



2020 – 2030

New technologies for microbial research in deep space

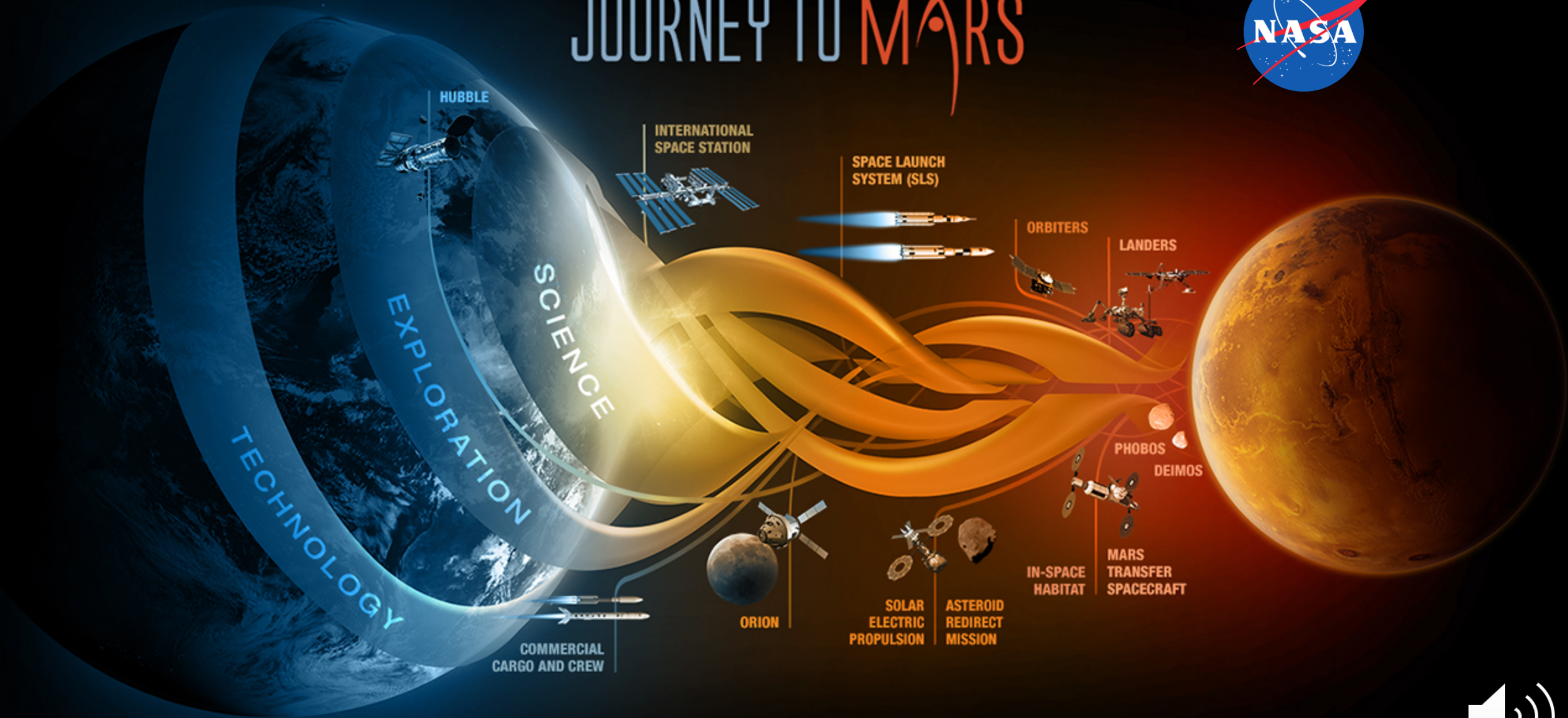


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JOURNEY TO MARS



We Start Here



LRO: Continued surface and landing site investigation



Artemis I: First human spacecraft to the Moon in the 21st century

2022



Artemis II: First humans to orbit the Moon in the 21st century

2024



Artemis Support Mission: First high-power Solar Electric Propulsion (SEP) system



Artemis Support Mission: First pressurized module delivered to Gateway



Artemis Support Mission: Human Landing System delivered to Gateway

2026



Artemis III: Crewed mission to Gateway and lunar surface



Commercial Lunar Payload Services

- CLPS-delivered science and technology payloads

Early South Pole Mission(s)

- First robotic landing on eventual human lunar return and In-Situ Resource Utilization (ISRU) site



Lunar Terrain Vehicle

- Increased astronaut mobility with unpressurized rover

Volatiles Investigating Polar Exploration Rover

- First mobility-enhanced lunar volatiles survey

Large-Scale Cargo Lander

- Increased capabilities for science and technology payloads



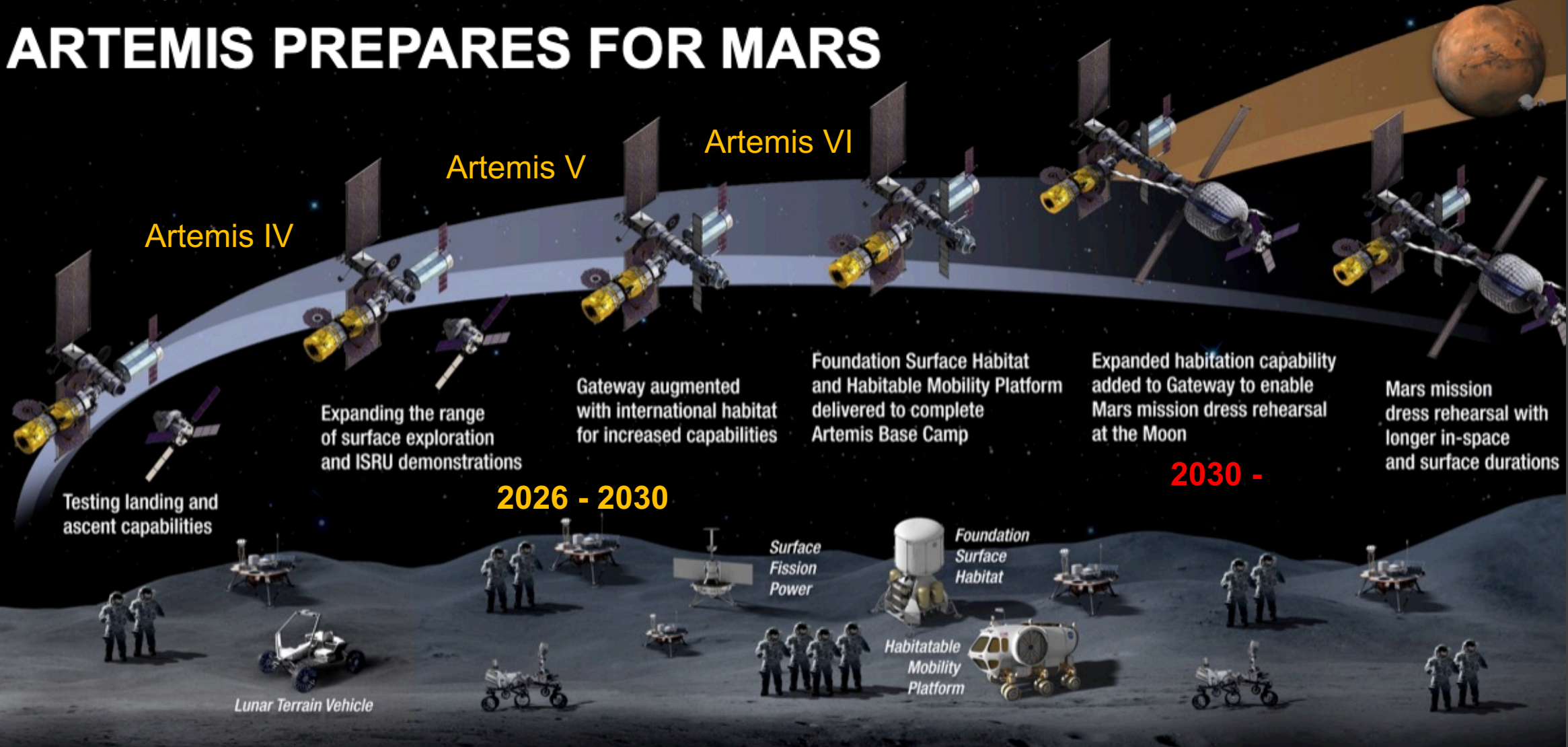
Humans on the Moon - 21st Century

First crew leverages infrastructure left behind by previous missions

LUNAR SOUTH POLE TARGET SITE



ARTEMIS PREPARES FOR MARS



SUSTAINABLE LUNAR ORBIT STAGING CAPABILITY AND SURFACE EXPLORATION

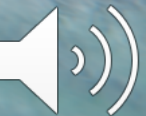
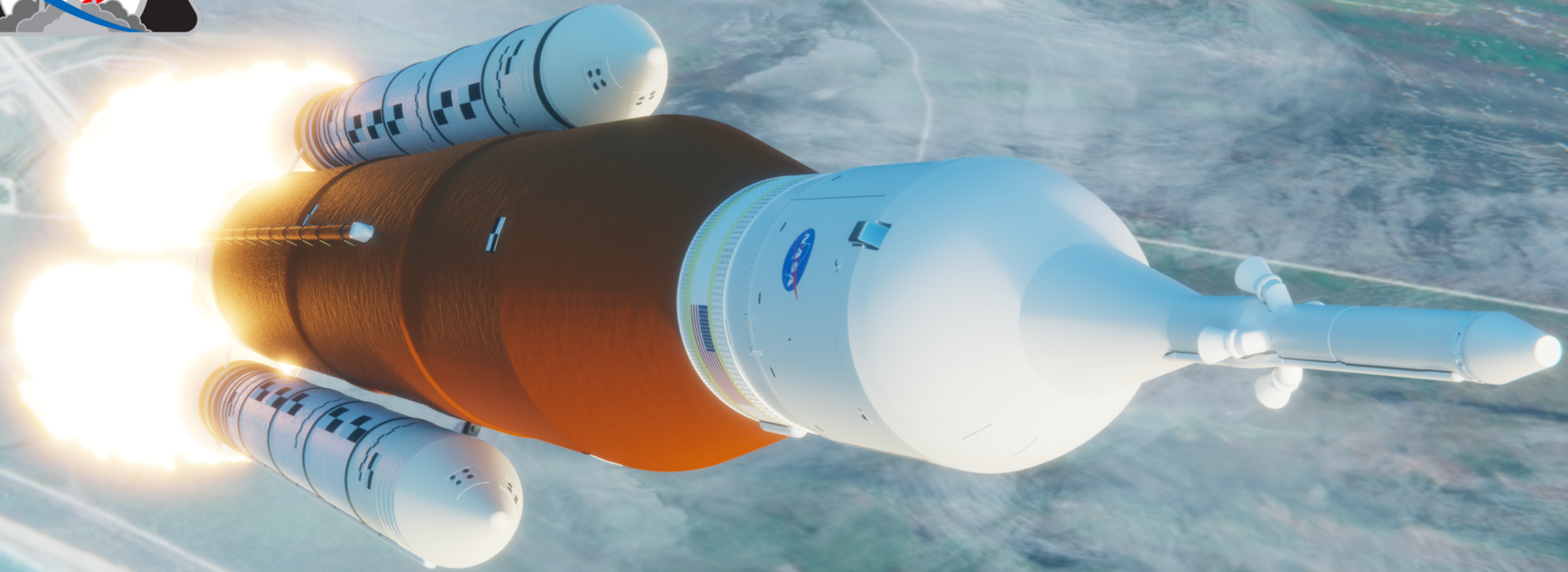
MULTIPLE SCIENCE AND CARGO PAYLOADS | INTERNATIONAL PARTNERSHIP OPPORTUNITIES | TECHNOLOGY AND OPERATIONS DEMONSTRATIONS FOR MARS





Artemis I – VI missions

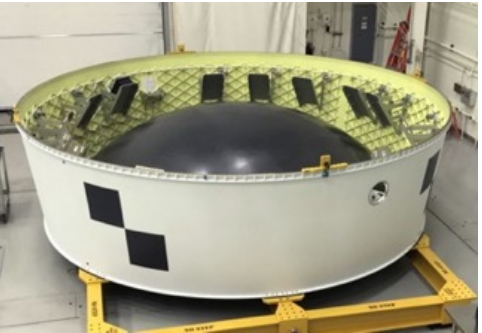
Vehicles for biological research beyond LEO



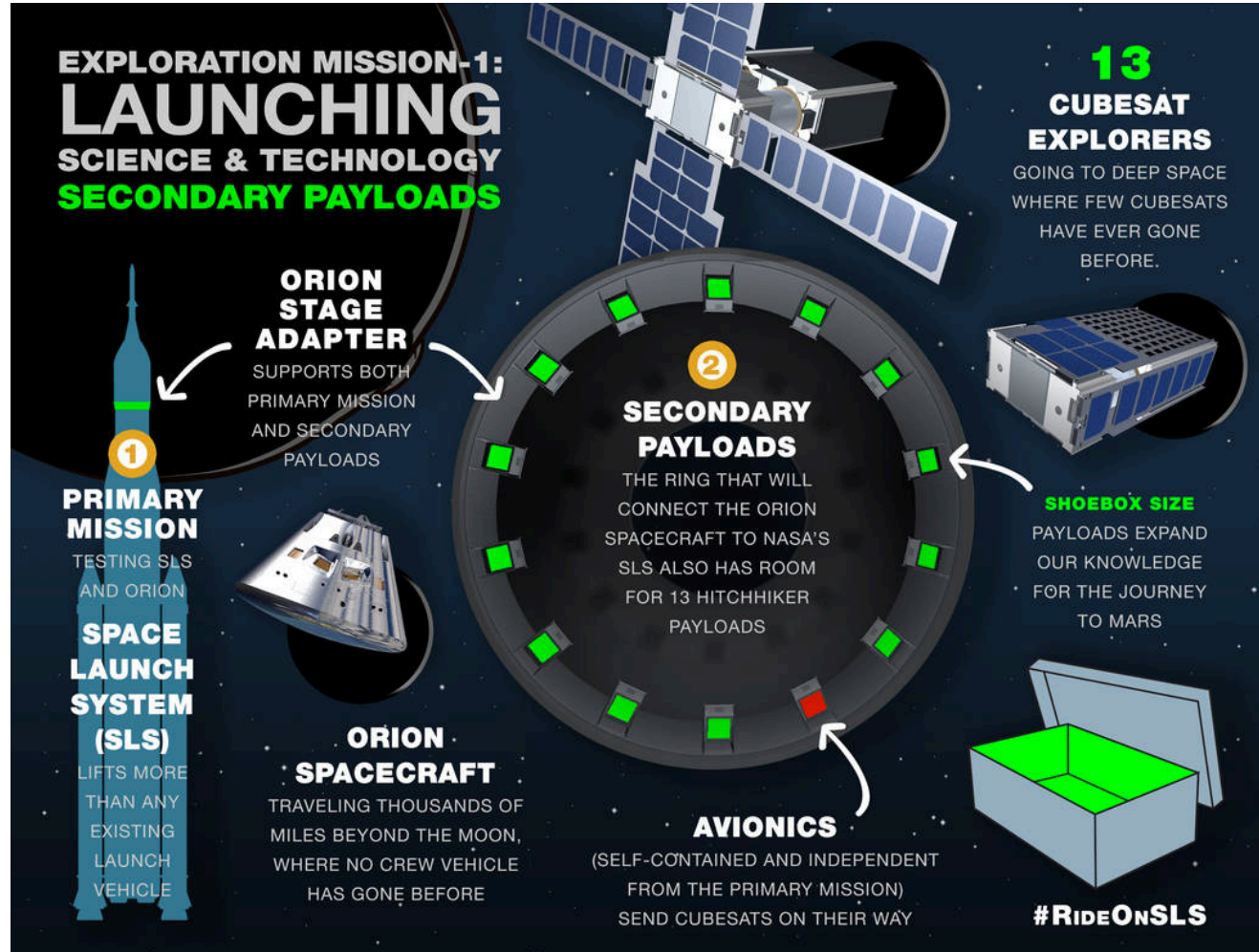


Artemis I – VI missions

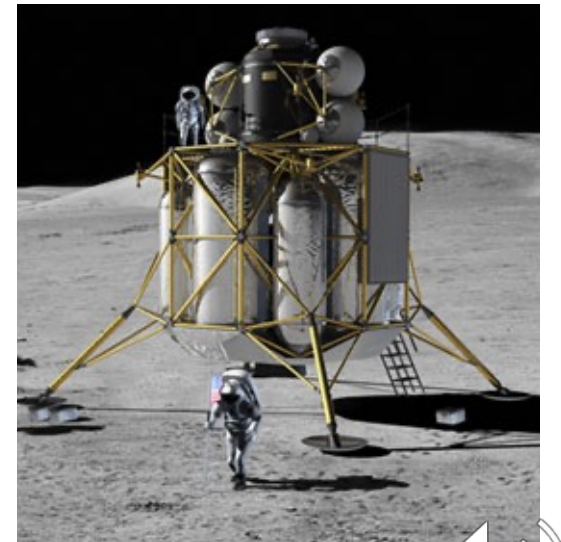
Vehicles for biological research beyond LEO



CubeSat missions
(secondary payloads)



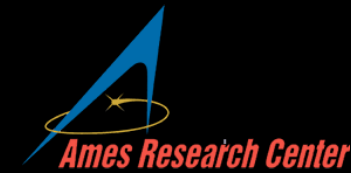
CLPS landers



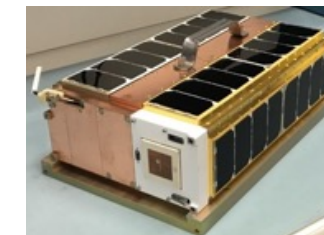
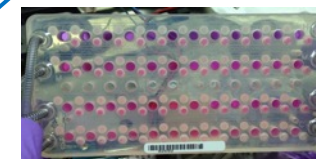
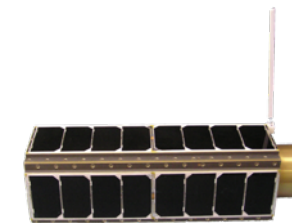
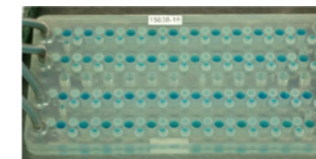
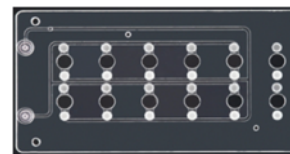
Human Lander System



NASA Ames pioneering bio CubeSat missions: 2006 – 2017



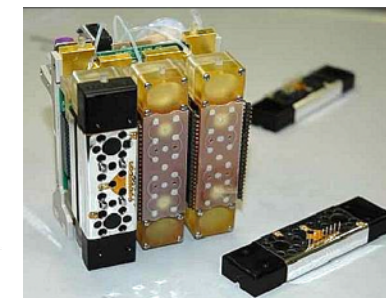
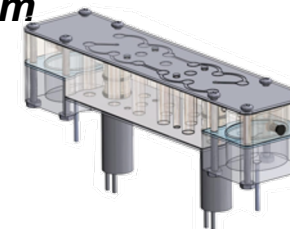
E. coli GeneSat-1 (2006 / 3U): **gene expression**
EcAMSat (2017 / 6U): **antibiotic resistance**



S. cerevisiae PharmaSat (2009 / 3U): **drug dose response**



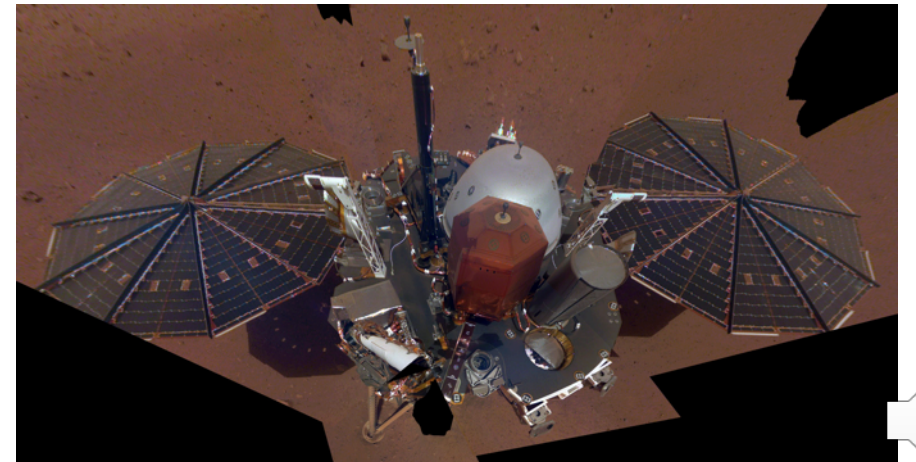
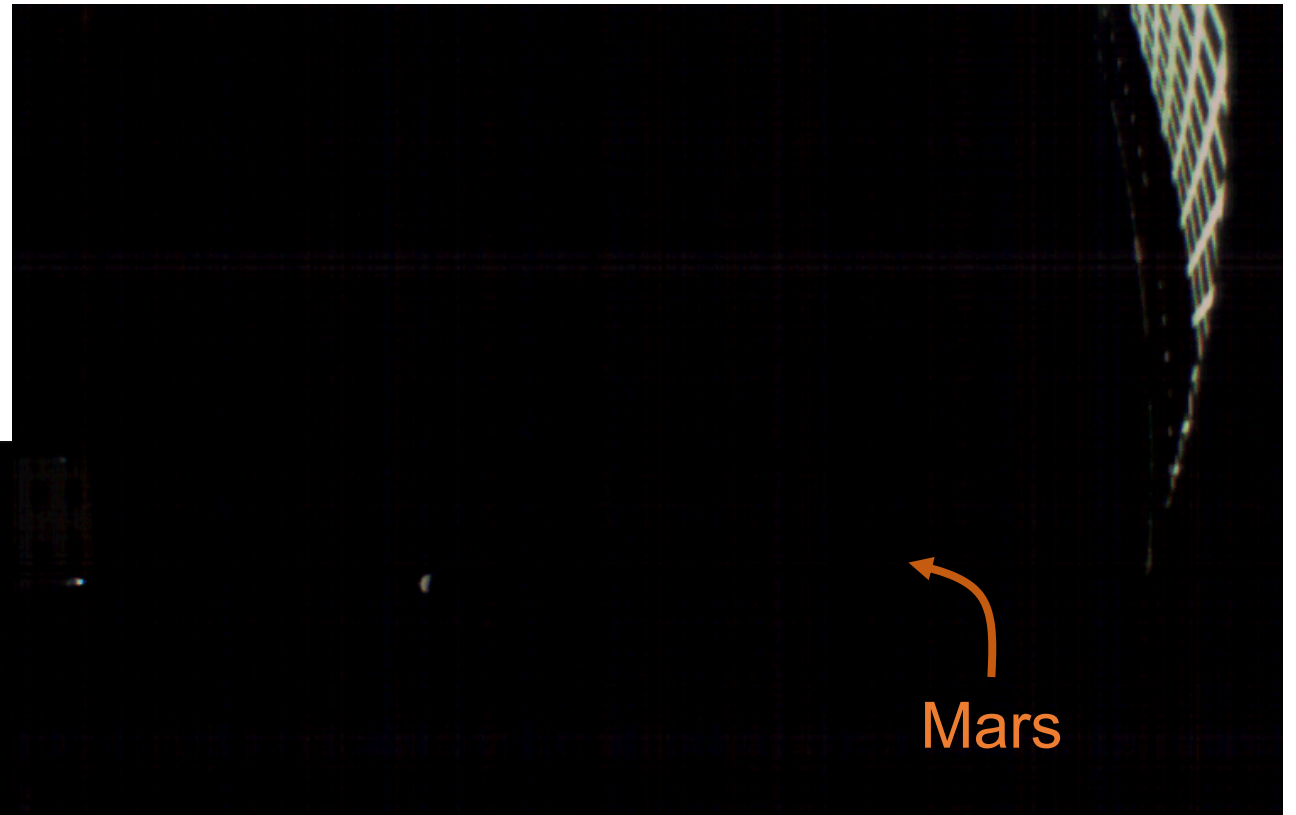
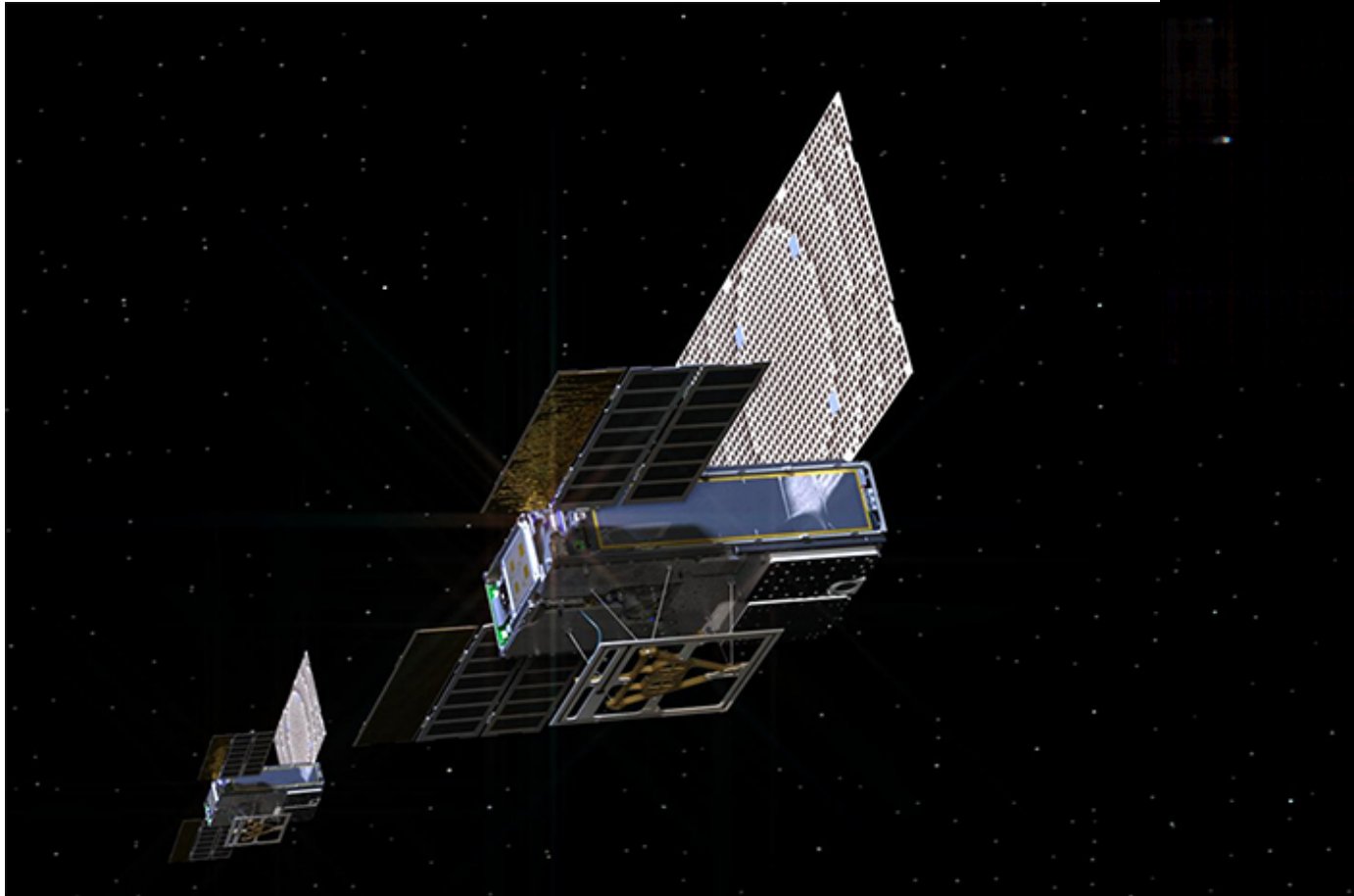
B. subtilis O/OREOS* (2010 / 3U): **survival, metabolism**
*Organism/Organic Response to Orbital Stress



C. richardii SporeSat-1 (2014 / 3U): **ion channel sensors, μ -centrifuges**

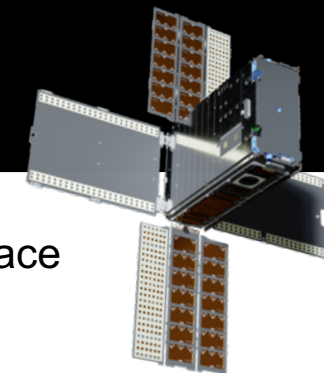


MarCO (Mars Cube One) 1st interplanetary CubeSats



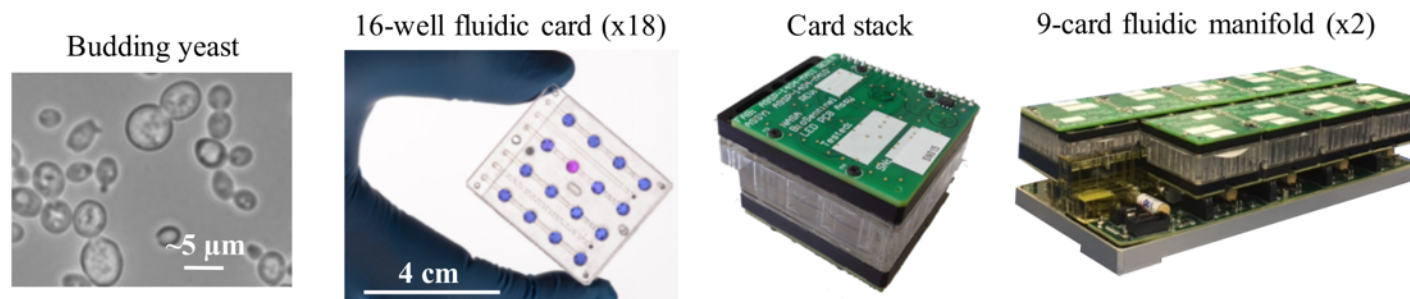


BioSentinel: the 1st interplanetary bio satellite



Objective: study biological response to deep space radiation & develop instrument to support bio in deep space

- First biological CubeSat to fly beyond LEO (*launched on Artemis I in 2022*)
- First CubeSat to combine biological studies with autonomous capability & physical dosimetry beyond LEO
- Far beyond the protection of Earth's magnetosphere (~0.3 AU from Earth at 6 months; ~40 million km)
- Control experiment on ISS (2022) & on the lunar surface (*Artemis III; radiation + partial gravity*)



ISS

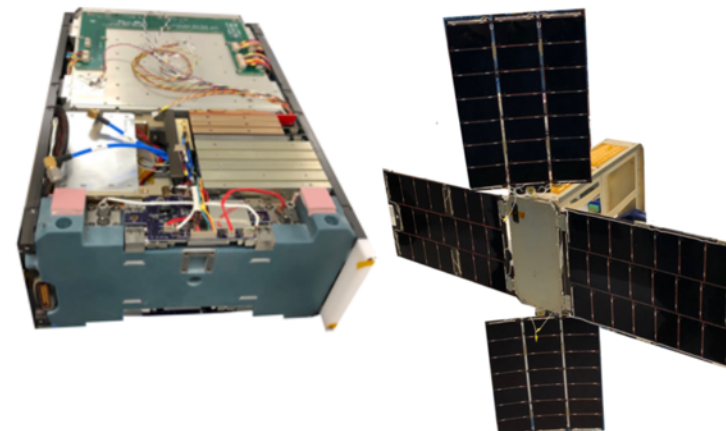
Moon
lander



4U BioSensor payload

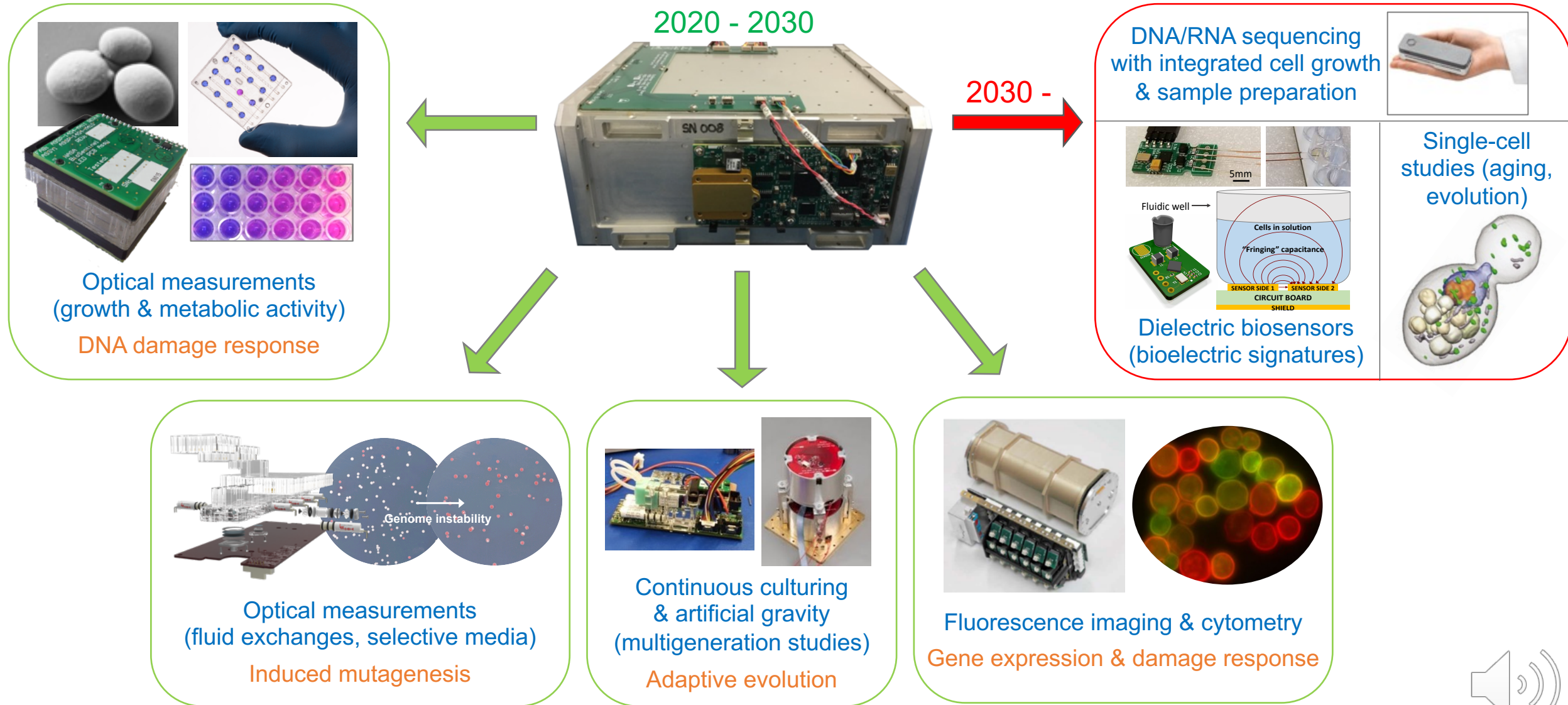


6U BioSentinel spacecraft





Technology miniaturization & evolution





Thank you!

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