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Mission Architecture Options for a Near Term Small Europa Lander

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Jovian Moon Impactor concept

James Shirley; Wayne Zimmerman

Europa Pathfinder concept

Jacklyn Green; Wayne Zimmerman; EPF Team

Europa Surface Science Package concept

Tibor Balint; New Product Development Team; Team X

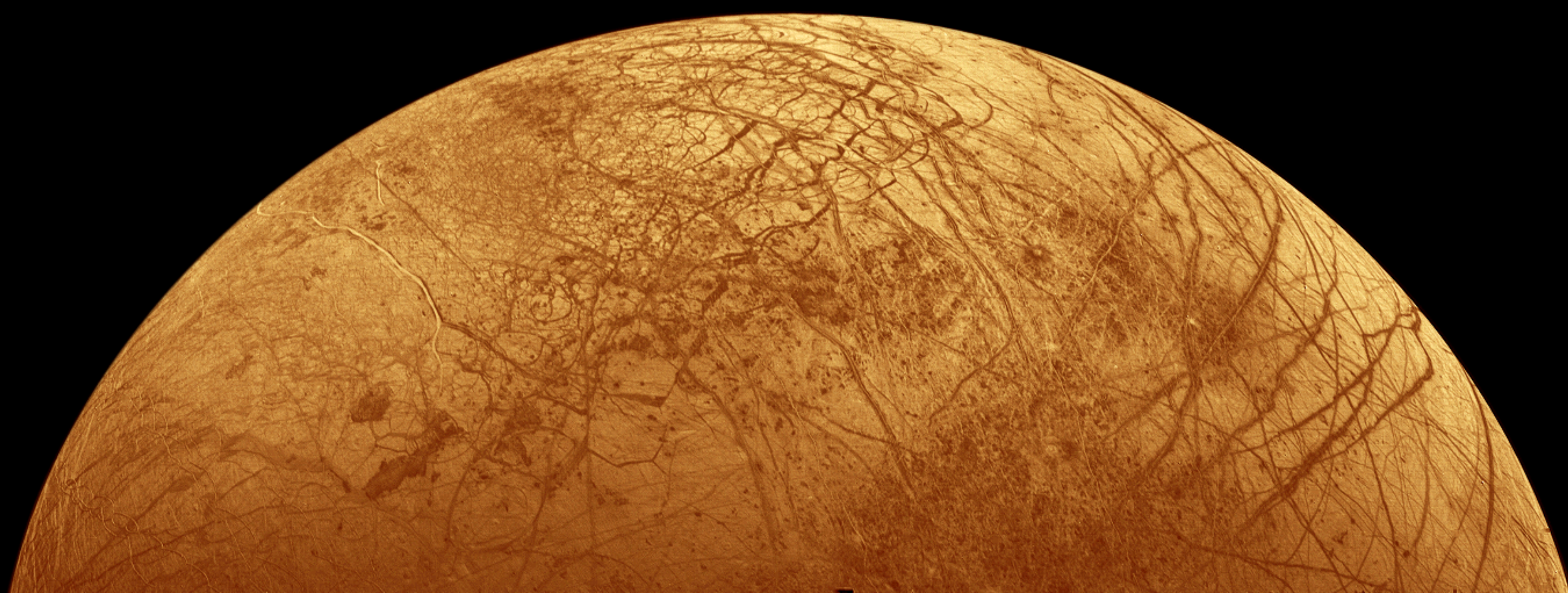
Icy Moons Lander concept

Michael Evans; James Shirley; Tom Rivellini; Wayne Zimmerman; Team P

Additional thanks to James Cutts, Karla Clark and Patricia Beauchamp

Note: These studies were completed at over a time span of several years. The scope of these studies and the initial assumptions were not uniform, which should be taken into account while comparing them.

Introduction



Introduction – Background

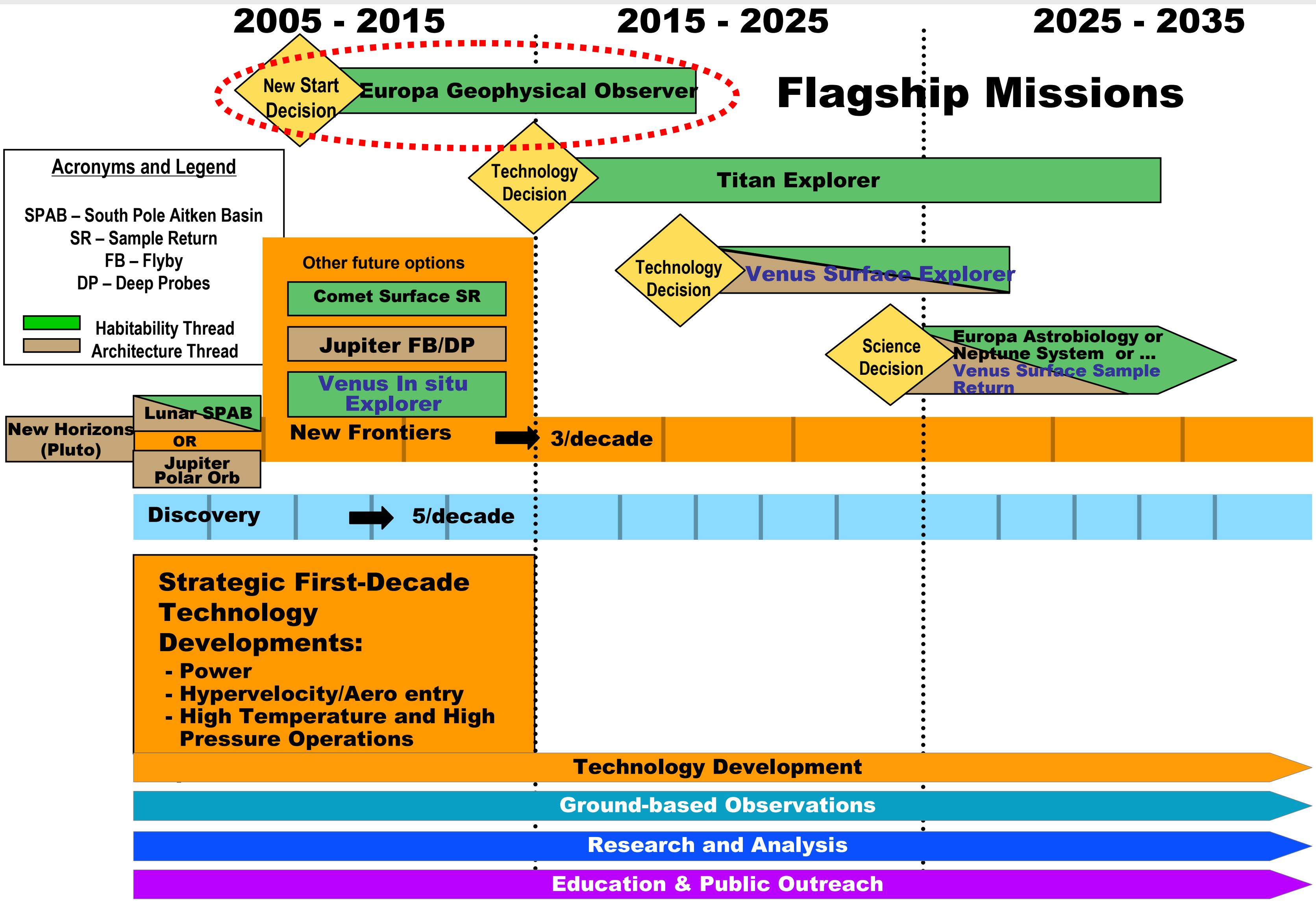
- **Europa is the single highest-priority target** for future flagship-class missions to the outer solar system.
  - Solar System Exploration **Decadal Survey** (NRC, 2002)
  - **Solar System Exploration Roadmap** (NASA, 2005)

- History of previous Europa concepts/studies:
  - **Europa Orbiter** (EO – 2001): Direct trajectory; limited 27 kg payload allocation
  - **JIMO** (Indefinitely postponed in 2005): NEP low thrust; 1500kg payload (maybe ¼ of it for a small lander)
  - **Europa Geophysical Explorer** (EGE – 2005): gravity assist allowed, larger payloads than EO
  - **Europa Explorer** (EE – 2006): built upon work started on EGE, JPL funded study; utilized existing technologies

- Science based on previous SDT and OPAG input organized by an ad hoc science team
  - The **EE concept study** identified an orbiter design that could potentially:
    1. Address most Europa Science Group science goals.
    2. **Have additional mass capacity** that could be used for mission enhancements, for example **potentially including a small Europa lander**.

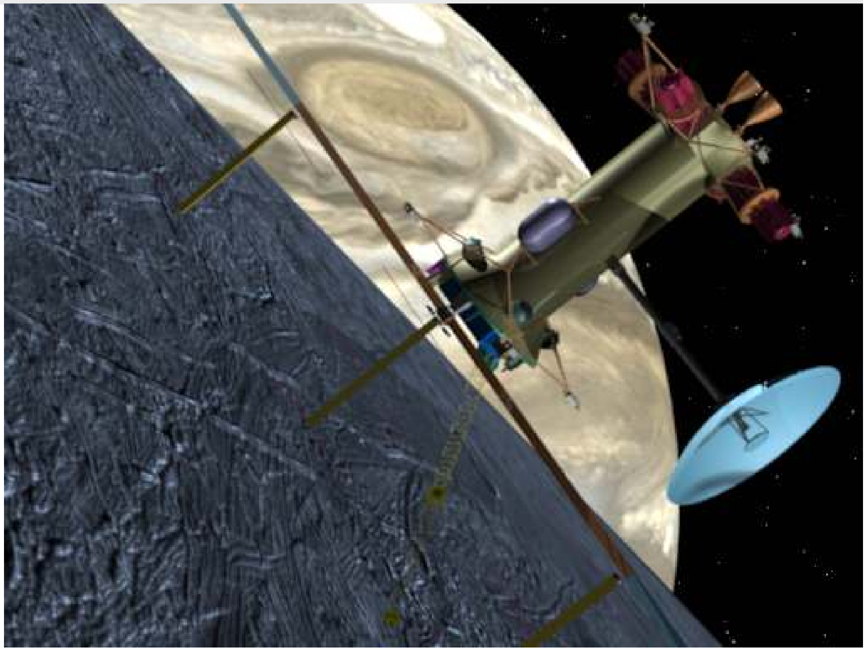
- As for Europa Landers:
  - JPL has performed **several Europa lander concept studies** over the past years to understand the feasibility and the trades between various lander architectures.

2005 SSE Roadmap

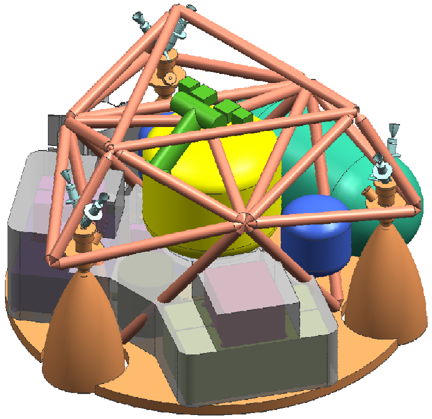


The potential small Europa Lander concepts discussed here target the first Flagship class Europa Explorer opportunity. The larger, dedicated astrobiology lander concept for the 3rd decade Flagship class mission will not be addressed.

- **How much mass** is potentially available **for a small lander**? (based on the recent Europa Explorer study)
- **Challenges of landing** on Europa
- Small Europa Lander Implementation Concepts
  - **Jovian Moon Impactor (JMI)**
  - **Europa Pathfinder (EPF)**
  - **Europa Surface Science Package (ESSP)**
  - *Icy Moon Lander (IML)*
- Summary and Conclusions



Europa Explorer concept



Europa Surface Science Package concept

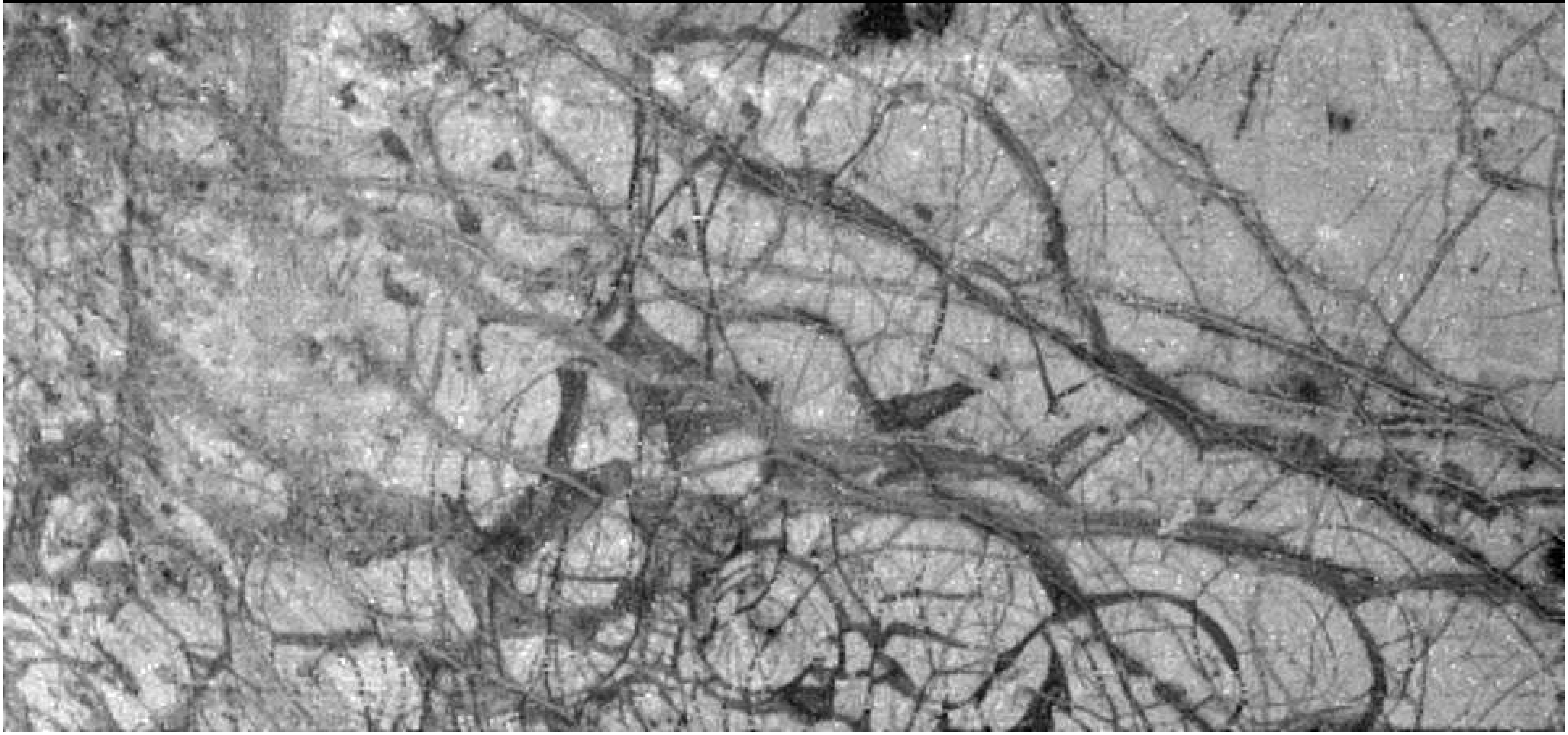
How much mass is potentially available for a Europa Lander?

Parameter	*Europa Orbiter (EO)*	*Europa Explorer (EE)*
Instrument Mass	**27 kg**	**180 kg**
Instrument Power (Orbital Average)	**27 W**	**100 W**
# Instruments	**4**	**10**
Lander	**Not Possible**	**340 kg**
Prime Mission		
Duration	**30 Days**	**90 Days**
Data Return	**100 Gbits**	**3000 Gbits**
Extended Mission		
Duration	**0 Days**	**135 Days**
Data Return (Assumes 24/7 DSN coverage)	**N/A**	**4500 Gbits**

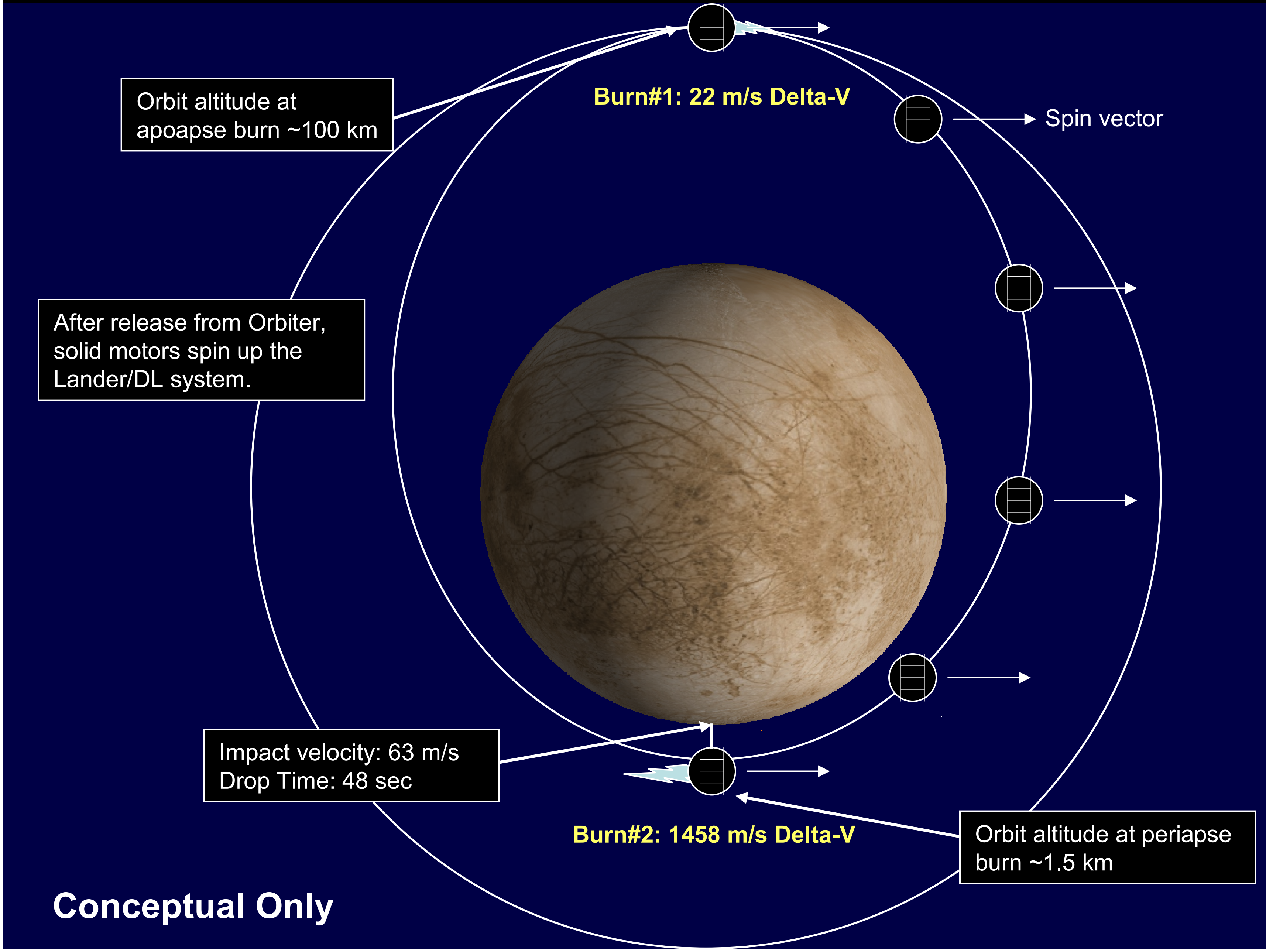
What has changed for the EE study?

- Available **Earth Gravity Assists**
- Increased understanding of the **radiation environment**
- Advances in **radiation-hardened components** and subsystems
- Developments in **radioisotope power systems** (RPS)
- Developments in **Launch Vehicle capability**

Challenges of landing on Europa

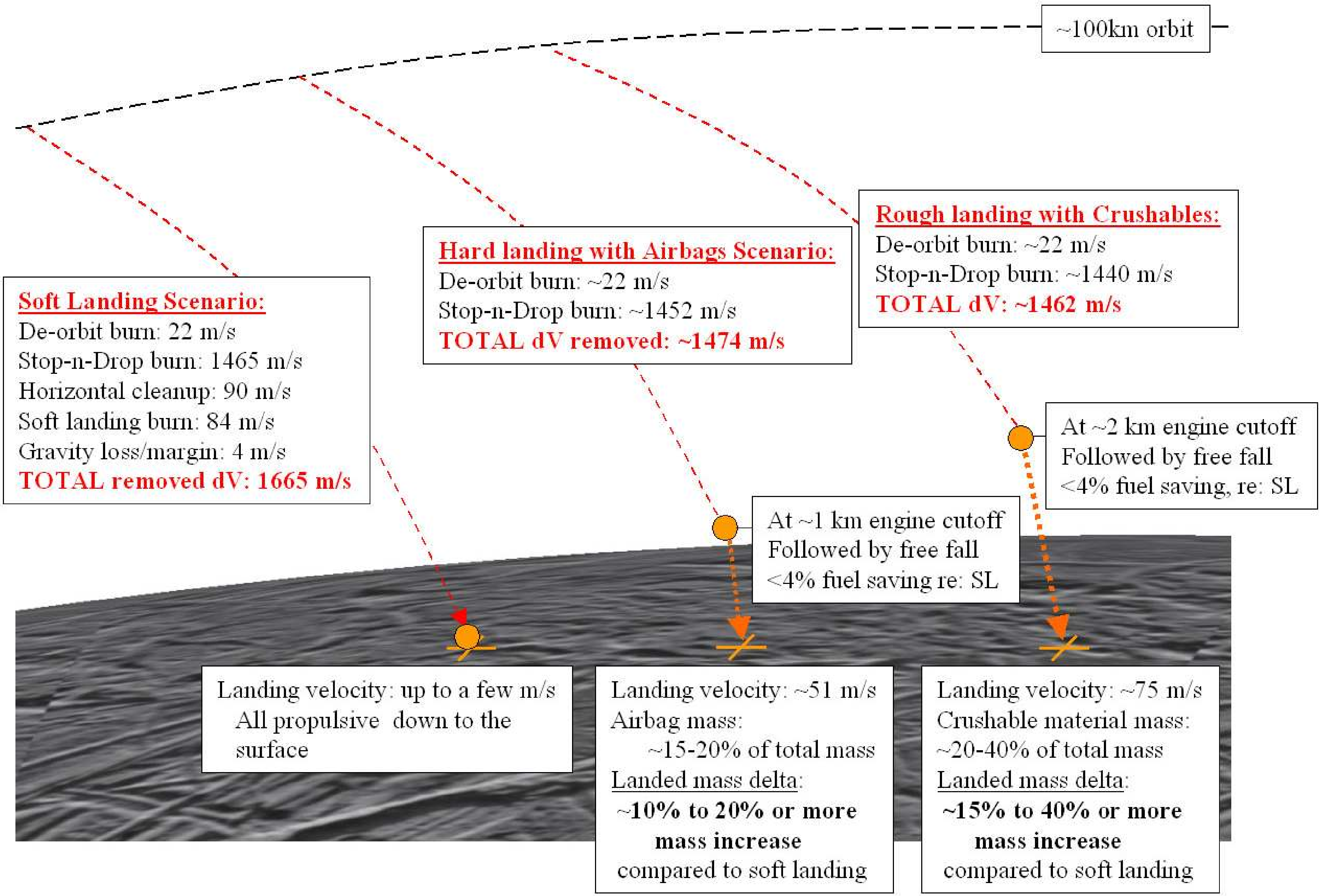


Typical Descent and Landing Sequence



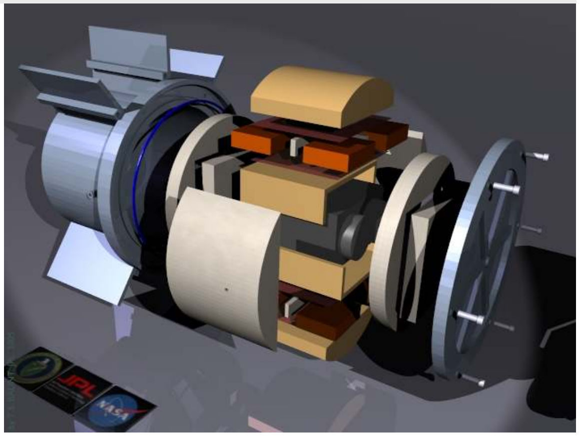
Conceptual Only

Comparison of Landing Methods
(soft – hard/airbag – rough/crushable)



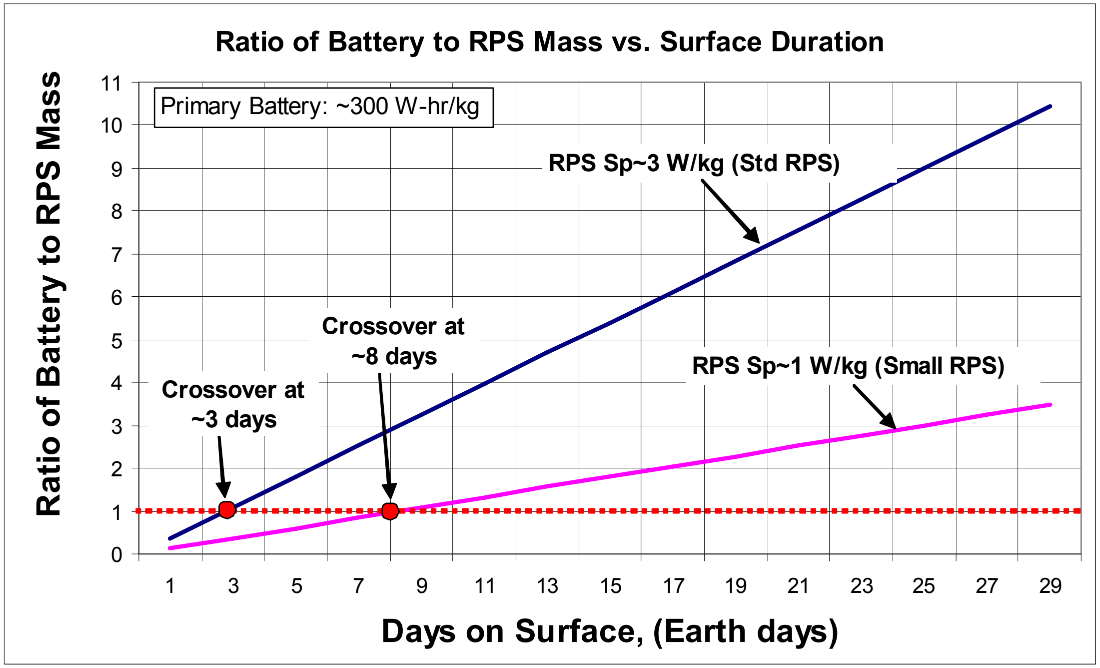
Mission Duration vs. Power Source Type

- Potential power options for a Europa lander include:
  - Primary batteries or fuel cells
  - Radioisotope Power Systems
- Solar power is not practical for a Europa lander due to
  - [1] the **high radiation** levels at Europa and
  - [2] the **distance from the Sun**. (5 AU → 4% of solar flux at Earth)



Small-RPS Concept

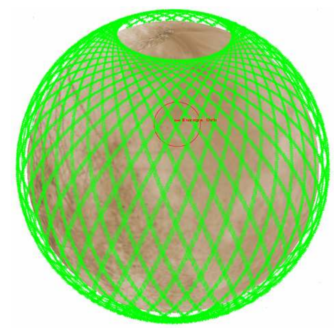
- For short (3 - 8 Earth days) surface missions, primary batteries potentially have a mass advantage over RPS.
- For longer surface missions, RPS would have a mass advantage compared with batteries.
- Both battery-based and RPS-based lander concepts will be presented along with their advantages and disadvantages.



Communication Constraints

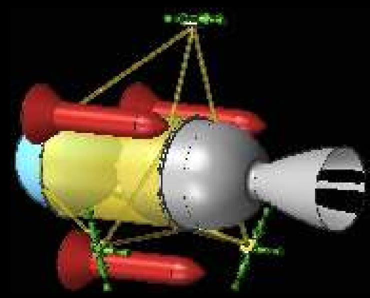
- **Direct to Earth communication is typically not practical for a Europa lander mission due to:**
  1) **Limited and infrequent line of site** between a lander and Earth resulting from:
     – The 3.5 day Europa orbit around Jupiter.
     – Potential blockage from any local hills or mountains (especially if probe lands in a valley).
  2) **Lower power** levels on these small landers compared to typical larger lander concepts.
  3) **Limited space** available on the lander for a large antenna.
  4) Difficulty and complexity of **pointing** a lander antenna to Earth.

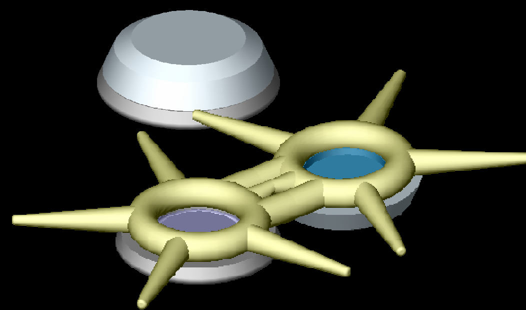
- **Generally require an orbiter to act as a telecom relay between the lander and Earth to:**
  – Would **increase**:
    - **Frequency** and **duration** of communication opportunities
    - Downlink **data rates** and data **volume**
    - Freedom in selecting **landing locations** (i.e., different latitudes, etc.)
  – Would **decrease**:
    - **Power** requirements of the lander communications system
    - **Antenna size** (permitting the use of omni-antennas which do not need to be pointed)

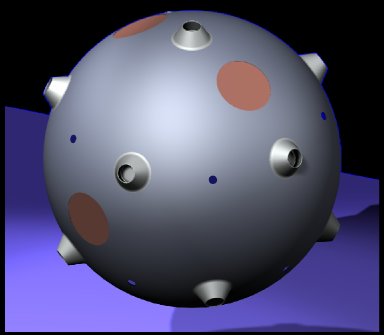


Typical coverage for 110° orbit

- **The downlink data rate from a Europa orbiter is likely to be limited to a few hundred kb/s assuming the use of the existing DSN antennas.**
  – The orbiter would likely have high data-rate instruments (radar sounder, topomapper, imagers, etc.)
  – Decisions would need to be made on how to allocate the available bandwidth between the orbiter-based science data and lander-based science data.

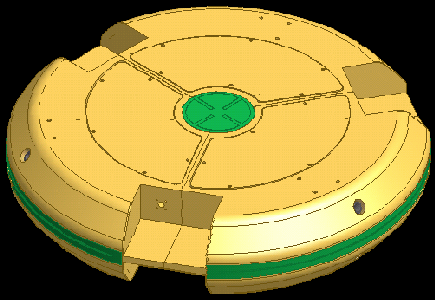


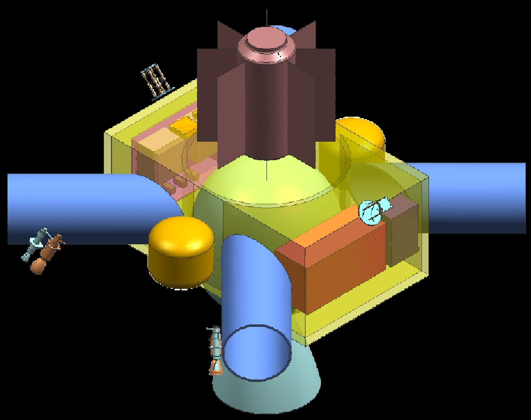




Potential
Europa Lander Concepts

~ 340 kg available
for possible surface science

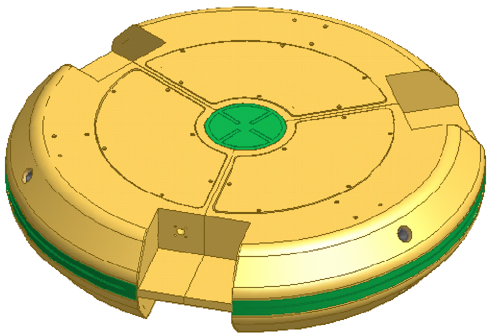




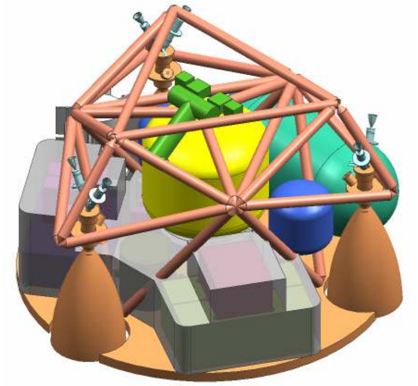
Europa Lander Concepts Considered

- **Four conceptual Europa lander** implementations are summarized in this presentation.
  - **Jovian Moon Impactor (JMI)**
  - **Europa Pathfinder (EPF)**
  - **Europa Surface Science Package (ESSP)**
  - *Icy Moons Lander (IML)*
- Each of these implementations satisfy **different science goals**, use different **architectures**, mission **assumptions** and **technology** requirements.
  - These factors drive the size of the lander, the amount of payload it can accommodate, the mission duration, and the downlink data volume.
- The science goals, instruments, and key performance parameters for each architecture will be presented, along with the benefits and issues for each implementation. Note that mass and power estimates are very tentative and are based on critical assumptions.

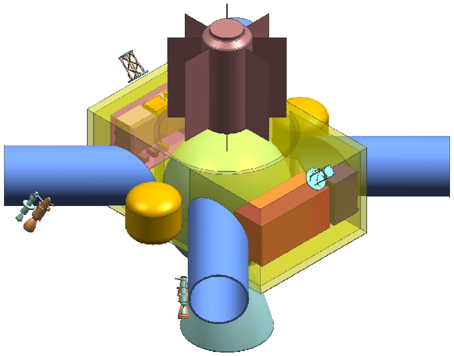
Jovian Moon Impactor concept



Europa Pathfinder concept



Europa Surface Science Package (ESSP) concept



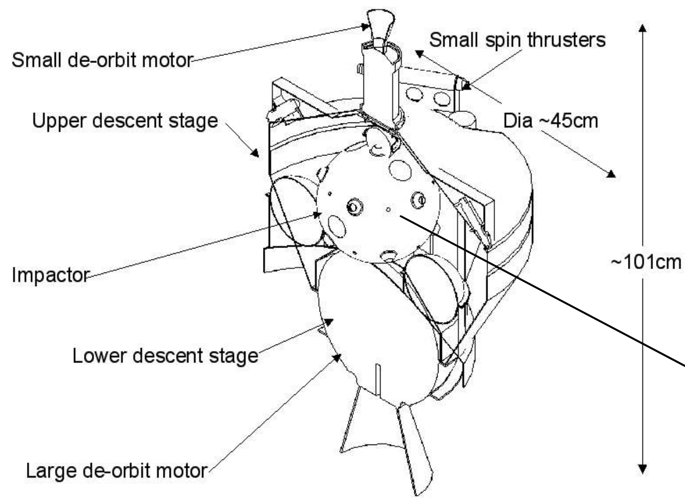
Icy Moons Lander concept

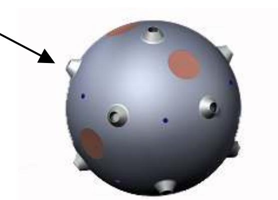
Note: concepts are not to relative scale

Jovian Moon Impactor

Concept Highlights

JMI is a **small**, **simple** science probe that would be **impacted** on Europa (5000 to 10,000g) and perform a **3.5 day** mission using batteries.





Performance:

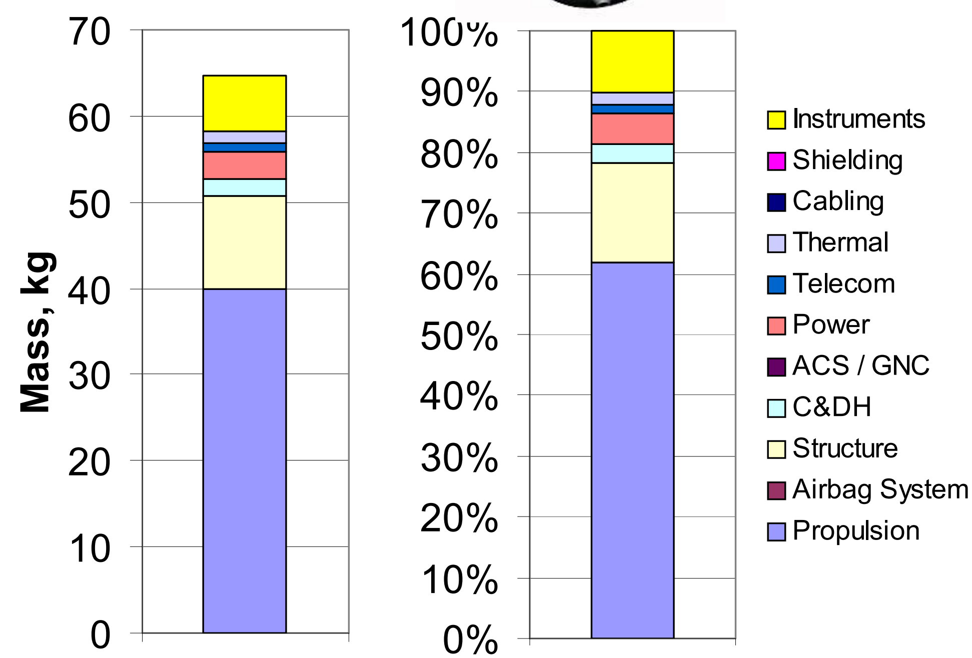
- **Wet Mass: 65 kg**
- **Instrument Mass: 6.5 kg** ***(~10%)***
- Power: 9.9 W
- Mission Duration: ~3.5 days
- Data Volume: ~255 Mbits

Science Payload

- Raman spectrometer
- pH sensor
- Microseismometer
- Imagers (Near and far-field)
- Redox potential sensors
- Accelerometers

Technology Requirements

- Very high g-tolerant systems (5000 to 10,000 g).
- Rad-hard systems (Mrad-class)
- Low-temperature electronics (Operate down to -170^{o}C)



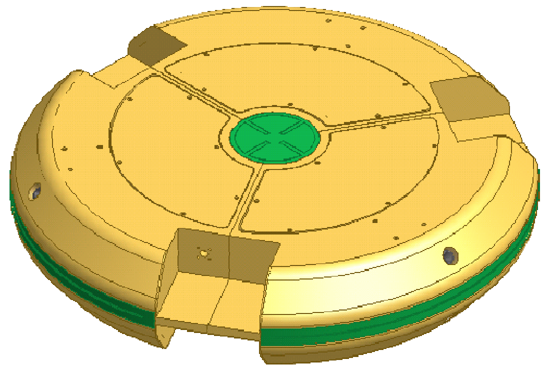
3/23/2006

Pre-decisional – for discussion purposes only

Europa Pathfinder (1 of 2)

Concept Highlights

EPF is a small science probe that would use **airbags** (~600g) to land on the Europa surface.
A **battery** version (**baselined**) would last **~3.5 day**; a **Small-RPS** version could last **much longer***.



Performance:

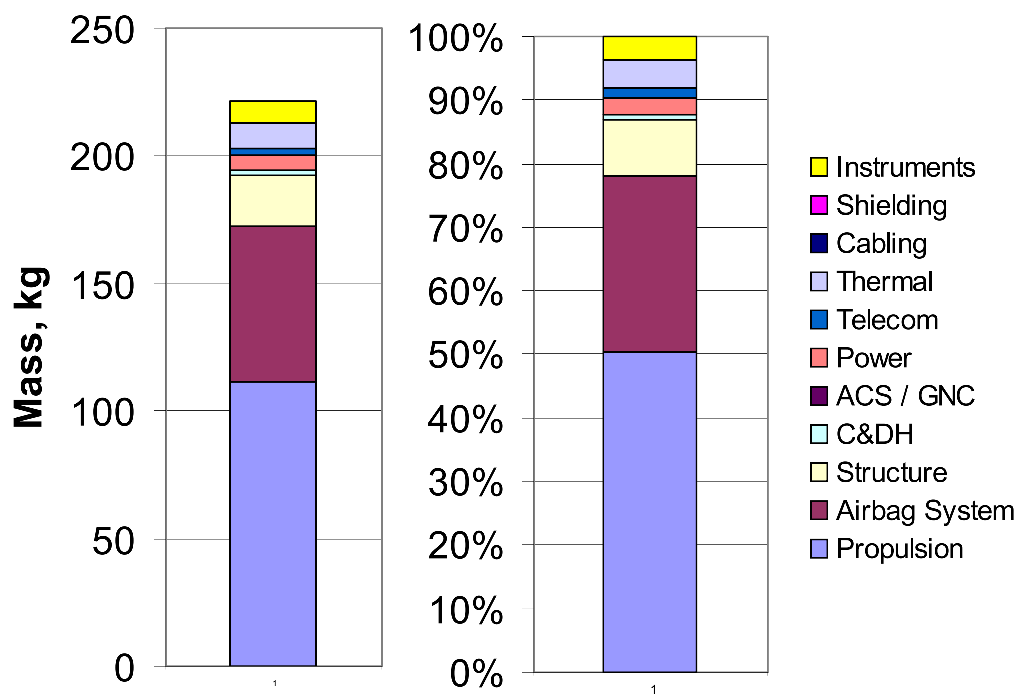
- **Wet Mass: 221 kg**
- **Instrument Mass: 8.3 kg** ***(4%)***
- Power: 7.5 W (average)
- Mission Duration: ~3.5 days
- Data Volume: ~255 Mbits

Science Payload

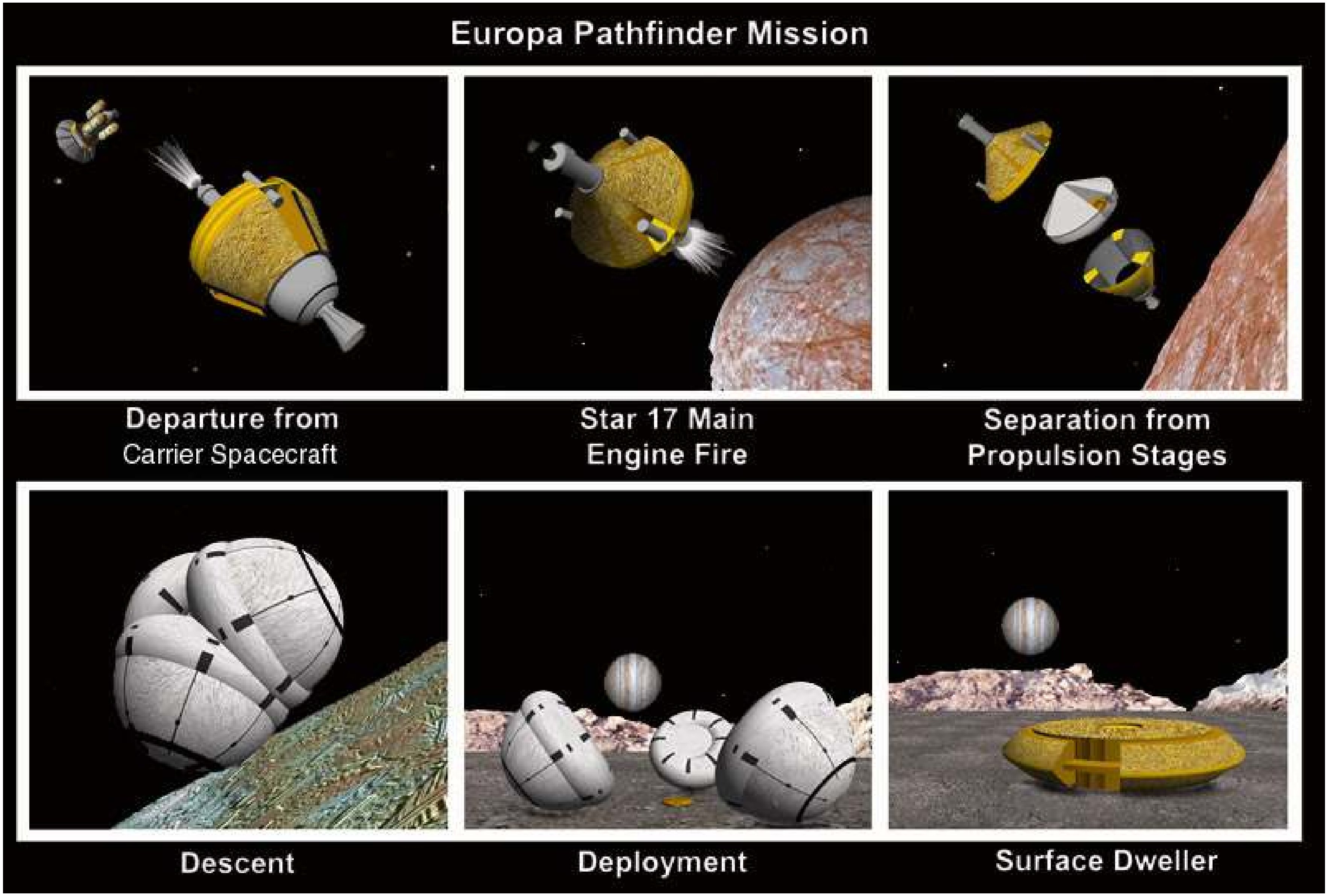
- Laser Inducted Breakdown Spectrometer
- Raman spectrometer
- Microseismometer
- Imagers (Near and far-field)
- Radiation sensors
- Temperature sensors

Technology Requirements

- High g-tolerant systems (600g)
- Rad-hard systems (Mrad-class)
- Low-temperature electronics (Operate down to -170°C)



Europa Pathfinder - Airbag Landing Concept (2 of 2)

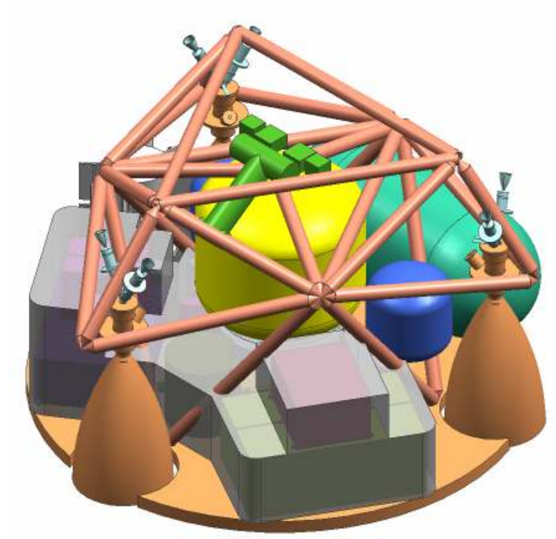


Europa Surface Science Package (ESSP) Lander

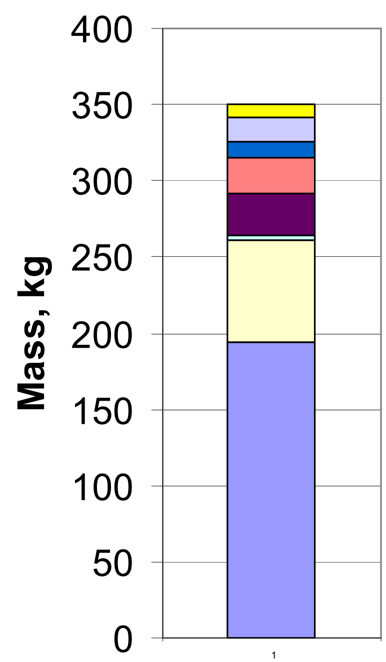
Concept Highlights
ESSP study examined the trade space for a JIMO lander. **Battery** power vs **small-RPS***. **Soft** vs hard landing. **3 to 14 days** life.

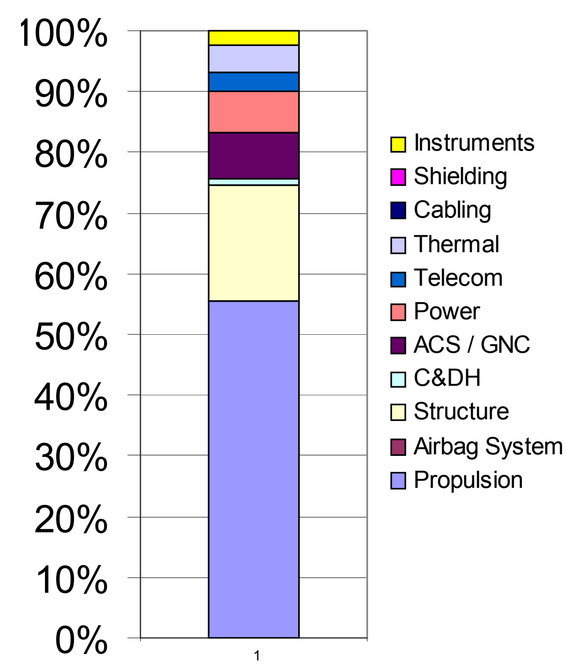
Science Payload
- GCMS
- Raman Spectrometer
- Wet Chemistry
- Microseismometer
- Imagers (Near and far-field)
- Magnetometers
- Radiation Sensors

Technology Requirements
- Small RPS (optional)
- Rad-hard systems (Mrad-class)
- Low-temperature electronics



Performance:
- **Wet Mass: 350 kg**
- **Instrument Mass: 8.3 kg** ***(~2.4%)***
- Power: 50 W
- Mission Duration: 3 days
- Data Volume: 344 Mbits (C)

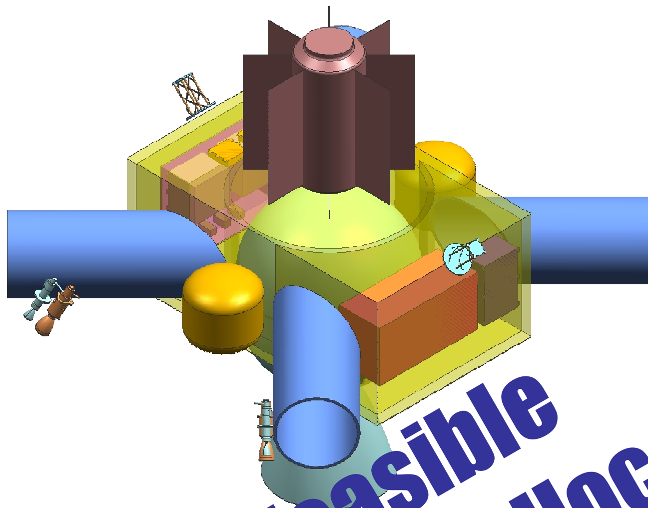




Icy Moon Lander

Concept Highlights

IML uses a semi-soft landing (<40g) and RPS to enable a 30 day surface mission. Multiple subsurface samples collected.



Performance:

- **Wet Mass: 825 kg[1]**
- **Instrument Mass: 41 kg** *(5%)*
- Power: 100 W
- Mission Duration: 30 d
- Data Volume: 7 Gbits (C)

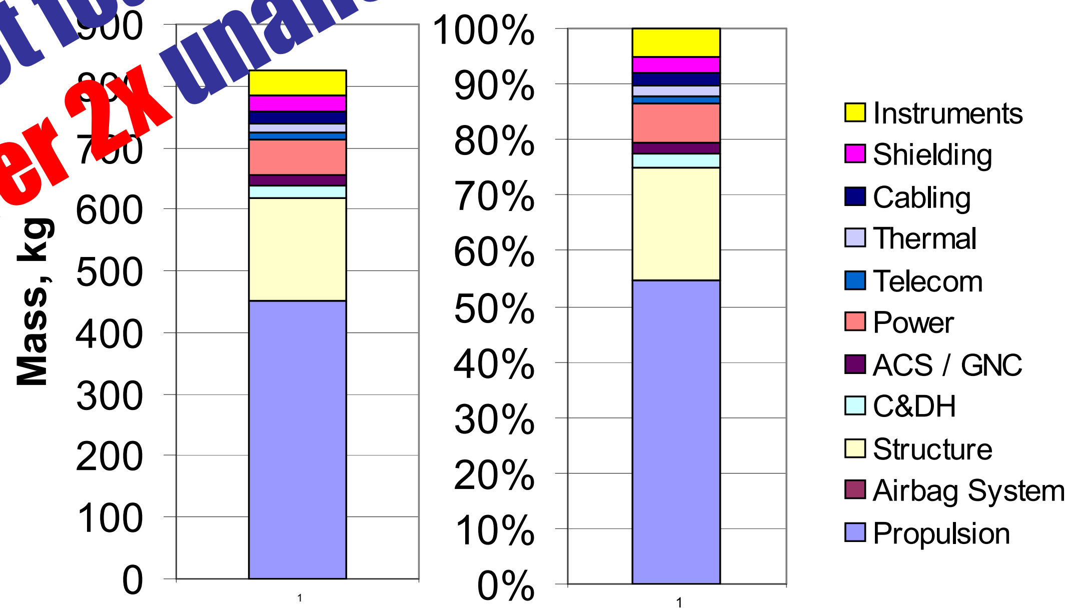
[1] Assumes use of advanced RTG (though MMRTG might be used.)

Science Payload

- GCMS
- Raman Spectrometer
- Wet Chemistry
- Microseismometer
- Imagers (Near and far-field)
- Magnetometers
- Radiation Sensors
- Temperature Sensors
- Accelerometers

Not feasible

Lander mass is over 2x unallocated mass on EE



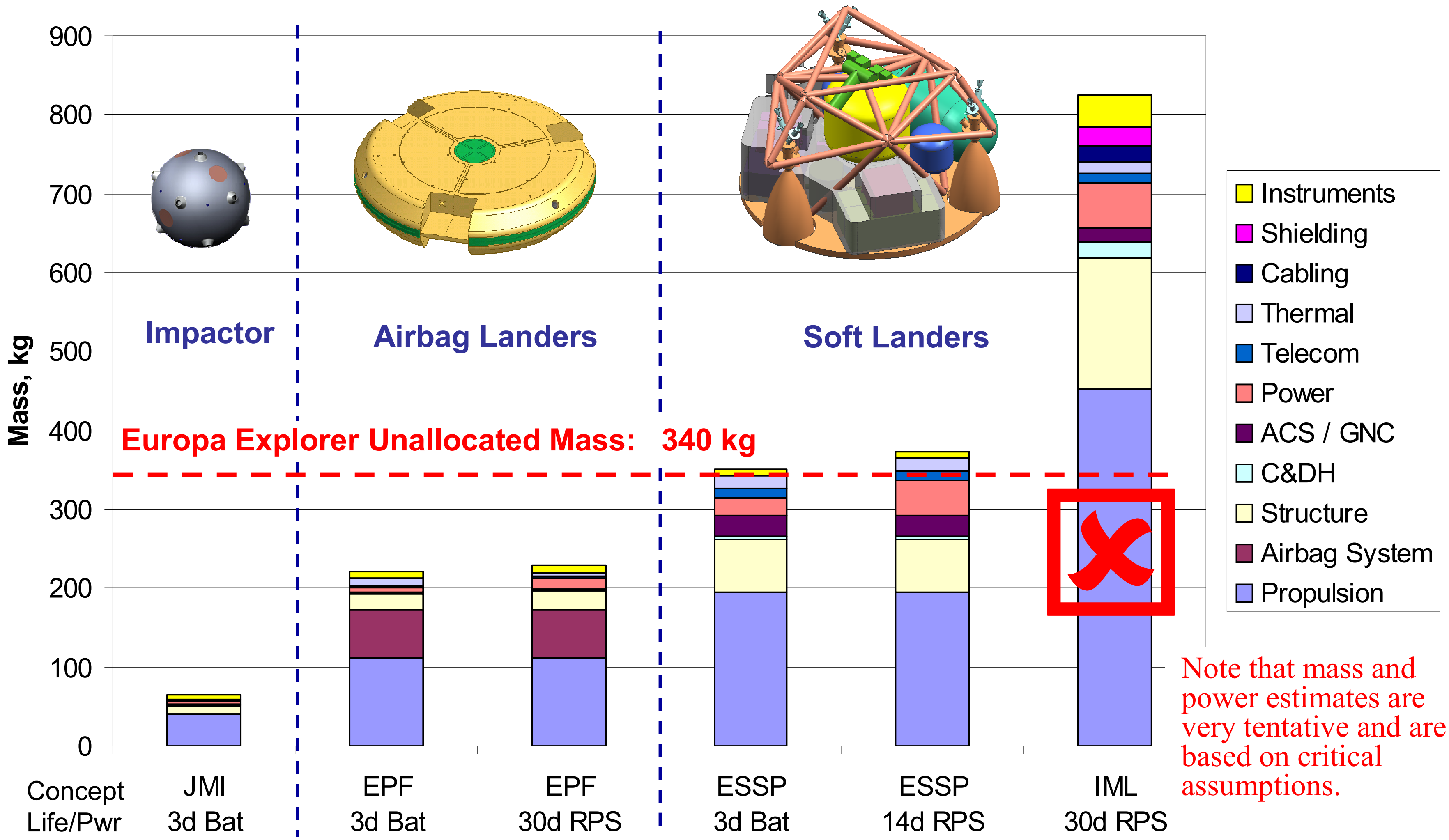
Technology Requirements

- RPS (MMRTG, Adv. RTG[1])
- Rad-hard systems (Mrad-class)
- Low-temperature electronics

Summary and Conclusions

Summary and Conclusions

Mass Requirements of Conceptual Small Europa Landers



NOTE: The propulsion+Structure typically uses up ~70%-86% of the initial mass!
At the same time the instruments mass varies ~2.5%-10% of the initial mass!

Note: The amount of available lander payload mass is dependant upon the mission and lander architecture. For example, payload mass can be traded for a higher performance communications system (greater data volume), more radiation shielding (longer mission duration), etc.

Summary and Conclusions

Impactors and Rough Landers

- **Impactors and rough landers** have the **advantage** of:
  - Being able to access a larger variety of landing sites.
  - Generating minimal contamination of the landing site due to propellants.
  - Having lower overall lander mass than soft landers (potentially allowing more than one probe to be included in a mission).
  - Lower-cost and lighter-weight guidance and control (G&C) systems than soft landers.

- **Impactors and rough landers** have the **disadvantage** of:
  - Requiring high-g tolerant electronics and subsystems.
    - Long-duration missions would require development of high-g tolerant small-RPSs.
  - Relatively small payloads.
  - Lack of precise control of where the lander would land.
    - Major axis of landing error ellipse ~2 km.

Summary and Conclusions

Soft Landers

- **Soft landers** have the **advantage** of:
  - Eliminating the need for high-g tolerant electronics and subsystems.
  - Extended mission durations (weeks) using simpler, lower g-tolerant RPSs.
  - Permitting larger, and more sophisticated science payloads.
  - Precise control over landing location compared with impactors and rough landers.

- **Soft landers** have the **disadvantage** of:
  - Reduced access to rough landing sites.
  - Potentially contaminating the landing site with propellants from the landing system.
  - Having higher overall lander masses than impactors or rough landers.
  - Requiring heavier, more sophisticated (and expensive) guidance and control (G&C) systems needed for hazard avoidance and pinpoint landing.
  - Potentially higher cost.

Summary and Conclusions

- In summary, the recent **Europa Explorer (EE) orbiter** concept study indicated that **additional mass** may be **available** for mission use. (Estimated at 340 kg)
- Options for using this potentially available mass include:
  - Holding extra mass in reserve for spacecraft growth (!!).
  - Increasing the amount of shielding in order to extend the mission duration.
  - Enhancing the orbiter instrument suite.
  - Enhancing the orbiter communications system to increase downlink data volume.
  - Adding a small Europa lander.
- Depending the available mass, mission architecture and landing concept the **size of the payload can vary between 2.5% and 10% of the lander's wet mass**

- The science community needs to consider each of these options and define the science priorities, **including astrobiology**, for allocating any available mass for a Europa mission.

Thanks for your attention.
Any questions?