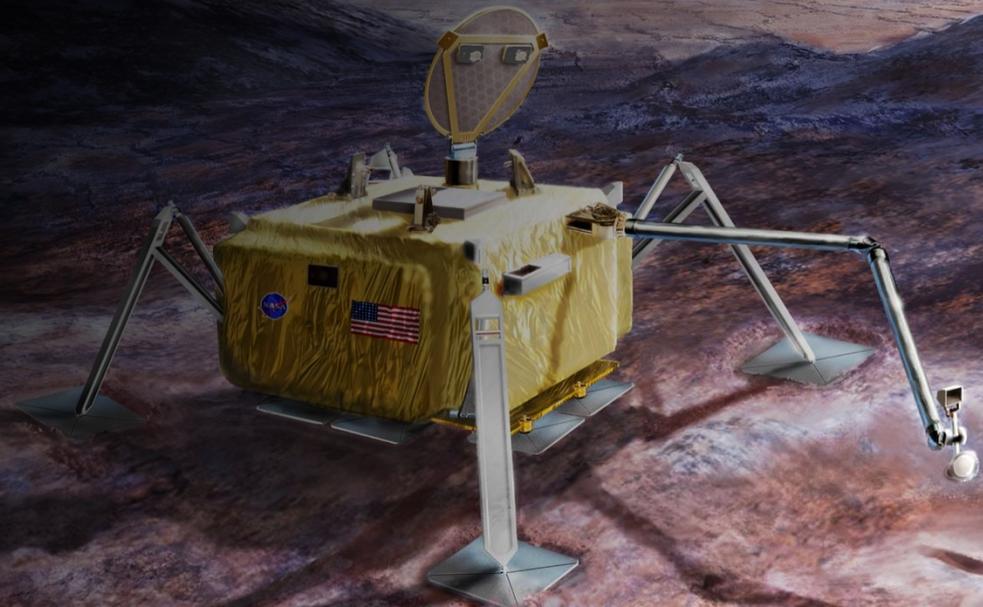


Landing on Europa: Key Challenges and Architecture Concept

Aline Zimmer, David Skulsky, Miguel San Martin, Steve Sell, Tejas Kulkarni, Devin Kipp
Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, USA

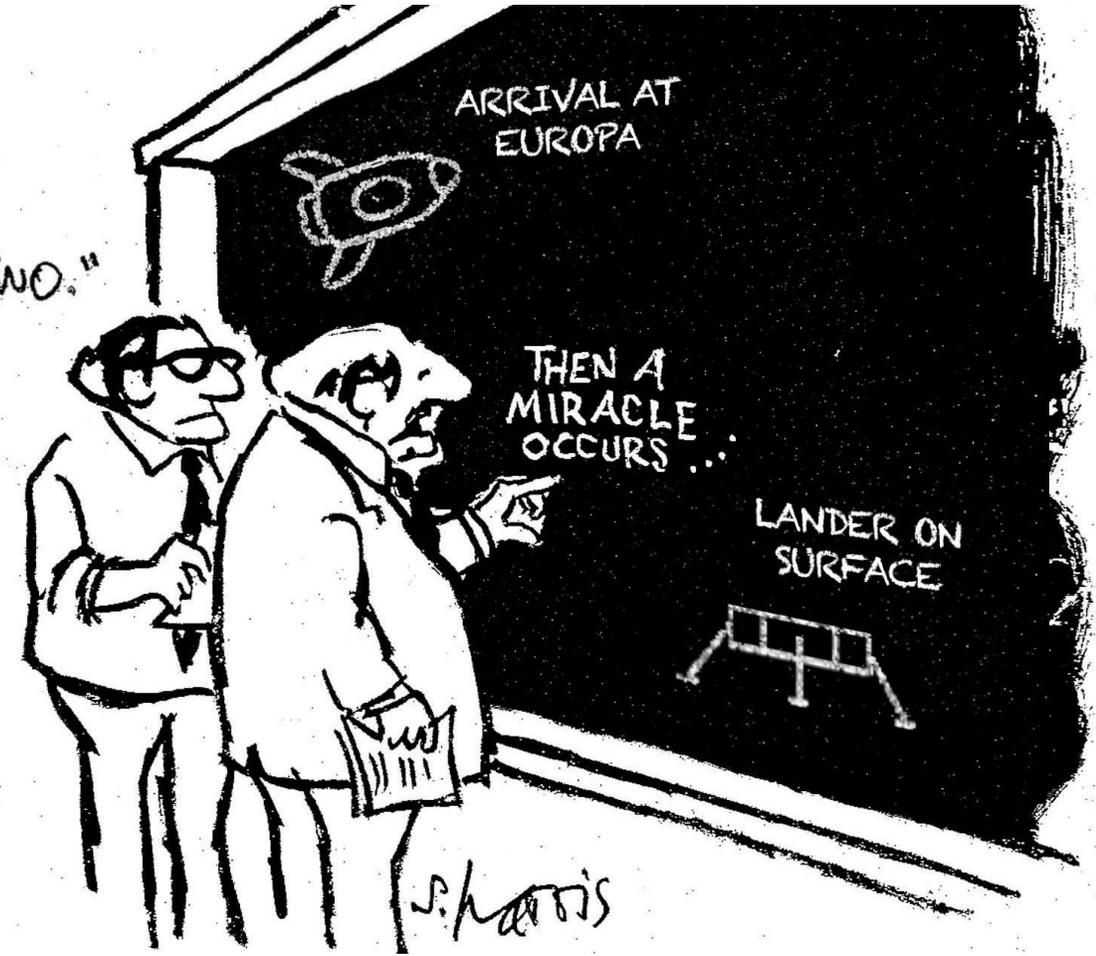
15th International Planetary Probe Workshop
Boulder, Colorado
June 2018





Motivation

"I THINK YOU SHOULD BE MORE EXPLICIT HERE IN STEP TWO."



OKAY, I'LL EXPLAIN...

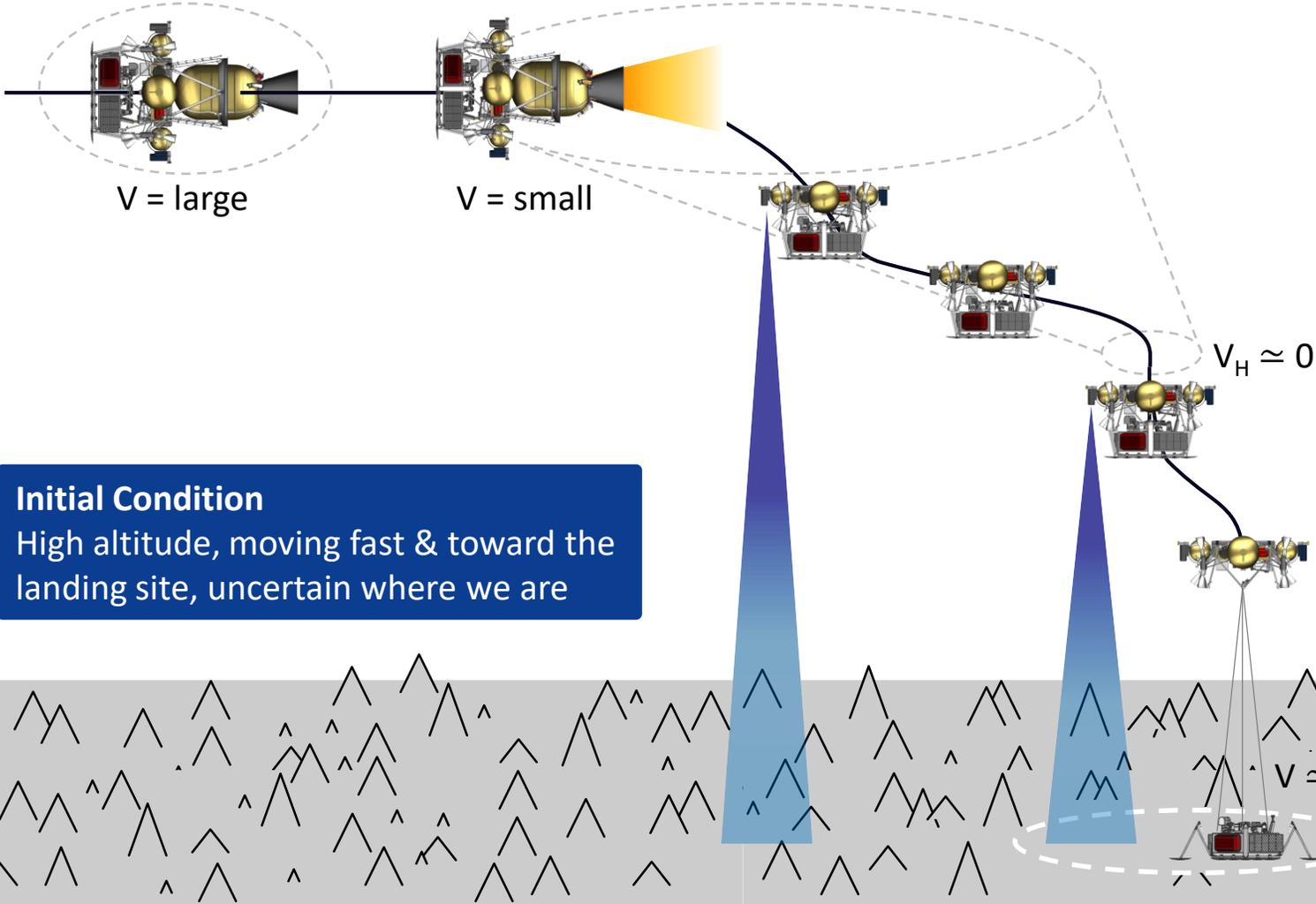
Based on cartoon by Sidney Harris, original image credit © Sydney Harris



Breaking Down "Step Two"

Nav uncertainty

Nav uncertainty + burn dispersions



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

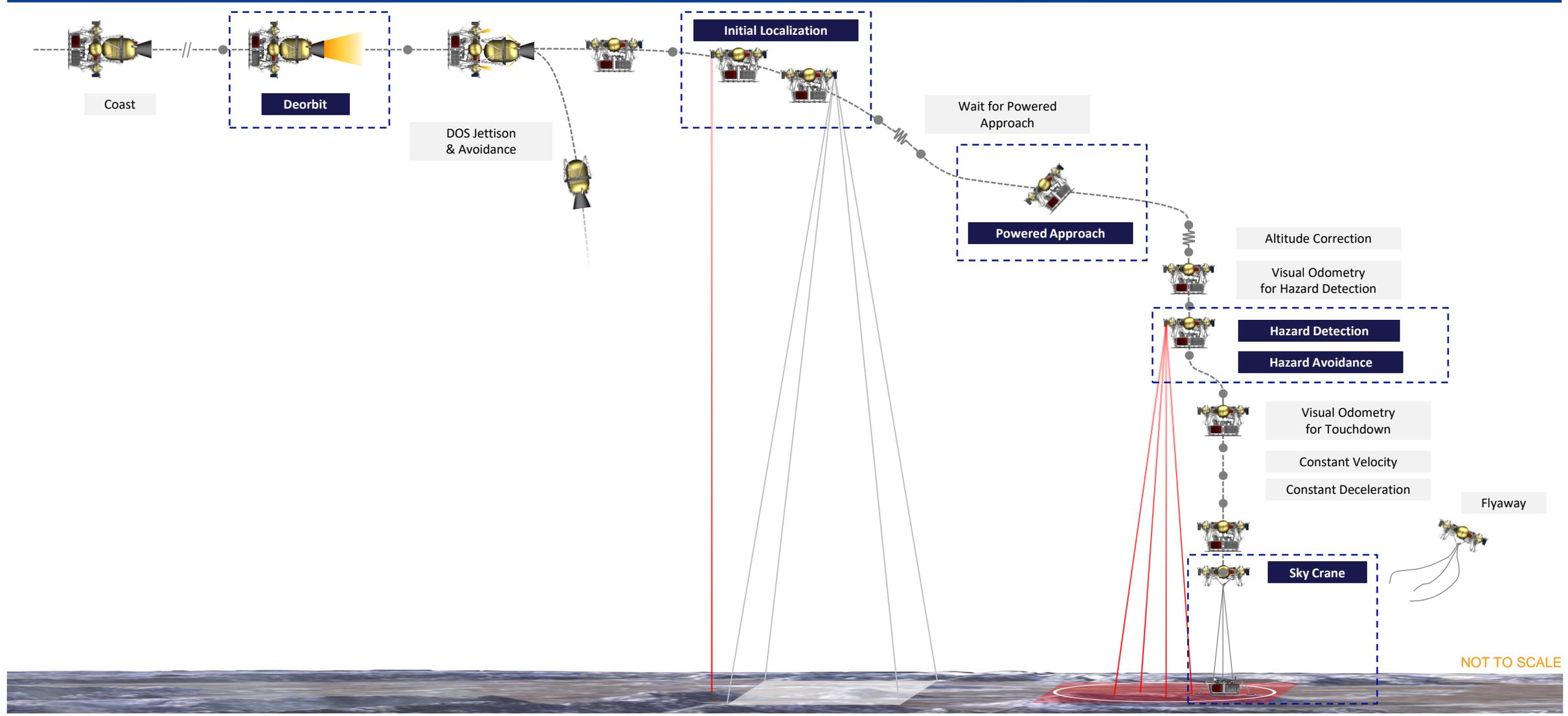
CHECKLIST FOR SAFE LANDING ON EUROPA

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

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

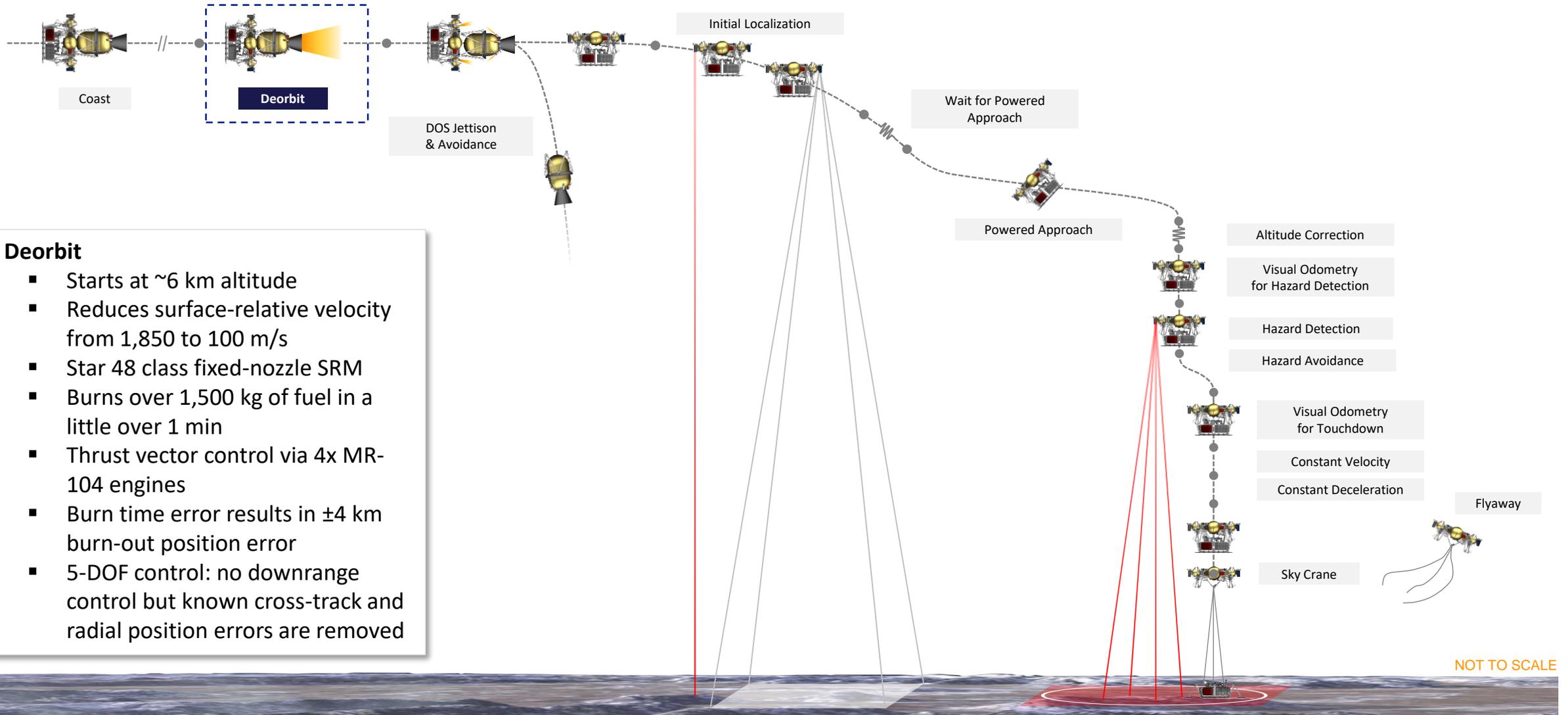


DDL Subphases





1. Slow Down



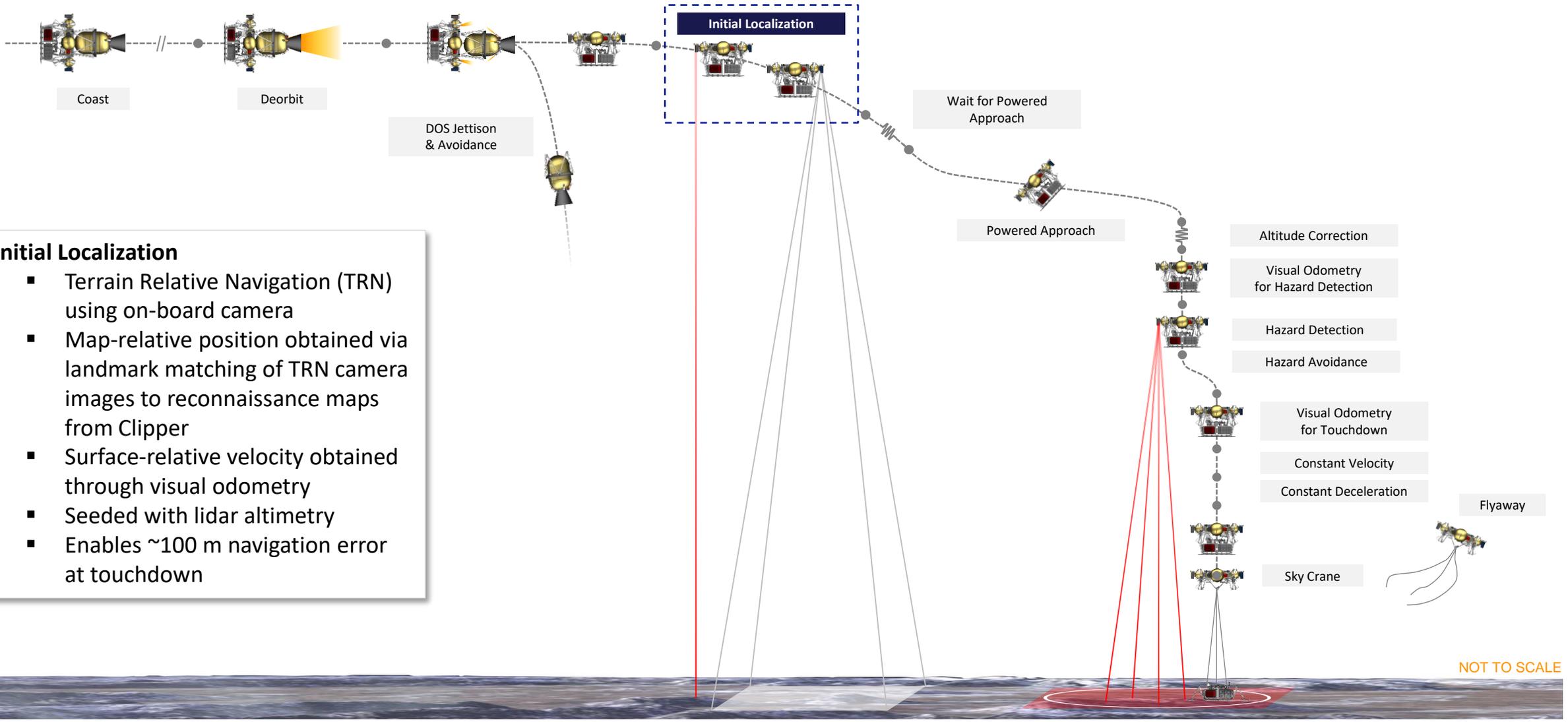
Deorbit

- 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
- Burn time error results in ± 4 km burn-out position error
- 5-DOF control: no downrange control but known cross-track and radial position errors are removed

NOT TO SCALE



2. Figure Out Where We Are

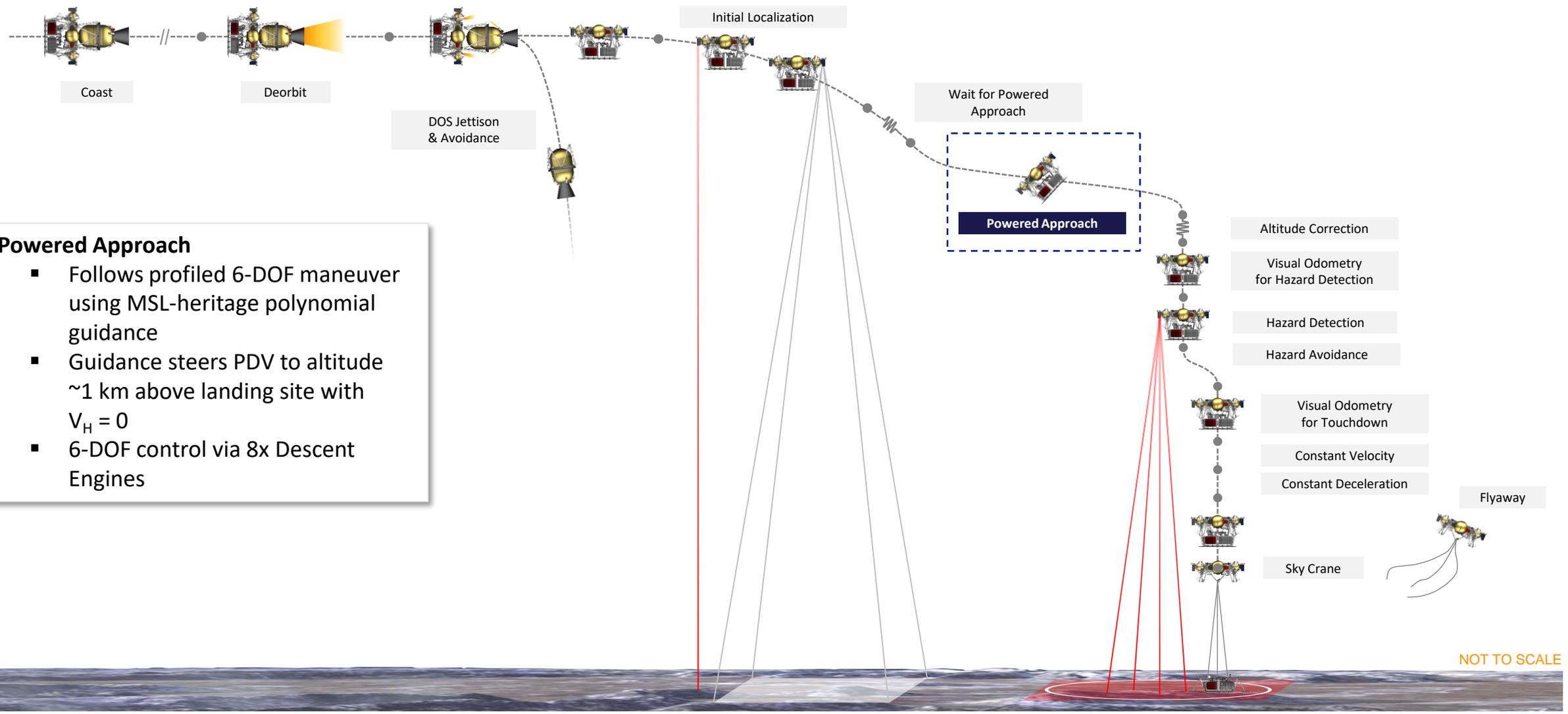


- Initial Localization**
- Terrain Relative Navigation (TRN) using on-board camera
 - Map-relative position obtained via landmark matching of TRN camera images to reconnaissance maps from Clipper
 - Surface-relative velocity obtained through visual odometry
 - Seeded with lidar altimetry
 - Enables ~100 m navigation error at touchdown

NOT TO SCALE



3. Fly to Target



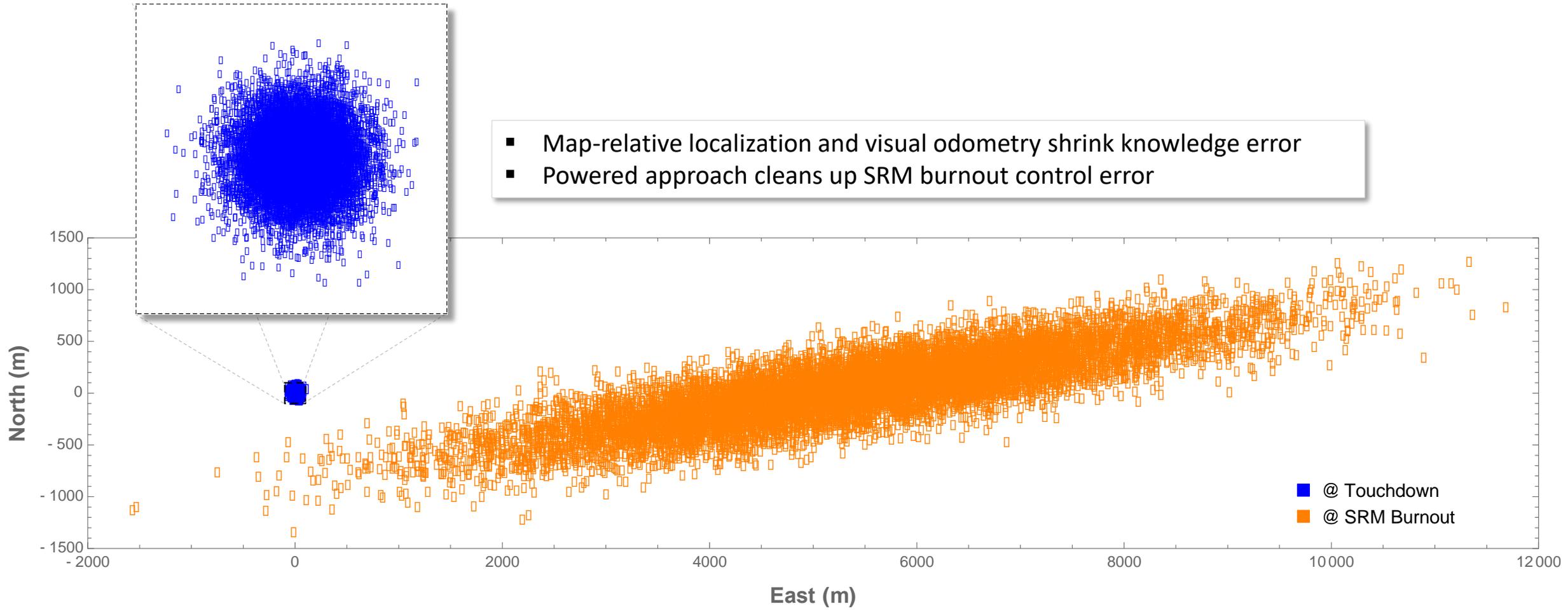
Powered Approach

- Follows profiled 6-DOF maneuver using MSL-heritage polynomial guidance
- Guidance steers PDV to altitude ~1 km above landing site with $V_H = 0$
- 6-DOF control via 8x Descent Engines

NOT TO SCALE

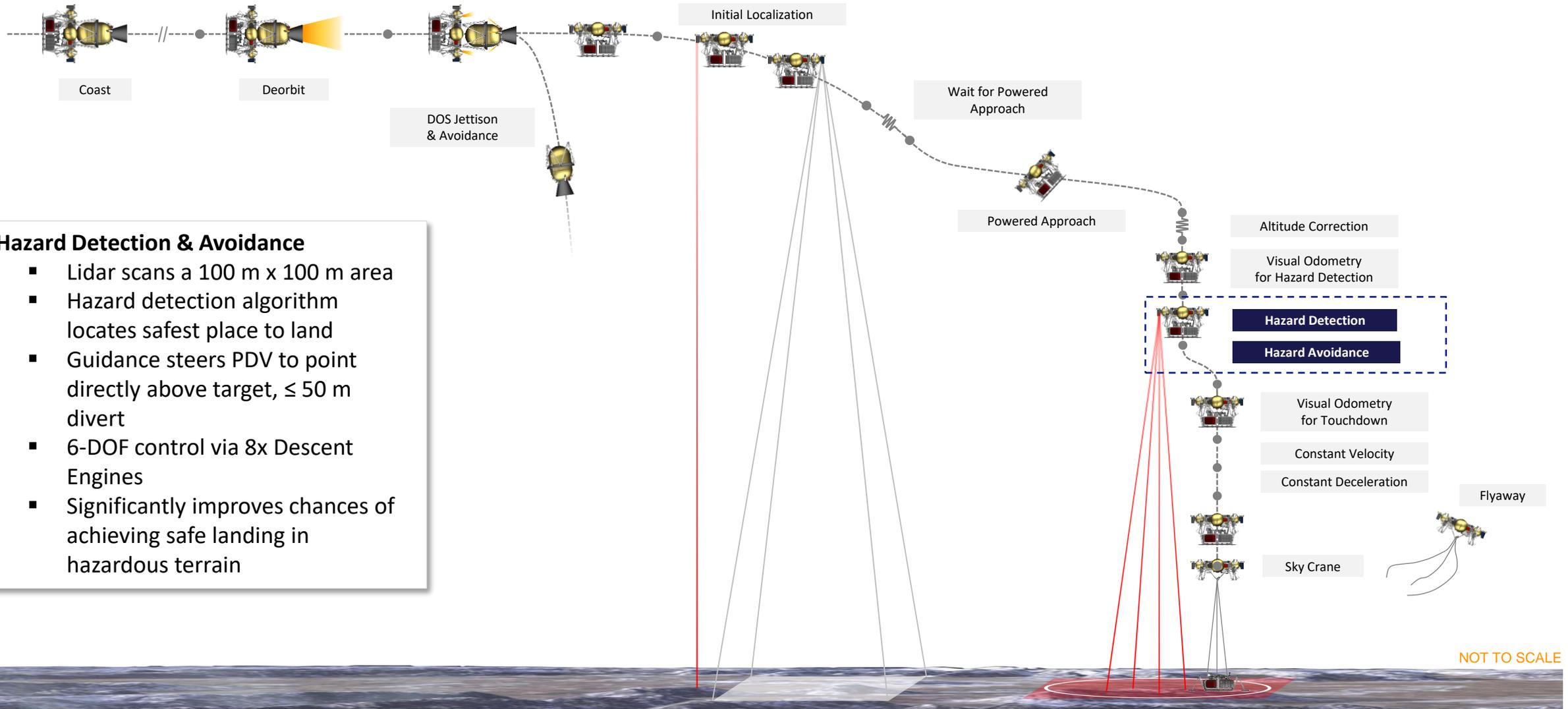


Position Dispersions Before & After





4. Find a Safe Place To Land and Go There



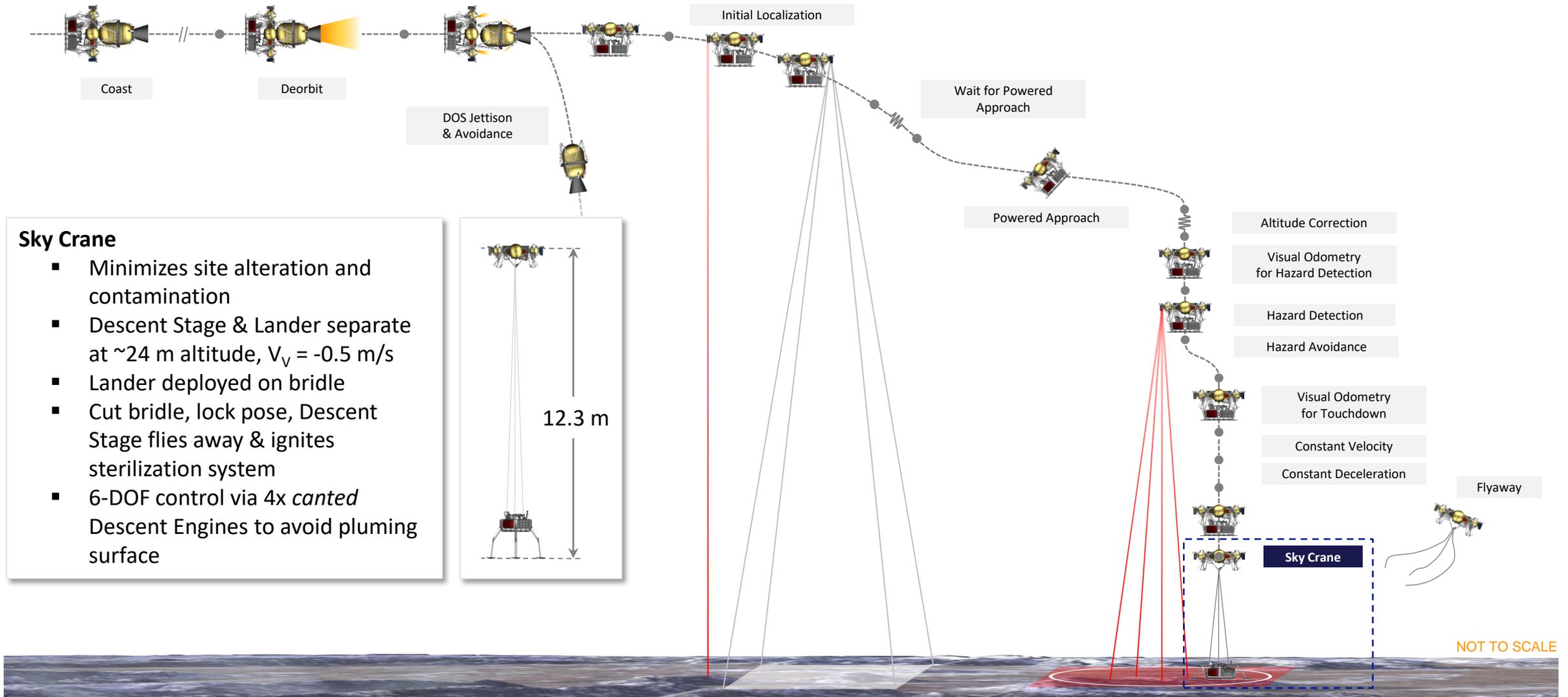
Hazard Detection & Avoidance

- Lidar scans a 100 m x 100 m area
- Hazard detection algorithm locates safest place to land
- Guidance steers PDV 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

NOT TO SCALE

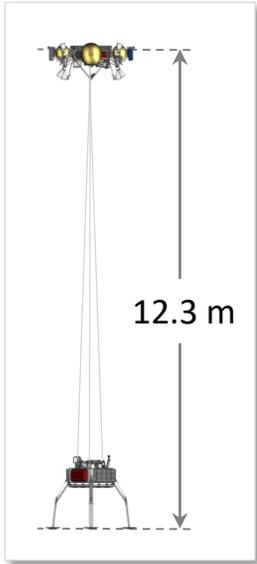


5. Gently Deliver Payload



Sky Crane

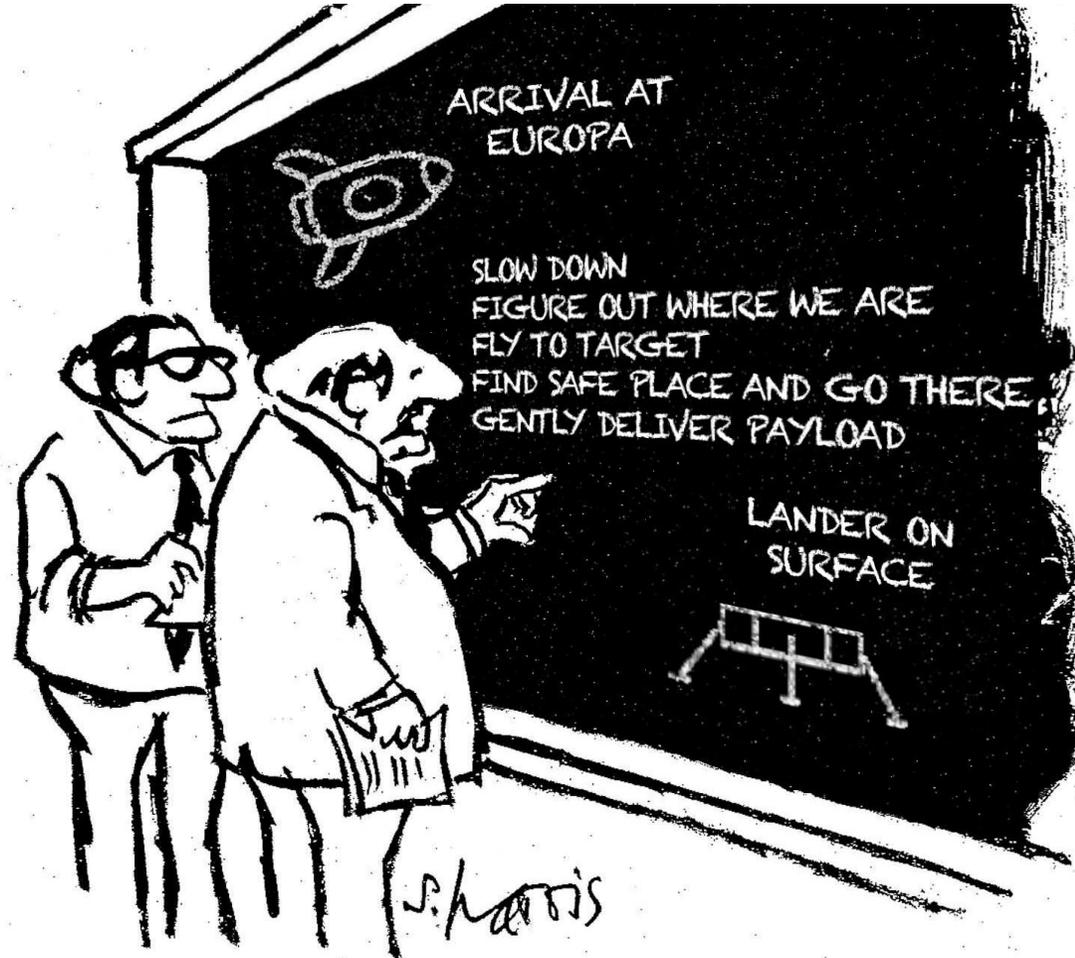
- Minimizes site alteration and contamination
- Descent Stage & Lander separate at ~24 m altitude, $V_v = -0.5$ m/s
- Lander deployed on bridle
- Cut bridle, lock pose, Descent Stage flies away & ignites sterilization system
- 6-DOF control via 4x *canted* Descent Engines to avoid pluming surface



NOT TO SCALE



Summary



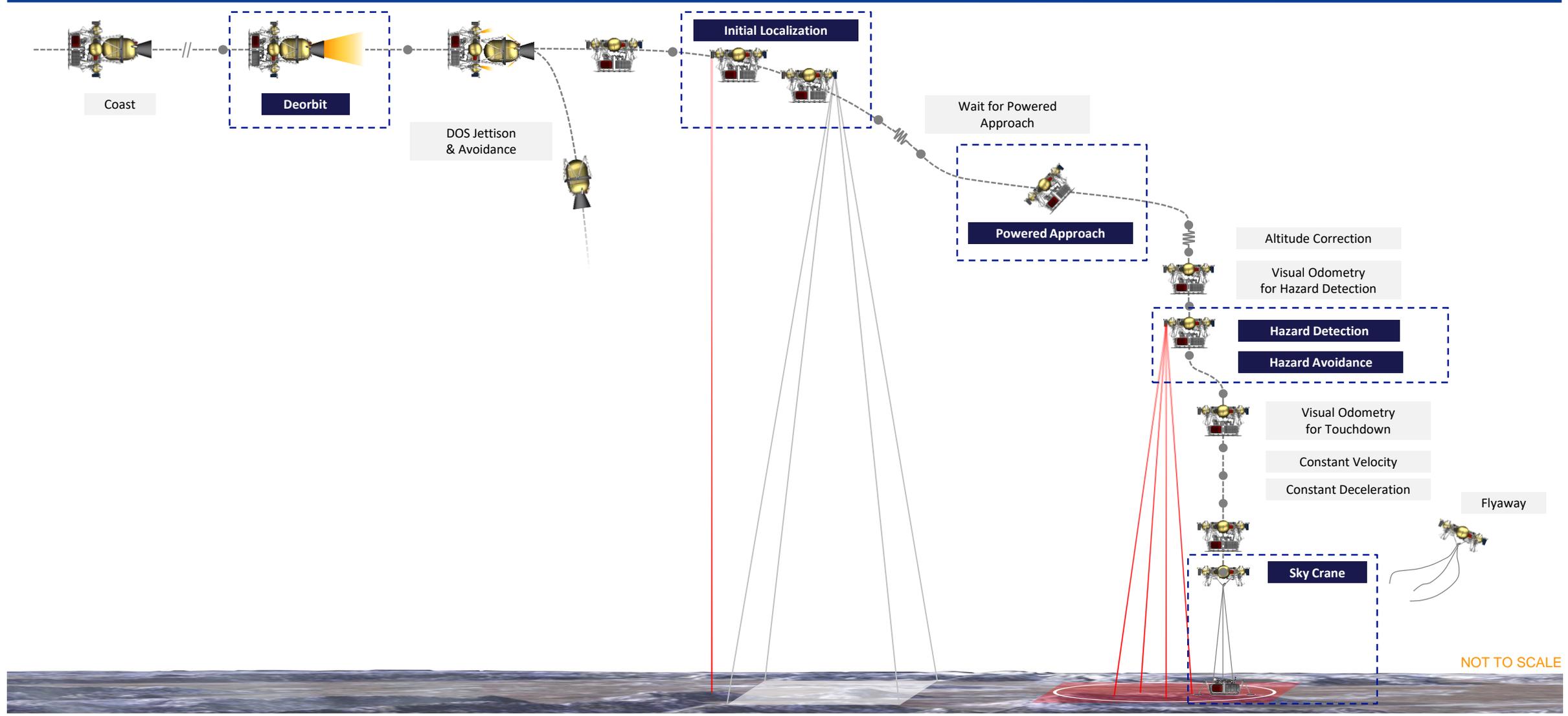
Based on cartoon by Sidney Harris, original image credit
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Backup



DDL Subphases



NOT TO SCALE