

Imaging Earth daily to help humanity

Commercial uses of tiny satellites may realize the 1990s NASA mantra "faster, better, cheaper."

"Why are spacecraft so expensive? Why are the computers 20 years old? Why is the camera on the Mars Rover only 2 megapixels? My smartphone is better than your spacecraft!" After hearing that rant repeatedly at NASA's Ames Research Center, Chris Boshuizen and two fellow physicists left the space agency in 2011 to found Planet Labs. The San Francisco-based startup company now has a staff of about 70 and is well on its way to achieving its goal of imaging the entire planet every day.

The company makes tiny satellites whose main payload is a camera. The satellites are dubbed "doves," because, as Boshuizen explained in a 2013 TEDx talk, "spacecraft often have really aggressive names, like Talon and Raptor, but we wanted something that was more fun and peaceful." In a blog post in August, CEO and cofounder Will Marshall wrote, "At Planet Labs, we're on a mission to image the whole world every day and provide universal access to it. We think the fresh and frequently updated global imagery can help humanity to take better care of the planet and life upon it, as well as create myriad new commercial opportunities." As of mid-September, the company had

launched 71 satellites, 24 of which were sending home images of Earth; another 28 were due to launch in late October. The plan is to have 100 to 150 satellites in orbit at any given time.

"We have heard for 30 years that the era of small satellites is coming," says Jonathan McDowell, a Harvard-Smithsonian astrophysicist and space watcher. "Planet Labs is the first company to deliver a sizable constellation. That is a breakthrough moment."

Strength in numbers

Planet Labs is among the earliest commercial adopters of CubeSats, which were developed by university researchers as a way for students to send projects into space. They have a cross section of 10 cm by 10 cm and can be 10, 20, or 30 cm long. In their first decade, from 2003 to 2012, says McDowell, about 100 CubeSats were launched. Another 100 were launched in the following two years, including 50 in one week alone in November 2013. (See the interview with CubeSat inventors Jordi Puig-Suari and Bob Twiggs at <http://www.physicstoday.org> in the Daily Edition's Singularities department.)

The Planet Labs satellites weigh less than 5 kg. In addition to a camera, each

ASTRONAUT KOICHI WAKATA, VIA TWITTER



Two Planet Labs satellites being released from the International Space Station in February 2014; the solar panels open a day or so after release, as part of a remote commissioning process.

Isolation Amplifier



SIM984 ... \$995 (U.S. List)

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The SIM984 is a wide bandwidth, low-noise isolation amplifier with gain of up to $\times 100$. The input stage floats up to 1000 V above or below ground and is optically coupled to the output stage. The all analog design insures no quantization artifacts can corrupt sensitive signals.

In addition to isolating and amplifying signals, the SIM984 can also be used to break ground loops and reduce common-mode interference.



SIM900 Mainframe loaded with a variety of SIM modules

carries electronics to download images and upload commands: They are tested, reprogrammed, and reoriented from the ground. In space, solar panels unfold to power the satellites.

The satellites image at visible wavelengths with a resolution of 3–5 meters, depending on altitude. “We can see cars, but not people. We wanted to avoid privacy issues,” says Mike Safyan, who leads launch activities and regulatory licensing at Planet Labs. (Boshuizen, Marshall, and the other cofounder Robbie Schlinger were not available to speak with PHYSICS TODAY.)

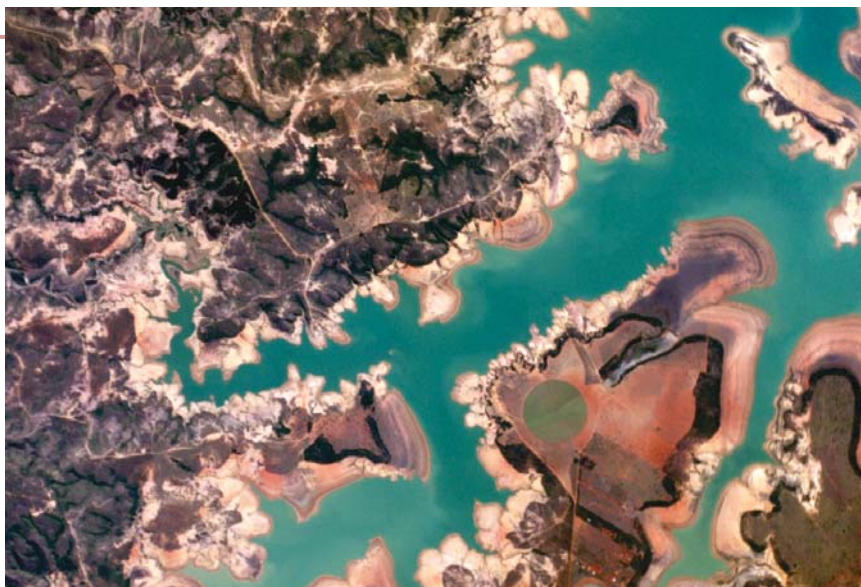
The Planet Labs satellites zip around Earth roughly every 90 minutes at altitudes ranging from 380 km to 620 km; orbits are determined by the host launcher. As with other CubeSats, the Planet Labs satellites hitch rides on government and commercial rockets; so far, carriers have included Russia’s Soyuz, the Russian-Ukrainian Dnepr, and the US’s Antares rockets. The higher the orbit, the longer the satellites can function before atmospheric drag pulls them down low enough so that they burn up.

In July, 28 Planet Labs satellites were ferried to the International Space Station. But the deployment ran into trouble when some of the satellites didn’t eject on command and later emerged unexpectedly. The misfiring is still under investigation, but Safyan says the 16 satellites that are still on the ISS are expected to be put into orbit early next year. “Launches are always a risk,” he says. “So we spread our launches across several opportunities. Right now, one of our biggest struggles is how often we can get into space. That dictates the number of satellites.”

Keeping up with the phones

The idea at Planet Labs is to have each satellite fly for up to two years and to continually replenish the fleet. “We take the approach of putting in the latest and greatest technologies and electronics,” says Safyan. “We are in a constant state of upgrading and folding advances into our satellites. We want them to stay at the same stage of development as smartphones.” In building the satellites, the company incorporates both off-the-shelf parts and in-house developments—for example, squeezing broadband downlink capability into the constrained volume of a CubeSat so it can transmit large images at more than 100 megabits/second.

Other, larger satellites get better resolution, but they either look at specific



A reservoir in Brazil imaged by Planet Labs on 31 July 2014. A comparison of this image with one taken a year earlier by the US Geological Survey’s *Landsat* shows that the water level has dropped; several such comparisons are on the company’s website.

areas on demand or they return to the same spot on much slower time scales—typically weeks or months, not a day. Bob Twiggs, a codeveloper of CubeSats who is now at Morehead State University in Kentucky, says Planet Labs’s “advantages are that they revisit quite often. And they can make improvements based on experience. It’s a whole different business plan. I don’t know what the market is. But if people get used to it, it could end up being useful.”

“This kind of archive has never existed,” says McDowell. Monitoring urbanization, agriculture, shipping traffic, deforestation, smog, wild fires, and parameters related to climate change, such as sea level and fall leaf colors, are the sorts of applications that come to mind at Planet Labs. “What is changing rapidly that would be important for people to know?” asks Erika Reinhardt, a software engineer and applications team leader at the startup. “You can see a progression. You don’t predict disasters, but we will have ‘before’ pictures that people can go back to after an event.”

“We are not focusing on specific issues. They are popping out at us from the images,” says Safyan. “The exciting part is when we start to release the data and others find applications.”

The company won’t say what their satellites cost to build, but a CubeSat typically runs a few hundred thousand dollars. Observers assume that Planet Labs gets the cost down further by building in quantity. In contrast, a traditional satellite might weigh up to a ton and cost hundreds of millions of dollars to build and launch. Planet Labs

has attracted about \$65 million in venture capital.

The company began rolling out data to customers this fall. To square its dual aims of doing good and making money, “customers may not all receive the same volumes and types of data,” says vice president of business development Josh Alban. “We have contracts with large customers that pay. At the same time, we are committed to and have begun to open this dataset to scientists, nonprofits, and developing countries that have been underserved by the traditional remote-sensing community.”

Disrupting the space industry

Another startup has set out to keep an eye on the oceans using CubeSats. Since its founding in 2012, Spire has launched 4 out of more than 50 planned RF sensors into orbit at 500–600 km. Because RF sensors can have a larger field of view than optical cameras, a smaller number can have a higher revisiting cadence—15 minutes in the case of the Spire fleet. Founder and CEO Peter Platzer is a particle physicist turned Wall Street analyst. “If you think of imaging,” he says, “the technology replacement threat can come from large and small satellites, helicopters, drones. . . . But as soon as you leave land and are over the middle of the ocean, the only way is satellites.” In studying who might be customers, Platzer found many, from governments interested in following illegal fishing activities and pirates to conservationists keen to keep tabs on migrating whales. “We found a niche,” he says.

Zac Manchester, a graduate student

in aerospace engineering at Cornell University, uses a CubeSat as a vehicle for even smaller satellites, so-called Sprites. Manchester's goal—at least for now—is not commercial; he wants to see “how small can we make a satellite?” He used Kickstarter to crowdfund his thesis project to send and detect radio signals with postage-stamp-sized satellites—electronics boards that can withstand the harsh conditions of space. One motivation, he says, is to bring down the cost and widen public access to space. His

satellites can be built for “single-digit dollars with parts from Radio Shack,” he says. But the small size also means the Sprites may not be easily trackable by US Air Force radar, which makes them a potential debris problem. For now, Manchester says, he has permission to fly them in orbits below 400 km so that they burn up within a few days.

“One of the nice things about companies like Planet Labs,” says Elwood Agasid, the Ames chief technologist for mission design, “is that they are driving

the industry. Small satellites have become a disruptive factor in the space industry.” NASA and other national space agencies are looking at small satellites to see what they can do to bring down the cost of research. Agasid notes that since 2006, NASA has launched 18 CubeSat missions. They include testing the effects of microgravity on living cells and networking among satellites to create spacecraft-to-spacecraft communications.

Toni Feder

Space, nuclear trade eyed at US-India summit

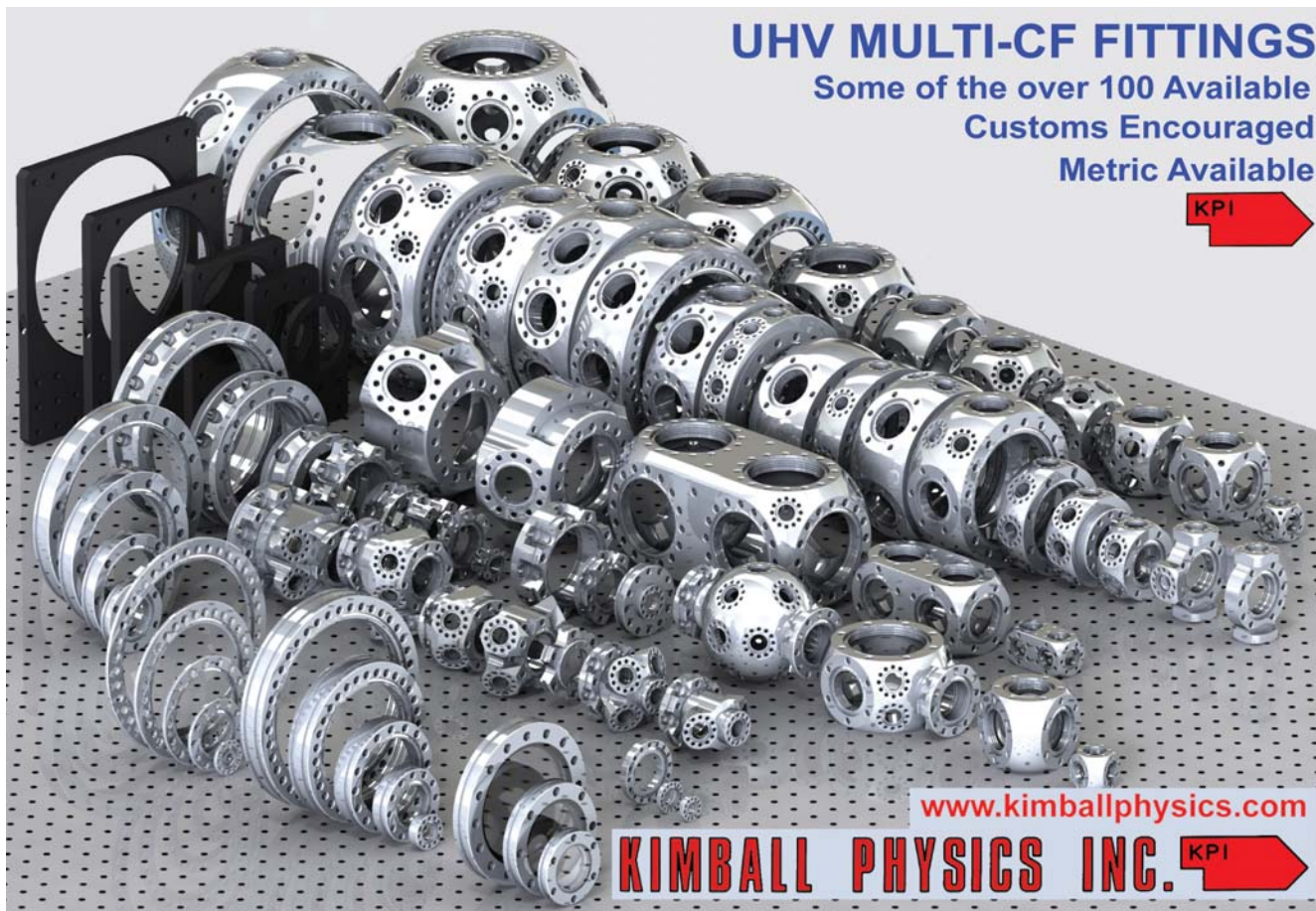
Meeting a few days after their countries' respective spacecraft entered Mars orbit, President Barack Obama and Indian prime minister Narendra Modi on 30 September pledged cooperation in space, clean energy, climate change mitigation, and other scientific programs. Coinciding with the summit, the heads of the two nations' space agencies signed separate agreements to delineate their respective roles in building and launching an Earth-orbiting satellite and to plan for a future joint Mars mission.

Obama and Modi also agreed to take further steps to implement the US-India civil nuclear cooperation agreement. Under that pact, which took effect in 2008, India agreed to open its civilian nuclear reactors—but not its nuclear weapons facilities—to international inspection. In exchange, the US agreed to export reactors, nuclear fuel, and other nuclear technologies to India. The 47 other countries that export nuclear-



WHITE HOUSE PHOTO BY PETE SOUZA

President Barack Obama and Indian prime minister Narendra Modi agreed to increase cooperation on space, energy, and nuclear commerce at their summit in Washington, DC, on 29–30 September.



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