KARI 한국항공우주연구원 Korea Aerospace Research Institute

National Aeronautics and Space Administration

KPLO DANURI

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Table of Contents

01 Introduction to KPLO

Image credit: KARI, NASA

The Korea Pathfinder Lunar Orbiter (KPLO), or Danuri (다누리), is the first Korea robotic lunar probe expected to carry out a lunar observation mission at a nominal orbiting altitude of ~100 km from the Moon. It is a cooperative project between the Korea Aerospace Research Institute (KARI), which will oversee the system, main body of the orbiter, and ground station, and a Korea university, research institutes, and NASA supporting the payloads, deep space communication, and navigation technology. The KPLO spacecraft consists of the main body of the orbiter, propulsion systems, tracking systems, three communications antennae, two solar arrays, and six payloads. The KPLO project involves mapping the lunar environment, technology demonstrations for planetary exploration, international cooperation, and establishing a deep-space network. The KPLO mission is a large portion of phase one of the Korea Lunar Exploration Program (KLEP) and Korea's exciting journey into space exploration.

The Six payloads onboard KPLO

1. LUTI

The Lunar Terrain Imager (LUTI) will capture 10-kilometer wide images (2.5 m pixel scale) of future landing sites on the Moon.

2. PolCam

The Wide-Angle Polarimetric Camera (PolCam) is comprised of two multi-band cameras. PolCam will capture polarimetric images for most of the Moon, except for polar regions. PolCam images will have medium spatial resolution with wider angles and investigate the detailed characteristics of the regolith.

3. ShadowCam

ShadowCam is a NASA-provided instrument that will image (1.7 m pixel scale) the reflectance of Permanently Shadowed Regions (PSRs) mapping the terrain and searching for signs frost or ice deposits. ShadowCam will observe each pole on a monthly basis in search of seasonal changes.

4. KMAG

The KPLO Fluxgate Magnetometer consists of three sensors mounted on the 1.2-meter-long boom, and will continuously measure the lunar magnetic field.

5. KGRS

The KPLO Gamma-Ray Spectrometer (KGRS) will measure gamma-rays emanating from the lunar surface to map the spatial distributions of the key elements.

6. DTNPL Technology Demonstration

The Delay/Disruption Tolerant Network Payload (DTNPL) will demonstrate space internet communications technology between DTN nodes in KPLO and the Earth. This experiment includes CCSDS File Delivery Protocol (CFDP), Asynchronous Message Service (AMS), and Bundle Streaming Service (BSS).

KPLO Hardware Locations

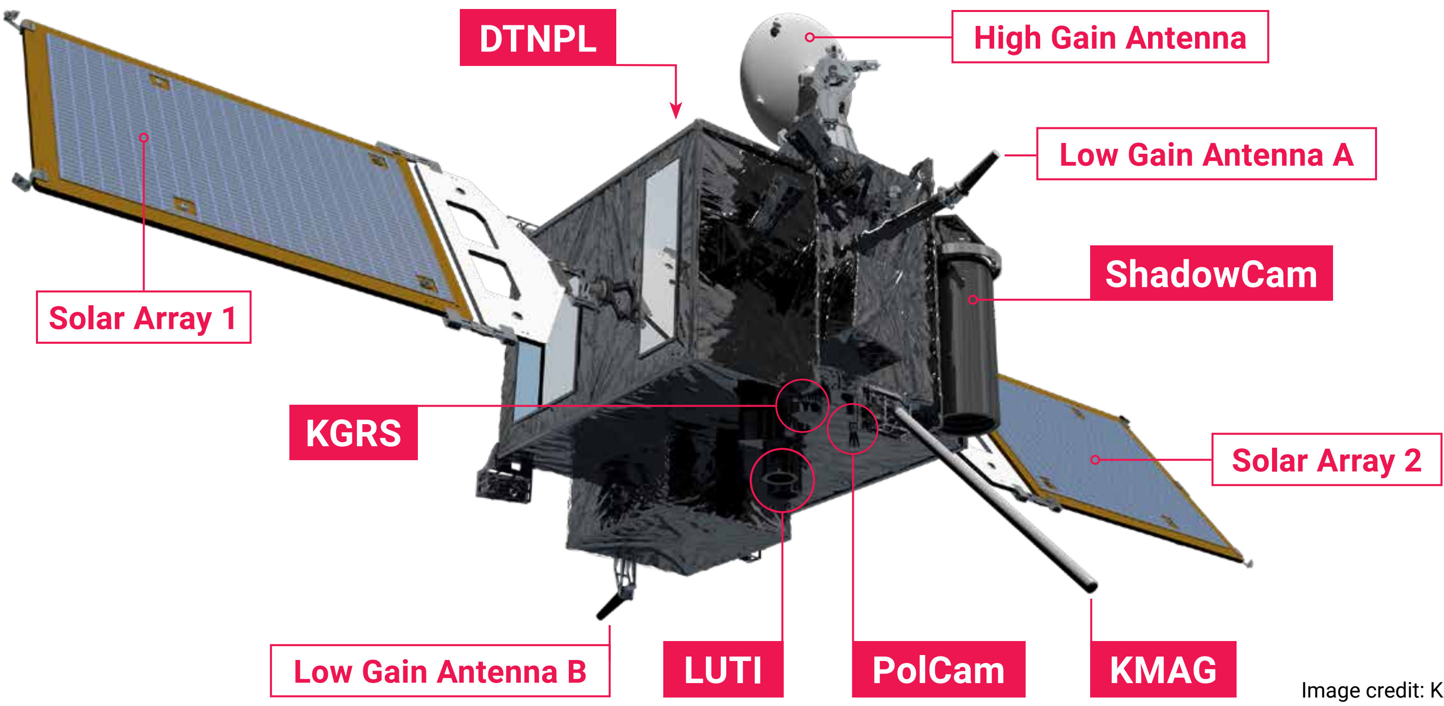


Image credit: KARI

KPLO & KARI Quick Facts

Launch Details

Time: Thursday, August 4, 2022 at 7:08 p.m. EST (23:08 UTC)
Location: Space Launch Complex 40 (SLC-40), Cape Canaveral Space Force Station, Florida, United States.
Live Streams: www.youtube.com/c/SpaceX

Additional Satellite Details

Weight: 678 kg (1495 lb)
Communications: S-band Uplink/Downlink, X-band Downlink
Electrical: Orbit-averaged 760W power generation
Dimensions: 3.18 x 6.3 x 2.67 meters (10.4 x 20.6 x 8.75 feet)
Mission Length: One year primary mission & possible extended mission
Additional Hardware: One Gyro Reference Assembly (GRA), two star trackers, four reaction wheels, four orbit maneuver thrusters (OMT), eight attitude control thrusters (ACT), and 10 sun sensors.

Korea Aerospace Research Institute (KARI)

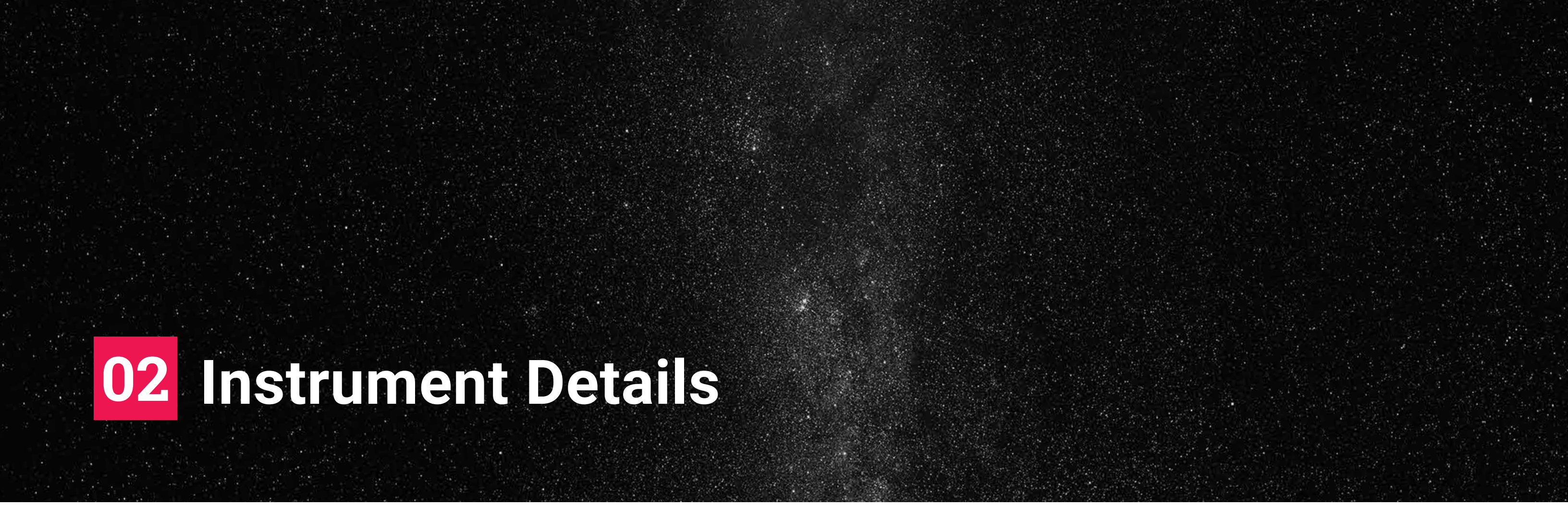
KARI is a space research and development institute in the Republic of Korea (South Korea). Since the 1990s, KARI has accumulated satellite development technology by launching a series of Earth observation satellites. KPLO is a Korea-built space exploration mission going beyond Earth orbit and a first step in the Korea Lunar Exploration Program (KLEP). Phase I (develop KPLO and launch using foreign launch vehicle) aims at developing core technology through domestic-led and international collaboration with NASA. Phase II will focus on developing a lunar lander and launching with a domestic launch vehicle.

Mission Objectives

The KARI mission objectives are: 1) the development of critical technologies for lunar exploration; 2) the scientific investigation of the lunar environment; and 3) the realization and validation of new space technology.

Why the Moon?

To the Moon, Mars, and Beyond is an inspiring goal shared by many international space research groups. However, space exploration is extremely difficult. What better place to work through these difficulties than in our own backyard? The Moon offers an accessible testing environment that applies to Mars and beyond.



02 Instrument Details

Image credit: KARI, NASA

Lunar Terrain Imager (LUTI)

LUTI is a high-resolution camera developed by KARI that will take images of possible landing sites for future lunar exploration missions and other specific target sites. The camera will collect lunar geology and topology data with a high spatial resolution of 2.5 meters per pixel at 100 km altitude.

Objectives

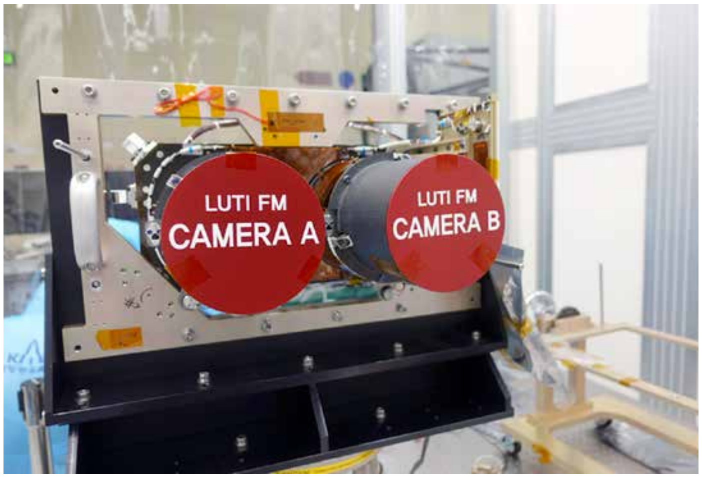
1. Investigate candidate landing sites for Korea's 2nd stage of lunar exploration (2030's)
2. Target observations of interesting places on the Moon

Instrument Overview

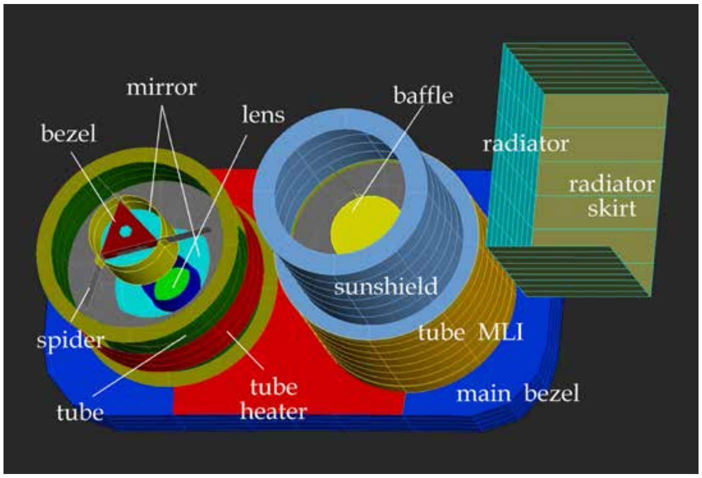
- Two cameras (450–850 nm)
- High dynamic range CCD sensor
- Provides digitized and compressed imagery
- Mass of 15 kg

Operations

LUTI is a dual push-broom imager that will collect a line-by-line, along track (direction of the spacecraft) scanned image. The two cameras are mounted side-by-side, each with a slight tilt of around 2.7 degrees in opposite directions, providing a 10 kilometer combined image width and a slight overlap between image pairs. Any residual gain difference (after pixel response non-uniformity correction) between the images will be corrected through on-ground image processing.



The LUnar Terrain Imager, High resolution camera. Image Courtesy of KARI.



Labeled Technical drawing of the LUTI instrument. Image courtesy of KARI.

Wide-Angle Polarimetric Camera (PolCam)

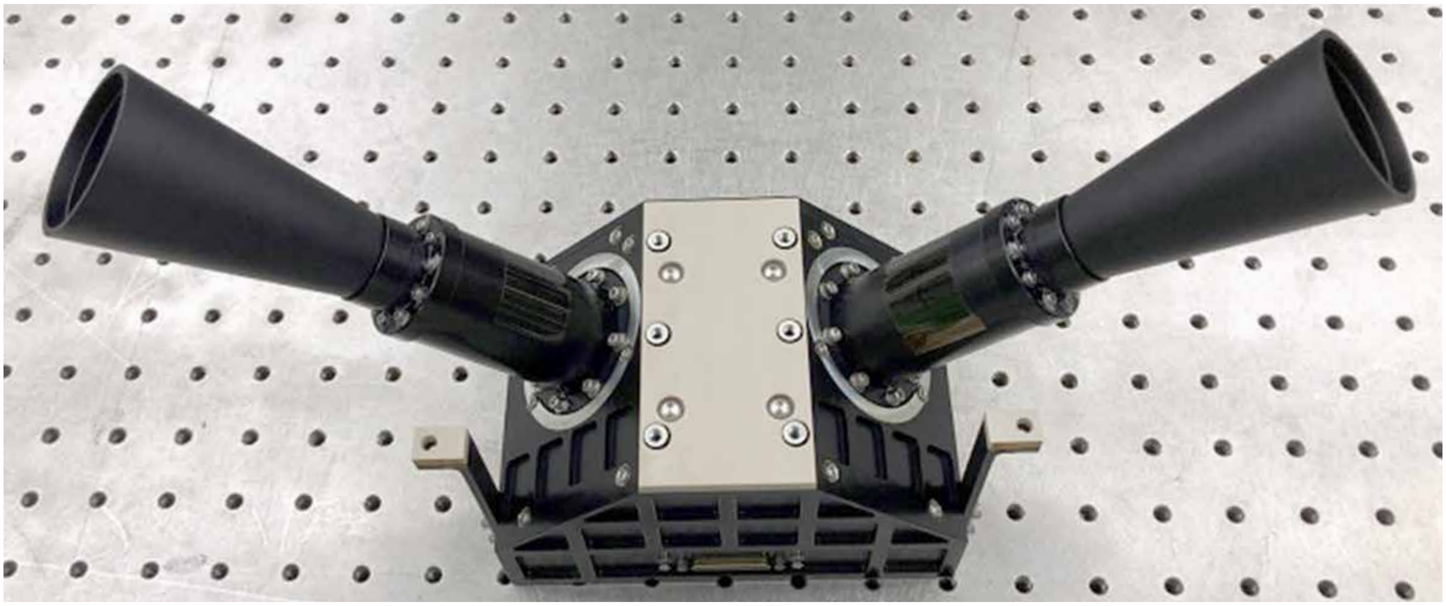


Image of the PolCam (wide angle POLarimetric CAMera) instrument. Image courtesy of KARI.

PolCam is a wide-angle polarimetric camera developed by the Korea Astronomy and Space Science Institute (KASI). Sunlight reflected by the lunar surface is partially polarized, or restricted to vibrating in one direction. PolCam will measure the degree of polarization providing information about grain size, composition, and space weathering. PolCam will be the first instrument to collect polarization measurements of the Moon from lunar orbit.

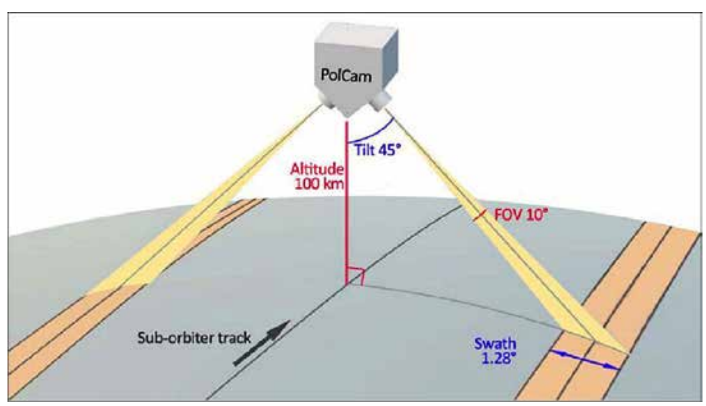
Four of the nine NASA KPLO Participating scientists will use PolCam observations to investigate pyroclastic (volcanic) deposits, the evolution of the topography and regolith, and lunar polarimetric anomalies. It is also possible to characterize the grain size of the regolith using polarimetric measurements. In addition to polarimetric measurements, the reflectance ratios at 320 and 430 nm will be used to map the titanium abundance of lunar soils.

Objectives

1. Polarimetric observations at 430 and 750 nm wavelengths and phase angles between 0° and 140°
2. Reflectance ratios at 320 and 430 nm of the Moon between 70˚S and 70˚N

Instrument Overview

- Two identical cameras at 45° angles from nadir, pointed in opposite directions
- Multispectral with filters centered at 320, 430, and 750 nm.
- 430 nm band has polarization filters for 0°, 60°, and 120°.
- 750 nm band has polarization filters for 0° and 90°.
- Spatial resolution of 70 m/pixel at 100 km
- Swath width of 35 km per camera at 100 km altitude
- Mass of 3 kg

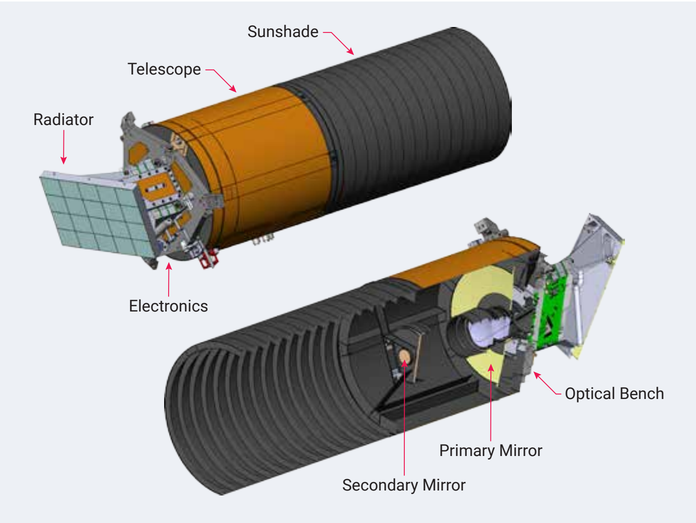


Schematic diagram of PolCam operations. Two identical cameras, each with a 10º field-of-view mounted in apposite directions at 45º angles across the orbiter track (image credit: KASI).

ShadowCam

View of the ShadowCam instrument (top) with a focused view of the instrument mounting hardware, electronics, and radiator (right). Images courtesy of ShadowCam & MSSS.

ShadowCam is a NASA-funded instrument that will collect high-resolution images of Permanently Shadowed Regions (PSRs). ShadowCam will provide critical information about the terrain of PSRs and the distribution and accessibility of water ice and other volatiles at spatial scales (1.7 m/pixel) required to mitigate risks and maximize the results of future exploration activities.



Labeled drawing of the ShadowCam instrument (Image credit: ShadowCam).

PSRs never see direct sunlight and are illuminated only by light reflected from nearby topographic highs; this secondary illumination is very dim. To see details within the PSRs, ShadowCam was designed to be over 200 times more sensitive than previous imagers, like the Lunar Reconnaissance Orbiter Camera Narrow Angle Camera (LROC NAC). As a result, ShadowCam images will allow for unprecedented views into the shadows but will saturate while imaging sunlit terrain.

Science Objectives

1. **Map albedo patterns in PSRs & interpret their nature:** ShadowCam will search for frost, ice, and lag deposits by mapping reflectance with resolution and signal-to-noise ratios comparable to LROC NAC images of illuminated terrain.
2. **Investigate the origin of anomalous radar signatures associated with some polar craters:** ShadowCam will determine whether high-purity ice or rocky deposits are present inside PSRs.
3. **Document and interpret temporal changes of PSR albedo units:** ShadowCam will search for seasonal changes in volatile abundance in PSRs by acquiring monthly observations.
4. **Provide hazard & trafficability information within PSRs for future landed elements:** ShadowCam will provide optimal terrain information necessary for polar exploration.
5. **Map the morphology of PSRs to search for & characterize landforms that may be indicative of permafrost-like processes:** ShadowCam will provide unprecedented images of PSR geomorphology at scales that enable detailed comparisons with terrain anywhere on the Moon.

For more information, news, and images, about ShadowCam, visit [shadowcam.asu.edu.](https://shadowcam.asu.edu)

KPLO Magnometer (KMAG)

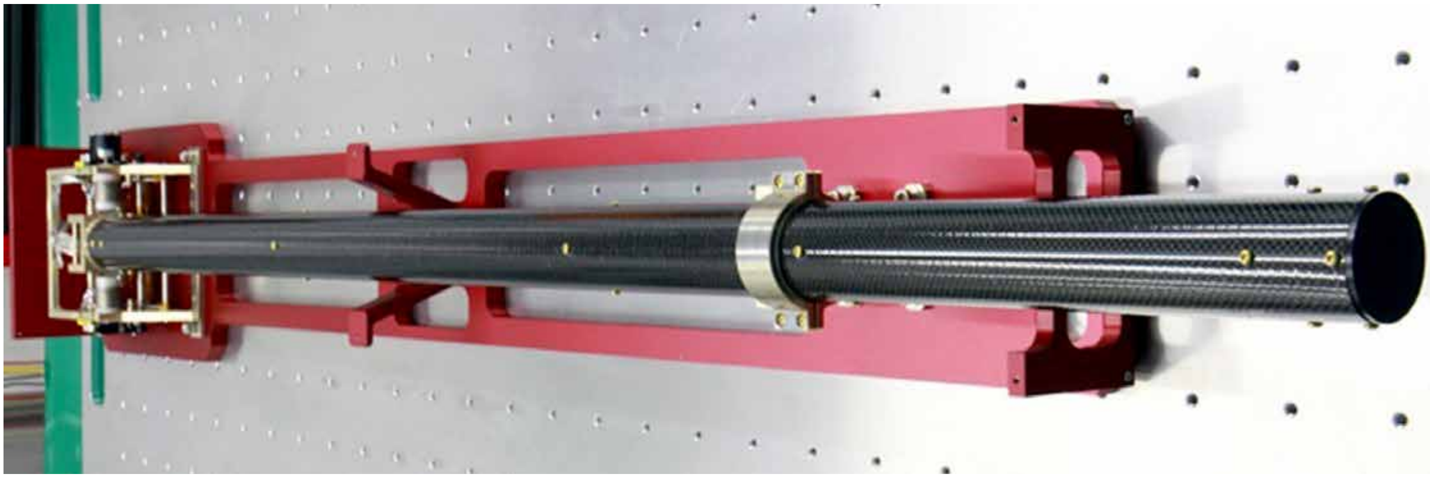


Image of the KMAG (Kplo MAGnetometer) instrument. Image courtesy of KARI/Kyung Hee University.

KMAG is a set of three magnetometers developed by Kyung Hee University (KHU) that will measure the lunar magnetic field from and around the Moon. The three magnetometers are mounted on a boom which minimizes spacecraft interference. Having three magnetometers provides redundancy and magnetic interference corrections; they can also be used together for a multi-sensor technical investigation. The boom will be nadir pointing during orbital operations.

Objectives

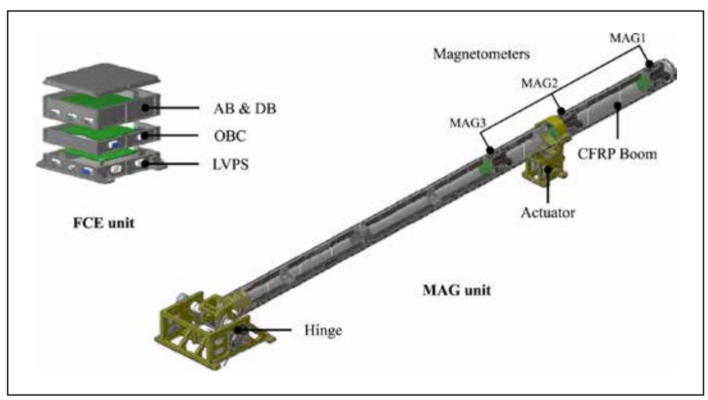
1. Investigate the lithospheric magnetism of the Moon
2. Measure the electromagnetic wave properties near-Moon space.

Instrument Overview

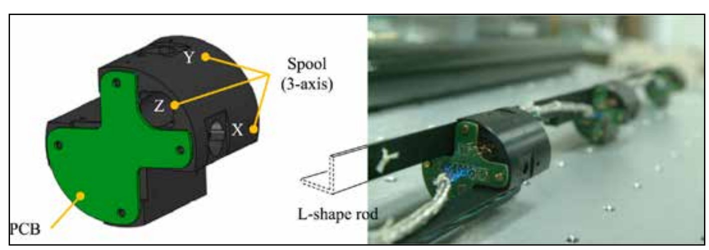
- Three tri-axial fluxgate magnetometers
- Measurable range: ±1000 nT
- Resolution: <0.2 nT at 10 Hz sampling rate
- Noise level: <50 pT Hz−1/2 at 1 Hz
- MAG1 is mounted at the end of the boom and is the primary magnetometer
- A Fluxgate magnetometer Control Electronics (FCE) unit controls the system
- Magnetometers are mounted on a 1.2 m boom
- Mass: 3.5 kg

KMAG has a measurement range of ±1000 nT to observe the wave properties and the magnetic field of the Moon and the surrounding space environment. KMAG will be operational at the same time as two other instruments measuring lunar magnetic fields: the THEMIS-ARTEMIS spacecraft and a magnetometer headed to Lacus Mortis as one of the Commercial Lunar Payload Services (CLPS) payloads. KMAG Calibration was performed in a special wooden building designed to minimize magnetic interference (Sensorpia Company).

For more information, visit KMAG online at sites.google.com/khu.ac.kr/kmag/home



Labeled drawing of the KMAG instrument (Image credit: Kyung Hee University).

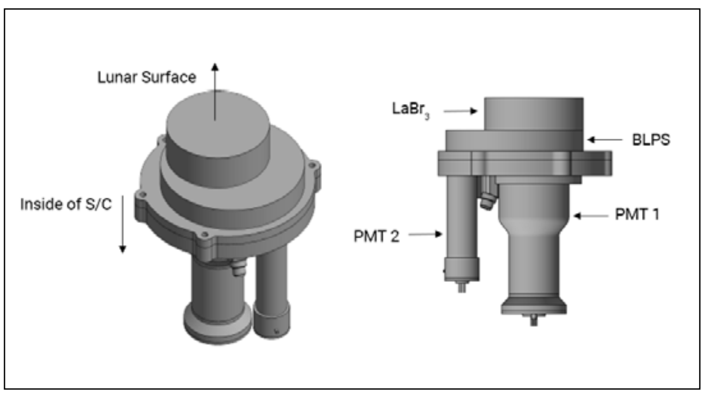


KMAG fluxgate magnetometer structure and the assembled engineering model. Three MAGs are assembled on an L-shape rod and inserted into the CFRP boom tube all at once (Image credit: Kyung Hee University).

KPLO Gamma-Ray Spectrometer (KGRS)

Side (left) and bottom (right) views of the KGRS (KPLO Gamma-Ray Spectrometer) instrument. Images courtesy of KIGAM.

KGRS is a gamma ray spectrometer developed by the Korea Institute of Geoscience and Mineral Resources (KIGAM). Elements (and isotopes) emit distinctive ranges energies; a gamma ray spectrometry measures these “fingerprints” allowing the identification of elements which make up the rocks beneath the spacecraft. The KGRS has an unprecedented energy range, starting at a very low 30 keV (kilo-electron-volt), which will allow the detection of Rn, U, and rare earth elements. In contrast, previous lunar orbiting gamma ray spectrometers only sensed as low as ~200 keV.



Labeled drawing of the KGRS instrument (Image credit: KIGAM).

Objectives

1. Map the spatial distribution of gamma-ray energy of 30 keV~12 MeV for a radiation map of the lunar environment
2. Map the distribution of lunar resources (water and volatile measurements, rare earth elements and precious metals, energy resources, major elemental distributions for prospective in-situ utilization)

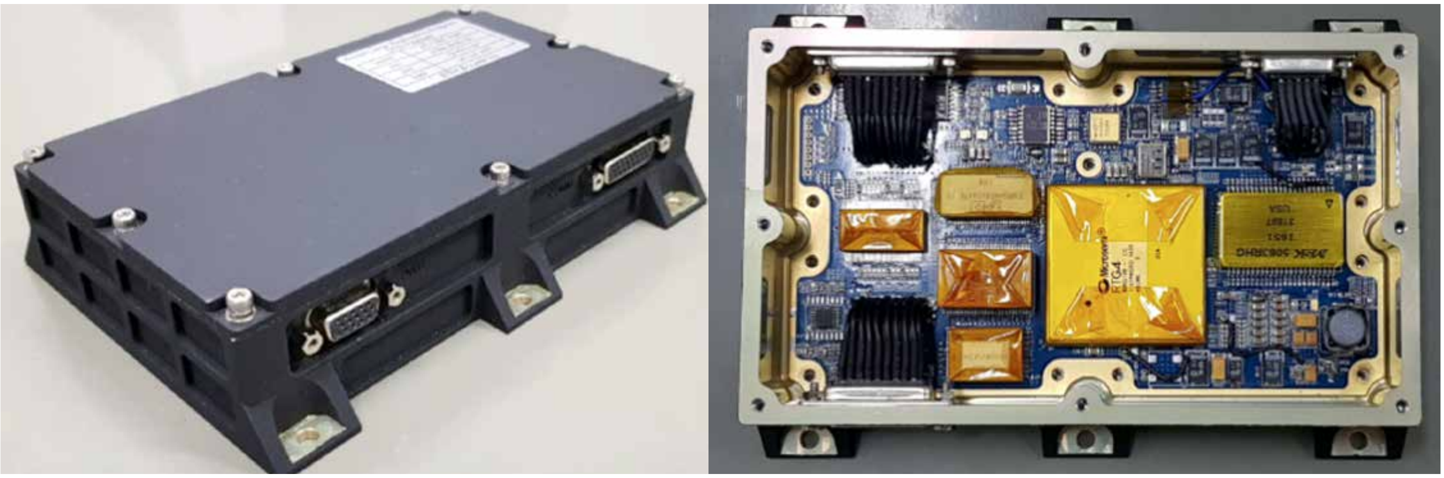
Instrument Overview

- Gamma-ray energy range from ~30 keV to 12 MeV
- Energy Resolution: < 5% full-width-at-half-maximum at 662 keV
- Can detect elements down to half a meter depth
- Data will be collected every 10 sec
- Main detector is a Lanthanum Bromide (LaBr3) scintillator
- Anti-coincidence counting module of boron-loaded plastic scintillators (BLPS) to reduce both low gamma-ray background from the spacecraft and housing materials and high energy gamma-ray background from cosmic rays
- Detect and map rock forming elements O, Mg, Al, Si, Ca, Ti, and Fe; radioelements K, Th, and U; the volatile element radon (Rn); and rare earth elements (Sm and Gd) on the lunar surface (down to 50 cm).
- Mass of 6.286 kg

Scientists will use radon (Rn) abundances to study the outgassing and transport of volatiles across the lunar surface. High abundances may indicate that the Moon is still geologically active. Direct identification of rare earth elements, Sm and Gd, could add new information about the last stage of crustal formation. Additionally, it may be possible to use the BLPS shield to detect and map hydrogen abundances in the permanently shadowed regions near the poles.

Visit KIGAM online at www.kigam.re.kr/english/

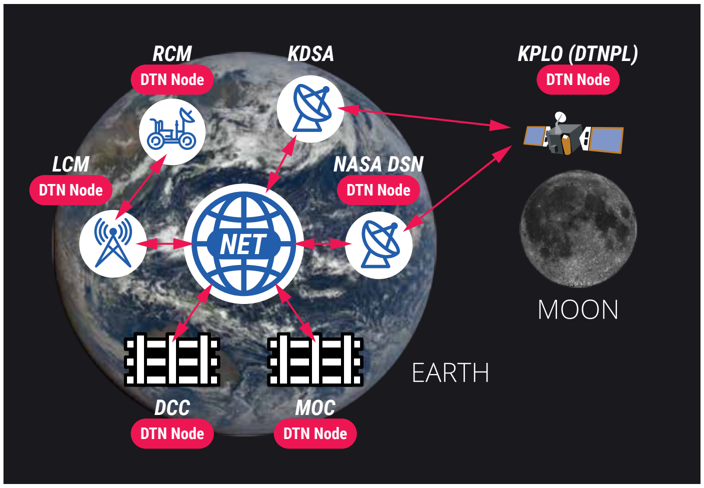
Delay/Disruption Tolerant Network PayLoad (DTNPL)



DTNPL external shape(left) and DTNPL inner shape(right). Image courtesy of ETRI, Korea.

The Delay/Disruption Tolerant Network Payload (DTNPL) is a space internet device developed by the Electronics and Telecommunications Research Institute (ETRI) of Korea. DTN is a type of interplanetary internet that is designed to handle delays and disconnections that occur frequently when utilizing internet technology in space.

DTN is a method modified to fit the space communication environment by adding Bundle Protocol (BP), a store-and-forward function that is not present in the existing terrestrial internet. DTN technology is an internationally standardized technology and will become a major means of communication network for future space exploration.



Network configuration of Space Internet Technology Demonstration. KDSA – Korea Deep Space Antenna, DSN – Deep Space Network, MOC – Mission Operations Center, DCC –DTN Communications Center, LCM – Lander Communications Module, RCM – Rover Communications Module (Illustration information courtesy of ETRI).

Objectives

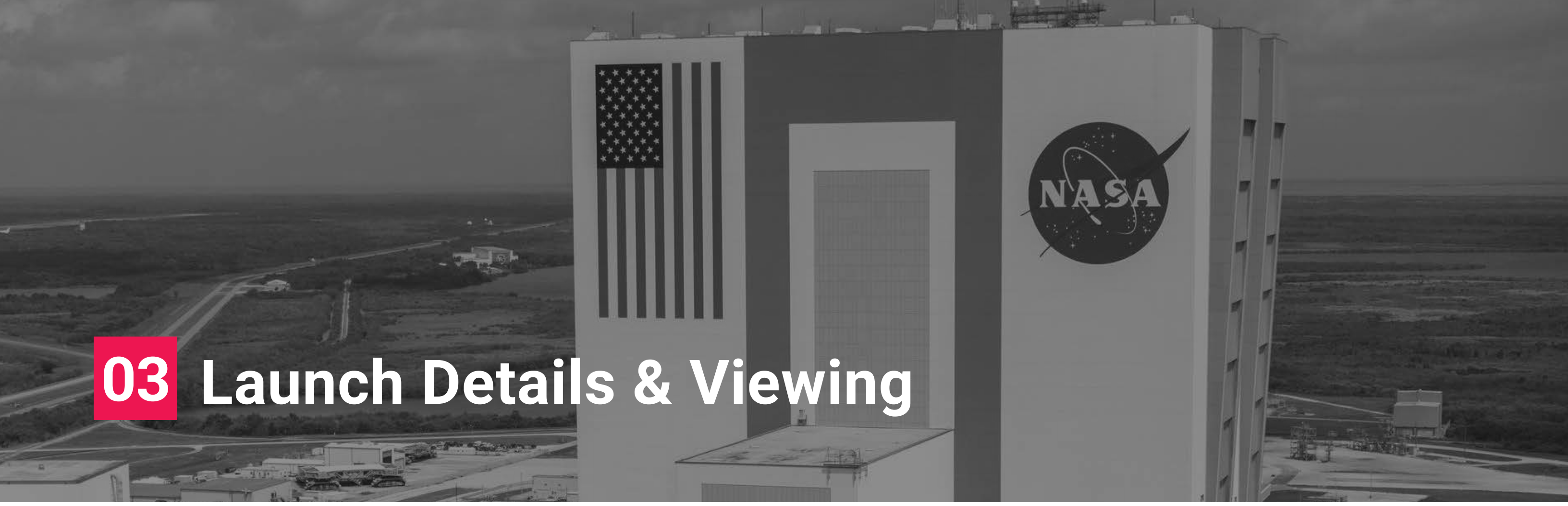
Demonstrate space internet communications between the Moon and the Earth using DTN technology.

Instrument Overview

1. Single Board Computer
   - Processor: 32-bit LEON3
   - Operating System: RTEMS
   - Mass: < 0.8kg
   - Power Consumption: < 5W
2. DTN Protocols
   - Bundle Protocol (BP)
   - Licklider Transmission Protocol (LTP)

Technology Demonstration

The technology demonstration includes CCSDS File Delivery Protocol (CFDP), Asynchronous Message Service (AMS), and Bundle Streaming Service (BSS). Network nodes for space internet technology demonstration are located in KPLO, NASA, KARI, and ETRI. The four seasons ETRI campus photos will be used for the demonstration of file delivery. A real-time streaming of K-pop band BTS' 'Dynamite' MV from KPLO is one of the technology demonstrations of Bundle Streaming Service. If the technology demonstration is successful, the DTN communication technology is expected to be used in Korea's lunar lander mission in the 2030's.



03 Launch Details & Viewing

Image credit: NASA

The KPLO launch is currently scheduled for lift-off from Cape Canaveral Air Force Station Space Launch Complex 40 (SLC-40) at 7:08 p.m. EST (23:08 UTC) on Thursday August 4, 2022. The SLC-40 launch complex has a long history dating back to 1965 with the maiden flight of the TITAN IIIC. Since then, more than 140 launches have taken place from SLC-40, including the launch of the Mars Observer spacecraft (1992) and the Cassini-Huygens mission to Saturn (1997). The US Air Force leased the complex to SpaceX for Falcon 9 launches.

For information on the history of Cape Canaveral, visit www.nasa.gov/offices/history/center_history/kennedy_space_center, or for KSC history, visit www.kennedyspacecenter.com/blog/31/history-of-kennedy-space-center-visitor-complex.

The KPLO launch is scheduled for the evening hours so normal NASA Kennedy Space Center (KSC) launch viewing areas will be closed to the public. However there are many viewing sites in the surrounding area.

Launch Viewing Areas

Jetty Park Launch Viewpoint

Large park with paid parking, restrooms, and activities like kayaking and watching large cruise ships make port. Beach rentals include chairs, umbrellas, and kayaks. There's a long, paved, and lit fishing pier; a children's playground with swings, monkey bars, and slides; pavilions with tables and grills.

Parish Park at Titusville

Located on both sides of SR-402 in Titusville, Parrish Park has access to the Indian River Lagoon for fishing and watersports. The park offers parking for cars and boat trailers and is noted as a great spot to watch a rocket launch.

Exploration Tower

Includes seven floors of exhibits and interactive play. Learn Port Canaveral's history, grab a bite, or enjoy panoramic views of the port and KSC. Noted as a great place to watch a rocket launch, but may be closed for some launches, so call ahead. Tickets are required.

Space View Park

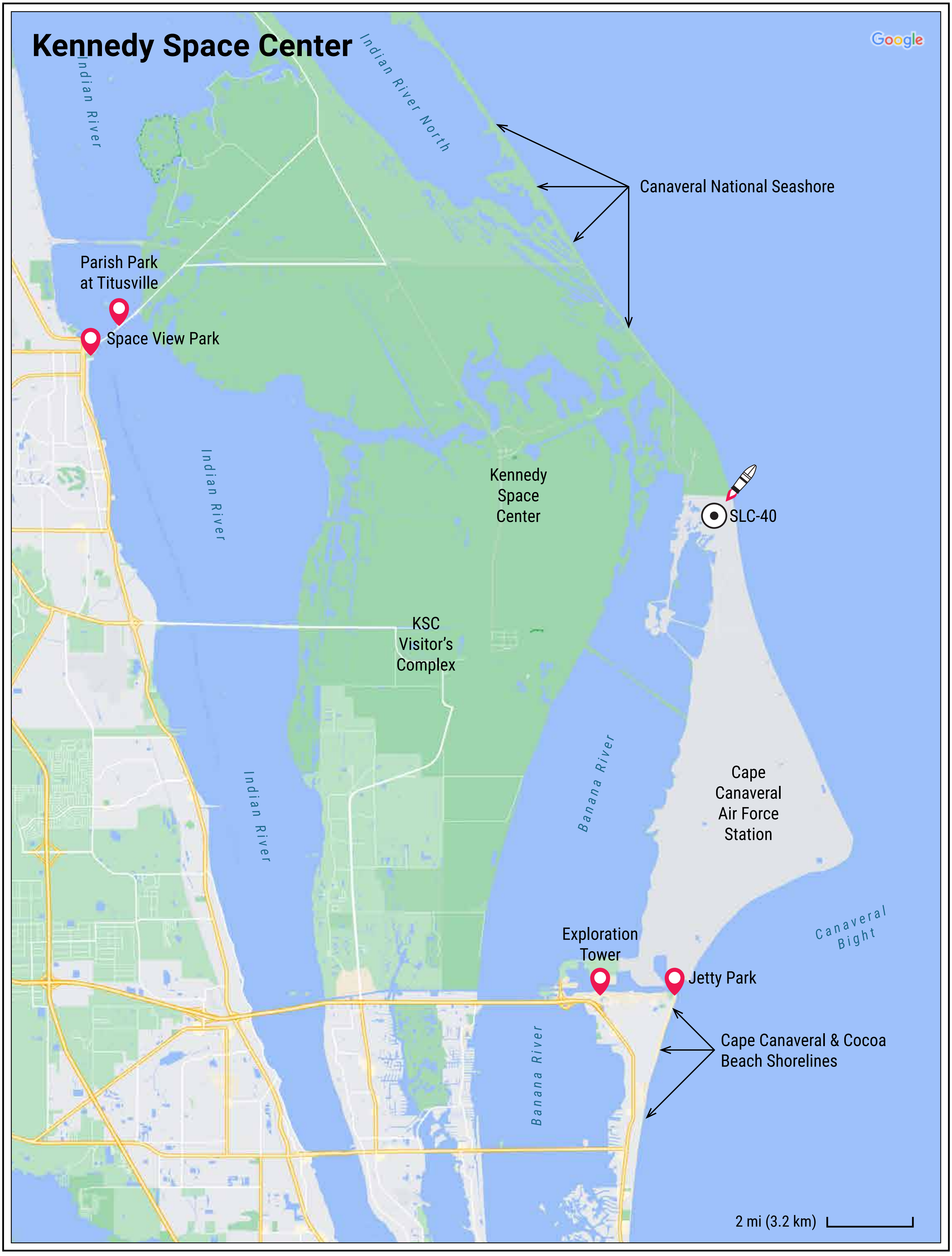
Close to Downtown Titusville and 15 miles across from the launch pads. Enjoy a walk through the history of space and compare your handprints to those of Mercury astronauts. This park is noted as a prime spot to watch a rocket launch.

Canaveral National Seashore

The Longest stretch of undeveloped Atlantic coastline in Florida. Experience undeveloped barrier island composed of dune, hammock and lagoon habitats while watching the launch rocket soar into space. Includes a host of public beaches. Closures near launch times are not uncommon. Check local restrictions, rules, and access prior to visiting.

Cape Canaveral & Cocoa Beach Shorelines

Beaches south of Cape Canaveral may provide decent views of the launch. A host of local businesses, piers, and parks offer watchers a place to relax, enjoy the local culture, and dine during the event.


Kennedy Space Center
Google
Indian River
Indian River North
Canaveral National Seashore
Parish Park
at Titusville
Space View Park
Indian River
Kennedy
Space
Center
SLC-40
KSC
Visitor's
Complex
Banana River
Indian River
Cape
Canaveral
Air Force
Station
Canaveral
Bight
Exploration
Tower
Jetty Park
Cape Canaveral & Cocoa
Beach Shorelines
Banana River
2 mi (3.2 km)

04 Launch Vehicle

Image credit: NASA, SpaceX

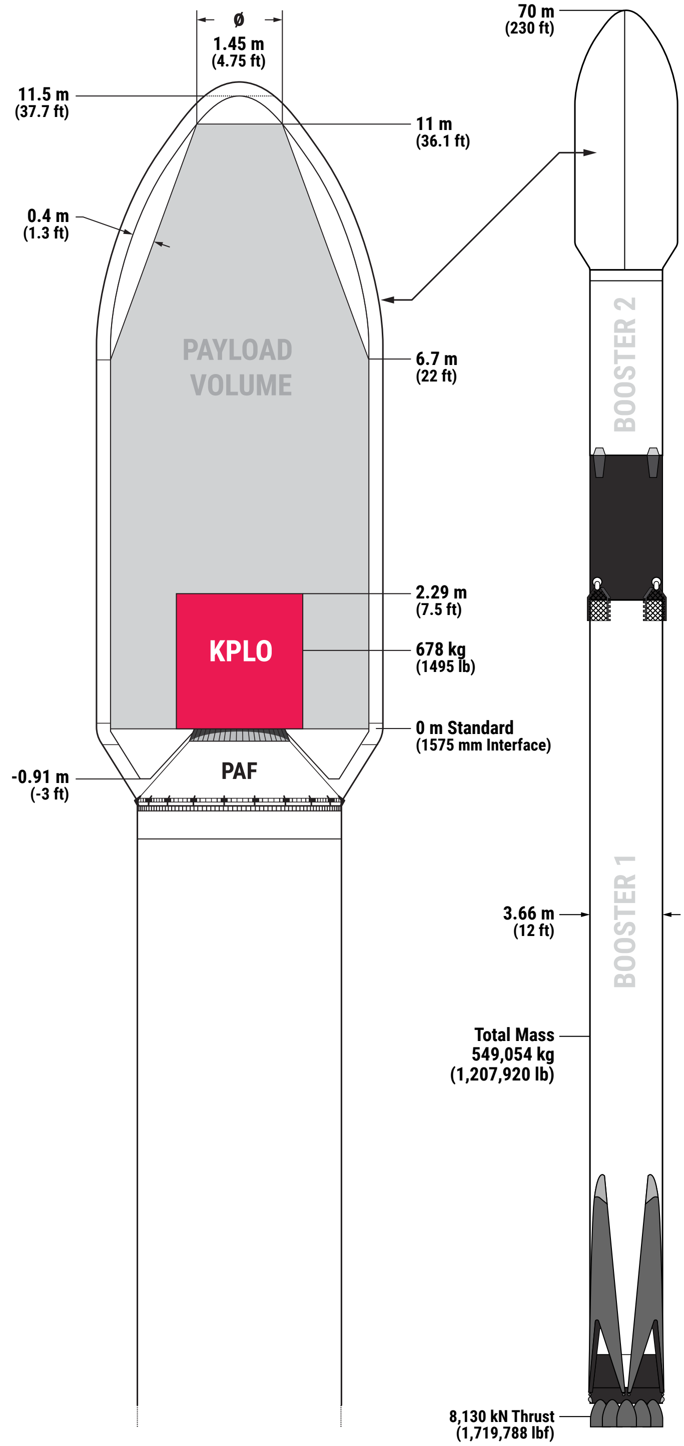
SpaceX Falcon 9 Block 5

The SpaceX Falcon 9 is a versatile, partially reusable, medium-lift launch vehicle that can carry cargo and humans into Earth orbit. The rocket has two stages: The first (booster) stage carries the second stage and payload to a certain altitude, after which the second stage lifts the payload to its ultimate destination. Below are some details from SpaceX outlining a small selection of features regarding the Falcon 9 launch vehicle.

The rocket evolved through several versions. V1.0 flew from 2010–2013, V1.1 flew from 2013–2016, while V1.2 Full Thrust first launched in 2015, encompassing the Block 5 Full Thrust variant, flying since May 2018. The first booster is capable of returning to Earth and landing vertically to facilitate reuse, which was first achieved on flight 20 in December 2015. Since then, SpaceX has successfully landed boosters more than 120 times. Individual boosters have flown as many as thirteen flights.

Both stages are powered by SpaceX Merlin engines, using cryogenic liquid oxygen and rocket-grade kerosene (RP-1) as propellants. The heaviest payloads flown to geostationary transfer orbit (GTO) were Intelsat 35e carrying 6,761 kg (14,905 lb), and Telstar 19V with 7,075 kg (15,598 lb).

Falcon launch vehicles are designed to support a countdown duration as short as one hour. Early in the countdown, the vehicle performs LOX, RP-1 and pressurant loading, and it executes a series of vehicle and range checkouts. The transporter-erector strongback is retracted just prior to launch. Automated software sequencers control all critical Falcon vehicle functions during terminal countdown (SpaceX, 2021, www.spacex.com/media/falcon-users-guide-2021-09.pdf)..



Launch & Delivery

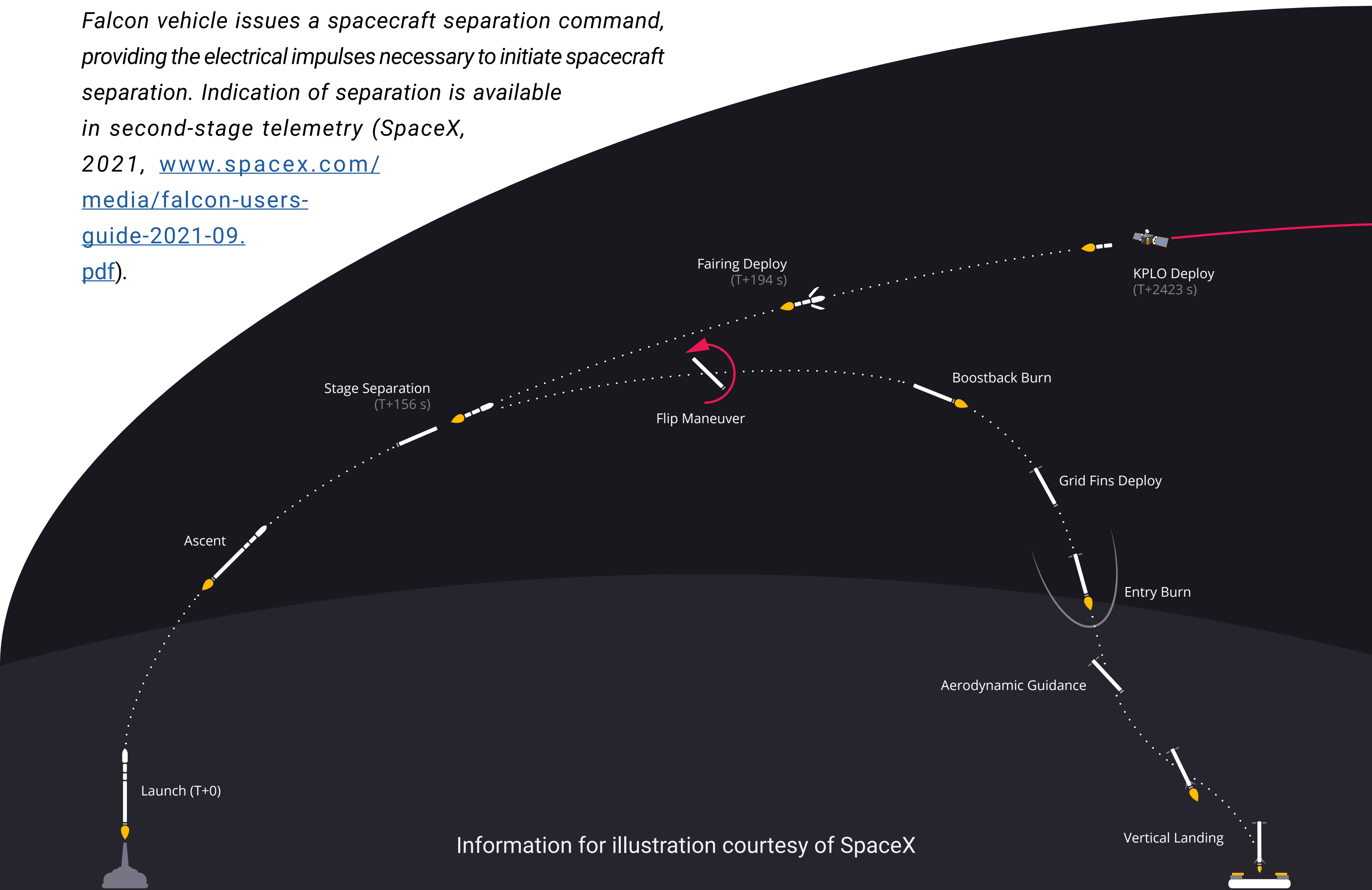
Final launch activities include verifying flight termination system status, transferring to internal power, and activating the transmitters. Engine ignition occurs shortly before liftoff, while the vehicle is held down at the base via hydraulic clamps. The flight computer evaluates engine ignition and full-power performance during the prelaunch hold-down, and if nominal criteria are satisfied, the hydraulic release system is activated at T-0. A safe shutdown is executed should any off-nominal condition be detected.

First-stage powered flight lasts approximately three minutes, with commanded shutdown of the nine first-stage engines based on remaining propellant levels. The second stage burns an additional five to six minutes to reach initial orbit, with deployment of the fairing typically taking place early in second-stage powered flight. Subsequent operations are unique to each mission but may include multiple coast-and-restart phases as well as multiple spacecraft separation events.

After reaching the spacecraft injection orbit and attitude, the Falcon vehicle issues a spacecraft separation command, providing the electrical impulses necessary to initiate spacecraft separation. Indication of separation is available in second-stage telemetry (SpaceX, 2021, www.spacex.com/media/falcon-users-guide-2021-09.pdf).

Time	Event
T - 3 s	Engine start sequence
T + 0	Liftoff
T + 74 s	Maximum dynamic pressure (max Q)
T + 152 s	Main engine cutoff (MECO)
T + 156 s	Stage separation
T + 163 s	Second engine start-1 (SES-1)
T + 194 s	Fairing deploy
T + 475 s	Second engine cutoff 1 (SECO-1)
T + 2036 s	Second engine start-2 (SES-2)
T + 2094 s	Second engine cutoff-2 (SECO-2)
T + 2423 s	KPLO deploy

Ascent Profile



Information for illustration courtesy of SpaceX

05 Journey to the Moon

Image credit: NASA, SpaceX

Danuri's journey to the Moon begins after launch vehicle separation. It will take up to 130 days, barring delays to the launch schedule. However, no matter the launch day, Danuri will arrive at the Moon at a fixed time, a benefit of the Ballistic Lunar Transfer (BLT) trajectory. The Earth- Moon cruise time can be adjusted to arrive at the desired time (5:22 p.m. UTC 16 December 2022, UTC), ensuring optimal lighting conditions for ShadowCam.

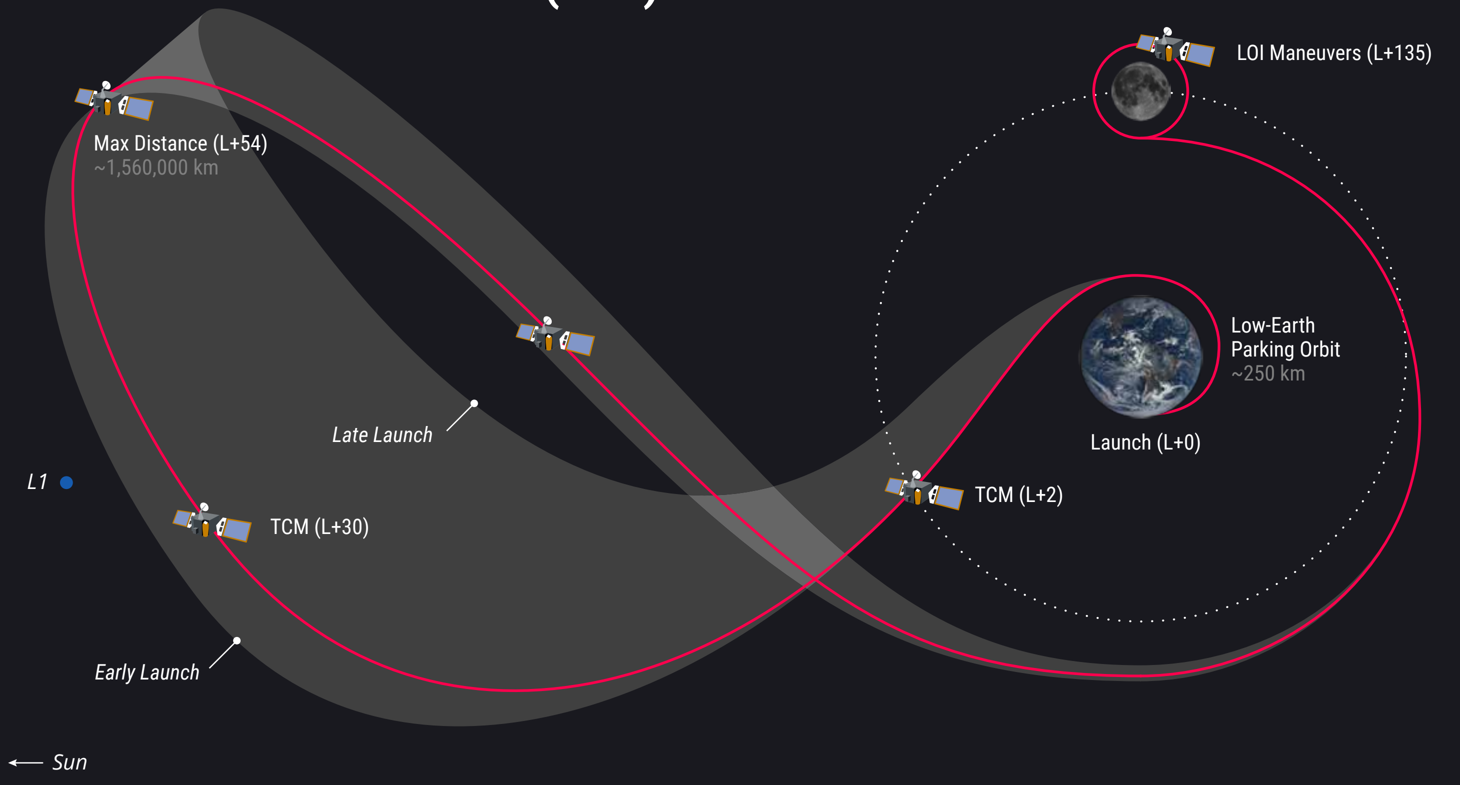
After launch, Danuri will leave Earth on a trajectory headed towards the Sun. It will insert itself into a Ballistic Lunar Transfer trajectory near Lagrange Point 1 (L1) between the Sun and Earth, approximately 1.55 million km (~1 million miles) away from Earth, where the Sun's gravity starts to counteract the Earth's. At L1, the Sun's gravity slows down the spacecraft relative to the Moon, minimizing the amount of fuel needed to put the spacecraft into the proper orbit.

During the Trans-Lunar Cruise (TLC), Danuri will perform a systems health check and up to nine Trajectory Correction Maneuvers (TCM). The health check will happen a few days after launch ensuring all systems are nominal. The first TCM maneuver will be performed two days after launch, correcting any launch vehicle injection errors. The next TCM will insert Danuri into the desired low-energy BLT trajectory. The remaining maneuvers are statistical and are scheduled to remove trajectory errors and target the final mapping orbit. The table below lists the TCM maneuvers, time, and primary purpose.

Once Danuri reaches the Moon, it will complete a series of Lunar Orbit Insertion (LOI) maneuvers. These maneuvers, or slow-down burns, are performed at periapsis, or the point where Danuri's orbit is closest to the Moon, to help the satellite reach its nominal 100 (+- 30) km circular orbit. This moment will mark the beginning of Danuri's year-long primary mission.

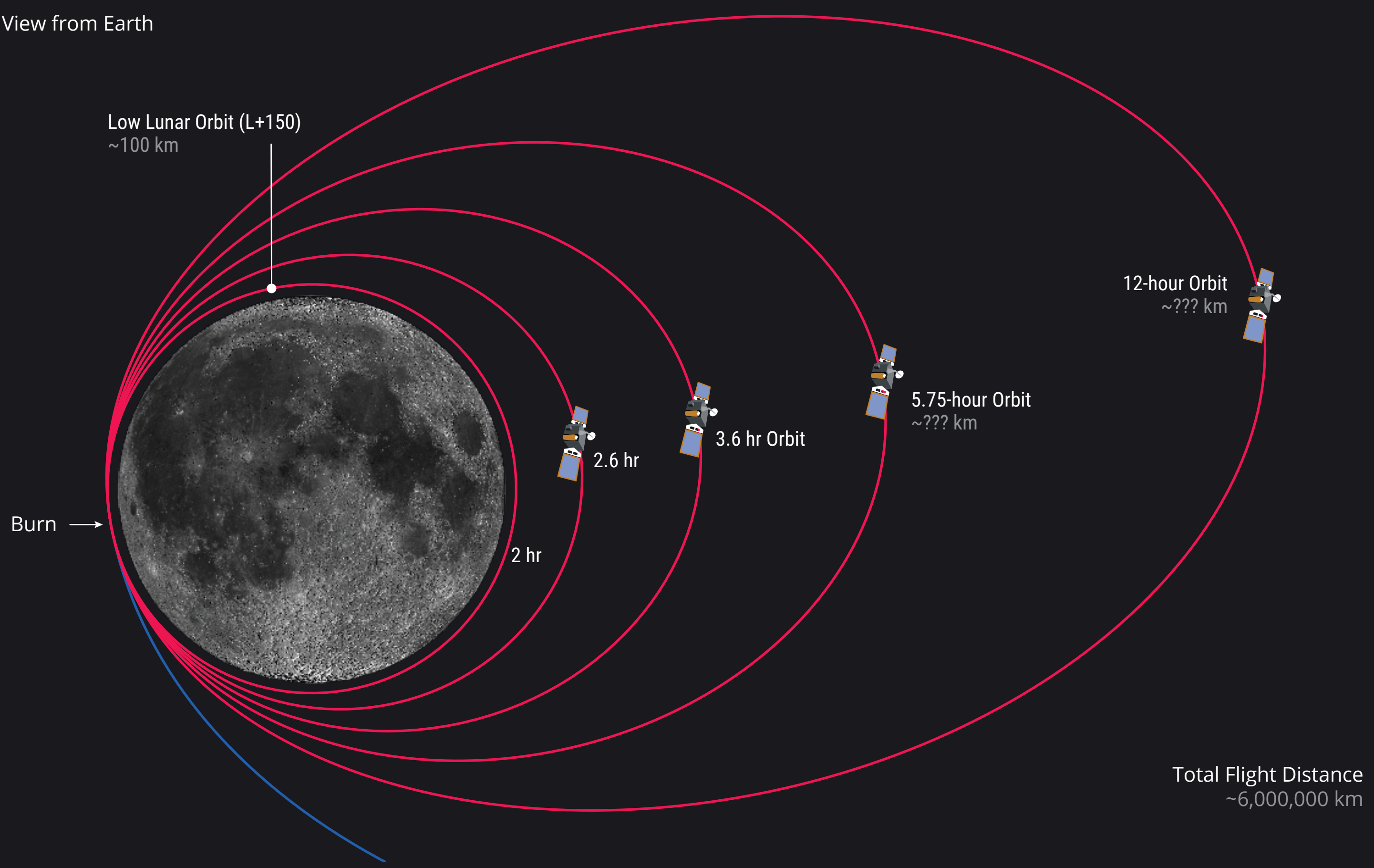
Maneuver	Time (UTC)	Purpose
TCM-1	7 August 2022, 01:00:00.000	Correct Launch Vehicle Injection Error
TCM-2	12 August 2022, 05:00:00.000	Ensure all spacecraft and all instruments are healthy
TCM-3	2 September 2022, 05:00:00.000	Manifold Insertion
TCM-4	16 September 2022, 05:00:00.000	Correct TCM-3 Error
TCM-5	4 November 2022, 05:00:00.000	Correct TCM-4 Error
TCM-6	18 November 2022, 05:00:00.000	Correct TCM-5 Error
TCM-7	25 November 2022, 05:00:00.000	Correct TCM-6 Error
TCM-8	2 December 2022, 05:00:00.000	Correct TCM-7 Error
TCM-9	9 December 2022, 05:00:00.000	LOI Targeting

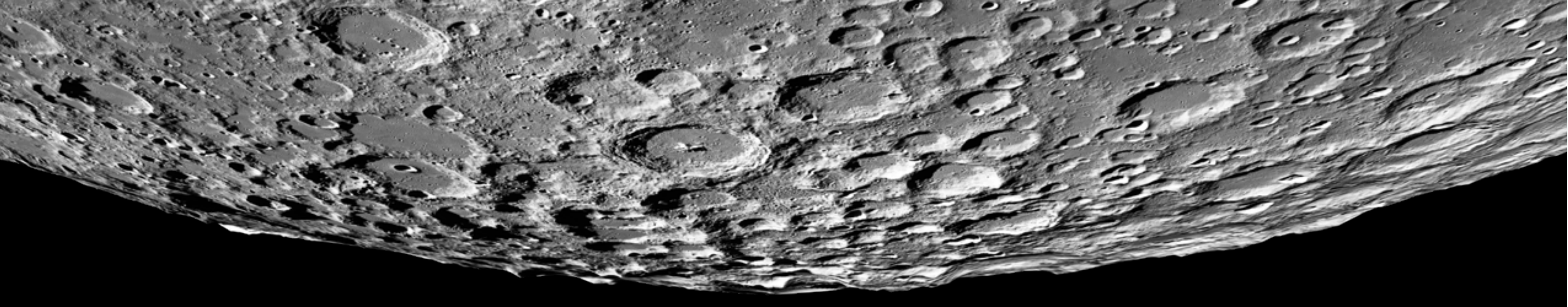
Ballistic Lunar Transfer (BLT)



Lunar Orbit Insertion (LOI)

View from Earth





06 Primary Mission

Image credit: KARI

KPLO is the first in South Korea's space exploration program. Therefore, the primary mission objectives have focused on building up core technologies for future, more challenging missions, like a lunar landing and Mars exploration. The past 30 years of accumulated technologies have attributed to KARI's success in developing the KPLO spacecraft, ground control system, and deep space antenna. KARI has also concentrated on collaboration efforts with NASA, which helps reduce risks and enhances cooperation in space between South Korea and the United States. KARI expects large quantities of scientific data from KPLO – data that will be shared with science communities all over the world.

Mission Objectives

1. Develop critical technologies for lunar exploration

- Develop lunar exploration technologies, i.e., orbiter bus, lunar orbit insertion and operation technologies, communication and control, and navigation
- Construct ground station for deep-space communications

2. Scientific investigation of the lunar environment

- Establish lunar topographic map to support the selection of future lunar landing sites
- Survey lunar resources and Investigate the radiation environment and surface environment of the Moon

3. Realization and validation of new space technology

- Technology demonstration and the validation of space internet technology i.e., Disruption Tolerant Network (DTN)

Scientific Objectives

1. Construct high-resolution images of the lunar surface

- Detailed geographic map for future landing sites
- Deep imaging of permanently shadowed regions (PSRs) around the lunar poles
- Target observation of selected regions

2. Investigate lunar geology & resources

- Distribution of lunar volatiles i.e., water & rare elements
- Characterize & map major elements & their distributions
- Investigate physical properties of lunar regolith
- Study space weathering i.e., interaction between lunar surface & cosmic particles

3. Map the environment on and near the surface of the Moon

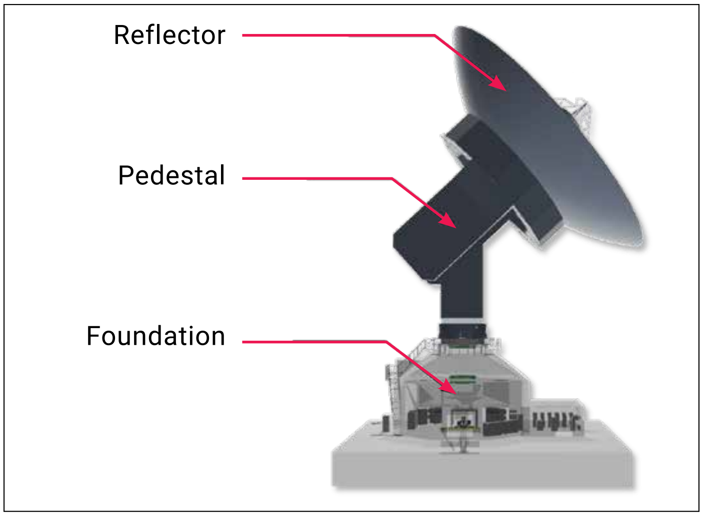
- Study the Moon for future crewed missions
- Obtain detailed 3D map of lunar magnetism
- Investigate intensity of radioactive radiation and density of high-energy particles

Korea Deep Space Antenna (KDSA)

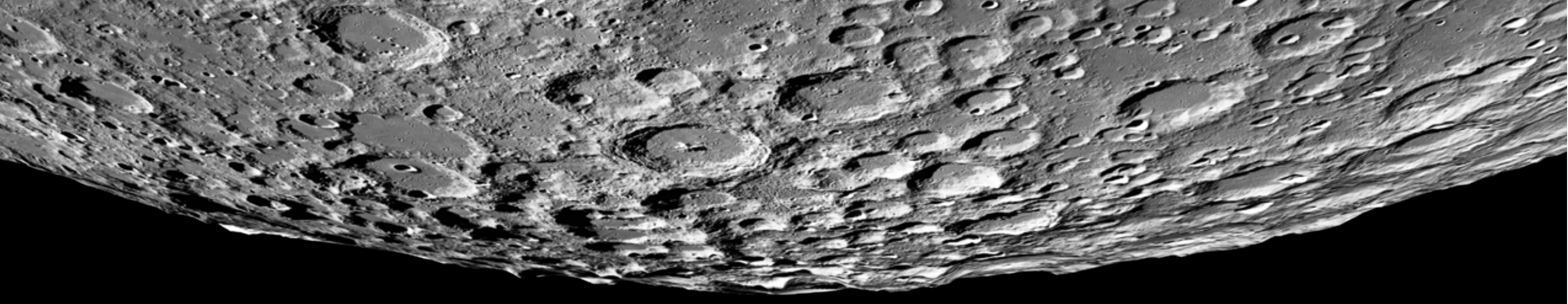
KDSA is designed to receive State of Health (SOH) and payload-observation telemetry and transmit commands to and from Danuri in S-Band (around 2~2.3GHz frequency band) and X-Band (around 8~8.5GHz frequency band) RF link. In addition, KDSA generates tracking files, including ranging and Doppler measurement data which are crucial for Danuri orbit determination and prediction. All telemetry, commands, and tracking files can be exchanged in real-time with KPLO Mission Control Center (KMOC) at the KARI campus in Daejeon, South Korea.

KDSA can host heavyweight units thanks to the specially designed Beam-Wave Guide (BWG) type mirrors. These allow KDSA to have a High Power Amplifier (HPA) and Cryogenic Low Noise Amplifier (LNA) with a helium compressor. The KDSA Antenna is composed of seven mirrors. One was polished for frequency selective surface, and the others are metal, curved plates. KDSA can track Danuri by moving from 3 to 90 degrees in elevation and -270 to +270 degrees azimuth with a maximum speed of 0.8 deg/sec. After Danuri separates from the Falcon-9 launch vehicle, cruising in BLT and in lunar orbit, the tracking speed requirements are much lower than 0.8 deg/sec.

In addition to S-Band 10kW Solid-State Power Amplifier (SSPA) for command transmission and 2:1 redundant cryogenic LNA Low Noise Amplifier (LNA) for telemetry reception, KDSA is equipped with a web-based scheduler for scheduling the antenna tracking and communication with Danuri. KDSA services are compatible with Consultative Committee for Space Data System (CCSDS), Space Link Extension (SLE), forward Communication Link Transmission Unit (CLTU), SLE return frames, and Tracking Data Message (TDM) standards.



Views of the Korea Deep Space Antenna (KDSA) at the SK Broadband satellite center site in Yeo-Ju. Images courtesy of KARI.



06 Additional Resources

Helpful Links

- KARI website: kari.re.kr/eng.do
- KPLO webpage: kari.re.kr/eng/sub03_07_01.do
- KPLO Addtl. Info.: planetary.org/space-missions/kplo
- KARI videos: youtu.be/wDpa_J2fQa0, youtu.be/Hpq_sibTeYc, youtu.be/ZkKTATOpM-U
- PolCam website: planetary.kasi.re.kr/polcam
- ShadowCam website: shadowcam.asu.edu
- LROC PSR featured images: lroc.asu.edu/posts/979, lroc.asu.edu/posts/989, lroc.asu.edu/posts/991
- LROC PSR library & map: lroc.asu.edu/psr/list
- PSRs on Quickmap: North Pole bit.ly/3EFpDz5; South Pole bit.ly/3OXwl7o
- SpaceX website: spacex.com
- KMAG: iopscience.iop.org/article/10.1088/1538-3873/abe55c
- LUTI: arc.aiaa.org/doi/pdf/10.2514/6.2018-2345
- KGRS: hou.usra.edu/meetings/lpsc2019/pdf/2276.pdf
- PolCam: hou.usra.edu/meetings/lpsc2020/pdf/1981.pdf, iopscience.iop.org/article/10.1088/1538-3873/ab523d
- ShadowCam: hou.usra.edu/meetings/lpsc2022/pdf/1659.pdf

Timeline of Articles

- ***2016*** NASA/KPLO announcement of opportunity: nasa.gov/feature/kplo-ao
- ***2017*** NASA selects ShadowCam for KPLO: nasa.gov/feature/nasa-selects-shadowcam-to-fly-on-korea-pathfinder-lunar-orbiter
- ***2017*** ShadowCam news article: ktar.com/story/1549268/camera-developed-by-asu-professor-to-find-frost-ice-on-moon/
- ***2019*** NAS/KPLO announcement of participating scientists: nspires.nasaprs.com/external/solicitations/summary!init.do?solId=%7bF2089122-FD2E-5813-FF94-24359D68D05C%7d&path=open
- ***2021*** NASA selects nine scientists for KPLO: nasa.gov/feature/nasa-selects-nine-scientists-to-join-korea-pathfinder-lunar-orbiter-mission
- ***2021*** ShadowCam sent to Korea: statepress.com/article/2021/09/asu-shadowcam-incorporated-into-korean-spacecraft
- ***2022*** KARI ready for Korea's first lunar mission: https://www.koreatimes.co.kr/www/tech/2022/06/419_330446.html
- ***2022*** South Korea set for first Moon mission: nature.com/articles/d41586-022-02066-3
- ***2022*** South Korea will join revivided race to explore the Moon: https://www.science.org/content/article/lunar-orbiter-south-korea-will-join-revived-race-explore-moon

Abbreviations

ASU: Arizona State University

BLT: Ballistic Lunar Transfer

CCSDS: Consultative Committee for Space Data Systems

CLTU: Communications Link Transmission Unit

DSN: Deep Space Network

DTNPL: Delay/Disruption Tolerant Network PayLoad

ETRI: Electronics and Telecommunications Research Institute

KARI: Korea Aerospace Research Institute

KASI: Korea Astronomy and Space Science Institute

KDSA: Korea Deep Space Antenna

KGRS: KPLO Gamma-Ray Spectrometer

KHU: Kyung Hee University

KIGAM: Korea Institute of Geoscience and Mineral Resources

KLEP: Korea Lunar Exploration Program

KMAG: KPLO Magnetometer

KPLO: Korea Pathfinder Lunar Orbiter

LUTI: Lunar Terrain Imager

PolCam: Wide-Angle Polarimetric Camera

KPLO PSP: KPLO Participating Science Program

SLE: Space Link Extension

SSPA: Solid-State Power Amplifier

TCM: Trajectory Correction Maneuvers

TDM: Tracking Data Message

TLC: Trans-Lunar Cruise

TT&C: Telemetry, Tracking and Command


KARI KASI KHU KIGAM ETRI ASU NASA
KPLO
KOREA PATHFINDER LUNAR ORBITER
LUTI | PolCam | KMAG | KGRS | DTNPL | ShadowCam