

FT Magazine

Eyes in the sky: a revolution in satellite technology

Scores of tiny 'CubeSats' circle our planet, surveilling everything from shrinking glaciers to fleeing refugees – but at what cost to our privacy?

John Thornhill YESTERDAY

In 1967 the ATS-3 satellite took one of the earliest, and most beautiful, photographs of our planet from outer space, forever changing the way we think about our place in the universe. The picture of a vivid blue, white and green marble hanging in a black void captured the Earth's fragility.

That single satellite image helped alter the sensibilities of a generation. It ran as the cover image for the first edition of the Whole Earth Catalogue, a counterculture magazine, energising the nascent environmental movement on America's west coast.

Today, a new revolution in satellite technology is unfolding at warp speed, and its consequences are just as unpredictable. The rapid adoption of billions of smartphones and other connected devices over the past decade has boosted the market for telecommunications satellites, transforming the demand side of the business. But the supply side of space has also been upended as a new generation of innovative space billionaires led by the mercurial Elon Musk, the founder of [SpaceX](#), has built cheap and reusable rockets, slashing launch costs.

That has enabled some smaller private companies to launch scores of tiny and cheap commercial satellites, known as CubeSats, reimagining [business opportunities](#) in space. One such entity is Planet, founded by three former Nasa engineers in a San Francisco garage in 2010. The company operates the world's largest private fleet of satellites, which circle the Earth and take daily photographs of every spot on the planet. It is now selling this space imagery to almost anyone willing to pay, as well as offering it for free to some non-governmental organisations and researchers.

Farmers can use the imagery to estimate crop yields around the world, investors are counting the number of oil storage tanks in China and estimating consumption trends, while human rights campaigners have used it to map the flight of the Rohingya population from Myanmar. On a daily basis, we can now study the shrinkage of glaciers, the expansion of cities, the deforestation of remote wildernesses and the devastation of armed conflict in intense detail.



Planet's "Dove" satellite © Charlie Bibby

This partial democratisation of space data, which some compare to the shift from mainframe to mobile computers, is enabling us to understand “patterns of life” on Earth more deeply than ever before. But it is also provoking concerns about the erosion of personal privacy and national sovereignty, as private companies and individuals gain insights into our world that were once mostly the preserve of governments and their agencies. All of us are increasingly exposed under the eye in the sky.

Since 1957, when Sputnik first circled the planet, some 41,000 man-made objects have been launched into space, although only about 5 per cent of them are thought to still be active. The flurry of new activity in the satellite industry has been brought about by two innovations: one in technology, the other in business models.

A significant impetus for producing cheaper, smaller satellites came in 1999 when two professors, Jordi Puig-Suari of California Polytechnic State University and Bob Twiggs of Stanford University, challenged their graduate students to design and build miniature spacecraft. That resulted in the creation of a whole new CubeSat, or nanosatellite, industry. Some CubeSats can be as small as 10cm x 10cm x 10cm and cost as little as \$20,000.



Satellite imagery of a Rohingya refugee camp in Bangladesh, August 29 2017



The same refugee camp has expanded considerably a few weeks later, September 21 2017

The second impulse was the realisation by a new generation of entrepreneurs that they could create a different business model using inexpensive technology. So long as CubeSats were good enough, they did not need to be perfect. Their tiny size significantly reduced manufacturing and launch costs, enabling operators to piggyback on others' missions.

“Seeing the whole Earth as a single entity is not new,” says Martin Rees, Britain’s astronomer royal. “But what is happening now is that we are monitoring it on a daily basis at high resolution. Satellites have enough resolution to observe every big tree in the world every day.”

Planet is at the forefront of the CubeSat revolution. For the moment, it is the only satellite company that can supply customers with near-constant imaging of our entire planet, seeding a fast-growing industry in geospatial data analytics.

Planet's satellite constellation

The satellites

The company has 190 satellites in orbit:



The orbit

The satellites are in Sun Synchronous Orbit (SSO) over the poles at altitudes of 500km-600km. One satellite orbits the Earth every 90 minutes. A series of ground stations distributed around the Earth allow for downlinking of more than 7 terabytes a day

What is SSO

The satellites are in a highly inclined orbit that crosses almost over each pole. Although the earth is rotating beneath them they are always facing the sun when on the day side of the Earth

Satellite orbits

Earth's rotation

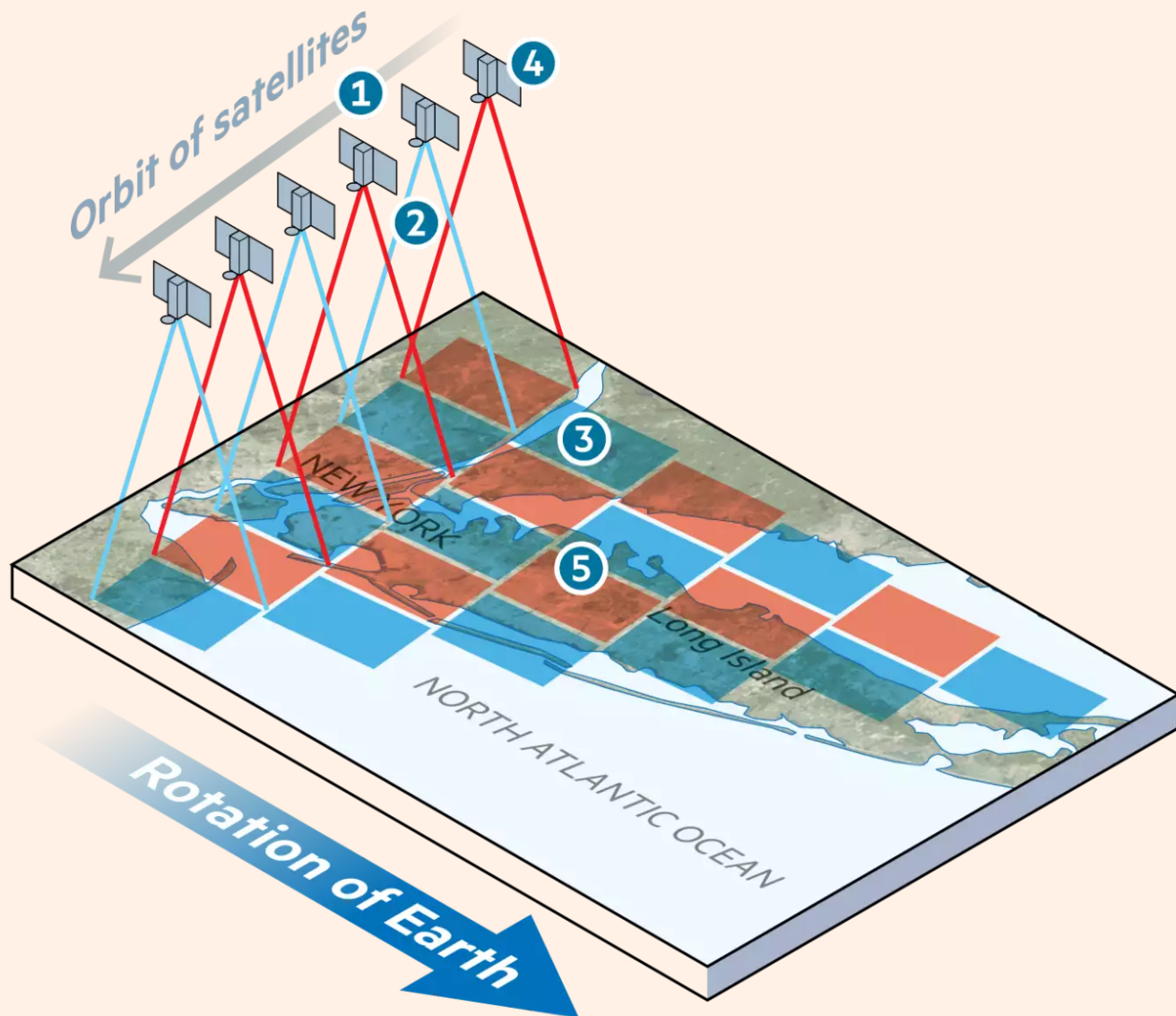
Sources: Company; FT research Graphic: Ian Bott
© FT

In the company's European headquarters in Berlin, one of Planet's three co-founders, Robbie Schingler, 39, holds a 5kg "Dove" satellite in the palm of his hand and shows me its component parts. He previously worked on space projects at Nasa but grew frustrated that the organisation was so focused on operational perfection rather than commercial opportunity. That view was shared by Planet's other two founders, Will Marshall, a Briton, and Chris Boshuizen, an Australian. The three vowed to build a very different organisation.

[Nasa](#)'s insistence that it run "exquisite, state-of-the-art missions" meant that failure was not an option, says Schingler, especially after the Space Shuttle Challenger blew up in 1986, killing all seven crew members on board. Satellite designs therefore had to build in a lot of redundancy, leading to a spiralling of size and cost. "Something that could have been the size of a table turned into the size of a room. What could have been done in two years turned into eight," Schingler says.

Planet adopted a radically different iterative approach to satellite development by embracing risk rather than trying to mitigate it. The company moved quickly to launch dozens of simple satellites into low orbit. If some of its satellites failed that did not matter, as long as the network remained intact.

How Planet's Dove satellites scan the whole world once a day



- 1 The constellation of satellites orbits the Earth from pole to pole at a speed of approximately 7.5km per second
- 2 The satellites capture images constantly as they move
- 3 As satellites move forward, the areas they have just photographed move away to the east due to the earth's rotation
- 4 The following satellites photograph the areas behind, then they also rotate east
- 5 In this way, the constellation builds up a comprehensive patchwork of photographs, eventually imaging the whole earth's surface

Sources: Company; FT research Graphic: Ian Bott
© FT

“We decided to leave Nasa and do it with [the kind of] capital that would allow for risk to be taken — which is venture capital,” Schingler says.

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We are now monitoring the whole Earth on a daily basis. Satellites have enough resolution to observe every big tree in the world every day

Martin Rees, Britain's astronomer royal

Since 2011, Planet has raised \$183m in debt and equity finance from investors, including the venture capital firms Draper Fisher Jurvetson and Data Collective and the International Finance Corporation, the private sector arm of the World Bank. That financial backing, combined with a nimble start-up culture, have enabled the company to update its technical capabilities and manufacturing techniques at speed. Over the past five years, Planet has taken advantage of the latest advances in chip and component design to update its satellite designs 13 times.

Last year, the company also bought [Terra Bella](#), a satellite photography business that included a group of high-resolution satellites called SkySats, from Google. Terms of the deal were not disclosed. But Google, which only acquired Terra Bella two years previously for \$500m, took an equity stake in Planet and acquired the rights to access all of the company's imagery. It is using this to improve its Google Maps products and possibly to blend with other data sets. “We can be a customer of Terra Bella but do not need to own it,” says one Google executive who has been involved in pruning back some of the tech company's sprawling investments.



The launch of US entrepreneur Elon Musk's Falcon Heavy rocket from the Kennedy Space Center, Florida, on February 7 © Jim Watson/AFP/Getty Images

Planet now has a fleet of 190 satellites in orbit, including 13 SkySat satellites. That network provides a steady feed of imagery — more than 1.3 million photographs a day — that can be combined with other data streams to create a comprehensive “space data processing platform”. The

company includes feeds from the Sentinel satellites, which operate as part of the EU's [Copernicus programme](#), and the US Landsat 8 satellite, adding infrared and radar capability.

Schlinger says that for him the most unexpected aspect about the company's imagery is how it highlights the constantly evolving nature of our planet. "Rivers change. Cities grow. Things shift over time," he says. "With computer vision and machine learning algorithms on top of that, you can actually understand patterns of life and anticipate what's about to happen."

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Robbie Schlinger, Planet co-founder

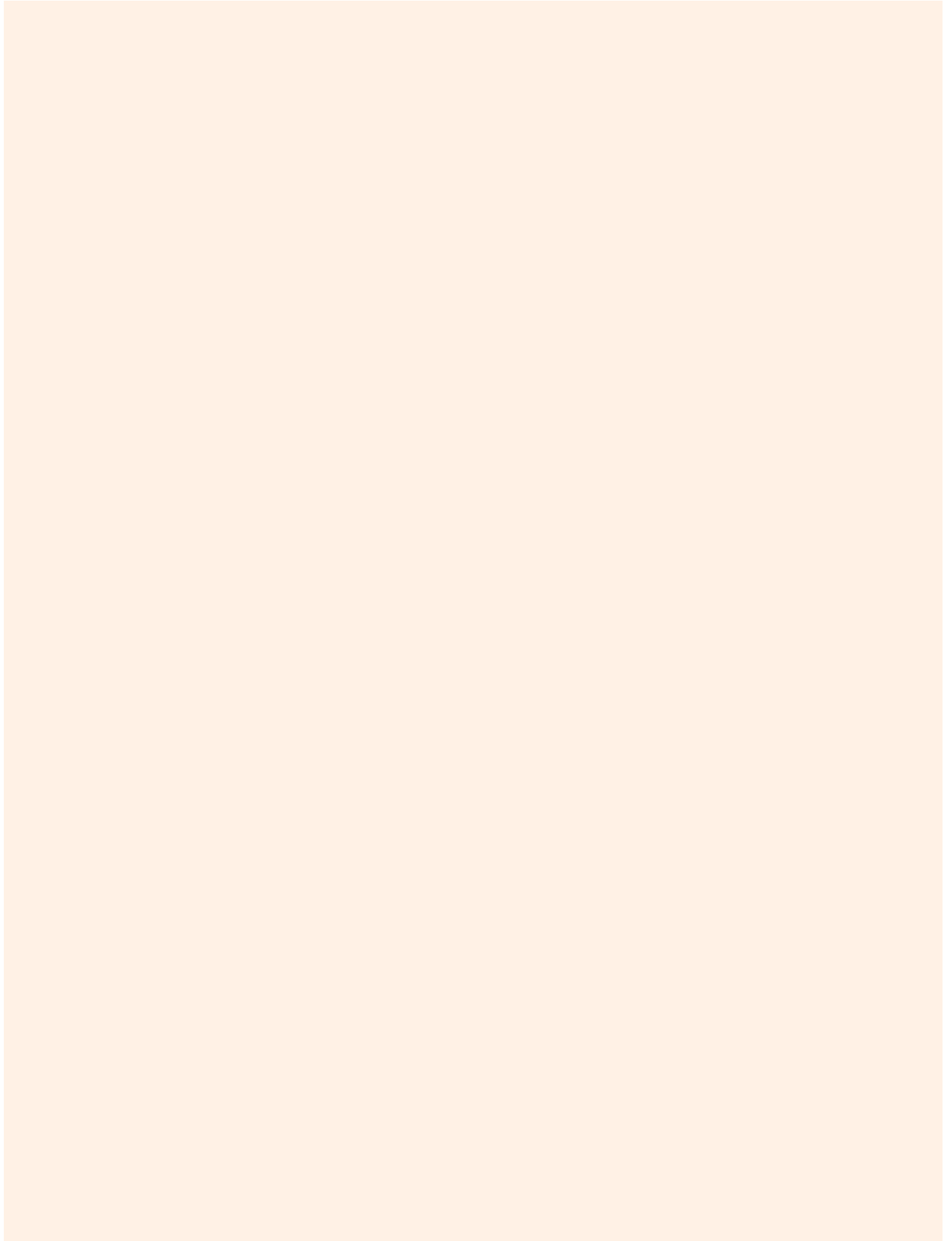
Some industry observers have likened Planet to a remarkable technological solution in search of a viable business model. As a private company, Planet has not released much financial data but it remains lossmaking — something the company attributes to its heavy investment programme. It is now rapidly trying to commercialise its services, seeing its role as a supplier of a data feed and analytics capability rather than as a producer of complete data products. Schlinger says he is constantly surprised by the ingenious uses that other companies find for Planet data. The company has encouraged experimentation by creating an Application Developer Programme, allowing start-up companies and small businesses to access the seven-plus terabytes of imagery it

generates every day.

One business idea to emerge from this programme was developed by a Canadian company called Tanka, which applies artificial intelligence to satellite imagery to auto-detect fires around the world. Emergency services are using this to respond to fires in remote regions while insurance companies use it to check disaster claims.

Governments are among Planet's biggest customers, using the imagery for intelligence, border monitoring, disaster response and environmental observation. Many intelligence agencies already operate their own powerful and extensive satellite networks. But commercial CubeSats can provide both global coverage and daily updates.

One of the most striking patterns observed by Planet's satellites has been the construction of artificial islands in the South China Sea by the Chinese and the Vietnamese. Confronted with clear photographic evidence, it is hard for governments to deny such activities.



The Dove satellite's main components

Camera

Captures images fast enough to cover a continuous strip of Earth's surface

Telescope

Covers an image area of 26km x 17km at a resolution of 3-5 metres

Lorem ipsum

How it self-checks its position

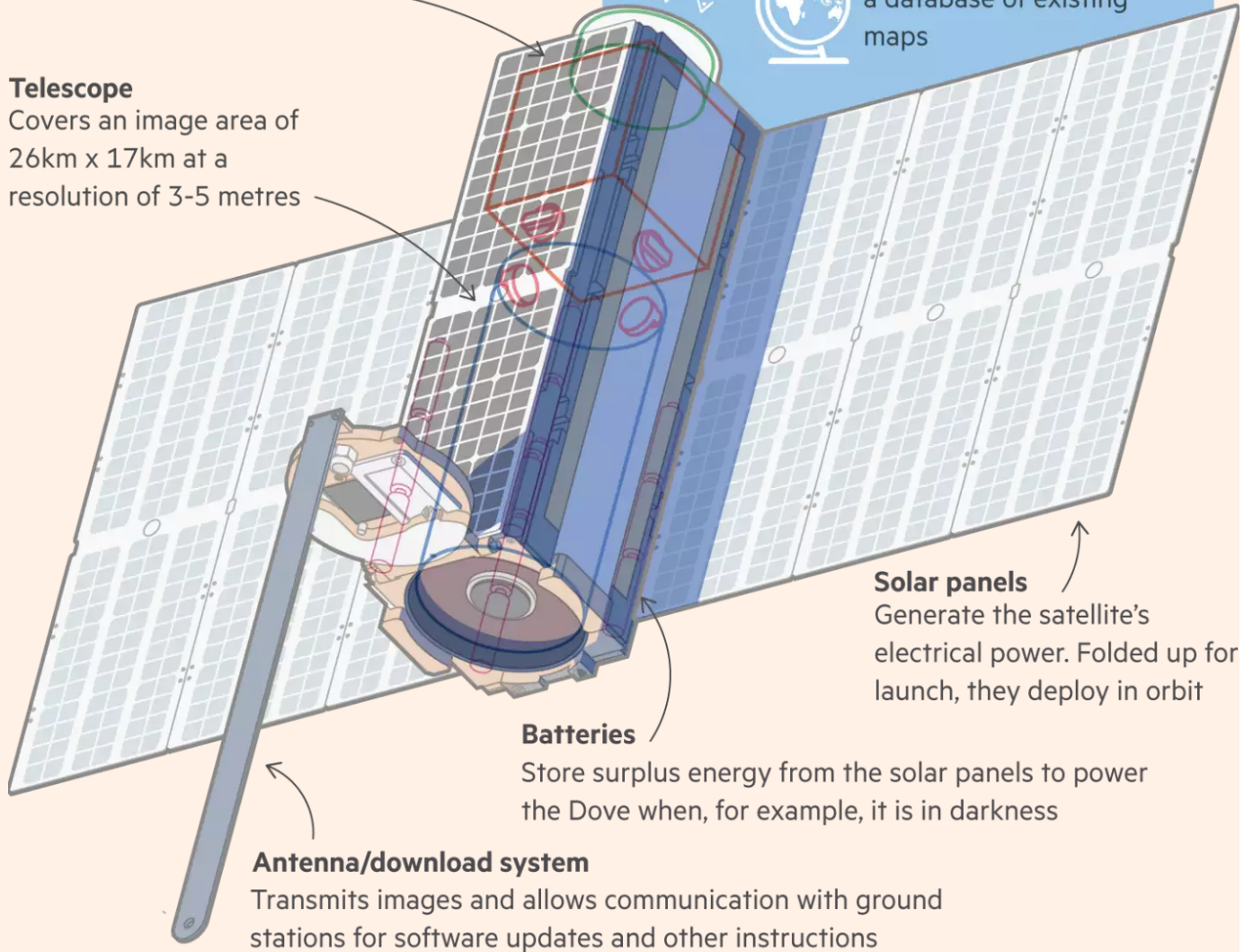
Astro-navigation

Using a star camera

GPS

Georeferencing

Images compared against a database of existing maps



Solar panels

Generate the satellite's electrical power. Folded up for launch, they deploy in orbit

Batteries

Store surplus energy from the solar panels to power the Dove when, for example, it is in darkness

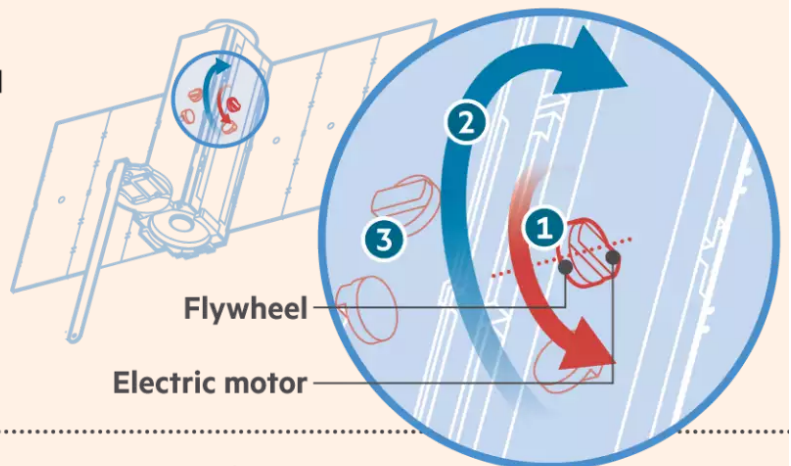
Antenna/download system

Transmits images and allows communication with ground stations for software updates and other instructions

How it manoeuvres

Reaction wheels

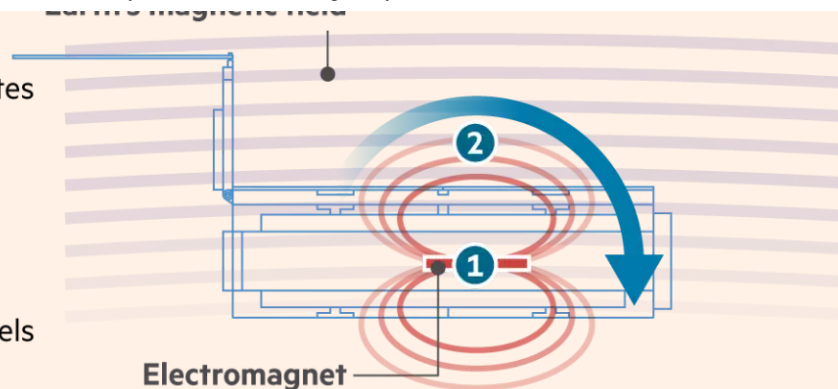
- 1 An electric motor turns a small flywheel
- 2 The torque reaction to this moves the satellite about its centre of mass in the opposite direction
- 3 Three wheels enable the Dove to be moved about every axis (satellite has four wheels for redundancy)



Earth's magnetic field

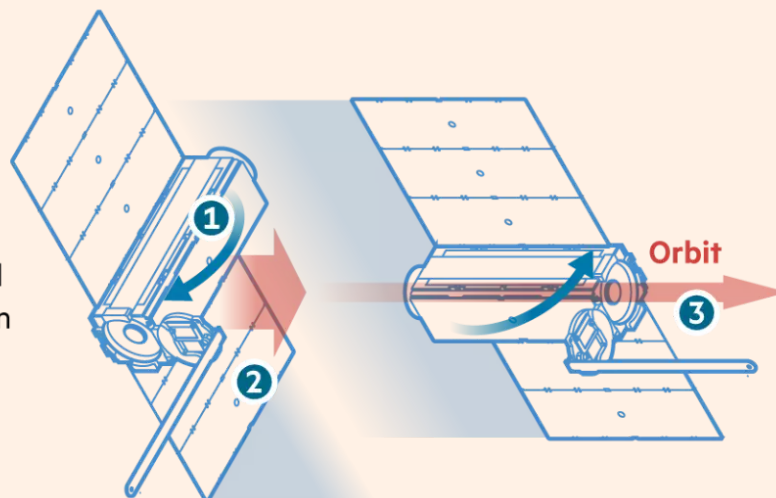
Magnetic torquer

- 1 An onboard electromagnet generates a magnetic field
- 2 This field interacts with the Earth's magnetic field and the torque generated rotates the satellite in a similar manner to the reaction wheels



Differential drag

- 1 Because the Doves are still within the thinnest limits of Earth's atmosphere, they can be turned to present varying aspects to the air
- 2 If the satellite's solar panels are rotated face-on to the air, drag will slow it down relative to other satellites...
- 3 ... and if they are turned edge-on, the reduction in drag will cause it to accelerate relative to other satellites



Sources: Company; FT research Graphic: Ian Bott
© FT

Schlinger suggests that the more extensive use of satellite imagery could have important geostrategic implications as it allows “history to be recorded” in near real time. “The 1972 Anti-Ballistic Missile Treaty became possible at the height of the cold war because the Russians and the Americans each had spy satellites to look at each other’s stockpiles,” he says.

Planet is just one of a growing number of start-ups making use of microsatellites across the world. Commercial satellite operators are bound by international law created by the [Outer Space Treaty](#) of 1967. Operators also have to register with a sovereign signatory and abide by its national rules, which can vary. For example, the US government limits commercial spatial resolution to 25cm per pixel, which is far more detailed than Planet can currently provide.



Alviso salt ponds, California, September 23 2016

But other governments allow for higher resolution, causing concern among some privacy campaigners. As with all technology, satellite imagery could be used for nefarious purposes, such as identifying future drug cultivation sites, spotting virgin forests for illegal logging or targeting sites for terrorist attacks.

Fred Abrahams, associate director for Human Rights Watch in Berlin, says microsattellites can provide huge benefits to many users, including human rights campaigners trying to expose atrocities in inaccessible or extremely dangerous places, such as Syria and Myanmar. He is less concerned by the issue of privacy. “Satellite imagery resolution is not incredibly high, it cannot see you sunbathing nude in the garden; it can’t really tell the make of a car,” he says.

The bigger concern, he suggests, is how closely we are followed on the ground by CCTV footage, drones and our mobile phones, which act as personal tracking beacons. More than 100 million surveillance cameras are sold around the world each year and it is estimated that about 2.5 trillion images are uploaded to the internet annually. “We shouldn’t be worrying so much about aerial imagery, we should be worrying about ground imagery, ground sensing,” Abrahams says.

Astronauts sometimes talk about the “overview effect”, the overwhelming emotion they feel when they see our planet in its entirety pulsing with life for the first time. At best, the new satellite revolution may provide striking fresh perspectives on our planet. Anousheh Ansari, an Iranian-American astronaut who spent nine days on the International Space Station in 2006, says that she was moved to tears when she looked out of the porthole and saw Earth for the first time.



Khurais oil fields, Saudi Arabia, May 17 2017

“You realise that all the lines on the maps really do not exist. You can’t even tell where one country starts and the other one stops. All those things that create conflict just melt away, and you can see our planet as one home for all of us,” she says.

Ansari now chairs Prodea Systems, a Texas-based technology company that is part of a new industry seeking to profit from the surge in connectivity brought about by the satellite revolution. Prodea helps companies integrate the mass of data now available from billions of connected devices on the Internet of Things to improve services, such as smart transport systems and remote patient monitoring.

“To me, it’s all about using all the data that can be now gathered from smart devices, from satellites, from everything around us,” she says. “And then using that data to create meaningful, beneficial services for everyone.”

As the saying goes, technology is neither good nor bad, but it is rarely neutral. Few civil rights groups appear to have wrapped their heads around how this space imagery could be combined with other data sets to produce harmful results. But the recent case in which Strava, the fitness tracking app, [inadvertently revealed](#) secret US military bases by posting a “heat map” of its users’ training routes highlights how new data releases can have wholly unintended consequences.



Durrat al Bahrain, an artificial island in Bahrain, October 30 2017

The lack of global regulations over this new commercial space race, and the speed with which satellite technology is advancing, raise serious questions about the rights of private individuals to remain “hidden” from microsatellites. While the image resolution of Planet’s satellites remains low, and the company itself is committed to transparency, it is not hard to imagine that in the future, other companies — or state operators — could enter the market with more complicated motives.

Over the past two years, Planet has sold its data services to hundreds of customers in about 100 different countries, including the US, UK and German governments and big companies such as Bayer, Monsanto and Wilbur-Ellis. Planet says it has strict ethical guidelines and vets its customers as best it can to ensure that sensitive images do not end up in the wrong hands.

Unsurprisingly, with a business to build and financial backers to repay, Schingler prefers to dwell on the commercial opportunities thrown up by the satellite revolution. He argues that it will help redress the “information asymmetry” that exists between governments and civil society, boosting democracy in the process. “With greater transparency and information, ultimately people make better decisions,” he says.

Schingler believes that the greatest benefit of pervasive satellite imagery will be to provide a fresh view of our planet, helping to raise awareness of its environmental vulnerability and reinforce our common destiny. The 172 Dove satellites are named after the bird of peace, with the intention of acknowledging the humanitarian aspect of their work. “These tools and visualisations can help us recognise how interconnected we are as a species on our home planet and get closer together when it comes to understanding the perils that exist in some areas,” he says.

John Thornhill is the FT’s innovation editor

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