Sailing Among the Stars

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Illustration of NanoSail-D. Image credit: NASA

(PhysOrg.com) -- NASA launch will evaluate how a nanosatellite spacecraft and its payload performs.

This fall, NASA researchers will move one step closer to sailing among the stars.

Astrophysicists and engineers at the Marshall Space Flight Center in Huntsville, Ala., and the Ames Research Center in Moffett Field, Calif., have designed and built NanoSail-D, a "solar sail" that will test NASA's ability to deploy a massive but fragile spacecraft from an extremely compact structure. Much like the wind pushing a sailboat through water, solar sails rely on sunlight to propel vehicles through space. The sail captures constantly streaming solar particles, called photons, with giant sails built from a lightweight material. Over time, the buildup of these particles provides enough thrust for a small spacecraft to travel in space.

Many scientists believe that solar sails have enormous potential. Because they take advantage of sunlight, they don’t require the chemical fuel that spacecraft currently rely on for propulsion. Less fuel translates into lower launch weight, lower costs and fewer logistical challenges. Solar sails accelerate slowly but surely, capable of eventually reaching tremendous speeds. In fact, most scientists consider solar sailing the only reasonable way to make interstellar travel a reality.

Of course, it's not as easy as it sounds.

For scientists to really make use of solar sails they must be huge. Because the particles emitted by the sun are so tiny and the spacecraft is so large, the sail needs to intercept as many particles as possible. It's almost like trying to fill up a swimming pool with rain drops; the wider the pool, the more rain it captures. The same is true with solar sails and the sun's energy. In fact, a NASA team in the 1970s predicted they would need a solar sail with a surface area of nearly six million square feet -- about the size of ten square blocks in New York City -- to successfully employ a solar sail for space exploration.

That's where NanoSail-D comes in. As the first NASA solar sail deployed in low-Earth orbit, NanoSail-D will provide valuable insight into this budding technology.

"One of the most difficult challenges solar sails face is trying to deploy enormous but fragile spacecraft from extremely small and compact structures. We can't just attach a giant, fully spread sail to a rocket and launch it into space. The journey would shred the sail to pieces," said Dean Alhorn, NanoSail-D principle investigator and aerospace engineer at the Marshall Center.

"Instead, we need to pack it in a smaller and more durable container, launch that into space and deploy the solar sail from that container," Alhorn said. "With NanoSail-D, we're testing a technology that does exactly that."

One objective of the NanoSail-D project is to demonstrate the capability to pack and deploy a large sail structure from a highly compacted volume. This demonstration can be applied to deploy future communication antennas, sensor arrays or thin film solar arrays to power the spacecraft.

NanoSail-D will be deployed 400 miles up after it's launched this Fall aboard a Minotaur IV rocket, part of the payload aboard the Fast, Affordable, Science and Technology Satellite, or FASTSAT. The relatively low deployment altitude means drag from Earth's atmosphere may dominate any propulsive power it gains from the sun, but the project represents a small first step toward eventually deploying solar sails at much higher altitudes.

When fully deployed, NanoSail-D has a surface area of more than 100 square feet and is made of CP1, a polymer no thicker than single-ply tissue paper. The first big challenge for researchers was to pack it into a container smaller than a loaf of bread and create a mechanism capable of unfolding the sail without tearing it.

"Think of how easily I can rip a piece of tissue paper with my hands," Alhorn said. "Designing a mechanism to unfurl a space sail about that thick without tearing is no easy task."

To accomplish their goal, engineers tightly wound the NanoSail-D sail around a spindle and packed it in the container.

During launch, NanoSail-D is stored inside FASTSAT. Once orbit is achieved, the NanoSail-D satellite will be ejected from the satellite bus and an internal timer will start counting down. When the timer reaches zero, four booms will quickly deploy and the NanoSail-D sail will start to unfold. Within just five seconds the sail will be fully unfurled.

"The deployment works in the exact opposite way of carpenter's measuring tape," Alhorn explained. "With a measuring tape, you pull it out, which winds up a spring, and when you let it go it is quickly pulled back in. With NanoSail-D, we wind up the booms around the center spindle. Those wound-up booms act like the spring. Approximately seven days after launch, it deploys the sail off the center spindle."

Researchers designing NanoSail-D have faced more than their fair share of challenges. When the project was commissioned in 2008, NASA set a deadline of just four months to design and test the new technology. The team had to make decisions quickly, often using whatever parts happened to be available.

"It wasn't a question of going off and doing an exhaustive study of what components to use," Alhorn recalled. "There was no time for that. We said, 'Okay, this is the size of component we need, this is its function' -- and as soon as we found one that worked, we used it."

After months of work in 2008, researchers and engineers finally completed the sail, which was set to launch that August and orbit Earth for one to two weeks. Engineers integrated the flight unit on the Falcon 1, a launch vehicle designed and manufactured by SpaceX of Hawthorne, Calif., but unfortunately the rocket experienced launch failure and NanoSail-D never made it to orbit.

Fortunately, the team had built a spare. For the past two years, Alhorn and his team have worked to refine the second flight unit, hammering out the manufacturing problems and cleaning up the spool and a few of the other internals. In addition to having a higher orbit, the second NanoSail-D will launch into space and remain there for up to 17 weeks, a big increase from the original mission. The new orbit, 400 miles above the earth, also will allow more astronomers to get pictures of the sail as it glides across the night sky. Most of the mission has remained the same, however. For example, because the sail will deploy relatively close to Earth, researchers will have a difficult time detecting the slight solar effects.

After a few months, NanoSail-D will begin to move out of orbit. This de-orbiting process will provide NASA researchers with information about how systems like NanoSail-D might one day be used to bring old satellites out of space. This will provide a means for future satellites to de-orbit after their mission is complete -- keeping them from becoming space junk.

For now, Alhorn and his team are anxiously awaiting NanoSail-D's second attempt.

"The most exciting thing about the upcoming launch is just being able to do it," he said. To get a second chance is invigorating. You rarely get one like this -- that's what motivates me to get up and keep doing this."

After the NanoSail-D flight, Alhorn hopes to continue developing solar sails for NASA. He's already started to design FeatherSail, a next-generation solar sail that will rely on insights gained from the NanoSail-D mission to take solar sailing to the next level.

More information: For more information about NanoSail-D visit: www.nasa.gov/mission_pages/sma … lsats/nanosaild.html

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