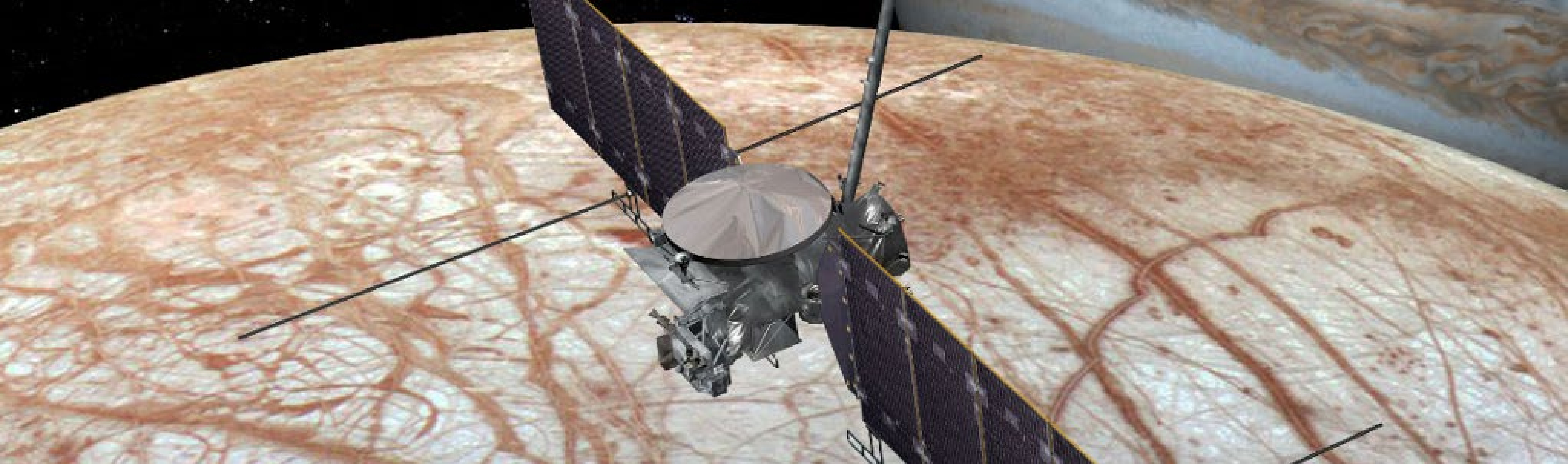

DEFENCE AND SPACE

# The photovoltaic design and test of the Europa Clipper Solar Array

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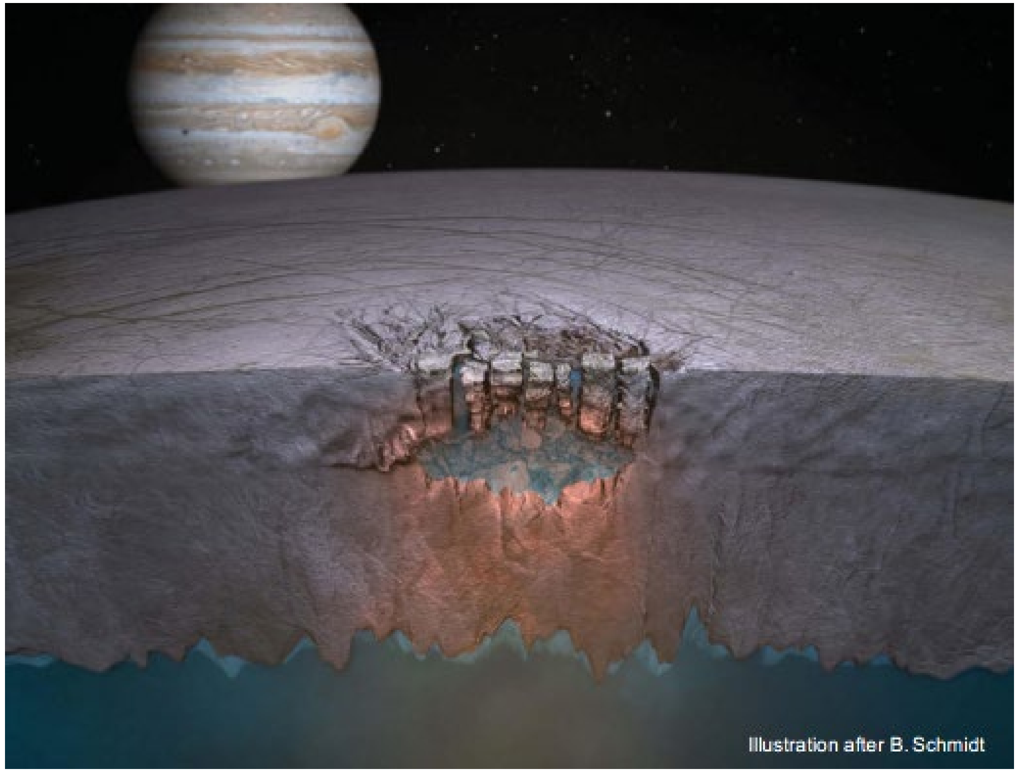
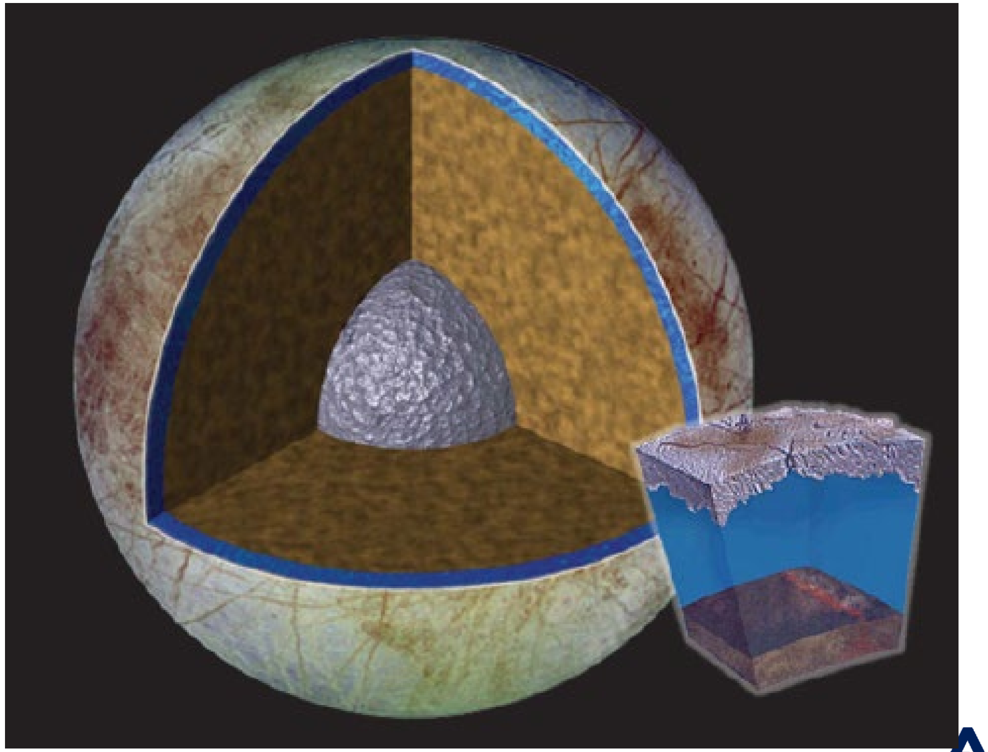
# Europa Clipper Mission Purposes

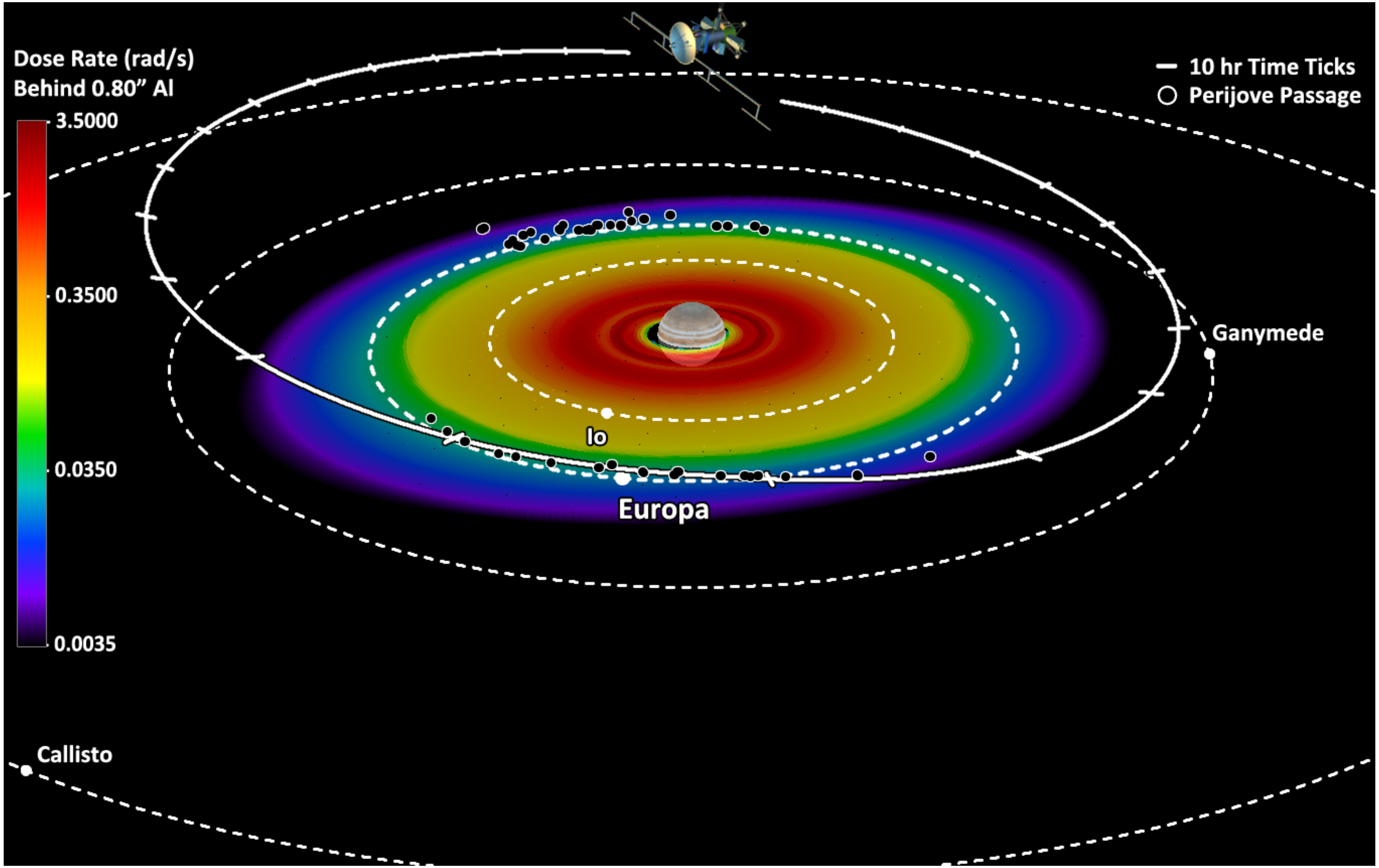
- Investigate the habitability of the Jupiter moon Europa
- Characterize water under or within the moon's ice
- Measure magnetic fields.
- Determine a landing site for the upcoming Europa Lander



Clipper's elliptical orbit minimizes radiation exposure. It will fly by Europa about 45 times.

(Figure courtesy of NASA/JPL-Caltech.)



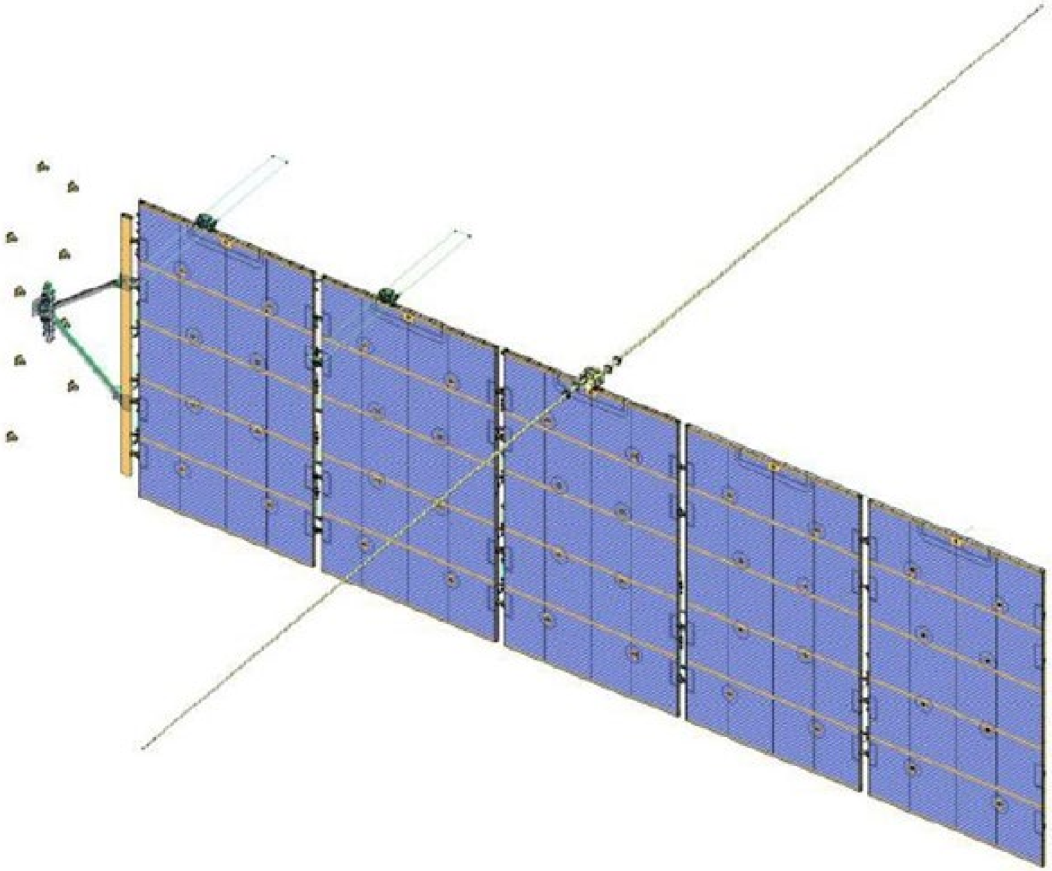
# Demands to solar array

- Resistance to temperatures from +130°C to -235°C.
- Solar cell technology capable of operating reliably at 0.03 AM0 and in a environment characterized by high irradiation levels at Jupiter temperatures (-130°).
- Large scale solar array to provide 700 W at Europa and to carry the radar antenna instruments.
- For the radar antennas the solar array needs to have a low ohmic grounding and generate a small magnetic field.

# Wing design

- 28,120 Low Irradiance Low Temperature (LILT) and high particle irradiation optimized solar cells, sized to 40x80 mm² (AM0 power would be ~32.5 kW).
- The ITO coverglasses are all grounded.
- At -130°C the high solar cell voltage leads to a string design with 19 solar cells which required a huge wiring effort on the panel.
- Shielded and non-shielded harness connections are performed by developed single pin connectors.
- Shielded wires are applied for all antenna lines and sensor lines (~ 150 per wing in total).

# Wing design

- Wings and antennas are deployable



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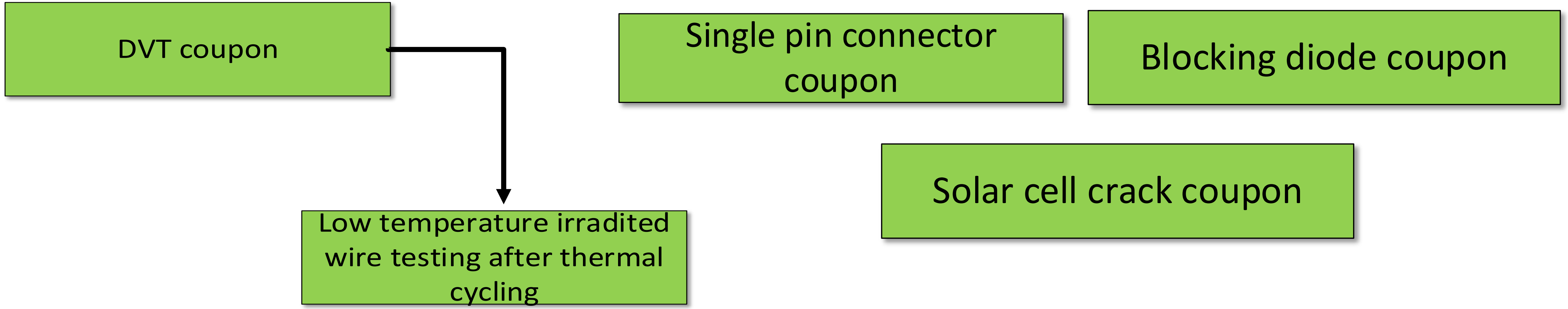
# PVA testing philosophy

- The harsh Jupiter environment requires a test as you fly philosophy to detect possible hardware failures.

- To test a high number of elements
- To test all elements electrically in-situ during thermal cycling
- To perform irradiation tests with proton and electrons with mission representative energies at low temperatures without ever raising the temperature above -130 °C.
- To combine irradiation tests with thermal cycling tests

# PVA testing philosophy – thermal cycling coupons




- All thermal cycling coupons were subjected to 201 Earth representative thermal cycles (range -170°C to +130°C) and 129 deep cycles (-240°C to -125°C).
- During cycling permanent electrical in-situ testing was performed on the coverglass grounding network, solar cell strings, thermal sensors, single pin connectors, and blocking diodes.
- A high number of parts were qualification tested on coupons (~250 solar cells, ~50 single pins connectors, ~100 blocking diodes and 100 small coupons with different solar cell cracks and chips).

# PVA testing philosophy – Coupons with low temperature irradiation and thermal cycling

Radiation and thermal cycling coupons

Coverglass irradiation and UV testing

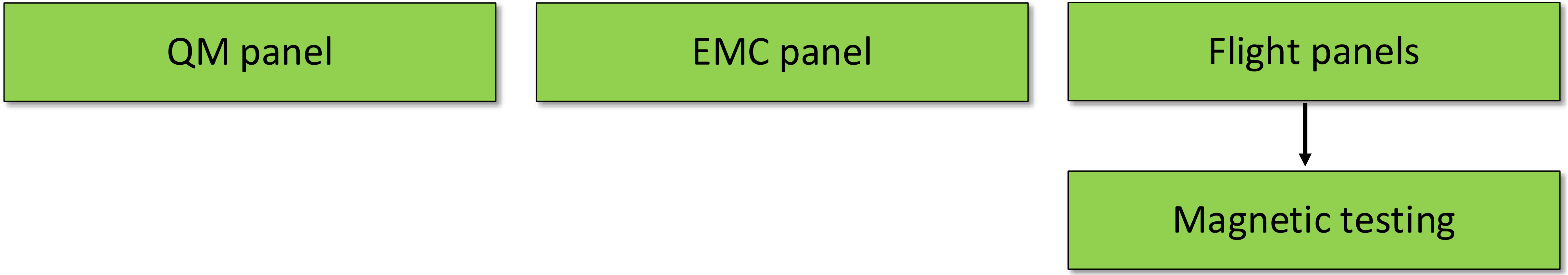
- Combined testing was applied also on radiation and thermal cycling coupons. On these coupons proton and electron irradiation was performed at low temperatures. Then thermal cycled with the DVT coupon cycles was performed.
- On bare coverglasses low temperature proton and electron irradiation with different energies was applied. The coverglasses were then exposed to UV-light. After covering with these coverglasses solar cells the coverglass loss factor was predicted.

# PVA testing philosophy – Other mission relevant coupons

- ESD coupons
- Charging coupons
- Angle of incidence and humidity coupon
- UV-coupons

- These coupons were produced in order to test the PVA under mission relevant conditions.
- The angle of incidence coupon was produced to enable performance prediction under off-pointed Solar array conditions which appear between Earth and mission cases close to the Sun.

# PVA testing philosophy – Panel hardware




- A QM panel was thermal cycled and also sine vibration tested.
- The flight panels were submitted to a bake out of 240 h and 10 acceptance cycles.
- For the QM and flight panels the in-situ verification during thermal cycling was key.
- On one flight panel a high accuracy magnetic test was performed on two axes to predict the magnetic field of the panel and verify compliance to the low magnetic requirements.

# Test results

- By testing in the combined ways not directly apparent results were made:
  - A circular multiple pin connector failed so that single pin connectors were introduced.
  - The coverglass loss factor increased due to low temperature irradiation effects.
  - Solar cell cracks did not propagate by deep cycling. Groups of different solar cell cracks had systematically different LILT behaviors. It was found that the solar cell performance is independent from the solar cell crack length.
  - Electrical biased magnetic testing showed that the electrical design compensations (back wiring where possible, alternating strings) have a high effect and only few nT were measured in cm range distance.

# Conclusion

- The design drivers to the Europa Clipper solar array by the mission and scientific instruments needs were described.
- The logic for qualification testing was described and all key qualification hardware is listed.
- Low temperature irradiation combined with thermal cycling allowed to get in depth knowledge of loss factors and material properties which were design drivers for the solar array.
- The in-situ testing of the panel hardware and coupons demonstrated flight hardware robustness and capabilities.

# Thank's to all co-workers and

A thorough and extensive effort demonstrated flight panel robustness and capabilities for this challenging array program.

The author thanks:

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# Thank you