# Thermal Challenges from GSFC Planetary Missions

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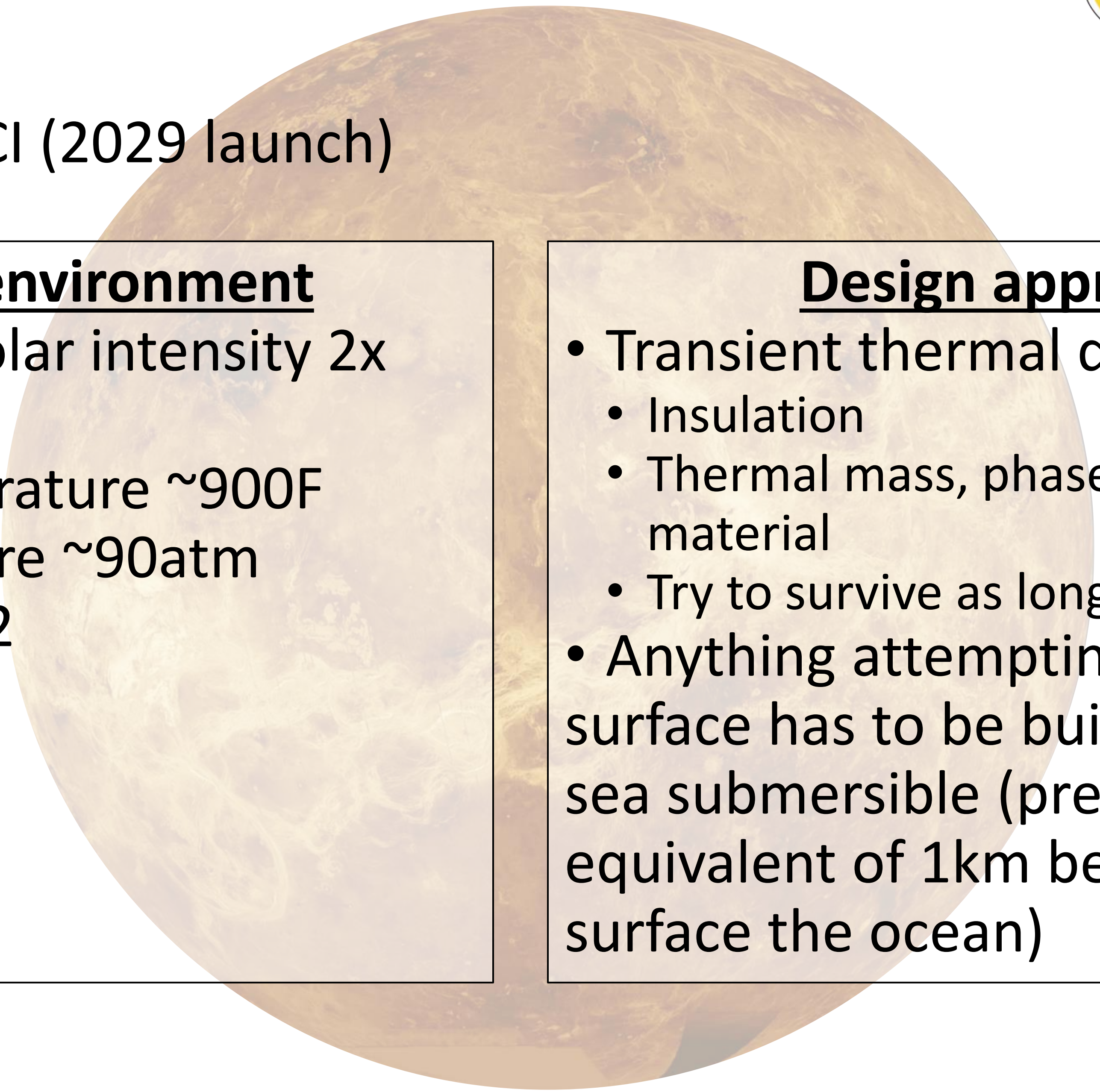
Recovering Thermal Engineer

# Topics

- Environmental Challenges from Recent GSFC Planetary Missions*
  - Venus
  - LLO
  - Lunar Surface
  - Interplanetary Space
  - Titan
- Technological Challenges from Recent GSFC Planetary Missions
  - Mass Spectrometers
  - Passive Cooling to Cryogenic Temperatures
- Future challenges from the Planetary Decadal Study

** Most of these missions are collaborations between GSFC and other organizations or NASA centers.*

# Venus



## Mission: DAVINCI (2029 launch)

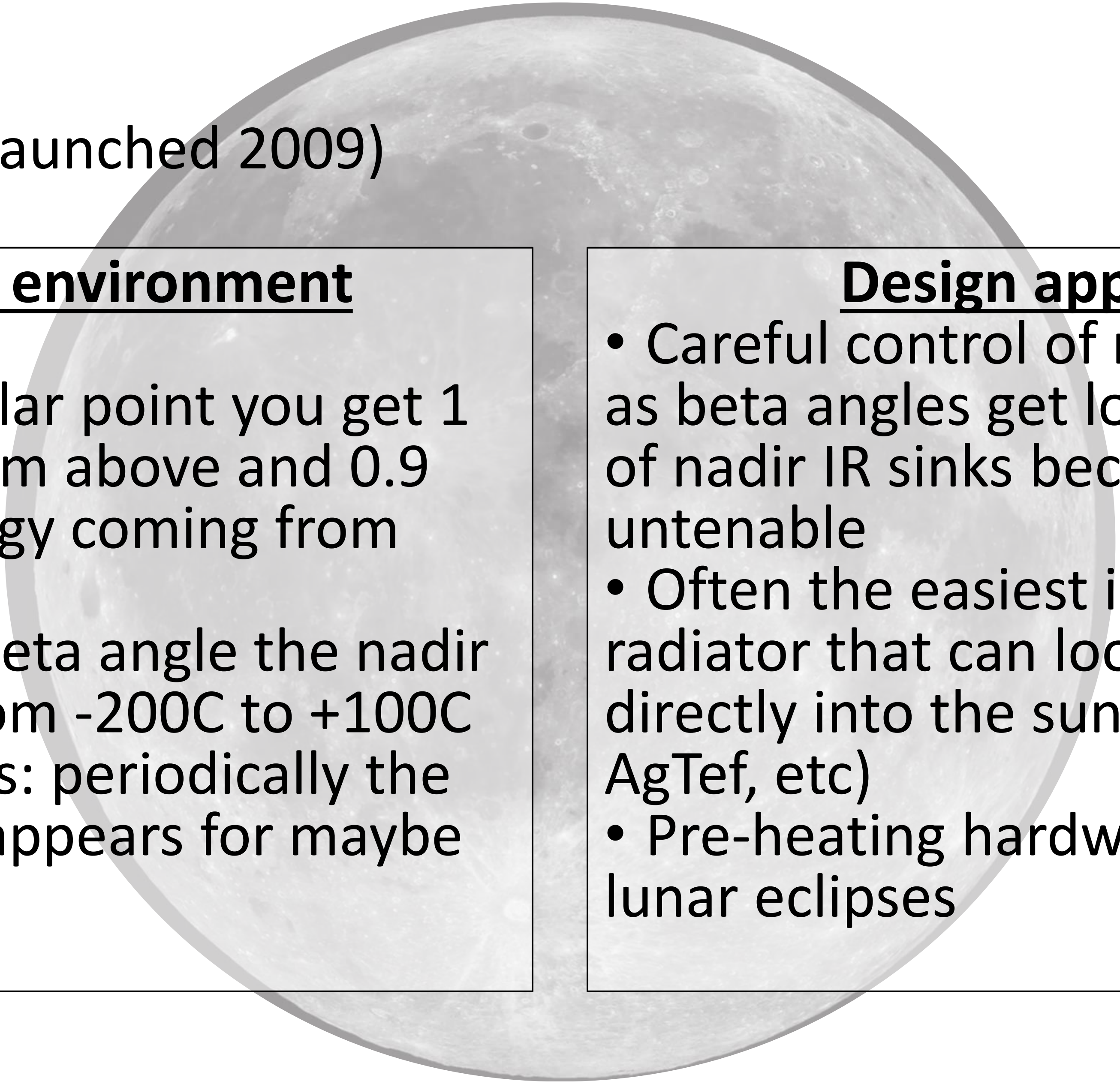
**Thermal environment**

- 80% albedo, solar intensity 2x that at Earth
- Surface temperature ~900F
- Surface pressure ~90atm supercritical CO2

**Design approach**

- Transient thermal design
  - Insulation
  - Thermal mass, phase change material
  - Try to survive as long as you can
- Anything attempting to reach the surface has to be built like a deep sea submersible (pressure is the equivalent of 1km below the surface the ocean)

# Low Lunar Orbit



Mission: LRO (launched 2009)

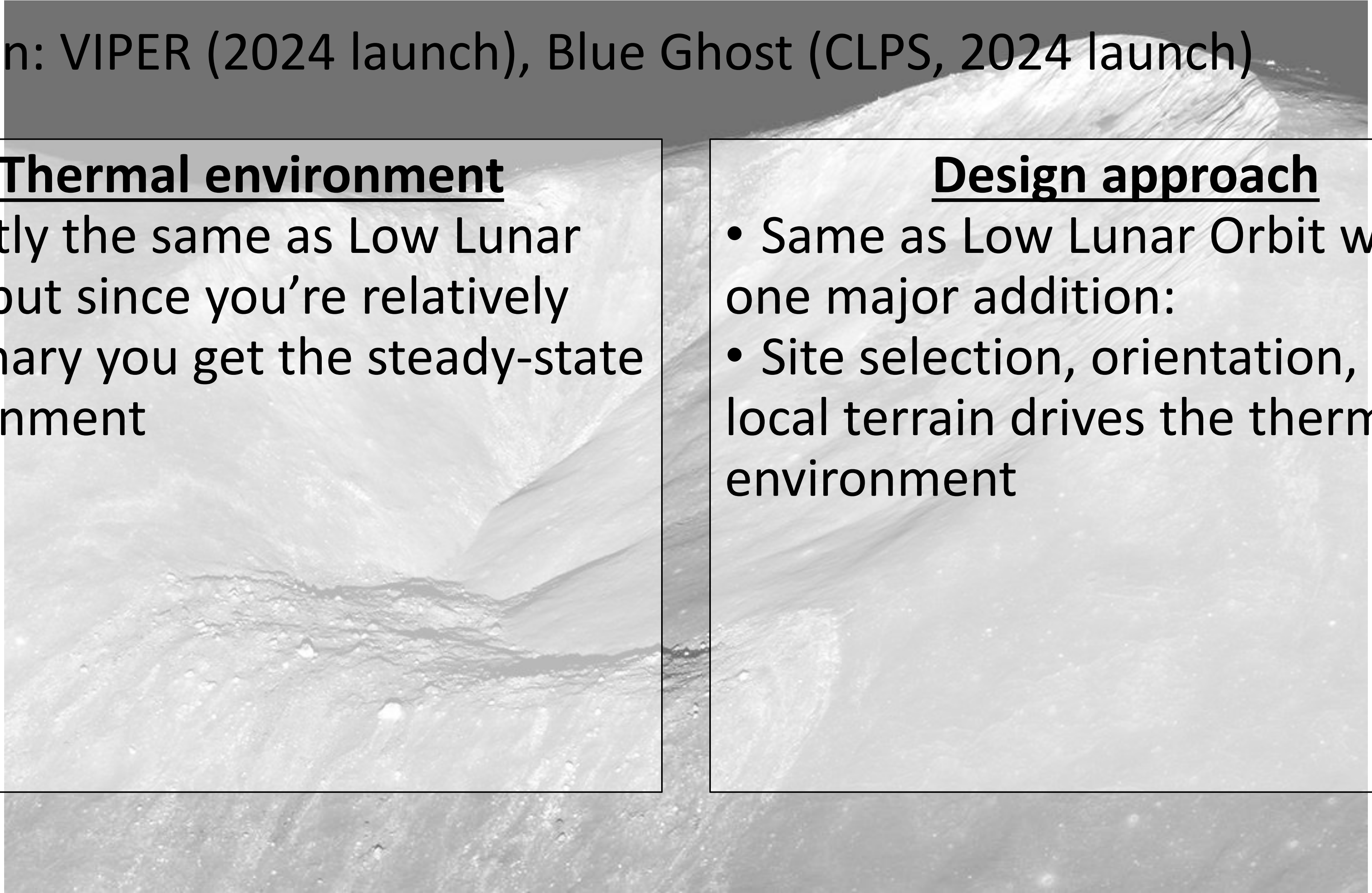
**Thermal environment**

- <10% albedo
- At the sub-solar point you get 1 sun coming from above and 0.9 suns of IR energy coming from below
- At 0 degree beta angle the nadir view ranges from -200C to +100C
- Lunar eclipses: periodically the solar input disappears for maybe an hour

**Design approach**

- Careful control of radiator views; as beta angles get lower the range of nadir IR sinks becomes untenable
- Often the easiest is to design a radiator that can look zenith directly into the sunlight (OSRs, AgTef, etc)
- Pre-heating hardware to survive lunar eclipses

# Lunar Surface



Mission: VIPER (2024 launch), Blue Ghost (CLPS, 2024 launch)

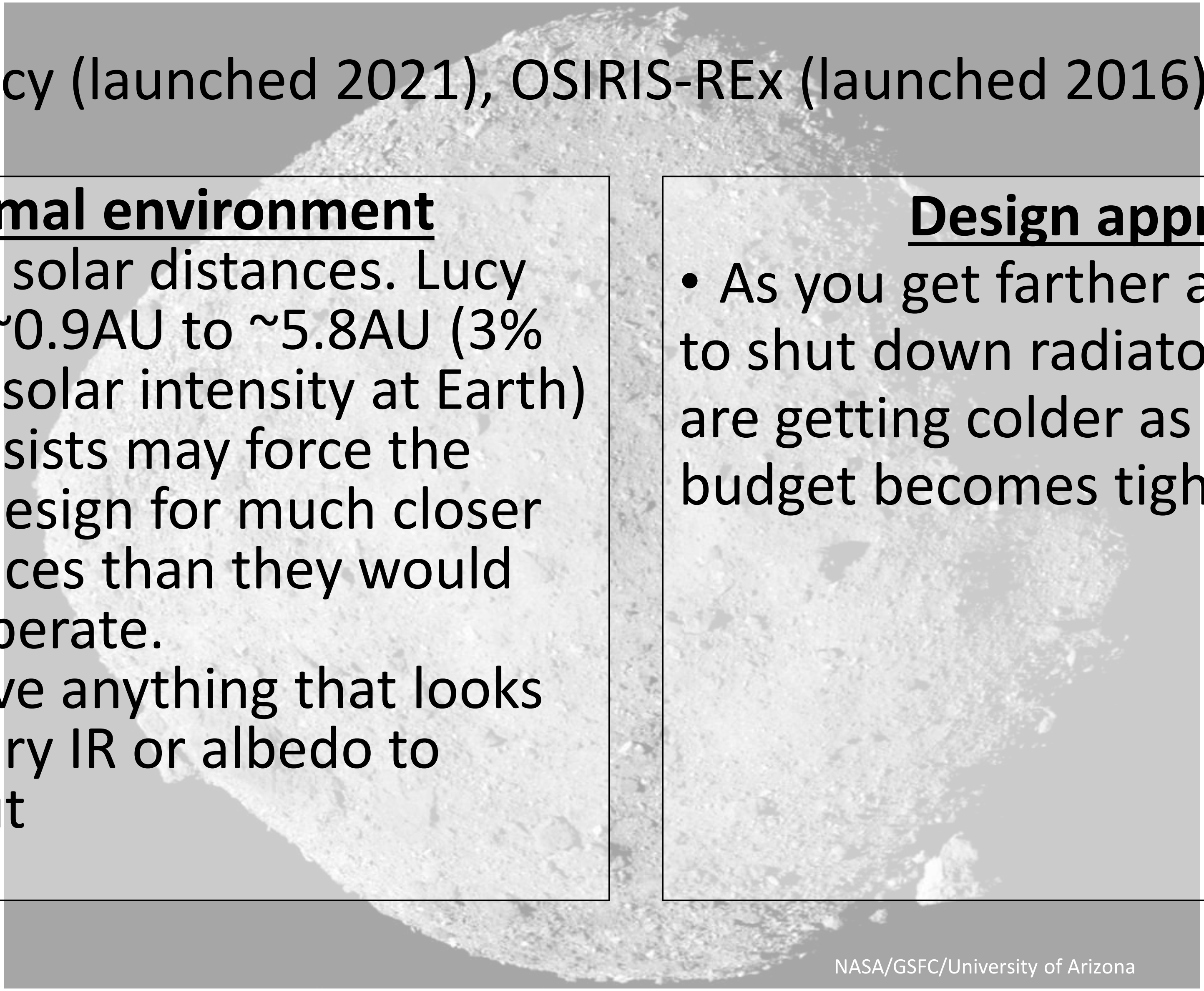
## Thermal environment

- Exactly the same as Low Lunar Orbit but since you’re relatively stationary you get the steady-state environment

## Design approach

- Same as Low Lunar Orbit with one major addition:
- Site selection, orientation, and local terrain drives the thermal environment

# Interplanetary Space



NASA/GSFC/University of Arizona

Mission: Lucy (launched 2021), OSIRIS-REx (launched 2016)

## Thermal environment

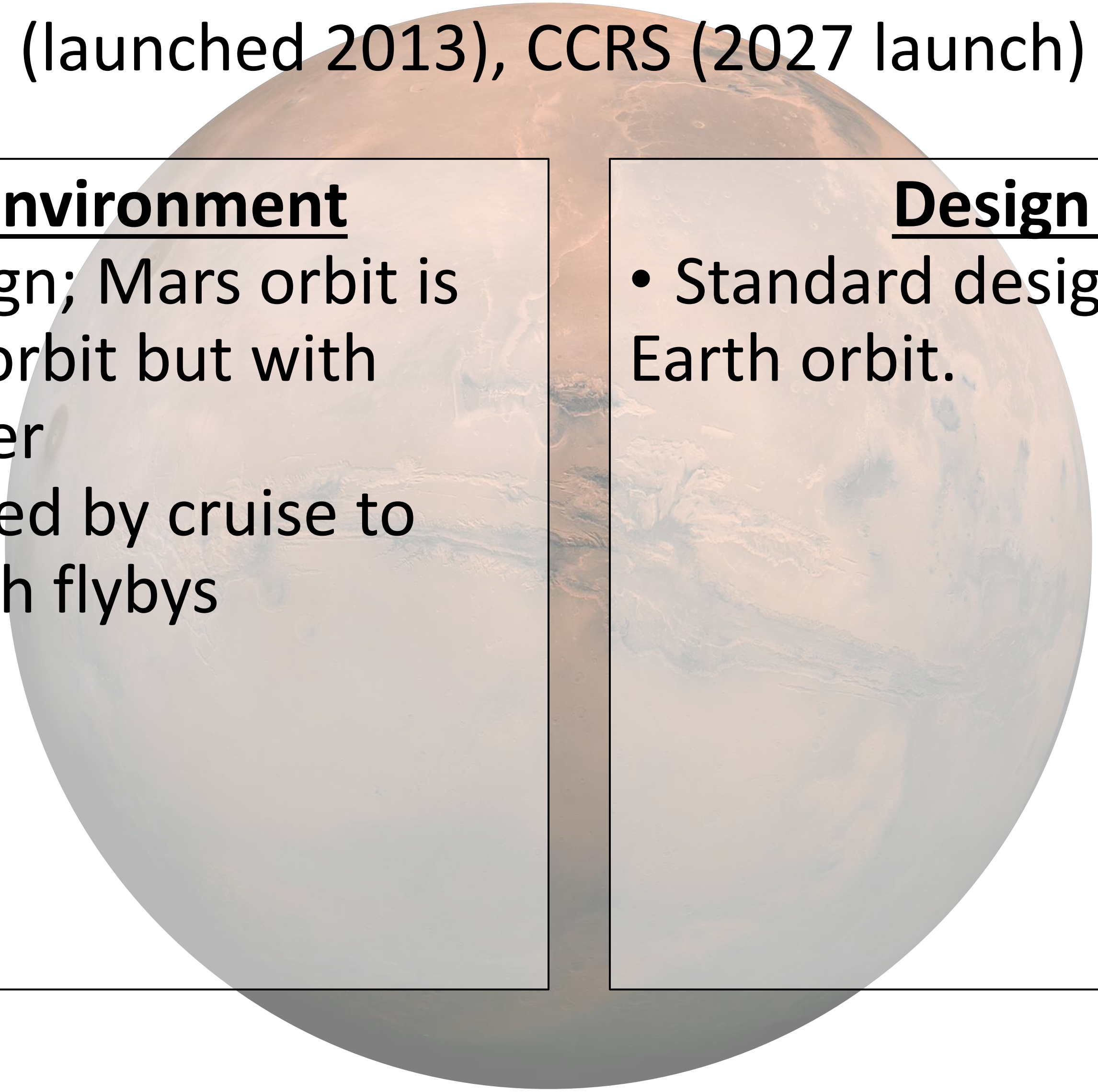
- Variety of solar distances. Lucy goes from ~0.9AU to ~5.8AU (3% to 120% of solar intensity at Earth)
- Gravity assists may force the system to design for much closer solar distances than they would normally operate.
- Rarely have anything that looks like planetary IR or albedo to worry about

## Design approach

- As you get farther away you need to shut down radiator area; things are getting colder as your power budget becomes tighter

# Mars Orbit

Mission: MAVEN (launched 2013), CCRS (2027 launch)



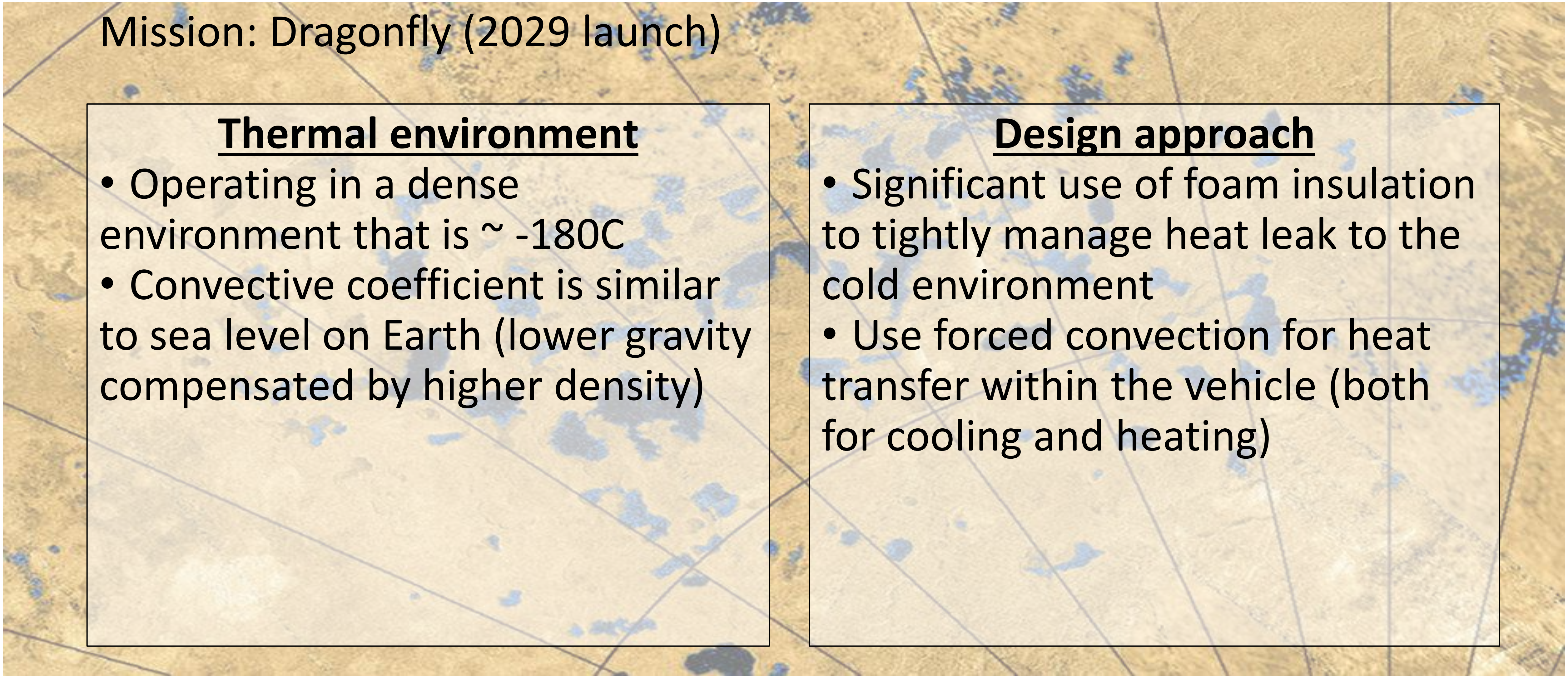
## Thermal environment

- Relatively benign; Mars orbit is similar to Earth orbit but with lower solar power
- Often dominated by cruise to Mars or any Earth flybys

## Design approach

- Standard design approaches for Earth orbit.

# Titan Surface



Mission: Dragonfly (2029 launch)

**Thermal environment**

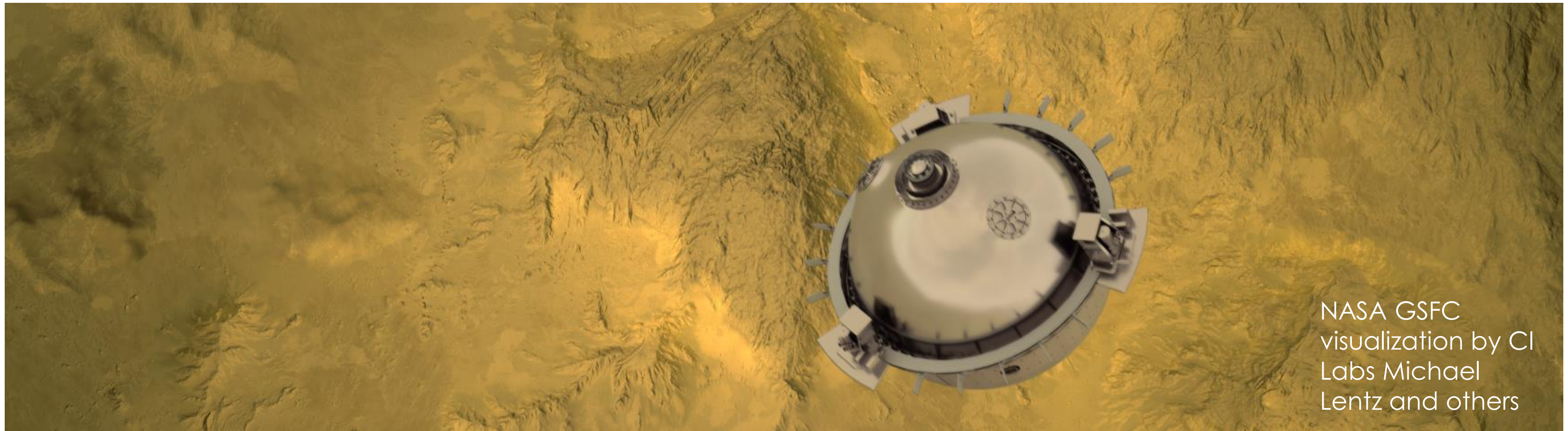
- Operating in a dense environment that is ~ -180C
- Convective coefficient is similar to sea level on Earth (lower gravity compensated by higher density)

**Design approach**

- Significant use of foam insulation to tightly manage heat leak to the cold environment
- Use forced convection for heat transfer within the vehicle (both for cooling and heating)

# In Situ Chemistry

- In Situ chemistry instruments like mass spectrometers are critical instruments to understand the chemical composition of planetary atmospheres (current or planned missions to Venus, Mars, and Titan)
- In order to have a pristine sample the ingest lines and manifolds are often heated to >100C
- Noble gas measurements are key to understanding the origin of atmospheres. Enriching noble gases typically requires cooling down a gas trap to -50C then rapidly warming it up.



NASA GSFC visualization by CI Labs Michael Lentz and others

# Passive Cooling to Cryo Temperatures

- Infrared spectroscopy is a key tool for understanding the material composition of surfaces (current and planned missions to the moon and asteroids)
- Typically IR detectors require cooling down to temperatures <100K but planetary missions don't typically have the power for active cooling focal planes
- This can drive the need for large radiators with shades to prevent illumination from the sun or planets.

# Future Challenges from the Decadal

- Origins, Worlds, and Life: A Decadal Strategy for Planetary Science and Astrobiology 2023-2032 (released 2022)
- Recommended flagship missions that would build upon thermal challenges in previous and ongoing missions

| Decadal-recommended Flagships | Venus-like | LLO-like | Lunar Surface-like | Interplanetary-like | Titan-like | In Situ Chemistry | Passive Cryo |
|---|---|---|---|---|---|---|---|
| Uranus Orbiter and Probe | X | | | X | X | X | X |
| Enceladus Orbilander | | | | X | X | X | |
| Europa Lander | | | | X | X | X | |
| Mercury Lander | | Worse | Worse | X | | | |
| Neptune-Triton Odyssey | X | | | X | X | X | X |
| Venus Flagship | X | | | X | | X | |

- Recommended New Frontiers missions to Kuiper Belt, Ceres, a comet, Enceladus, the Moon, Saturn, Titan, Triton, and Venus

# Summary

- Thermal environments can present a defining thermal challenge for planetary science missions.
- Planetary science payloads often complicate thermal design because of their unique thermal control requirements
- Future planetary missions will require more complicated and creative thermal control systems

# Acronyms

| Acronym | Definition |
|---|---|
| CCRS | Capture, Containment, and Return System |
| CLPS | Commercial Lunar Payload Services |
| DAVINCI | Deep Atmosphere Venus Investigation of Noble gases, Chemistry, and Imaging |
| IR | Infrared |
| LRO | Lunar Reconnaissance orbiter |
| MAVEN | Mars Atmosphere and Volatile Evolution |
| OSIRIS-REx | Origins, Spectral Interpretation, Resource Identification, Security, Regolith Explorer |
| OSR | Optical Solar Reflector |
| VIPER | Volatiles Investigating Polar Exploration Rover |