Landing on Europa: Key Challenges and an Architecture Concept

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Motivation

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Initial Condition
High altitude, moving fast & toward the landing site, uncertain where we are

Final Condition
Gently deliver the payload to a safe and scientifically interesting location

Nav uncertainty

Nav uncertainty + burn dispersions

V = large

V = small

V ≃ 0

VH ≃ 0

CHECKLIST FOR SAFE LANDING ON EUROPA
1. Slow down
2. Figure out where we are
3. Fly to target
4. Find safe place to land and go there
5. Gently deliver payload
**Step 1: Slow Down**

**Deorbit**
- Starts at ~6 km altitude
- Reduces surface-relative velocity from 1,850 to 100 m/s
- Star 48 class fixed-nozzle SRM
- Burns over 1,500 kg of fuel in a little over 1 min
- Thrust vector control via 4x MR-104 engines
- 5-DOF control: no downrange control but known cross-track and radial position errors are removed
- Burn time error results in ±4 km burn-out position error
Step 2: Figure Out Where We Are

Initial Localization
- Seeded with lidar altimetry
- Map-relative position obtained via landmark matching of on-board camera images to reconnaissance maps fromClipper
- Surface-relative velocity obtained via feature tracking = visual odometry
- Enables ~100 m navigation error at touchdown
Step 3: Fly to Target

Powered Approach
- Vehicle follows 6-DOF profile using MSL-heritage polynomial guidance
- Guidance steers vehicle to altitude ~1 km above landing site with $V_H = 0$
- 6-DOF control via 8x Descent Engines
Position Dispersions Before & After

- Map-relative localization and visual odometry shrink knowledge error
- Powered approach cleans up SRM burnout control error
Step 4: Find a Safe Place To Land and Go There

Hazard Detection & Avoidance
- Lidar scans a 100 m x 100 m area
- Hazard detection algorithm locates safest place to land
- Guidance steers vehicle to point directly above target, ≤ 50 m divert
- 6-DOF control via 8x Descent Engines
- Significantly improves chances of achieving safe landing in hazardous terrain
Step 5: Gently Deliver Payload

Sky Crane
- Minimizes site alteration and contamination
- Descent Stage & Lander separate at ~24 m altitude, $V_v = -0.5$ m/s
- Lander deployed on bridle
- Cut bridle, lock pose, Descent Stage flies away & ignites sterilization system
- 6-DOF control via 4x canted Descent Engines to avoid pluming surface

12.3 m
Summary

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