This is a presentation about LightSail, a historic crowd-funded program to demonstrate flight by light for CubeSats. In this presentation, you'll learn about the science of solar sailing, The Planetary Society’s solar sailing projects, and the ongoing LightSail 2 mission.

This presentation was prepared by The Planetary Society, the world's largest and most effective nonprofit space organization. Supported by over 50,000 members around the world, The Planetary Society empowers the world’s citizens to advance space science and exploration through education, advocacy, global collaboration, and science and technology projects.

So, what is solar sailing and why do we need it?

Solar sailing is an alternative way of propelling a spacecraft through space. Spacecraft gain most of their momentum when they are launched from Earth, but most still need some extra acceleration once they’re in space in order to reach their destinations as quickly as possible or to change course. The standard way to increase speed or change course is by using chemical rockets that burn fuel that the spacecraft carries on board. But more rocket fuel means more weight, which limits how much can be carried. Eventually, the fuel carried onboard a spacecraft will run out, and the spacecraft will stop accelerating. From there, it will coast through space at whatever maximum speed it has reached unless it can get a boost from the gravity of another planet.

But what if you could provide a spacecraft with continuous, practically limitless acceleration? A spacecraft traveling through space with constant acceleration could attain incredible speeds, making it possible to reach more distant destinations.

Solar sailing is one way to provide this continuous acceleration to a spacecraft. But it is a nascent technology that still needs to be proven. We're going to learn in a moment how The Planetary Society's LightSail 2 mission is about to make a huge contribution to our understanding of solar sailing. But first, let's learn a little more about how solar sailing works.

This slide: An artist’s depiction of an astronaut sailing through space on a catamaran.
Slide 4

Solar sailing is actually a very simple technology. It uses sunlight to propel a spacecraft through space.

Light is made up of particles called photons. Photons don’t have any mass, but they do have momentum. When light hits a solar sail—which has a bright, mirror-like surface—the photons in that light bounce off the sail (i.e. they reflect off it, just like a mirror). As the photons hit the sail their momentum is transferred to it, giving it a small push. As they bounce off the sail, the photons give it another small push. Both pushes are very slight, but in the vacuum of space where there is nothing to slow down the sail, each push changes the sail’s speed.

When a solar sail faces the Sun directly, photons push the spacecraft forward, away from the Sun. But a solar sail can move in other directions by tacking like a sailboat, changing the angle of the sail relative the Sun. It’s even possible to shift the spacecraft’s orbit around the Sun, by angling the sail so that solar photons push against the direction it is traveling. Solar sails can also control their direction in other ways, such as changing their center of mass or using tip vanes (small turnable solar sails at the tips of the main sails).

Slide 5

Solar sailing is a concept with a long history, dating all the way back to an idea Johannes Kepler shared with his friend Galileo Galilei in 1608. After realizing that a comet’s tail is created by sunlight heating material from the comet’s surface, the notion of the sun’s rays interacting with a celestial object led Kepler to believe that a space sail might one day capture sunlight the way a boat sail catches the wind. In his letter to Galilei, Kepler wrote that humans might one day use the technology to set a course for the stars.

Since then, there have been many proposals for missions to harness the sun’s energy using solar sails. One prominent idea was to build an enormous solar sailing spacecraft that would fly to the very comet that Kepler had observed: Halley’s Comet. Planetary Society co-founder Louis Friedman worked on this proposal, which involved the spacecraft illustrated on this slide: the Heliogyro solar sail, with 12 spinning blades that were each four miles long. This mission wound up being too ambitious and was never conducted, but the concept of solar sailing was now much more real in people’s minds.

This slide: An artist’s rendition of the solar sailing spacecraft designed to visit Halley’s Comet.
The three founders of The Planetary Society—Louis Friedman, Carl Sagan, and Bruce Murray—were all enthusiastic about the idea of solar sailing. Carl Sagan even promoted the concept during an appearance on The Tonight Show with Johnny Carson, introducing the world to the idea of sailing on sunlight. It didn’t seem possible, though, that an organization like The Planetary Society would be able to pursue this idea alone.

In 1999, though, the Russian government offered the organization a chance to launch a spacecraft for free on one of their rockets, making the idea of a citizen-funded solar sailing mission a real possibility. The Society’s board of directors approved the idea, and its members provided the funding. Named Cosmos 1, this would be the world’s first solar sail spacecraft. It would orbit the Earth rather than heading to a distant world, providing a first demonstration that the technology was viable.

Cosmos 1 had eight triangular solar sails deployed and held rigid by inflatable booms, each about 15 meters long. Motors allowed the sails to be individually tilted, which allowed the sail to be controlled in roll, pitch, and yaw. This meant that Cosmos 1 could be turned in any direction so that it could track the Sun.

This slide: TPS co-founder Louis Friedman with the Cosmos 1 spacecraft.

The mission was launched on June 21, 2005, on a Volna rocket, launched out of a submarine from the Barents Sea. Tragically, the first stage of the rocket failed and the entire payload crashed into the sea. Cosmos 1 never got the chance to fly. The first successful solar sail took flight in 2010, when Japan's IKAROS spacecraft was deployed from a Venus-bound probe named Akatsuki.

This slide: Left: An artist’s depiction of a submarine launch. Right: The Volna rocket.
Slide 10

In the late 2000's NASA had begun its own solar sail program, testing the use of solar sails to de-orbit CubeSats via atmospheric drag. Inspired by this program, The Planetary Society decided to construct a CubeSat similar to Nanosail-D that would demonstrate true solar sailing, not just using sails to de-orbit. In 2009, The Planetary Society restarted its solar sailing program, this time under the name LightSail.

This slide: An artist's depiction of a LightSail spacecraft in space.

Slide 11

Traditional spacecraft are very large, heavy, and costly to build and launch. CubeSats, on the other hand, are very small spacecraft. A standard 3U CubeSat is made of three cube-shaped parts, each about 10cm x 10cm x 10cm, added together to make a spacecraft body about the size of a loaf of bread. These small, inexpensive spacecraft are opening up access to space for small companies, new spacefaring nations, and even student groups. Solar sailing may be one of the best ways to propel CubeSats through space since they’re so small that traditional engines and fuel may not be practical. The Planetary Society set out to demonstrate that solar sailing for CubeSats was possible.

This slide: LightSail 1 undergoing testing.

Slide 12

Inside the small CubeSat you can fit a surprisingly large sail. Each LightSail spacecraft’s sail has 4 sections that combine to an area of 32 square meters or 344 square feet. The material the sails are made of—Mylar—is very thin, only 4.5 microns or 1/5000th of an inch. All 4 sections are folded up above four booms, which unfurl to extend the full sail. The spacecraft the size of a loaf of bread is then propelled by a sail the size of a boxing ring.

This slide: LightSail 2 undergoing deployment testing. Both LightSail 1 and 2 are the same size.
In May 2015, the LightSail 1 spacecraft launched from Cape Canaveral, Florida, into low Earth orbit. The Planetary Society’s members around the world watched as the spacecraft they had funded was sent into space. It was an exciting moment.

*This slide: Planetary Society members and supporters watching the launch of LightSail 1.*

The LightSail 1 mission was designed to test the spacecraft and the sail deployment without solar sailing. The mission team was able to operate the spacecraft in orbit and to learn lessons to apply to LightSail 2. The sail did successfully deploy and the onboard camera took a selfie, sending back to Earth a photo of its sails reflecting the Sun’s light. The mission was a success, demonstrating that the basic mechanics of a solar sailing CubeSat functioned.

*This slide: LightSail 1’s sails deployed in space.*

The Planetary Society’s CEO Bill Nye followed in his predecessor Carl Sagan’s footsteps, sharing the idea of solar sailing with the public in an appearance on late-night television, this time on the Late Show with Stephen Colbert in 2017.

LightSail 1 was just the first step. It showed that the basic mechanics of the spacecraft worked, but was never intended to reach a high enough orbit to actually sail on sunlight. LightSail 2, the follow-up mission, was designed to take that next step, propelling the spacecraft using the sun’s light.

*This slide: The LightSail 2 spacecraft.*

LightSail 1’s mission success gained the public’s attention and helped get the funding needed to move on to LightSail 2. The Planetary Society launched a Kickstarter crowdfunding campaign with the goal of raising $200,000 for the mission. In the end, the campaign raised $1,241,615, exceeding its goal by over a million dollars and engaging over 23,000 donors. The LightSail
Kickstarter project still holds the record for the most backers of a space project in Kickstarter’s history.

*This slide: A screenshot of the announcement of the Kickstarter campaign’s enormous success.*

**Slide 18**

The public support for this mission was amazing. People showed how much it meant to them to be able to be a part of something so exciting. Although The Planetary Society set out to demonstrate solar sailing technology, they also showed the potential for crowd-funded space missions.

*This slide: A quote from a LightSail Kickstarter backer.*

**Slide 19**

The Society also engaged thousands of people in the LightSail mission via social media by encouraging them to send in a selfie, which would be uploaded to a mini-disk aboard the LightSail 2 spacecraft and sent into space. The “Selfies to Space” campaign brought people around the world into the LightSail mission and showed that people of all walks of life are a part of this mission.

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On June 23rd, 2019, the LightSail 2 spacecraft successfully launched to Earth orbit aboard a SpaceX Falcon Heavy rocket. Ten years after the LightSail program started, its final mission launched to demonstrate to the world that solar sailing is a viable means of propulsion for CubeSats.

LightSail 2’s launch was part of the US Air Force’s STP-2 mission, which launched 24 satellites in total including several other CubeSats. LightSail 2 was stowed inside the Georgia Tech Prox-1 spacecraft and ejected from Prox-1 a week after launch.

*This slide: The Falcon Heavy rocket launching, and Planetary Society members watching on in awe.*
Slide 21

On schedule, LightSail 2’s sails deployed on July 24th, 2019, marking the first major milestone of mission success. On July 31, 2019, The Planetary Society officially announced that LightSail 2 has succeeded in raising its orbit solely on the power of sunlight. Over the 7 days since deploying its sails, LightSail 2 raised its orbital high point, or apogee, by about 2 kilometers.

Eventually, atmospheric drag will drag the spacecraft back into the atmosphere where it will burn up. The LightSail 2 team estimates that this will happen about a year after launch, but timing will depend on atmospheric variations.

Until then, LightSail 2 will continue teaching us about solar sailing, giving us more insight into how humanity may one day set sail for the stars.

This slide: LightSail 2’s sails unfurled in orbit.

Slide 22

To learn more about LightSail and The Planetary Society go to sail.planetary.org.