Jet Propulsion Laboratory
California Institute of Technology

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

Contamination Control Modeling Effort in Preparation for Europa Clipper System Level Thermal Vacuum Testing

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Europa Clipper Introduction

Outgassing Rate Requirement:

View Factor	Definition	Outgassing Rate (g/cm2/sec)
High	External Components	$1x10^{-14}$
Medium	Underneath MLI	$5x10^{-14}$
Low	Inside Radiation Vault	$1x10^{-12}$

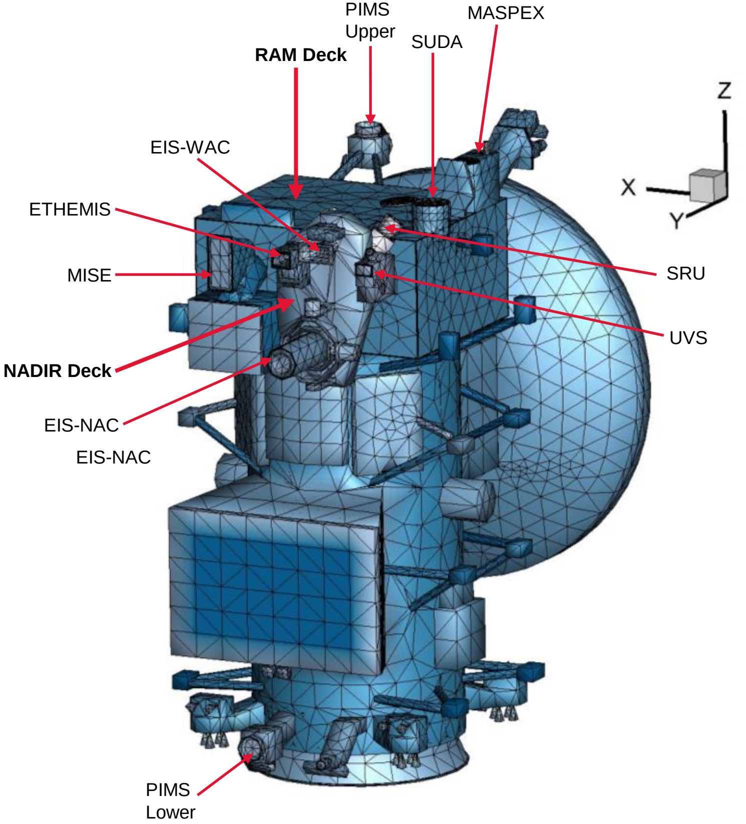
Instruments on Europa Clipper are highly sensitive to molecular contamination. The effects could include:

- Erroneous measurements (MASPEX, etc.)

  Instruments measuring chemical species or noise as a result of outgassing rather than the intended target

- Optical property degradation (EIS, etc.)

  Thin films deposited on optical surfaces may change the properties of the system



Simplified model of Europa Clipper

JPL's 25 Foot Space Simulator

Europa Clipper will utilize JPL's 25 foot chamber to simulate the mission profile through cruise and tour phases

- The chamber operates ten cryogenic pumps and two turbo-molecular pumps
- The chamber operates at ~$1x10^{-6}$ torr
- The chamber shrouds and floor will be cryogenically cooled to -180˚C
- The solar simulator will provide up to ~2000 W/m^2 of solar flux with a mirror temperature of -65˚C
- The thermal vacuum test will be conducted over 17 days

JPL 25-foot space simulator during testing of the Mars 2020 spacecraft

System TVAC Contamination Control Objectives

In preparation of STVAC, the following items were identified as the primary objectives for Europa Clipper Contamination Control:

1. Monitor the molecular environment around NADIR Deck (largest concentration of instruments)
2. Monitor the molecular environment around RAM Deck (instrument with most stringent molecular requirements)
3. Identify outgassed molecular species in the environment using a mass spectrometer and residual gas analyzer (RGA)

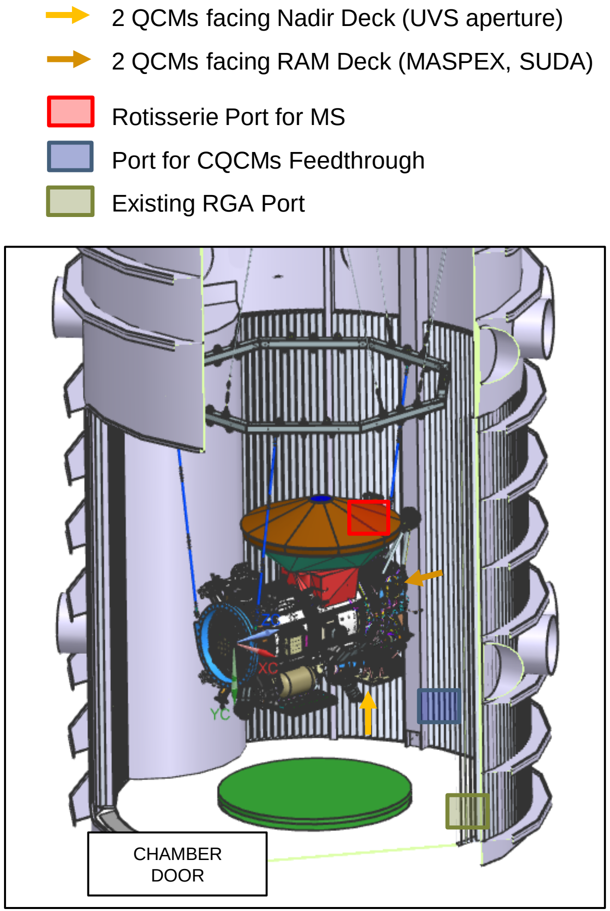
Quantifying Contamination in TVAC

Methods of monitoring contamination

- Non-volatile residue samples
- Non-volatile residue witness plates
- Quartz crystal microbalance (QCM) outgassing rate monitoring, cryocooled to -113°C to represent sensitive surface temperature on Clipper
- QCM thermogravimetric analysis (QTGA)
- Residual gas analyzer (RGA) and mass spectrometer measurements

Methods of mitigating contamination

- Bake out all components at lower-level assembly
- Bake out all GSE
- Maintain a cool chamber shroud to act as a getting surface



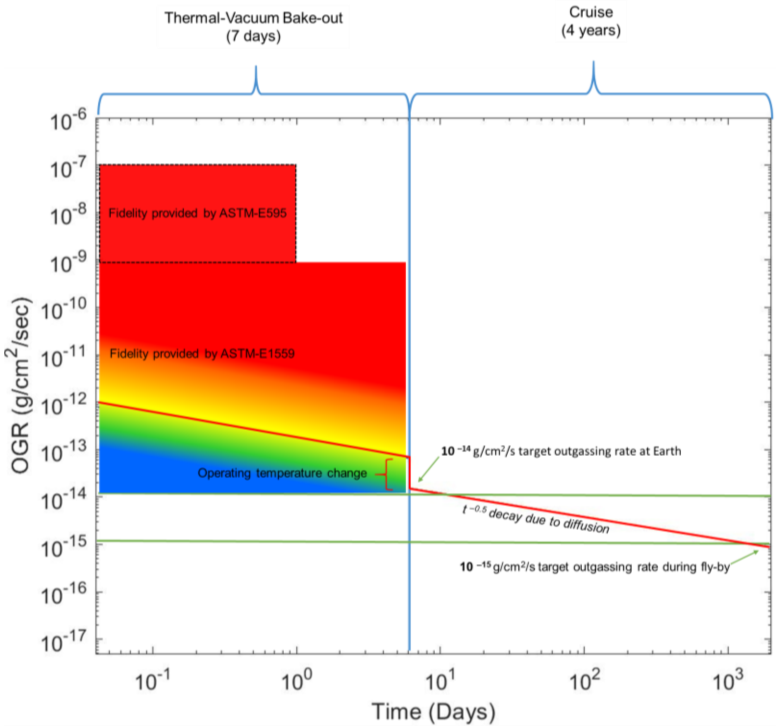
Modeling Motivation

The efficacy of QCM measurements is dependent upon the test setup, including:

- Test geometry
- Test thermal profile
- Chamber background outgassing

Because of Clipper's sensitivity to contamination, placement of the QCMs is critical to collect meaningful data. By modeling the molecular contamination, the following questions can be addressed:

- What is the ideal position for the QCMs?
- What order of magnitude of outgassing can be measured from the spacecraft?



Example of outgassing rate for components on Europa Clipper over the course of lower-level assembly bakeout to start of tour. Hardware on Clipper is outside of the range of fidelity provided by ASTM-E595 for material selection.

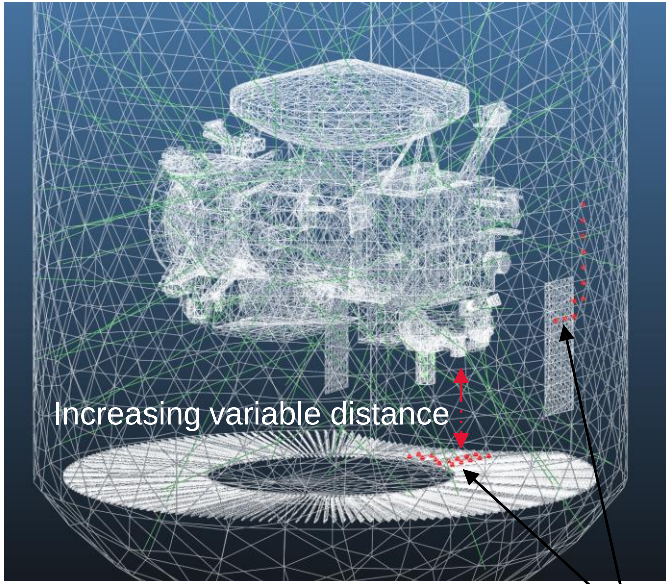
Simulating Contamination

Heritage methods of calculating transmission fractions use area ratios. This assumes uniform transport, neglecting geometric effects.

JPL CC simulates the vacuum chamber environment using ray-tracing Monte Carlo schemes to quantify the transmission fractions from outgassing sources to the QCM(s).

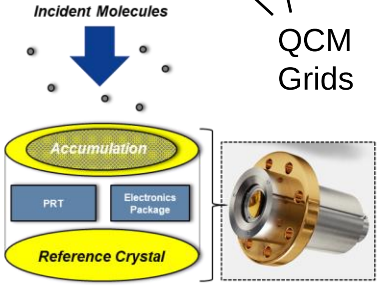
Clipper STVAC Molecular Transport Approach:

- Assess loss of signal relative to QCM distance and angles
- Assess the selected positions for expected outgassing signal from Clipper



QCM Grids

MolFlow view of Clipper in the 25-foot chamber with QCMs in grid formation for variable distances relative to Clipper from 30 cm to 180 cm.



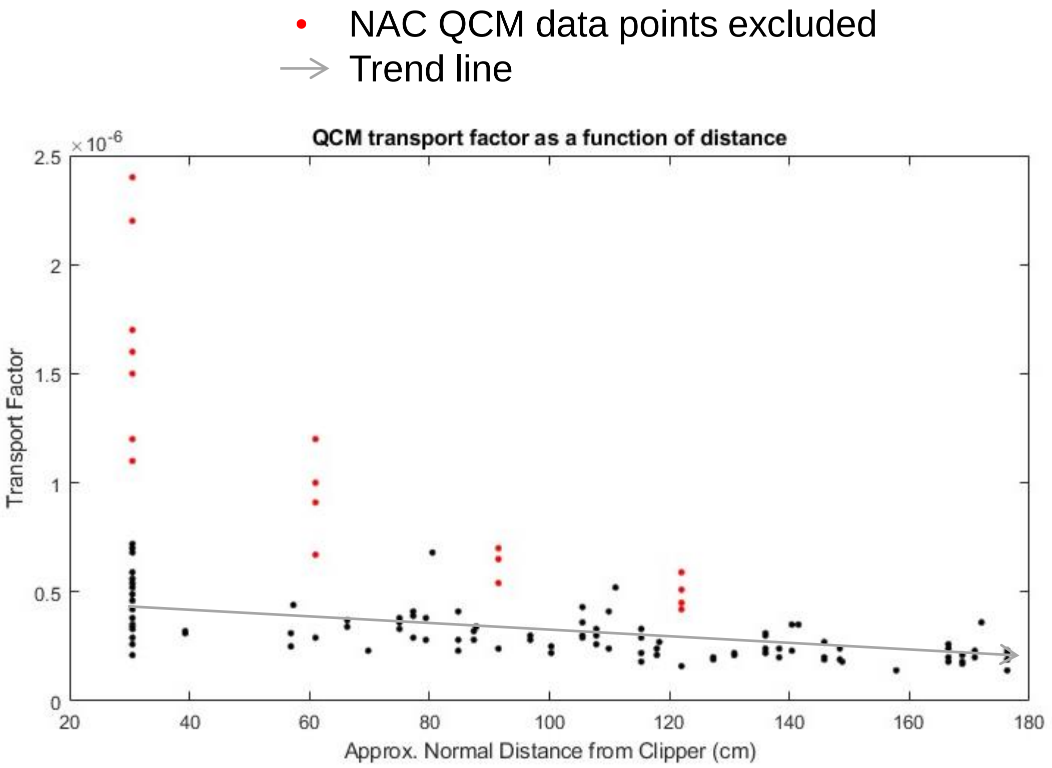
Photograph: QCM Research Mk. 10 TQCM used in JPL ETL TVAC testing.

Distance Results

The transport factor shows a slight decrease as distance from the outgassing source increases. This trend is informative in selecting a QCM position, however, does not drive the decision.

QCMs directly above NAC:

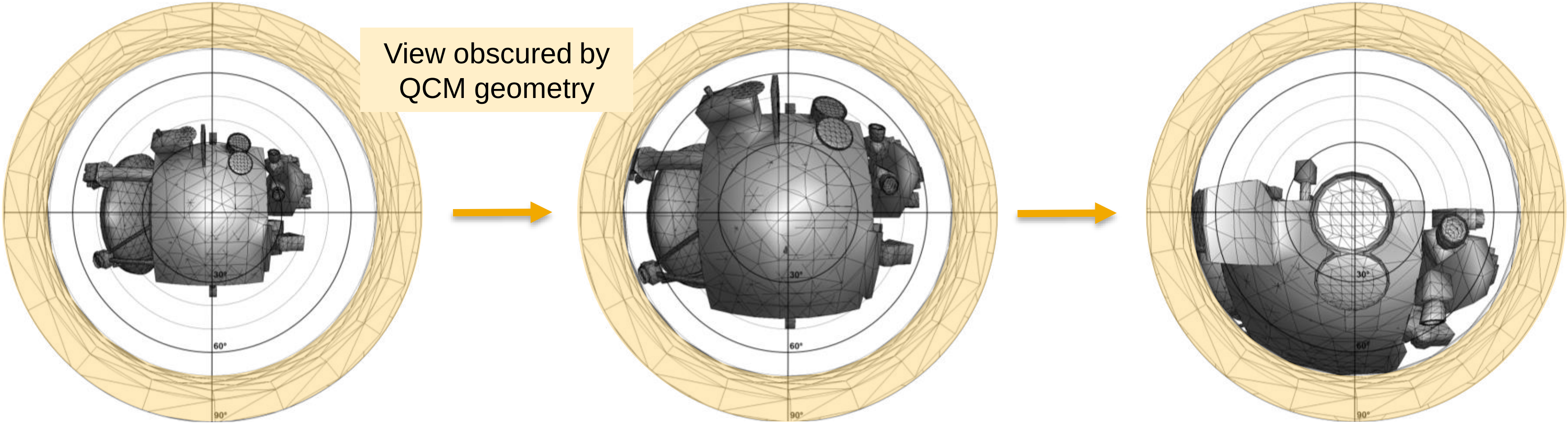
- Increased transport factor as a result of NAC barrel geometry
- Placement directly above NAC is not likely to be used for system TVAC and so is excluded



Fisheye Views

- Assess objects in the field of view of the QCMs to determine ideal angles and distances to monitor key instruments
- Qualitative assessment is performed with the fisheye views in conjunction with the quantitative molecular transport model

Sequence of fisheye views with distance from Clipper decreasing

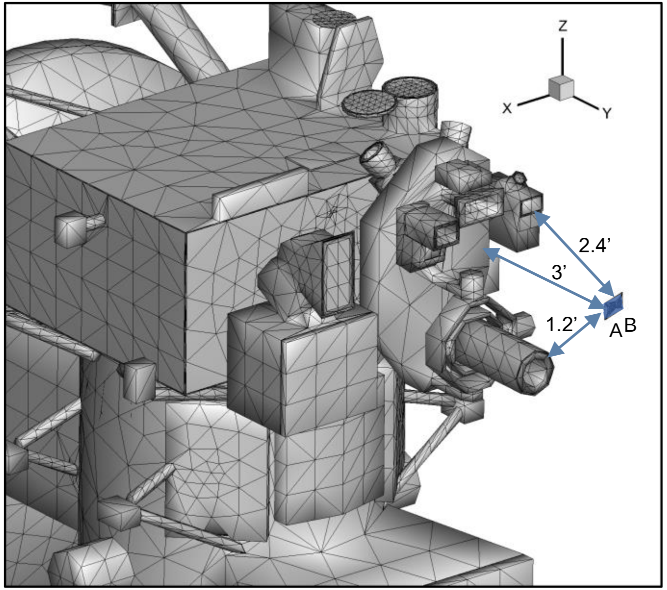


- QCM centered on +Z vault panel
- QCM collector face **152cm** from +Z vault panel

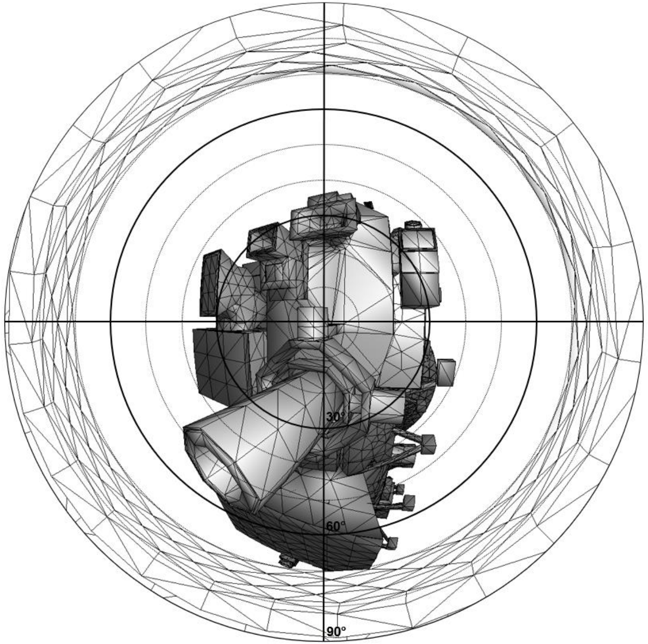
- QCM centered on +Z vault panel
- QCM collector face **91cm** from +Z vault panel

- QCM centered on SUDA
- QCM collector face **61cm** from +Z vault panel (~43cm from SUDA)

NADIR Deck Final Selection



Distances are approximate, based on available model

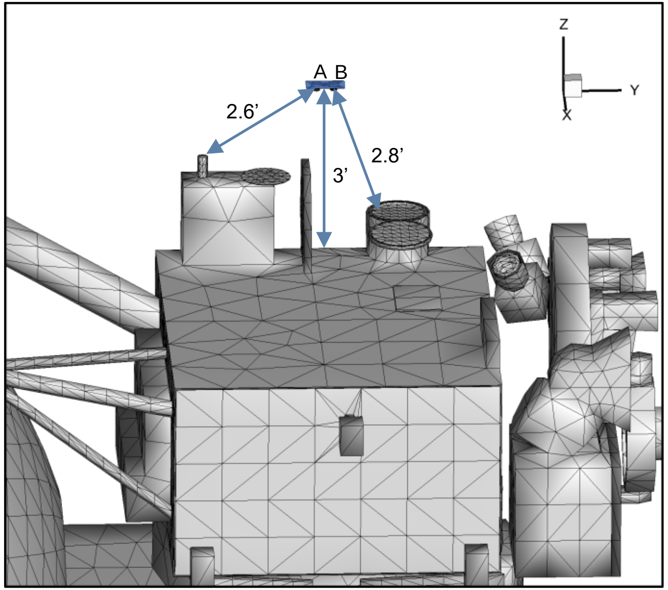


Transport factor
QCM A: 5.24e-7
QCM B: 3.58e-7

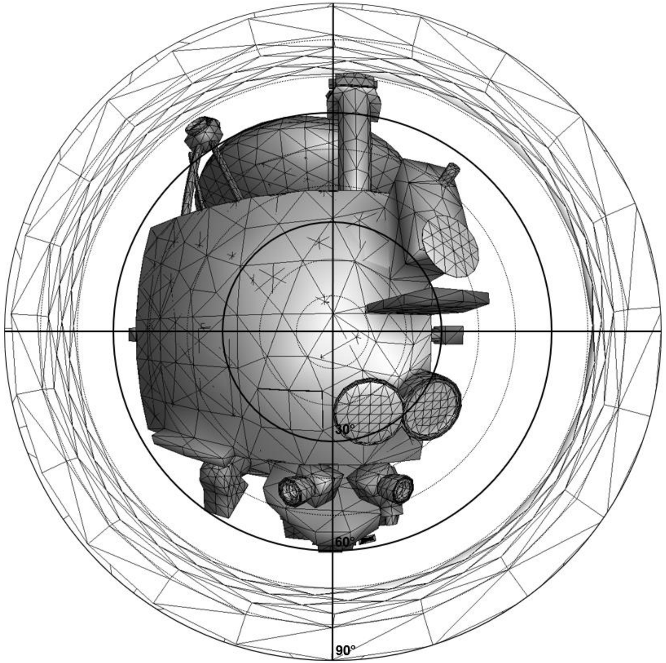
Expected QCM Measurement
(assuming 1e-12g/cm²/s)
QCM A: ~2 Hz/hr
QCM B: ~2 Hz/hr

- QCM **centered on -X edge** of NADIR Deck
- QCM has **20°** angle off the YZ-plane
- QCM collector face **91cm** from NADIR Deck

RAM Deck Final Selection



Distances are approximate, based on available model



<u>Transport factor</u>

QCM A: 3.64e-7

QCM B: 3.64e-7

<u>Expected QCM Measurement</u>

(assuming 1e-12g/cm^2/s)

QCM A: ~2 Hz/hr

QCM B: ~2 Hz/hr

- QCM **centered on -X half** of +Z vault panel
- QCM collector face **91cm** from +Z vault panel

Conclusion

- The relative distance from the QCMs to Clipper was determined to have a minor effect on the transport factor. This allows for more flexibility in selecting QCM position.
- The QCM fisheye view was informative in selecting ideal positions because it allowed for visualization of components with direct line of sight to the QCMs.

Work to go:

- Perform modeling assessment of GSE to determine level of acceptable outgassing.

  Location of the GSE will be constrained to minimize risk of contamination to sensitive instruments on the spacecraft. The molecular transport modeling with help determine keep out zones.
- Take a background measurement for JPL’s 25 foot space simulator in the configuration being used for Clipper.

  Recent chamber background data for JPL’s 25 foot space simulator was conducted with the shrouds a 50°C and QCMs at -50°C. The outgassing accumulation on the QCM in this configuration is not comparable for determining what level of background interference can be expected.

Application to Future Missions

- QCM fisheye views can be used as a starting point for determining placements of QCMs. They are informative for visualizing the direct line of sight outgassing components on the spacecraft. Additionally, it can be easily determined if GSE is in direct view of the QCMs.

- Molecular transport simulations allow for quantifiable assessment of QCM positioning. Because the simulation accounts for the geometric effects, differences in transmission factor due to QCM position are accounted for and the efficacy of the QCM measurement is improved.

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