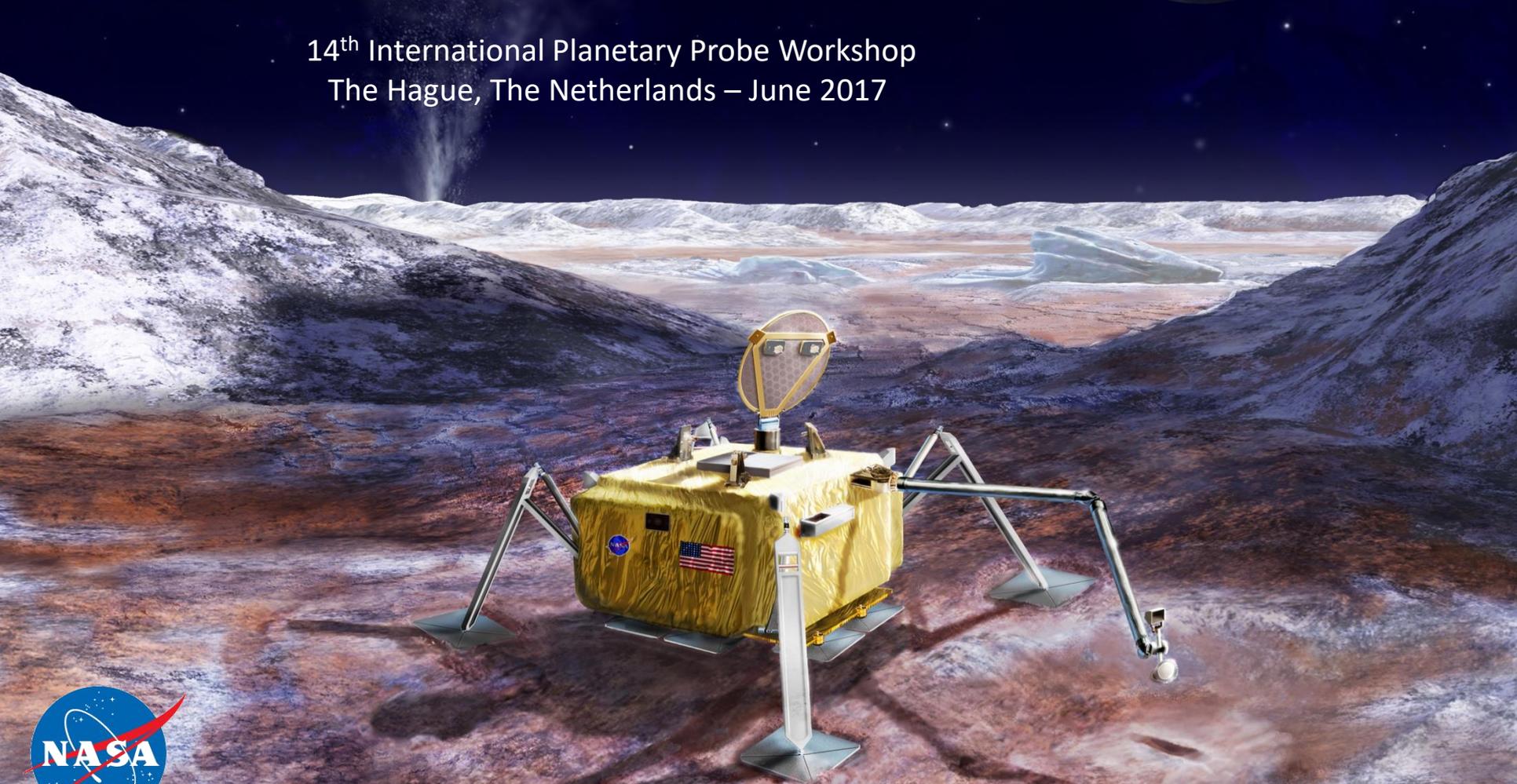


De-orbit, Descent and Landing on Europa: Key Challenges and an Architecture

Aline Zimmer, Devin Kipp, David Skulsky, Miguel San Martin
Jet Propulsion Laboratory
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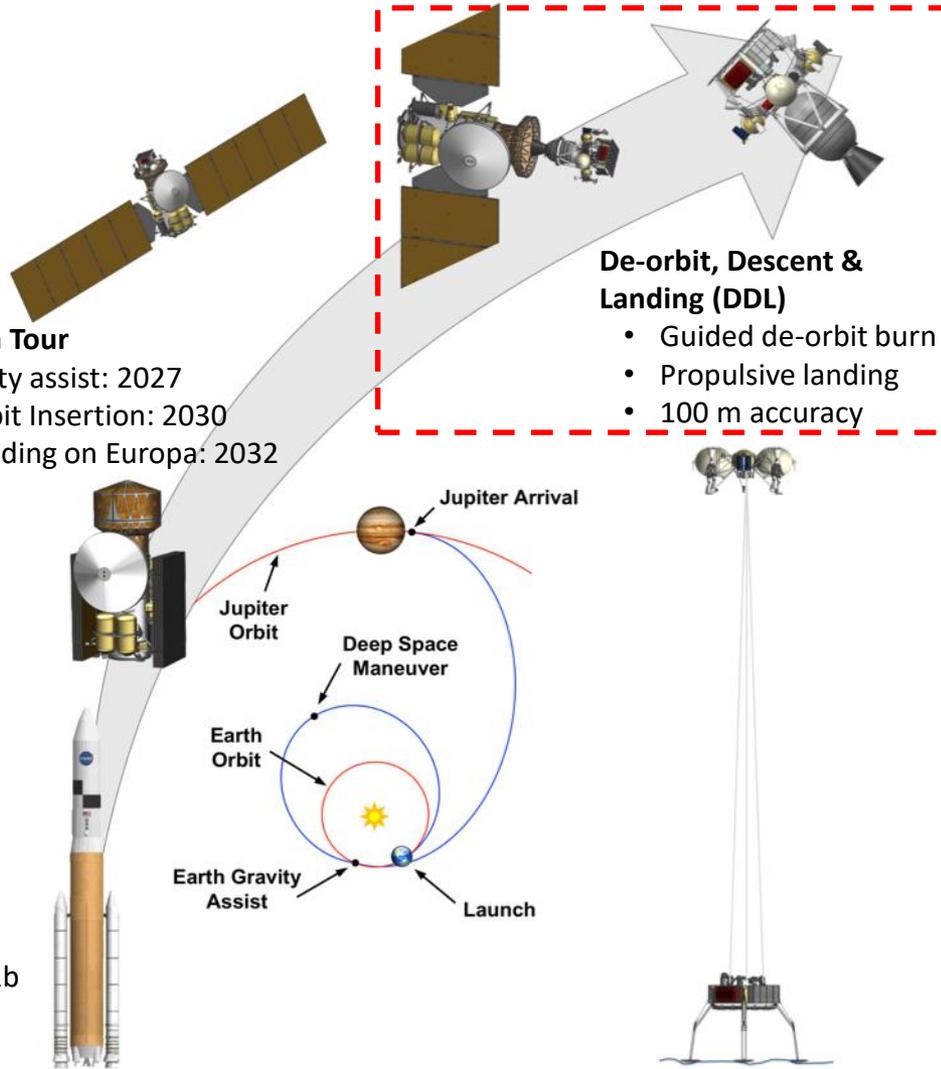
Europa Lander Mission Concept

Cruise & Jovian Tour

- Earth gravity assist: 2027
- Jupiter Orbit Insertion: 2030
- Earliest landing on Europa: 2032

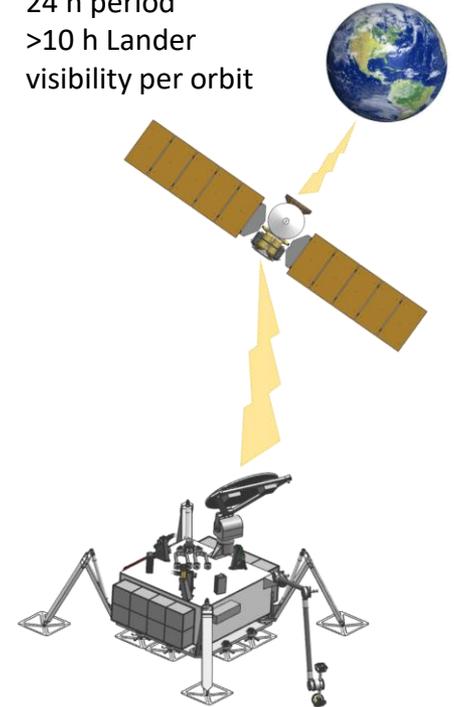
Launch

- SLS Block 1b
- 2025



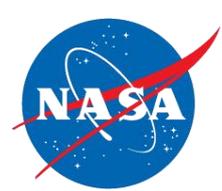
Carrier Relay Orbit

- 24 h period
- >10 h Lander visibility per orbit

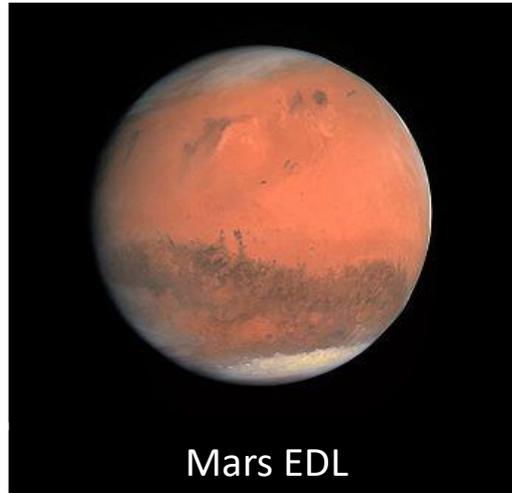


Surface Mission

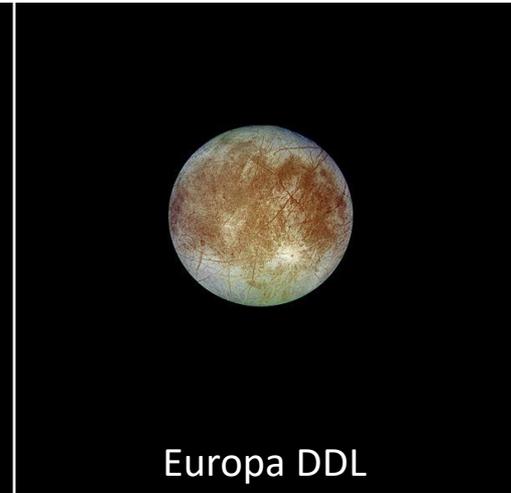
- 20+ days surface mission
- 5 samples
- Relay communications through Carrier or Clipper (backup)
- 3-4 Gbit data return
- 45 kWh battery



Landing on Mars vs Landing on Europa



Mars EDL

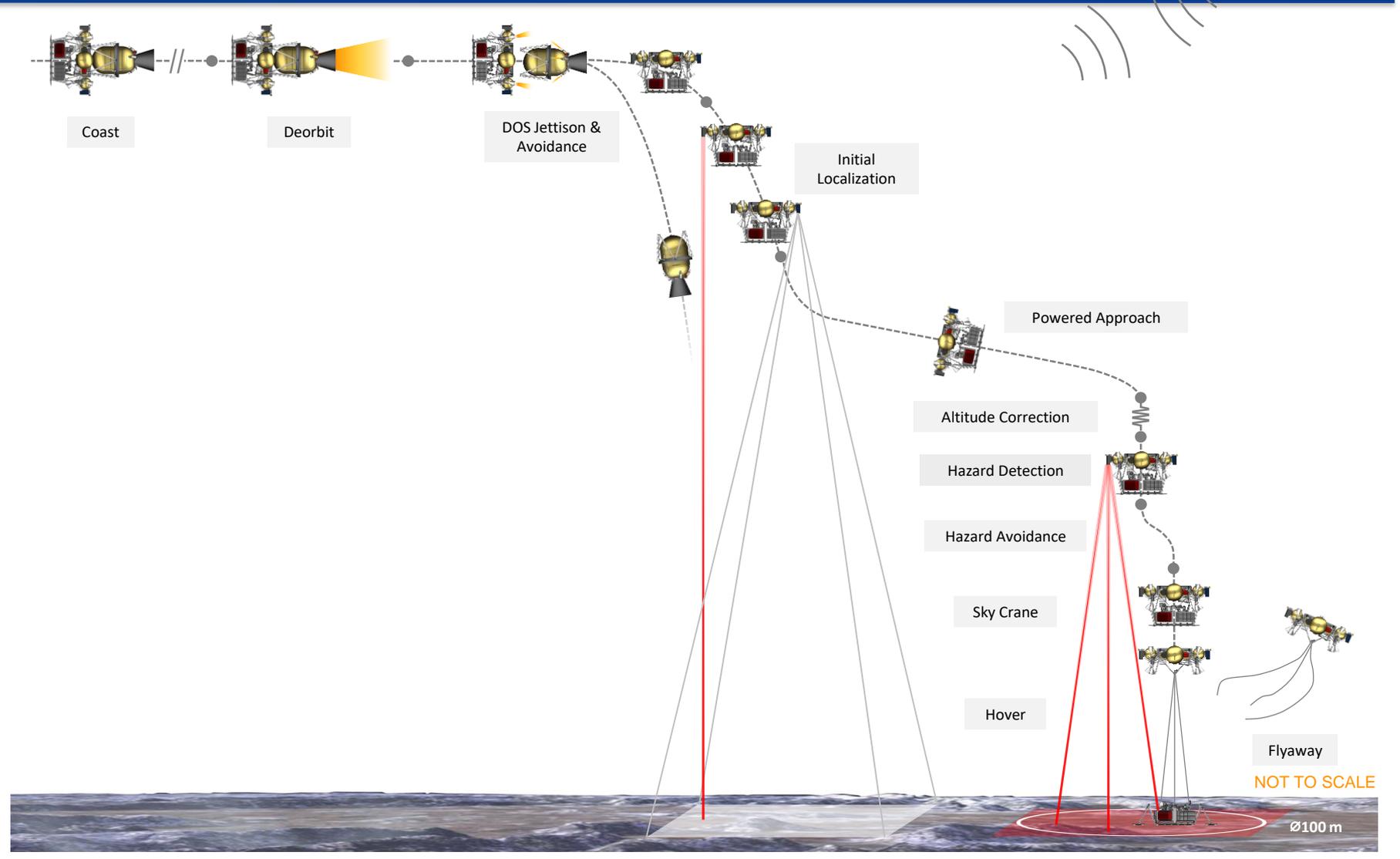
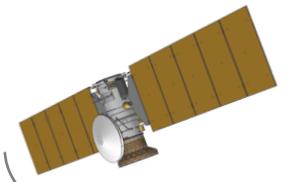


Europa DDL

Primary method of deceleration	Atmospheric drag (aerothermal, parachute)	Propulsive
Environment challenges	Atmosphere (wind, dust, temperature)	Radiation
Landing ellipse control	Inertial & entry guidance	Precision landing via terrain-relative navigation
Planetary protection	Well understood & demonstrated	New and extremely challenging
Terrain knowledge	Global imaging of Mars, much at high resolution	Practically none

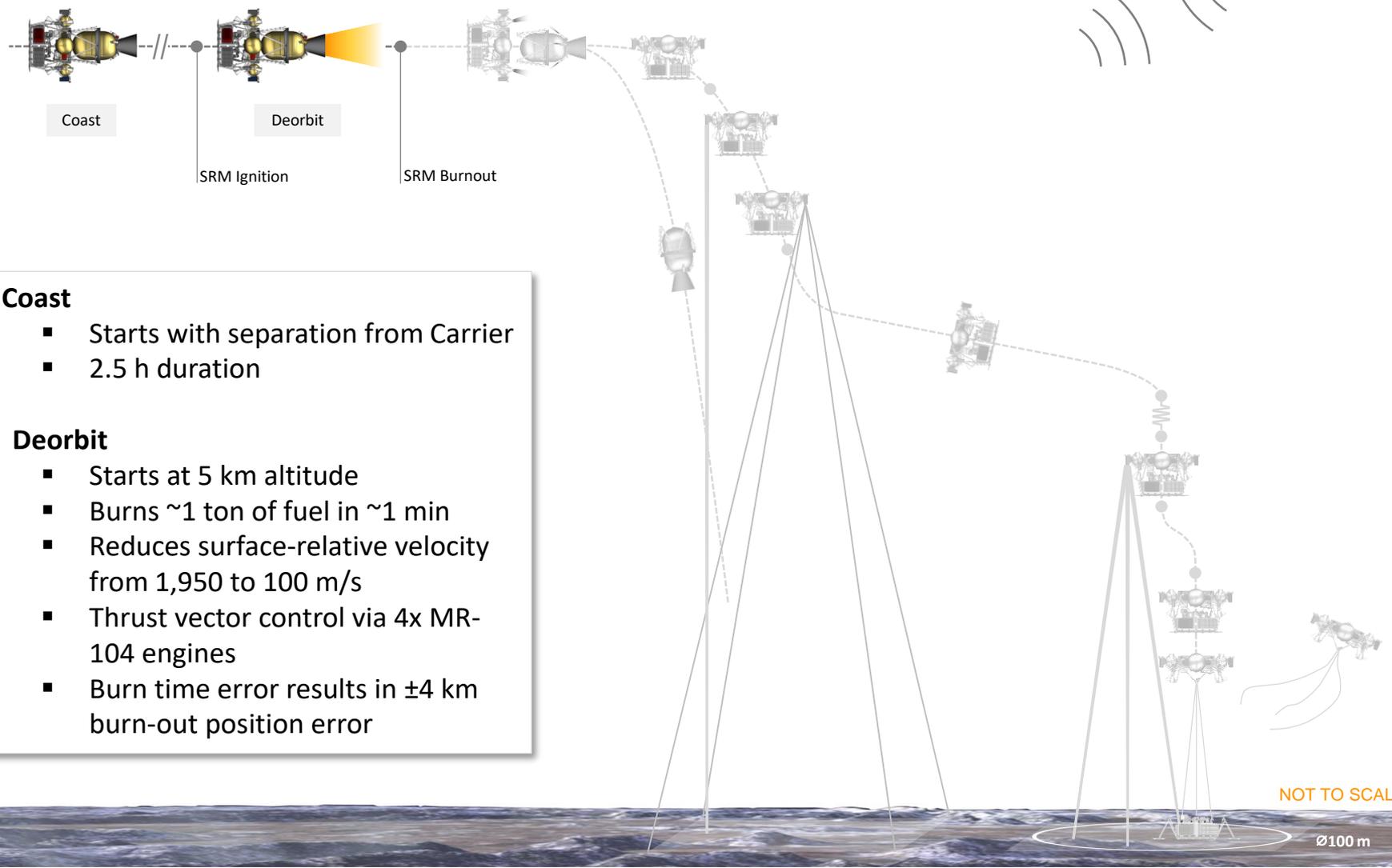
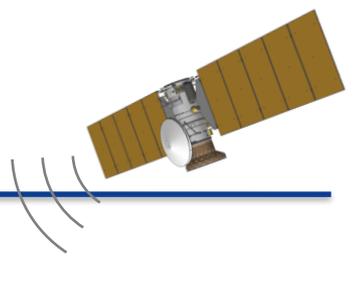


DDL Concept of Operations





DDL Concept of Operations



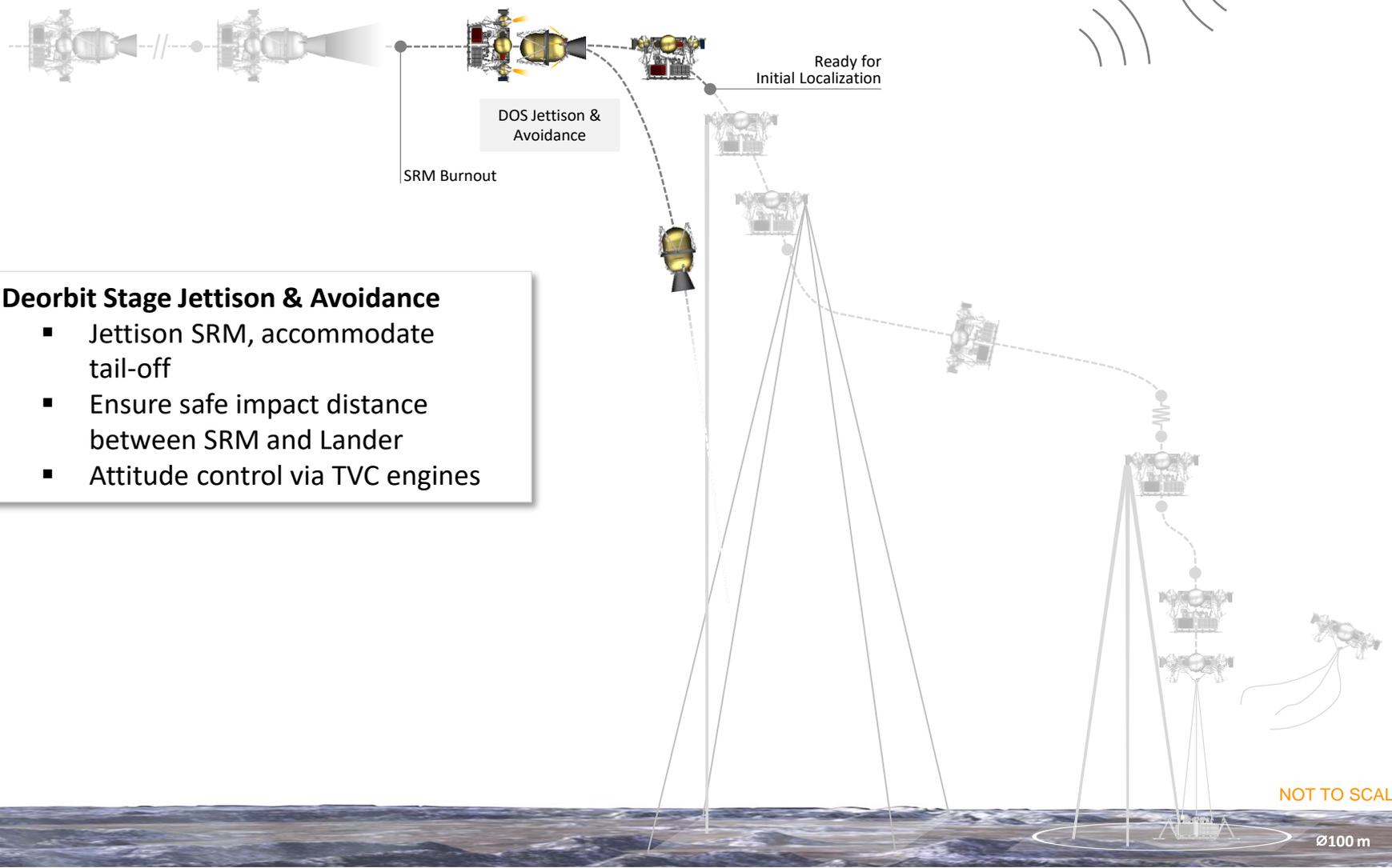
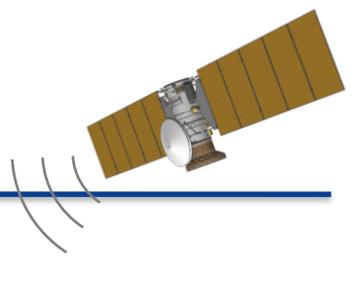
- Coast**
- Starts with separation from Carrier
 - 2.5 h duration
- Deorbit**
- Starts at 5 km altitude
 - Burns ~1 ton of fuel in ~1 min
 - Reduces surface-relative velocity from 1,950 to 100 m/s
 - Thrust vector control via 4x MR-104 engines
 - Burn time error results in ± 4 km burn-out position error

NOT TO SCALE

Ø100 m



DDL Concept of Operations



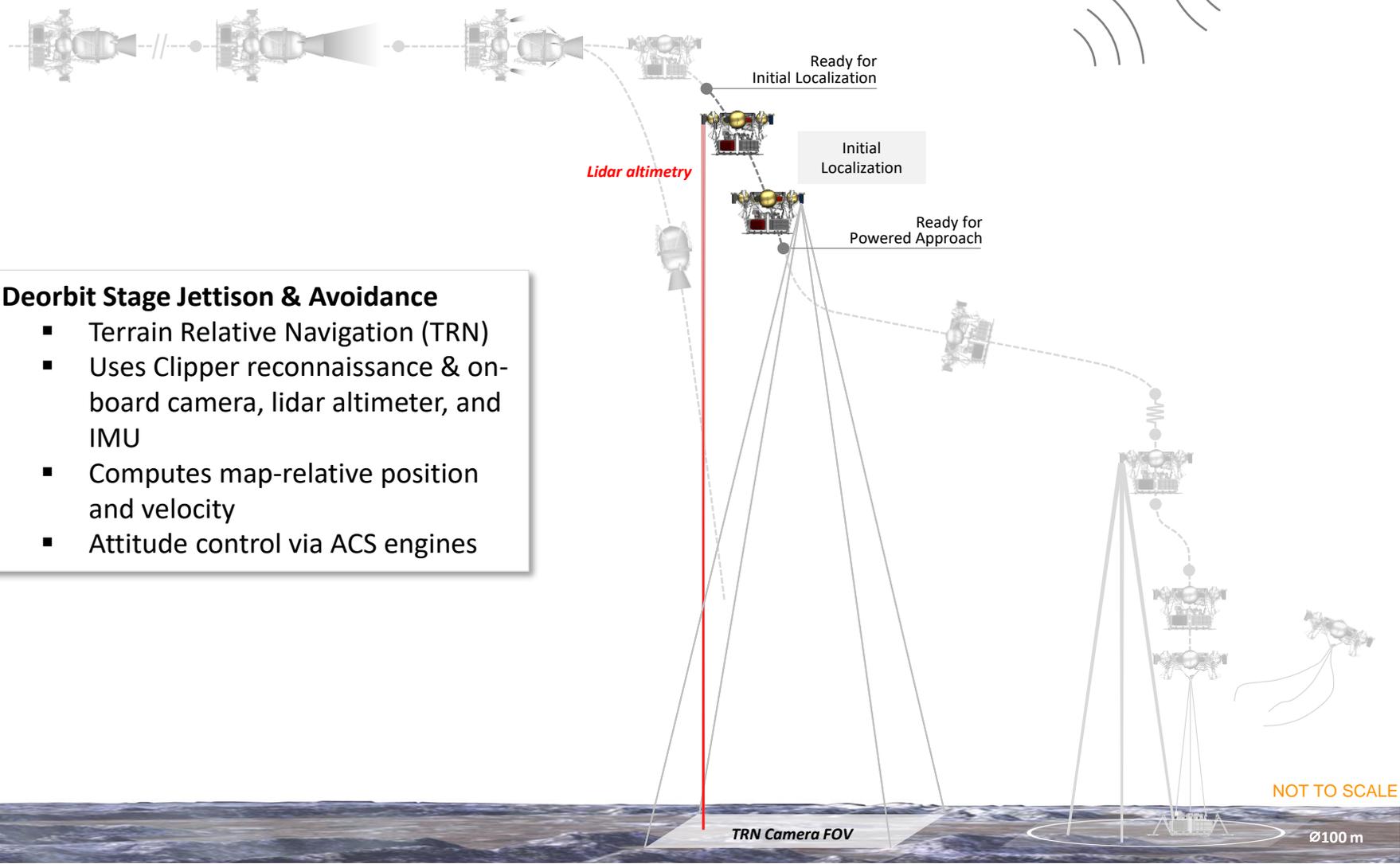
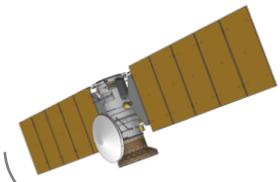
- Deorbit Stage Jettison & Avoidance**
- Jettison SRM, accommodate tail-off
 - Ensure safe impact distance between SRM and Lander
 - Attitude control via TVC engines

NOT TO SCALE

Ø100 m



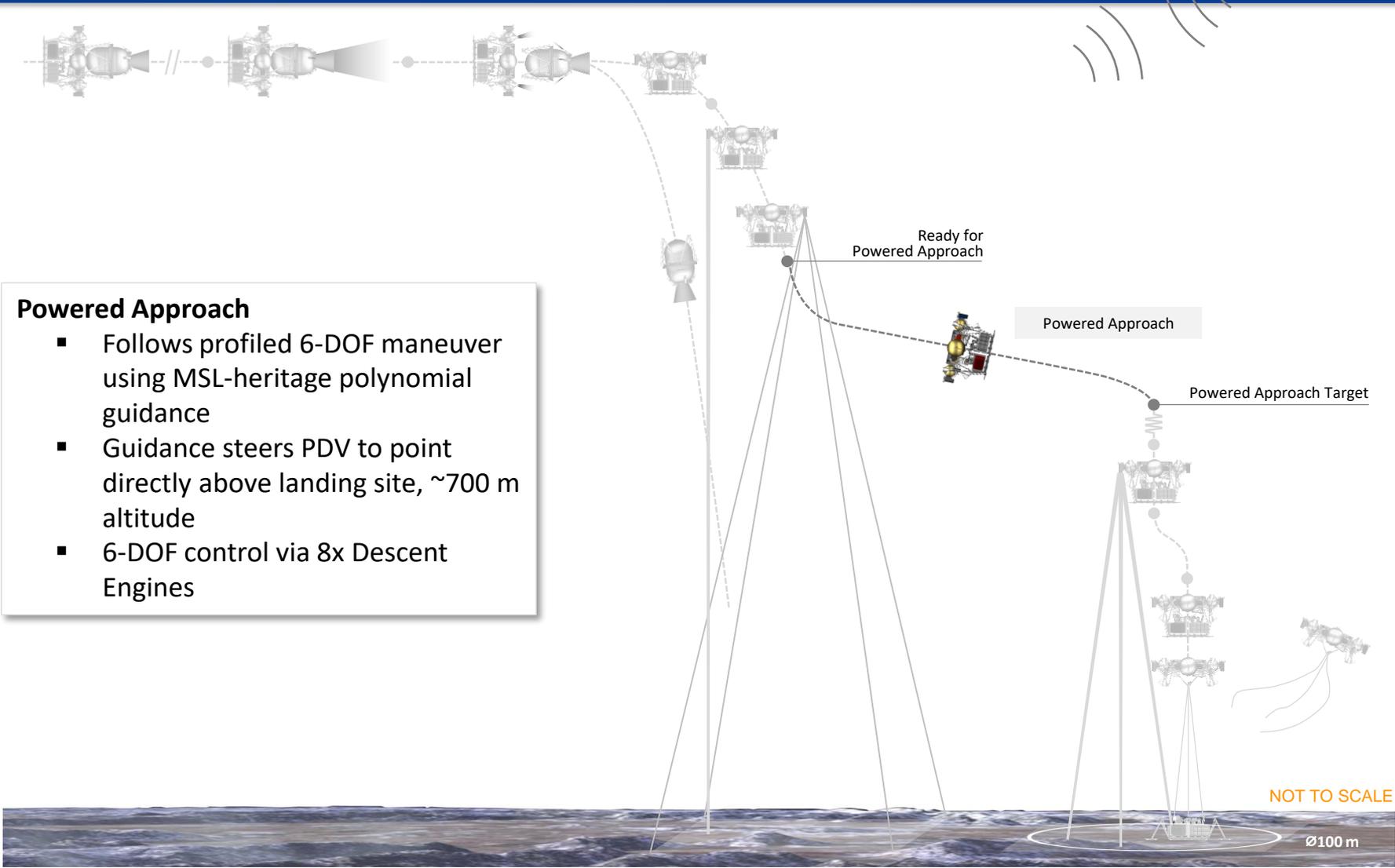
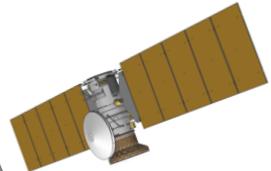
DDL Concept of Operations



- Deorbit Stage Jettison & Avoidance**
- Terrain Relative Navigation (TRN)
 - Uses Clipper reconnaissance & on-board camera, lidar altimeter, and IMU
 - Computes map-relative position and velocity
 - Attitude control via ACS engines

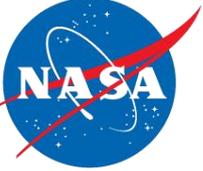


DDL Concept of Operations

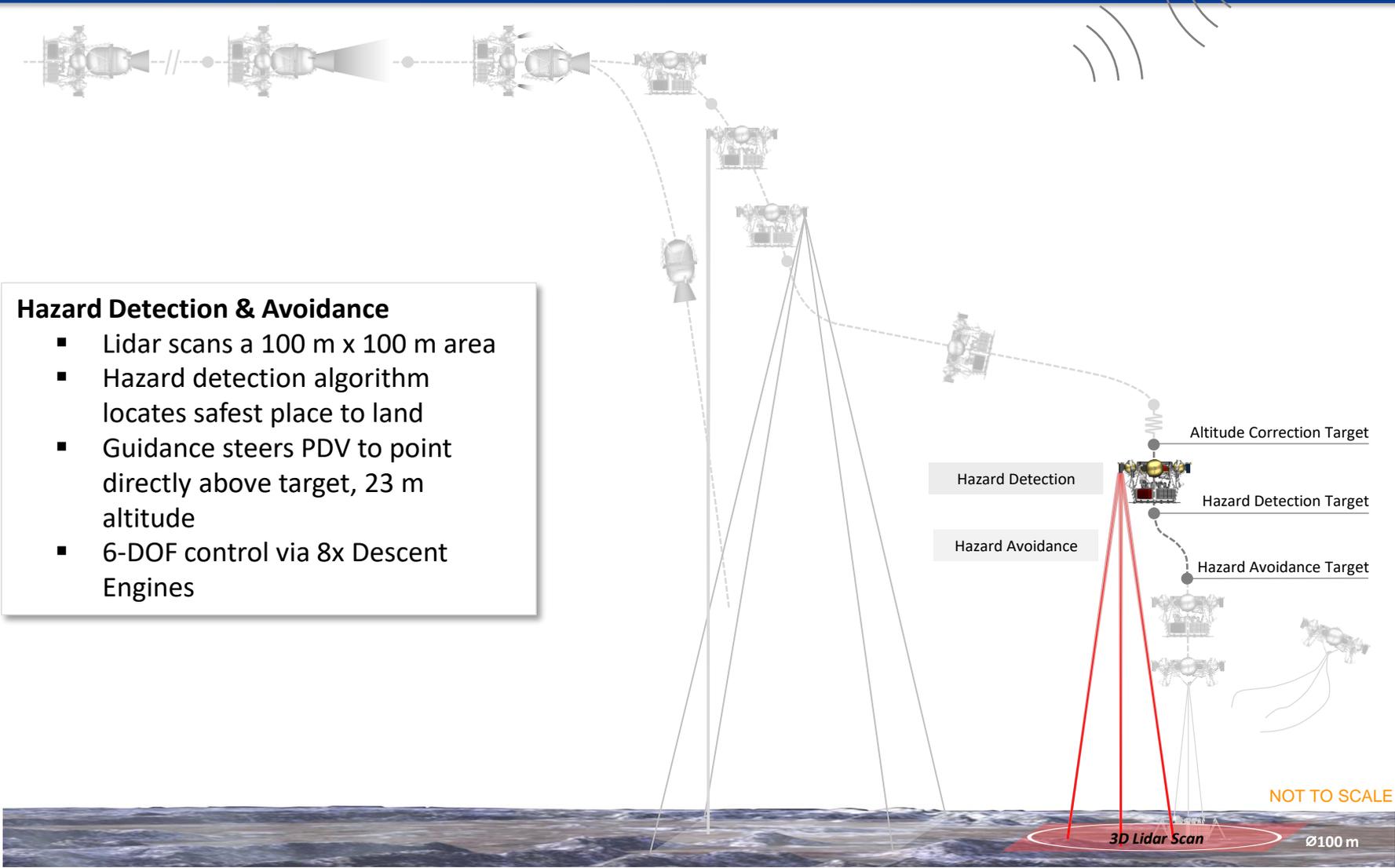
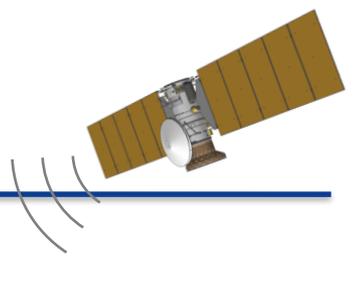


Powered Approach

- Follows profiled 6-DOF maneuver using MSL-heritage polynomial guidance
- Guidance steers PDV to point directly above landing site, ~700 m altitude
- 6-DOF control via 8x Descent Engines



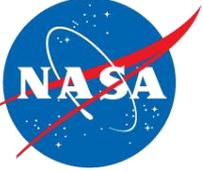
DDL Concept of Operations



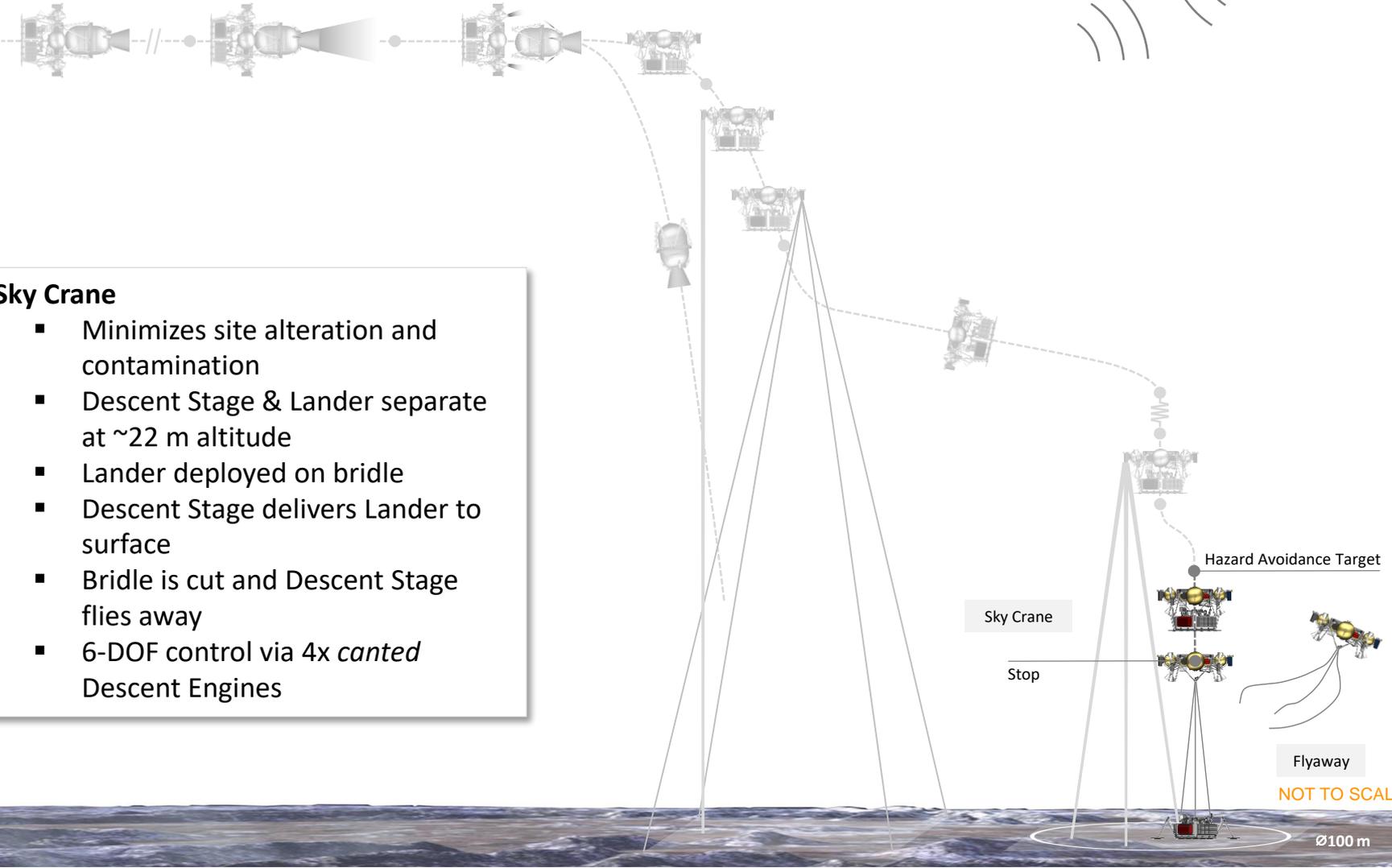
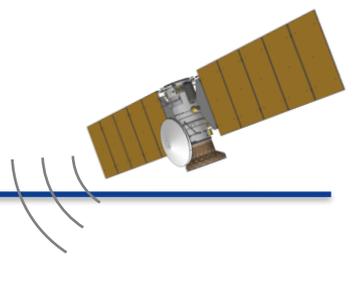
- Hazard Detection & Avoidance**
- Lidar scans a 100 m x 100 m area
 - Hazard detection algorithm locates safest place to land
 - Guidance steers PDV to point directly above target, 23 m altitude
 - 6-DOF control via 8x Descent Engines

NOT TO SCALE

3D Lidar Scan Ø100 m



DDL Concept of Operations



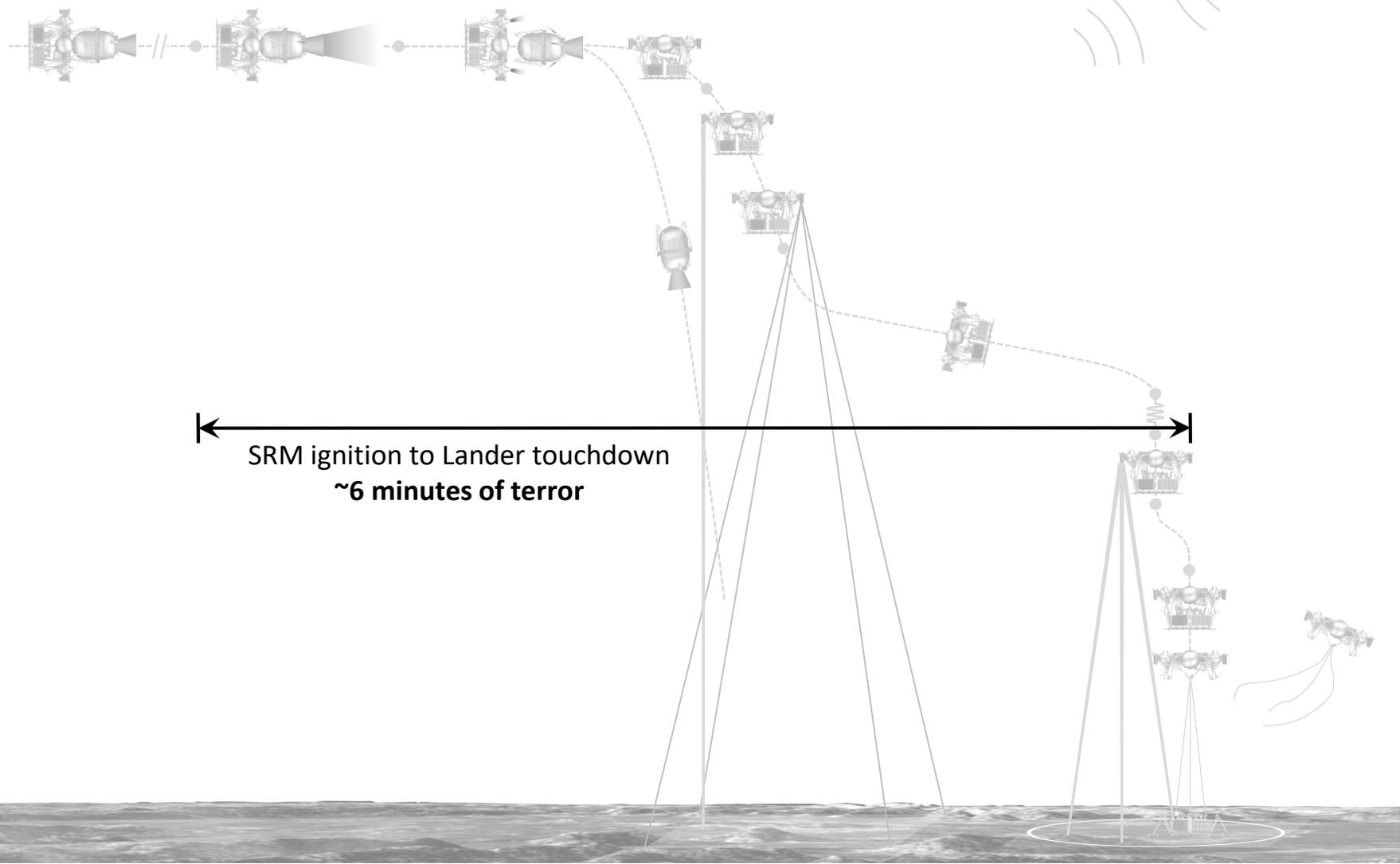
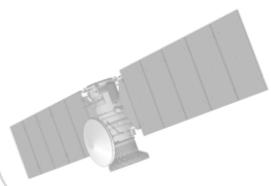
- Sky Crane**
- Minimizes site alteration and contamination
 - Descent Stage & Lander separate at ~22 m altitude
 - Lander deployed on bridle
 - Descent Stage delivers Lander to surface
 - Bridle is cut and Descent Stage flies away
 - 6-DOF control via 4x *canted* Descent Engines

NOT TO SCALE

Ø100 m



DDL Concept of Operations

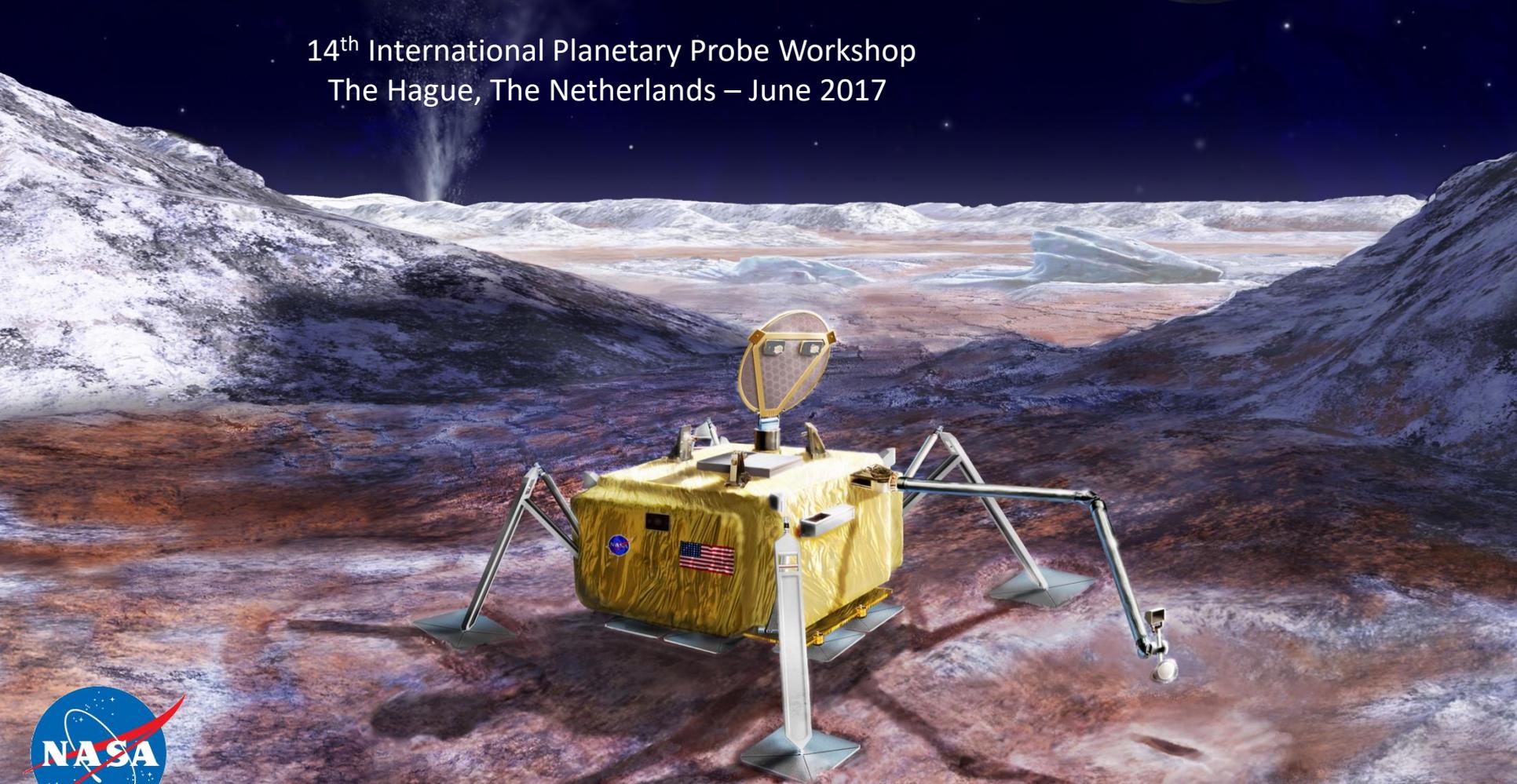


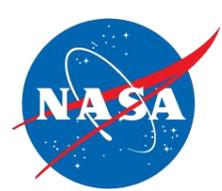
← SRM ignition to Lander touchdown
~6 minutes of error →

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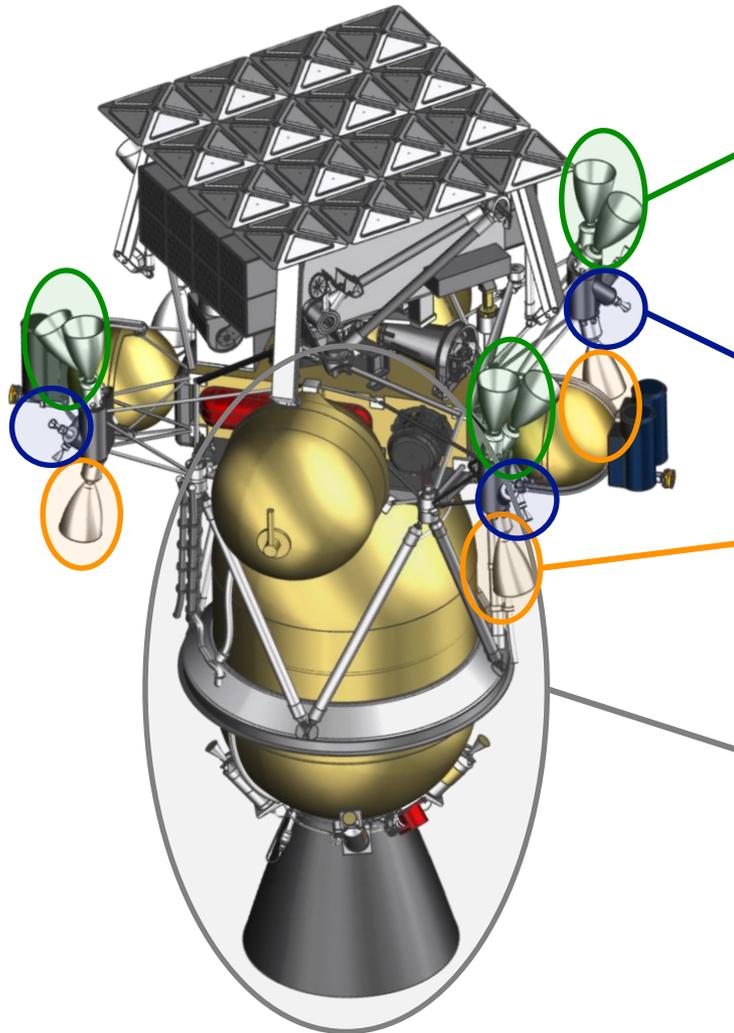
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Deorbit Vehicle Concept: Engine Sets



Descent Engines

- 4x MR-104 canted 5°
- 4x MR-104 canted 30°
- 600 N thrust per engine

ACS Thrusters

- 8x MR-106
- 22 N thrust per engine

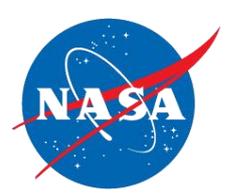
TVC Engines

- 4x MR-104
- 600 N thrust per engine

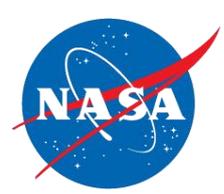
Deorbit Motor

- Star-37 class, fixed-nozzle SRM
- 47 kN average thrust
- 3,700 kNs total impulse

ACS Attitude Control System
TVC Thrust Vector Control
SRM Solid Rocket Motor



Backup



DDL Concept: Landing Ellipse

