

Powering the Next Frontier:
Manufacturing Solar Cells in Space

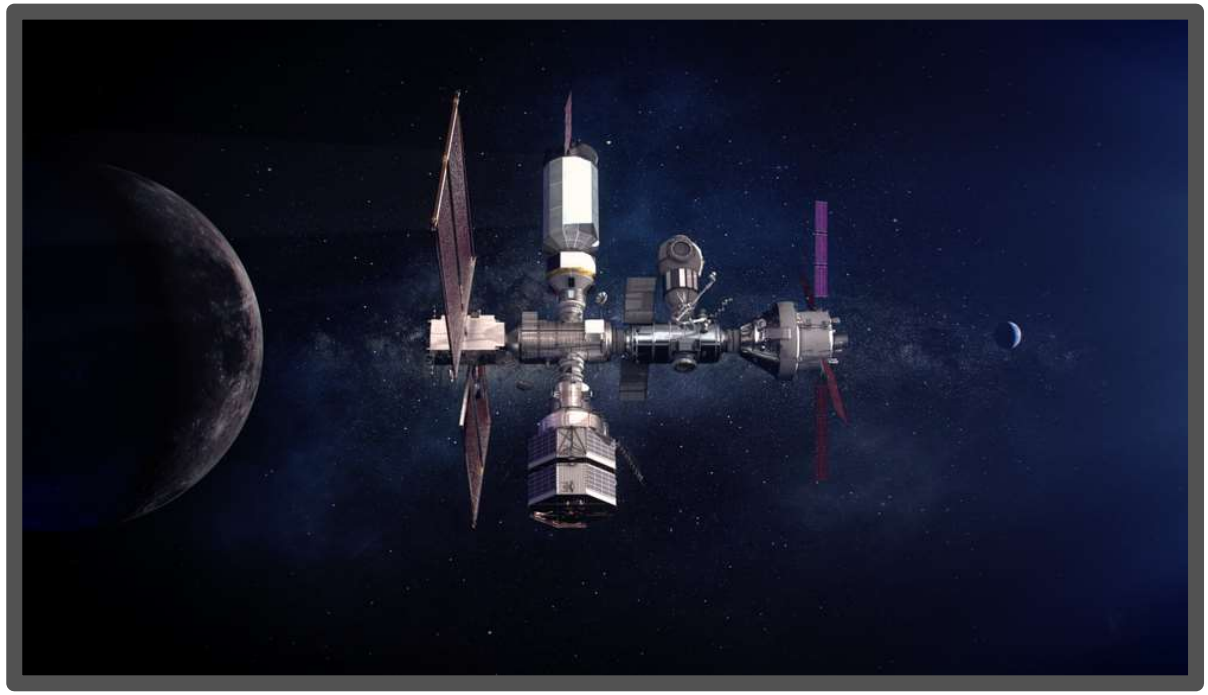
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Science of Origins | April 19, 2022


ARTEMIS
HUMANITY'S RETURN
TO THE MOON



What is a solar cell?

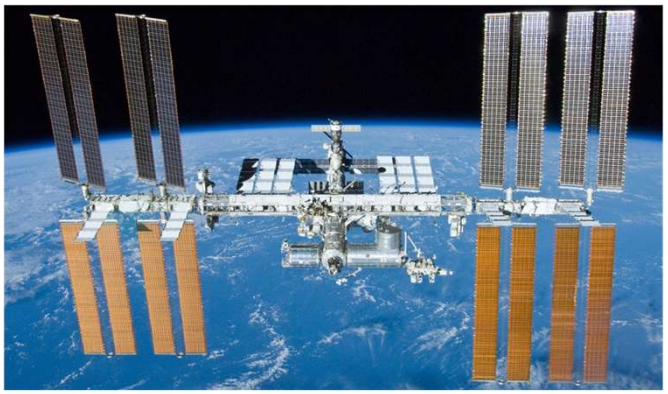
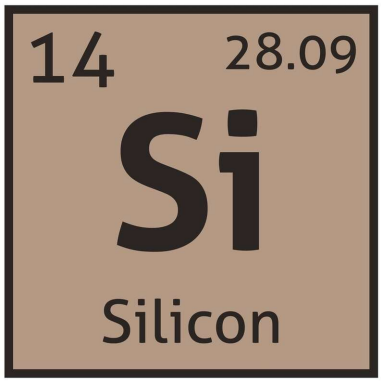


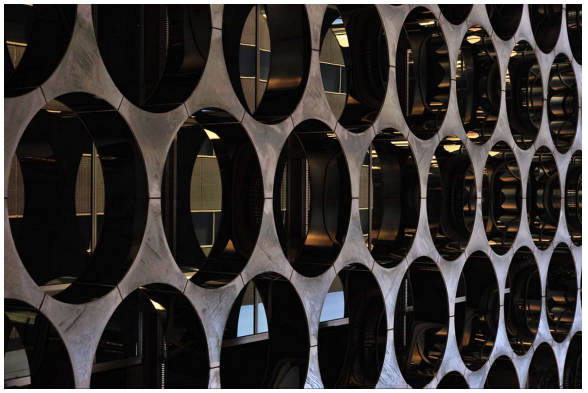
Image Credit: NASA



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"Solar panels" by wallheater CC PDM 1.0



"silicon wafer" by toshisyung CC BY-NC-ND 2.0.

Solar Cells Power Our Exploration



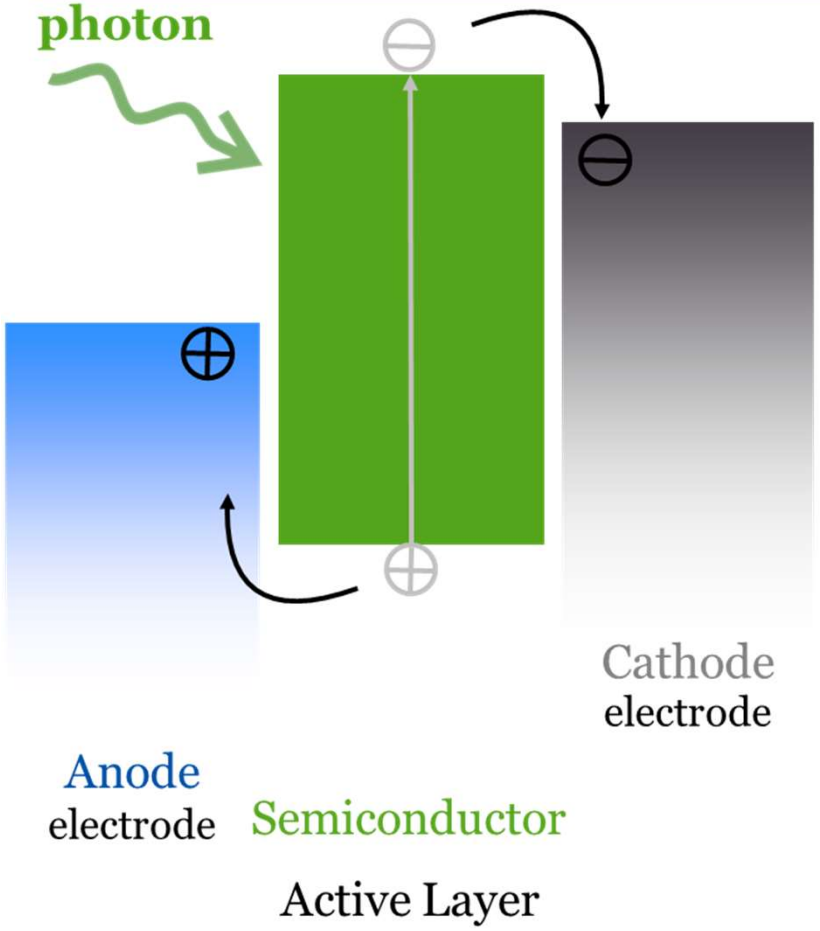






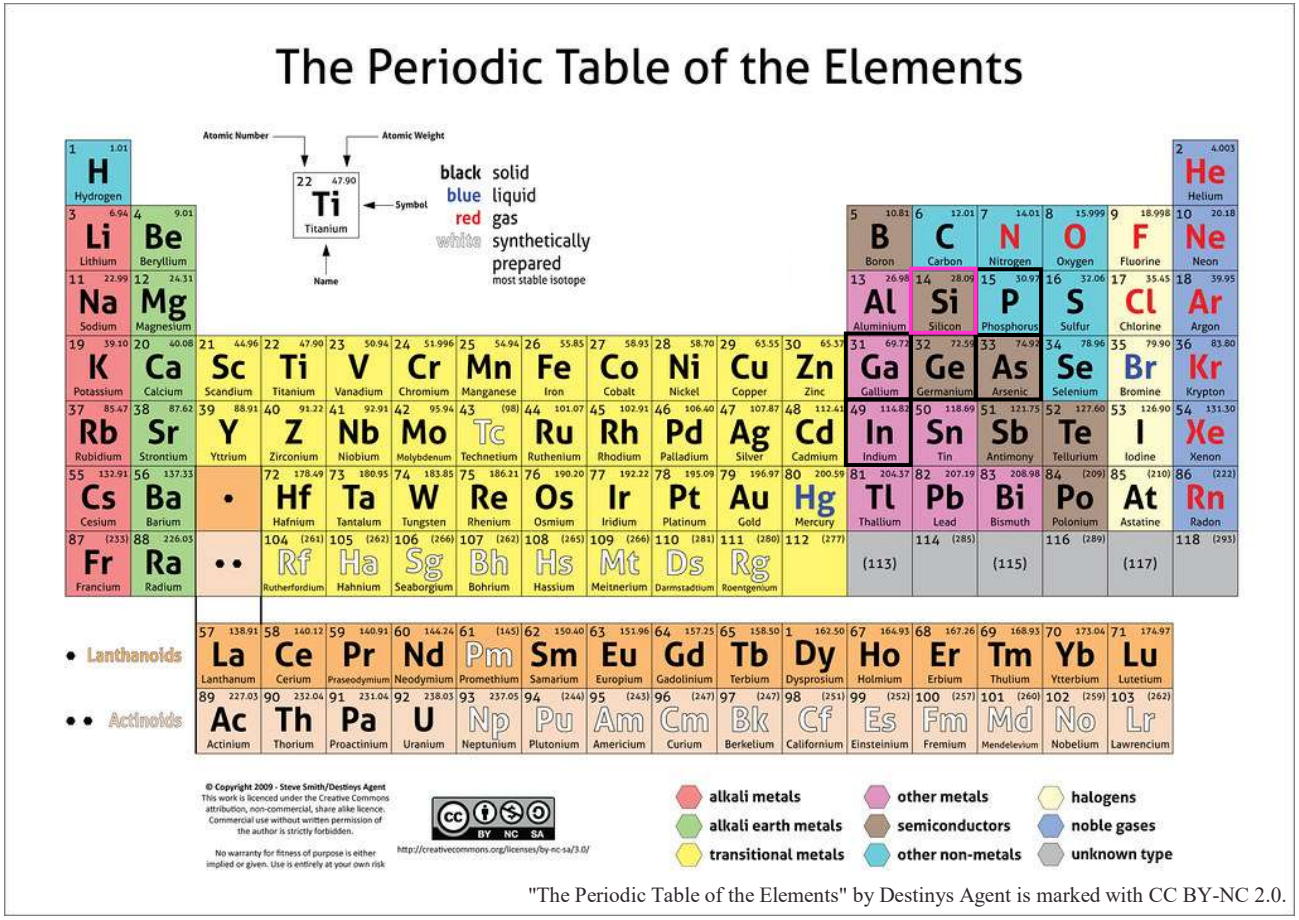


How does a solar cell work?



- Converts sunlight directly to electricity
- Photon absorbed by semiconductor
- The electron is excited to the conduction band
- Creation of electron-hole pair
- Collection of electrons in cathode
- Collection of holes in anode

Current State of the Art



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International Space Station

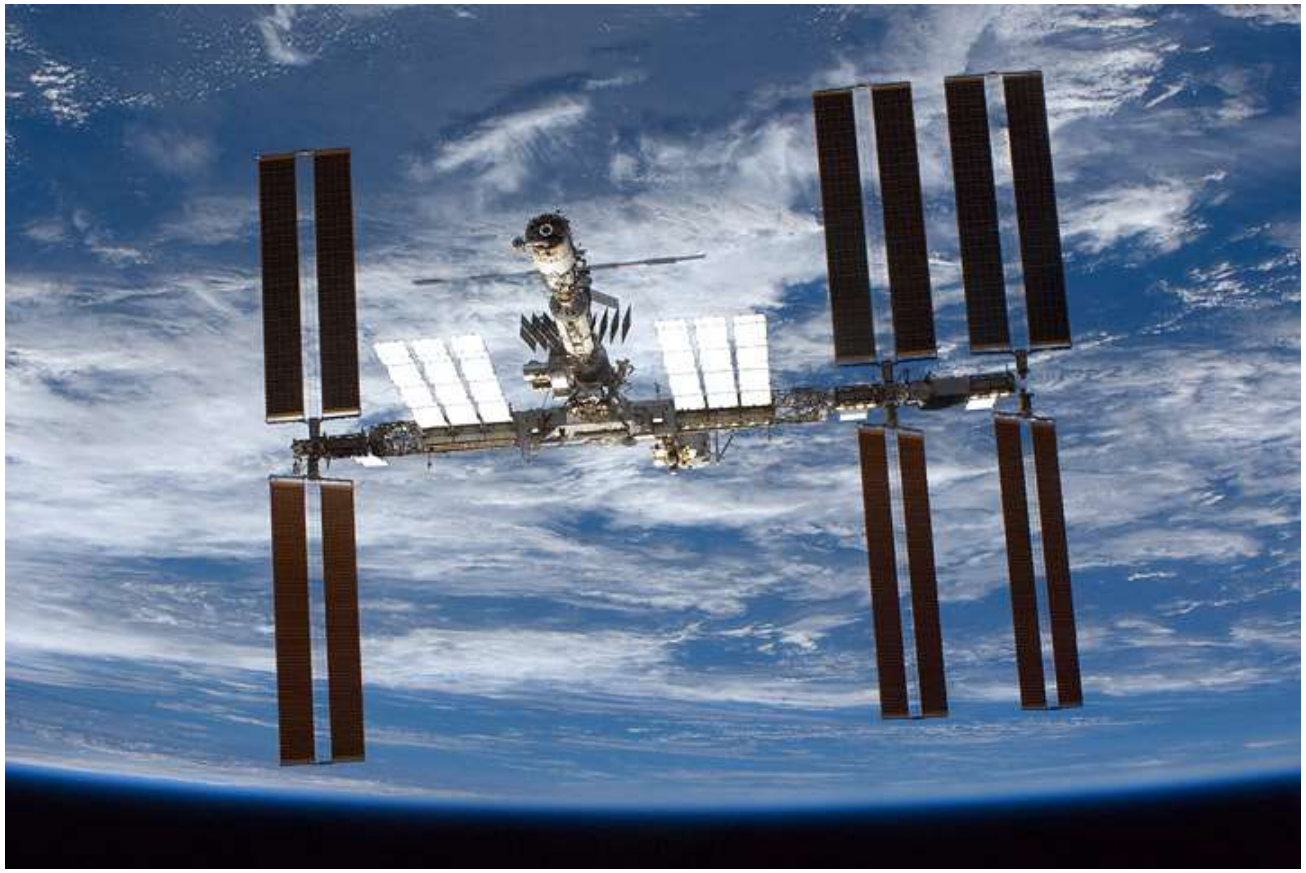


Image Credit: NASA

International Space Station



Image Credit: NASA

Roll Out Solar Array (ROSA)

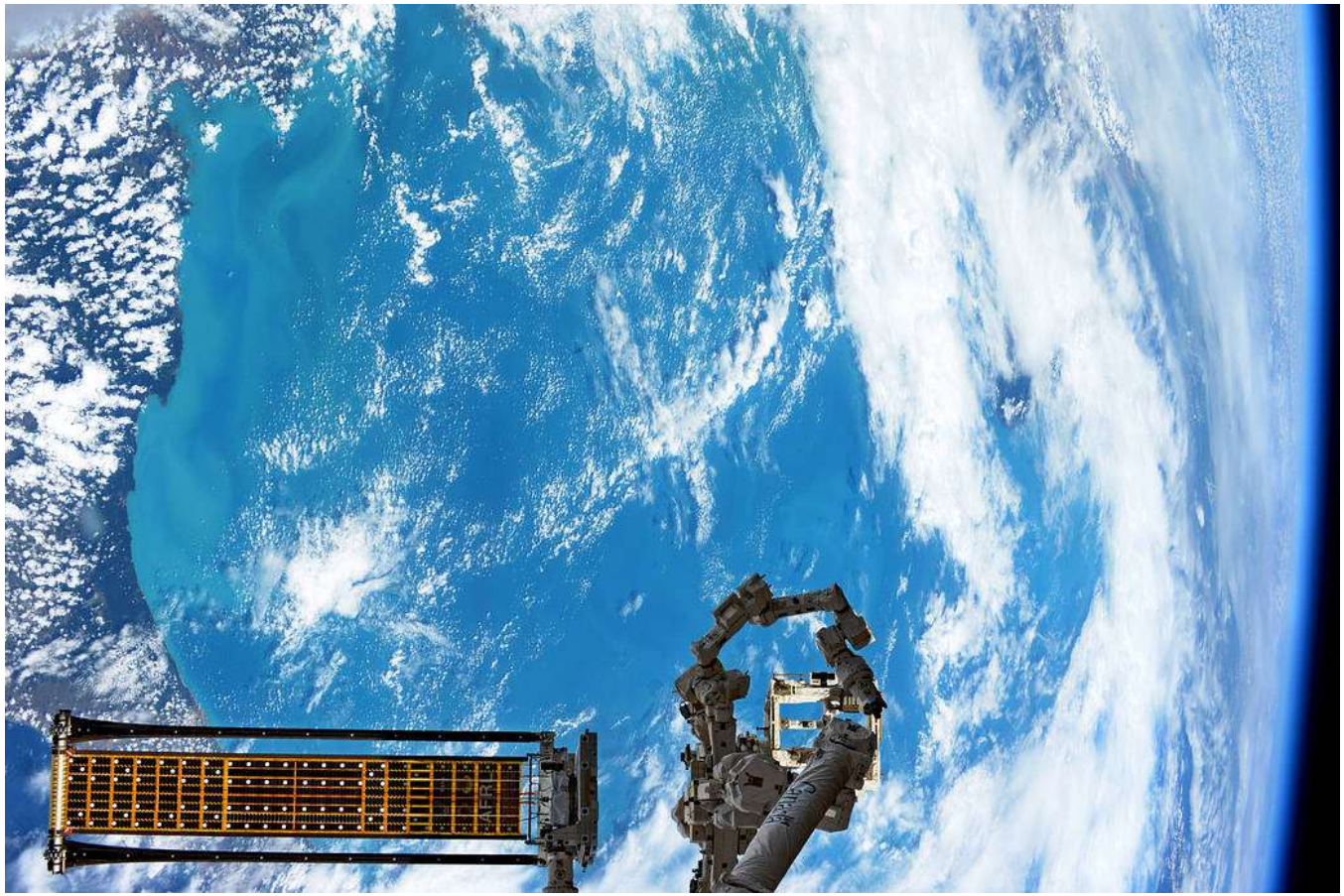
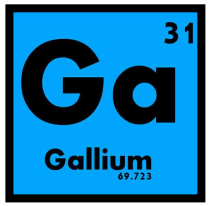


Image Credit: NASA

Room for Improvement







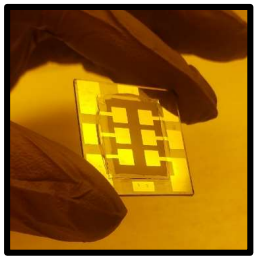
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Perovskites, the Next Generation

Perovskite: a calcium titanium oxide mineral. $CaTiO_3$

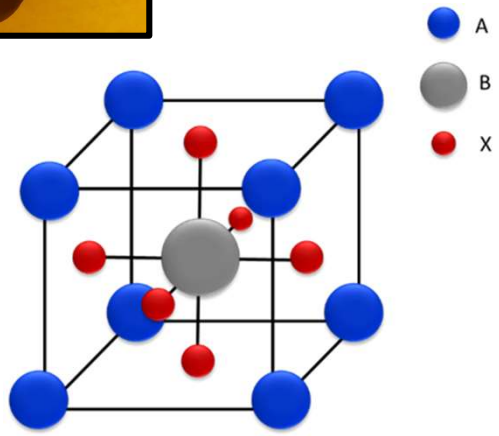
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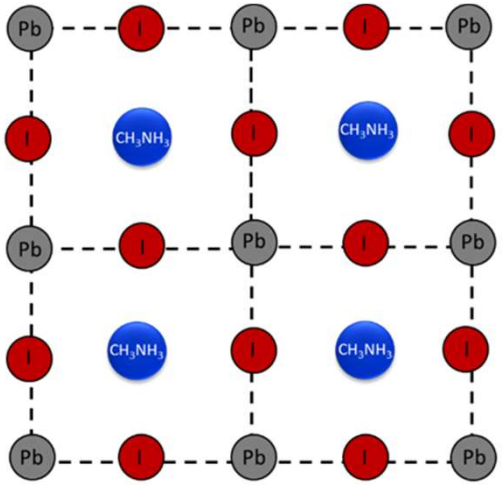
$(MA/FA)PbI_3$





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Benefits and Opportunities

- Thin films (250 nm)
- Radiation hard[1]
- Defect tolerant[2]
- Liquid or vapor phase processable
- Potentially very flexible
- Lightweight (no encapsulant)
- Low cost
- Tandem opportunities[3]

- Vacuum Stability[4]
- Thermal Stability
- Moisture Sensitivity[5]
- Oxygen Sensitivity[5]

[1]F.Lang, et al. Adv. Mater **28** (2016) 8726-8731
[2]J. Berry, et al. ACS Energy Lett. **1** (2016) 360-366
[3]Z. Song, et al. Semicon. Sci. Technol. **34** (2019) 093001
[4]E. Smecca, et al. Phys. Chem. Chem. Phys **18**(19) (2016) 13412-13422
[5]L.McMillon-Brown, et al. 48th IEEE PVSC Proceedings (2021) 222-225

Meet the Team

NASA

- Dr. Lyndsey McMillon-Brown
- Dr. Timothy J Peshek
- Dr. Kyle Crowley
- Dr. Kaitlyn VanSant
- Jeremiah Sims







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- Prof. Sayantani Ghosh
- William Delmas
- Samuel Erickson





NREL
NATIONAL RENEWABLE ENERGY LABORATORY

- Dr. Joey Luther



NASA Space Technology Mission Directorate's
Early Career Initiative Program

Our Vision

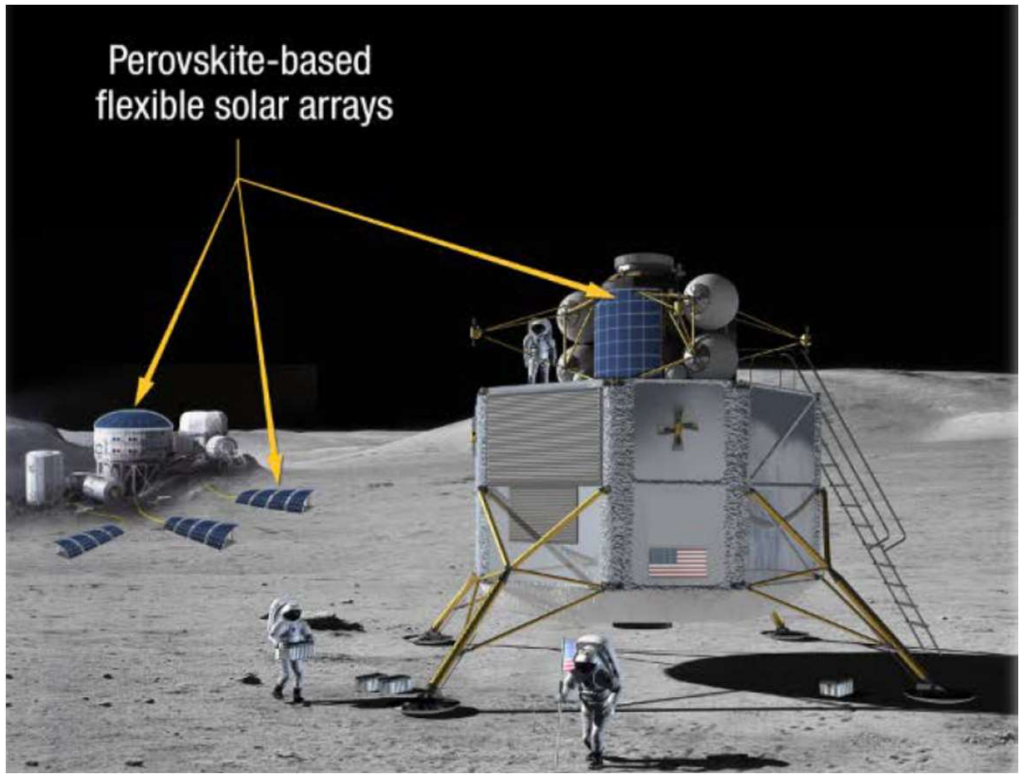
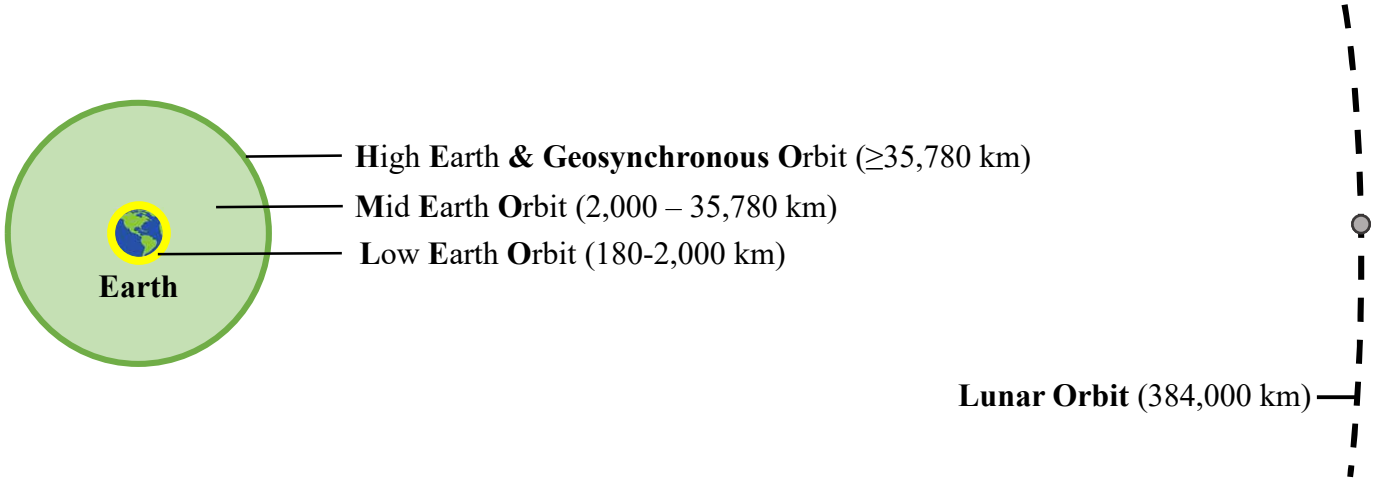


Image Credit: NASA

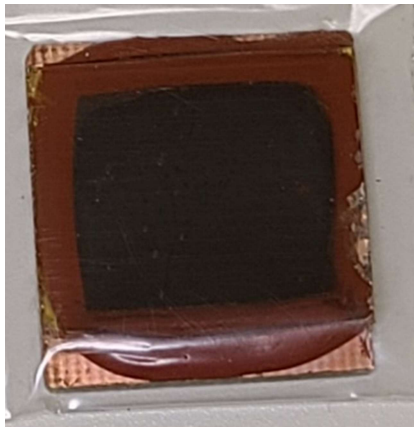
Where are we going?



International Space Station in LEO at 408 km (254 mi)
Lunar Orbit (238,606 mi)

In Space Testing

- LEO exposure via external mount on ISS
- Investigate the long-term exposure of materials
- $MAPbI_3$ film encapsulated survived **10 months** on MISSE-13
  - Integrated October 2019, Launched March 2020, Landed January 2021, Returned March 2021



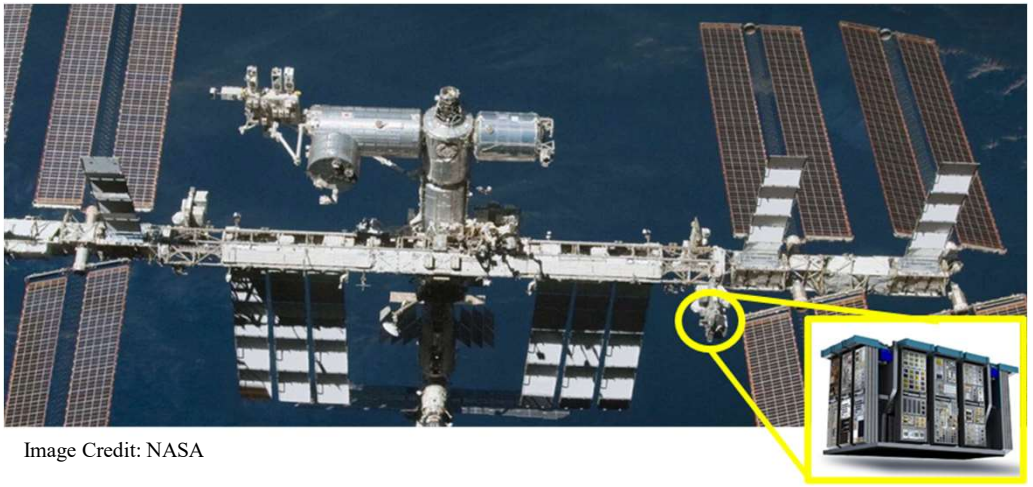
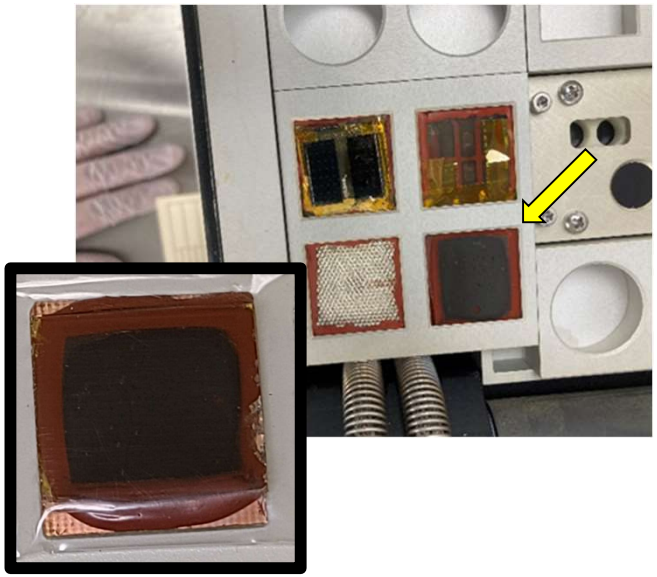
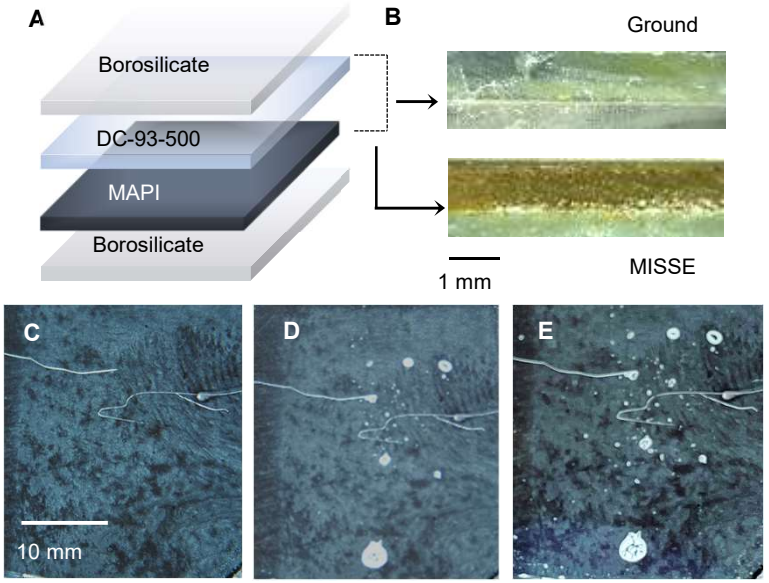


Image Credit: NASA

MISSE-13 Flight Results

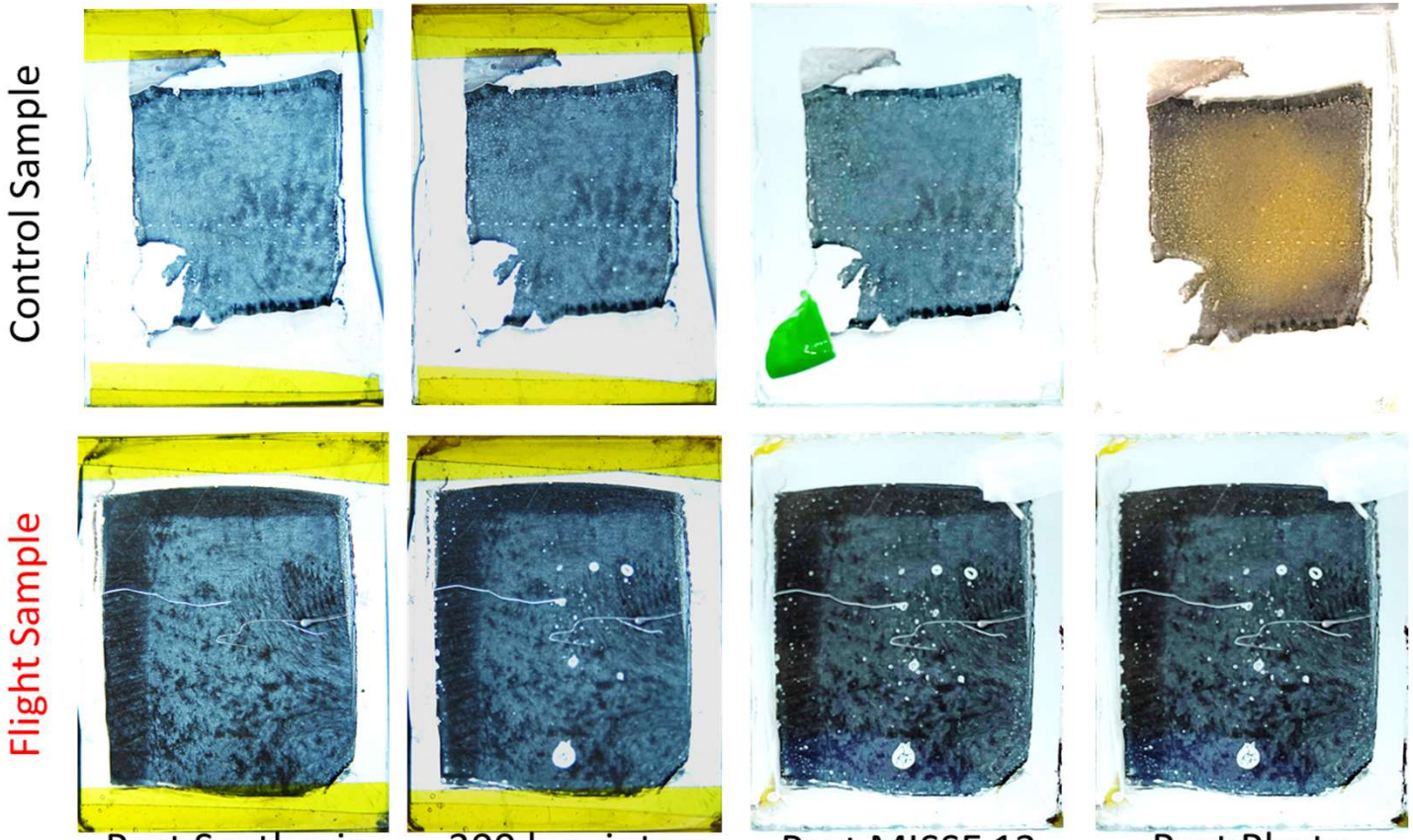
- Sample aligned in zenith direction
- -20 ºC ≤ T_{MIN} ≤ 0 ºC
- 65 ºC ≤ T_{MAX} ≤ 85 ºC



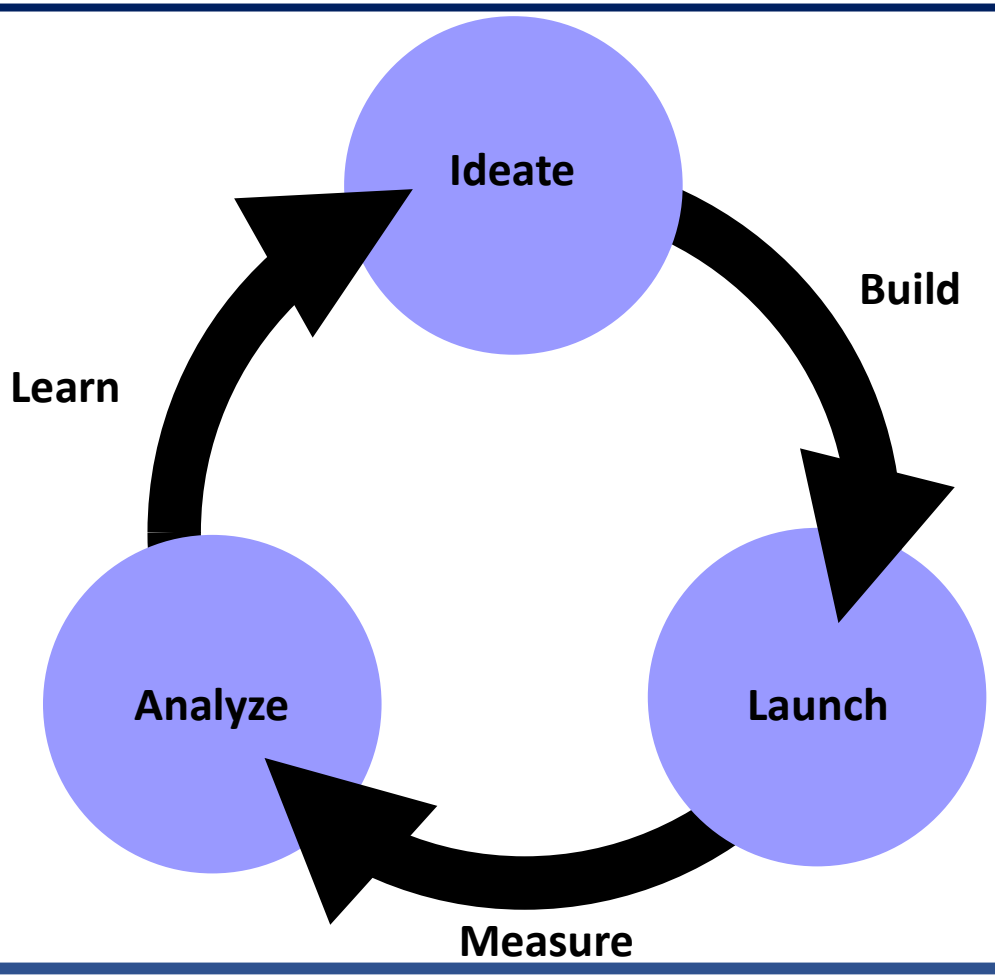


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Sample Timeline



Innovation Cycle



MISSE-15 Launch



SpaceX Dragon spacecraft 23rd cargo resupply mission with Perovskites on board!

Image Credit: NASA TV



Image Credit: SpaceX

What would it take to manufacture solar cells in space?

- Overcome thermal, vacuum, and humidity challenges
- Address radiation concerns
- Find light weight space ready substrates
- Leverage the vacuum of space for deposition
- Leverage the sun to create high quality films

1 MW solar array can be printed while transporting 26.4 lb of condensed material to orbit.

Printing Solar Cells in Space

