SAND2019-2275C

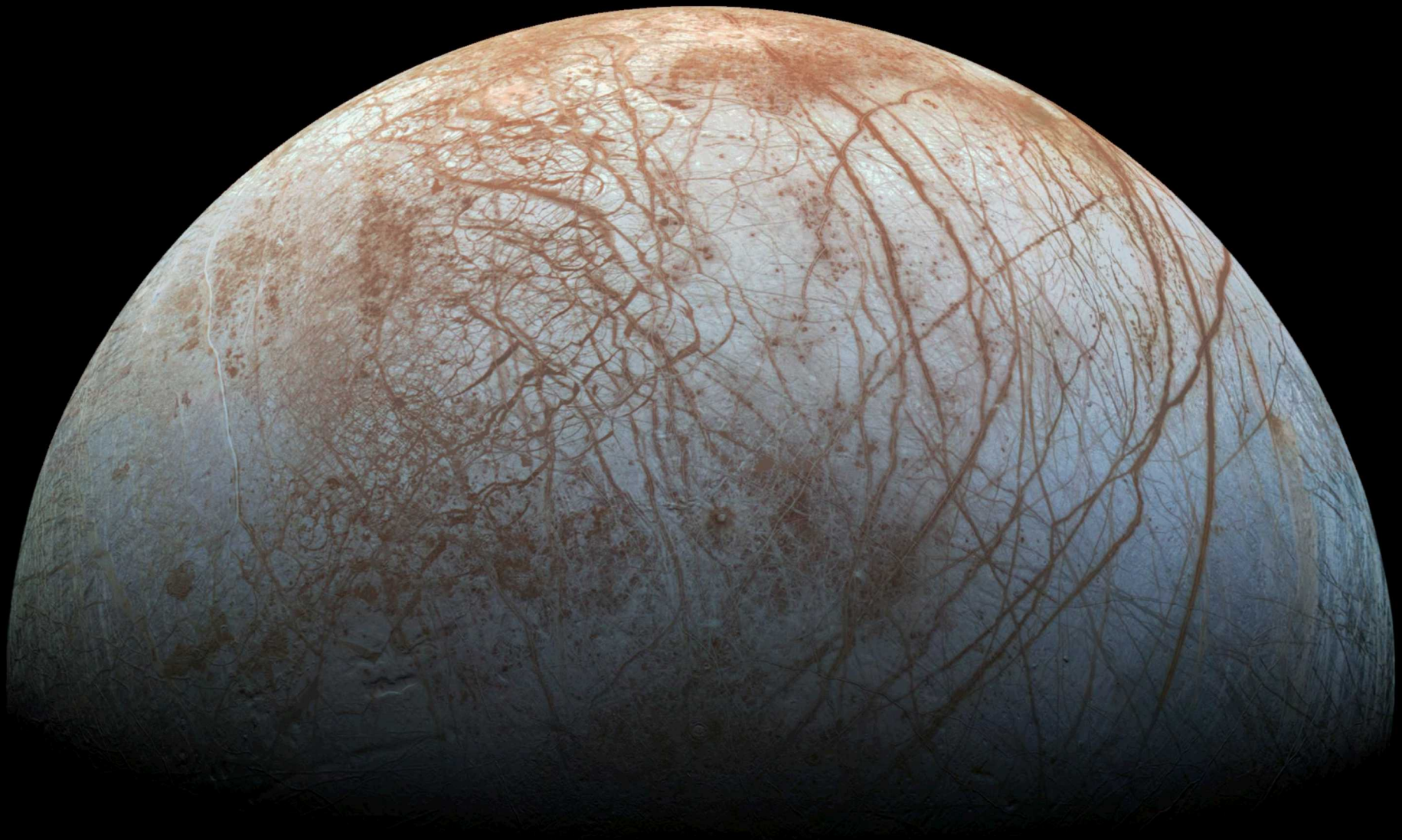
# Radiation and Dosimetry Considerations for NASA Europa Missions

Maryla Wasiolek, PhD, CHP

SAND2019-XXXX

Sandia National Laboratories is a multimission laboratory managed and operated by National Technology and Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International, Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.

TA-V LEADING NUCLEAR TECHNOLOGIES



Slightly smaller than Earth's Moon, Europa’s water-ice surface is crisscrossed by long, linear fractures. Like our planet, Europa is thought to have an iron core, a rocky mantle and an ocean of salty water. Unlike Earth, however, Europa’s ocean lies below a shell of ice probably 10 to 15 miles (15 to 25 kilometers) thick and has an estimated depth of 40 to 100 miles (60 to 150 kilometers).

# Outline

- Radiation in space
- Radiation exposure in orbit and on Europa
- Missions to Europa
- Radiation testing at GIF as part of radiation hardness assurance
- Radiation testing at GIF as part of planetary protection

# Radiation in Space

- Sources of radiation in space
  - Galactic cosmic rays and solar energetic particles; composed primarily of protons and alpha particles (99%), with a small amount of heavier nuclei (~1%); some particles may have extremely high energies
  - Charged particles trapped by planetary magnetic fields (mainly protons and electrons)
- Radiation effects
  - Material/surface degradation – cumulative effects dependent on total ionizing dose (TID) and displacement damage dose (DDD)
  - Prompt effects on electronics – single-event effects (SEE), transient radiation effects
  - Spacecraft charging

# Radiation in Space

- Radiation damage mitigation strategies
  - Spacecraft orbits avoid regions with strong radiation fields
  - Using parts not susceptible to damage, e.g., rad-hardened
  - Shielding – strategic positioning of sensitive equipment within spacecraft and applying shielding
  - Equipment redundancy
  - Equipment size (larger components can survive radiation damage better)

# Radiation on Europa

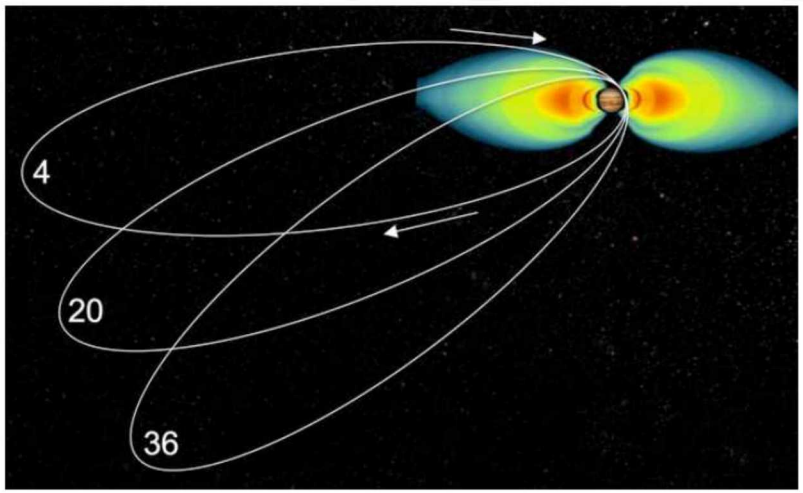
- Europa lies within Jovian radiation and plasma environment
  - Radiation types – electrons, protons, heavy ions, neutrons, gamma
  - Sources:
    - Charged particles trapped in Jovian magnetosphere
    - Galactic cosmic rays and solar energetic particles
    - Secondary particles

# Mission to Europa – Juno

By National Aeronautics and Space Administration (NASA)

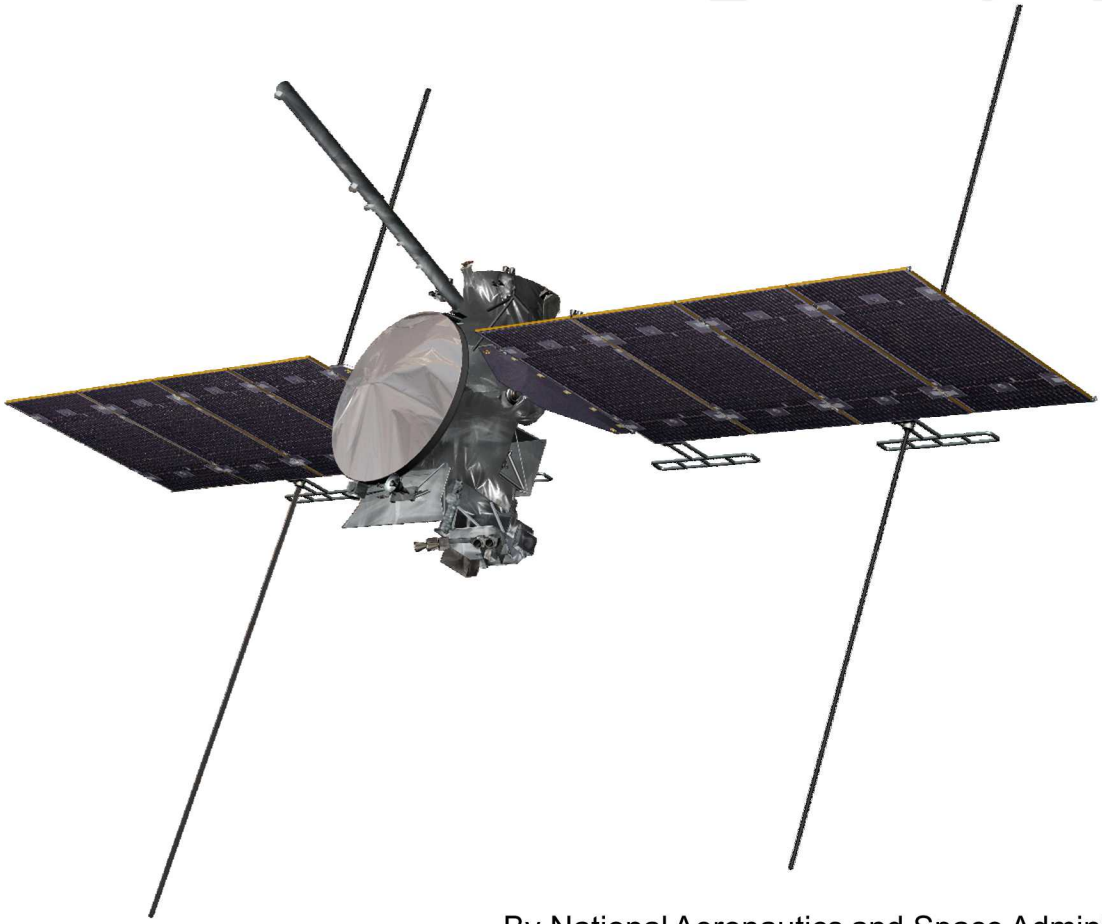
# Missions to Europa - Juno

- Launched in August 2011, arrived in July 2016
  - Lots of shielding to limit exposure
  - Avoid equatorial regions that have strongest radiation fields
  - Elliptical, polar orbit
  - Rad-hardened electronics
  - Larger components to compensate for damage
  - Electronics located in the shielded vault
  - Design to withstand 40 Mrad




Juno's elliptical orbit.
Source: Popular Science

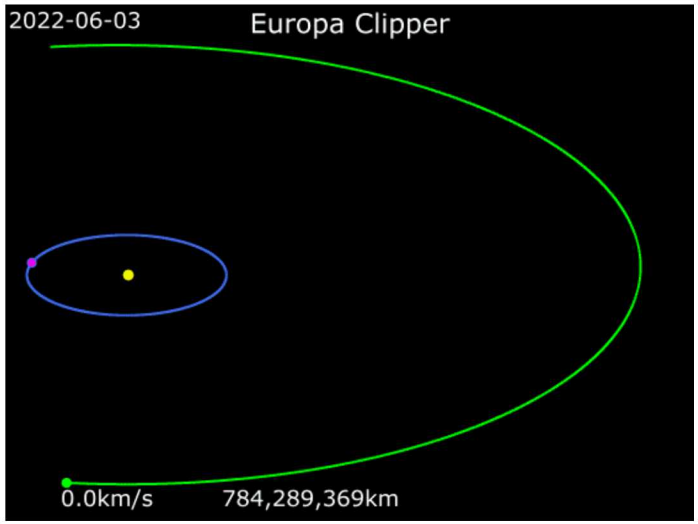
# Missions to Europa - Clipper

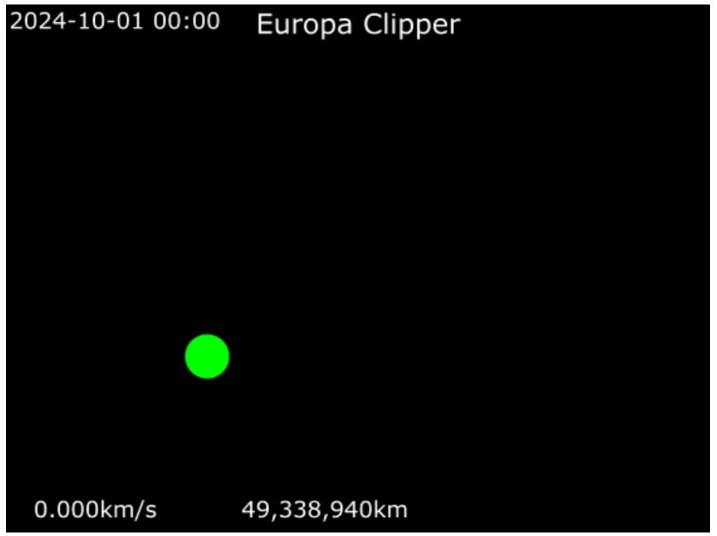


By National Aeronautics and Space Administration (NASA)

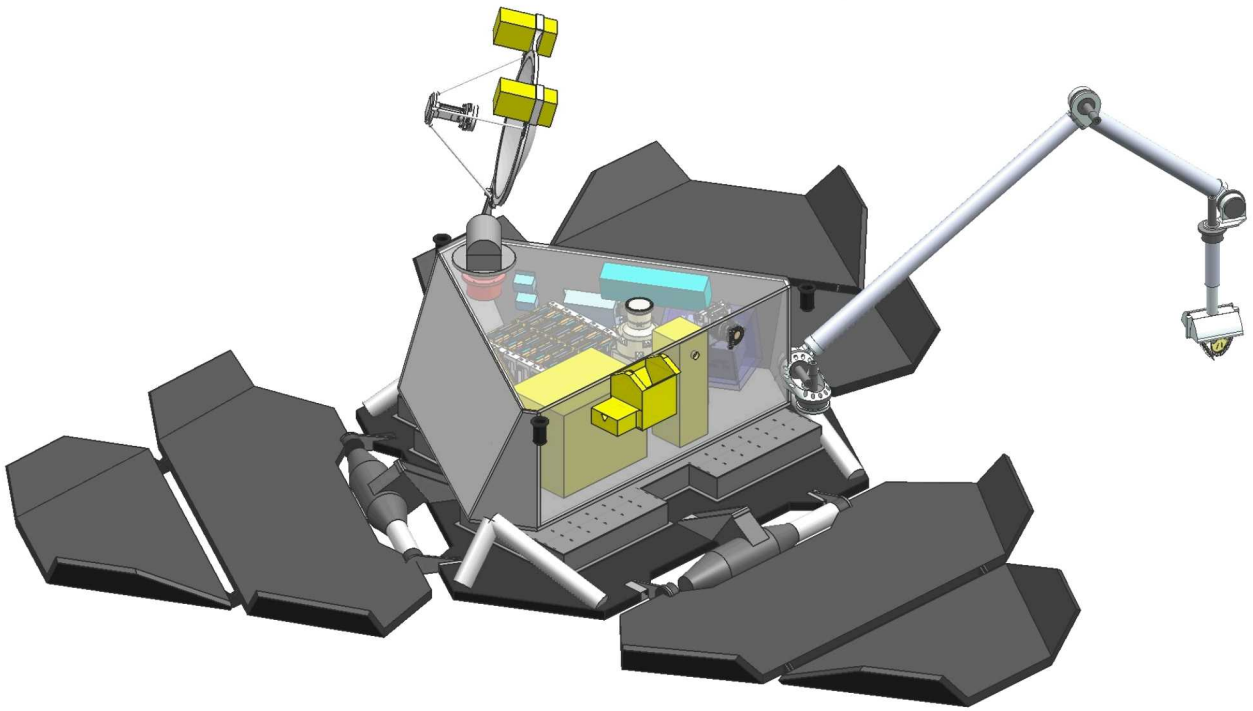
# Missions to Europa - Clipper

- Set for a launch in 2023
- Investigate habitability and aid in the selection of a landing site for the future Europa Lander
- The *Europa Clipper* will not orbit Europa, but instead orbit Jupiter and conduct 45 flybys of Europa at altitudes from 25 to 2,700 km (16 to 1,700 mi) each during its 3.5-year mission.



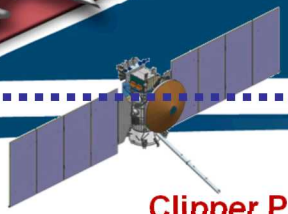



# Mission to Europa - Lander

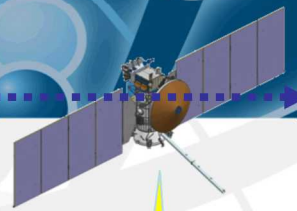


Source: NASA, Jet Propulsion Laboratory

# Mission to Europa - Lander

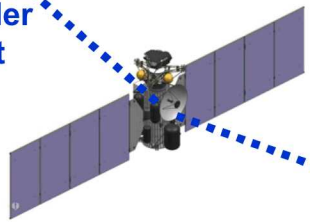


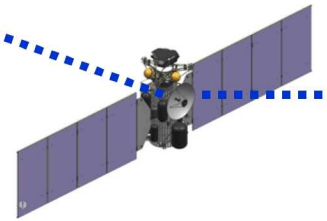
Clipper Primary Mission
Completes Surface Recon



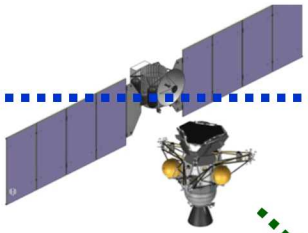
Clipper Continues in its
14-day orbit as backup relay

Carrier/Lander
Jupiter Orbit
Insertion

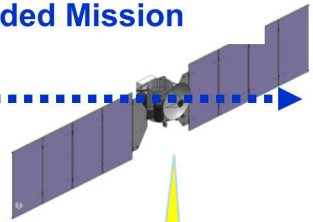




Lander Separation After
Site selection



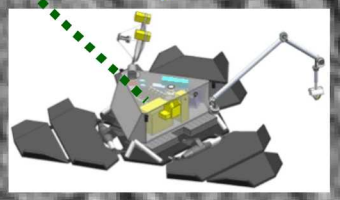
Carrier is the Prime
Relay, can Continue
as an Asset post-
Landed Mission



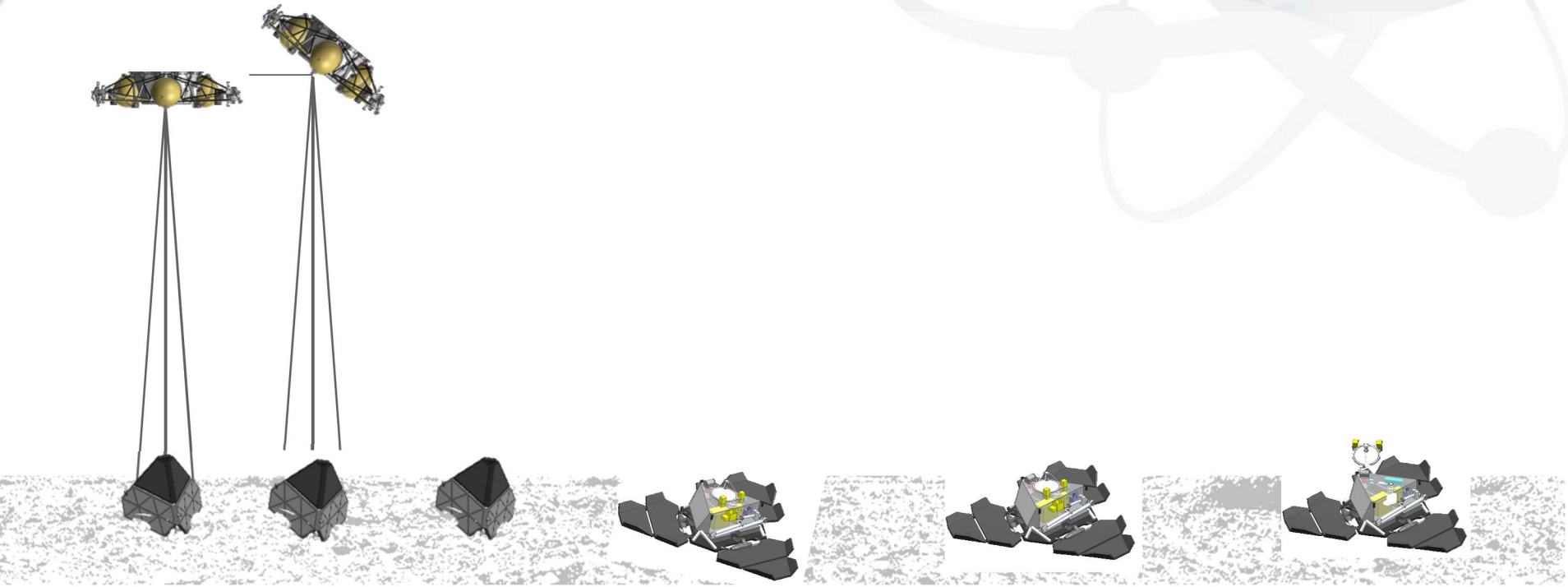
Carrier/Lander Transfer
to Low Energy Orbit

Source: NASA, Jet Propulsion Laboratory

Surface Mission with
Carrier as Primary Relay



# Mission to Europa - Lander



Source: NASA, Jet Propulsion Laboratory

# Radiation Testing at GIF for Europa Missions

- Material and equipment testing for radiation hardness
- Equipment testing to determine its performance after irradiation for planetary protection

# Radiation Testing at GIF for Europa Missions

- Effects on batteries
- Effects on materials – material surface degradation
  - Radiation effects on composite overwrapped pressure vessel (COPV) strands for Europa Clipper
  - Cable and harness materials, (connectors were shielded for future functionality testing)
  - Paint samples
- Doses typically in low tens of Mrad.

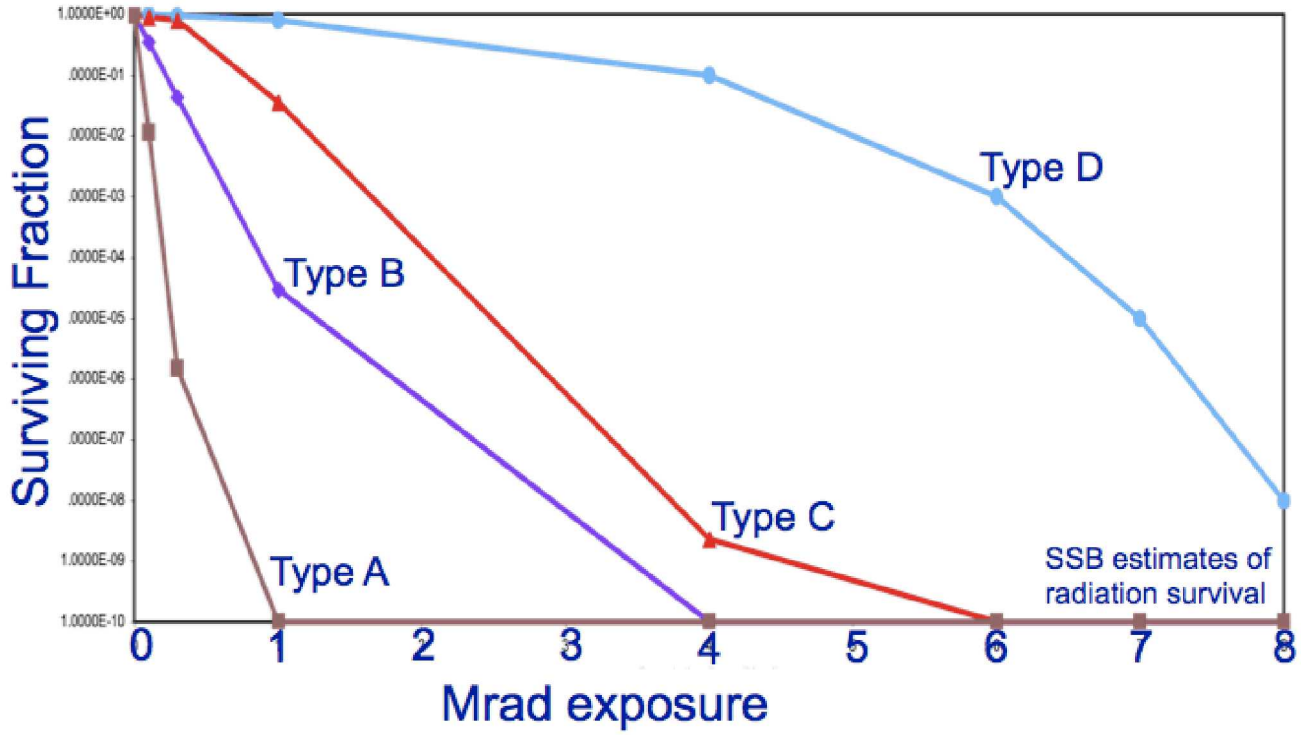
Example of COPV: Casing of the Altair rocket stage
Source: Wikipedia

# Planetary Protection

- Planetary protection requirement – the probability of inadvertent contamination of an ocean or other liquid body must be less than $1 \times 10^{-4}$ per mission.
- Bioburden reduction:
  - During manufacturing, installation and testing
  - During launch, cruise, tour, landing
    - Vacuum of space (vacuum desiccation)
    - Lack of water
    - Low temperatures
    - Ionizing radiation
    - Planet/moon surface irradiation and other environmental factors
- Initial findings indicate that despite the initial bioburden reduction, probability of contamination is $> 1 \times 10^{-4}$

# Microbes are More Radiation Resistant than Electronics...

Type A: Typical, common microbes
Type B: Spores of typical microbes
Type C: Dormant microbes that are especially radiation-resistant;
Type D: Rare but highly radiation resistant non-spore microbes (e.g., *Deinococcus radiodurans*).




Source: NASA, Jet Propulsion Laboratory

TA-V LEADING NUCLEAR TECHNOLOGIES

# Planetary Protection

- Initial findings indicate that although there is bioburden reduction en-route, prior to arrival of a spacecraft at its destination, probability of contamination may still be $> 1 \times 10^{-4}$ if bioburden is not reduced before launch.
- Different radiation sensitivities of organisms
  - Radiation sensitive/resistant
  - Spore/non-spore formers

# Planetary Protection

- Common sterilization methods
  - Thermal sterilization
  - Ethylene oxide (EO)
  - Radiation
    - Gamma – gamma irradiators typically using cobalt-60 sources
    - eBeam – high-current electron beam accelerators
    - X-rays – conversion of electron beam to X-rays
- Equipment testing at GIF to determine its response to gamma irradiation for sterilization purpose.
- Equipment-specific selection of sterilization methods

# Future of Europa Missions

- The Lander mission lost its supporter when Representative John Culberson (R-TX), a leading member of the House of Representatives spending panel did not get re-elected in November 2018.
- The Lander mission was shut out in the 2019 federal budget proposal
- The federal budget request, which was released on Feb. 12, allocates $19.9 billion to NASA in 2019.
- The request axes five Earth-science missions and one high-profile astrophysics project. It continues funding for high-profile planetary projects such as the Mars 2020 rover and Europa Clipper, a $2 billion multiple-flyby mission to the icy moon scheduled to launch in the 2020s — but, just like last year, there's no money for the companion Europa Lander that NASA is developing.
- NASA still aims to see it fly.

# Questions?