PLANETARY PROTECTION
ORGANIC INVENTORY WORKSHOP
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Implementation

Characterization of Organic Footprint From Moon and Mars Landing Systems (Robotic and Human) — Comprehensive Organic Inventory and Development of Requirements

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Current Organic Inventory and Archive Framework

- NASA Procedural Requirement document NPR 8715.24: “An inventory of bulk constituent organics is required if the probability of impact is considered significant.”
  - The intent of archiving organic materials is to characterize Earth contamination sources in preparation for returned sample science investigations and analyses.
  - A “false-positive” indication of life via life-detection instruments on board the spacecraft, or in the sample after it is returned to Earth, impacts successful completion of mission science objectives and could lead to increased Planetary Protection requirements for future missions.
- For all launched hardware, if the bulk organic constituents are greater than 1kg, an organic materials inventory is required.
  - The current inventory framework consists of materials usage & identification lists (MIULs), parts lists, and data relevant to organic material identification.
  - Also included are locations of landing sites and condition of the landing spacecraft to assess spread of organic contamination.
  - This requirement also applies to the Moon. If the bulk organic constituents are greater than 25kg, then 50g samples of all organic materials is required for archiving.
- A database provides information on the materials collected and their physical location at the archive.
  - The archive currently has organic samples from the following missions: Viking, Mars Pathfinder, Mars Reconnaissance Orbiter, Phoenix Lander, Mars Exploration Rovers, Mars Science Laboratory, Maven, Insight and Perseverance.

Issues with Current Organic Inventory and Archive Framework

- The current framework only addresses one contamination vector, materials outgassing, and only partially
  - Materials Identification & Usage Lists (MIULs) templates are typically deficient in capturing quantities (mass, volume) and location of applications
  - MIUL submissions also contain a large number of blank entries (i.e., lack quantities, location of application and processing)
  - Materials used in quantities lower than the specified threshold may be significant sources of organic contamination
- Other significant contamination vectors and sources of landing site alteration are not a part of the current framework:
  - Thruster plumes (descent and landing)
  - Vacuum venting
  - Leakage

How can we evolve the existing framework into a Comprehensive Organic Inventory?

- Characterize all contamination vectors and sources of landing site alteration:
    - Materials outgassing
    - Thruster plumes (descent and landing)
    - Vacuum venting
    - Leakage
- Initial study: leverage existing experience in conjunction with modeling and analysis capabilities to define relative contributions for each vector
- Joint review of study results (Planetary Protection, Contamination Control, Science)
- Develop Comprehensive Organic Inventory strategy and framework
    - Characterize relative contributions from all organic contamination vectors, for all classes of landers/rovers
    - Establish policy based on technical rationale that accounts for all organic contamination vectors
    - Protect current and future mission science requirements

Materials Outgassing

Materials Identification & Usage Lists

- Use of enhanced template (include entry fields for mass, volume, vacuum exposed surface area and location of application) – i.e., Europa Clipper enhanced template
- Enforce population of required entries

Multi-Species Materials Outgassing Testing and Modeling (see John Alred's presentation)

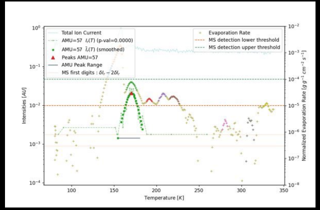
- ASTM E595 is only a screening criteria – it is inadequate to characterize organic contamination
- ASTM E1559 only provides contaminant composition data if the test is customized with Mass spectrometry and QCM thermogravimetric analysis
- New multispecies testing and modeling framework reduces testing requirements (schedule and cost), compared to ASTM E1559 testing, and provides information on organic contaminant composition
- Multispecies outgassing testing and modeling has already been used on Mars 2020 and currently in evaluation for Artemis

Archival threshold for material mass could also have dependency on contaminant transport factor and material type

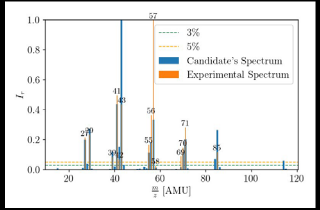
- Certain spacecraft materials are significant sources of organic contamination

Archival of condensate from spacecraft thermal-vacuum, along with mass spectrometry would also provide valuable information during science investigation phase

QCM Mass Spectrometry Correlation



Single matched spectra for single species



Ranking of all matched molecules

Rank	Name	DART % Relative Intensity	Mass	MS2DeepScore <3.0%	Spec2Vec <3.0%	RMSLE-similarity <3.0%	Composite <3.0%
1	Oxalic acid, allyl nonyl ester	56.5	256.167	1.391	1.672	1.031	1.638
2	Octane	100.0	114.141	1.370	1.687	0.924	1.614
3	Hexane, 2,4-dimethyl-	100.0	114.141	1.304	1.740	0.922	1.613
4	Hexane, 3,3-dimethyl-	100.0	114.141	1.356	1.639	0.797	1.544
5	Pentane, 2,3,3-trimethyl-	100.0	114.141	1.360	1.596	0.913	1.541
6	Heptane, 2-methyl-	100.0	114.141	1.366	1.586	0.883	1.531
7	Hexane, 3,4-dimethyl-	100.0	114.141	1.220	1.663	0.900	1.506
8	Carbonic acid, prop-1-en-2-yl undecyl ester	56.5	256.204	1.290	1.607	0.809	1.486
9	Heptane, 3-methyl-	100.0	114.141	1.260	1.578	0.955	1.480
10	Pentane, 2,2,3-trimethyl-	100.0	114.141	1.179	1.647	0.887	1.468

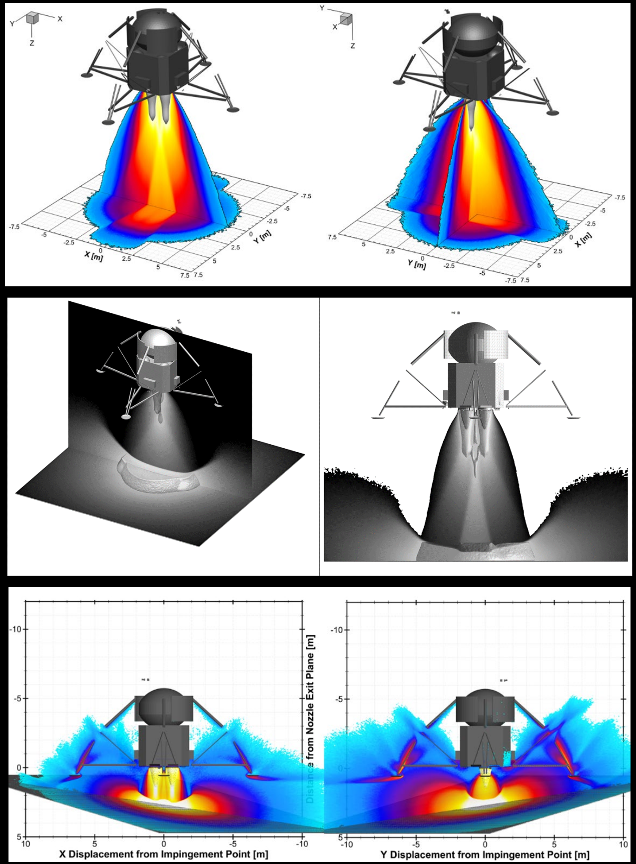
Thruster Plume Contamination

Highly dependent on thruster type and propellant combination

- Monopropellant systems
- Bipropellant systems
- LOX/hydrocarbon
- Cold gas

Source of both contamination and alteration of landing site (see William Hoey's presentation)

- Contamination with organic compounds from FORP (fuel/oxidizer reaction products)
- Penetration of contaminants in the dust/regolith layer
- Erosion of landing site
- Acceleration and dispersion of contaminated dust/regolith



Thruster Plume Contamination

Results from the chemical analysis of the UDMH/MON FORP residue collected on ISS (note that this was UDMH, not MHH, but they have similarity).
Ratio of organic to inorganic compounds: 45:55 (27 compounds with m/z from 17 to 127)

Inorganic components (ratio 1:1)

1. NO
2. NO_2

Organic components (ratios 10:2:23:18:6:33:7)

1. Dimethylamine
2. UDMH
3. Nitrosodimethylamine (NDMA)
4. Dimethylaminoacetonenitrile
5. N, N-dimethylformamide
6. 1-methyl-1H-1,2,4-triazole
7. 1H,1,2,4-triazole 3,5-diamino

Figure 1: First layer of the 4-ply swipe (direct contact with residue)

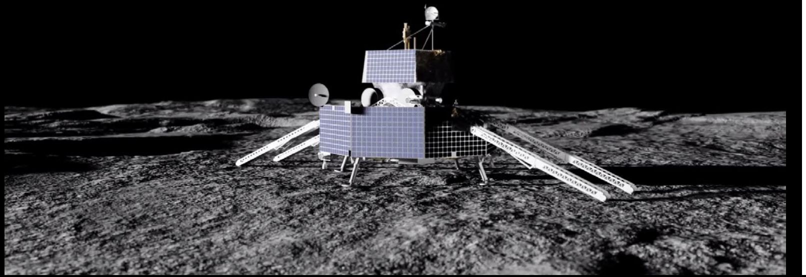
Figure 2: The second layer of the 4-ply swipe

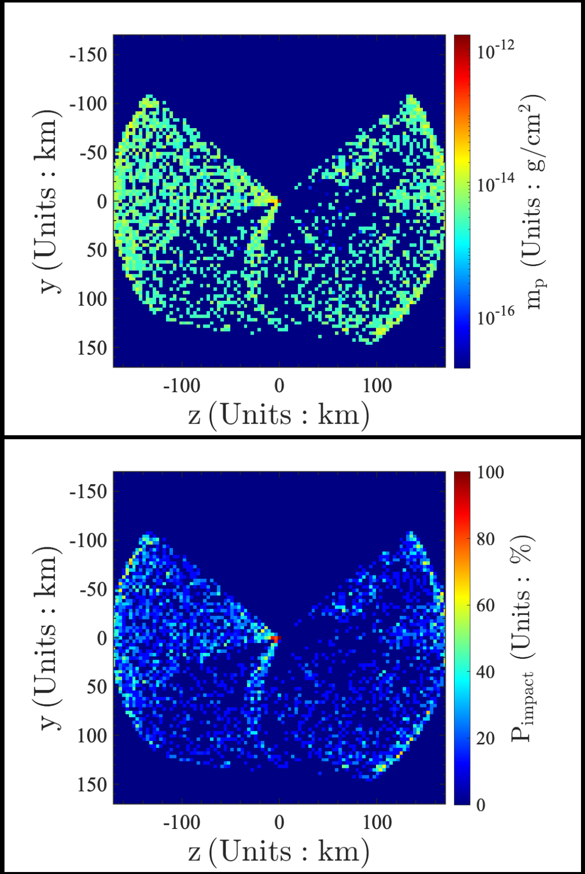
FORP residue collected from a test of a modern MMH/NTO bipropellant thruster

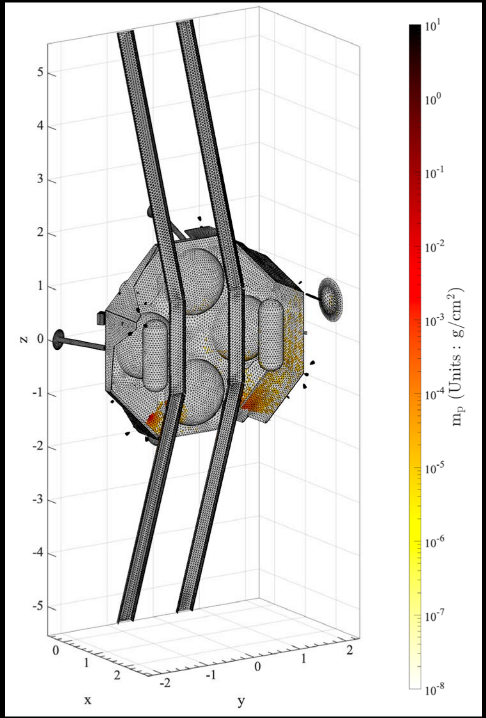
Vacuum Venting

Vacuum venting plumes can be multiphase (gas/liquid/solid) and produce both molecular and particulate contamination

- Vacuum venting in crewed systems are significant source of organic contamination
- Mitigation options can be effective in lowering contamination (i.e., preferential venting and filters); however, will not eliminate contamination

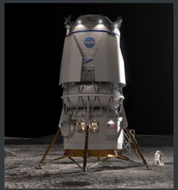
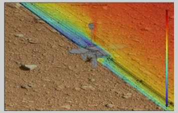
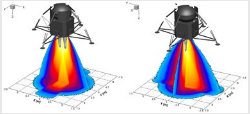
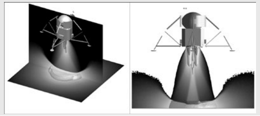
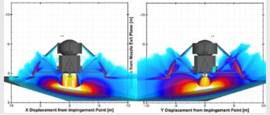
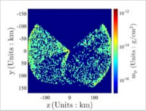
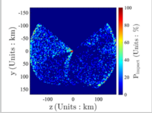
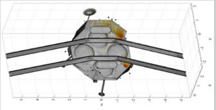
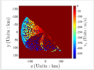
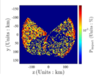
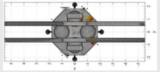






Comprehensive Organic Inventory

An initial study would target order-of-magnitude characterization of organic contamination and landing site alteration for selected thresholds (broad composition and radius of organic contamination)

Lander Type **Organic Contamination Vector**	 **Small Lander (CLPS Class lander)**	 **Medium Lander (Apollo Class Lander)**	 **Large Lander (Blue Origin Concept)**	 **Monolithic Lander (SpaceX Starship)**
Materials Outgassing	*Radius and broad composition of organic contamination for selected thresholds*			
Thruster Plume Induced Contamination				
Vacuum venting (vehicle and science payloads)				
Leakage				

Topics for Discussion

- **Spacecraft vacuum venting is a source of organic contamination with significance to the organic inventory for Moon and Mars missions**
    - *Flight observations from the International Space Station provides a number of examples*
- Vacuum venting can produce alteration of landing sites with deposition of organics
- Modeling/analysis framework is in place to characterize landing site alteration at selected thresholds
    - *Empirical tools exist with well-defined uses and limits (i.e. ISS bipropellant plume contamination models).*
- ***Mitigation options can be developed to minimize landing site alteration***
- **Existing capabilities can be leveraged to characterize contamination and alteration of landing sites**
    - *Define landing site alteration for pre-selected thresholds (order-of-magnitude)*
    - *Selection of vent types, effluents, flow rates and operational frequency based on current and proposed rover designs (Flagship to CLPS), Artemis architecture*

Acknowledgements

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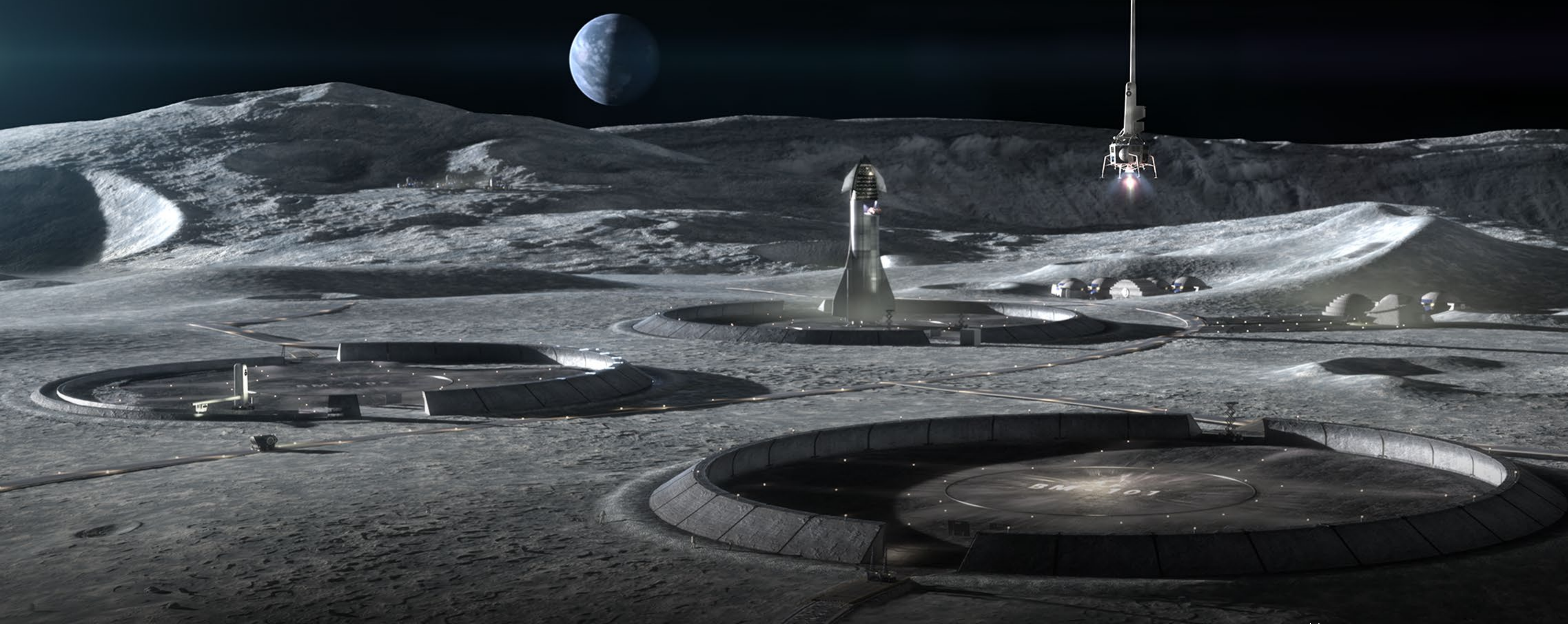

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