Touchdown System for a Europa Lander Concept

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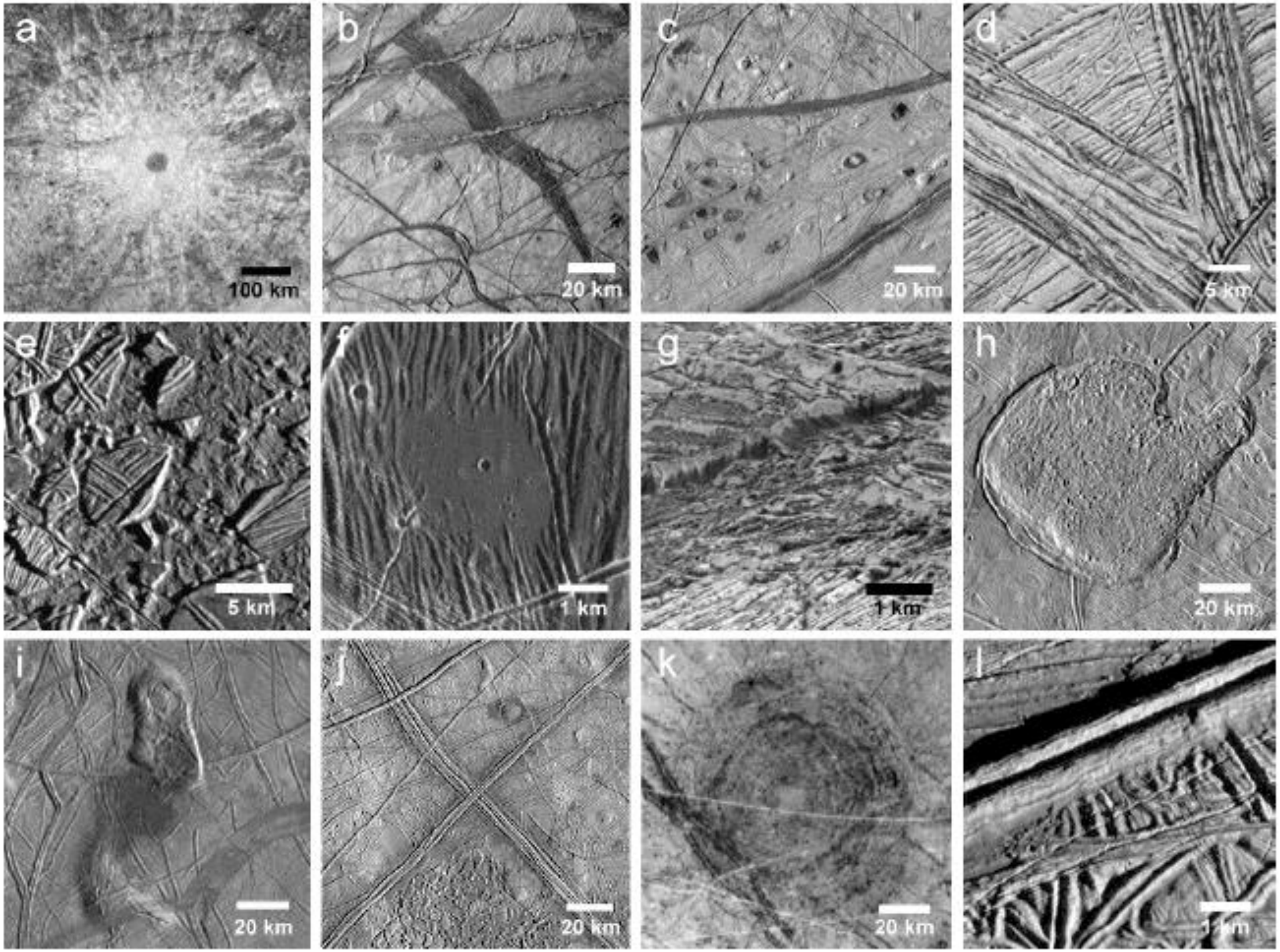
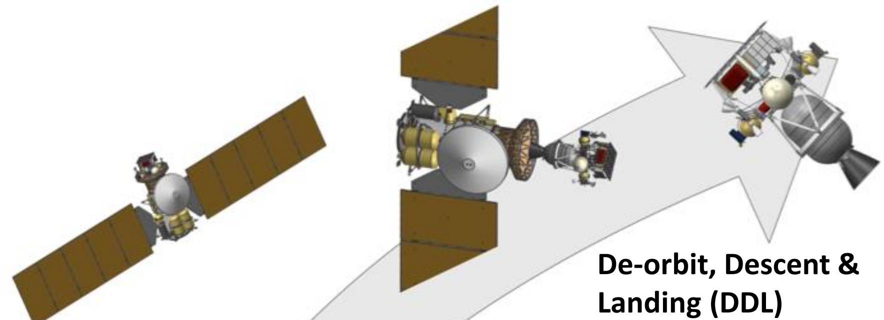
Motivation

- Relatively little is known about the surface of Europa on length scales relevant to a landed mission
- Although NASA's planned Europa Clipper mission would return high-resolution images of the surface, the development schedule for the Europa Lander concept would have the lander being designed, built, and launched *before* the high resolution images are returned
- This work presents a touchdown system concept to achieve high stability and large terrain relief to accommodate this unknown surface topology

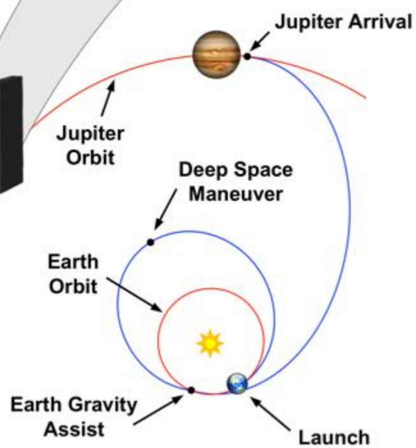
Galileo Images Show Europa Having Rugged, Unusual Terrain



Mission Concept uses Sky Crane Landing Approach

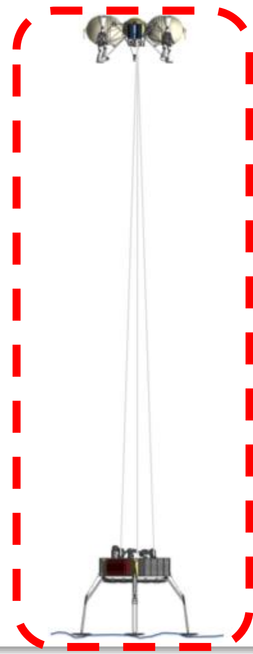


Cruise & Jovian Tour
- Earth Gravity Assist: 2027
- Jupiter Orbit Insertion: 2030
- Earliest landing on Europa: 2032

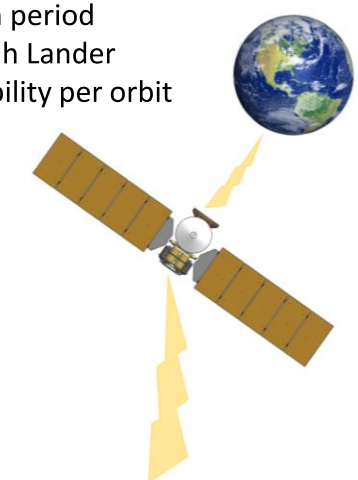


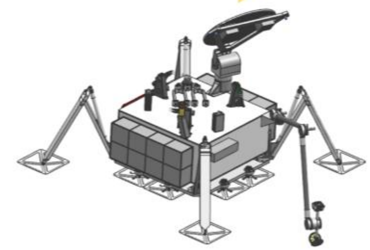
Launch
- SLS Block 1b
- 2025

De-orbit, Descent & Landing (DDL)
- Guided de-orbit burn
- Propulsive landing
- 100 m accuracy



Carrier Relay Orbit
- 24 h period
- >10 h Lander visibility per orbit



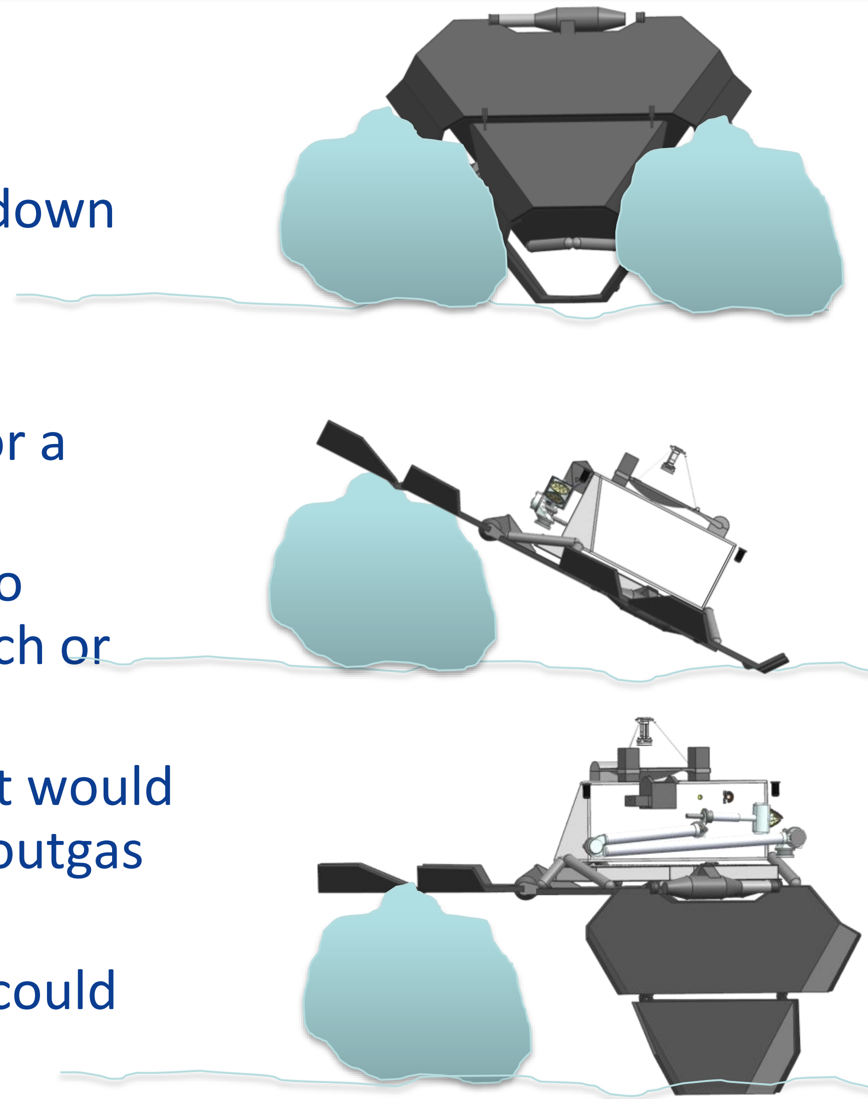


Surface Mission
- 20+ days surface mission
- 5 samples
- Relay communications through Carrier or Clipper (backup)
- 3-4 Gbit data return
- 45 kWh battery

Why not use the Tetrahedron?

- Advantages
  - Protect payload in tumble
  - Doesn't require gentle touchdown
  - Self-righting

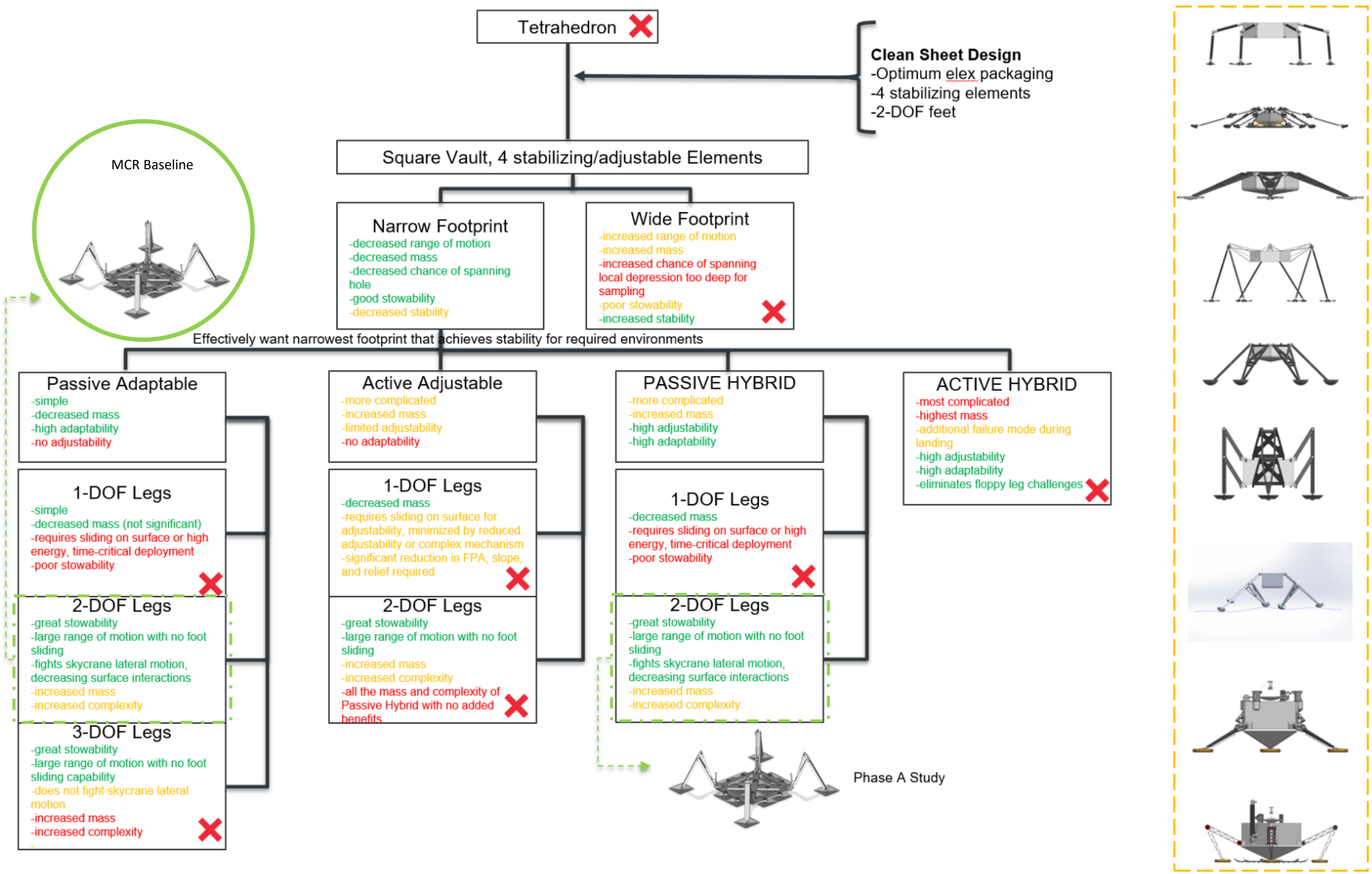
- Reasons it is not a good choice for a Europa lander
  - Unknown terrain could lead to getting stuck/wedged in a ditch or between terrain features
  - Could drop a tetrahedron, but would require airbags which would outgas solid propellant byproducts
  - Self-righting with large relief could lead to unstable geometries



Desired Features of the Touchdown System

- Accommodate large terrain relief over the footprint of the lander
- Adapt to the surface during touchdown event
- Get the main body as close to the surface as possible
- Rigidize to provide stability for the surface mission operations
- Maintain the main body of the lander relatively level
- Have compliance to allow lateral motion during the touchdown event

Lander Evolution Pathways



The Contenders

THE STANDARD

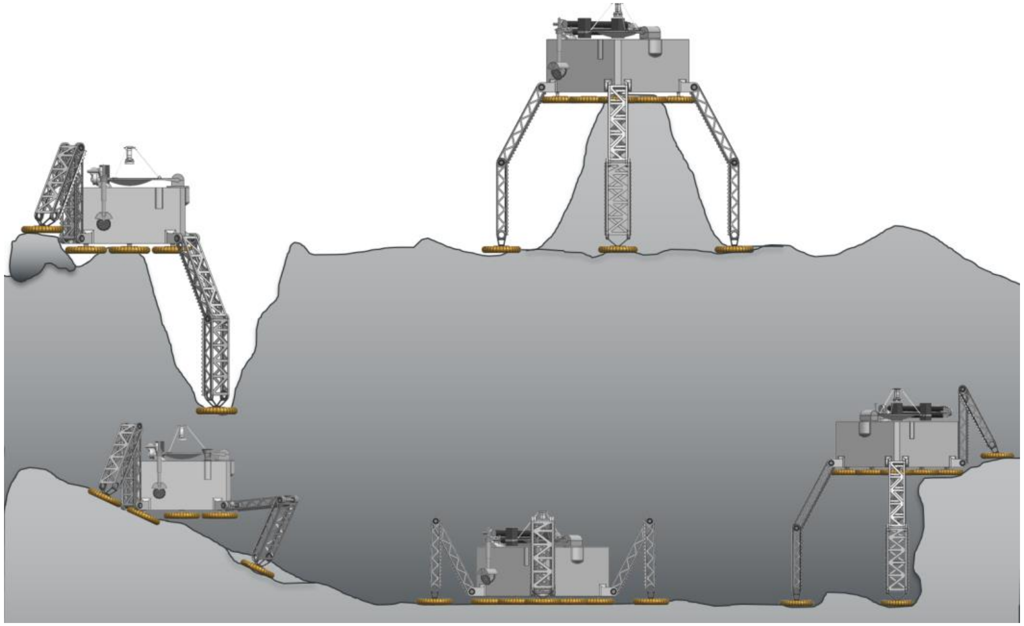
-adjustable
-simple
-decreased mass
-does not fight skycrane lateral motion, increasing surface interactions
-no adaptability
-large reduction in slopes, reliefs, and FPA and/or increase in footprint required to avoid rolls

THE CRICKET

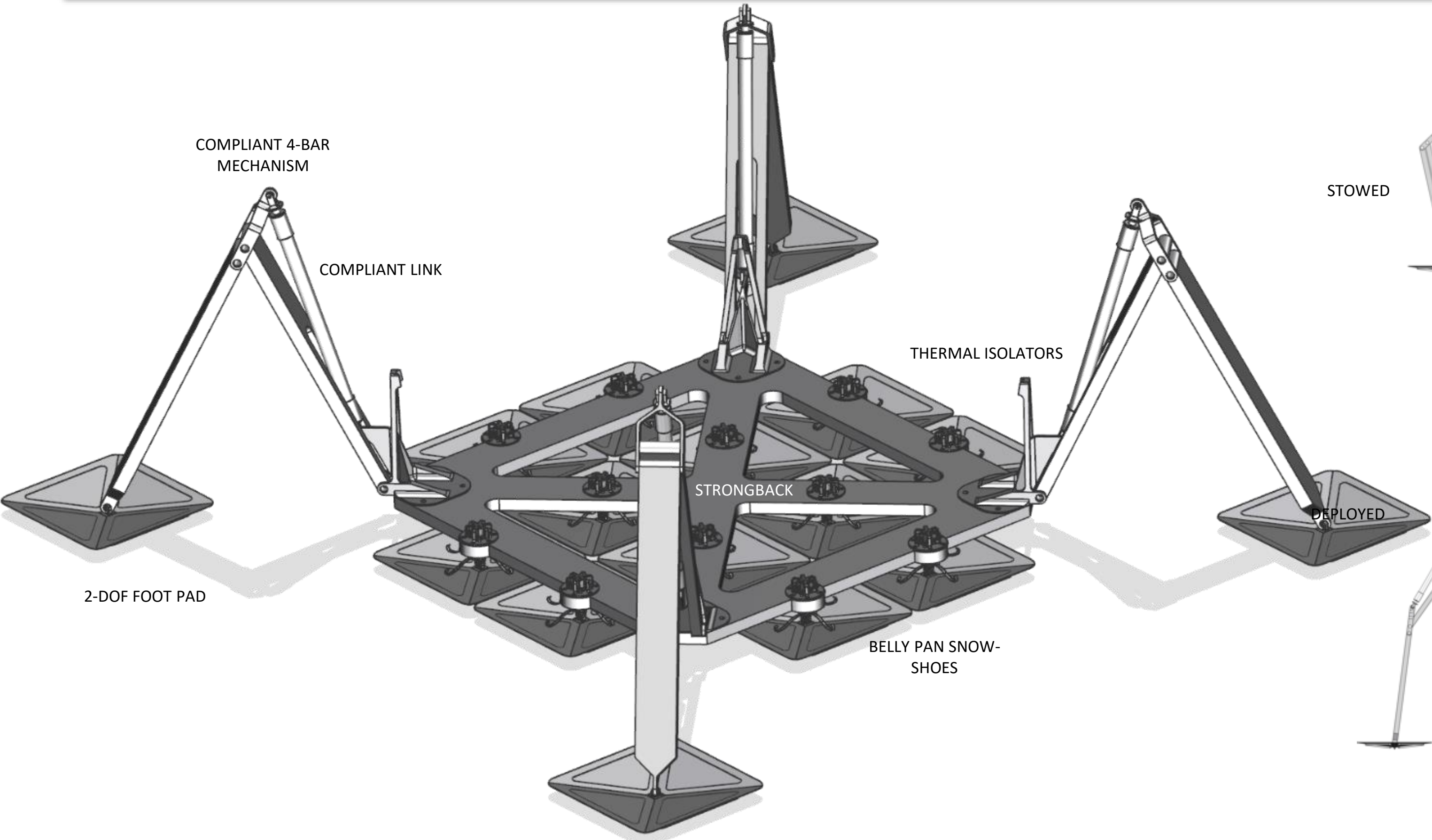
-highly adaptable
-can handle high slopes, reliefs, and FPA
-great stowability
-fights skycrane lateral motion, decreasing surface interactions
-medium mass
-no adjustability

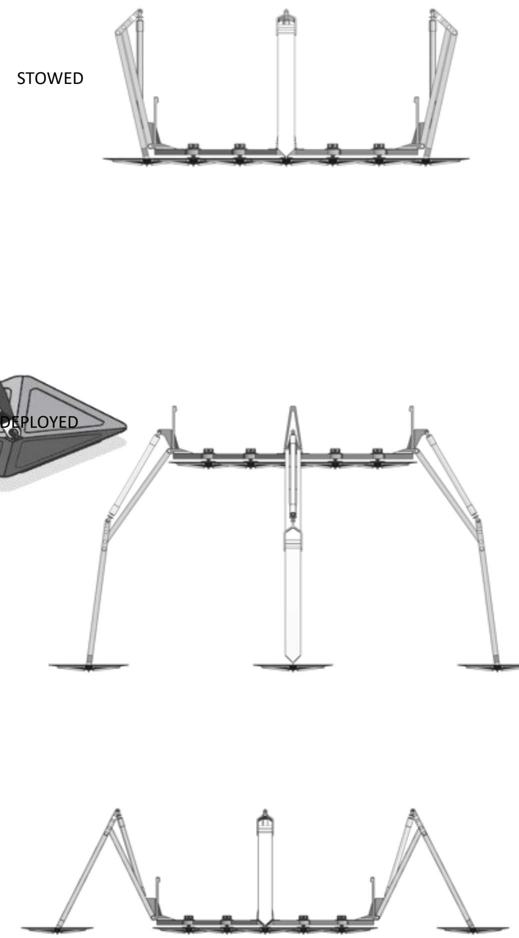
THE HYBRID

-highly adaptable
-adjustable to highly adjustable depending on implementation
-great stowability
-fights skycrane lateral motion, decreasing surface interactions
-robust to unknown unknowns
-can alter initial state to allow in-situ trading of relief capability vs stability
-increased mass



Touchdown System Concept

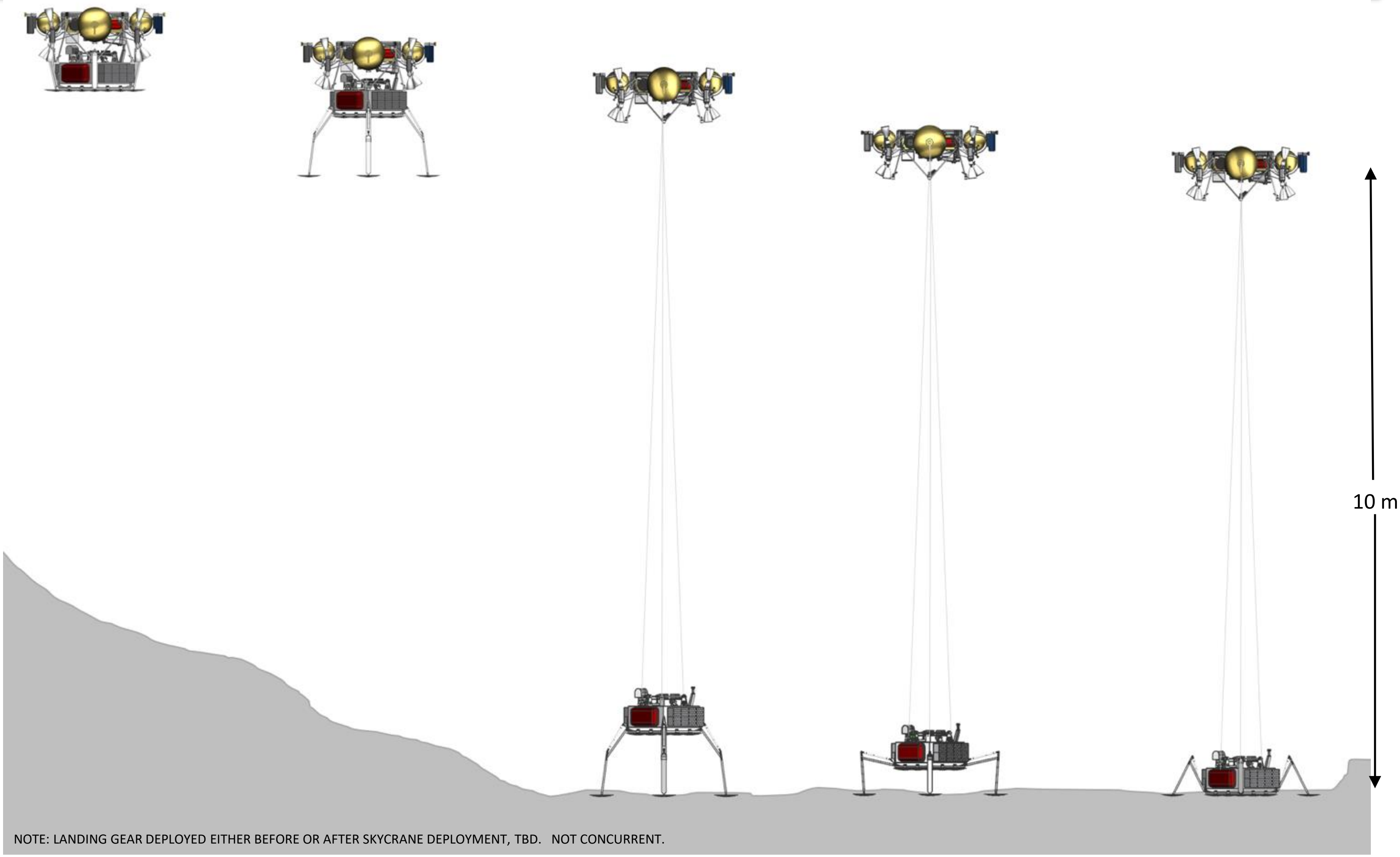




-Narrow 4-Bar mechanism provides near vertical motion of foot pads

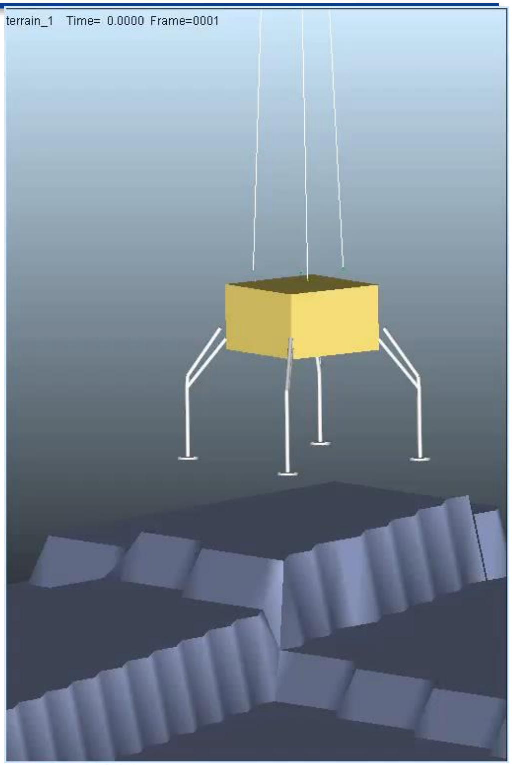
-Compliant element avoids kinematic lock-up in foot stuck scenarios (does not require sliding of feet on surface for functionality)

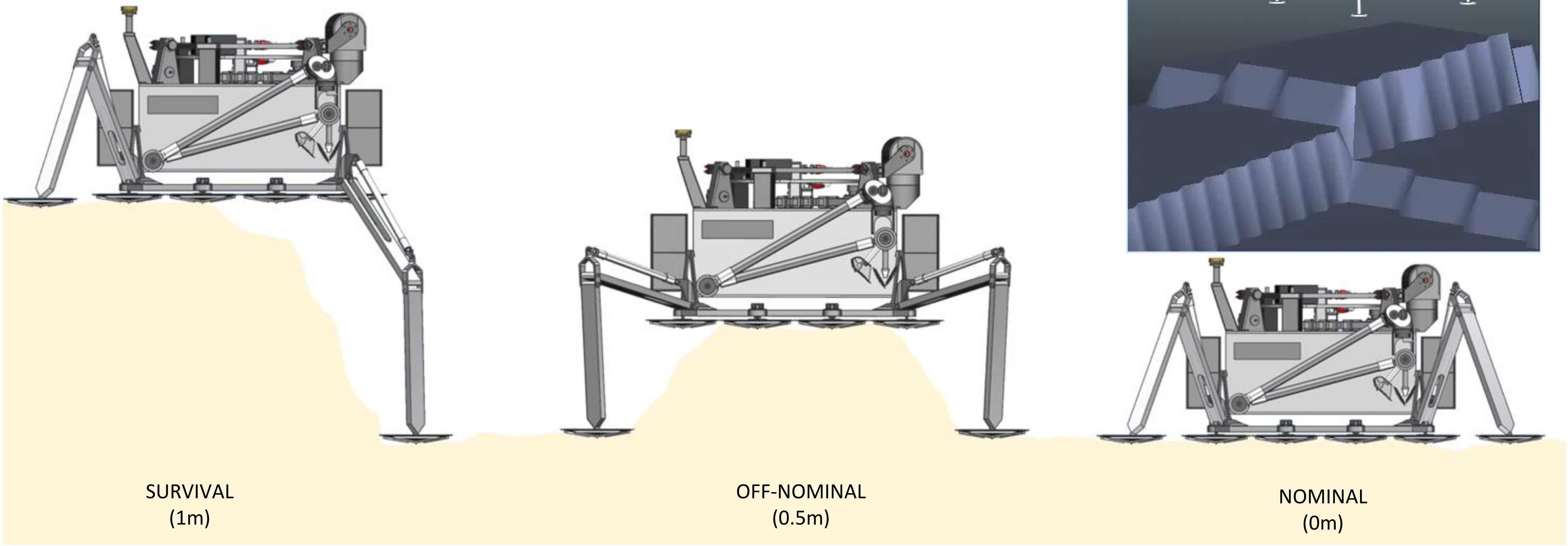
Europa Lander Concept - Touchdown System Operations



Europa Lander Concept - Touchdown Stabilizer Performance

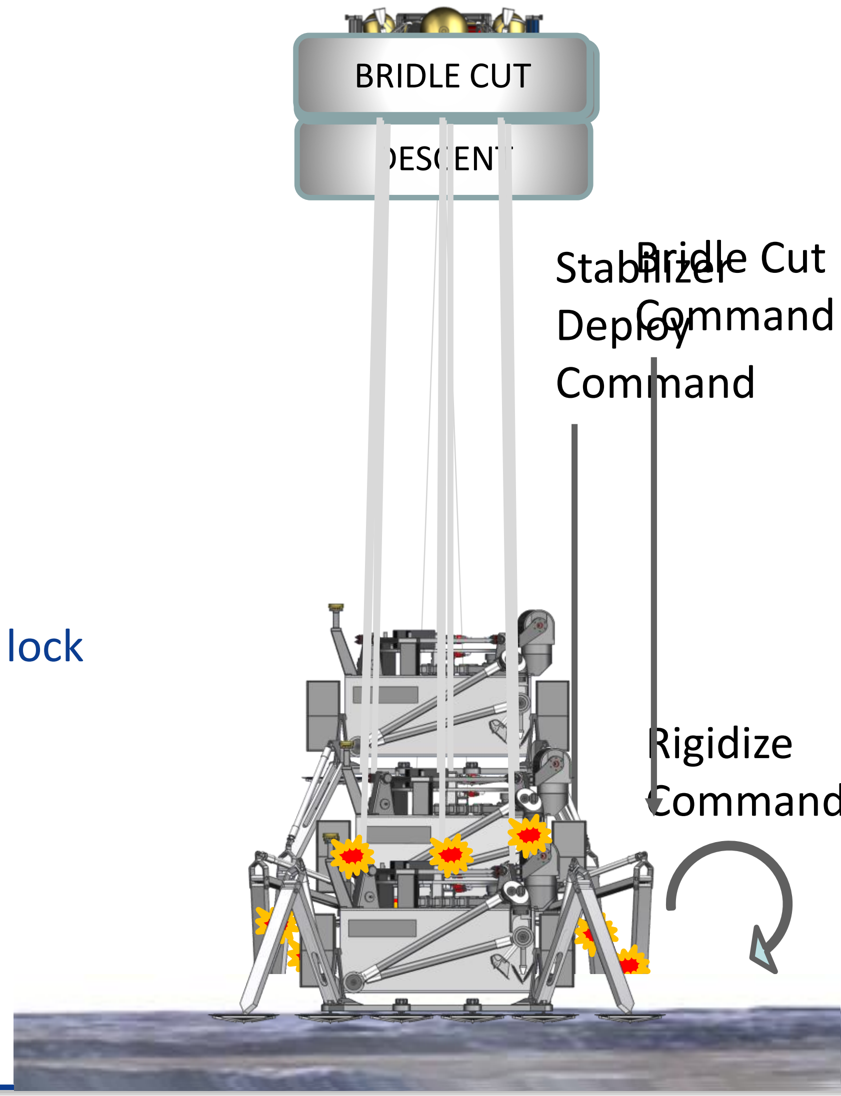
- Max Vertical Descent Rate: 0.8m/s
- Max Lateral Descent Rate: 0.3 m/s
- Max Landing Path Angle: 30 deg
  - Equivalent to 0.5m/s vert/0.3m/s lateral
- <5 deg vault tilt expected





Touchdown System Concept of Operations

- Descent
  - DS commands stabilizer deployment
  - Lander executes stabilizers deployed
- Initial Stabilizer Contact
  - No DS or Lander state change
- Conform
  - Lander stabilizers begin to offload
  - No DS or Lander state change
- Rigidize
  - Lander bellypan sensor triggers pose lock
  - DS detects Lander off load
- Bridle Cut
  - DS commands bridle cut
  - Lander executes bridle cut



Conclusions

- The Passive Adaptable touchdown system achieves the design goals
  - Adapts to Large terrain relief (on the order of ½ lander length scale)
  - Maintains a quasi-level lander body
  - Accommodates the Sky Crane landing system

- The touchdown system inherits its concept of operations from previous successful landings

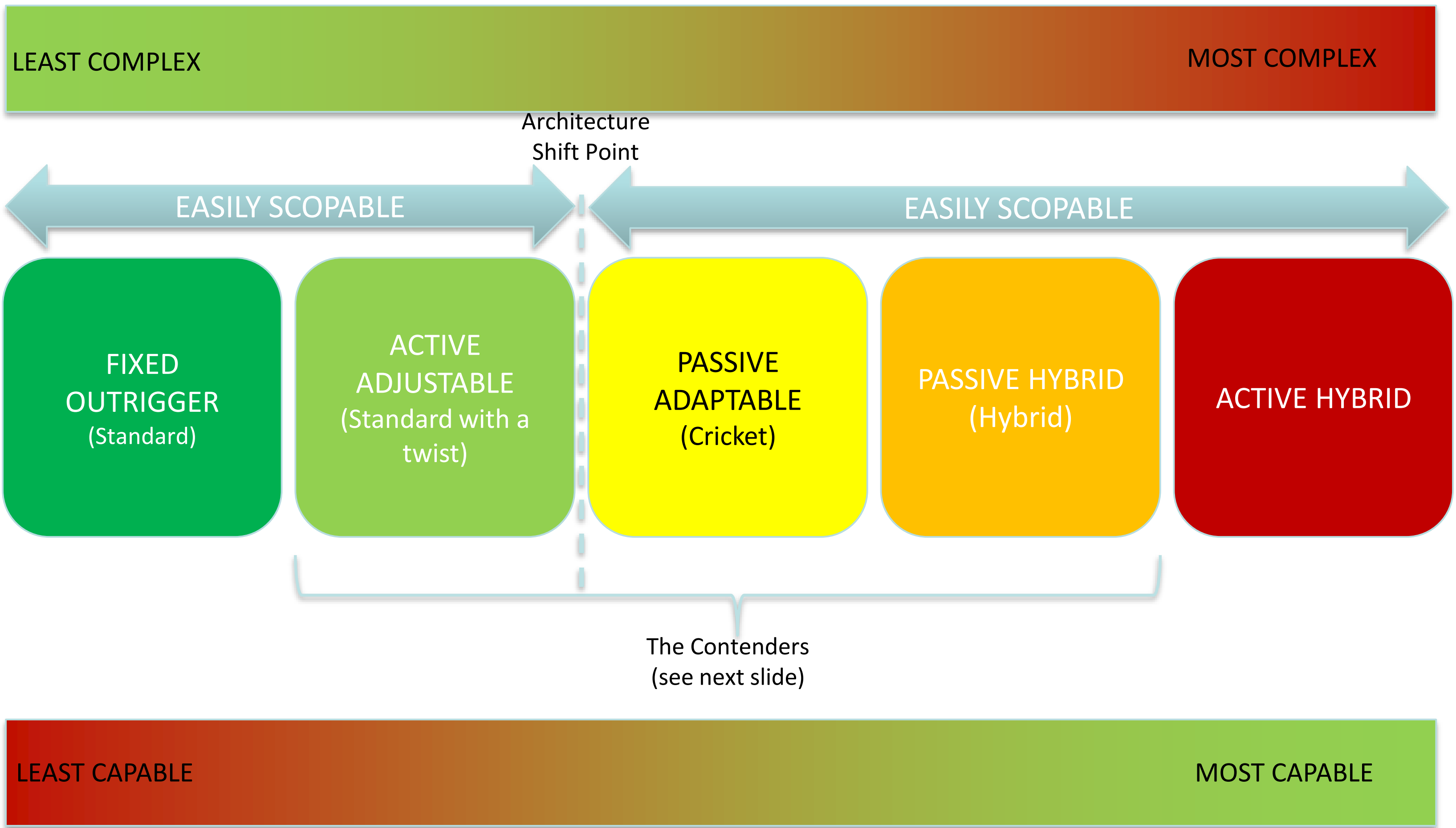
- The Passive Adaptable touchdown system meets the needs of the Europa Lander Concept

Backup After Here

Types of Adaptable/Adjustable Lander

- Standard Legs
- Passive Adaptable
  - Passive, peri-landing, adaptable
  - Fixed, post-landing, non-adjustable
  - Posed with respect to gravity…fixed
- Active Adjustable (AA)
  - Fixed, peri-landing, non-adaptable
  - Active, post-landing, adjustable
  - Posed w/respect to local surface…adjustable to gravity
- Passive Hybrid
  - Passive, peri-landing, adaptable
  - Active, post-landing, adjustable
  - Posed w/respect to gravity….adjustable to local surface
- Active Hybrid
  - Active, peri-landing, adaptable (force feedback)
  - Active, post-landing, Adjustable
  - Posed w/respect to gravity….adjustable to local surface

Graduated Relative Difficulty vs Capability Scale



Important to note that it is still scopable across the architecture shift point, it is just a larger architectural shift