

# Lander Launched Impact Probe: Mars Caves

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## Problem

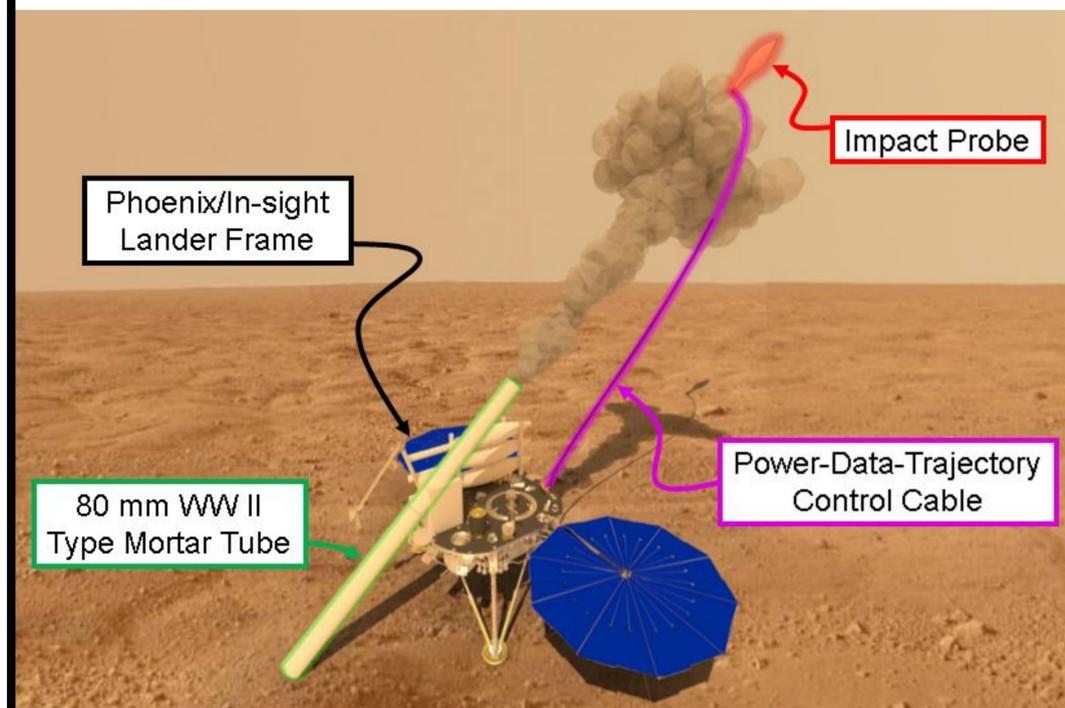
**Scientists** want to explore the most extreme regions:  
Mars caves, Europa/Enceladus Ice Geysers, Io Volcanos, Titan Lakes, Lunar mare pit craters

**Engineers** are risk adverse and want to land in "safe" places:  
flat, away from shear rock faces, cleared of rocks, equatorial

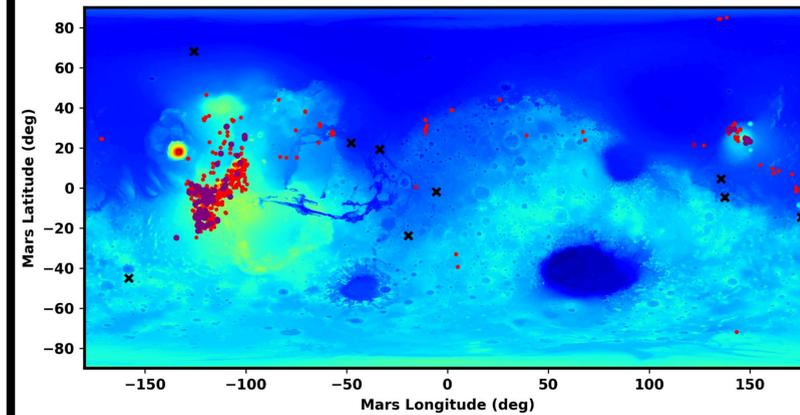
**Travel Time** from "safe" places to scientific interest can be years  
**Science mission operations are numbered in days (<90d)**

## Solution

Land in the "safe" place & launch a sample collecting probe or science instrument to the extreme region of interest



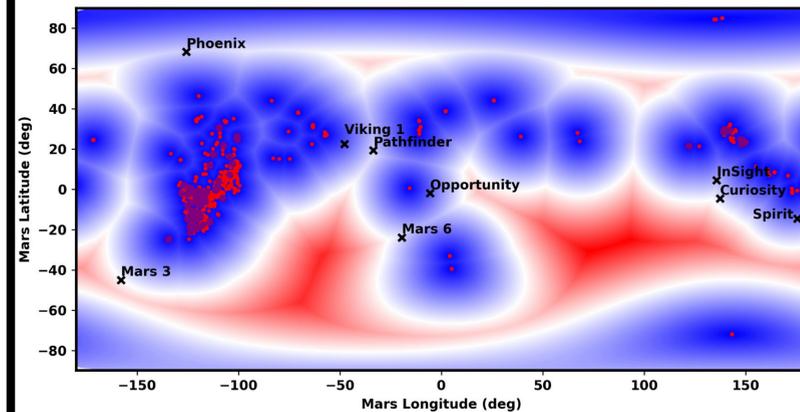
## Mars Cave Mission Feasibility



**Takeaway:** Most Lava tube skylights (purple) appear at high altitudes

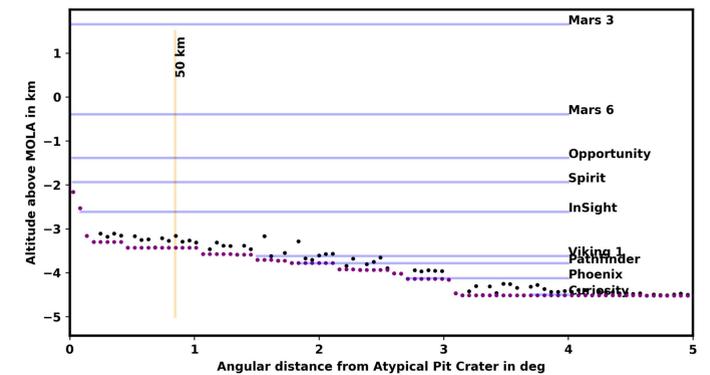
**Takeaway:** Some Atypical Pit Craters (red) appear at low altitudes

**Takeaway:** No mission has landed near these cave entrances

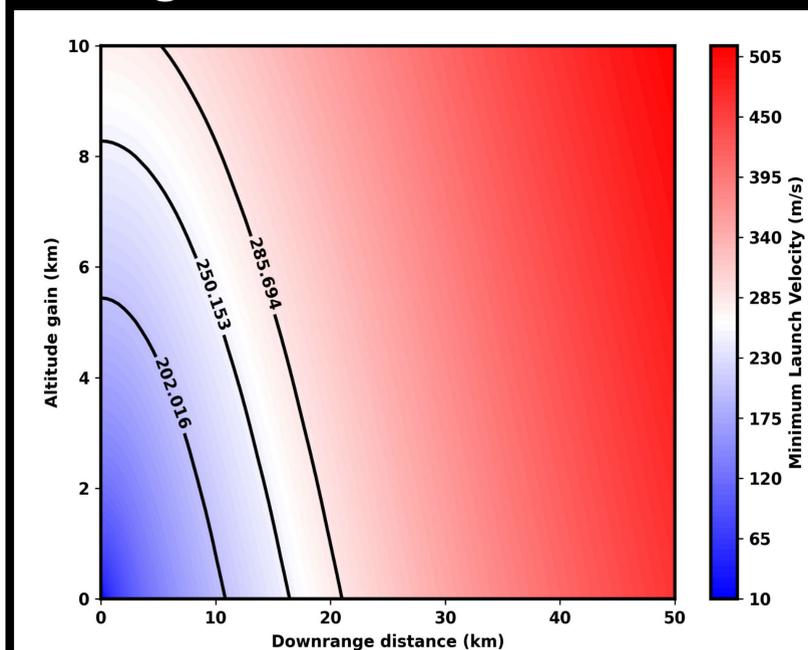


**Takeaway:** A launched impact probe can explore regions at a higher altitude than the lander is capable of reaching

**Takeaway:** Past Mars missions (In-sight, Spirit, Opportunity) have landed at altitudes high enough for a Lander Launched Impact Probe to be within range of Atypical Pit Craters

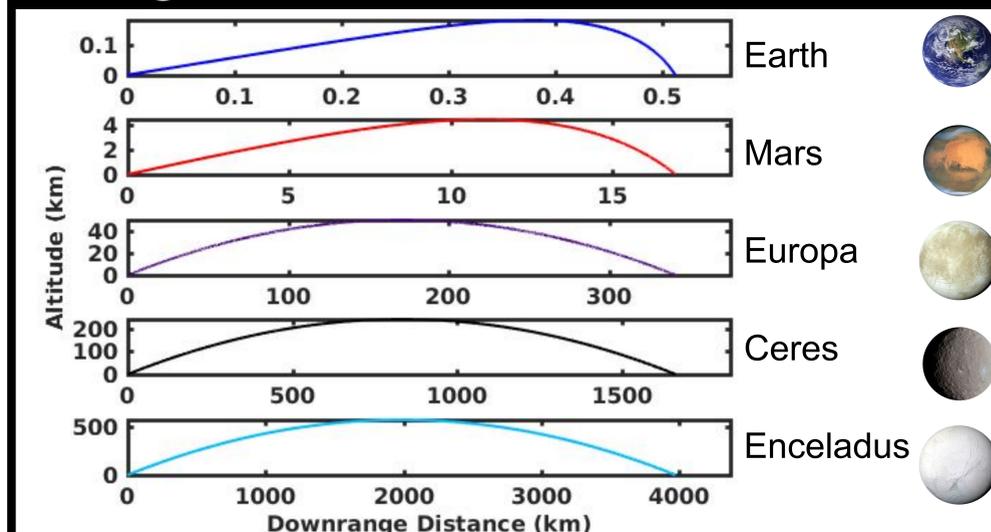


## Range: On Mars



**Takeaway:** Mortar launch velocities can provide substantial down-range and altitude gain

## Range: Other Planets

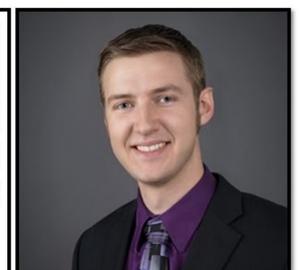


**Takeaway:** Simple probes on Earth have limited range due to atmospheric drag and high gravity

**Takeaway:** Simple probes can be launched 100's-1000's of km on different planetary bodies from an initial landing location

## Conclusions

- A Mars cave mission is feasible
- Impact Probes, launched from a lander, can explore a region far from and above an initial landing site
- Launched Impact Probes are a technology enabling exploration of the most extreme planetary regions



Zoom Link <https://cornell.zoom.us/j/97611802851?pwd=UXdNckhyVW16bS9MNWhBSmtwaXQyZz09>



# Appendix

**Table 1:** Vehicle Travel Distances on OtherPlanetary Bodies

Rover	Distance	≈Speed	Total Time
Opportunity	45.16 km	1 cm s <sup>-1</sup>	15 yr
Lunokhod 2	39 km	0.55 m s <sup>-1</sup>	4 mo
Apollo 17[14]	35.74 km	5 m s <sup>-1</sup>	4 hr 26 min
Apollo 15[14]	27.8 km	5 m s <sup>-1</sup>	3 hr 2 min
Apollo 16[14]	27.1 km	5 m s <sup>-1</sup>	3 hr 26 min
Curiosity	20.31 km	3.88 cm s <sup>-1</sup>	7+ yr
Lunokhod 1	10.5 km	0.55 m s <sup>-1</sup>	321 d
Spirit	7.7 km	1 cm s <sup>-1</sup>	6 yr
Sojourner	0.1 km	6.66 cm s <sup>-1</sup>	85 d
Yutu	0.1 km	-	42 d

The pioneer 13 mission sent 4 **atmospheric probes** on an entry trajectory into Venus's atmosphere. The large probe had a parachute but the other 3 smaller probes descended to the surface in free-fall. Two of these small probes survived impact with the surface. On transmitted for an additional 2 seconds. **The other continued transmitting for 67 minutes and 35 seconds after a free-fall impact with the surface.**

**Table 2:** Lander Mission Information

Mission Name	Latitude (°)	Longitude (°)	Altitude (km)	Landing Ellipse (km)	Source	Success
Mars 3	45 S	158 W			[20]	Yes
Mars 6	23.90 S	19.42 W			[20]	Yes
Viking 1	22.483 N	47.82 W			[21]	Yes
Viking 1	22.483 N				[22]	Yes
Viking 1	22.272 ± 0.002 N	47.94 ± 0.2 W			[22][23][24]	Yes
Viking 2	47.670 ± 0.002 N	225.71 ± 0.2 W		100 × 300	[22][23][25]	Yes
Viking 2	47.968 N				[22]	Yes
Pathfinder	19.33 N	33.55 W		100 × 200	[26]	Yes
Beagle 2	11.53 N	90.50 E		57 × 174	[27]	No
Spirit	14.571892 S	175.47848 E		8 × 73	[28][29]	Yes
Opportunity	1.9462 S	5.5266 W		10 × 73	[30][29]	Yes
Phoenix	68.219 N	125.752 W		20 × 110	[31]	Yes
Curiosity	4.5965 S	137.4019 E		10 × 10	[32][33]	Yes
In-Sight	4.502 N	135.623 E		27 × 130	[34][35]	Yes
ExoMars Rover 2020	-	-	-	-	-	-
Mars 2020	-	-	-	-	-	-
Red Dragon	-	-	-	-	-	-
Blue Moon	-	-	-	-	-	-

**Figure 1:** Largest Mars Caves North of Arsia Mons on Mars (Cushing et. al. 2015)

