Landing on Europa:
Key Challenges and an Architecture Concept

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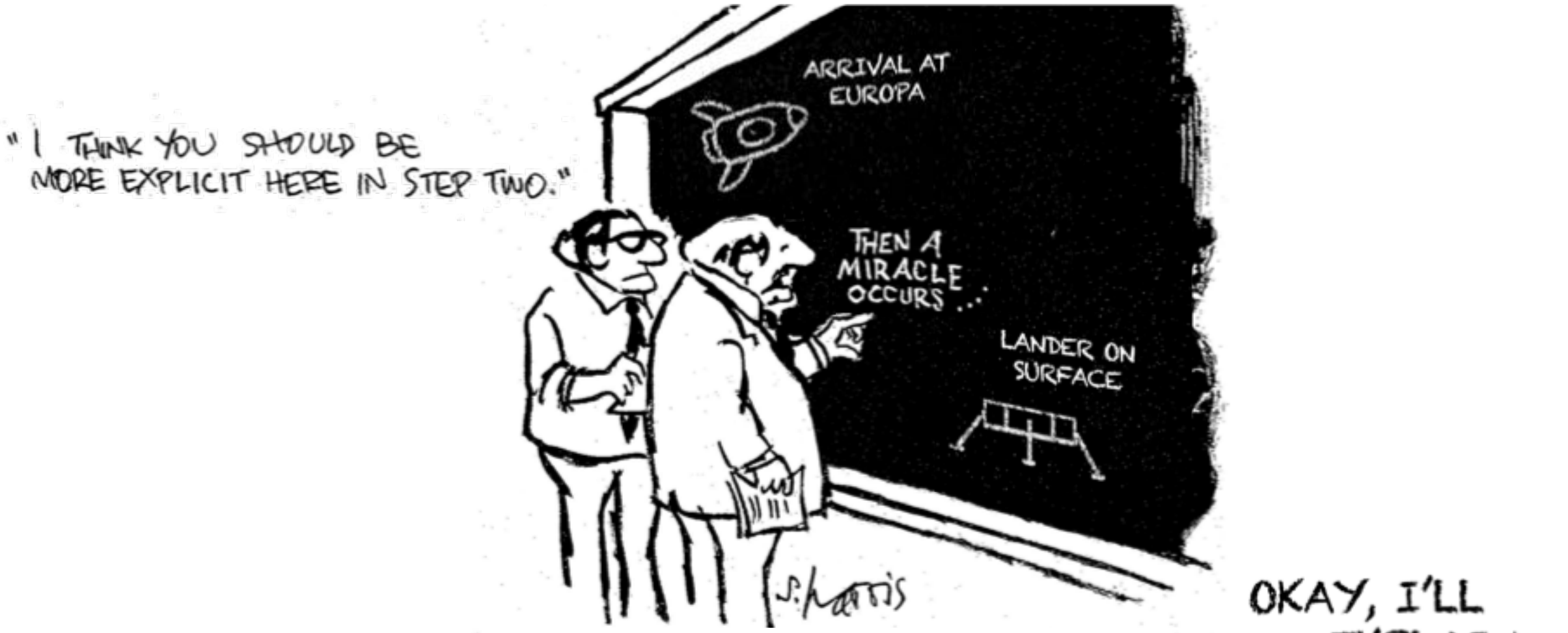
Motivation



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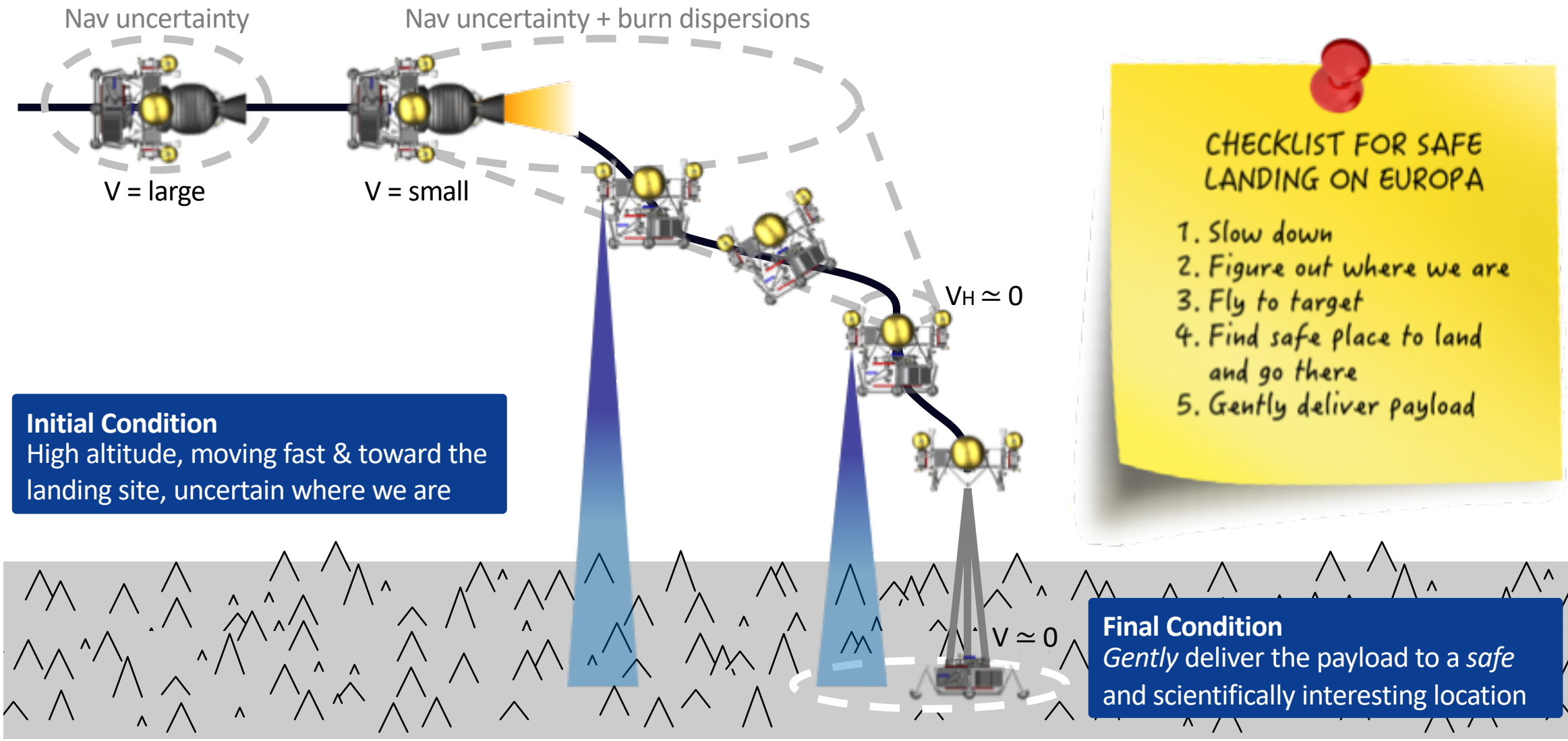
Breaking Down “Step Two”



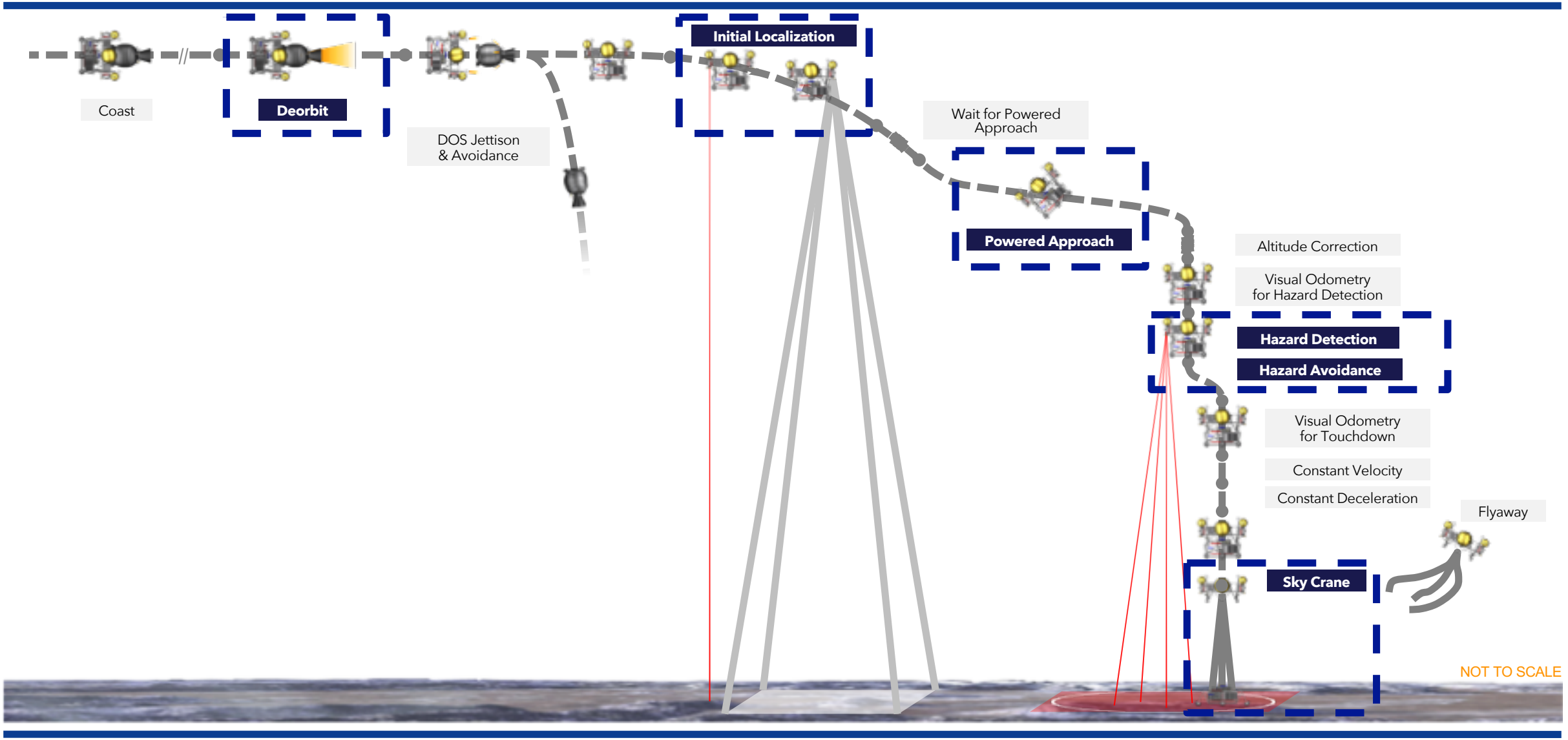
Initial Condition
High altitude, moving fast & toward the landing site, uncertain where we are

CHECKLIST FOR SAFE LANDING ON EUROPA

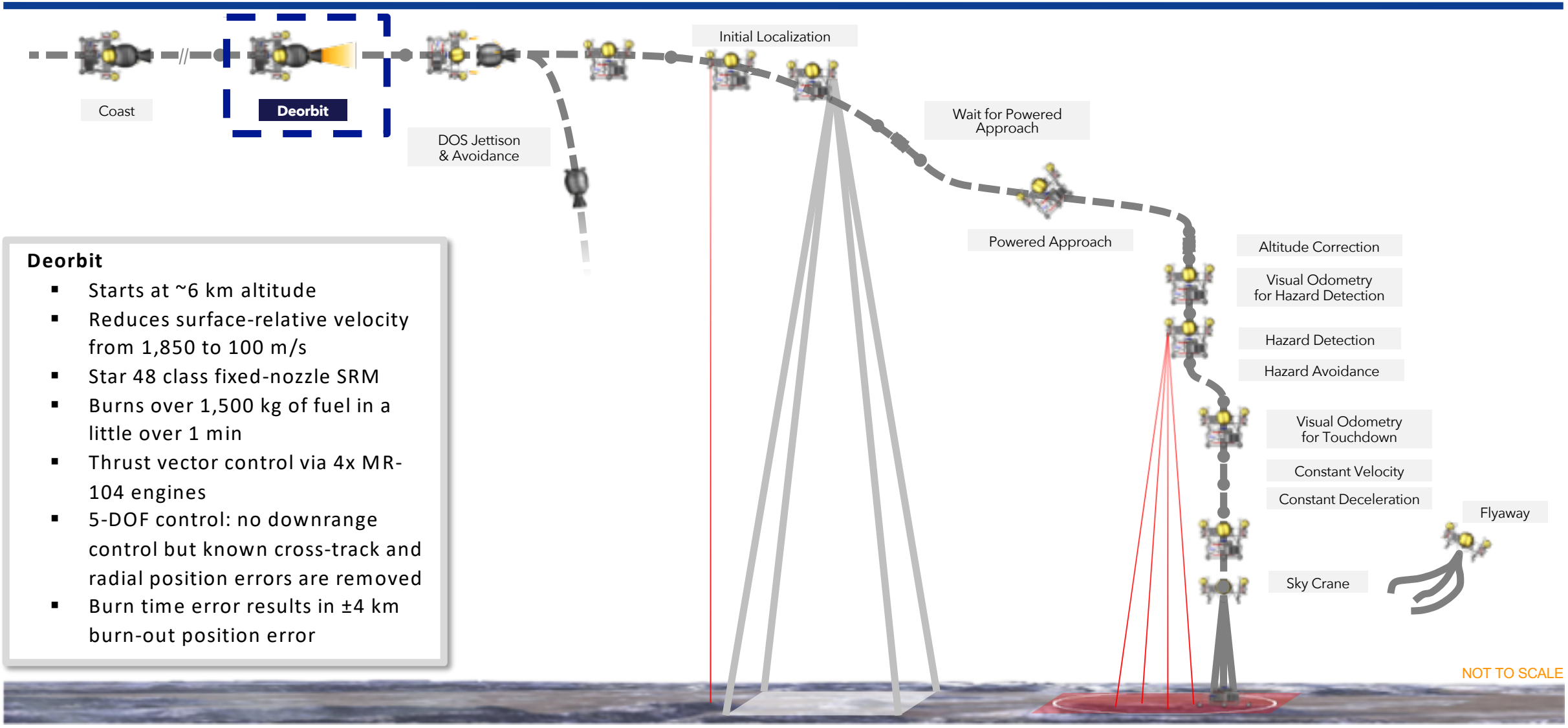
1. Slow down
2. Figure out where we are
3. Fly to target
4. Find safe place to land and go there
5. Gently deliver payload

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

DDL Subphases



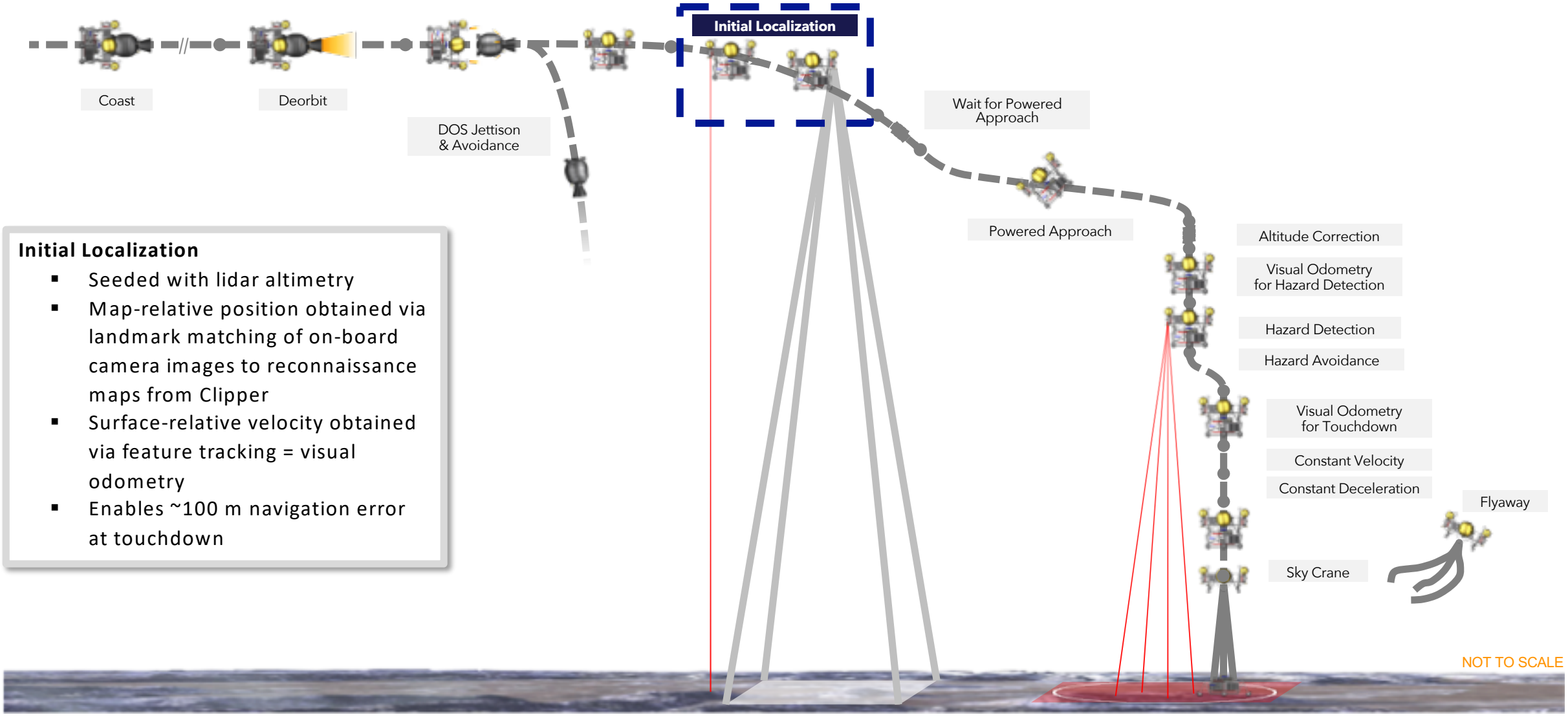
Step 1: Slow Down



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

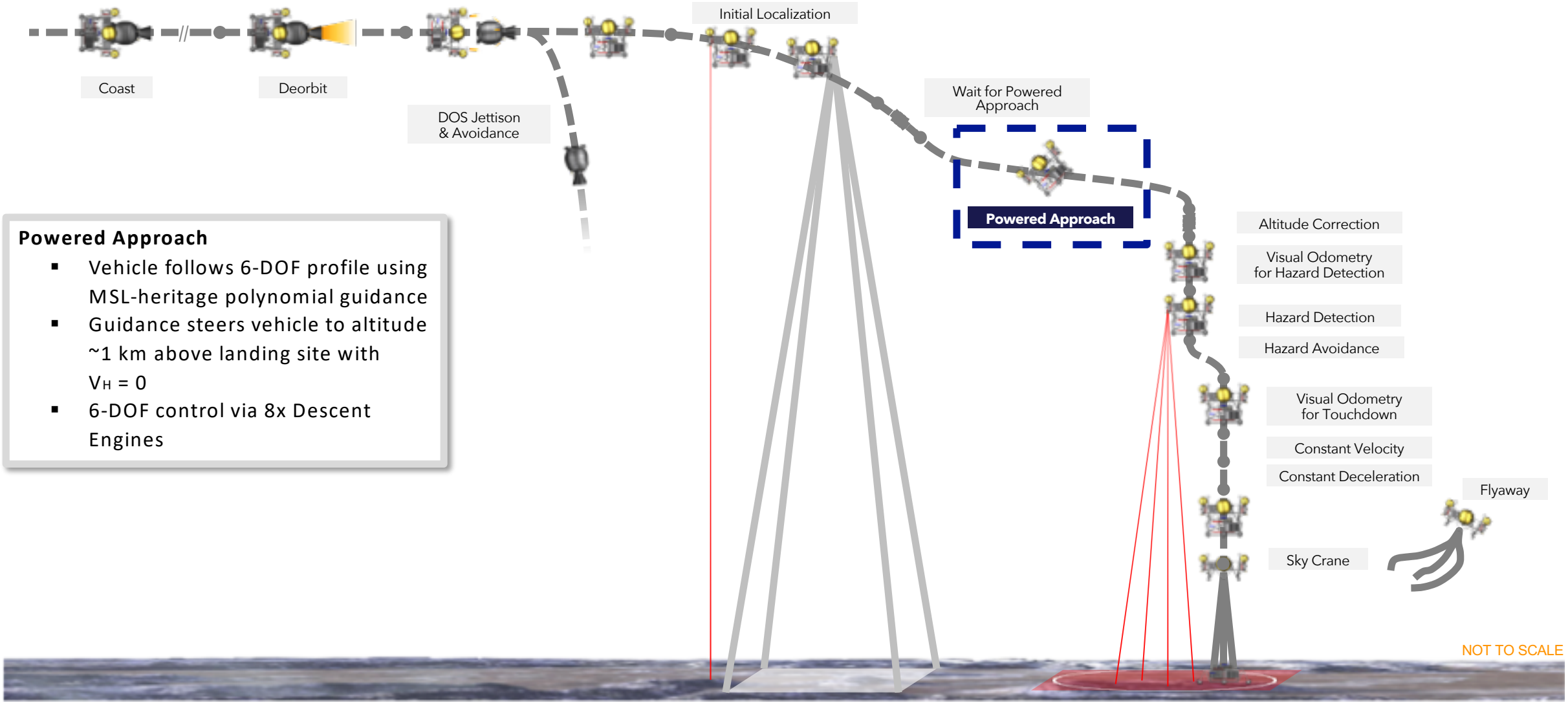
Step 2: Figure Out Where We Are



Initial Localization

- Seeded with lidar altimetry
- Map-relative position obtained via landmark matching of on-board camera images to reconnaissance maps from Clipper
- Surface-relative velocity obtained via feature tracking = visual odometry
- Enables ~100 m navigation error at touchdown

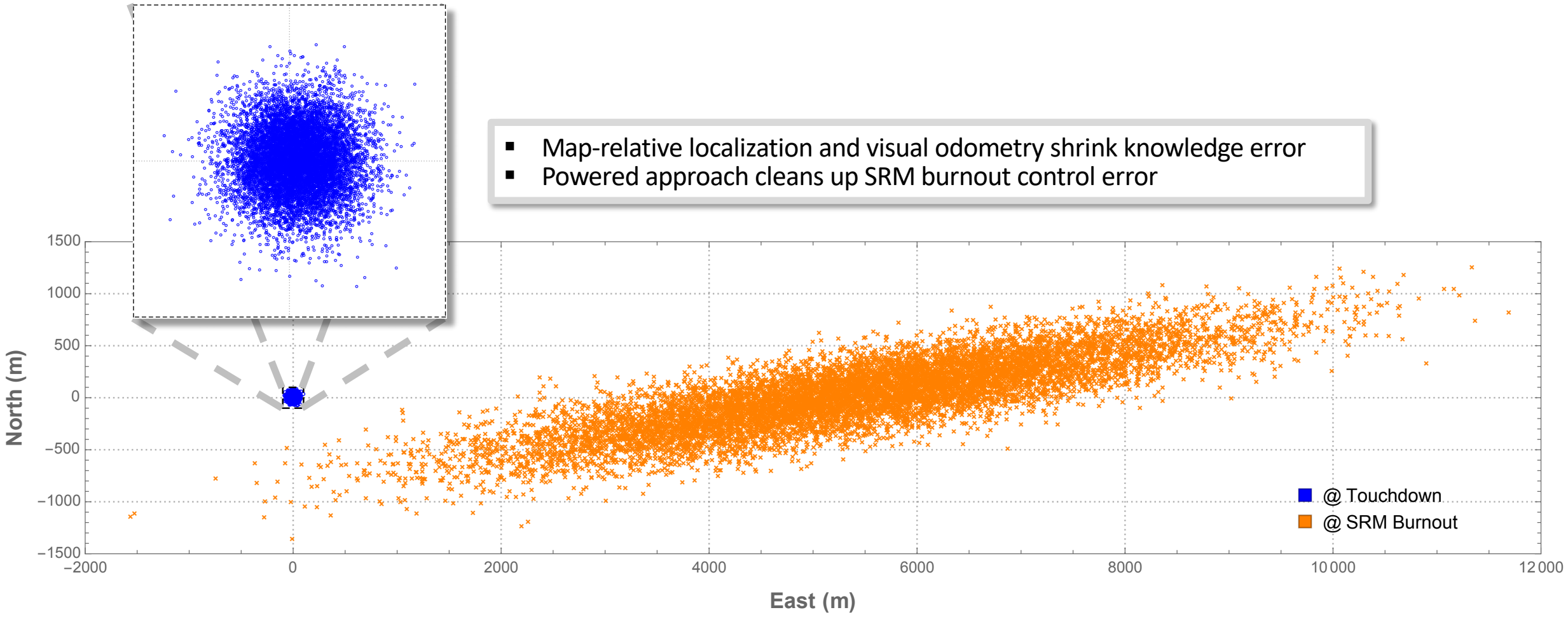
Step 3: Fly to Target



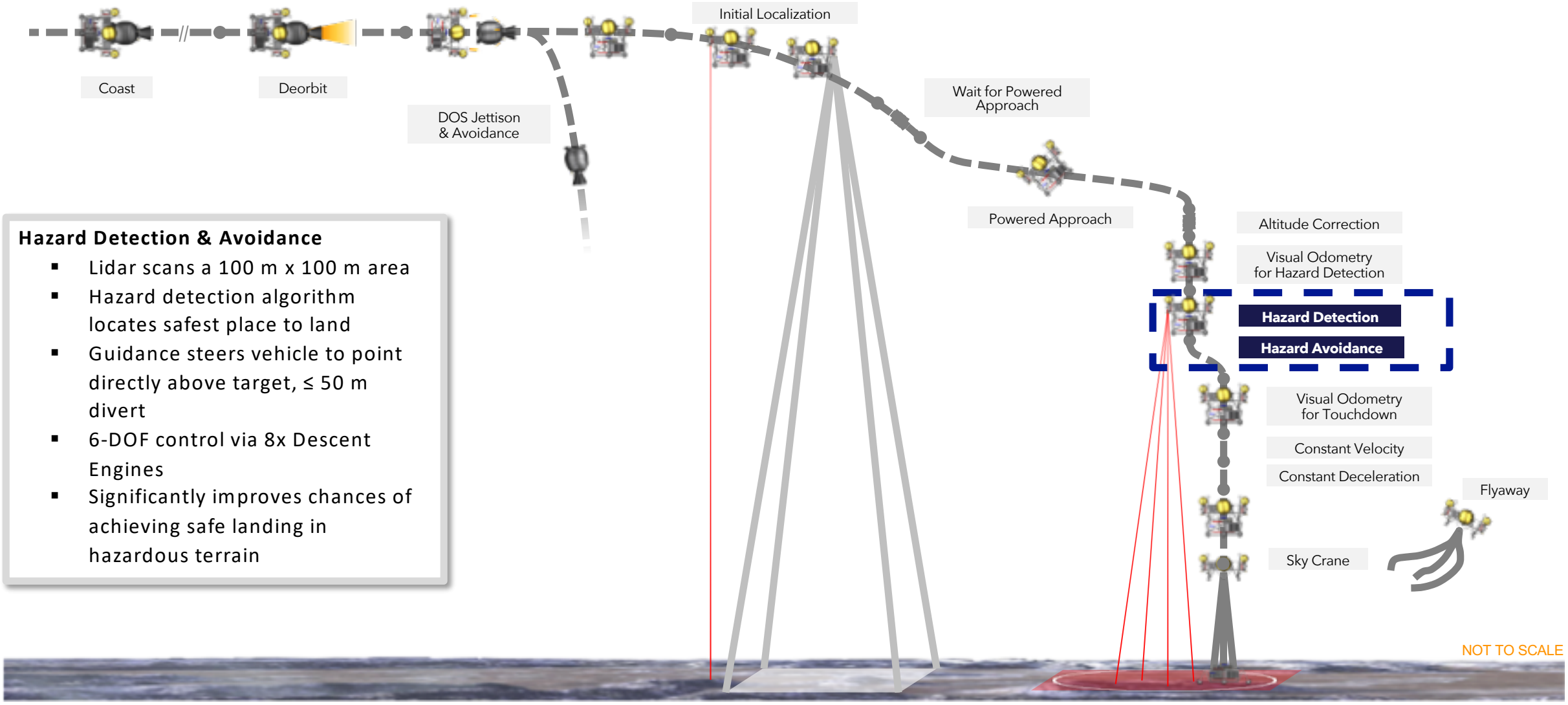
Powered Approach

- 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



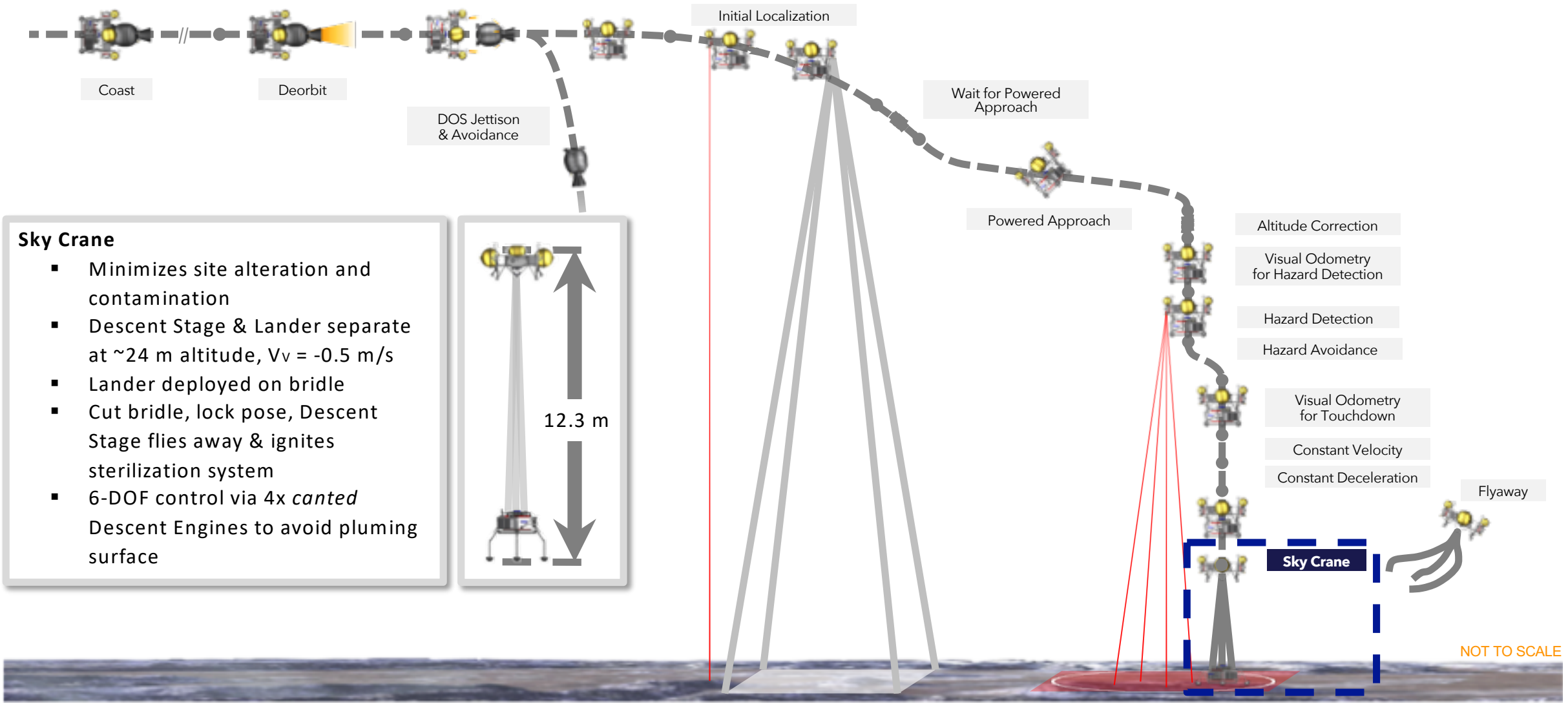
Step 4: Find a Safe Place To Land and Go There



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

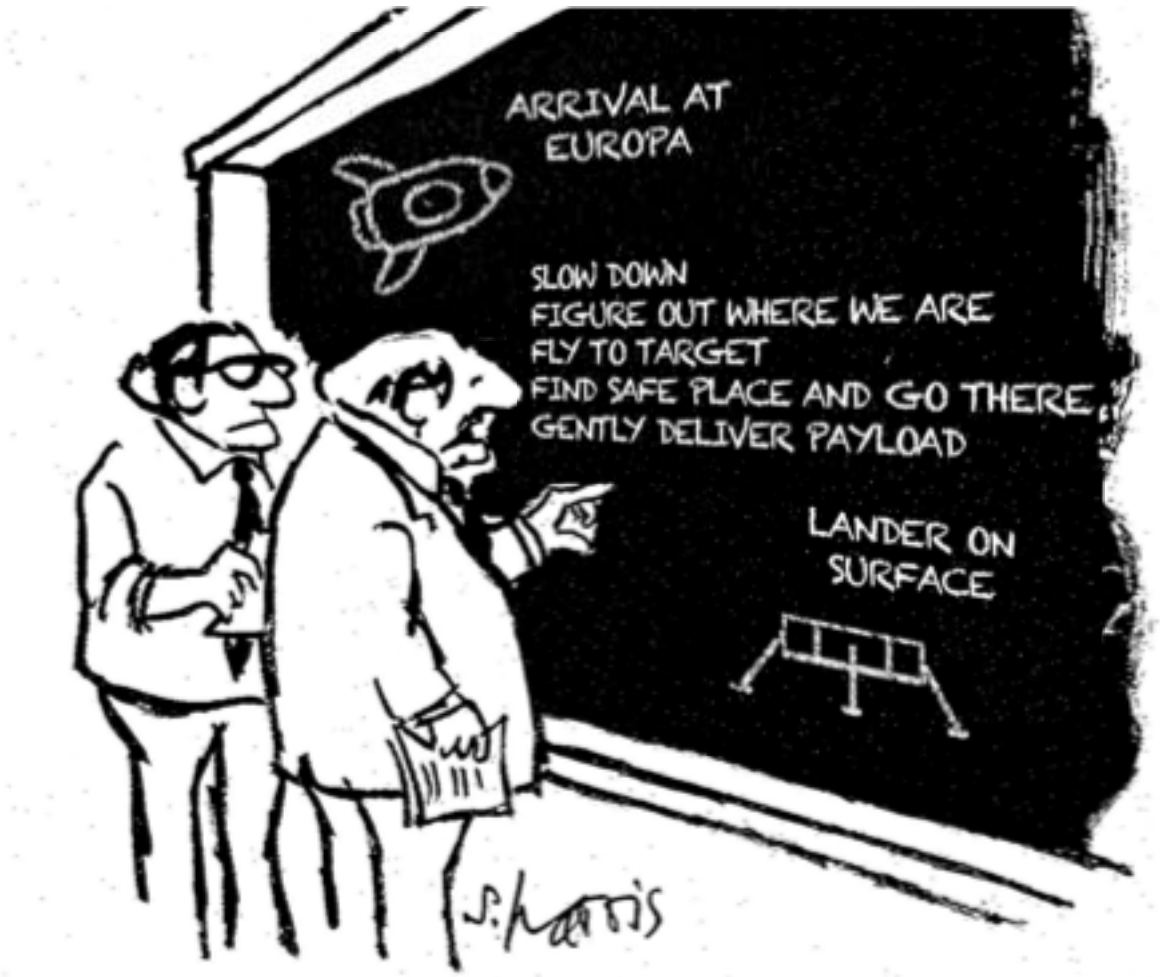
Step 5: Gently Deliver Payload



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

Summary



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