

Google Lunar X Prize hopefuls struggle to lift off

The finalists face long odds to land a rover on the Moon in time to claim the \$20 million grand prize.

It's been more than 10 years since Google and the X Prize Foundation (now XPrize) announced the Lunar X Prize, which offered \$20 million to the first privately funded team to land a spacecraft on the Moon, navigate 500 m across the lunar surface, and beam high-definition images back to Earth. Of the competition's initial field of 29 teams, 5 confirmed their launch plans in time to make the cut as finalists: teams from India, Israel, Japan, and the

US, and an international team that boasts members from six continents. To have a chance of claiming the grand prize, one of them will have to get its spacecraft off the ground before 31 March.

Lunar X Prize or no, the teams are determined to reach the Moon. As they hustle to complete preflight testing, raise last-minute funds, and prepare for launch, some are already setting their sights on a more distant and potentially

more lucrative prize: a foothold in the burgeoning commercial space industry.

The new space race

The task the contestants face is immense. Since the culmination of the Cold War-era space race, nearly 50 years ago, only China has soft-landed a spacecraft on the Moon. And its *Yutu* rover, after touching down in late 2013, wheeled less than 120 m across the rugged lunar surface before malfunctioning and losing mobility.

Although China hasn't disclosed the cost of the mission that carried *Yutu* to the Moon, the US Apollo program and its Soviet counterpart, *Luna*, each cost billions of dollars. In essence, the X Prize is challenging teams composed largely of academics, space entrepreneurs, and neophyte rocket scientists to reach the Moon at a minute fraction of that cost.

To keep their budgets lean, all but one of the finalists have opted to hitchhike their way to space: Instead of flying on a dedicated rocket, their lunar landers and rovers will nestle inside commercial

EDITORS' NOTE: As this issue went to press, XPrize announced that none of the remaining teams would launch their spacecraft by the contest deadline. The \$20 million grand prize will therefore go unclaimed. Read more at www.physicstoday.org.



TEAM HAKUTO, one of five teams still vying for the Lunar X Prize, tests its *Sorato* rover on a simulated moonscape.

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THE LUNAR LANDER built by Team SpaceIL will end its mission with a giant hop: Instead of deploying a rover to navigate across the lunar surface, it will relaunch and land again.



rockets alongside communications satellites, CubeSats, and other payloads. The rockets will deposit the spacecraft in Earth orbit. The teams will have to complete the rest of the 380 000 km journey to the Moon on their own.

"With one stage of spacecraft, we need to get from Earth orbit to a lunar orbit, do the energy-intensive lunar-capture maneuver, and then land—which itself requires lots of energy," says Eran Privman, CEO of the Israel-based finalist SpaceIL. "That mission has never been done."

SpaceIL has contracted to launch its lunar lander to geostationary orbit on a SpaceX Falcon 9 rocket. Once the lander touches down on lunar soil, it will use an unorthodox approach to complete the final 500 m leg of the Moon race: Instead of deploying a rover, it will relaunch and touch down again at a distant site.

"The team joined the competition on the last day of registration, without any knowledge of space rovers or Moon rovers," Privman explains. By skipping the development of the rover, he says, they were able to make up for lost time and inexperience.

The US-based finalist, Moon Express, founded by space entrepreneur Bob Richards, will also forgo a rover in favor of a "hop" strategy. But the team's launch provider, RocketLab, will deposit the lander not in a 35 000-km-altitude geostationary orbit but in low-Earth orbit,

some 33 000 km below, where it will still need to expend considerable energy to escape Earth's gravity well.

The Indian and Japanese finalists, Teams Indus and Hakuto, won't have that problem. Both teams contracted to launch their spacecraft to geostationary orbit on one of the Indian government's Polar Satellite Launch Vehicles. And the teams will share more than just a rocket: The Indian contestants will allow Hakuto's rover to ride all the way to the lunar surface on their lander, in return for an undisclosed transport fee.

"That's allowed us to focus on miniaturizing our rover," says Takeshi Hakamada, team leader of Hakuto. The final version, *Sorato* ("space rabbit") weighs just 4 kg and is about the size of a microwave oven.

If *Sorato's* wheels ever do kick up lunar dust, the vehicle will find itself in a 500 m dash against Team Indus's *ECA*, short for *Ek Choti si Asha* ("a small hope"). The two rovers will squeeze into Team Indus's 2-m-tall lunar lander along with a soda-can-sized biology experiment that was designed by high school students as part of the team's Lab2Moon contest.

Only Synergy Moon, the international finalist, has dared to build its own rocket. The brainchild of adventurer and documentary filmmaker Nebojša Stanojević, the team formed when Stanojević's Human Synergy Project

merged with US team Interplanetary Ventures in the early days of the contest. Since then, the collaboration has incorporated a dozen teams and companies representing 15 countries.

One of those companies, the US aerospace manufacturing firm Interorbital Systems, has been working for years to develop a series of inexpensive, modular rockets. Synergy Moon is counting on one of those rockets to fly its three-wheeled rover to the Moon.

Flight delays

When the Lunar X Prize was announced in 2007, contestants had only until the end of 2012 to claim the \$20 million grand prize. After that, the reward would drop to \$15 million, and if no team reached the Moon by the end of 2014, the competition would end altogether.

When it became clear, however, that none of the entrants could meet the ambitious deadlines, contest organizers kept the prize at \$20 million and granted a string of extensions. They eventually gave teams until 2017 to complete the mission, provided they had secured launch contracts by the end of 2016. Last August, when the five remaining teams still weren't ready to hurl their crafts into space, XPrize granted one last reprieve, to 31 March 2018.

If the deadline slips again, the competition risks losing some of its thunder;

the Indian government is planning to send its own rover to the Moon in early 2018 as part of its Chandrayaan-2 mission. Why is it taking so much longer than expected for X Prize contestants to get to the Moon?

"Missions are planned by optimists but executed by pessimists," says Scott Hubbard, Stanford University adjunct professor and former director of NASA's Ames Research Center. As teams come to realize that a single misstep can scuttle an entire mission, he explains, corner-cutting measures that initially seemed prudent are often deemed too risky. Not only does that send teams back to the drawing board, Hubbard adds, "it leads to cost growth."

Indeed, most of the finalists have seen their budgets swell to more than double the \$20 million payout. And those unexpected costs present their own challenges. "The difficulty is not in the technology," explains Team Hakuto's Hakamada. "It is in the fundraising."

Hakamada recalls that several teams struggled to raise money during the early days of the competition. But he and his colleagues largely avoided that fate by limiting their scope to rover design. As the Moon race enters the home-stretch, Hakuto finds itself in the enviable position of being ahead of schedule and in the black: The team has raised the roughly \$10 million it needs to cover costs, completed testing of its rover, and shipped it to the planned launch site in Bangalore, India. All that remains is to blast the diminutive robot into space.

There's just one big problem: Its ride, Team Indus, is reportedly still scrambling to raise the \$70 million it needs to complete its own rover and lander. As PHYSICS TODAY went to press, an Indian news publication reported that India's space agency had canceled Team Indus's launch contract due to missed payments.

The other finalists also face potentially show-stopping delays. As this year began, SpaceIL was still assembling its lander, which would then need months of preflight testing; Moon Express's launch provider, RocketLab, had yet to demonstrate that it could deliver a payload into orbit; and Synergy Moon had yet to demonstrate that it could even get its rocket off the ground.

Moon or bust

If the Lunar X Prize is canceled after March, it wouldn't be the first time

XPrize called off one of its global challenges: In 2013 the foundation abandoned a \$10 million competition to spur rapid human-genome sequencing, citing that technological innovations in the field had rendered the contest unnecessary.

Still, the Lunar X Prize hopefuls say they would rather miss the March deadline—and launch later—than rush an unproven craft into space. In fact, some teams have already shifted their sights to a more distant reward: a stake in the emerging lunar exploration industry.

According to the nonprofit Space Foundation, space has become a \$300 billion economy, driven mostly by commercial activities at geostationary altitudes and below. With the commercialization of the Moon, that market could grow substantially.

Space entrepreneurs have floated proposals to mine the Moon for water that could one day support lunar colonies, harvest helium-3 for use on Earth, and establish the Moon as a waystation for missions to Mars and other deep-space realms. Hakuto is eyeing the Moon for many of the same reasons. Its parent company, the Japanese startup Ispace, recently raised \$90 million to develop a lunar lander for two return trips to the Moon by 2020.

Meanwhile, Moon Express has already lined up paying clients for its maiden lunar voyage: It will deliver a telescope for the nonprofit International Lunar Observatory Association; a laser array for scientists from the University of Maryland and Italy's National Laboratory of Frascati; and cremated remains for Celestis, a Texas-based company that offers memorial spaceflights and space burials. Only after the team's spacecraft completes those deliveries will it attempt the 500 m scamper to win the Lunar X Prize.

Even SpaceIL, the lone nonprofit among the finalists, would be deterred by the prize's cancellation. Funded largely by Israeli philanthropist Morris Kahn and the Adelson Family Foundation, the team hopes it can create an "Apollo moment" that will inspire young Israelis to pursue careers in science.

"Because of that, we are going even if we launch after the end of the competition," says the team's CEO Privman. "And it will be very worth it."

Ashley G. Smart **PI**

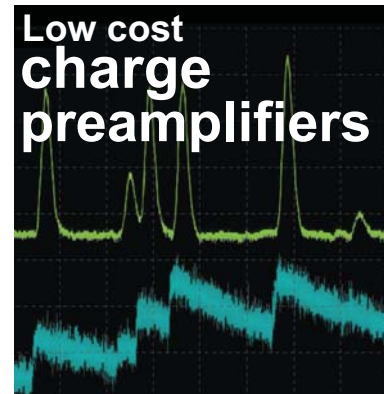
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