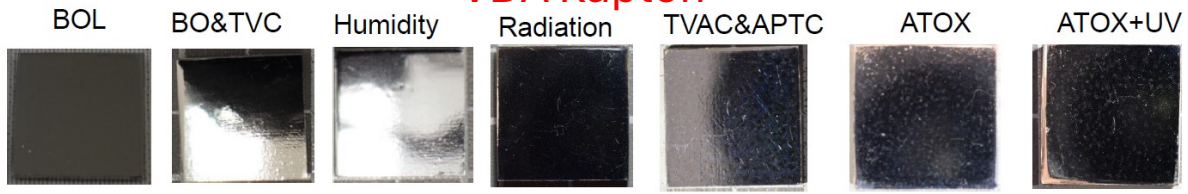
COTS Phosphorescent: Dhi Afterglo



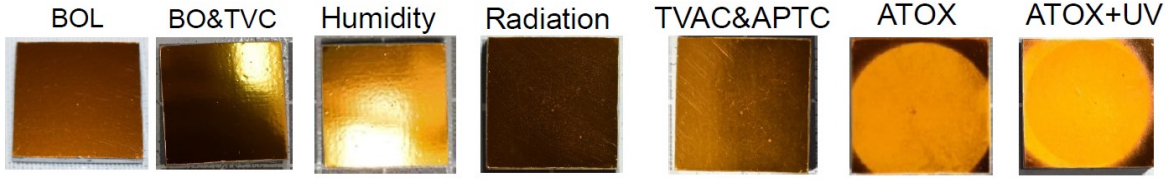
ADM Phosphorescent: MSN Afterglow



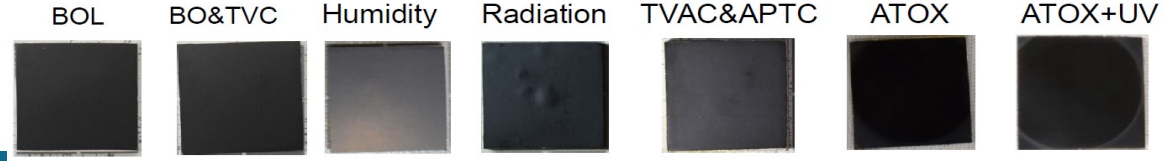
VDA Kapton



Kapton

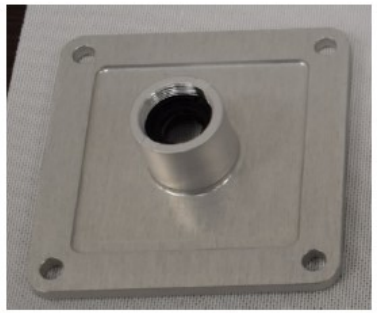
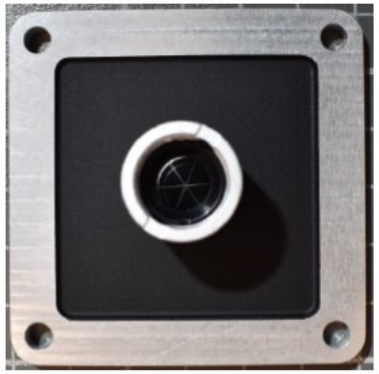
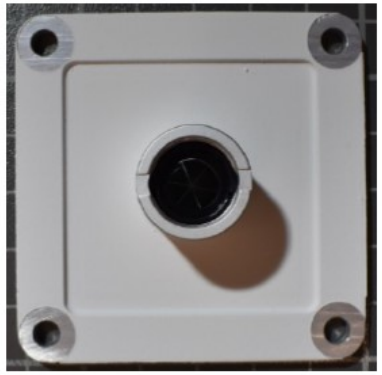


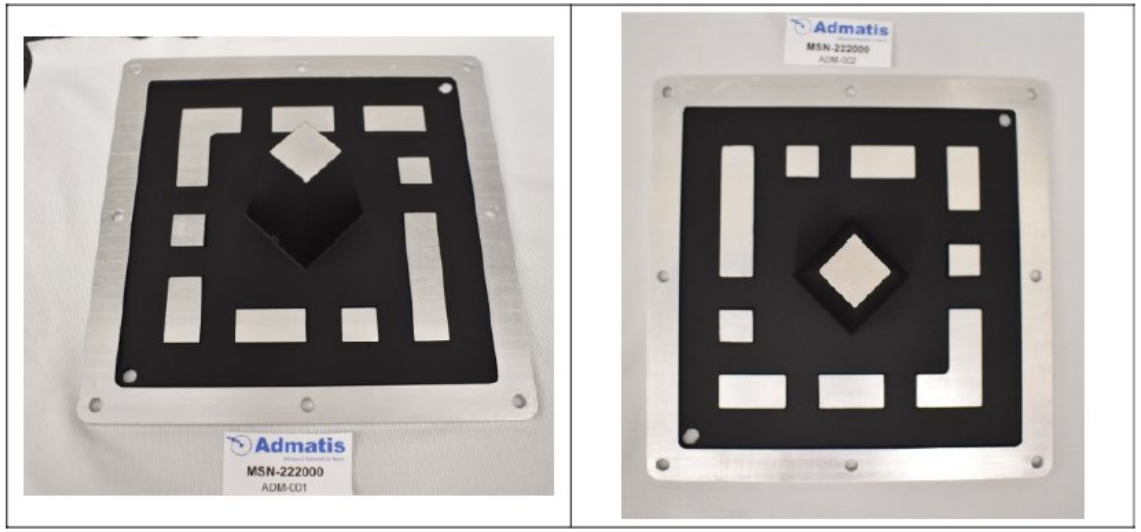
Black Kapton

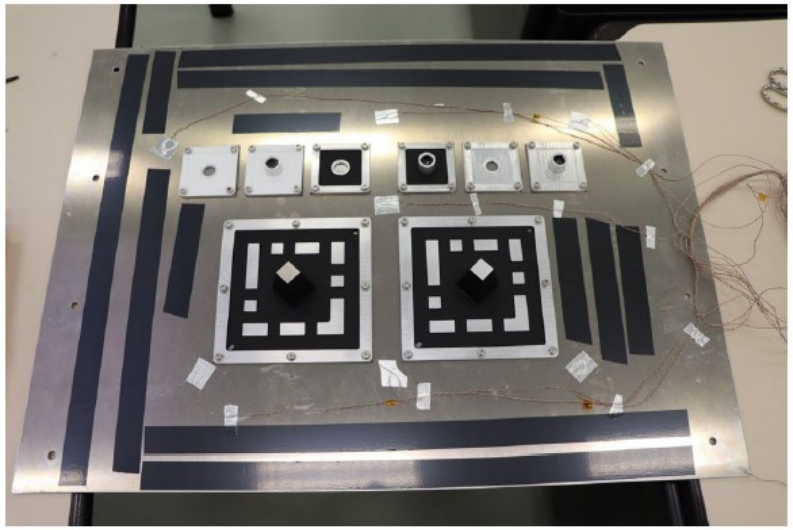


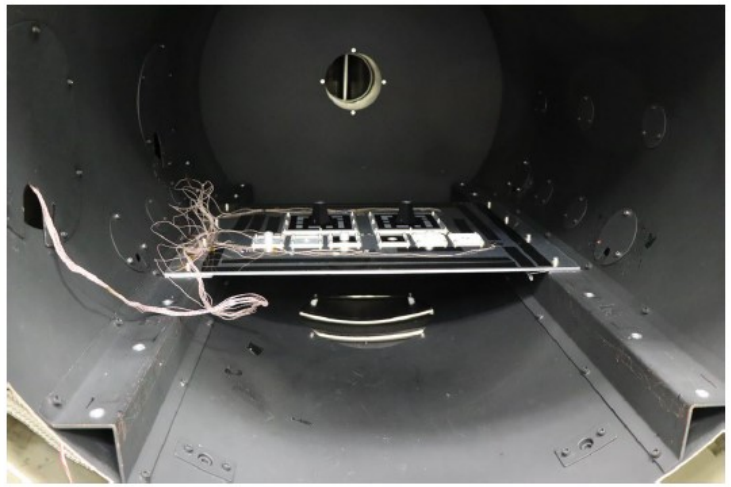
MSN: TRL 6

BB MANUFACTURING AND TVAC TESTING

MSN-212000-1 ADM-001	MSN-212000-3 ADM-001	MSN-212000-2 ADM-001
		





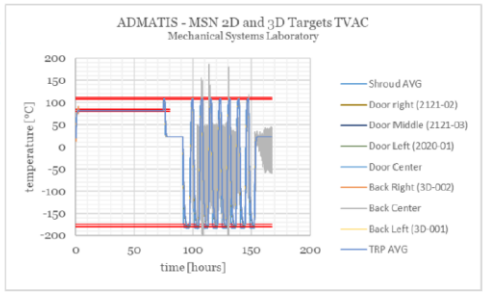


TVAC Test

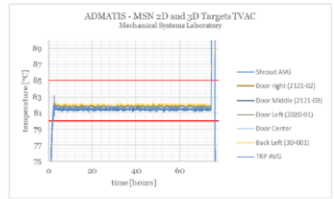
Test parameters

Bake Out:	T= +80°C (+5/-0)°C / 72 hours dwell
Temperature:	T_{max} = +107°C (+5/-0)°C / T_{min} = -175°C (+0/-5)°C
Dwell time TV cycling:	> 60 minutes
Number of cycles:	8
Maximum $T_{change\ rate}$:	<10°C/min

Test results



TVAC Diagram



Bake out Diagram

Thermal qualification of 3D and 2D Marker BBs was succesful.

MSN-FD: TRL 6

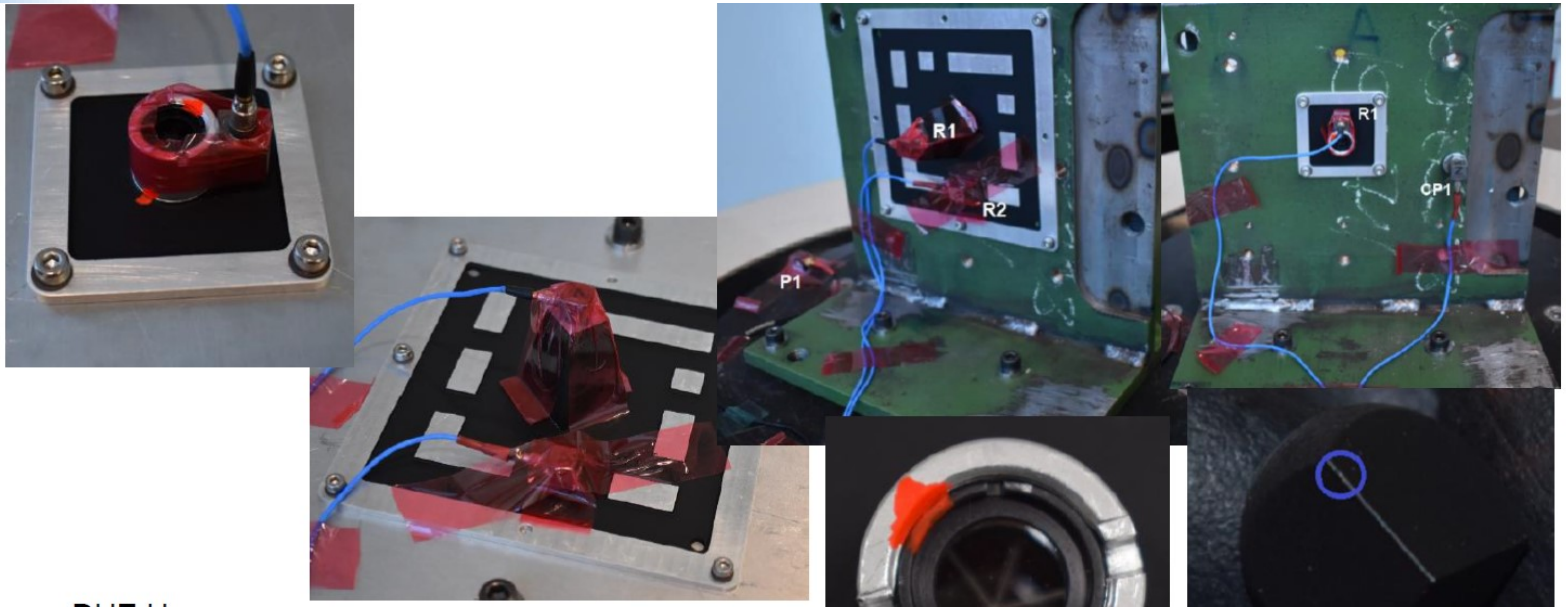
PROJECT OVERVIEW

Parallel with the MSN activity, the MSN-FD project was started in 2021 to identify and test more potential marker materials, including inorganic black coating and conversion coating with different surface roughness of the substrate. Besides, development of Laser Retroreflector Unit to be used on the 2D Marker and design consolidation of both type of markers have been finished, reaching TRL6 for the navigation markers.

DESIGN CONSOLIDATION

3D and 2D Marker BB vibration test

- 3D and 2D marker design has been qualified according to HPCM requirements
- Vibration test proved that screwed LRR design is a viable solution

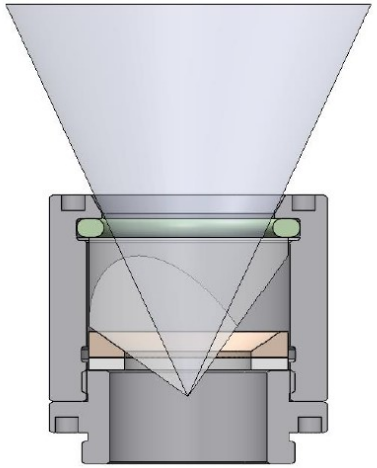


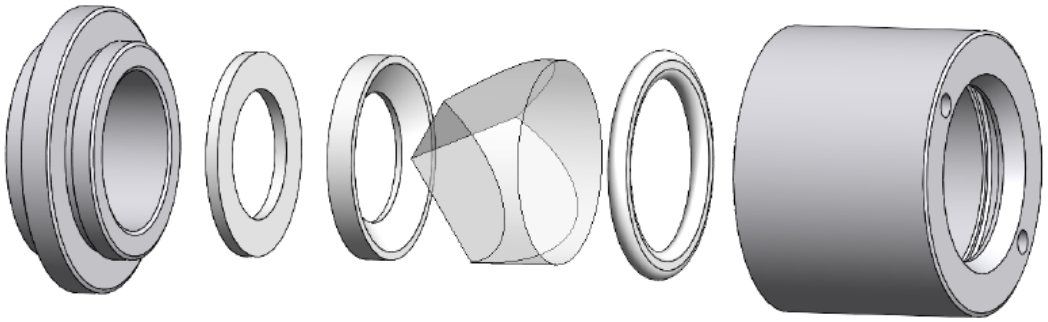
- DUE Hungary
- Sine and random against HPCM requirements
- Visual inspection: PASS. Slight rubbing marks on CCR edges
- Torque check: PASS

19

MSN-FD: TRL 6

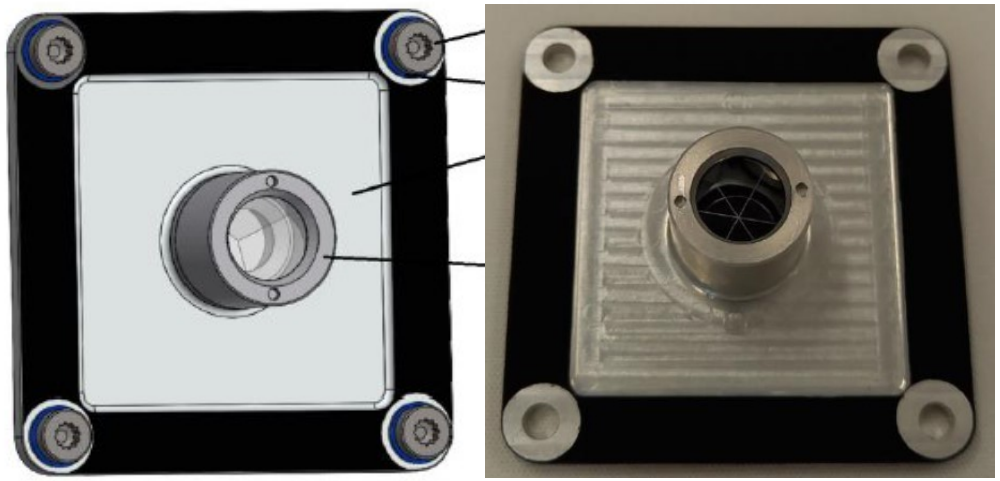
ADM LRR DEVELOPMENT



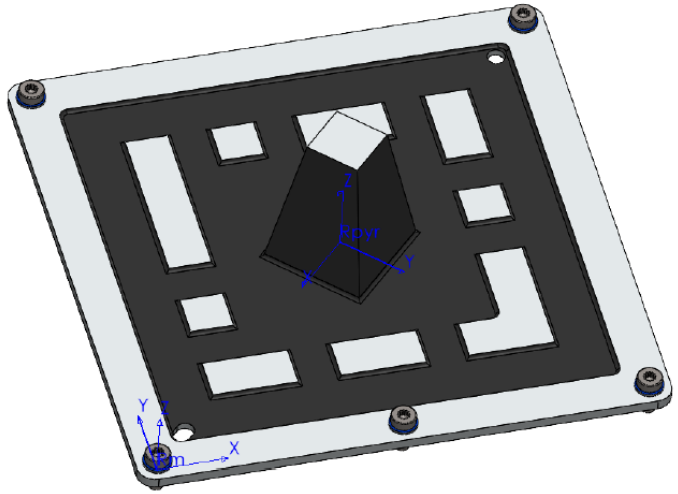


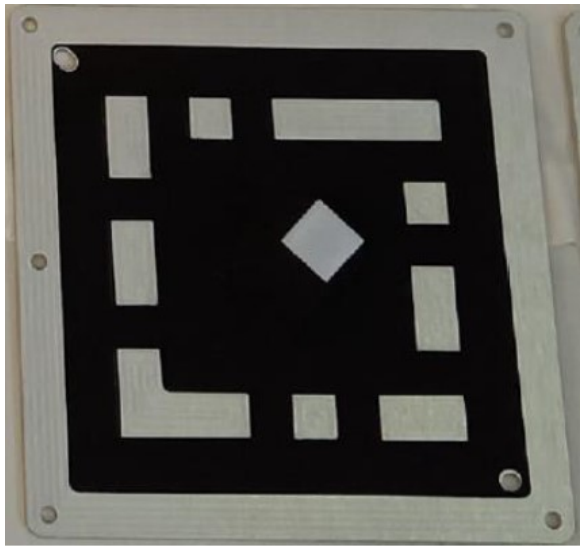
- Tube
- O-ring
- EO CCR
- Support ring
- Spacer ring
- Retaining ring

DEVELOPMENT OF QMs



2D Marker QM with ADM LRR



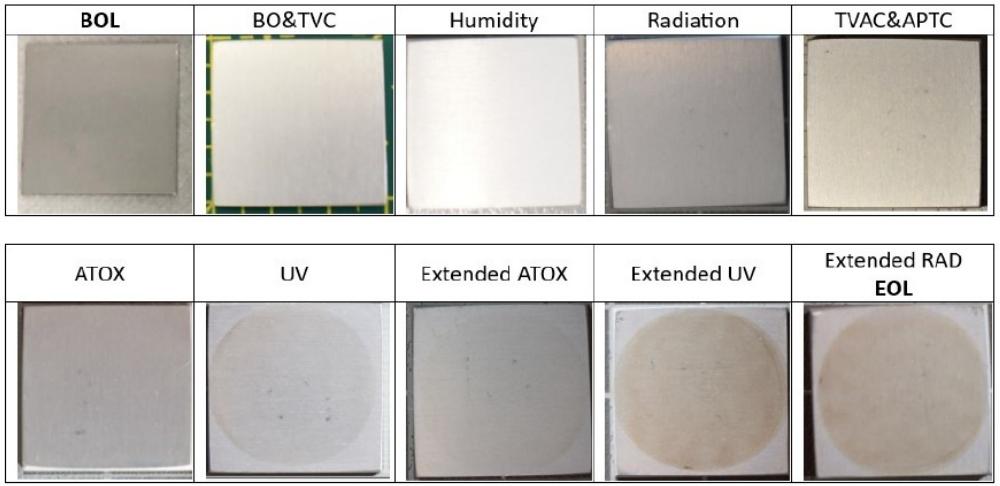


3D Marker QM with five interface holes

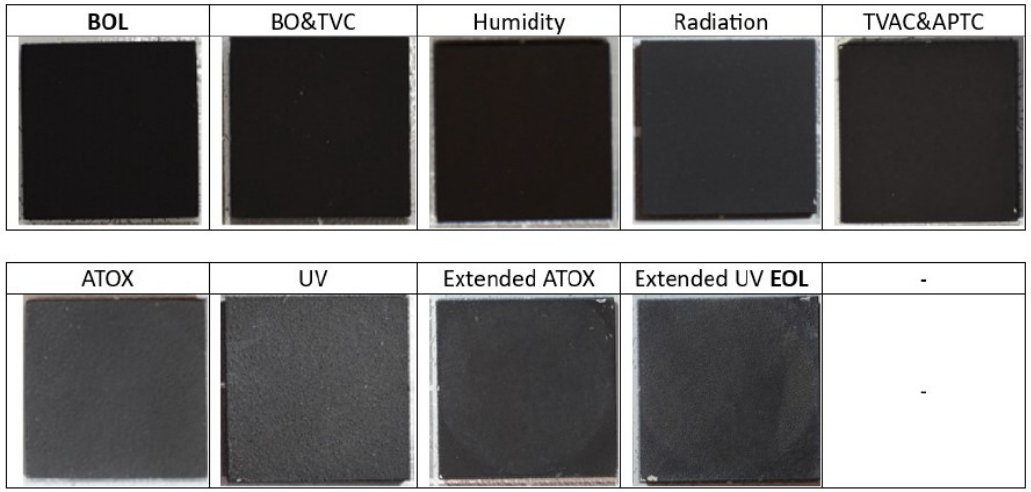
MSN-FD: TRL 6

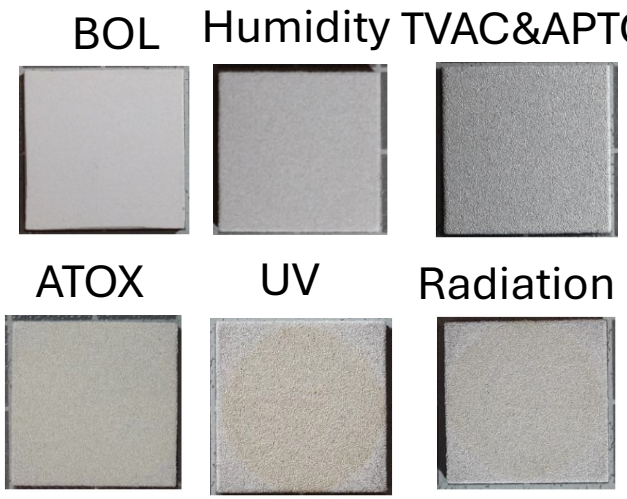
NEW MATERIALS & AGEING TESTS

- Succesful delta-qualification of coatings due to higher ATOX, UV and radiation requirements

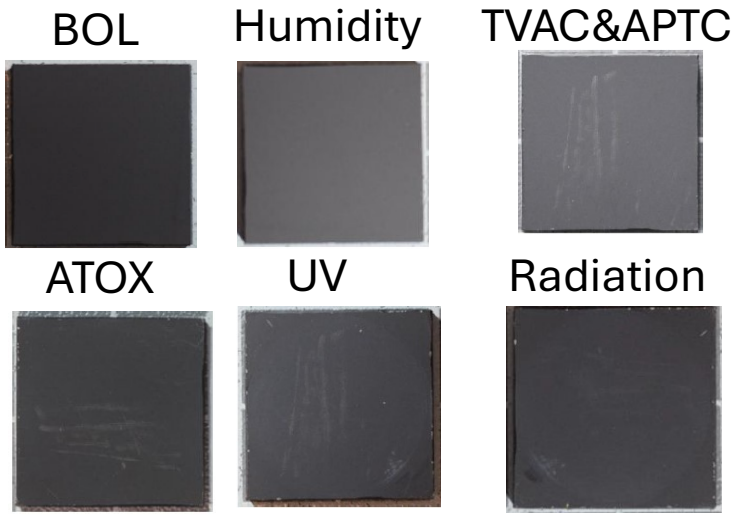


- Surtec
- PNC





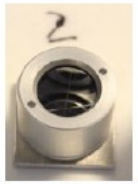
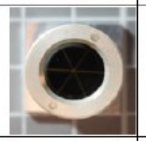
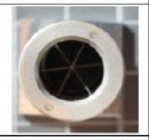
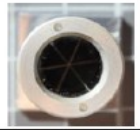
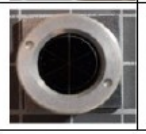
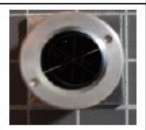
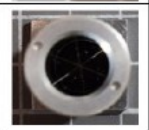
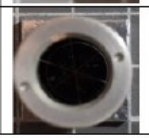
- Qualification of new materials: Surtec with different Ra

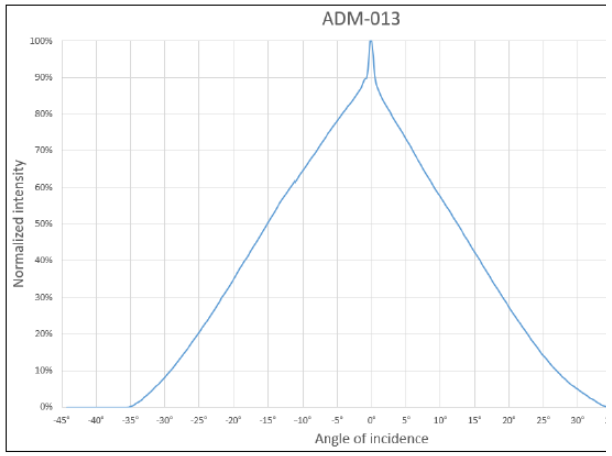


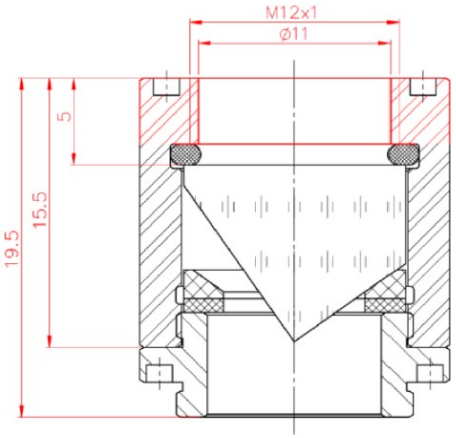
- Inorganic black (Kepla-coat)

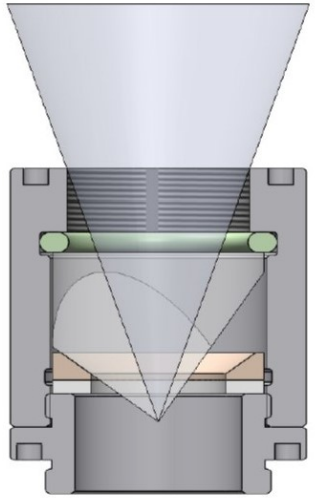
MSN-FD: TRL 6

LRR AGEING TESTS AND FOV MEASUREMENT

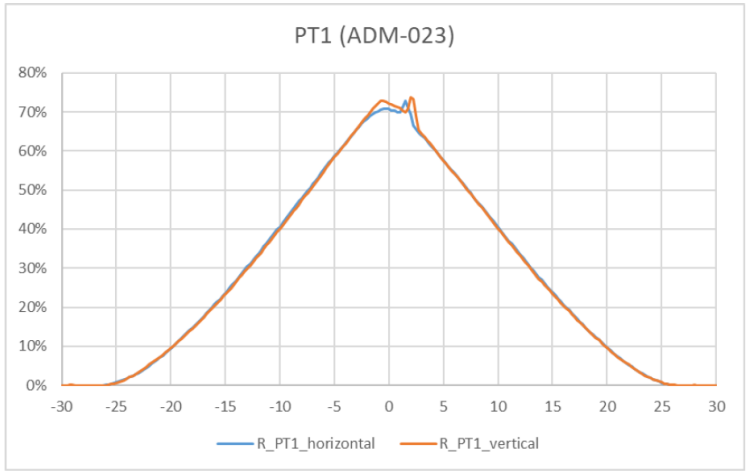
	LRR 1	LRR 2	LRR 3	LRR 4	LRR 5	LRR 6
BOL						
After ATOX						
After UV						
After Radiation						







- normalized reflected intensity value of 14.1% at 25° angle of incidence and 20.3% at -25° angle of incidence.



- No practical change in WFE RMS
- Max. reflectivity decrease is 30%

- Reflected beam intensity is below 1% at 25 deg

3D and 2D marker assemblies design have been consolidated and reached TRL 6 ready for qualification.

MSN-Q: TRL 7

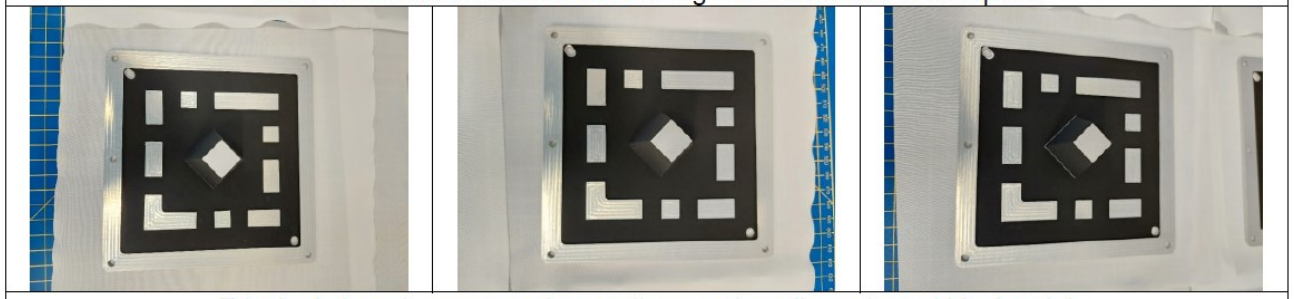
PROJECT OVERVIEW

- MSN Qualification activity focused on the qualification of MSN markers to be used on Copernicus Expansion satellites, by increasing the 2D and 3D marker assembly TRL level from 6 to 7.
  - requirements have been consolidated
  - 3D and 2D Marker design including LRR has been and finalized

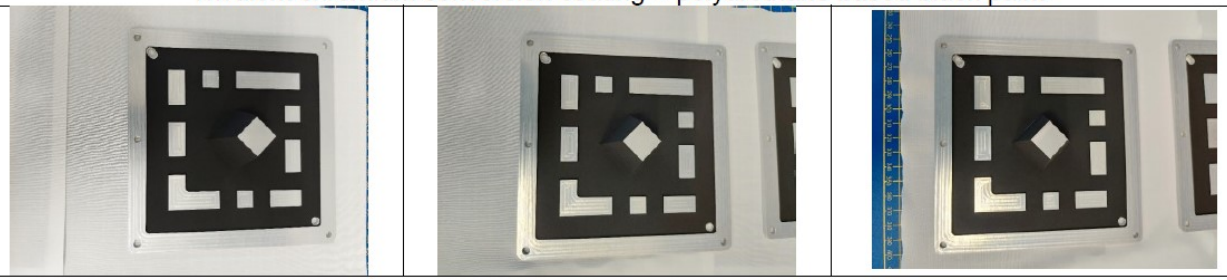
MANUFACTURING

- two sets of markers with different thermo-optical coatings

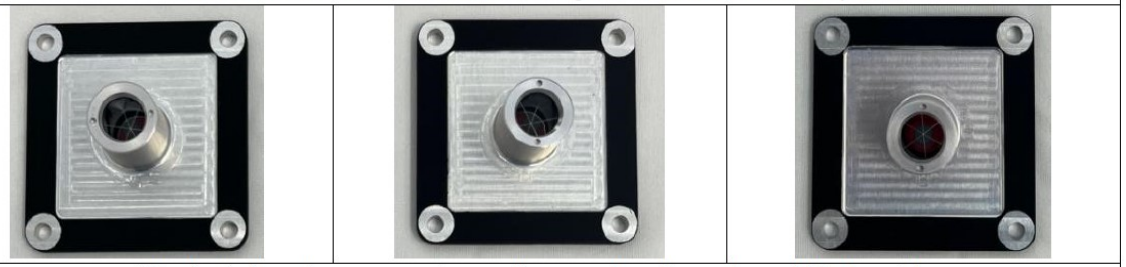
Trivalent chromium conversion coating + silicone based black paint



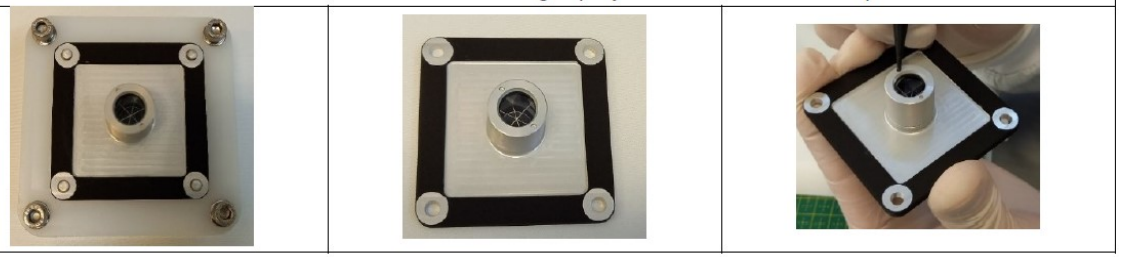
Trivalent chromium conversion coating + polyurethane based black paint



Trivalent chromium conversion coating + silicone based black paint



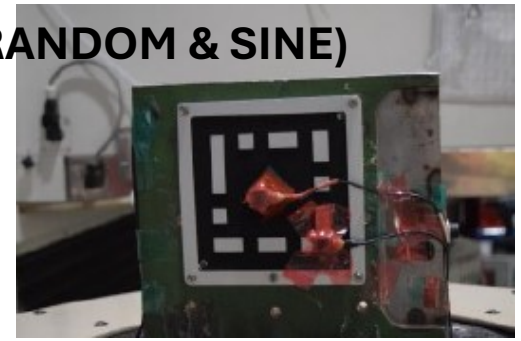
Trivalent chromium conversion coating + polyurethane based black paint



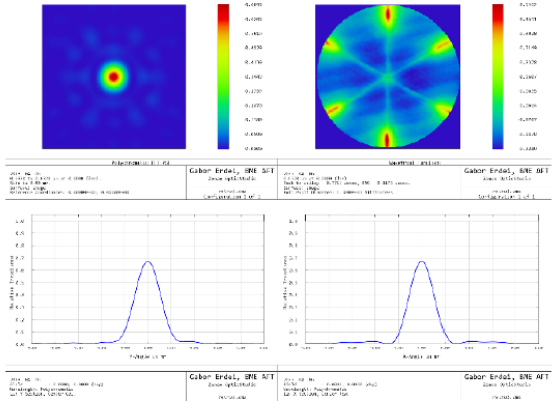
MSN-Q: TRL 7

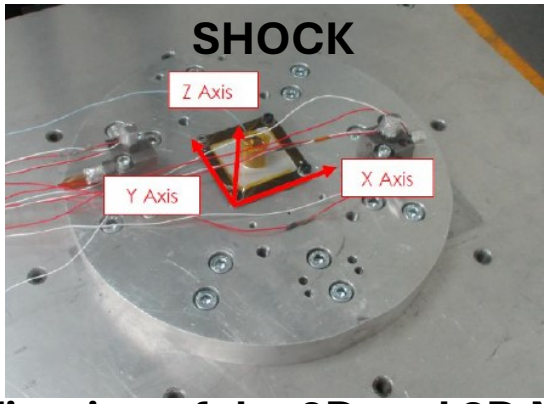
QUALIFICATION TESTING

- These two sets of markers have then been subjected to qualification testing including ***bakeout, humidity, vibration, thermal vacuum cycling and shock test*** following the life cycle of flight hardware.



OPTICAL MEASUREMENTS





Based on the above, the qualification of the 2D and 3D Markers was successful in terms of the HPCM missions' qualification environment and reached TRL7 at the end of the qualification.

MSN-I: TRL 8

OVERVIEW

As a first step of the MSN industrialization 6 pcs of 2D Marker have been manufactured for the AVS LUR-1 CAT In Orbit Demonstration satelit, which was launched on August 16, 2024.

The manufacturing of a total of 88 2D Markers and 6 3D Markers (excluding internal spares) for LSTM and CRISTAL satellites (*prime AIRBUS*) began in March and is currently in the acceptance testing phase.

The contract is currently being finalized for the production of 64 2D Markers and 4 3D Markers for the CO2M mission (prime OHB), and a similar quantity planned for the CHIME mission (prime Thales Alenia Space).

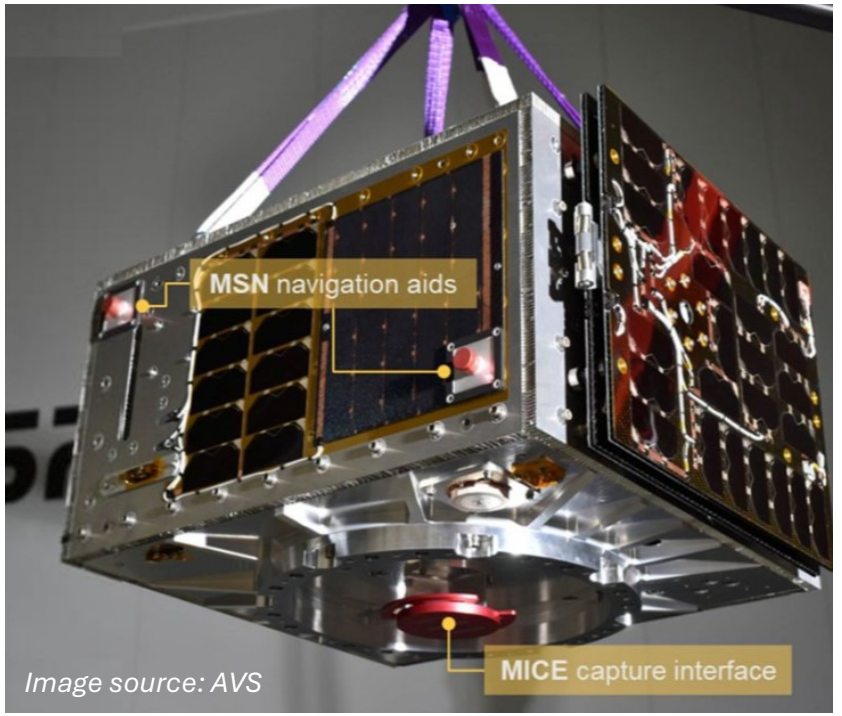
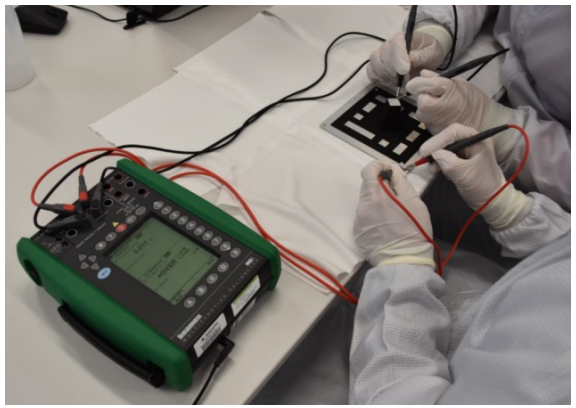
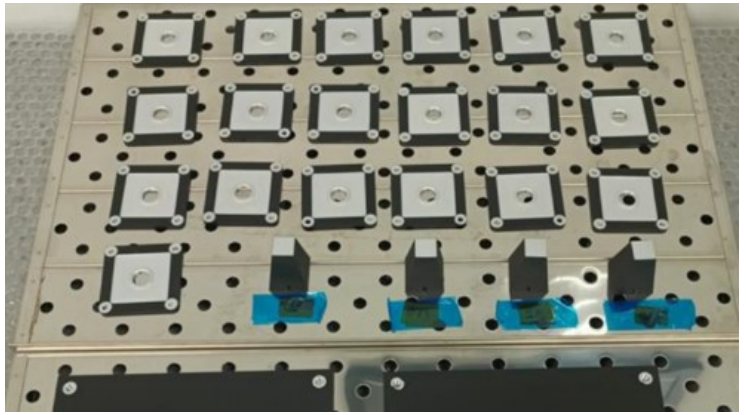
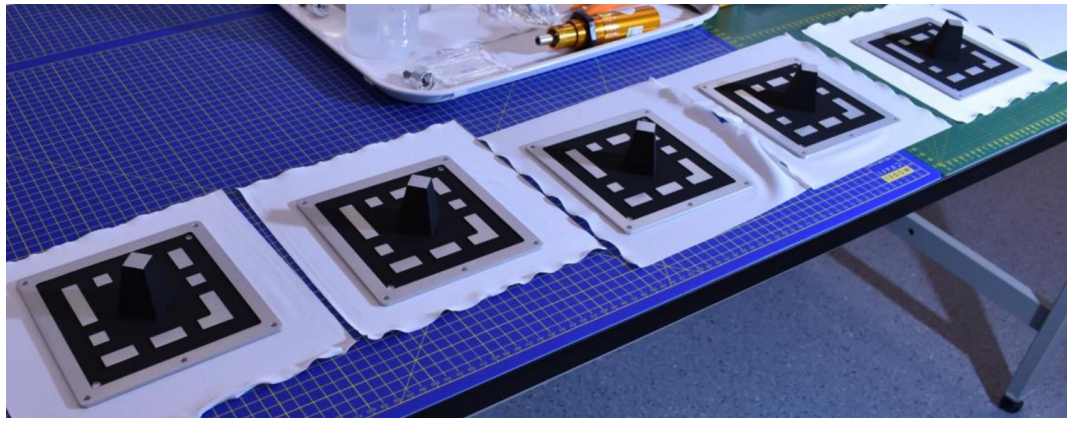


Image source: AVS



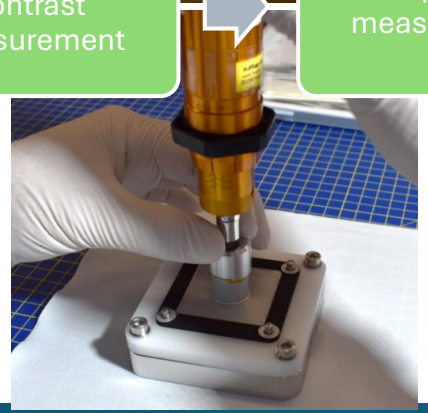


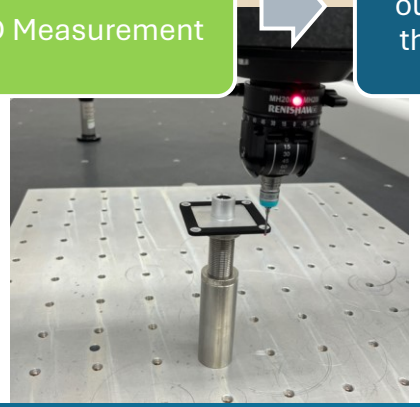


MSN-I: TRL 8

OVERVIEW

Metal machining → Inspection (KIP) → Surface finishing → Trivalent Chromium Conversion Coating → Inspections (KIP) → Painting → Inspections → Curing → Inspections (KIP) → Assembly → Inspection → Grounding and Mass measurement → Acceptance contrast measurement → Optical measurement → Acceptance Vibration Test (MIP) → Inspections 3D Measurement → Bake out/Acceptance thermal cycling → Critical cleaning and Pacaging





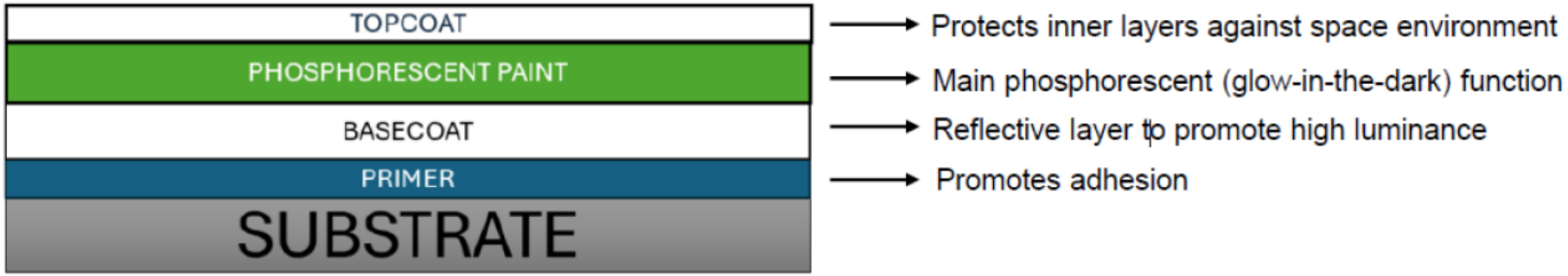
PHOSPHORESCENT MSN: PHM

OVERVIEW

This activity aims at further developing the use of phosphorescent paints for the purpose of support rendezvous and navigation.

- The objectives of the activity are:
- Develop and test phosphorescent paints to support navigation in all illumination conditions
- Develop and test a marker concept using the phosphorescent paint developed.

DESIGN CONCEPT



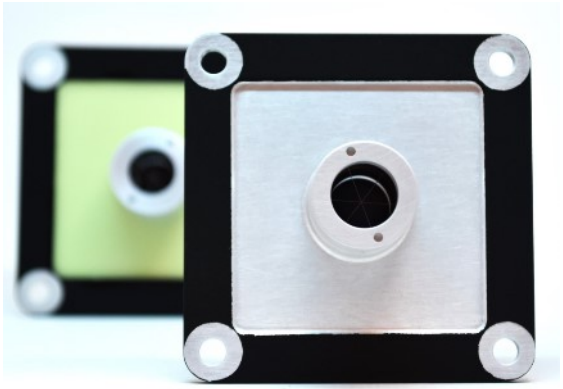
Most challenging task is to protect the phosphorescent paint system from degradation caused by the space environment

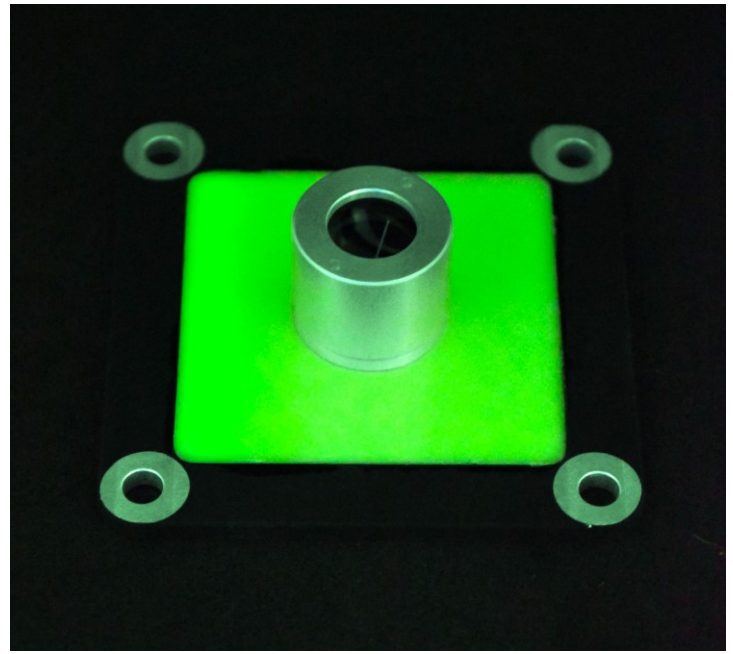
- Preliminary requirements have been defined by GMV, as main supplier of ADM in the project
- Comprehensive SOA and trade study have been prepared regarding the phosphorescent materials, paints and processes
- More than 100 kind of phosphoresecent pigments have been ranked, and the best performing 12 kinds have been selected
- Further pigment selection is in progress to reduce the possibilites, and select the most appropriate binders and topcoats

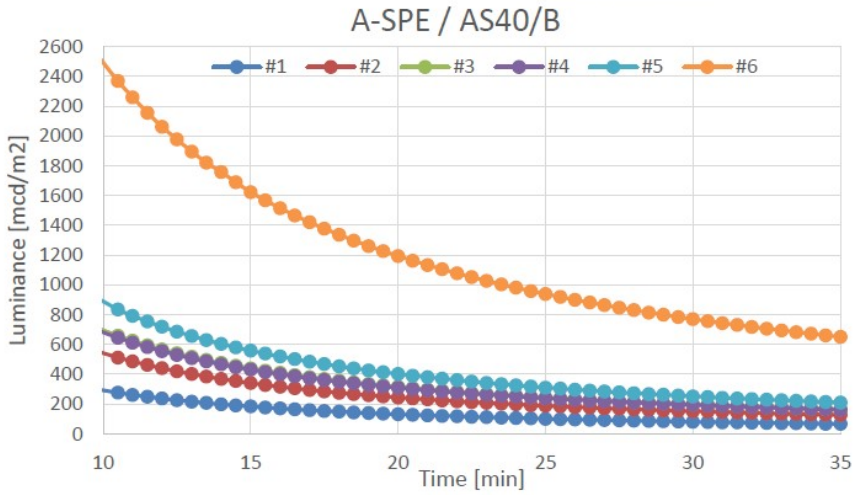
PHOSPHORESCENT MSN: PHM

MATERIALS AND PROCESS DEVELOPMENT

Currently, almost 100 pieces of test samples have been manufactured with different kind of pigments, layer thicknesses and binders. Evaluation is in progress and focusing on best afterglow and adhesion properties. Selection of viable paint system solutions is expected by the end of this year.







Time	#1	#2	#3	#4	#5	#6
5	636,7	1175	1495,4	1476	1900	5026
10	292,4	542,1	695,8	681,3	889	2491
15	184,1	340,9	440,4	430,9	558,7	1621,1
20						
25	101,7	188,5	244,7	239,6	311,3	938,8
30	80,68	152,6	198,2	194,6	252,2	769,8
35	67,1	127,6	165,6	162,5	210,8	651,4
TH	**196,0**	**400,2**	**492,0**	**472,8**	**658,2**	**3880,0**

MSN 2ND GENERATION: M2N

OVERVIEW

Markers to Support Navigation (MSN) - Second Generation development and low-cost design definition

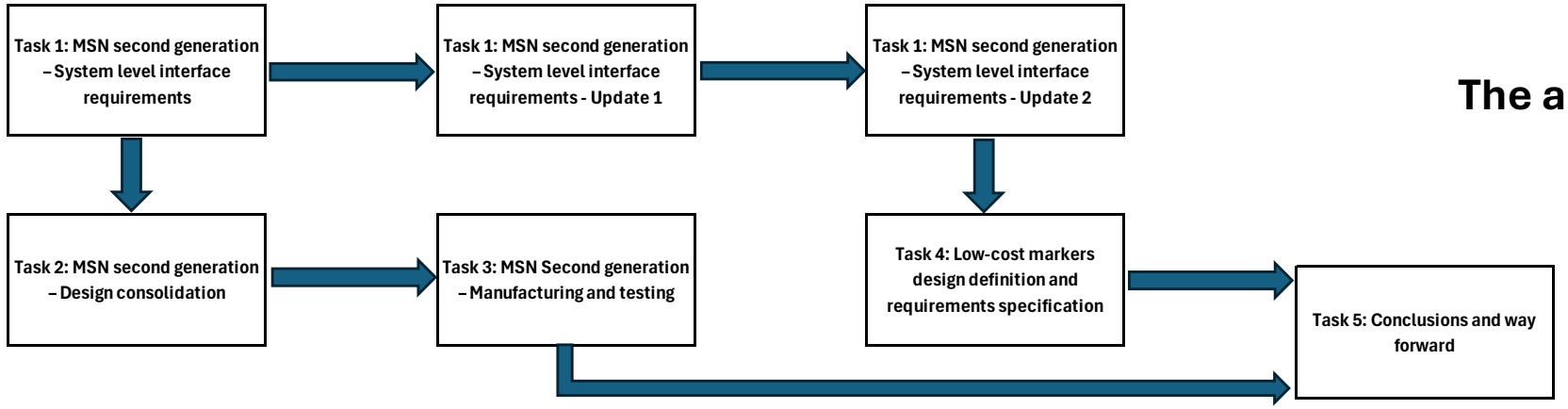
- The major objective of the M2N project is improving the current first generation of Markers to Support Navigation, as well as to define the design for low-cost markers.
  - The objectives of the activity are:
    - Develop a second generation of Markers to Support Navigation with performance improvements with respect to the MSN first generation, including optical performance improvements, AIV improvements and LRR improvements.
    - Consolidate the MSN interface requirements ***at all levels***, considering the marker design, LRR design, GNC and CPO, positioning, environment, etc.
    - Develop a low-cost 2D and 3D markers design for large constellations and manufacture a breadboard of them.

PROJECT TEAM

- Contractor is Admatis Ltd, (expertise in materials and processes, manufacturing and testing)
  - Suppliers:
    - GMV (expertise in GNC)
    - BME (expertise in optical measurements)
    - TU Berlin (expertise in SLR)

MSN 2ND GENERATION: M2N

WORK LOGIC



The activity is planned for 16 months.

- ***Task 1: MSN second generation – System level interface requirements***
  - Consolidate the MSN second generation requirements at all levels, considering the markers design (size, pattern), the LRR design, positioning of the markers at system level. Flow down requirements from system to unit level.
- ***Task 2: MSN second generation – Design consolidation***
  - Consolidate the improvements suggested from MSN first generation. This includes optical performance improvement (decrease reflection), AIV improvement by inorganic coatings application, LRR improvements by fixing of current design which results in some optical performance loss and define a new LRR design glued.
- **Task 3: MSN Second generation – Manufacturing and testing**
  - Manufacture and test the MSN Second Generation. Testing will include environmental and functional testing.
- **Task 4: Low-cost markers design definition and requirements specification**
  - Define requirements, design of low-cost markers for large constellations and manufacture a prototype **.**
- **Task 5: Conclusions and way forward**
  - Provide overall study conclusions and elaborate technology development roadmap for these technologies up to qualification

THANK YOU FOR YOUR ATTENTION!

Admatis
Advanced Materials In Space