How will Energy be Leveraged for Future Life in Space

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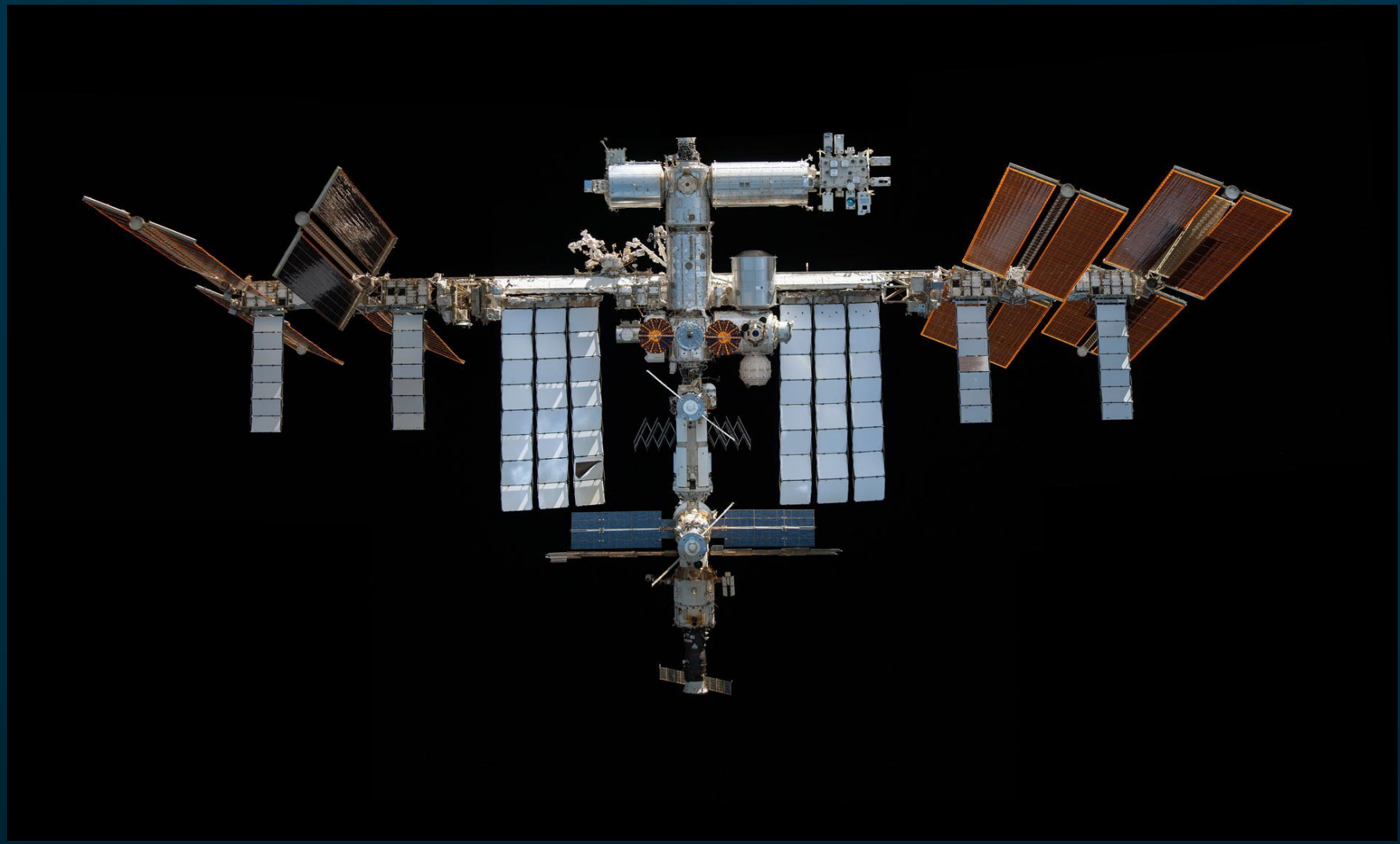
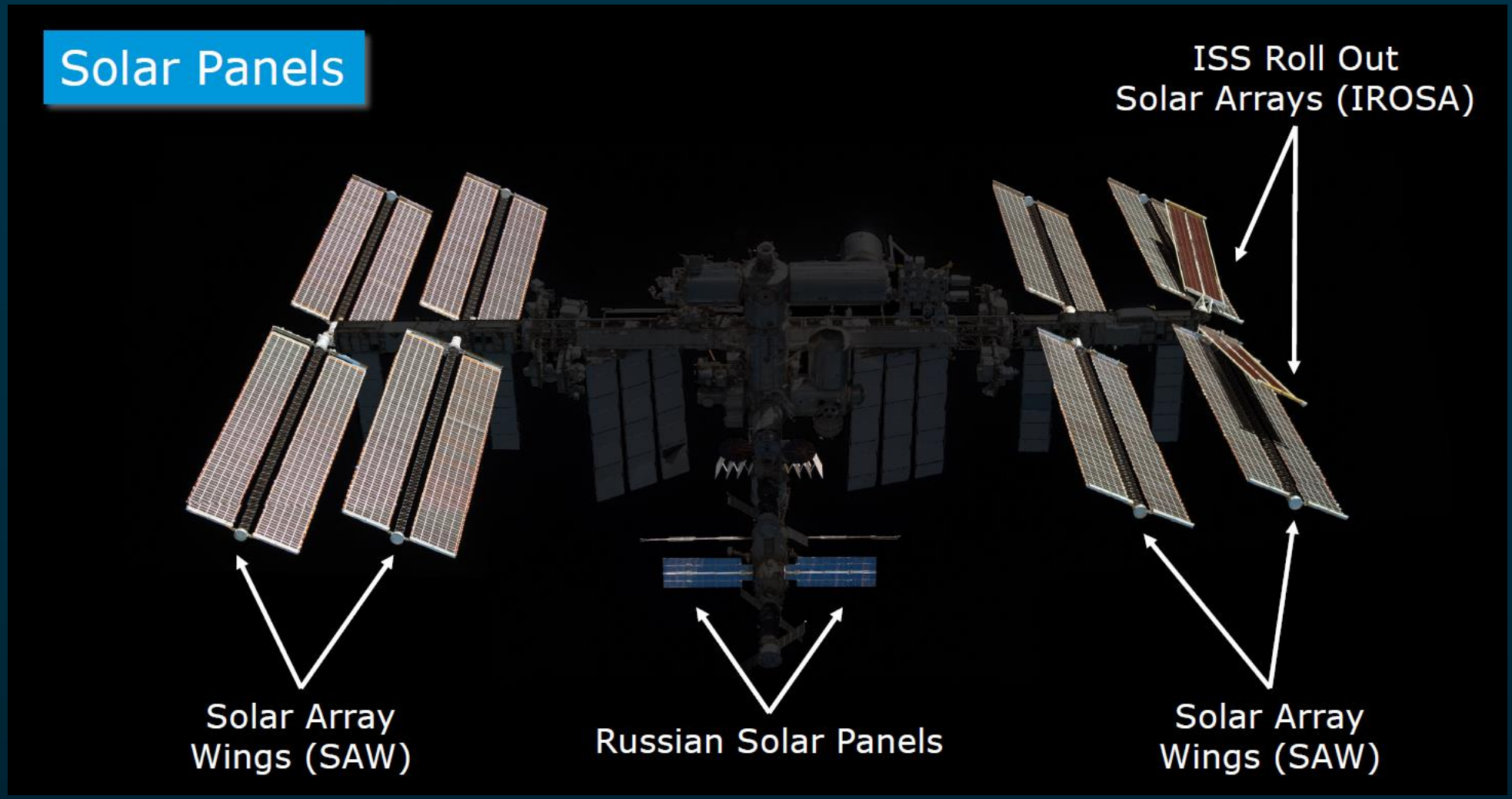
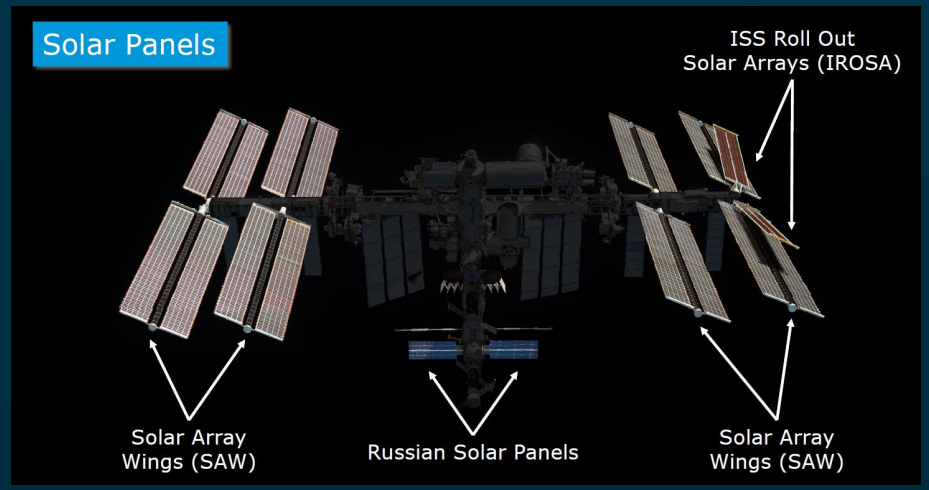
How does energy support life in space in Low Earth Orbit?

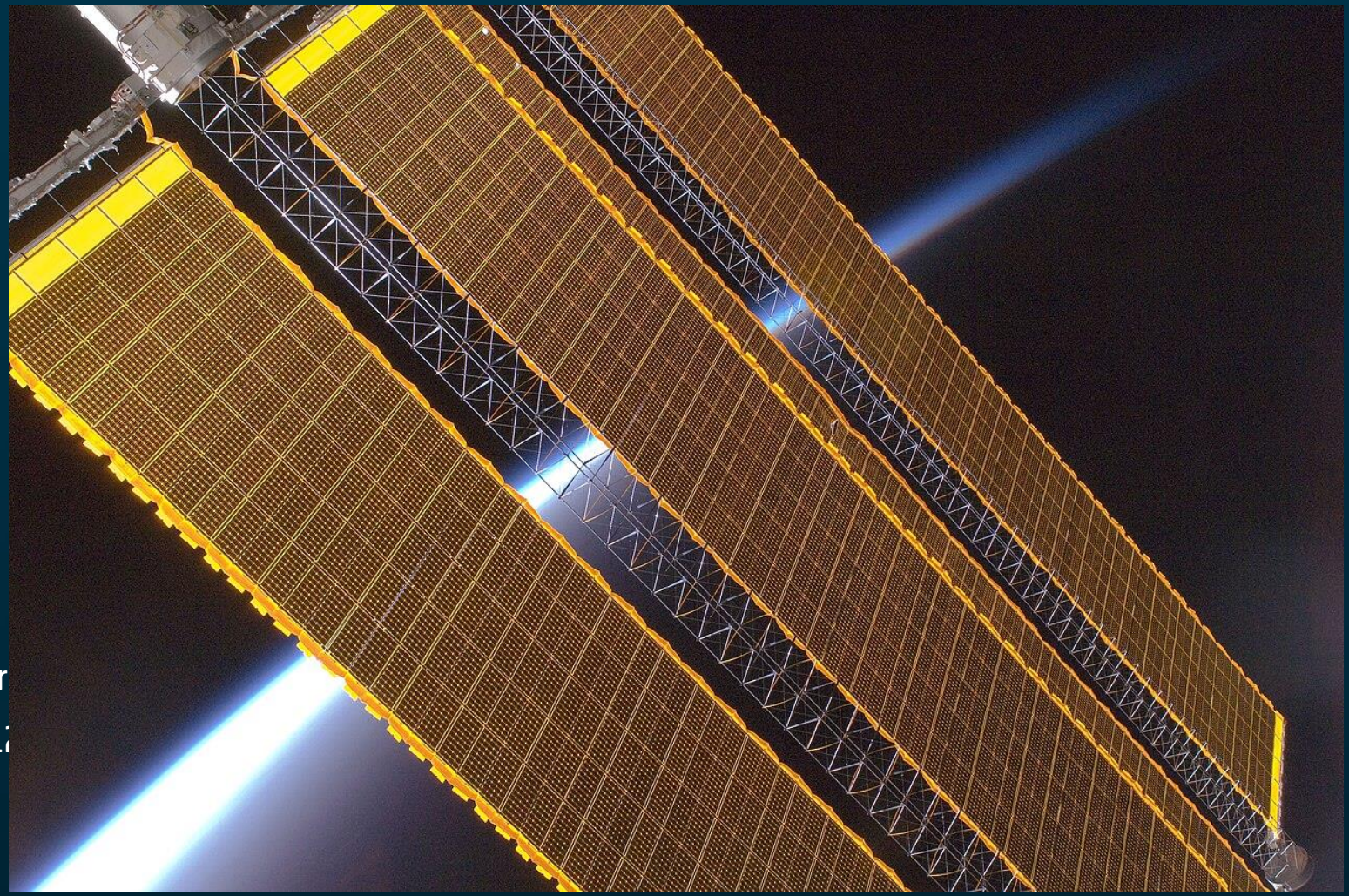


The electrical system of the International Space station



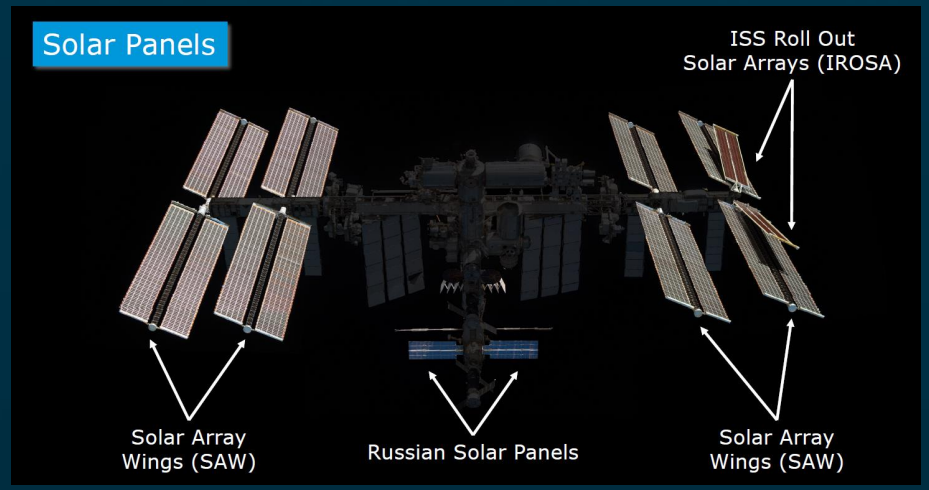
The Solar Array Wings (SAW)

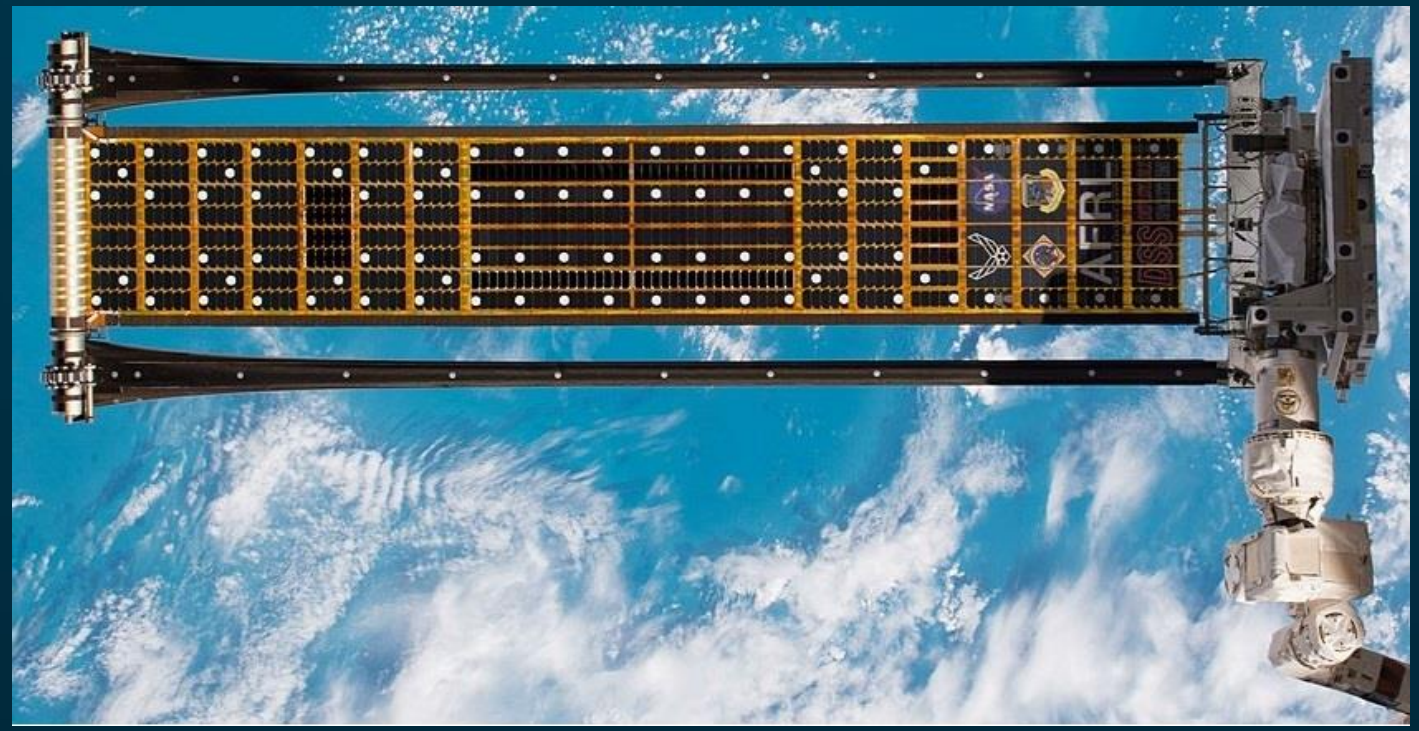




- 8 wings
- Each SAW has a size of 35x12m
- Largest ever deployed in space
- Each SAW produces 31kW of direct current power
- 240 kW in direct sunlight, 1 orbit average of 84-1
- 2 Degree of freedom to maximize exposure
- Originally designed for 15-year life service

ISS Roll Out Solar Arrays (iROSA)

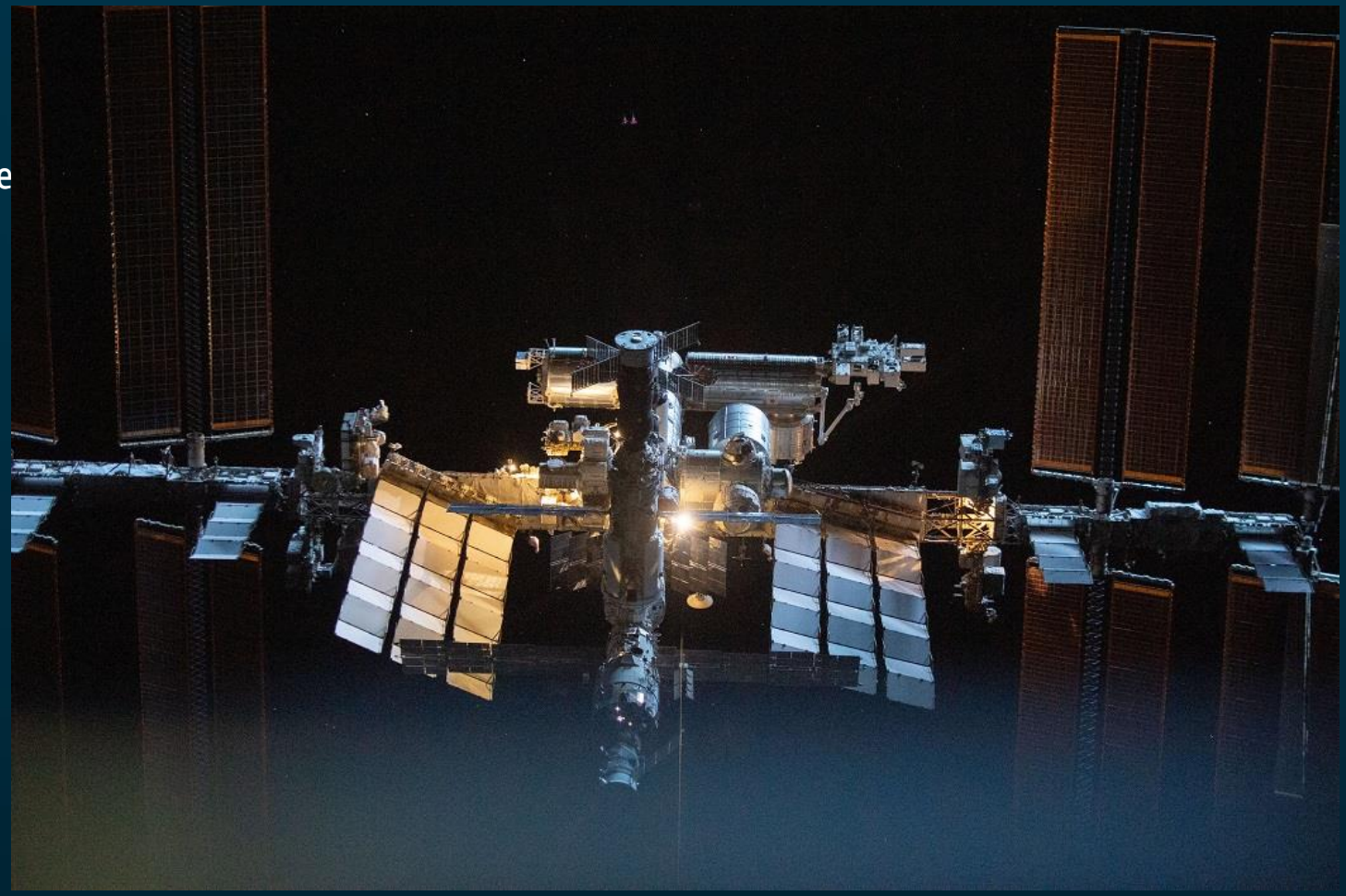




- More efficient technology
- Rollable and flexible solar arrays
- Gain in mass & volume at launch
- 7th and 8th set of iROSA to be assembled in 2025

Batteries

- Originally Nickel-Hydrogen batteries (6.5 year lifetime)
- Replaced (2017 to 2021) with Lithium-Ion batteries
- Li-Ion batteries have twice the capacity of Ni-H2 batte
- Designed for 60,000 cycles and 10year lifetime



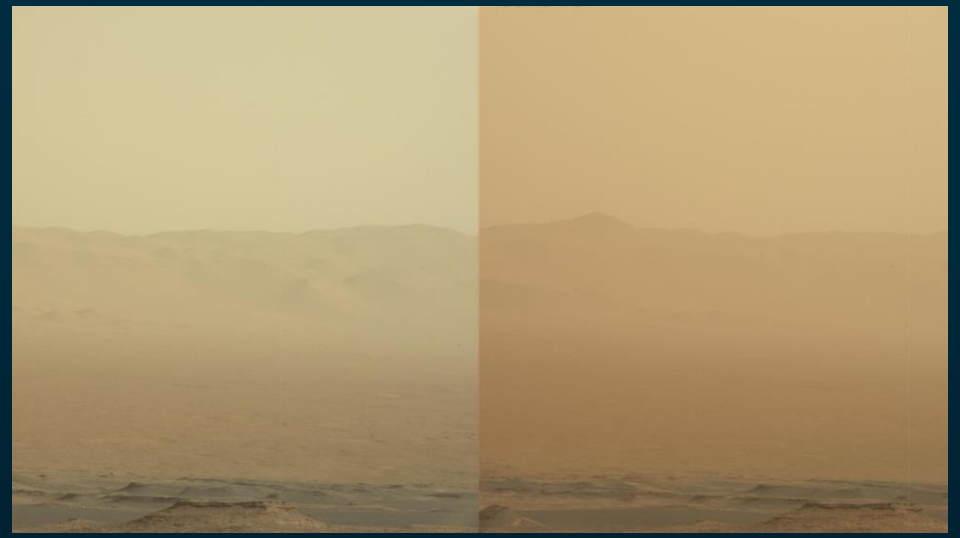
What if the environmental conditions change?

- Long lunar night (up to 354 hours of darkness)
- Month-long dust storms and diminished sunlight at higher Mars latitudes

Limited/unreliable/non-existing access to solar illumination

- Need to satisfy future long-duration human exploration goals
- Early missions will require 10s of kW; later missions could require 100s of kW or megaW
- Chemical-based energy storage solutions present significant mass penalties
- A battery providing 200W during the 14-days lunar night have a mass of > 300 kg
- Not compatible with transportation cost towards Moon/Mars

Nuclear Power Systems



Nuclear Power System for Space Applications (1)

Category	Mission driver
Radioisotope Power System (RPS) (heating and electricity)	Can operate for decades and produce 100s of watts in packages that weigh around 100 kg or less. Small robotic science platforms on Moon, Mars, and the outer solar system, robust thermal survival of human exploration systems on Moon (night) and Mars (dust storm season)
Fission Power System (FPS) (nuclear reactors)	High energy density and scalability: potential to exploit fission technology for power levels from 10s of kilowatts to 100s of megawatts **Small:** Habitation and science modules on Moon and Mars, ISRU pilot and research plants and small-scale industrial activity **Large:** ISRU, operations-scale industrial capability on the Moon and Mars
Nuclear Thermal Propulsion (NTP)	Crew transportation to and from Mars, fully reusable shuttles to and from the lunar surface

RPS on the Perseverance

Cassini-Huygens mission to Titan

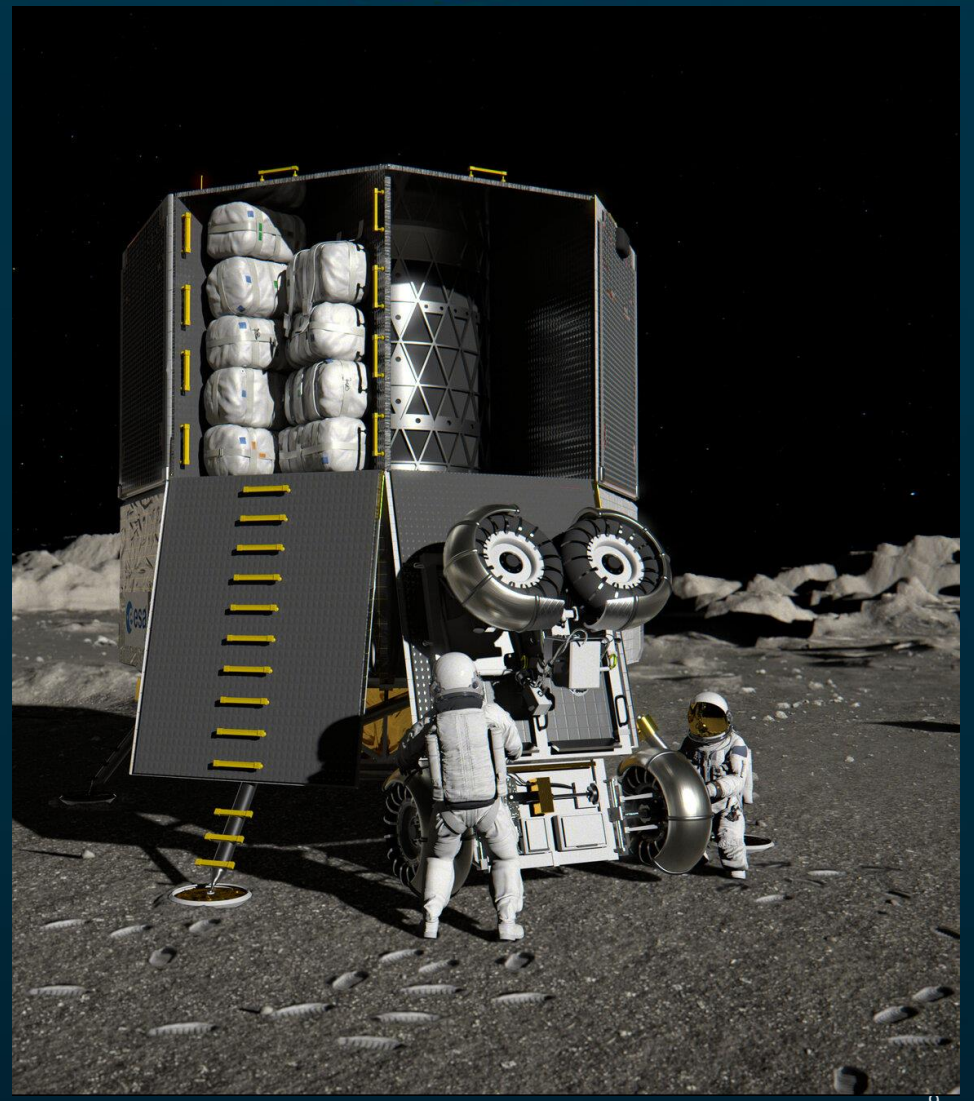
Nuclear Power System for Space Applications (2)

Some challenges (other than the technical ones):

- Safety (especially at launch & reentry)
- Launch certification
- Common Regulatory Constraints on nuclear proliferation & transportation of nuclear material
- Absence of internationally governing regulatory framework
- Shortage of radioisotope and reactor fuel supply for space applications exists at the current time

ESA Activities: "EuropeaN Devices Using Radioisotope Energy" (ENDURE)

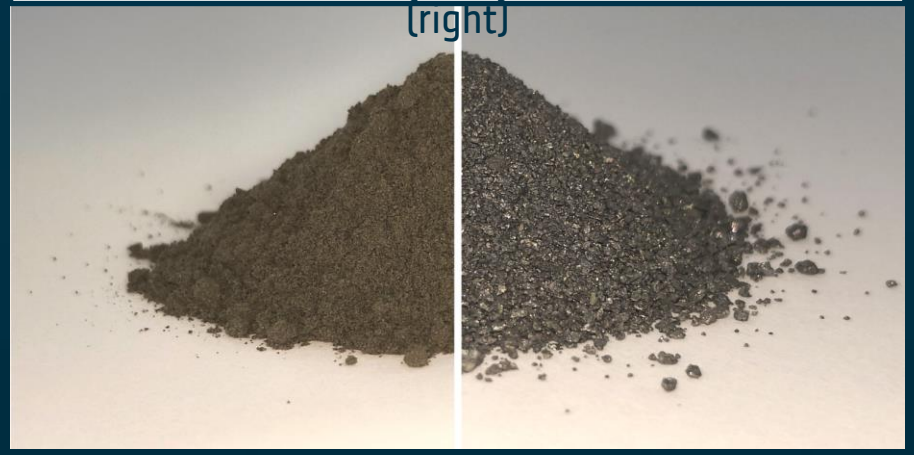
- dedicated program to bring this technology to flight readiness
- supply science and exploration missions with nuclear technology capabilities for the survival of cold, dark environments such as the Moon, Mars, and the vast space of the outer Solar System.
- The likely first application of a European radioisotope device will be on the European Large Logistic Lander /Argonaut



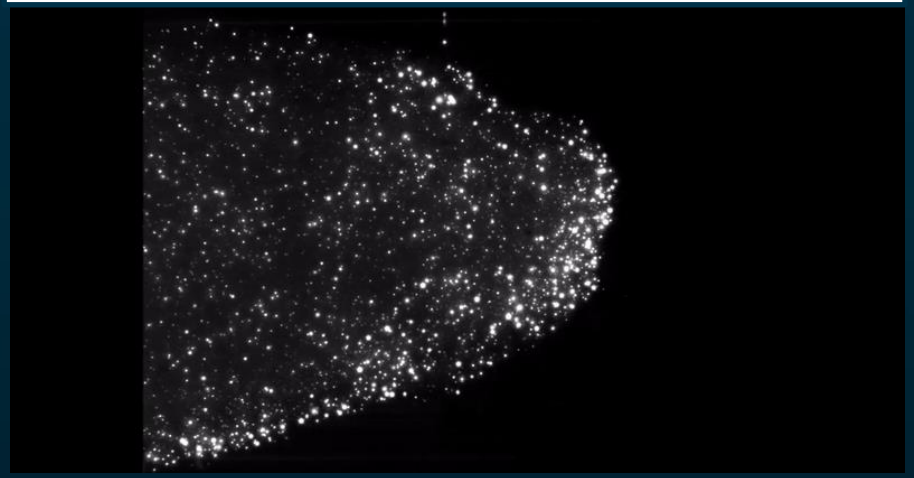
What about In Situ Resource Utilization (ISRU)?

- **Lunar regolith contains about 45% oxygen which is bound to metals such as iron and titanium:**
  - Successful extraction of oxygen demonstrated on simulated lunar regolith
  - The oxygen generated would mostly be used to make rocket fuel, but could also provide air for lunar settlers
- **The leftover Iron can be used as green fuel:**
  - Carbon-based fuel produces the greenhouse gas carbon dioxide
  - .With iron, the leftover product after combustion is iron oxide, more commonly known as rust
  - No carbon dioxide is produced, and the rusty iron can be easily collected as it doesn't form a gas: burning iron emits no noxious gases at all.
  - Successful demonstration on parabolic flight showed feasibility of this type of combustion in low gravity environments

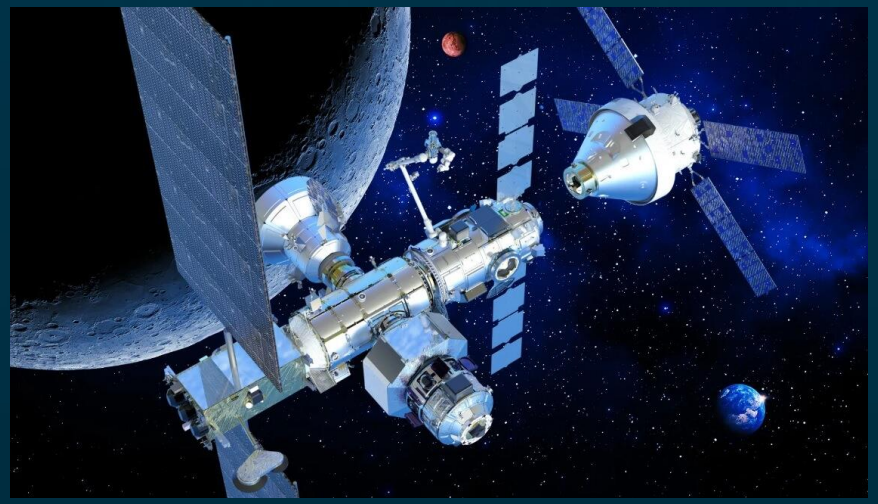
Regolith (left) and Oxygen extraction leftovers (right)

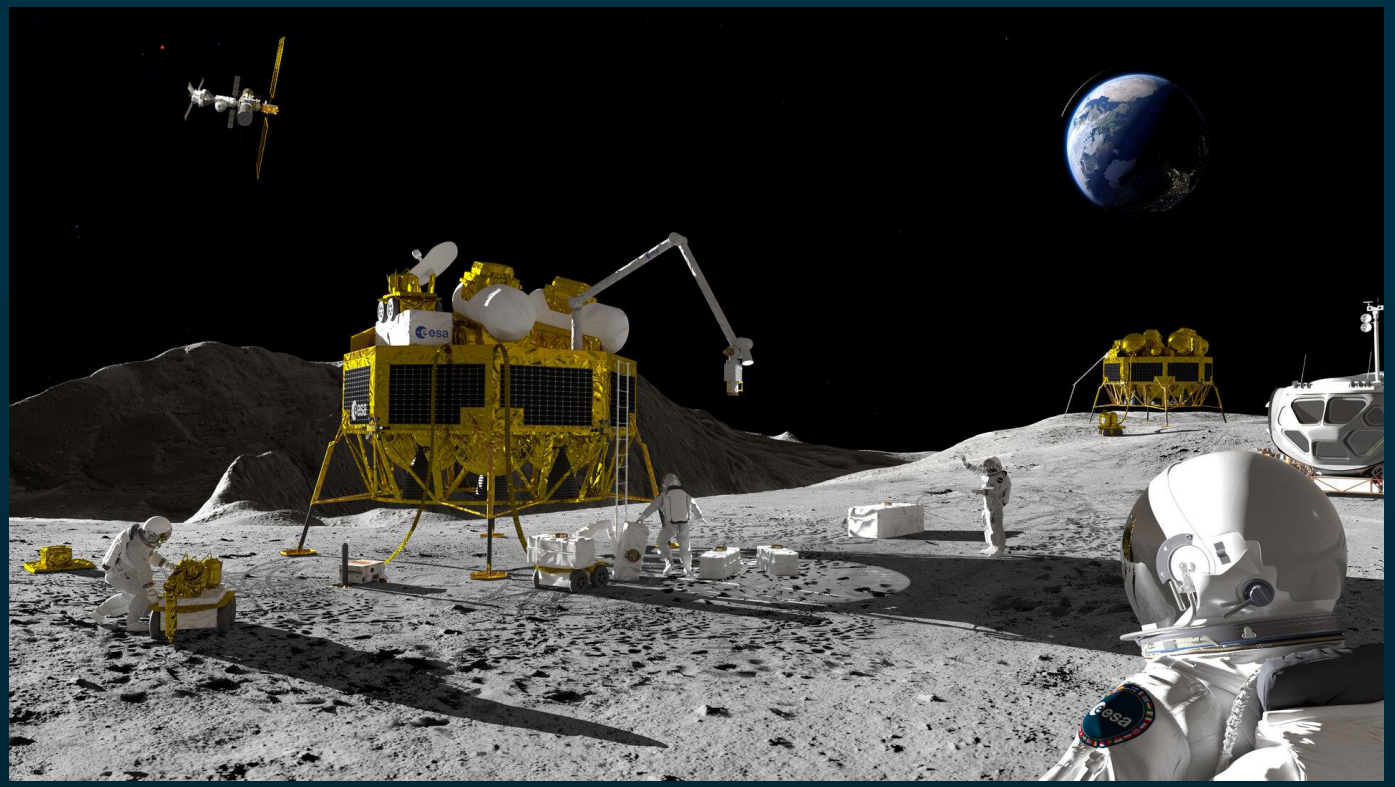


Iron dust combustion during a parabolic flight



All these building blocks are needed for human exploration!





Thanks for your attention!

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