National Aeronautics and
Space Administration

EXPLORE SPACE TECH

Entry, Descent and Landing & Precision Landing

Michelle M. Munk | NASA

IllinoisX Space Technology Talk | 17 March 2021

NASA’s Space Technology Thrusts

Go

Rapid, Safe, & Efficient Space Transportation

Land

Expanded Access to Diverse Surface Destinations

Live

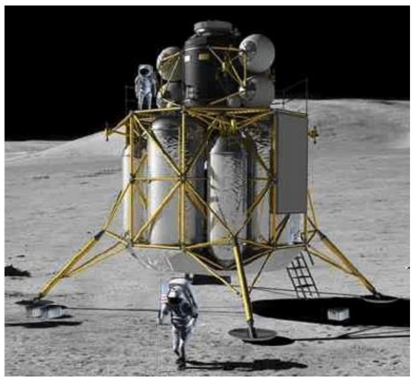
Sustainable Living and Working Farther from Earth

Explore

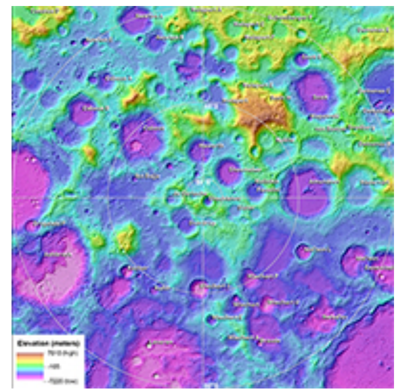
Transformative Missions and Discoveries

Technology Goals for LAND

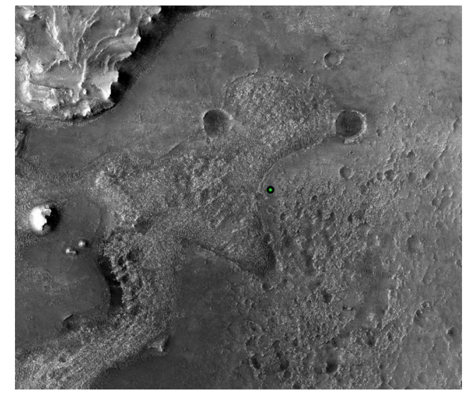
Enable Lunar and Mars global access with ~20t payloads to support human missions



Land payloads within 50 meters accuracy while also avoiding local landing hazards



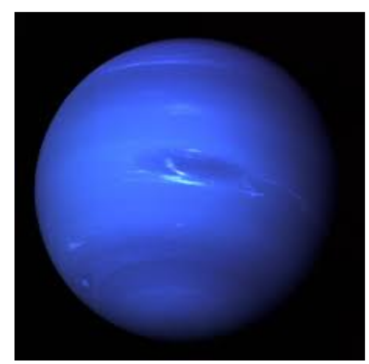
Credit: LPI



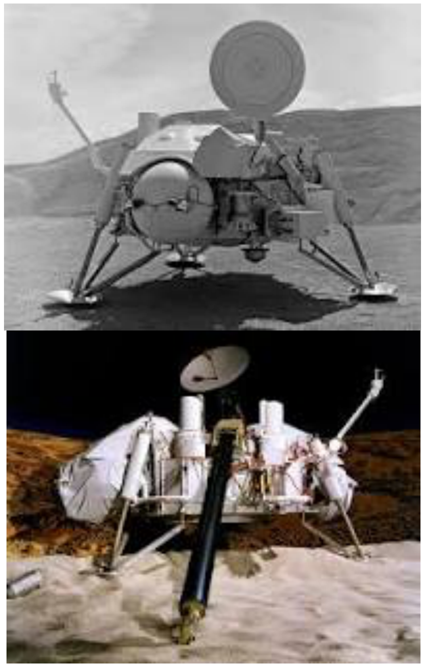
Enable science missions entering/transiting planetary atmospheres and landing on planetary bodies

Credit: NASA-GSFC

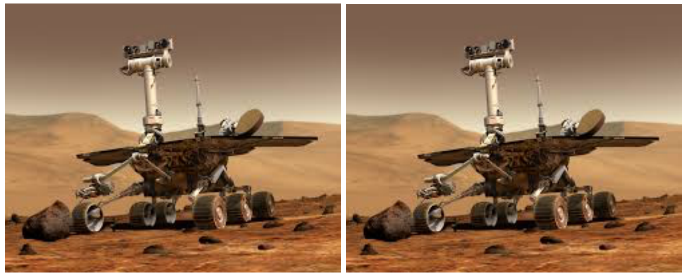
Credit: JHU/APL



How Do We Land on Mars, Today?

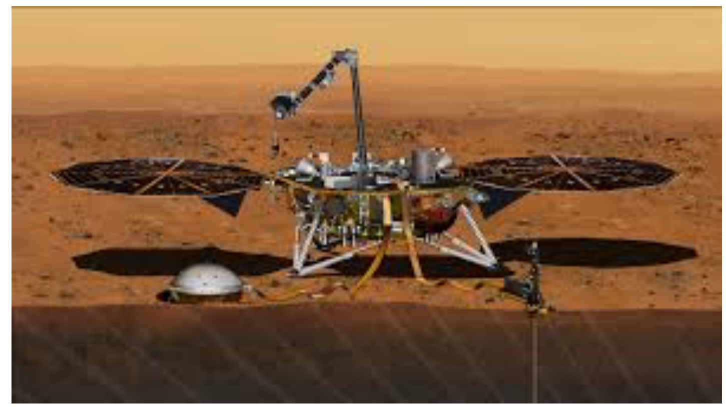


Viking 1 and 2 - 1976



Spirit and Opportunity - 2004

Phoenix - 2008



InSight - 2019

Pathfinder - 1997

Curiosity - 2012

Perseverance - 2021

Perseverance Mission Objectives

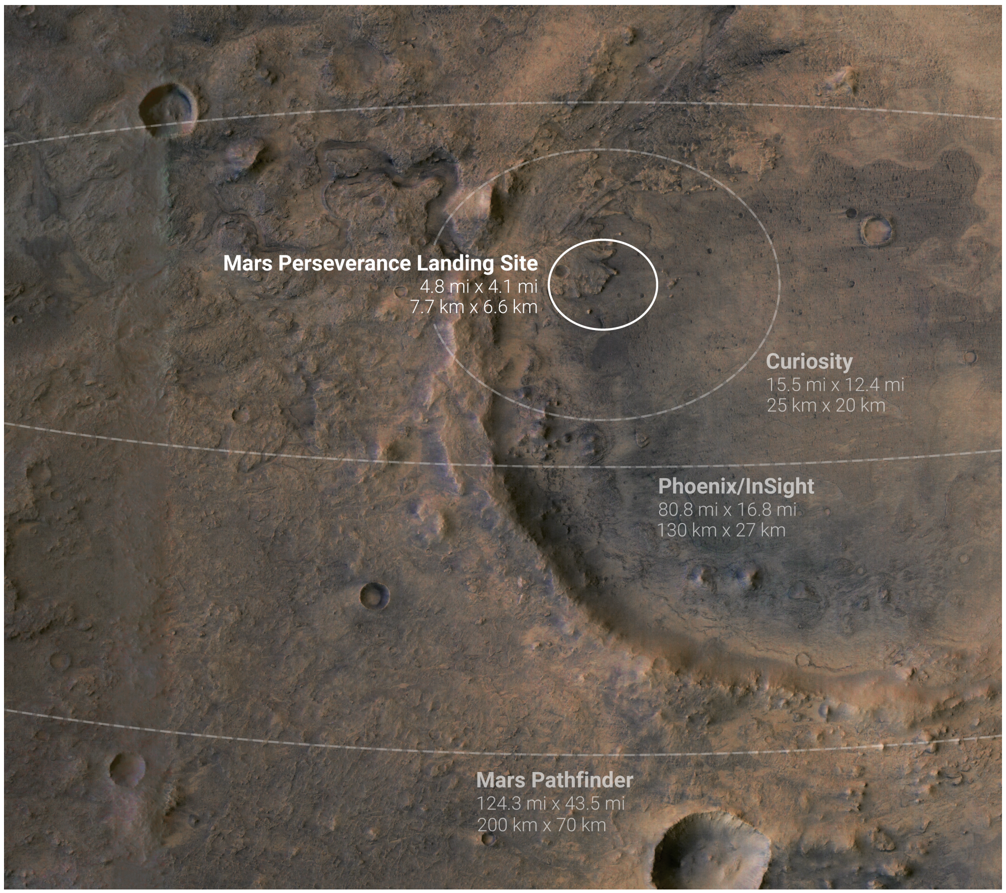
Courtesy NASA/JPL-Caltech

- **Explore a geologically diverse landing site**
- Assess **ancient habitability**
- **Seek signs of ancient life**, particularly in special rocks known to preserve signs of life over time
- **Gather rock and soil samples** that could be returned to Earth by a future NASA mission
- **Demonstrate technology** for future robotic and human exploration

Launched: July 30, 2020 from Cape Canaveral Air Force Station, Florida

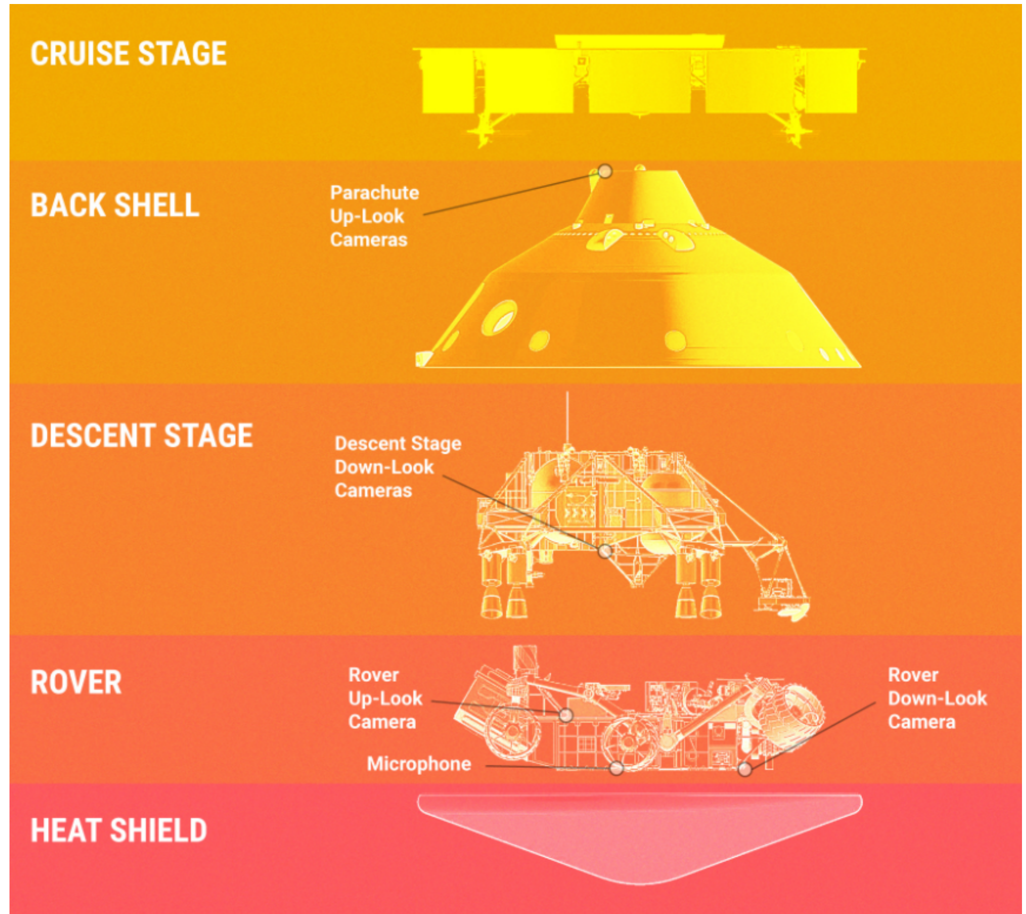
What's New about Perseverance EDL?

Terrain-Relative Navigation



Courtesy ESA/DLR/FU-Berlin/NASA/JPL-Caltech

EDL cameras

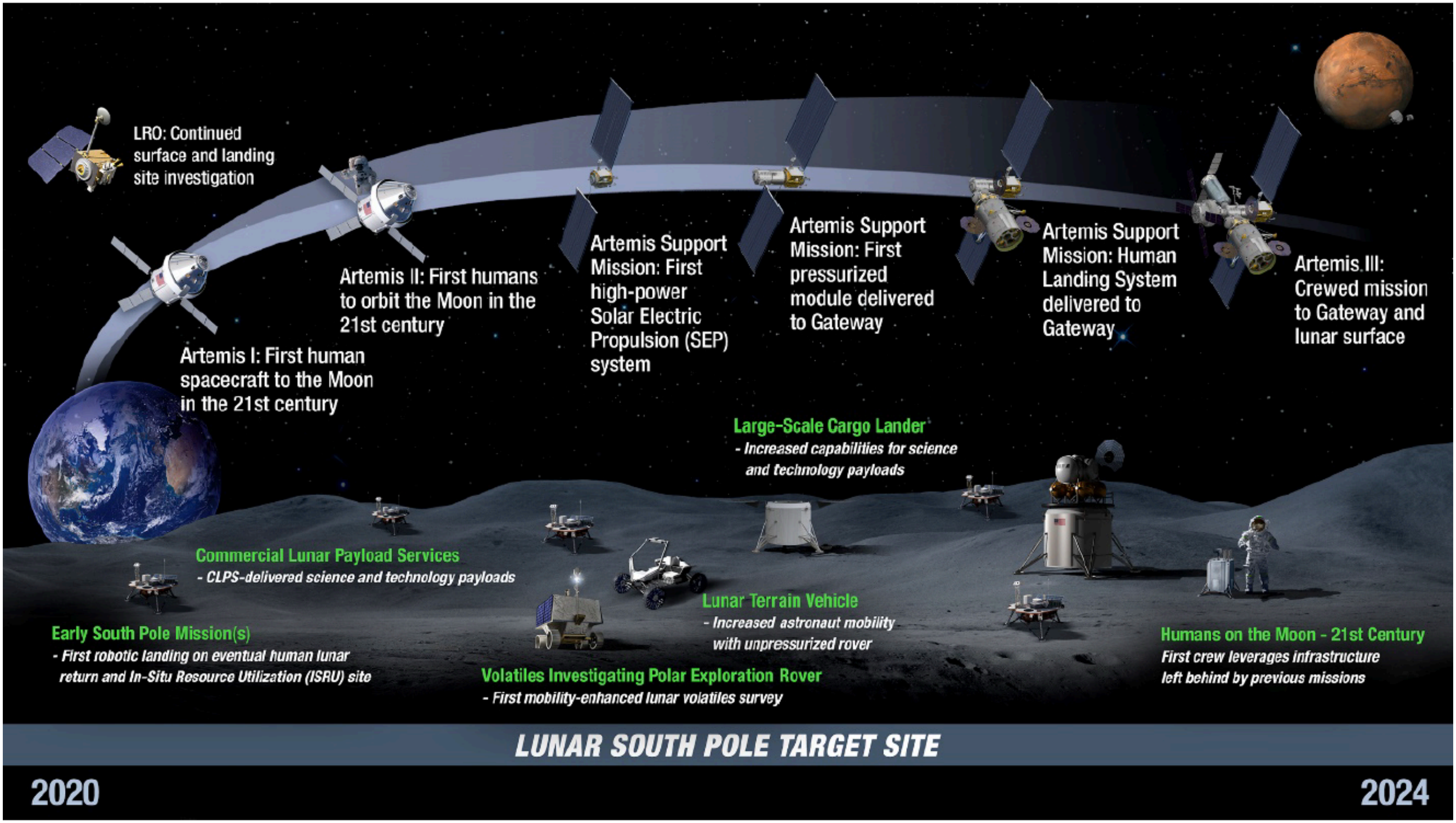


Courtesy NASA/JPL-Caltech

Perseverance Landing: First-Hand Look

Courtesy NASA/JPL-Caltech

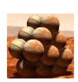
NASA's Artemis Program: Boots on the Moon by 2024

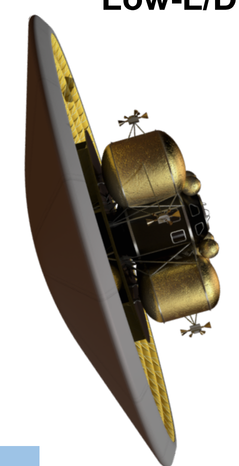


Human Mars Landers: A Leap in Scale

Human-scale Mars landers require new approaches to all phases of Entry, Descent, and Landing

- Cannot use heritage, low-L/D rigid capsules → deployable hypersonic decelerators
- Cannot use parachutes → retropropulsion, from supersonic conditions to touchdown

	Viking	Pathfinder	MERs	Phoenix	MSL	InSight	M2020	Human-Scale Lander (Projected)
Entry Capsule (to scale)								
Diameter (m)	3.505	2.65	2.65	2.65	4.52	2.65	4.5	16 - 19
Entry Mass (t)	0.930	0.584	0.832	0.573	3.153	0.608	3.440	40 - 65
Parachute Diameter (m)	16.0	12.5	14.0	11.8	19.7	11.8	21.5	N/A
Parachute Deploy (Mach)	1.1	1.57	1.77	1.65	2.2	1.66	1.75	N/A
Landed Mass (t)	0.603	0.360	0.539	0.364	0.899	0.375	1.050	26 - 36
Landing Altitude (km)	-3.5	-2.5	-1.4	-4.1	-4.4	-2.6	-2.5	+/- 2.0
Terminal Descent and Landing Technology	 Retro-propulsion	 Airbags	 Airbags	 Retro-propulsion	 Skycrane	 Retro-propulsion	 Skycrane	Supersonic Retropropulsion



Steady progression of "in family" EDL

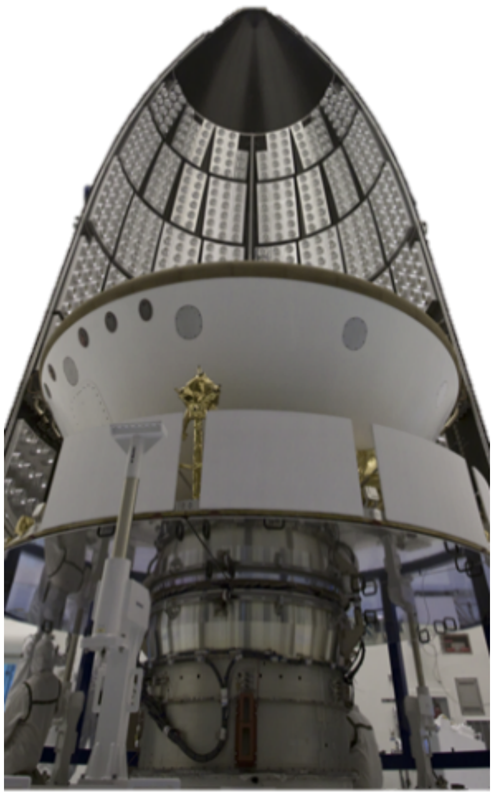
Payloads up to ~ 1 t, footprints in km

New EDL Paradigm

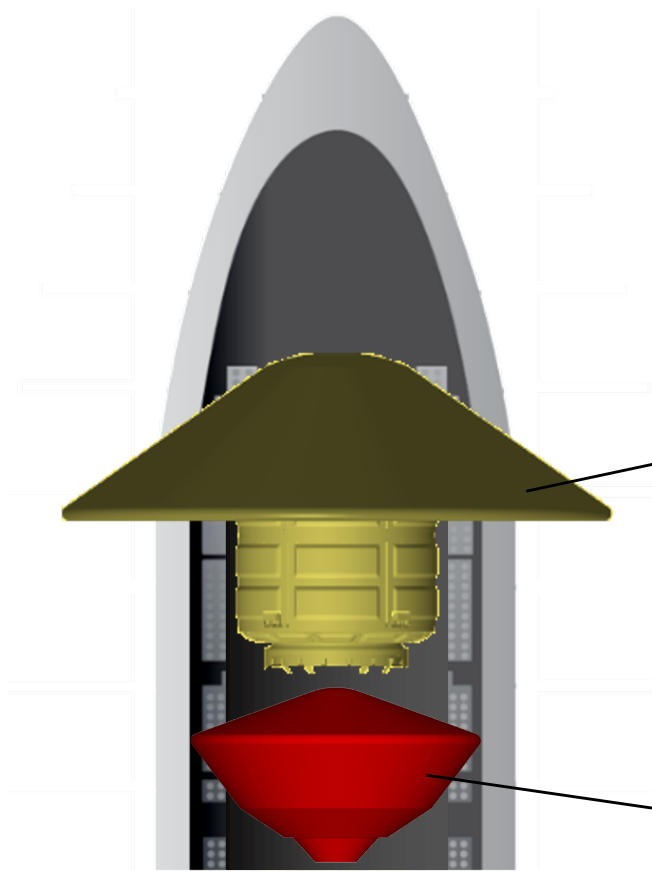
Payloads 20+ t, footprints < 100 m

Inflatable Heatshields Make it Possible

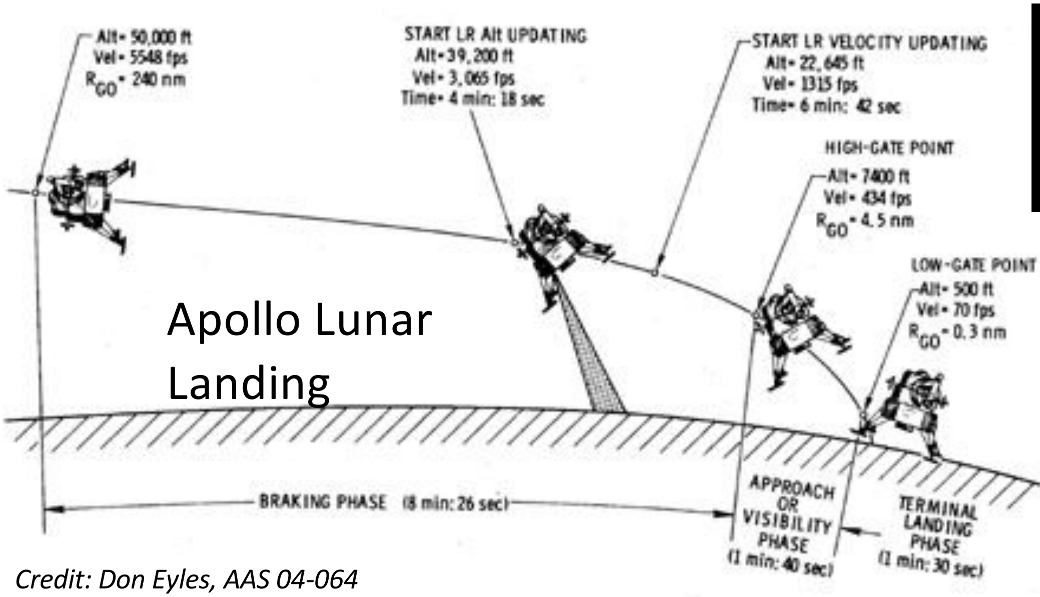
To slow down a big Mars lander, we need a bigger heatshield than will fit inside a launch vehicle



Courtesy NASA/JPL-Caltech



Landing: Moon vs Mars



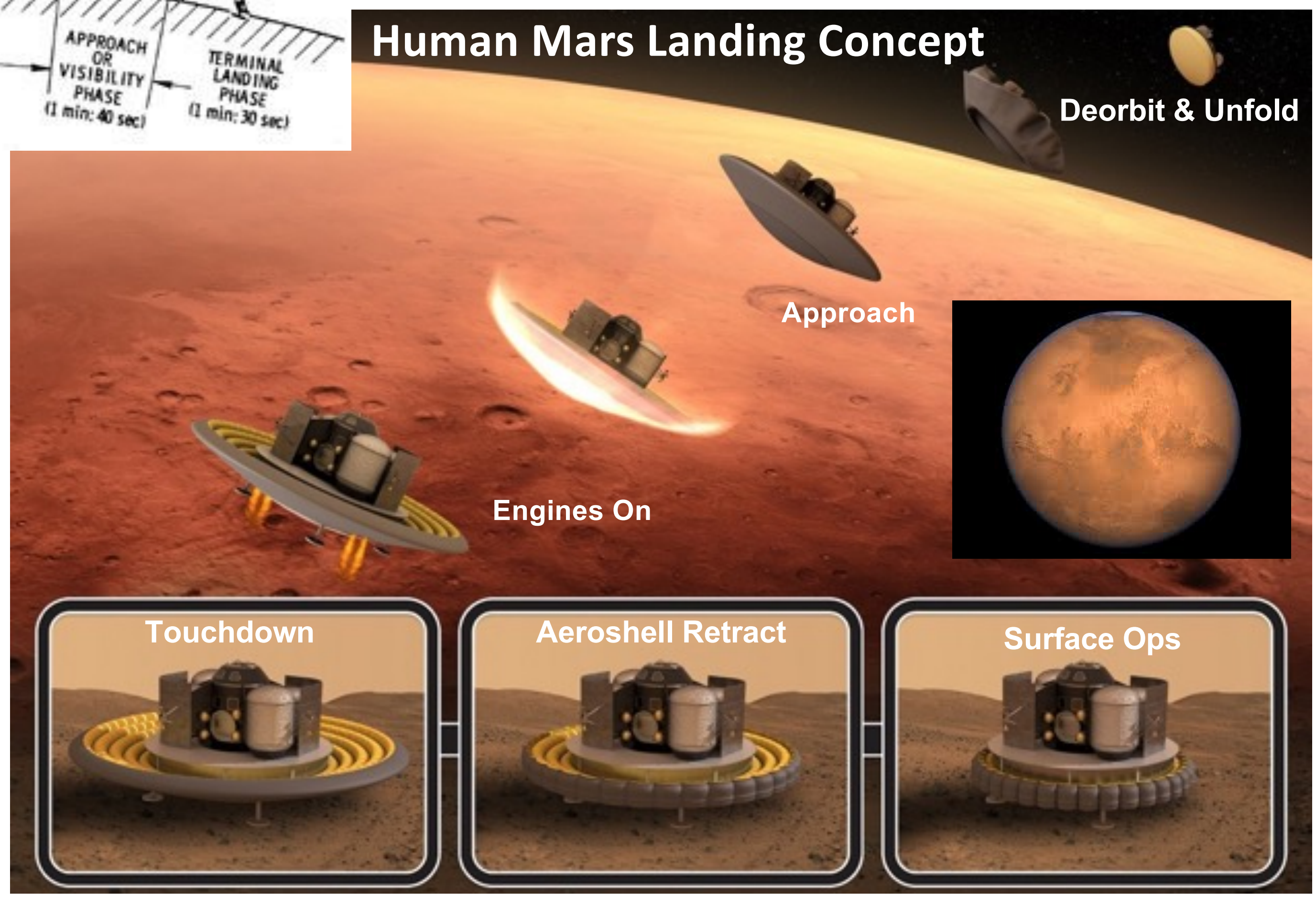
Credit: Don Eyles, AAS 04-064

Differences:

- Atmosphere
- Gravity
- Lighting
- Temperature extremes
- Type of soil/dust

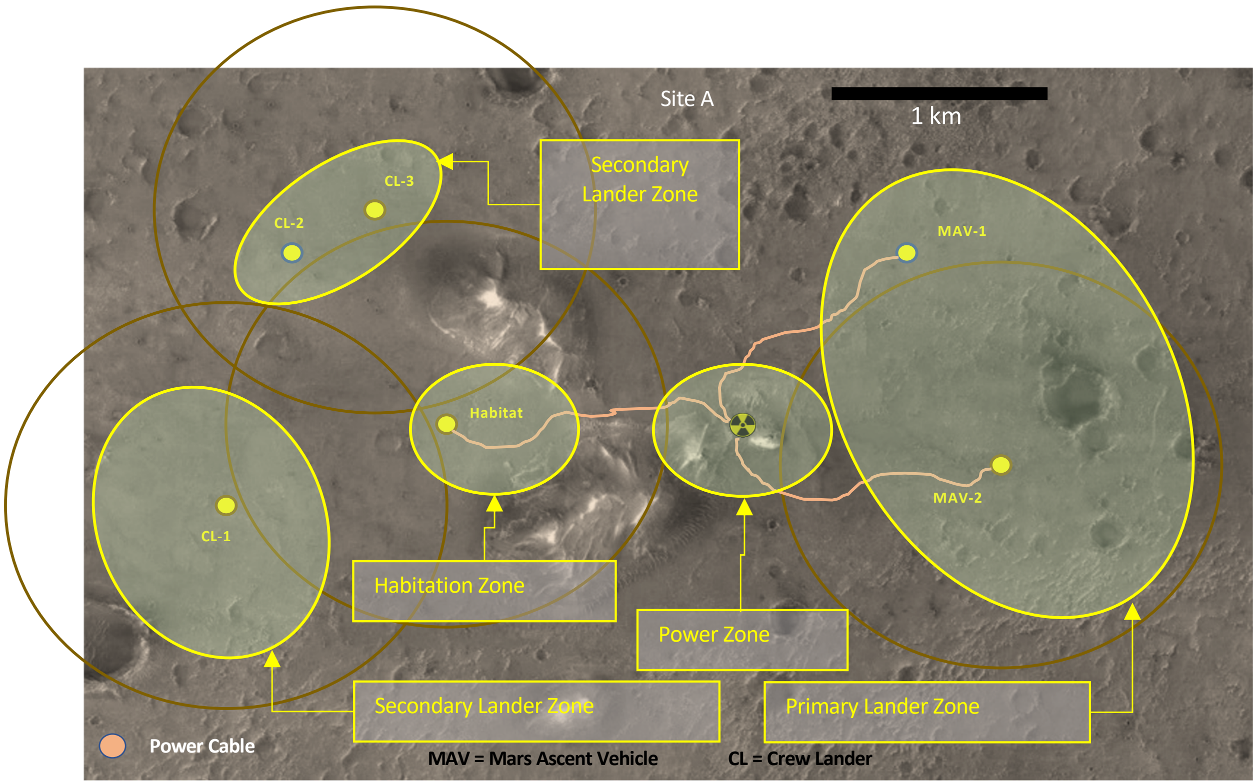
Similarities:

- Environment unknowns
- Need to land precisely
- Need to avoid hazards
- Engines will disturb surface



The Moon is a Stepping Stone to Mars

- Before we send people all the way to Mars, it would be good to “practice” a little closer to home. How are the missions similar?
  - We’re landing big vehicles on both of them, with big engines
  - We need to land many pieces close together without them hitting rocks, craters, or each other → need precise landings
  - Rocks and soil are going to fly away from the engine plumes



EDL & Precision Landing Challenges (2020-40)

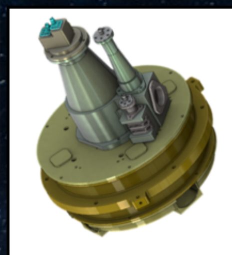
- Landing precisely on the Moon, first with small, commercially-provided landers, then at human-scale by 2024
  - **EDL Challenges:**
    - ➢ Lightweight, cost-effective sensors for precise landing (feeds to Mars); integrating them on commercial landers with high-performing computers
    - ➢ Plume/surface/vehicle interactions near touchdown (feeds forward to Mars)
    - ➢ Integrated simulations for assessing landers and GN&C approaches (feeds forward to Mars)
- We want to return a sample from Mars by late 2020's or early 2030's
  - **EDL Challenges:**
    - ➢ Landing ~1300 kg precisely, next to samples that Mars 2020 caches
    - ➢ Autonomously launching a rocket from Mars to a target orbit
    - ➢ Returning the samples to Earth in a capsule with very low (one-in-a-million) probability of failure
- We want to explore Venus, Ice Giants, Ocean Worlds, and Outer Planets
  - **EDL Challenges:** rugged terrain, unknown atmospheres, high entry speeds
- We have the long-term goal of landing humans on Mars
  - **EDL Challenges:** high mass, precise landing, risk posture for humans

Entry, Descent and Landing (EDL) and Precision Landing - Summary

Lunar Capabilities (feeding forward to Mars)

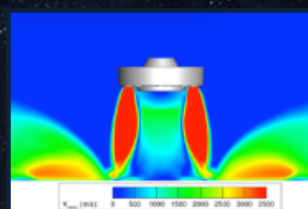
Precision Landing and Hazard Avoidance

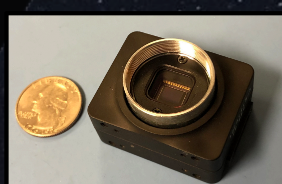
Safely and precisely land near science sites or pre-deployed assets



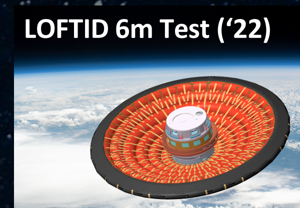
Plume Surface Interaction

Reduce lander risk by understanding how engine plumes and surfaces behave



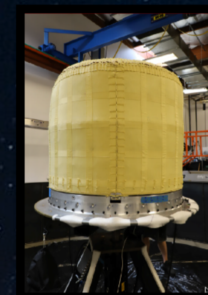


Mars Capabilities



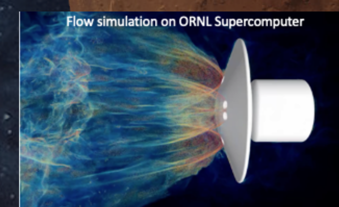
Land 20 t on Mars

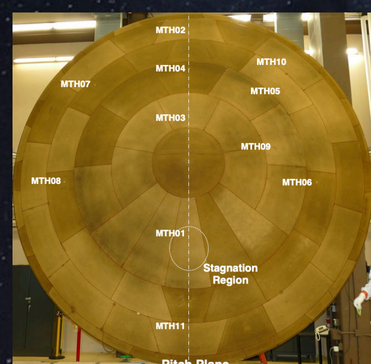
Large structures, including deployables, that can deliver high-mass payloads

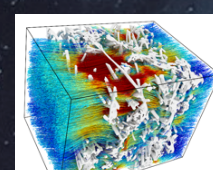


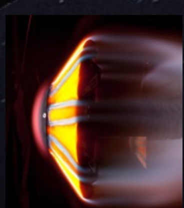
Retropropulsion Testing

Wind tunnel testing of Mars-relevant configurations; CFD modeling comparisons







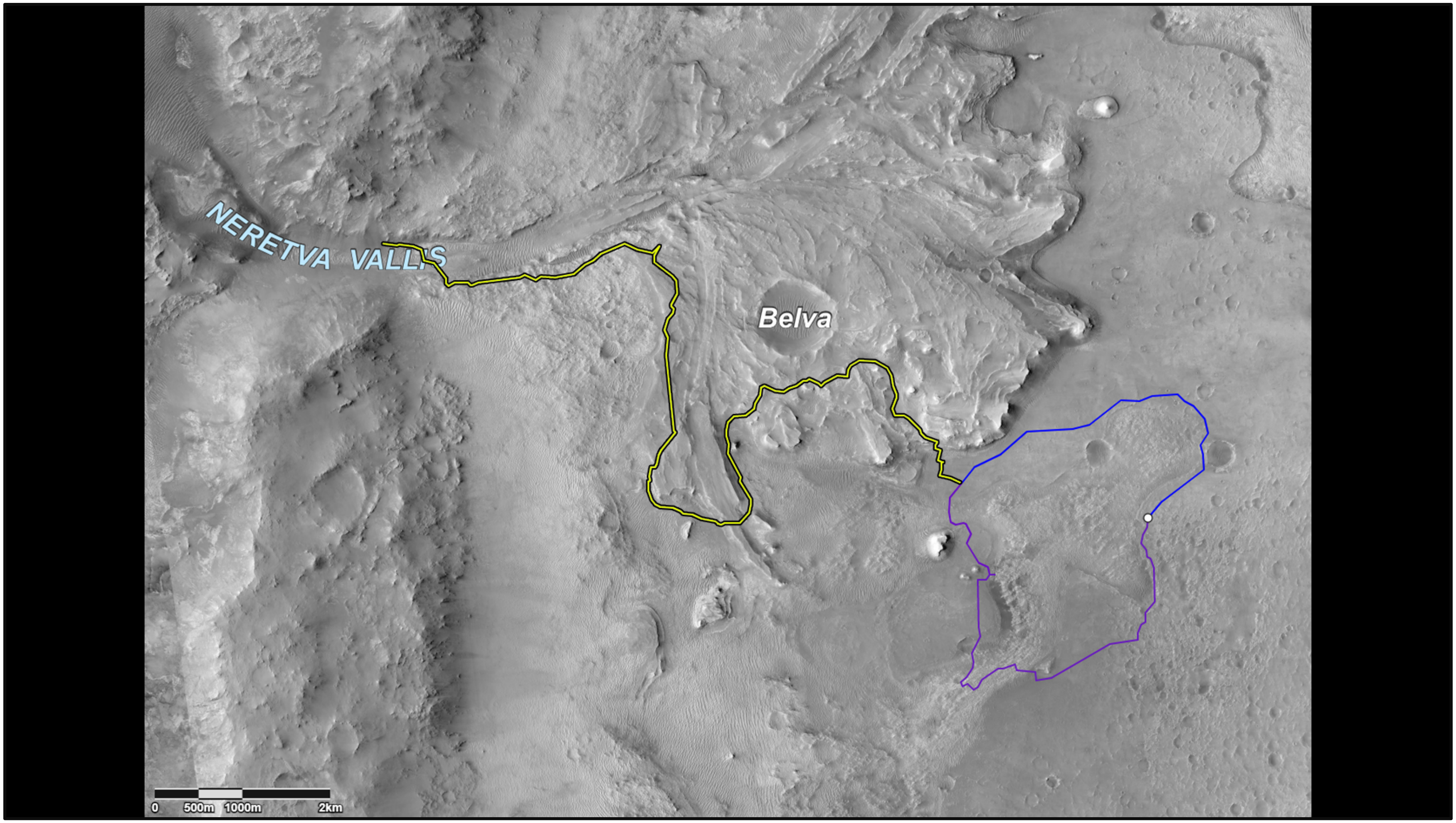


Data Return and Model Improvements

Measure EDL system performance via flight instrumentation and update unique, critical simulations for Moon, Mars, and other Solar System bodies. Includes ground-test diagnostics and uncertainty quantification; moving tools towards high-end computing capabilities and machine learning approaches.


EXPLORE
MOONtoMARS

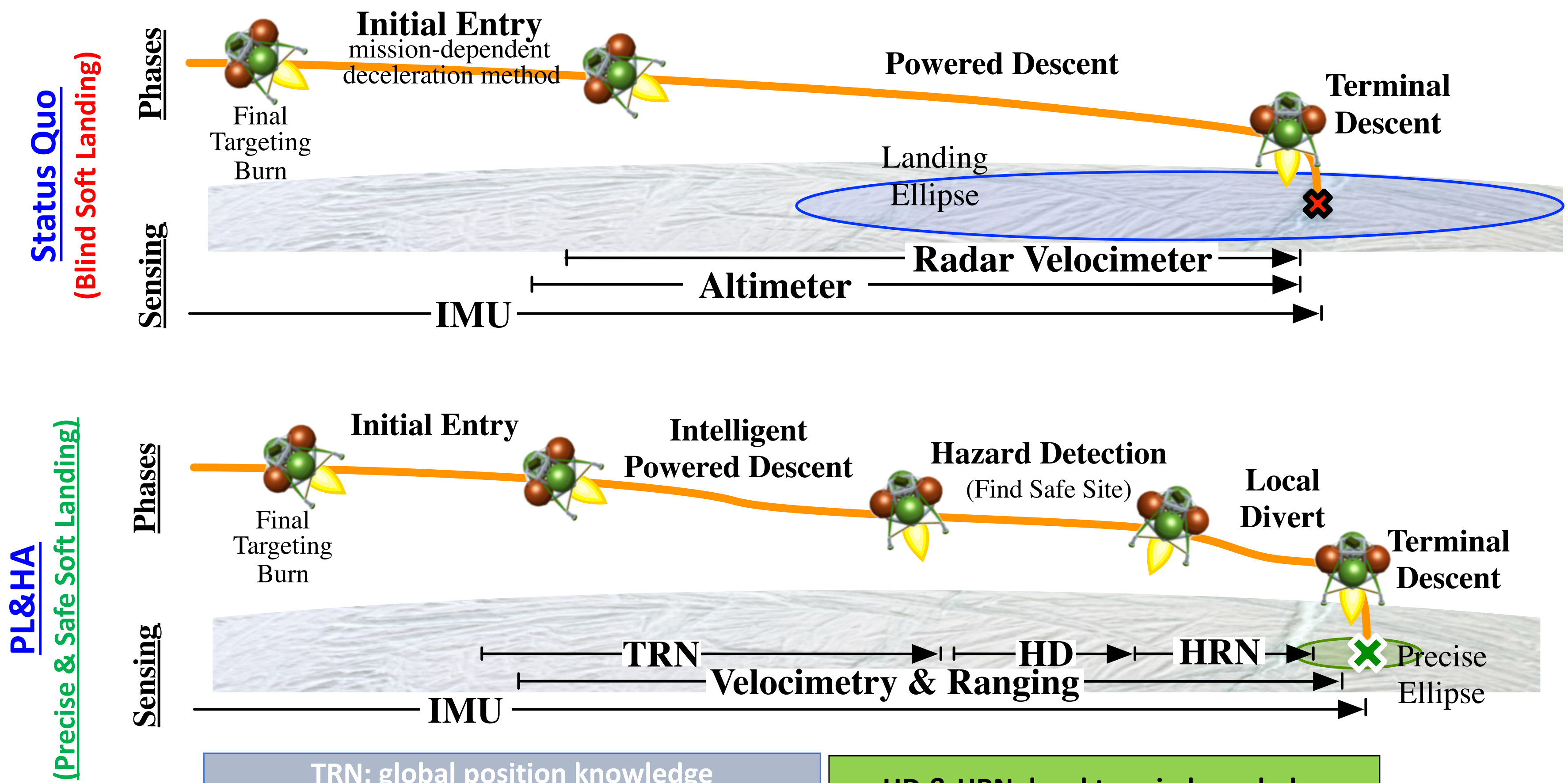
Where is Perseverance Going?



Courtesy NASA/JPL-Caltech

Landing Guidance Navigation and Control: Status Quo vs. PL&HA

Mission landing needs & risk posture define which PL&HA capabilities to use



TRN: global position knowledge
Minimizes landing ellipse & avoids large hazards seen in reconnaissance maps

HD & HRN: local terrain knowledge
avoid small hazards & minimize local landing error

Velocimetry & Ranging: precise soft landing
Significantly improves navigation precision

Advanced GN&C Algorithms
provide precise state knowledge and intelligent maneuvering commands

TRN	Terrain Relative Navigation
HD	Hazard Detection
HRN	Hazard Relative Navigation