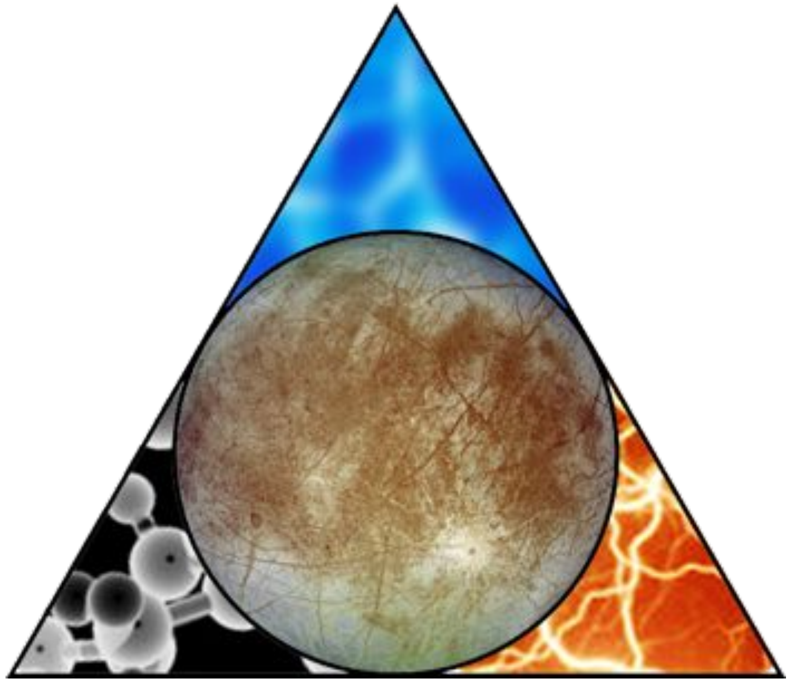


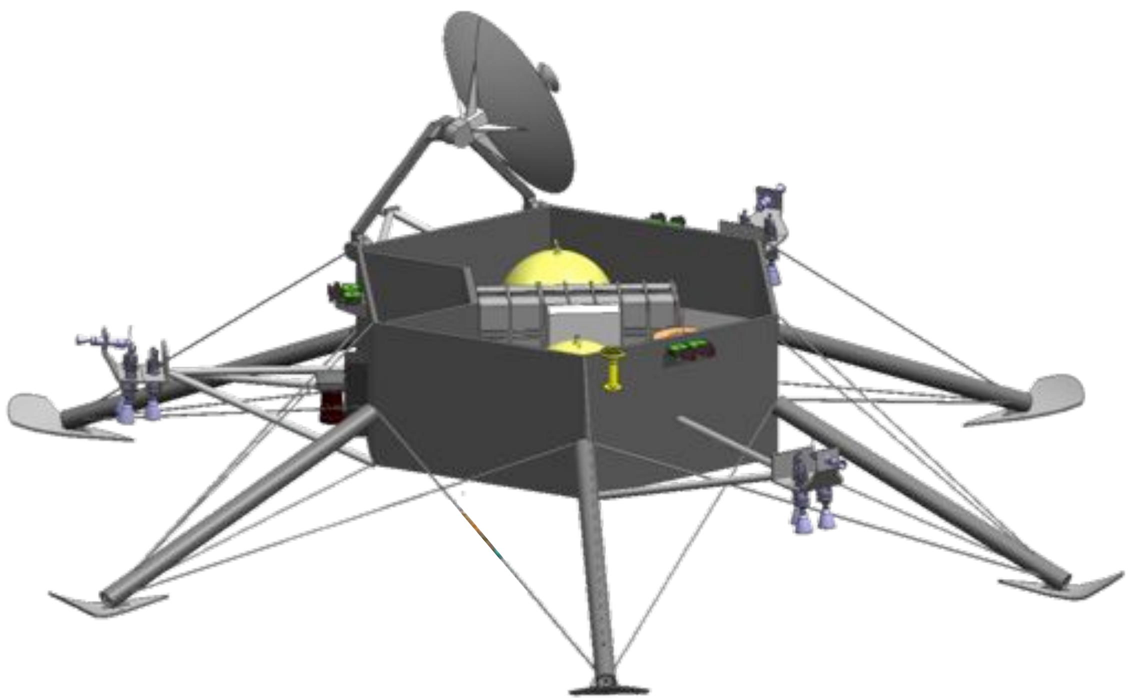
Europa Lander Study Background

Brian Cooke

Outer Planets Assessment Group, Nov 2011

Outline

- Discuss current charter from NASA
- Background and history
- Current concept summary



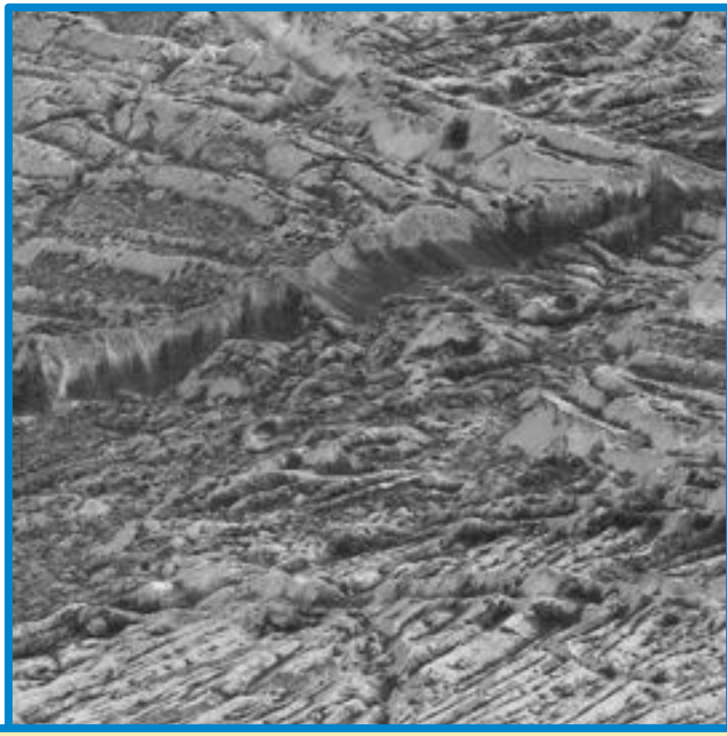
Charter from NASA

NASA HQ has requested that the Europa Study Team investigate the feasibility of a Landed Element

- Study prime objective is to develop a scientifically compelling, well margined, feasible concept and produce a reliable cost estimate
  - $1.5B is a targeted goal but not an input condition
- Atlas and Delta launch vehicles are acceptable
  - LV cost is not included in the cost estimate
- Nuclear power system is acceptable if justified
- Mission concept and cost estimate shall be independently reviewed

Challenge of Landing on Europa

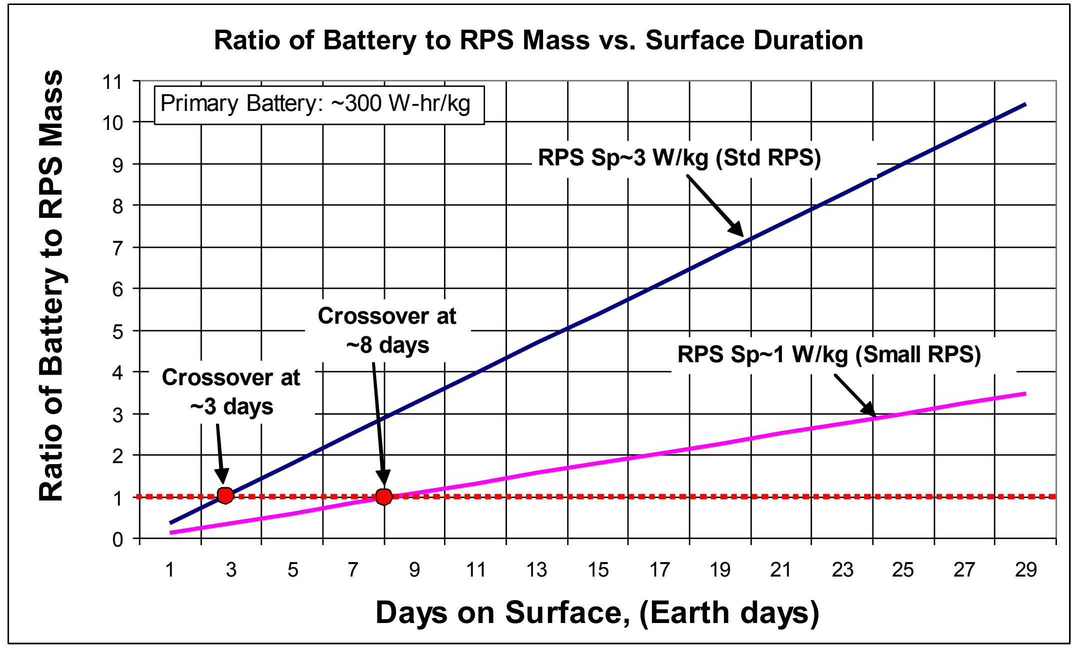
- Uncertain terrain
- Power source / Surface Lifetime
- Radiation
- Planetary protection
- Communications
- Surviving landing



The surface of Europa is unlike that of the Moon or Mars. This Galileo image shows topographic relief of hundreds of meters on Europa's surface. Is Europa's surface as rough as this on scales of centimeters to meters?

Challenge of Landing on Europa

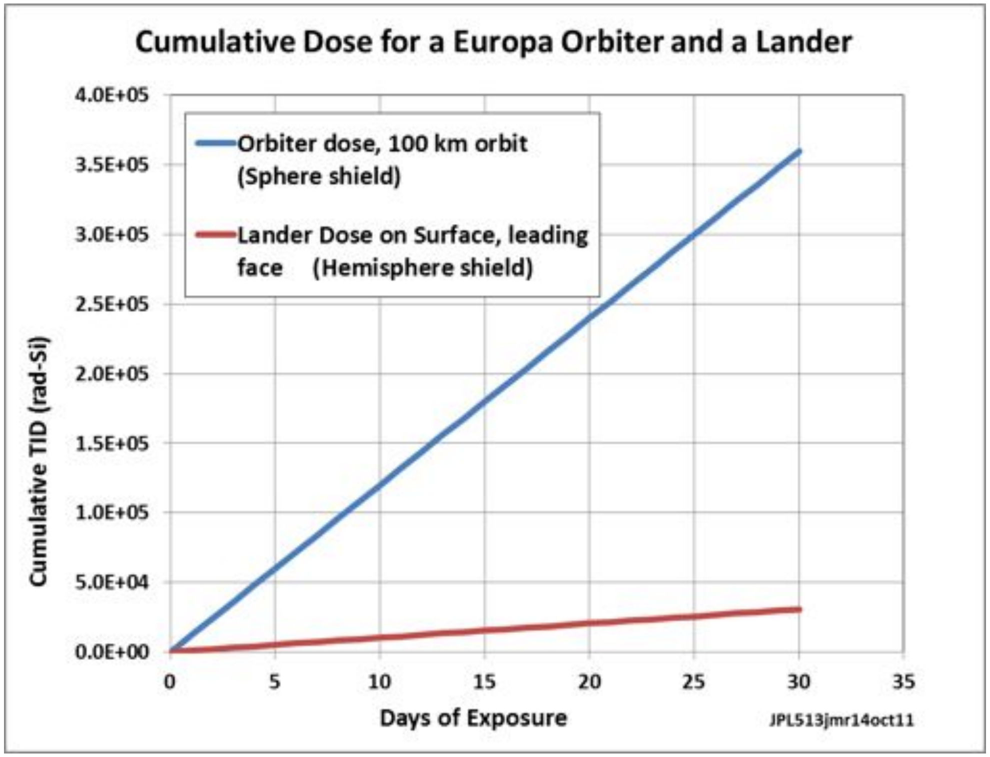
- Uncertain terrain
- **Power source / Surface Lifetime**
- Radiation
- Planetary protection
- Communications
- Surviving landing



For short (3 - 8 Earth days) surface missions, primary batteries potentially have a mass advantage over RPS. RPS are an advantage for longer missions, but are not currently rated to take large landing loads.

Challenge of Landing on Europa

- Uncertain terrain
- Power source / Surface Lifetime
- Radiation
- Planetary protection
- Communications
- Surviving landing



Landed surface element will benefit from significantly reduced radiation at surface as compared to 100 km orbit.

1. Needs to be designed to get to surface quickly to benefit
2. Orbital carrier would still receive high dose

Challenge of Landing on Europa

- Uncertain terrain
- Power source / Surface Lifetime
- Radiation
- Planetary protection
- Communications
- Surviving landing

Article IX of the Outer Space Treaty of 1967 requires the prevention of "harmful contamination" of extraterrestrial solar system bodies. NASA's compliance with this treaty is documented in NPR 8020.12C. Europa missions, in particular, are covered in section A. 3.1 stating:

"Requirements for Europa flyby, orbiter, or lander missions, including microbial reduction, shall be applied in order to reduce the probability of inadvertent contamination of an Europan ocean to less than 1×10^{-4} per mission."

Landed element would have to ensure less than 10^{-4} probability of forward contamination of Europa

1. Design must accommodate significant sterilization before launch
2. Radiation dose must be balanced between sterilization and survivability

Challenge of Landing on Europa

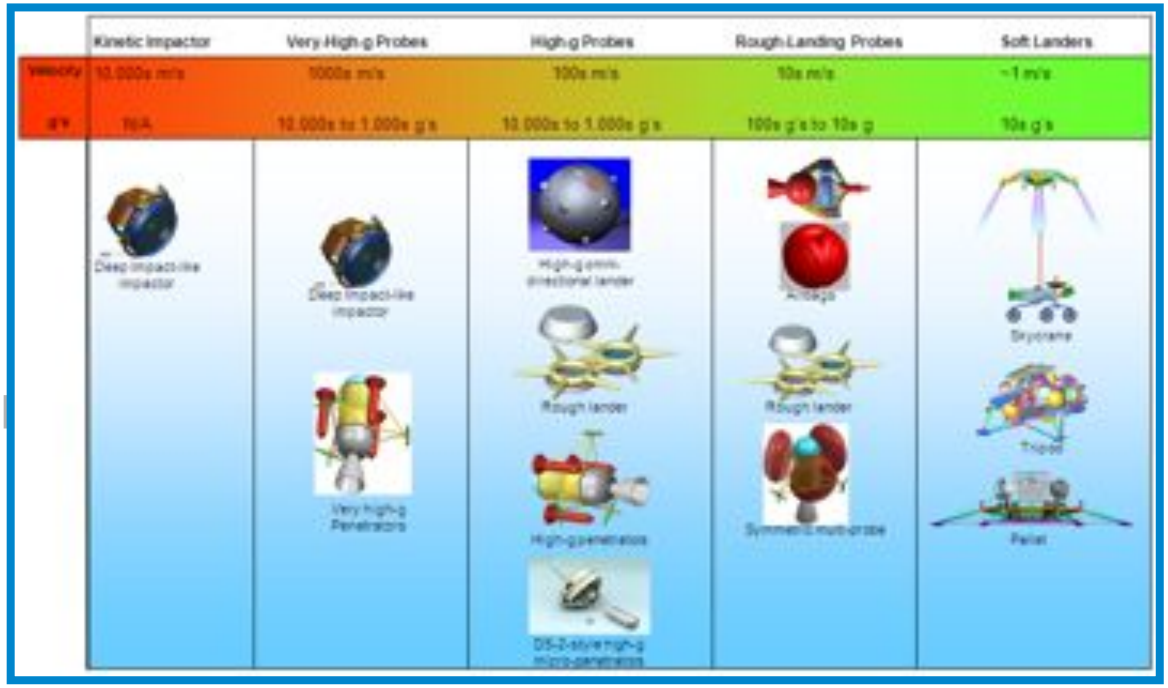
- Uncertain terrain
- Power source / Surface Lifetime
- Radiation
- Planetary protection
- Communications
- Surviving landing

Vertical features on the scale of 10 stories next to survivable landing sites:

1. Could significantly obscure telecom fields of view
2. Large but survivable slopes could impact telecom range of motion

Challenge of Landing on Europa

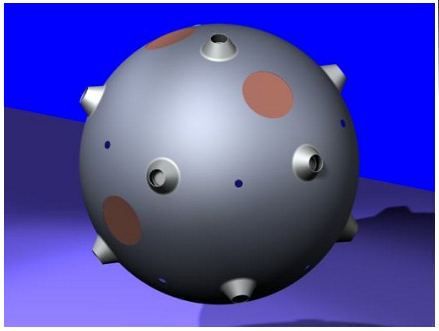
- Uncertain terrain
- Power source / Surface Lifetime
- Radiation
- Planetary protection
- Communications
- **Surviving landing**



- Europa landing dynamics comparable to lunar landing
- Landing survivability risk is dominated by terrain uncertainty

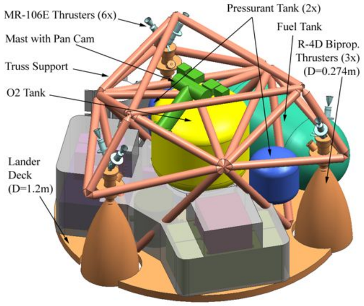
Many options have been studied…

Description: Jovian Moon "Impactor" (JMI) is a small, rough landing probe that would impact Europa at 5000 to 10,000 g.



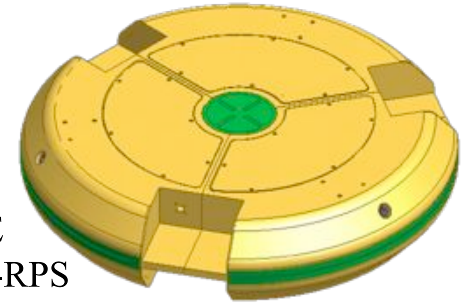
Performance:
Duration – 2-3 eurosols
Payload Mass – 5 kg
Total Mass – 59 kg CBE
Power – Battery + mini-RPS

Description: Europa Surface Science Package is a soft lander examined for JIMO. Investigated power sources, lander types, and lifetime options.



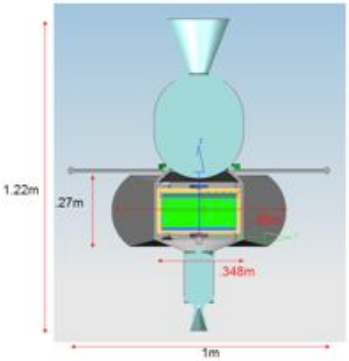
Performance:
Duration – 1-3 eurosols
Payload Mass – 12.5 kg
Total Mass – 385 kg (for RPS)
Power – Battery or small-RPS

Description: Europa Pathfinder is a small science probe that would use airbags (~600 g) for landing on the Europa surface.



Performance:
Duration – 1 eurosol
Payload Mass – 8.3 kg
Total Mass – 221 kg CBE
Power – Battery or small-RPS

Description: JEO Surface Science Package is a rough lander with crushables that uses a "stop and drop" de-orbit sequence to reach the surface



Performance:
Duration – 1 eurosol
Payload Mass – 5 kg
Total Mass – 101 kg CBE
Power – Battery

Surface Element Option Summary

Landing Option	Pro	Con
Soft (~0 m/s velocity)	•Best landing control •Highest landed mass capability means more payload •Potential to have longer lifetime •Most direct use of existing technology	•Highest complexity •Possible surface contamination at landing site •Least capable of dealing with widely varied landing conditions •Likely can only accommodate one surface element
Rough (~50 m/s velocity)	•Can accommodate more robustness for surface topography •Potential for more than one surface element •Potential to have longer lifetime	•System must tolerate higher g-loads •Possible technology development required
Hard (~500 m/s velocity)	•Most robust to surface topography •Simple operations after release •Potential for more than one surface element within mass allocation	•System high g tolerance required •Limits payload size •Lifetime limited - RPSs are not currently qualified for high g environments •Most likely to need extensive technology development

Europa Lander Study Summary

Brian Cooke

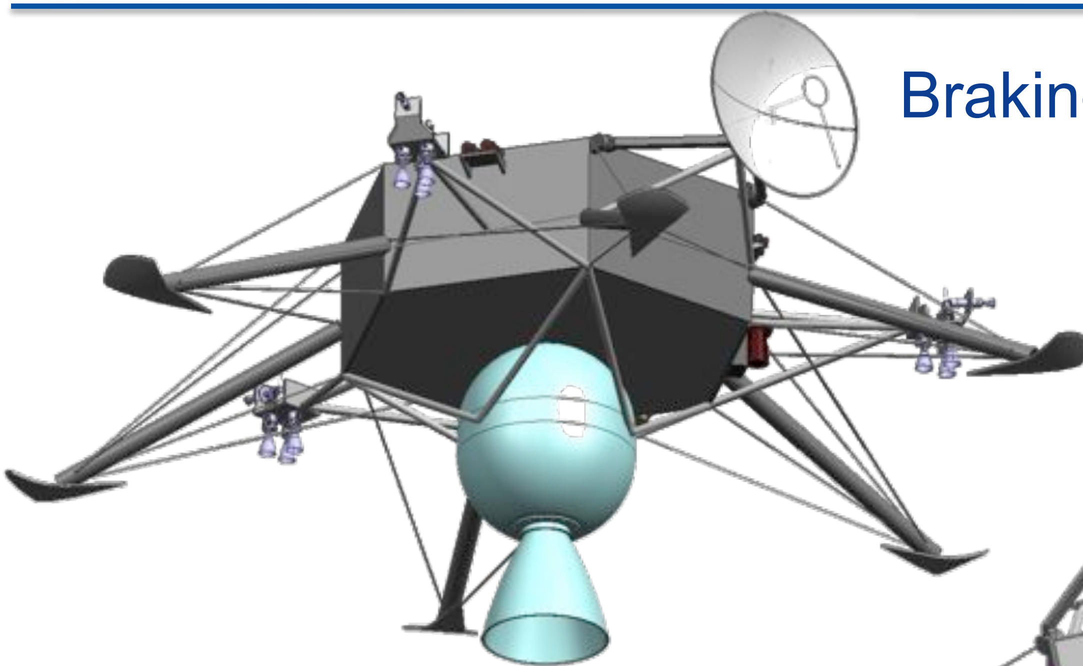
Outer Planets Assessment Group, Nov 2011

Europa Surface Element Goals

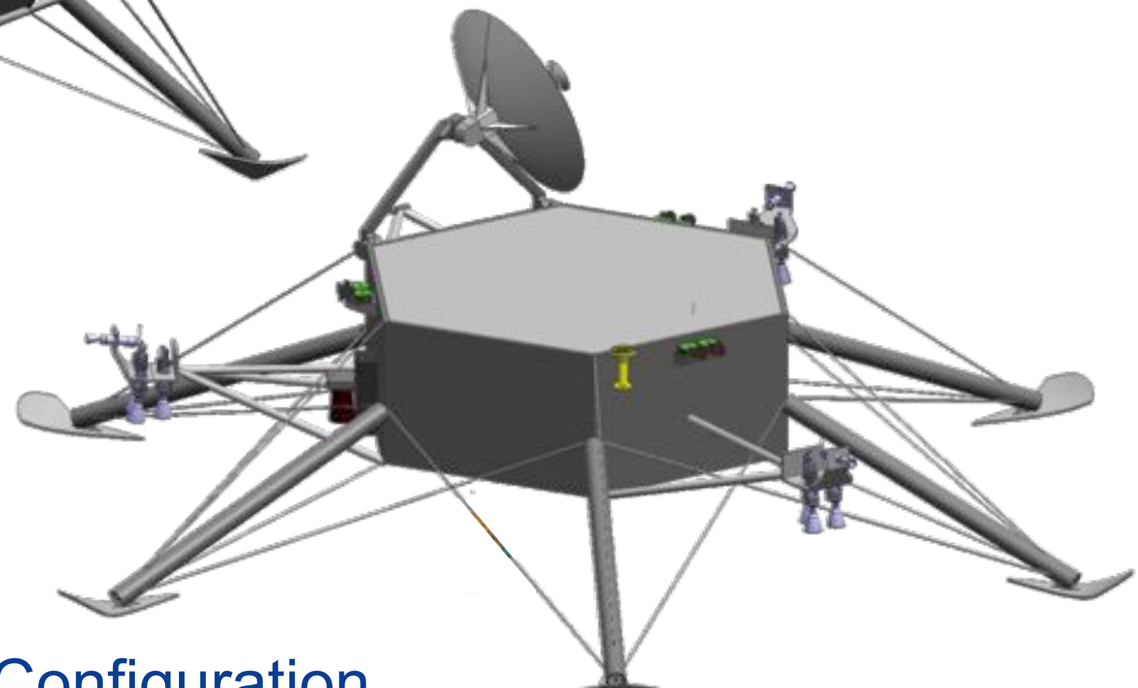
- Primary objective: **Develop platform for compelling landed science; Lander success is primary mission objective**

Performance Criteria		Comment
Launch Vehicle	Delta IV-H	Heaviest current existing LV
Target Surface Element Mass	200 - 500 kg	Incl. delivery system; excl propellant
Target Surface Lifetime	3 eurosols	9 eurosol goal (~30 Earth days)
Target Science Payload Mass	50 kg	50W available p/l power
Target Max Impact Velocity	< 1 m/s	Soft lander
Communication Link	DTE	Explore relay options
# Surface Elements Desired	2 (Identical)	"Fly 2 to get 1 down safely"
Nuclear Material	Acceptable	ASRGs / RHUs
Orbiter Deployment Altitude	5 km	"Stop and drop" w/ controlled descent

Concept Lander Configuration



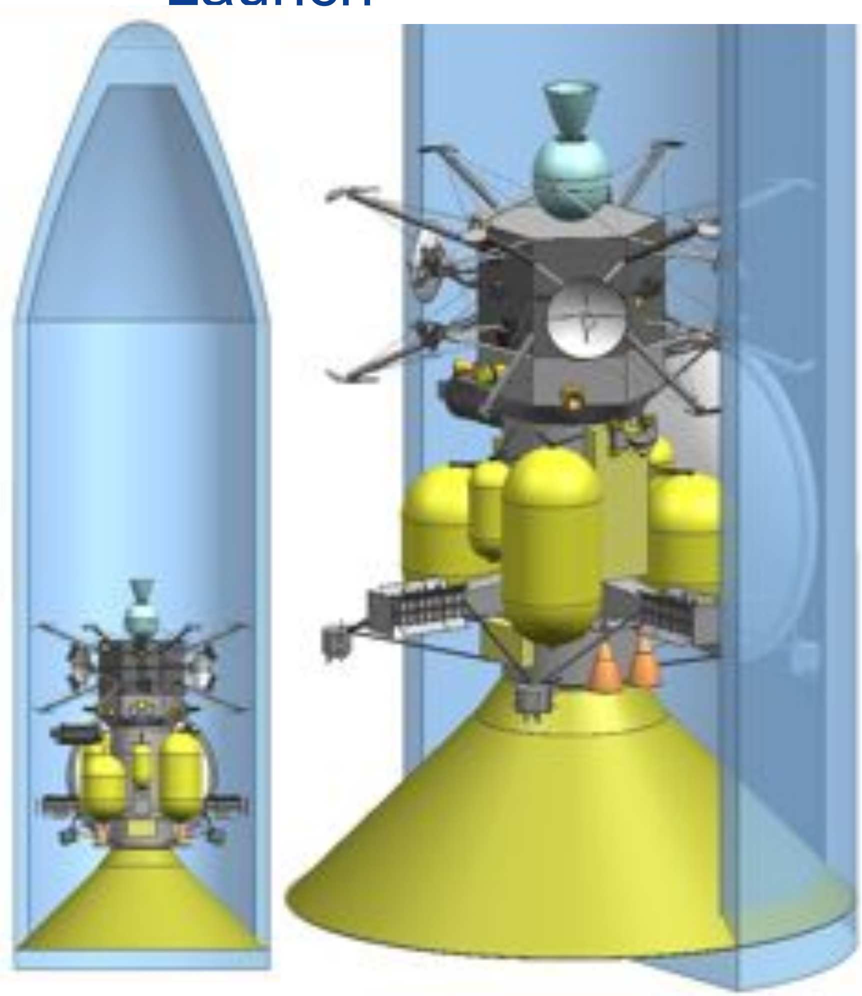
Braking Configuration

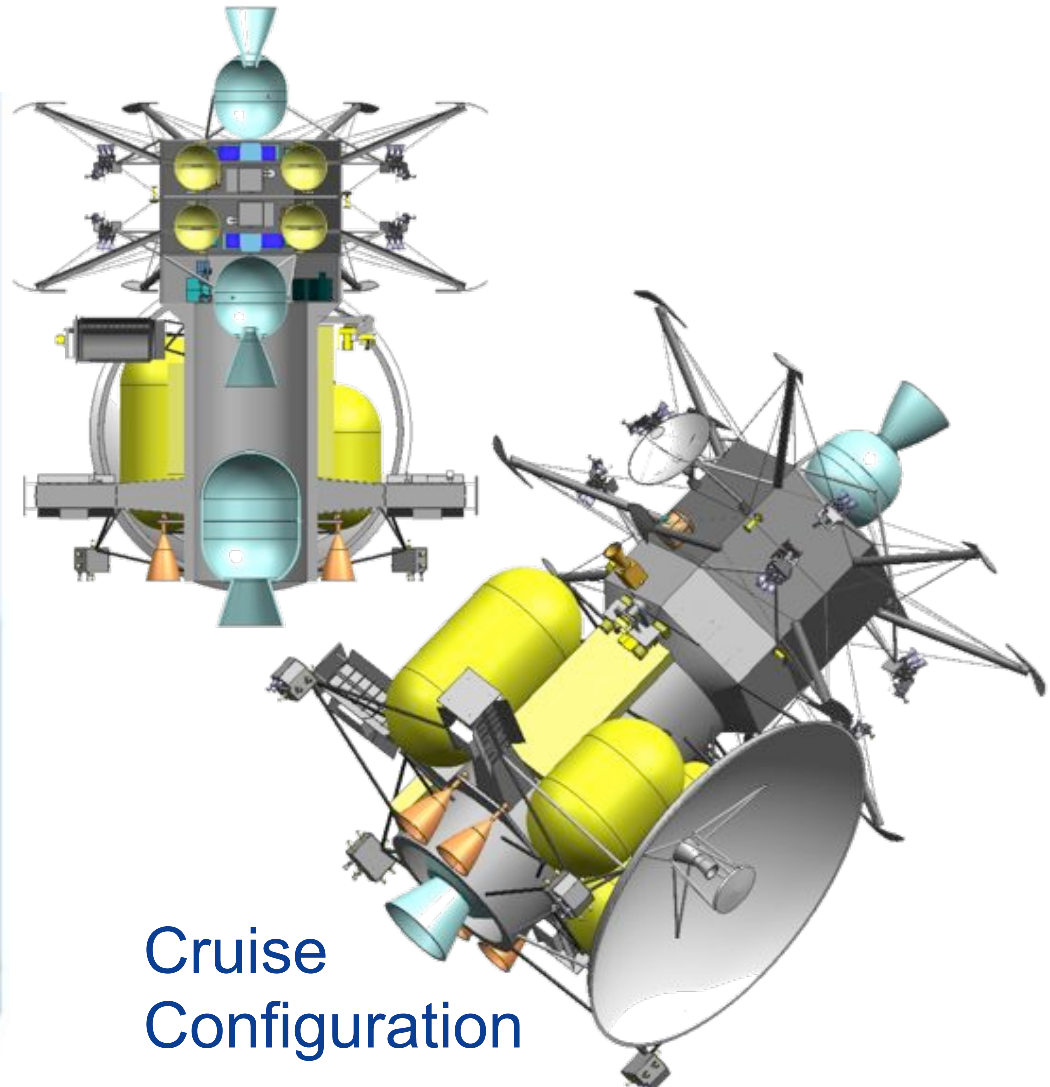


Landed Configuration

Concept Spacecraft Configuration

Launch

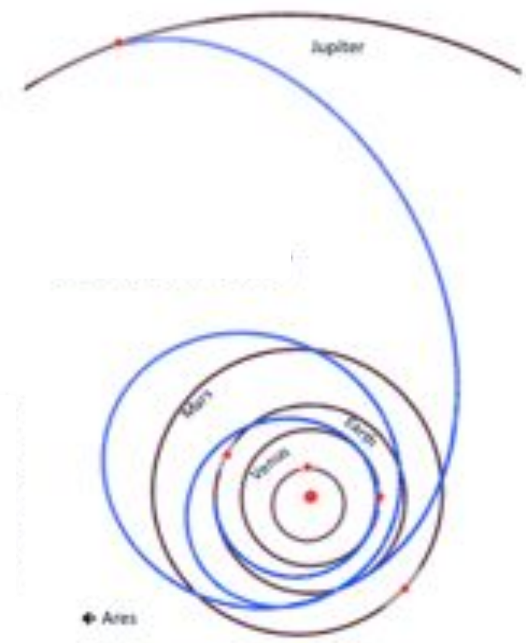


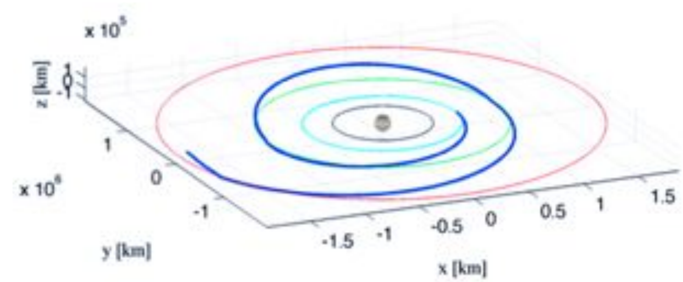


Cruise Configuration

Concept Mission Scenario

- Launch in March 2019 on VEEGA trajectory
  - TCMs and Statistical DVs on Bi Prop
- JOI in Feb 2026 using Bi Prop and Ganymede gravity assist
- 20 month Jupiter Tour
  - 16 more Ganymede and Callisto flybys
- EOI to 50 x 410 km orbit in Oct 2027
  - using Star 37 SRM and Bi-Prop
- One to a few orbits to phase the landing site and get precise orbit determination
- Lower orbit to 5 X 410 km for Lander release
  - Landers released at 5 km altitude on same or consecutive orbits
- Raise orbit to ~50 x 410 km if enhanced orbiter science option is chosen

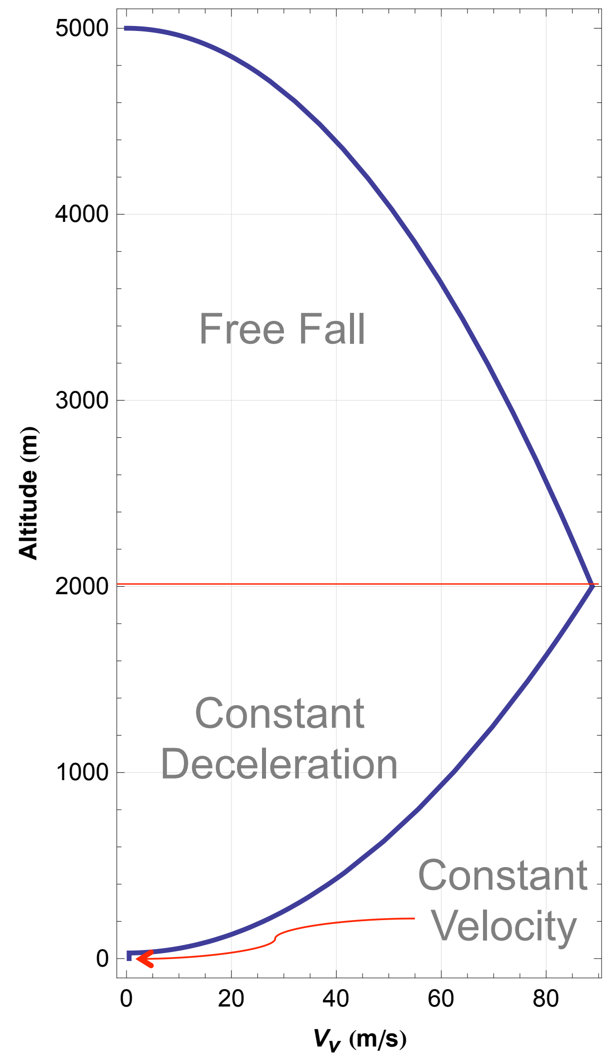




Landing Concept Overview

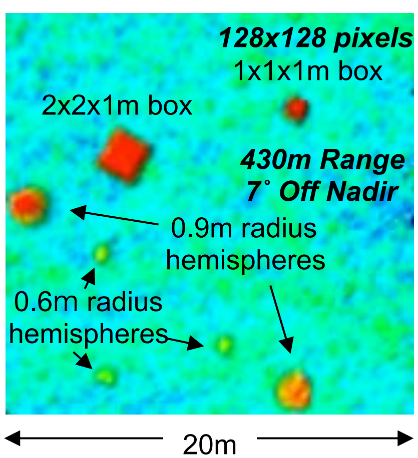
- Landing risk on an unknown terrain mitigated in multiple ways:
  - Hazard Detection and Avoidance
  - Touchdown velocity minimization
  - Landing System Robustness

- Descent Sequence:
  - At 5 km altitude Landers brake to 50 m/s using Star-27 w/ Descent Prop provides Thrust Vector Control
  - SRM jettison
  - Lander velocity cleanup, then free fall from 5 km to 2 km
  - Final descent on Descent Prop with active hazard avoidance
  - Touchdown

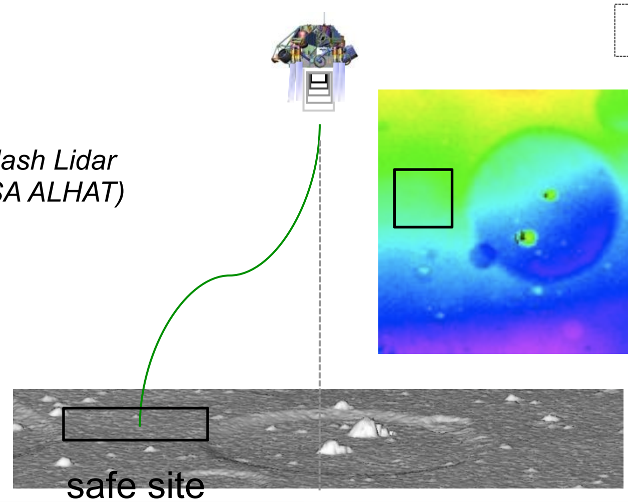


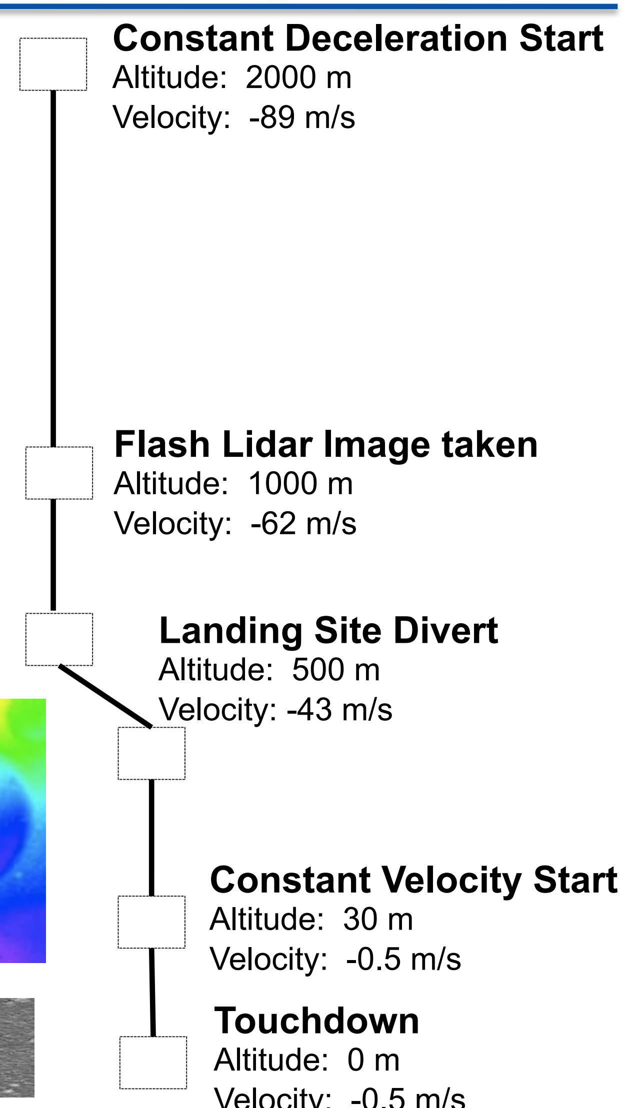
Landing Terminal Descent Concept

- Constant deceleration phase beginning at 2000 m
- Flash Lidar hazard avoidance begins at 1000 m
  - Detects topographic hazards (e.g. slopes, rocks, holes, etc) not visible from orbit and directs the lander to target the safest visible landing site
  - Hazards as small as 1m wide are identified
  - Slope of landing area assessed
  - Lander determines safest landing site with area
- Lander performs divert maneuver to selected landing location
- Constant 0.5 m/s velocity descent from 30 m to surface



Example Flash Lidar Image (NASA ALHAT)

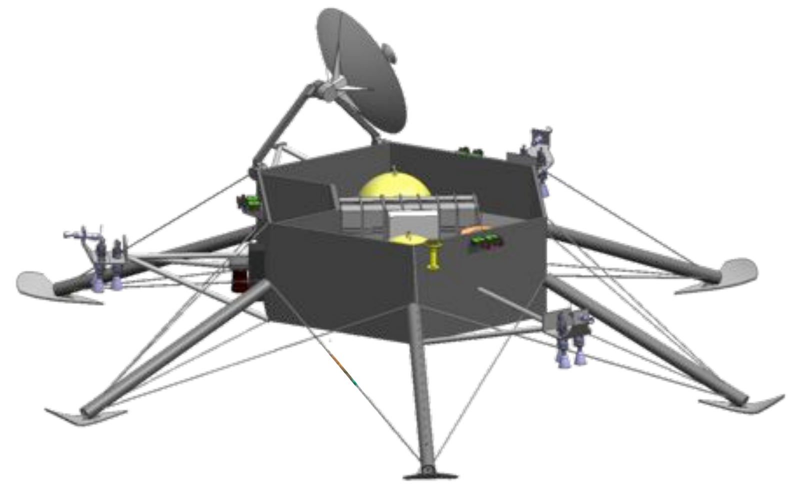




Landing and Surface Operations Concept

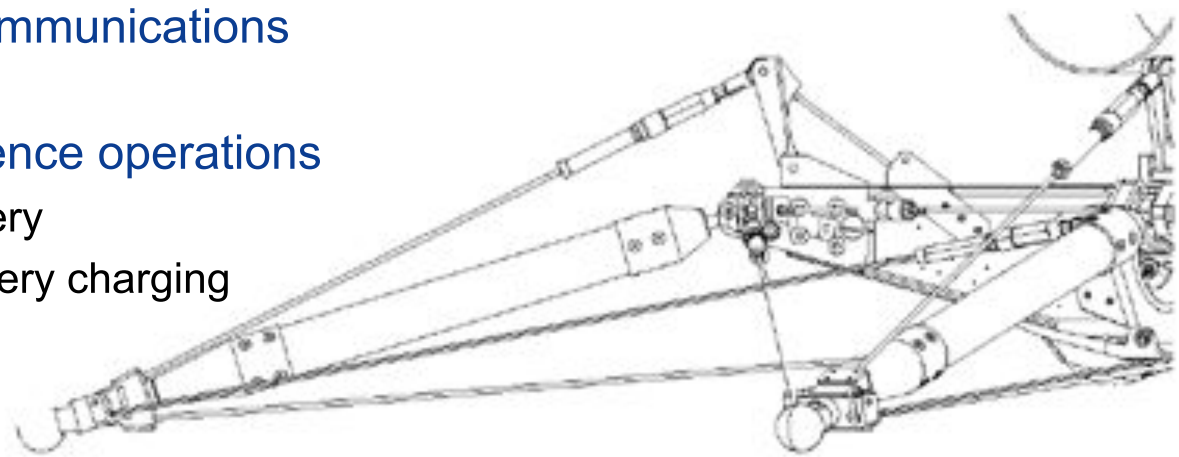
Touchdown:

- Soft landing occurs at 0.5 m/s
  - Extremely stable pallet lander design robust to rough surface topography
- High Gain Antenna deployed for DTE or relay communications



Surface Operations:

- ASRG or battery powers science operations and telecommunications for at least 2 eurosols
- Likely 2 modes of science operations
  - High power via battery
  - Low power with battery charging



Summary

- Europa Study Team will explore a Europa Landed Element Concept
  - The Goal is to support a 50 kg, 50 W science payload on the Europa surface for at least 2 eurosols
  - Robust landing system design as tolerant as possible to surface conditions
  - Active hazard avoidance
  - Soft landing (~0.5 m/s)
  - Stable landing pallet
  - “2 to get 1” redundancy philosophy