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Supplementary information

Surface characteristics of the Zhurong Mars rover traverse at Utopia Planitia

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Supplementary Information for

Surface Characteristics of the Zhurong Mars Rover Traverse at Utopia Planitia

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Supplementary Text

Routing path mapping of Zhurong rover

The base map is a high-resolution (~0.7 m/pixel) digital orthophoto map (DOM)[9] generated from the High Resolution Imaging Camera (HiRIC) images. The landing site location is 109.925° E, 25.066° N in the planetocentric frame tied to the IAU/IAG 2000 Mars coordinate system, and its accuracy has been verified to be within a pixel of the orbital DOM compared to the newly acquired orbital image with the visibility of the lander[8]. The rover positions derived from visual localization presented in the source data of Fig. 2a are provided in the landing site cartographic coordinate frame, which takes the lander as its origin. Its *z*-axis is up; its *x*-axis points to the east, and its *y*-axis points to the north pole. The rover positions derived from visual localization firstly obtained in the LSL coordinate frame and transferred to this frame for mapping. The rover positions can be mapped to the high-resolution DOM based on the definitive frame origin and axes.

Supplementary Table 1. Parameters of the Yutu-2 rover wheel.

Parameter name	Value
Wheel radius r (mm)	150
Wheel width b (mm)	150
Height of the wheel grouser h (mm)	10
Number of wheel grousers	24
Shearing radius of a wheel r_s (mm)	156.5
Normal force on each wheel F_N (N) (under quasi-static state)	36.5
Wheel slip ratio s	~0.1
Wheel sinkage z (mm)	~10

Note. Considering the gravity on the Moon, the vertical load on each wheel is estimated based on the rover configuration and mass distribution at 36.5 N under a quasi-static state. Each wheel is equipped with 24 lugs arranged in two stagged rows.

Supplementary Table 2. Parameters of typical soils on the Earth.

Terrain	n	k_c (kPa/m^{N-1})	k_φ (kPa/m^N)	K_s (kPa/m^N)	c (kPa)	φ (°)
Dry sand (Land Locomotion Lab., LLL)	1.1	0.99	1528.43	1533.38	1.04	28
Sandy Loam	0.7	5.27	1515.04	1576.39	1.72	29
Sandy loam	0.9	52.53	1127.97	1390.62	4.83	20
Sandy loam	0.3	2.79	141.11	155.06	13.79	22
Clayey soil	0.5	13.19	692.15	758.1	4.14	13
Heavy clay	0.13	12.70	1555.95	1619.45	68.95	34
Lean clay	0.2	16.43	1724.69	1806.84	68.95	20
LETE sand (Wong)	0.79	102	5301	5811	1.3	31.1
Upland sandy loam (Wong)	1.10	74.6	2080	2453	3.3	33.7
Rubicon sandy loam (Wong)	0.66	6.9	752	786.5	3.7	29.8
North Gower clayey loam (Wong)	0.73	41.6	2471	2679	6.1	26.6
Grenville loam (Wong)	1.01	0.06	5880	5880.03	3.1	29.8
Snow (U.S)	1.6	4.37	196.72	218.57	1.03	19.7
Snow (Sweden)	1.44	10.55	66.08	118.83	6	20.7

Note. n, k_c, k_φ, c, φ are original data from reference 21, while the values of K_s for different soils are derived based on k_c and k_φ according to Zhurong's wheel width of 0.2 m. N is the variable sinkage exponent of wheel-terrain interaction; for typical value of the of bearing characteristics, $N = n$ (intrinsic sinkage exponent of the terrain on the Earth).

Supplementary Table 3. Soil properties of previous sites of Mars landing missions.

Mars mission	Landing site	Cohesion *c* (kPa)	Internal friction angle *φ* (°)
Viking 1 Lander[22]	48.22° W, 22.70° N	5.1±2.7	30.8±2.4
Viking 2 Lannder[22]	134.29° W, 47.64° N	1.1±0.8	34.5±4.7
Mars Pathfinder[23]	33.22° W, 19.13° N	0.120-0.356; avg: 0.238	32°-41; avg: 36.6
MER-Spirit[24]	175.4726° E, 14.5684° S	~1-15	~20-25
MER-Opportunity[25]	354.4734° E, 1.9462° S	~0.5-5	~20
Curiosity[26]	137.4403° E, 4.5919°S	1-3	~30
Phoenix Lander[27]	25.7° W, 68.22° N	0.2-1.2	38±5
InSight Lander[28]	135° E, 4.5° N	>1-1.9	30~50

Supplementary Table 4. The parameters of the NaTeCam[3], HazCam and Wi-Fi camera.

Camera	Parameter	Value
NaTeCam	Baseline	270 mm
	Waveband (colour system)	~400-700 nm
	Focal length	13.1 mm
	Field of view	46.5°×46.5°
	View distance	0.5 m-∞
	Best focusing distance	1 m
	Image resolution	2048×2048
HazCam	Field of view	120°
	Pixel number	1024×1024
Wi-Fi camera	View distance	1-50 m
	Pixel number	1280×1024