# Some Considerations for Achieving Precision Mars Landings

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# Factors That Impact Landing Precision

### *Navigation*

- Approach navigation state accuracy
- Map tie errors (inaccuracy of mapped position of target site)

### *Mars Atmospheric Effects*

- Density variations that affect the entry trajectory
- Vehicle/decelerator descent wind drift

### *Guidance and Control (G&C)*

- Control authority and mass cost
- Realizable time responses to steering commands

# The Recent EDL Mission Architecture

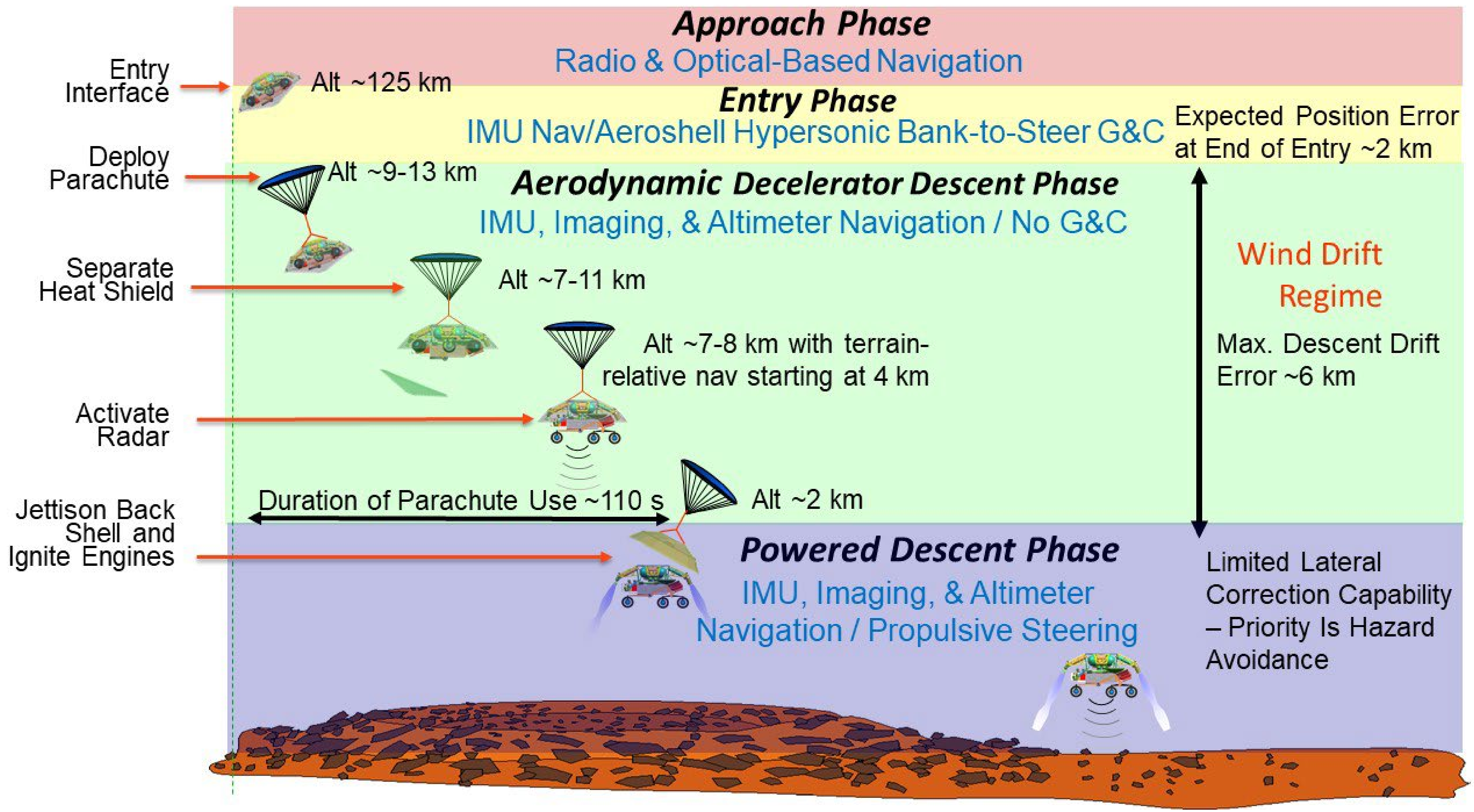


Diagram Adapted from Prior Draper/JPL Paper Figure

# Precision Landing Design Options and Considerations: Navigation Accuracy

## Optical Aiding During Approach

- Utilizes images of planet limb and relative locations of stars
- An ensuing mid-course correction burn applies the resulting inertial state corrections to precisely target the entry interface location
- Image processing needed to derive resulting navigation update is not tightly time constrained

## Surface-Relative Landmark Tracking from Orbit and/or During EDL

- Utilizes images of surface feature positions and their relative orientations along the vehicle track
- Provides basis for landing-target-relative state update (mitigating map-tie errors)
- Image processing must be done onboard within a tight time limit (seconds at most)
  - Can necessitate a separate, dedicated processor
  - Requires storage space for a feature characterization database

# Precision Landing Design Options and Considerations: Atmospheric Effects

## Atmospheric Density Impact

- Use atmospheric density forecasts to update the predicted entry deceleration profile and aerodynamic decelerator descent rate
- Effects of dust storms on atmospheric density need to be addressed

## Wind Drift Mitigation

- Bias end of the entry phase target to offset predicted decelerator wind drift
  - Requires high-quality wind data or forecasts to be effective
- Provide decelerator steering to null out errors detected at start of decelerator descent
- Remove uncompensated decelerator-phase wind drift errors using powered descent path steering

# Precision Landing Design Options and Considerations: Descent G&C Factors

## Decelerator

- Actuators that pull on designated parachute canopy sectors can induce a lateral “slip” force
  - Parachute high mass ratio on Mars ([canopy mass]/[entrained air mass]) makes control response times much slower than on Earth
  - Actuators add mass compared to un-steered parachutes
- Inflatable decelerator design asymmetry can provide a directable lateral force
  - Inflated shape rigidity is essential for well-managed path control
  - Realizable rotation rates for inflatables determine their control response time, likely also quite slow

## Powered Descent

- The powered descent propellant mass hit to correct targeting errors at the end of the decelerator descent grows rapidly with lateral correction distance
  - Will want to keep needed lateral correction for unpredicted decelerator phase wind drift well under 1 km