SPACECRAFT MATERIALS RESPONSE TO RADIATION EXPOSURE IN FLIGHT-LIKE CONDITIONS. A. T. Wong[1], D. A. Fugett[1], J. R. Anderson[1], C. E. Soares[1], W. A. Hoey[1], W. Kim[1], D. Thorbourn[1], E. Martin[1], [1] NASA Jet Propulsion Laboratory, Pasadena, CA 91109, USA.

Introduction: Intense radiation environments encountered in space – particularly within the Jovian system – can induce significant damage to spacecraft materials. We find that the damage induced by radiation is affected by the combined impacts of materials exposure to extreme cold and vacuum environments, and that radiation exposure in flight-like conditions can both increase a material's outgassing rate and alter the chemistry of its outgassed species [1–3]. These effects act to increase spacecraft self-induced contamination of instrumentation suites and other sensitive surfaces.

Background: Science missions targeting the detection of organic or biological signatures originating from icy moons (e.g. Europa) will employ state-of-the-art, highly-contamination-sensitive mass spectrometers to measure the composition of plume effluents and exospheres. Mission science is reaching a threshold such that scientific objectives are threatened by even small (i.e. ppb) quantities of molecular contamination, which could make it difficult to unambiguously detect potential organic or biological signatures. It is therefore critical for missions traveling into harsh radiation environments to characterize the increase in their rates of contaminant outgassing under realistic combined cryogenic, vacuum, and radiation environments for relevant spacecraft materials. While there presently exist standard testing apparatuses for thermal vacuum stability screening (ASTM-E595) and for outgassing rate testing (ASTM-E1559), there are no known combined effects chambers capable of testing vacuum exposed surface materials of a spacecraft in a flight-like environment as relevant to the Europa Clipper multi-flyby mission or a proposed Europa Lander mission.

Methodology: Therefore the JPL Contamination Control group, in coordination with the JPL Natural Space Environments and JPL Radiation Effects groups, has designed and implemented a Radiation Induced Outgassing Testing (RIOT) campaign to evaluate 'threatening' (high-usage and/or high-risk) spacecraft materials under flight-like conditions in support of the Europa Clipper mission. This campaign makes use of the Dynamitron Particle Accelerator Laboratory at NASA's Jet Propulsion Laboratory (as depicted in Fig. 1). The test articles are of both specific, and archetypal materials that are relevant to Europa Clipper but will also maintain relevance to other missions in the future. The testing chamber is instrumented with quartz crystal microbalances (QCMs) for quantitative mass collection and a mass spectrometer for qualitative species evolution as induced by radiation exposure.

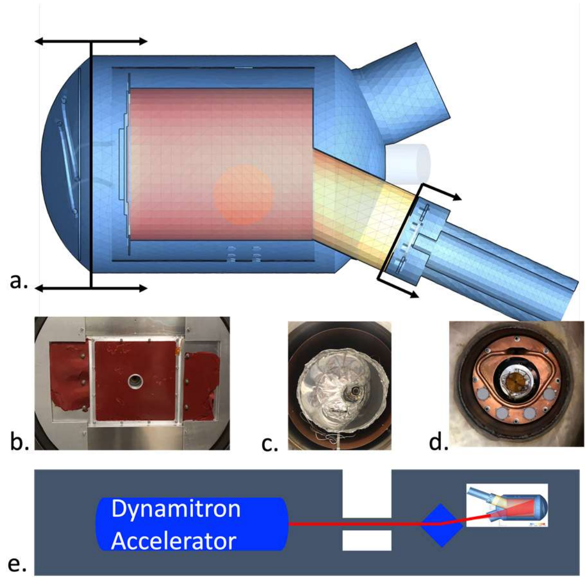

Fig. 1: JPL Radiation Induced Outgassing Test setup.

a. Top-down view of Dynamitron multipurpose vacuum chamber with sample mounting door on the left, beam inlet port on the top right, and instrumentation port on bottom right.

b. RIOT sample of Wacker RTV-S 691.

c. Interior of vacuum chamber showing inner conductance tube (silver), copper cold shroud and chamber wall, from inside to out.

d. Close-up of instrumentation including an Extrel MAX 1000 quadrupole mass spectrometer in the center of the copper instrument cold plate which contains the cryo-QCM array (4 QCM Research Mk. 18 units) along the bottom half.

e. Schematic layout of Dynamitron facility showing beam path from Dynamitron accelerator through wall pass-through into measurement room.

Results: Completion of an initial pathfinder test and subsequent materials tests have generated novel materials data, an example of which is given in Fig. 2, and created a further understanding of the radiation induced outgassing phenomenon which will be valuable to future missions and mission concepts, particularly those which aim to visit Europa.

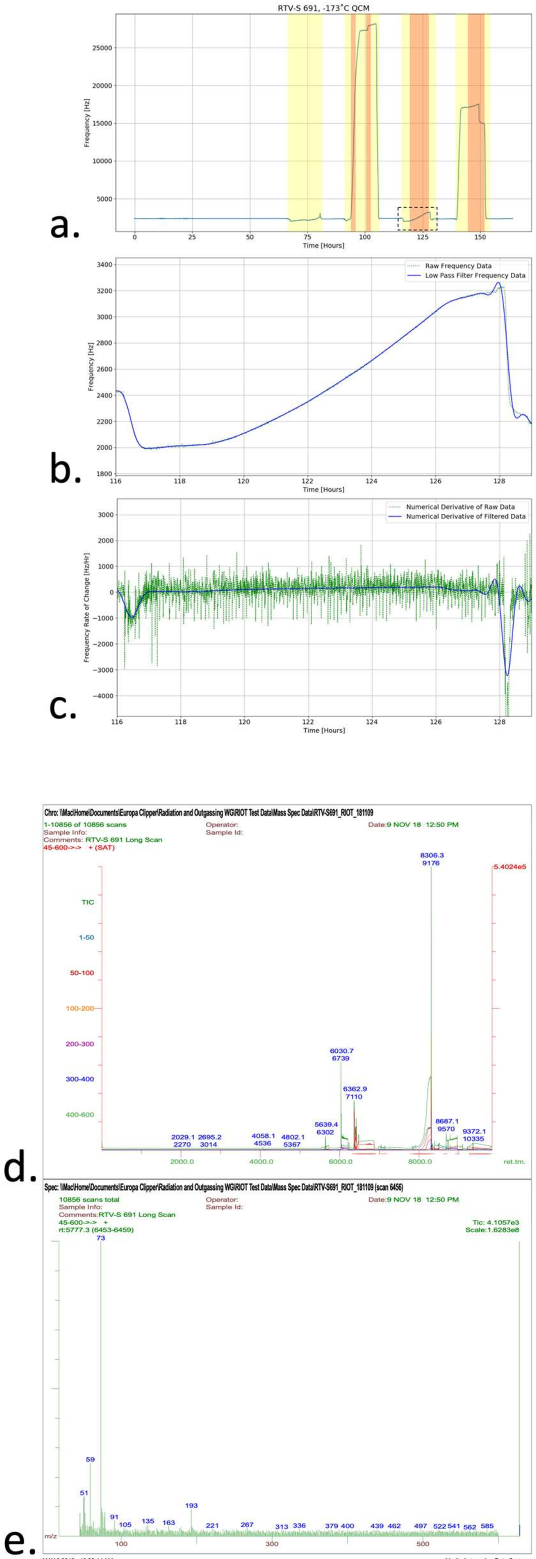

Fig. 2: Data and data analysis techniques for JPL Radiation Induced Outgassing Testing (RIOT).

Fig. 2 (detailed caption):

a. Full duration data log for QCM 2 frequency measurement spanning 7 day test. QCM measurement time is highlighted in yellow, radiation exposure periods are highlighted in red.

b. Expansion of radiation exposure 3 showing overlay of raw QCM 2 frequency data and processed data using a bandpass filter.

c. Numerical derivative of raw and filtered QCM 2 frequency, for data shown in Fig. 2b.

d. Total ion current in mass spectrometer data spanning full duration of 7 day test.

e. Example mass spectra spanning m/z from 1-600 Da for Wacker RTV-S 691 test.

References: [1] Wong, A. T. et al. (2019), *ASEC*. "Evaluating the In Situ Outgassing Characteristics of Silicone Adhesives in a Europa-Like Environment." [2] Soares, C., Wong, A., Fugett, D., Hoey, W., Alred, J., Ferraro, N., Thorbourn, D., (2019) *IAC*. "High-Energy Radiation Testing and Effects on Spacecraft Materials Outgassing.*"* [3] Anderson, J., Wong, A., Fugett, D., Hoey, W., (2020) *IEEE Aerospace*. "Modeling Radiation Influence on Spacecraft Materials Outgassing."

Note: The decision to implement the Europa Lander mission will not be finalized until NASA's completion of the National Environmental Policy Act (NEPA) process. This document is being made available for information purposes only.