PLANETARY PROTECTION
ORGANIC INVENTORY WORKSHOP
FEBRUARY 27-28, 2024 - NASA HEADQUARTERS

Engineering Models

Organic Contamination From Venting and Leakage (Environmental Control, Life Support Systems, IVA Science and Spacecraft Systems) - The ISS Experience

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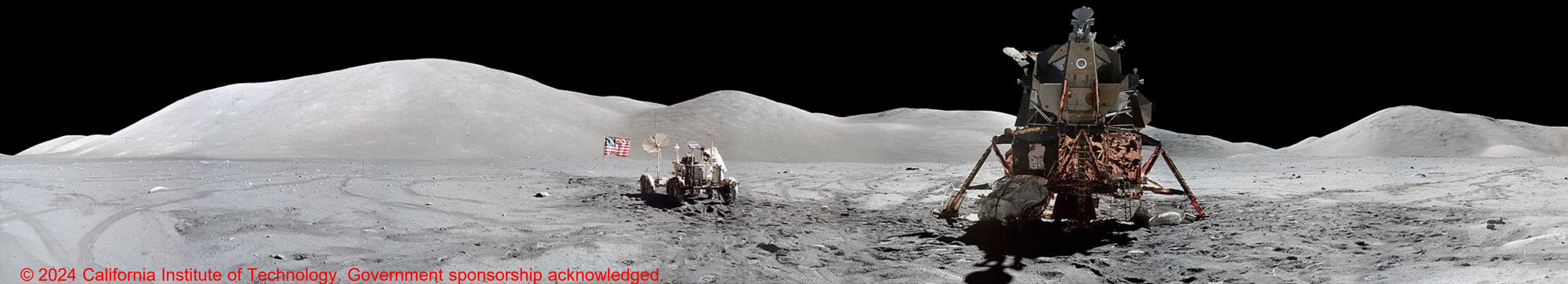


Spacecraft Vacuum Vents as a Source of Organic Contamination

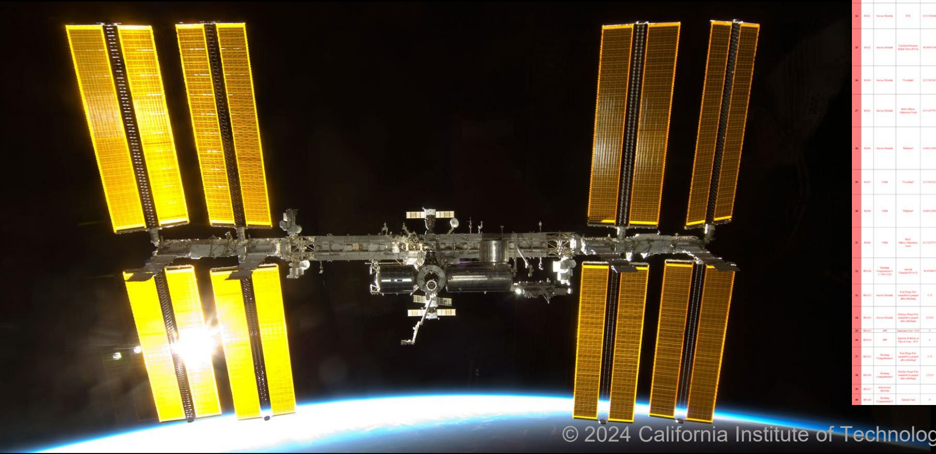
Spacecraft vacuum vents are concentrated sources of contamination (in many cases, organic contamination). The following table illustrates common types of vents present in crewed and robotic spacecraft systems and science payloads:

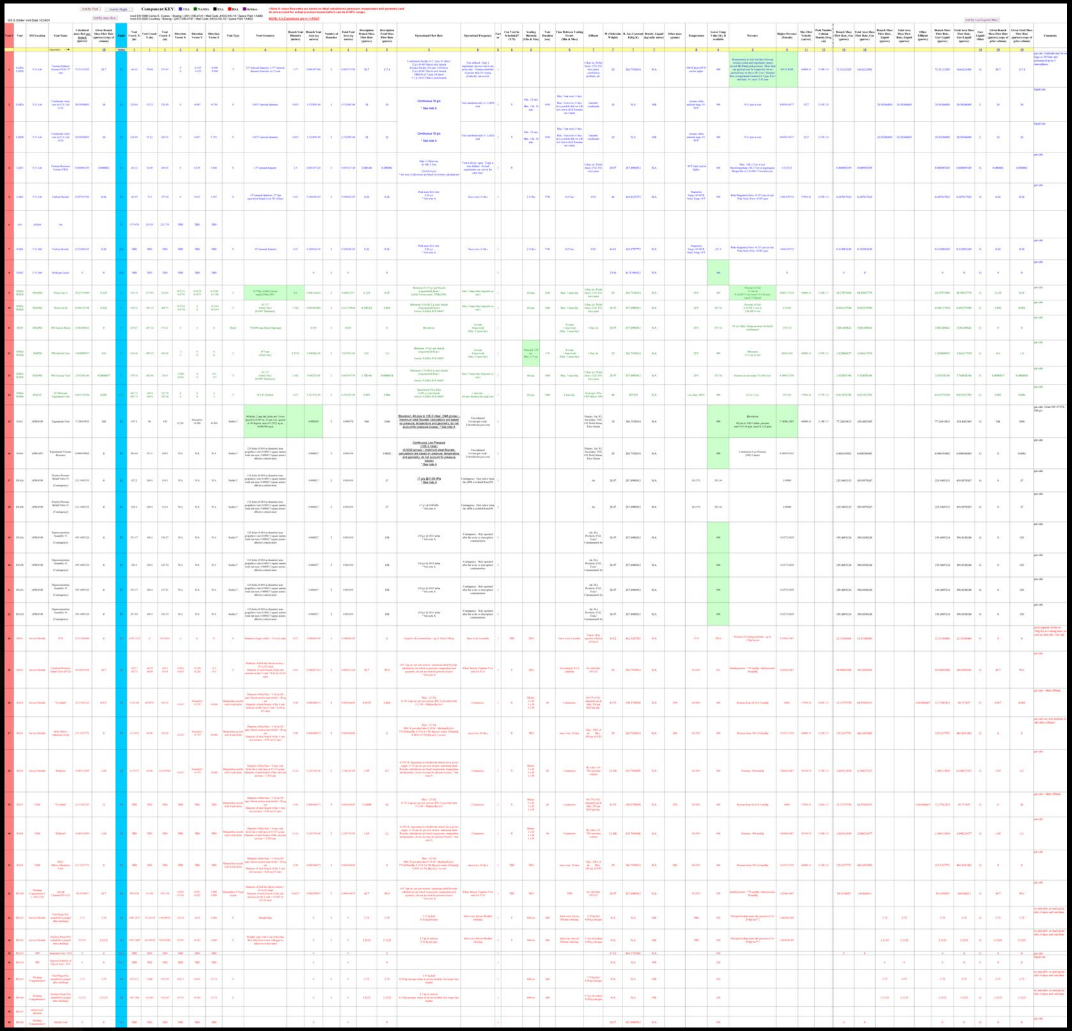
Vent Type	Source (or system)	Effluents
Environmental Control and Life Support Systems	Carbon dioxide Condensate water Cabin air (airlocks) Waste gas Waste water	Cabin air, noble gases, CO_2, CO, **amines, waste water**
Thermal control systems	Active thermal control systems	**Ammonia, ethylene glycol, siloxanes**
Propulsion systems (propellant purging)	Monopropellants and bipropellant propulsion systems	**Hydrazine**, **MMH, MON (nitrogen tetroxide), methane**, oxygen
Science payloads (experiment vents)	Vacuum exhaust systems (blowdown) Vacuum resource systems (maintain vacuum)	**Combination of organic compounds** from science experiments
Leakage	Fluid (gas and liquid) systems	Varied compounds

Issue: organic content is sometimes not identified in vent system specifications; only major constituents (i.e., amines in carbon dioxide sorbent beds)

International Space Station:
33 Active Vents (over 40 vents in total)

- ISS has 33 active vacuum vents with high frequency of operation
- Vent effluents often contain organic content
- High level of organic content have rendered one vacuum vent inoperable and required redirection through another vehicle vent



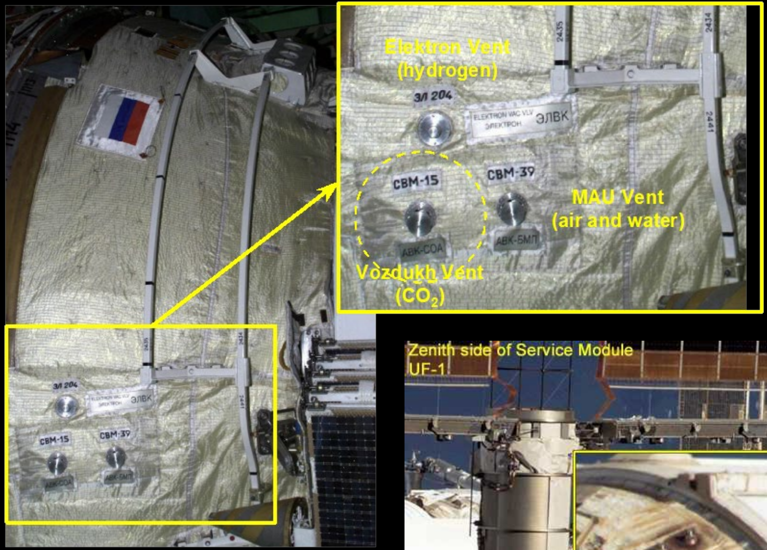


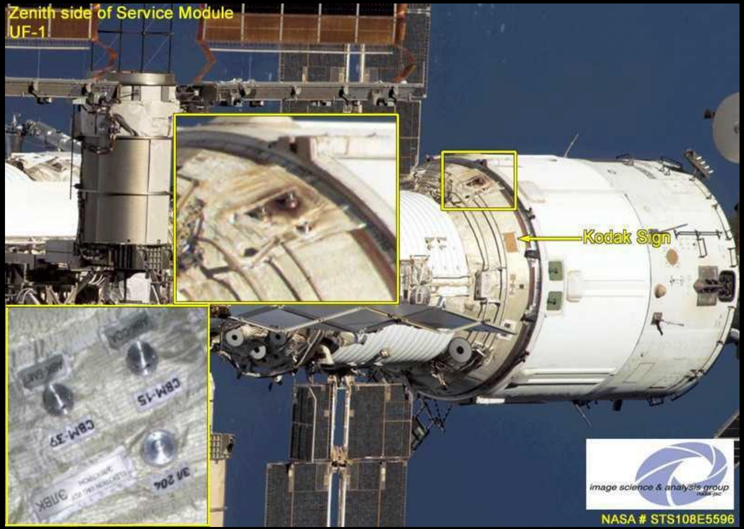
Release of Organics from Life Support System Vents

- The Vozdukh vacuum vent on the Service Module exhausts primarily carbon dioxide (CO_2, 80 to 97%) in conjunction with a small amount of air and water. [Vozdukh is the name of the Russian carbon dioxide removal system.]

- The carbon dioxide scrub system is based on solid-phase amine CO_2 sorbents. The amines react with the airborne CO_2 and water vapor, scrubbing the cabin air. The system can be thermally regenerated as the chemisorption reactions are reversed under heat and/or vacuum. The vacuum vent is used to eliminate the trapped CO_2 and water vapor during the regeneration phase.

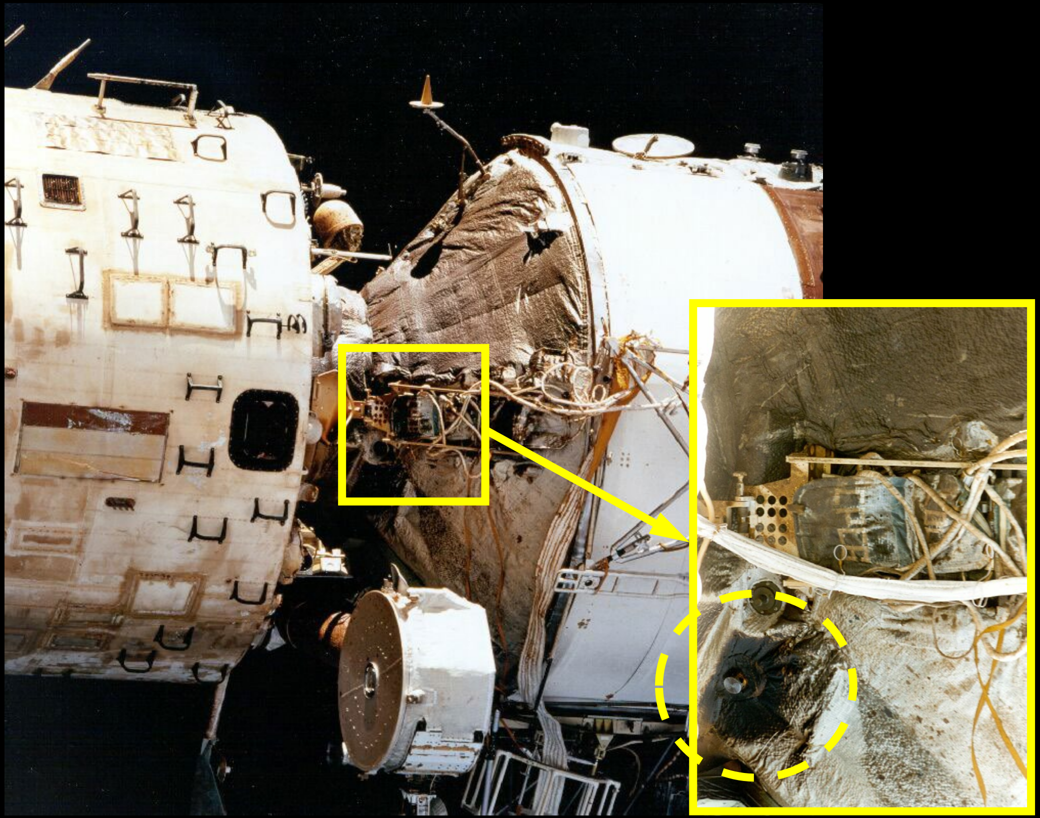
- On-orbit observations; however, have shown darkening in the area around the Vozdukh vent. The cause of this darkening is amine compounds released by the CO_2 scrub system.





Mir Space Station – Vacuum Venting

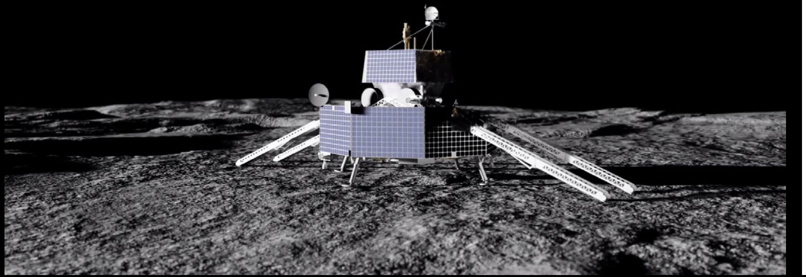
- The Mir Space station had the highest recorded levels of organic contamination from vacuum venting
- High levels of molecular organic contaminant deposition on vehicle surfaces (in excess of 10,000 Angstroms per year)
- Significant impacts to thermo-optical properties

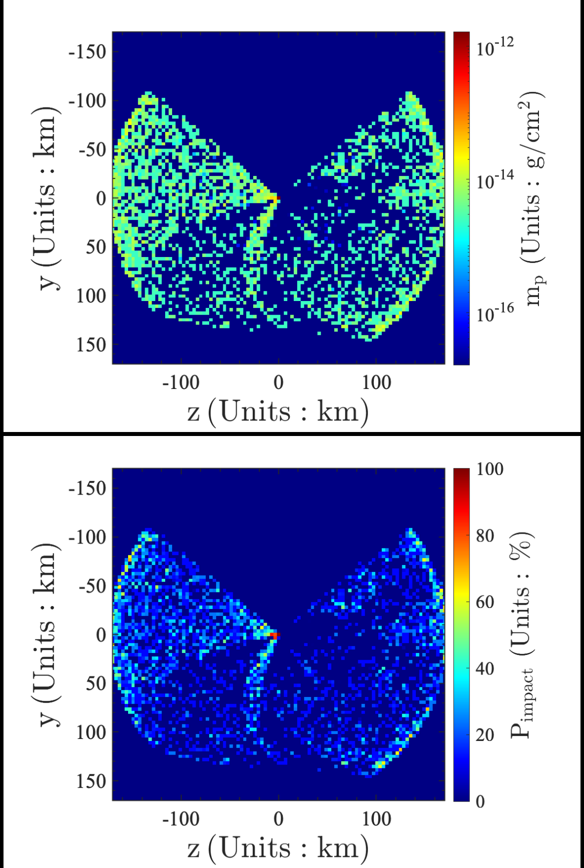


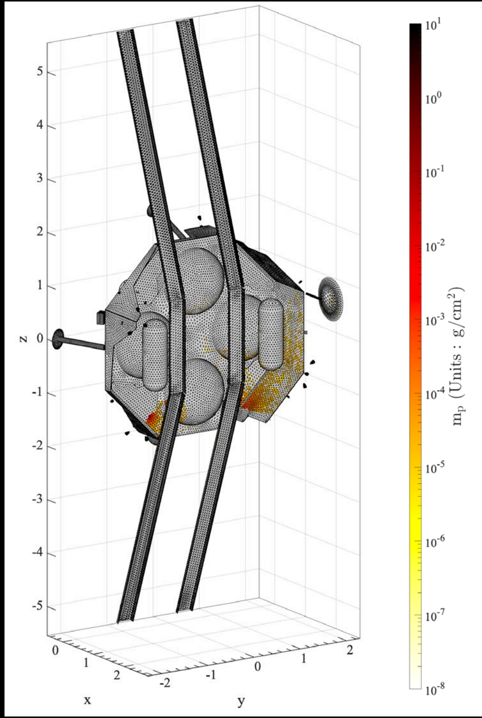
CLPS VIPER/Astrobotic Griffin Lander Venting

Venting analysis by JPL Contamination Control, leveraging existing capabilities in support of lunar landing missions

- Simulations performed for each vent orientation with two particle distributions informed from ISS observations
- Worst case scenario for spread of particulate during the start-up and shutdown phases of venting (the length and termination of this phase is dependent on geometry and nozzle configuration).







Characterization of Organic Contamination

Organic contamination releases, transport and deposition can be characterized through physics-based modeling

- JPL Contamination Control has an analysis framework that can address multi-phase vacuum vent, molecular and particulate transport, and deposition onto landing sites

Required input data in support of organic inventory

- Vent type
- Effluent composition. * Organic components, even if release is not anticipated (i.e. amine sorbents)
- Mass flow rates
- Operational frequency

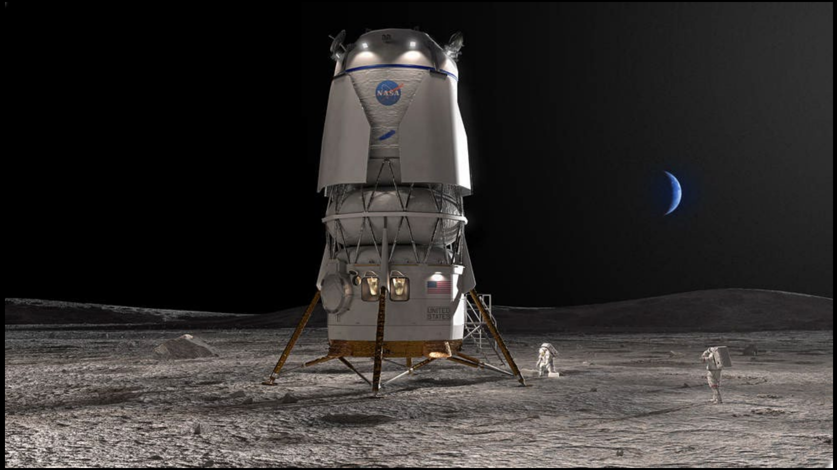
Existing capabilities can be leveraged to characterize contamination and alteration of landing sites

- *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*

Mitigation Options

Landing site alteration from vacuum vent induced organic contamination can be reduced through;

- Preferential venting: preferred venting direction is zenith
- Nadir venting is worse-case for landing site alteration
- Use of filters and sorbents to trap organics (could be an area of future R&D)



Conclusions

- **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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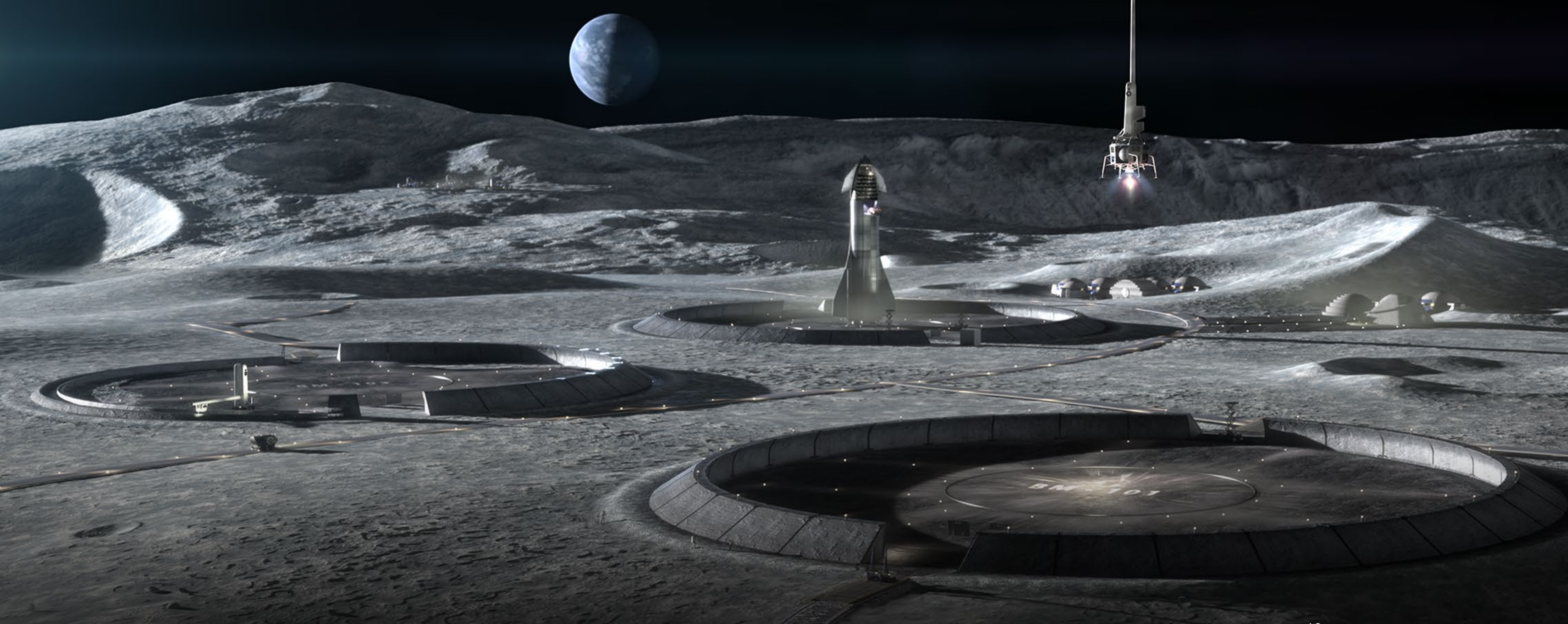

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