The moon, where no satnav has gone before

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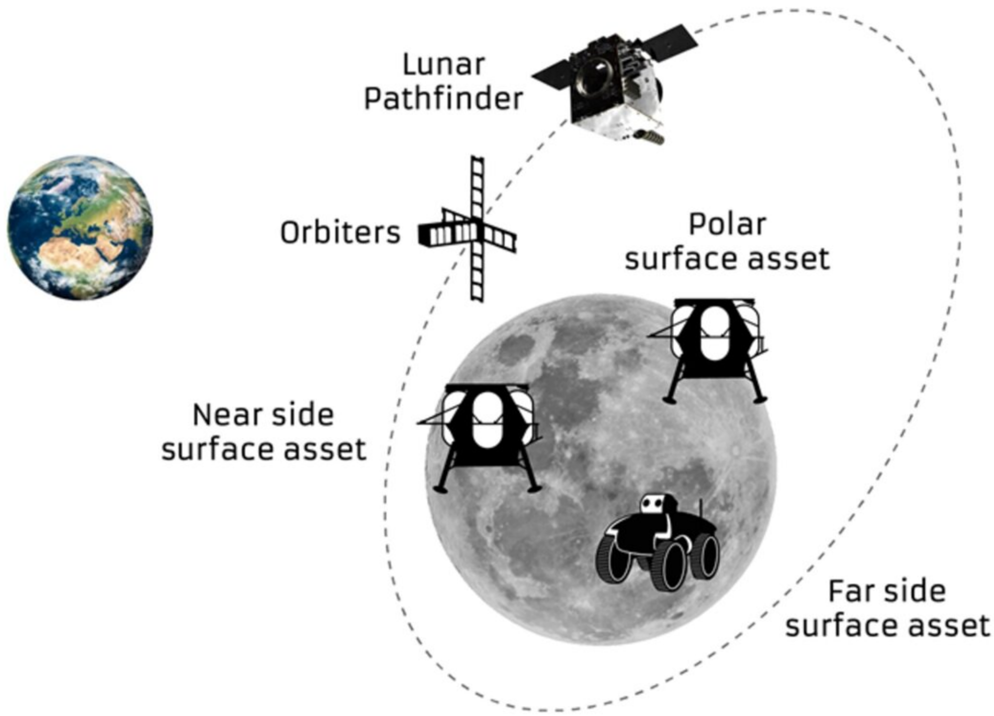


Lunar Pathfinder will relay communications from orbital and surface missions. Credit: SSTL

The test version of a unique satellite navigation receiver has been delivered for integration testing on the Lunar Pathfinder spacecraft. The NaviMoon satnav receiver is designed to perform the farthest ever positioning fix from Earth, employing signals that will be millions of times fainter than those used by our smartphones or cars.

"This engineering model of our NaviMoon receiver is the very first piece of hardware to be produced in the context of ESA's moonlight initiative, to develop dedicated telecommunications and navigation services for the moon," explains Javier Ventura-Traveset, Head of ESA's Navigation Science Office and managing all ESA lunar navigation activities.

"It will be flown aboard the Lunar Pathfinder mission into orbit around the moon, from where it will perform the furthest satellite navigation positioning fix ever made, at more than 400 000 km away to an accuracy of less than 100 m. This represents an extraordinary engineering challenge, because at such a distance the faint Galileo and GPS signals it makes use of will be barely distinguishable from background noise. This demonstration will imply a true change of paradigm for lunar orbiting navigation."

The washing-machine-sized Lunar Pathfinder is being built as a commercial mission by Surrey Satellite Technology Ltd, SSTL, in the UK. ESA is funding guest payloads for it including the 1.4 kg NaviMoon receiver that will be accommodated beside the spacecraft's main X-band transmitter that links it with Earth.

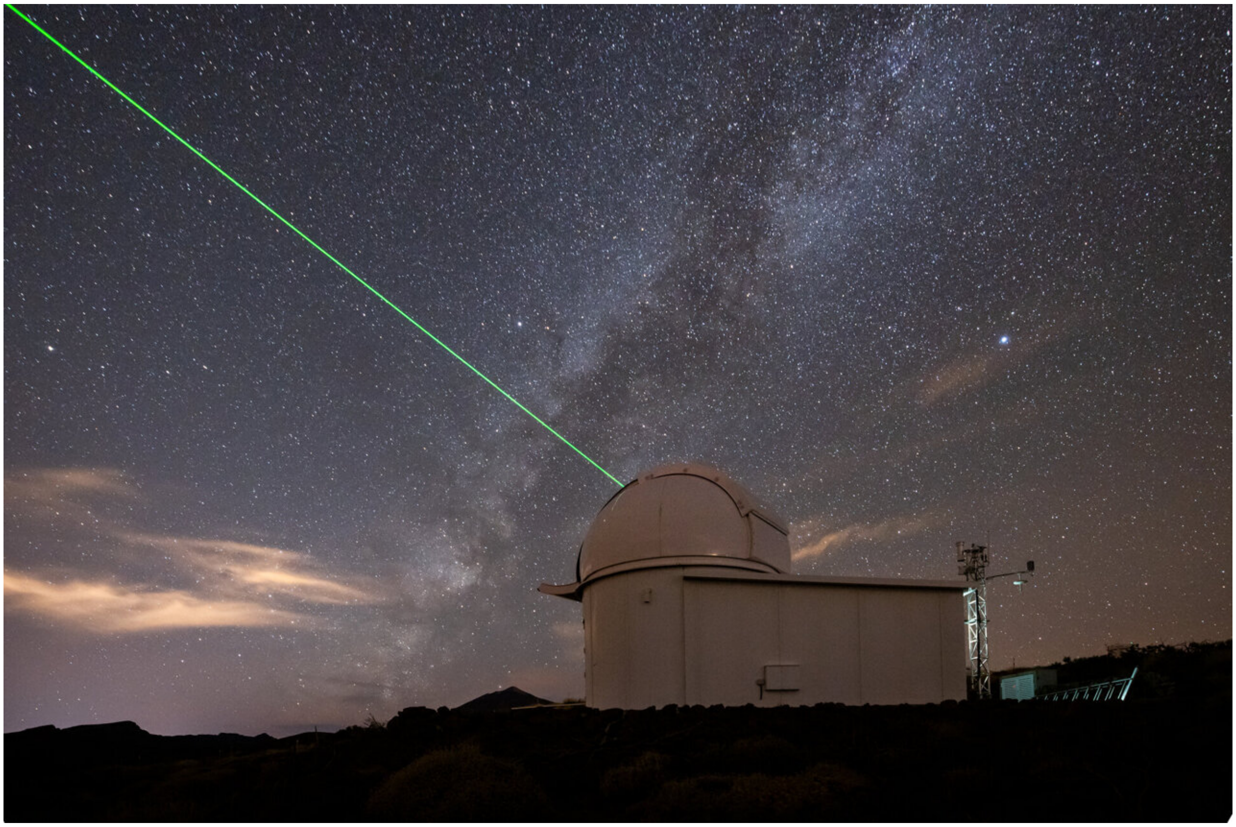
"Receiving physical hardware for a mission is always fantastic," remarks Lily Forward, SSTL system engineer. "This engineering model receiver will be integrated into our 'FlatSat Test Bed' version of the mission to test all our systems communicate and work together properly, ahead of receiving the flight model receiver and antenna later this year."

This will be SSTL's first full-fledged mission beyond Earth, she adds: "Laying the foundations for numerous scientific missions that will come after it, Lunar Pathfinder is a communications relay satellite, intended to serve assets on both the nearside and farside, orbiting in an 'elliptical lunar frozen orbit' for prolonged coverage over the South Pole—a particular focus for future exploration. Then during regular intervals we will orient the spacecraft towards Earth to test out the NaviMoon receiver."

Satnav position fixes from the receiver will be compared with conventional radio ranging carried out using Lunar Pathfinder's X-band transmitter as well as laser ranging performed using a retroreflector contributed by NASA and developed by the KBR company.

"This will be the first time these three ranging techniques will be used together in deep space," explains ESA navigation engineer Pietro Giordano. "There is a long heritage of lunar laser ranging, going back to the Apollo missions, and the retroreflector we are using is an evolution from NASA's Lunar Reconnaissance Orbiter. The combination of all ranging techniques will improve the orbit estimation further, potentially beyond what radio ranging can achieve.

"In principle this could mean that future missions could navigate themselves to the moon autonomously using satellite navigation signals alone with no help from the ground."



Laser ranging station. Credit: ESA

Finding ultra-faint satnav signals

The satnav signals employed down here on Earth are already vanishingly faint, equivalent to a single pair of car headlights shining all across Europe. By the time these signals reach the moon after they have crossed distances of more than 20 times further still, attenuating through space like ripples from a stone splashed in water.

"Adding to the difficulty, the satnav constellations are not designed to transmit up into space but keep their antennas facing Earth," adds Pietro. "So we are reliant on much weaker 'side lobe' signals, like light spilling from the sides of a flashlight. To be able to make use of these signals we turned to a specialist in space-based satellite navigation, whose signal-processing techniques have really proven the magic ingredient."

SpacePNT, based in Switzerland, oversaw the NaviMoon receiver design. "We began working on the idea of lunar-distance satnav positioning back in 2013 as something of a scientific challenge," explains Cyril Botteron, heading the company.

"The combination of Galileo dual frequency signals with those of the existing GPS satellites is what started to make it feasible. Although, along with the extreme sensitivity that is demanded, the other big problem is that from the moon all the satnav satellites are in the same narrow geometry of sky around Earth, periodically rotating out of view."

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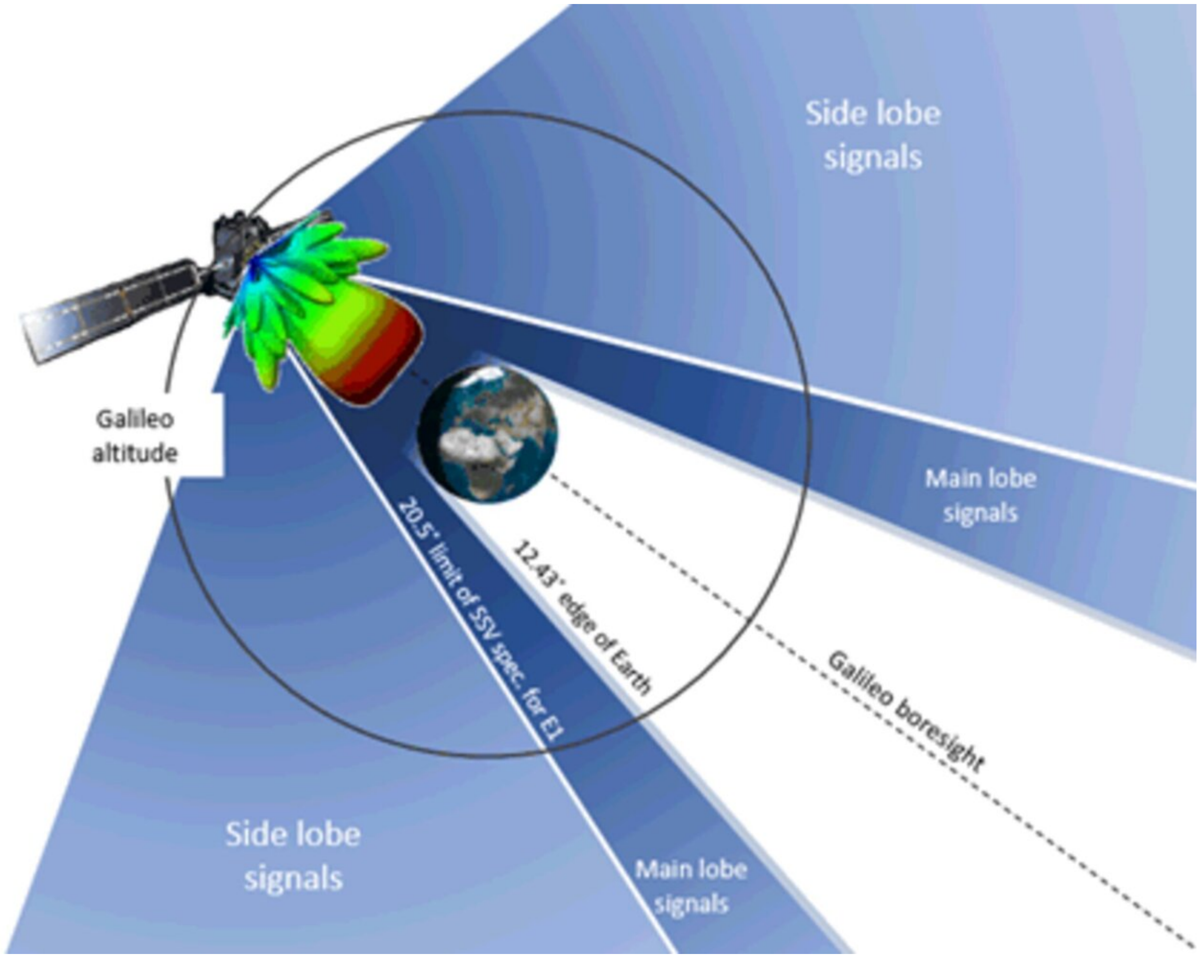

Galileo 'side lobe' signals. Credit: ESA

The solution that SpacePNT came up with leverages more than half a century of lunar exploration. The company installed a dynamic software model of all the forces acting upon the satellite into the receiver, including the gravitational influences of the moon, Earth, sun and planets as well as the very slight push from sunlight itself—solar radiation pressure—along with factors such as clock error and the radio signal direction.

Cyril explains: "As we experience a given acceleration the receiver can judge it is most probably at one particular point in its orbit. Usually a satnav receiver needs signals from four satellites to fix its position, but with this approach even less than four signals is still enough to obtain useful information, constraining the model to minimize any error drift."

European Engineering & Consultancy, EECL, in the UK was assigned the task of turning SpacePNT's design into fully-tested hardware, additionally designing the crucial low noise amplifier that sifts through noise to boost usable signals.

"The amplifier is a high-end custom diplexer covering the dual frequency satnav bands, hand-tuned using the best possible components and incorporating heat sink technology to further reduce unwanted noise," says Ben Kieniewicz, ECCL founder.

"Along with contributing to other design aspects, we also built, tested and delivered the receiver to SSTL, making use of our space-qualified cleanroom assembly and test area."

Lunar Pathfinder will be ready for launch at the end of 2024, offering near side, farside, orbit and polar services to missions launching in the coming years, laying the foundations for a constellation of combined telecommunications and navigation satellites around the moon.

"Our moonlight initiative proposes the initial placing of three to four satellites in lunar orbit, offering at least five consecutive hours of service in any 24 hours, focused on the lunar south pole where most of the missions are initially planned," adds Javier. "Our system is conceived to be expandable and the idea is to progressively enlarge the constellation, and most likely to also include surface beacons on the moon. This will enable full coverage across the lunar surface, higher availability and excellent accuracies—a great opportunity for Europe."

Provided by European Space Agency