2023 NASA Contamination, Coatings, Materials, and Planetary Protection Workshop (CCMPP)

Mitigating Radiation Induced Contamination on Europa Clipper PIMS Instrument

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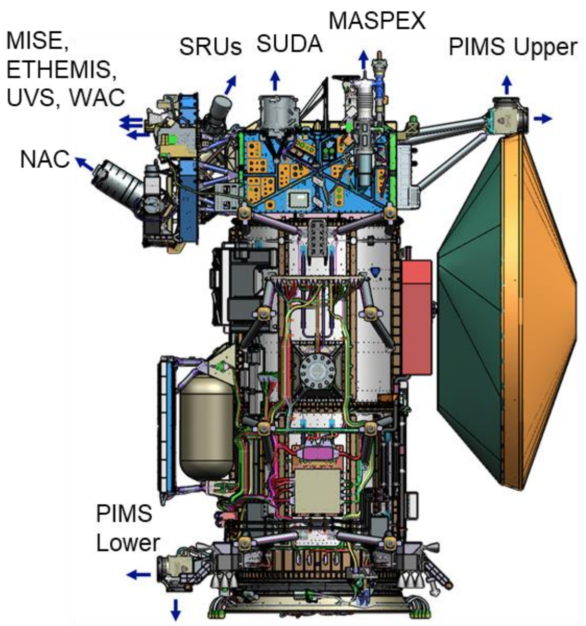
Europa Clipper Sensitivities

Europa Clipper carries many instruments sensitive to both molecular and particulate contamination.

- The Contamination Control (CC) team evaluates **molecular outgassing contamination**; particle contamination (e.g. dusts, fibers); and thruster and propellant contamination vectors.
- This presentation will focus primarily on molecular outgassing contamination.

Clipper Instruments and their Aperture Open Directions



Sensitive Instrument	Function	Contamination Sensitivity Effects / Threats
MASPEX	Mass spectrometer	Signal noise / Particle redistribution and outgassing
UVS	UV spectrograph	Signal noise / Humidity (purge reqt.), particulate redistribution and outgassing
SUDA	Dust Analyzer	Signal noise / Particle redistribution and outgassing
NAC	Camera	Obscuration, scatter, signal noise / Particle redistribution and outgassing
WAC	Camera	Obscuration, scatter, signal noise / Particle redistribution and outgassing
E-THEMIS	Thermal imager	Obscuration and signal noise / Particle redistribution and outgassing
PIMS Upper	Plasma sensor	Electrical shorting / Particle redistribution from fairing Conductive path & barrier for ions/ molecular outgassing
PIMS Lower	Plasma sensor	Electrical shorting / Particle redistribution from fairing and thruster firing Conductive path & barrier for ions/ molecular outgassing
MISE	IR spectrometer	Obscuration and signal noise / Particle redistribution and outgassing
SRUs	Imager	Obscuration and scatter / Particle redistribution from fairing Throughput loss / molecular outgassing

Radiation Induced Outgassing

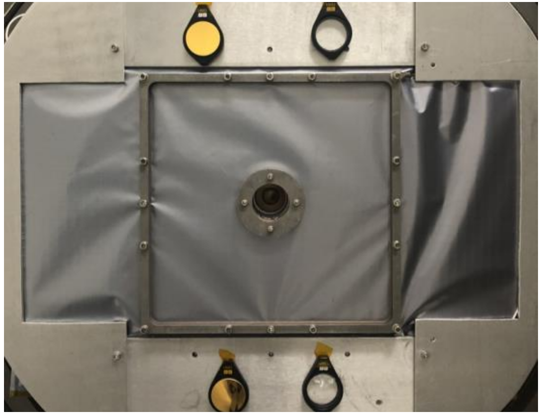
High energy radiation is known to increase the outgassing rate of certain non-metallic materials. JPL Contamination Control conducts outgassing testing in radiation environment using the JPL Dynamitron. The test includes in-situ QCM and Mass Spectrometer measurements during high-energy radiation (~1.5 MeV electron) exposure [1]

Testing of Europa Clipper materials showed that the Clipper MLI using Stamet Coated Black Kapton experiences increased outgassing under radiation [2]

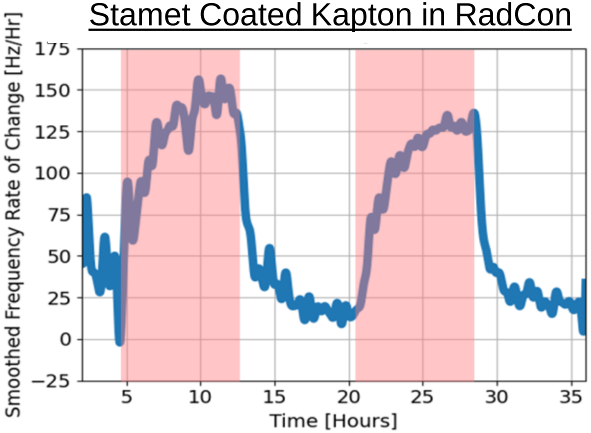
The outgassing rate increased during radiation exposure, then falls back to a lower level after radiation is taken away.

On Europa Clipper, each 14 day orbit will include about 20-40 hours of high energy radiation exposure. The increased outgassing during these 20-40 hours is concerning to instruments sensitive to molecular outgassing and deposition.

Stamet Coated Kapton in Dynamitron



-173° C QCM Measurement from Stamet Coated Kapton in RadCon



Red bars indicate radiation exposure

Switch to Clampband Design

Design change of the Launch Vehicle Adapter (LVA) to clampband configuration means that the LVA will be present on Clipper throughout Europa Tour

CC analysis of the new LVA configuration showed a significant exceedance of the molecular contamination requirement for PIMS Lower –Z.

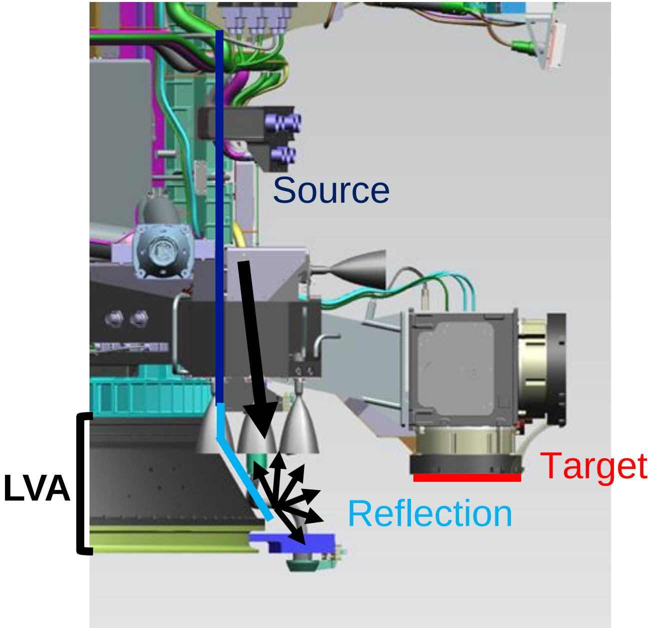
The contamination is generated by radiation induced outgassing of the Spacecraft thermal blankets. The contamination is reflected into PIMS by the LVA

Mitigations are needed to ensure the spacecraft can meet PIMS's contamination requirements

PIMS Deposition Exceeds Requirement with LVA Clampband

Before LVA Change	After LVA Change	PIMS requirement
140 Å	**900 Å**	200 Å

Europa Clipper LVA and PIMS Lower –Z.



Clampband Adds a Reflection Point for Contamination to PIMS Lower -Z

PIMS Shield Development

A working group consisting of Contamination Control, Mechanical, Thermal, and Materials and Processes developed the PIMS Shield. Shield design was reviewed with the PIMS team at multiple points.

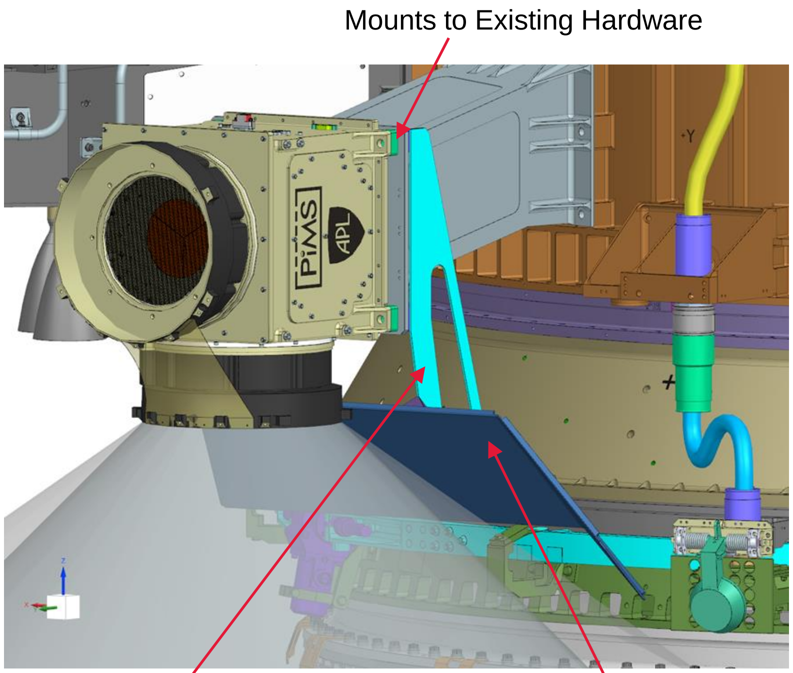
Requirements:

- The PIMS shield is designed to block direct line of sight from all spacecraft surfaces to the PIMS Lower –Z aperture without impinging on PIMS' field of view
- The PIMS shield must be low outgassing, non-magnetic, conductive, and designed such that it does not significantly change the interface temperature of the PIMS bracket

Design:

- Shield is primarily bare titanium and aluminum
- Thermal analysis showed heat leak is manageable even with no MLI around the shield
- The shield mounts to the edge of the PIMS bracket using the same fasteners as the PIMS assembly

PIMS Shield Design



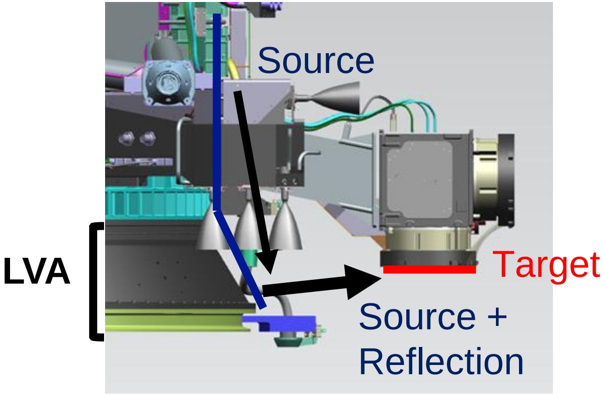
Problems Discovered

LVA Blanket

- During PIMS Shield Design, it was determined that the shield needed to be designed such that the LVA could itself be blanketed.
- This change makes the LVA blanket the largest possible source

PIMS requirement	Before LVA Change	After LVA Change- No MLI	After LVA Change- With MLI
200 Å	100 Å	**900 Å**	**>10,000 Å**

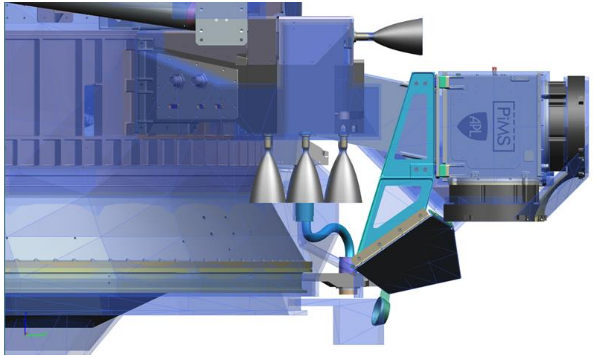
LVA Blanket Adds Significant Possible Outgassing Source



CC Model Alignment

- The Mechanical team would design the PIMS Shield CAD model, then send to the CC team for incorporation into the CC model
- If the CC model of the spacecraft was not exactly aligned with the Mechanical CAD model of the SC, then surfaces that should have been blocked by the shield would not be blocked in the CC model
- Mechanical team was able to superimpose the CC model over the Mechanical Cad so detailed adjustments could be made

CC Model Superimposed Over Mechanical CAD



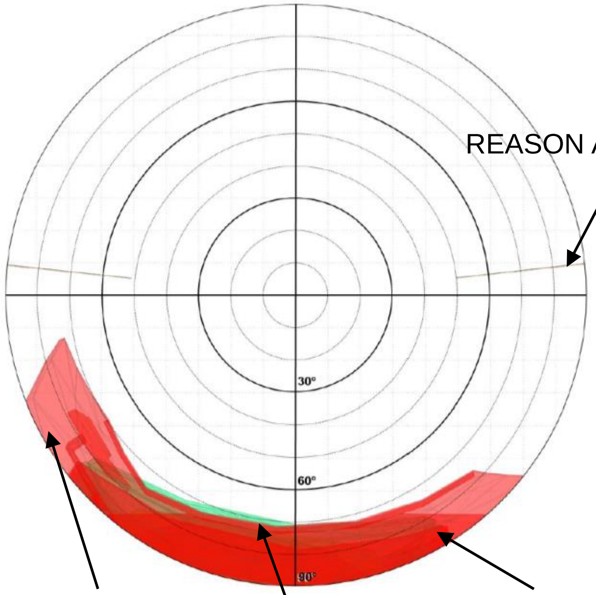
PIMS Shield Results

A hemispherical FOV diagram was created to determine which surfaces have a direct line of sight to the PIMS aperture. In the last shield design, only a part of the passive ring (all metallic) and the REASON HF Antennas are in the FOV

After 12+ iterations of the PIMS shield shape, a design was shown to bring the deposition level on PIMS to within requirement.

- Deposition from radiation induced outgassing of the thermal blanket was brought down from >10,000 Å to 30 Å
- When combined with other sources (i.e. Launch Vehicle, initial cleanliness state, thermal based outgassing) the resulting deposition is 170 Å, within PIMS' requirement

PIMS Lower –Z Hemispherical FOV



PIMS Deposition Within Requirement with the PIMS Shield

PIMS requirement	After LVA Change- No MLI	After LVA Change- With MLI	Results with PIMS Shield
200 Å	900 Å	>10,000 Å	**170 Å**

Other Solutions Considered

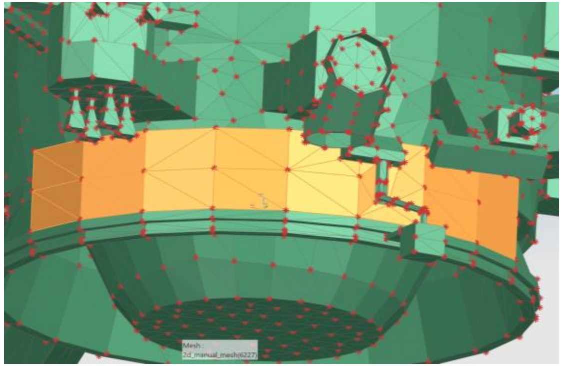
Shield on LVA

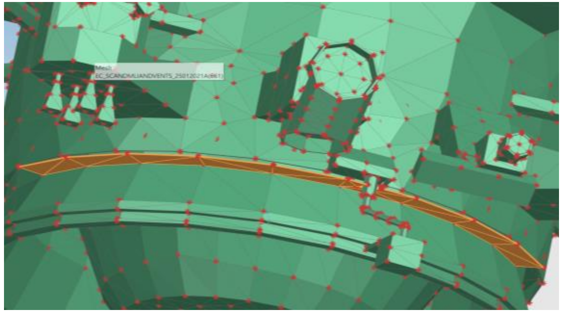
- In the beginning multiple different shield designs were considered, including shields on the LVA.
  - Benefit is that a LVA shield is less impact to PIMS, and less impact to hardware that had already been fabricated
  - Downside is that the shield would need to be larger
- Initial CC assessment of the shields showed that shields positioned on the LVA were effective. However once LVA needed to be blanketed the shield near PIMS became the only option.

Metallic Blankets

- A metallic blanket used on key sources (like the harness, thrusters, and PIMS bracket) was shown to significantly reduce the level of deposition on PIMS
- Concern for developing a blanket with a metallic outer layer is tear propagation prevention and unknown handleability
- Ultimately shield design was effective enough that metallic blankets were not needed

LVA Shield Parallel and Perpendicular to the SC

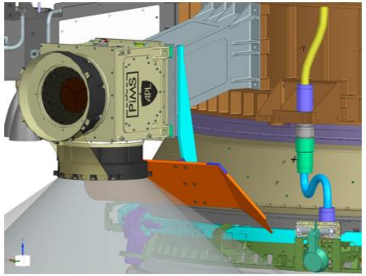


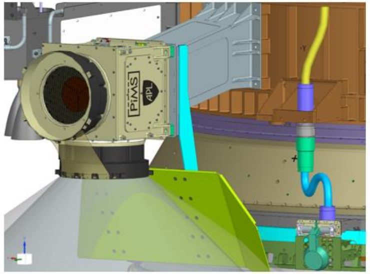


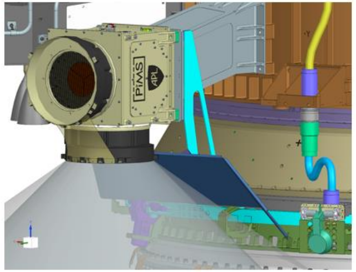
Conclusions

- Europa Clipper carriers a suite of contamination sensitive surfaces. One of the largest drivers for outgassing around the spacecraft is radiation induced outgassing from the thermal blankets.
- The design change to the clampband design means that the LVA will be flying with Clipper to Europa. The LVA provides a reflection surface for outgassing to make it to PIMS Lower –Z
- The JPL CC, Mechanical, Thermal, and M&P teams worked together to design a shield that blocks direct line of sight from the LVA to PIMS.
- After many iterations and different approaches were considered, the team landed on a shield design mounted to the backside of the PIMS bracket.
- CC analysis shows that the latest design of the PIMS shield allows PIMS to remain within its allocation for molecular deposition for the mission.
- Exercise demonstrated an approach in which CC modeling was used to identify a contamination problem and a multi-disciplinary working group including CC solved the contamination problem on the Europa Clipper Mission

Iterations of the PIMS CC Shield







References

[1] Soares, C. E., Wong, A. T., Fugett, D. A., Hoey, W. A., Alred, J. M., Ferraro, N. W., & Thorbourn, D. O. (2019). High Energy Radiation Testing and Effects on Spacecraft Materials Outgassing. *International Astronautical Congress*.

[2] Fugett, D. A., Soares, C. E., Wong, A. T., Anderson, J. R., Ricchiuti, V. L. Hoey, W. A., (2022). Contamination Control Approach to Mitigating Radiation Induced Outgassing on Europa Clipper. *IEEE Aerospace 2022*

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