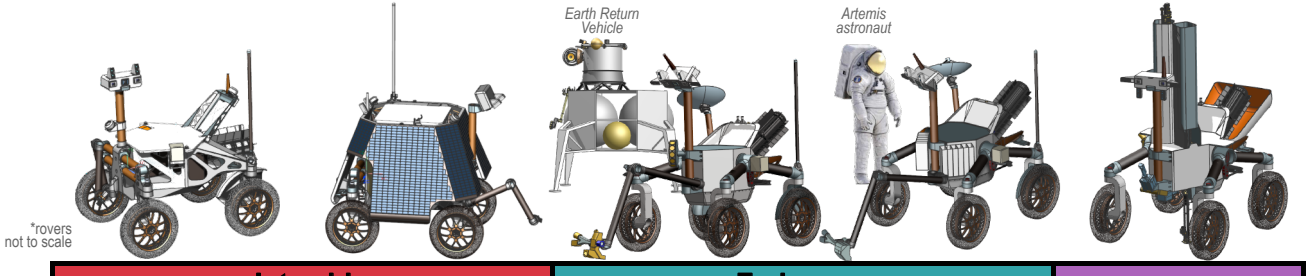

LONG-RANGE LUNAR ROVER MISSION CONCEPTS

five rovers with a common design lineage

2023–2032 Planetary Science and Astrobiology Decadal Survey

	Intrepid		Endurance		INSPIRE
	Intrepid (RTG) (baseline Intrepid)	Intrepid (Solar)	Endurance-R (R = robotic sample return)	Endurance-A (A = astronaut sample return)	(In Situ Solar System Polar Ice Roving Explorer)
	Pre-Decadal Planetary Mission Concept Study (PMCS)		Decadal Survey Mission Concept Study		
	PI: Mark Robinson (ASU)		Science Champion: James Tuttle Keane (JPL) Deputy Science Champion: Sonia Tikoo (Stanford)		Science Champion: Jennifer Heldmann (NASA Ames)
			Study Lead: John Elliott (JPL)		

							Notes:
CONCEPT SUMMARY:	Description:	Long-range lunar rover for investigating six diverse geologic regions on the lunar nearside, to determine the evolution of lunar interior, characterize the diversity of styles of magmatism, and post emplacement modification of magmatic materials.		Long-range lunar rover for exploring, collecting, and returning samples and the largest and oldest impact basin on the Moon, South Pole–Aitken (SPA) basin, in order to answer critical questions about Solar System chronology and planetary evolution. Endurance-R delivers samples to a separately landed robotic Earth Return Vehicle.	Endurance-R delivers samples to a Artemis astronauts at the Moon's south pole	Long-range lunar rover for exploring the Moon's permanently shadowed regions (PSRs) to determine the origin, age, and evolution of lunar volatiles.	Intrepid, Endurance, and INSPIRE all address different priority planetary science questions—as detailed in their respective reports.
	Landing Site:	Lunar nearside, Oceanus Procellarum (6.5°N, -58.9°E)		Lunar farside, Poincaré basin (57.2°S, 163.0°E)	Lunar farside, central South Pole–Aitken basin (57.9°S, -161.7°E)	Lunar south pole, Cabeus crater (84.7°S, -45.2°E)	
	Lunar Delivery:	Rover delivered by a CLPS lander (for comparison, VIPER a ~500-kg rover will be delivered by CLPS to the lunar south pole in 2022)					
	Nominal Launch Date:	2030 (set by RTG availability for most options; launch dates for the Moon are extremely flexible)					
	Nominal Traverse Distance:	1,800 km		1,750 km	2,000 km	750 km	
	Mission Duration:	4 years (including 1 year of margin)	7 years (including 1 year of margin)	4 years (including 1.3 years of margin)	4 years (including 1.1 years of margin)	3 years (including 1 year of margin)	
COST:	Total A-D Development Costs (with 50% reserves):	$1,049M	$997M	$1,778M	$1,105M	$1,157M	Team-X costs reported, following Decadal Survey concept study guidelines.
	Total E-F Operations Cost (with 25% reserves):	$242M	$350M	$252M	$233M	$184M	Endurance-R has higher costs (Flagship class) because it includes the development and operations of a separate Earth Return Vehicle. The cost of just the Endurance-R rover would be very nearly identical to the costs for Endurance-A.
	Launch and Commercial Lunar Payload Service:	$220M	$200M	$400M	$200M	$200M	Intrepid (Solar) has a higher operations cost than Intrepid (RTG) because the solar-powered version requires a longer mission duration (since it cannot do substantial operations at night).
	Total Project Cost:	$1,511M	$1,547	$2,430M	$1,538M	$1,541M	Intrepid (RTG)'s launch service costs included an extra $20M for RTG special services. For Endurance and INSPIRE, all RTG costs are carried in A-D costs.
	Mission Class:	New Frontiers	New Frontiers	Flagship	New Frontiers	New Frontiers	
SCIENCE INSTRUMENTS	Instruments:	Stereo cameras					Intrepid, Endurance-R, and Endurance-A have identical instrument suites. INSPIRE's instrument suite is largely distinct.
		Long-range camera (FarCam)				Near-IR spectrometer (NIRVSS)	
		Visible/Near-IR point spectrometer				Neutron spectrometer	
		Hand lens imager (HLI)				Mass spectrometer (MSolo)	
		Alpha-particle X-ray spectrometer (APXS)				Ion and electron detector (IES)	
		Magnetometer				Thermal-IR spectrometer (TIRS)	
		Gamma-ray and neutron spectrometer (GRNS)				Mini Ground Penetrating Radar (Mini-GPR)	
		Radiation monitor (ARMAS)					
		Electrostatic analyzer (ESA)					
		Laser retro-reflector (LRR)					
	Arm:	1-m long arm (0.5-m links)		2-m long arm (1-m links)		No arm	Endurance's arm is identical to Intrepid's arm, but with longer links to extend the workspace for sampling and, for Endurance-R, to facilitate transfer of the sample canister to the Earth Return Vehicle.
		5-degrees of freedom					
	Drill:	No drill				2-m TRIDENT drill	
	Sample Collection:	No sample collection		Combined scoop and rake Sample container, capable of storing 2.2-kg (total) of lunar regolith and rocks in 12 individually sealed chambers Rover delivers samples to robotic Earth Return Vehicle	Scoop Sample boxes, capable of storing 100-kg (total) of lunar regolith and rocks in 12 open-air boxes Rover delivers samples to Artemis astronauts at the lunar south pole	No sample collection	Endurance-R's combined scoop and rake separates out regolith fines (<0.5 cm diameter) and rocklets (0.5–2 cm diameter). Endurance-A's simple scoop is just that—a scoop. Both are designed off of successful Apollo sampling equipment. Both Endurance sample systems are substantially simpler than the Perseverance (Mars 2020) sample collection and caching system.
ROVER DESIGN AND SUBSYSTEMS:	Rover Mass:	500 kg	500 kg	570 kg	570 kg	655 kg	Masses are fully margined. Endurance is heavier than Intrepid (RTG) largely due of the addition of the high-gain antenna, heavier RTG, and dual-rocker mobility system. INSPIRE is heavier than than Intrepid for the same reasons as Endurance, and INSPIRE is heavier than Endurance largely due to the addition of a larger battery and the drill system.
	Rover Size:	width: 1.8-m length: 2.7-m height: 3.0-m	width: 2.4-m length: 2.4-m height: 3.0-m	width: 2.1-m length: 2.7-m height: 2.8-m	width: 2.1-m length: 2.7-m height: 2.8-m	width: 2.1-m length: 3.0-m height: 3.4-m	INSPIRE is taller because of the drill.
	Mobility:	Four-wheel, all-wheel drive steering 0.8-m diameter mesh compliant wheels Single front-rocker		Dual side-rocker and differential			Endurance and INSPIRE opted for a dual side-rocker mobility system to enable traversing steeper slopes (<20°) than Intrepid (<15°).
	Autonomy:	Preplanned traverse with onboard decide autonomy for traverse and science operations					Intrepid, Endurance, and INSPIRE all take a common approach to traverse operations, including substantial pre-planning, autonomy, and prioritizing traverse speed and accomplishing science objectives.
	Communications:	Direct-to-Earth communications via Deep Space Network (DSN) CXS-610 radio S-band directional low giant antennae (x2)		Communications to Earth via lunar relay orbiter (Lunar Pathfinder baselined) UST-Lite radio 0.75-m, S-band, high gain antenna			Endurance-R and Endurance-A operate on the lunar farside, and INSPIRE operates at the south pole, frequently out of view of the Earth, so these concepts require orbital communications relays. There are several relays planned in the next decade, including Lunar Gateway, Lunar Communications Pathfinder, and Andromeda. Lunar Pathfinder was baselined.
		S-band omnidirectional low gain antenna					
	Power:	12-GPHS NextGen RTG (beginning of life power: 300-W)	Fixed, wrap-around triple junction solar arrays (6.3 m² total,1.3 m² illuminated at any time; beginning of life power: 317-W)	Mod-1 NextGen RTG (beginning of life power: 245-W)			Endurance-R, Endurance-A, and INSPIRE were required to use different RPS, due to changes in the NextGen RTG program. Intrepid (Solar) has a large battery for night survival, and INSPIRE has a large battery for drill operations.
		Secondary Li-Ion battery (20 amp-hr)	Secondary Li-Ion battery (612 amp-hr)	Secondary Li-Ion battery (20 amp-hr)		Secondary Li-Ion battery (100 amp-hr)	
	Attitude Control System (ACS):	Cameras Inertial Measurement Units (IMUs) Sun sensors Star trackers Headlights (for night driving)					Intrepid did not require headlights, since it could utilize Earthshine for night driving. Endurance and INSPIRE are designed for substantial operations at lunar night or in permanent shadow.
	Thermal:	Radiator, thermal switch, electronics placed in central Warm Electronics Box (WEB)				Two-phase pumped loop system to distribute RTG heat	INSPIRE required additional thermal capabilities to survive in cold permanently shadowed regions.
	Command and Data Handling (C&DH):	Dual-string Sabretooth					