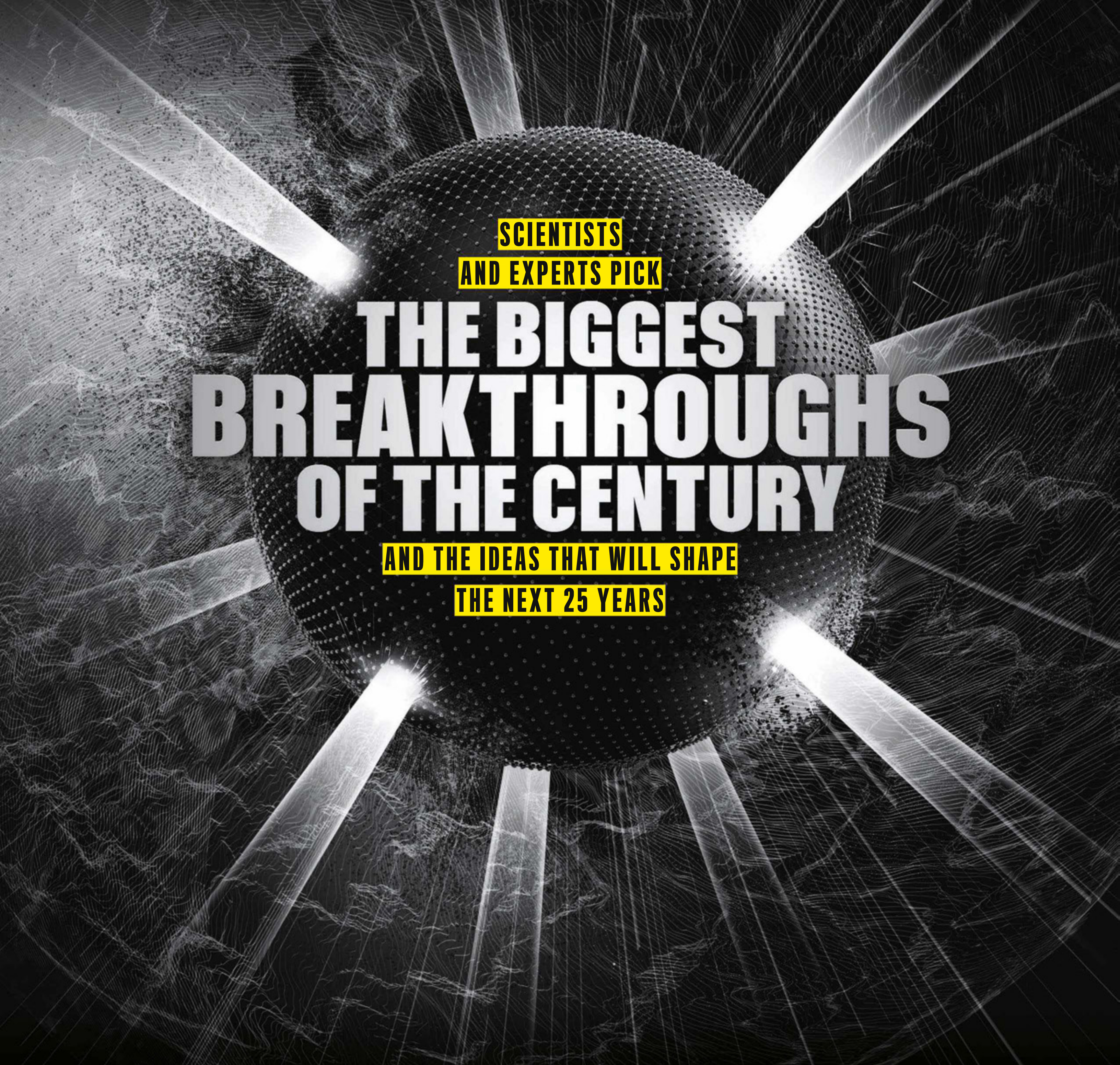
BBC HOW TO CHANGE YOUR PERSONALITY

Science Focus

Inside the
PENTAGON'S UFO FILES

How human activity is
CHANGING EARTH'S SPIN

Which makeup is
HARMING YOUR HEALTH?



SCIENTISTS AND EXPERTS PICK

THE BIGGEST BREAKTHROUGHS OF THE CENTURY

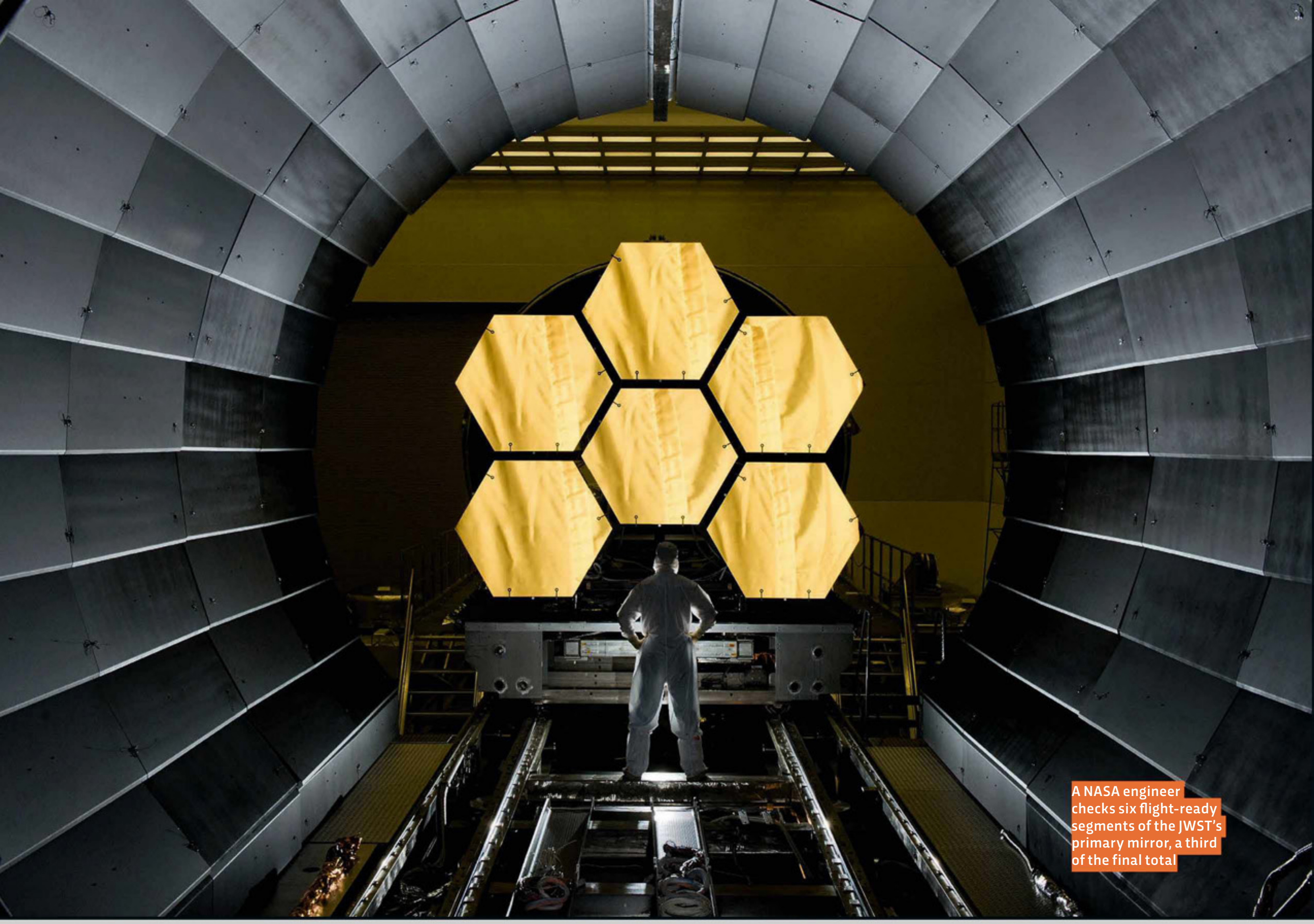
AND THE IDEAS THAT WILL SHAPE THE NEXT 25 YEARS

IN THIS ISSUE

Tech
The terrible ideas we wish inventors had kept to themselves

Sleep
How 'cognitive shuffling' can put your mind at ease

Psychology
Can you overcome your brain's biggest blind spot?



A NASA engineer checks six flight-ready segments of the JWST's primary mirror, a third of the final total

THE JAMES WEBB SPACE TELESCOPE

➥ **Pete Lawrence**

Astronomer and presenter of BBC Sky at Night

Launched aboard an Ariane-5 rocket on Christmas Day 2021, the James Webb Space Telescope (JWST) is nothing short of a technological marvel. Augmenting and improving on the role established by the Hubble Space Telescope, the JWST is designed for infrared astronomy in the wavelength range of 0.6-28.5 microns.

The JWST targets many important areas of astronomy and cosmology, from studying the first stars and initial galaxy formation, to spotting exoplanets and analysing their atmospheres.

A technologically and financially ambitious project, it hit many snags along the way to final deployment. The JWST's large primary mirror was too large to be carried inside the rocket's payload bay, for one. The problem was solved by designing the mirror so that it could fold up for transit and open like the petals of a flower at its destination.

That destination needed to be far from any bright radiation sources, such as Earth and the Moon, for JWST's extremely sensitive infrared detectors to work. Consequently, its base observation site is located 1.5 million kilometres from Earth, on the opposite side to the Sun. Fortunately, upon its arrival, JWST deployed without incident, which is just as well, because being so distant, there's little we could have done to fix any problems.

In December 2022, JWST discovered the most distant, and therefore earliest, galaxies ever observed. A galaxy survey project called JWST's Advanced Deep Extragalactic Survey looked at an area where Hubble had recorded 10,000 galaxies, and detected a mind-blowing 100,000 galaxies in the same patch of sky. It's not just unfathomably distant objects that have had the JWST treatment, though. Jupiter, Saturn, Uranus and Neptune have all come under JWST's scrutiny, and spectacular new details about each world have been revealed as a result.

As time goes on, JWST continues to break new ground and its observations are challenging existing theories about object evolution, posing many more questions along the way.

iPLAYER
Watch *BBC Sky at Night: Ancestral Skies* on BBC iPlayer now

EXOPLANETS

➥ **Lord Martin Rees**

Astronomer Royal, Emeritus Professor of Cosmology and Astrophysics, University of Cambridge

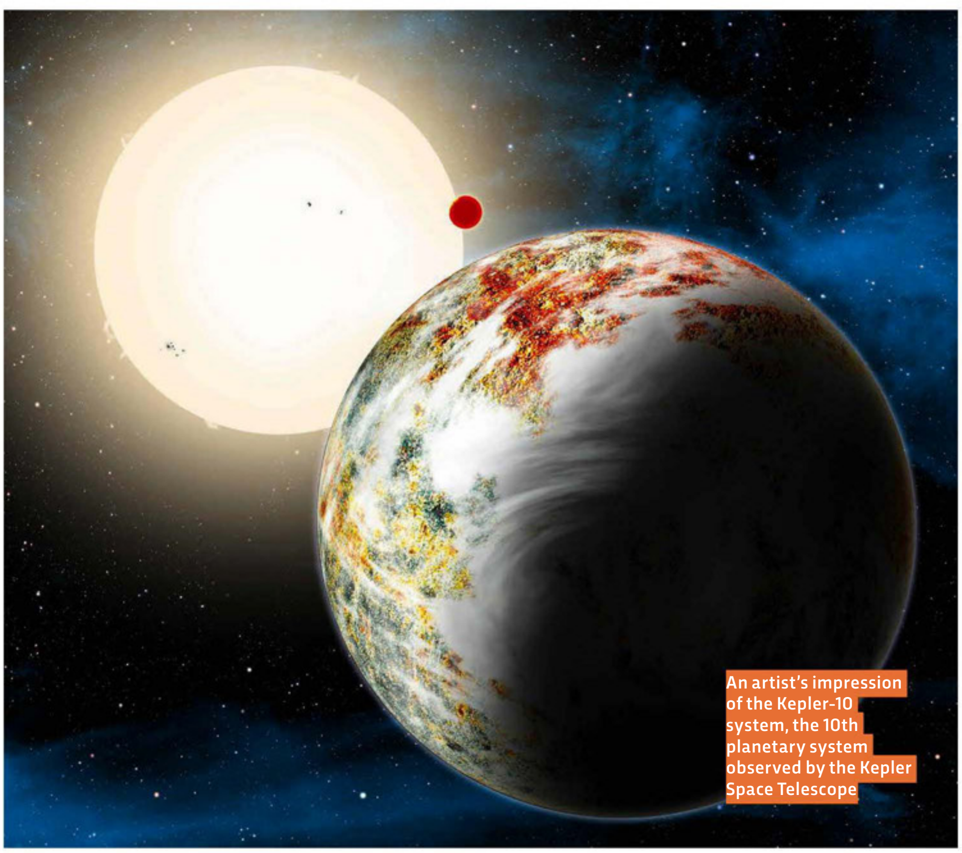
It makes the night sky far more interesting if we think of every star as being at the centre of a system of planets, like in our Solar System. Of special interest is the possibility that many of those planets are like Earth: the same size and at a distance to their parent star that allows water to exist. Could there be life on them?

Though they were officially discovered in about 1995, most of what we know about exoplanets has come in the last few years. We've now detected over 5,000 of them, mainly with the 'transit method.' This is where you don't actually detect any light from the planets, but the effects on the brightness of a parent star when a planet passes in front of it.

The most successful way we've carried out the transit method is by looking through the Kepler Space Telescope. Though the telescope has revealed a lot, it doesn't tell us about what the surfaces of these planets are like. For that, you've got to detect some light reflected from the planet. That's much harder and, so far, has only been done for really big planets, not Earth-sized ones. The challenge for the coming 25 years is going to be detecting the light from the Earth-like planets orbiting nearby stars.

The James Webb Space Telescope may do some of this, but a giant ground-based telescope – the Extremely Large Telescope – is being built by a consortium of European countries in Chile. Its mirror is 39m (128ft) across, so it could collect a lot more light from faint objects than the Webb telescope, which is 'only' 6.6m (21ft) across.

There's so much this new area of study could show us. I think if I were talking to a young person embarking on an astronomical career, I would advise focusing on exoplanets. The field is clearly going to be expanding and full of a high rate of discoveries in the coming decades.



An artist's impression of the Kepler-10 system, the 10th planetary system observed by the Kepler Space Telescope

NASA/JPL X2

...BUT ALSO GRAVITATIONAL WAVES

Gravitational waves are significant for two reasons. Firstly, they're an important physical phenomenon that tells us about the nature of gravity, confirming a further consequence of Einstein's General Theory of Relativity. Secondly, detecting them has been an amazing technical achievement.

The Laser Interferometer Gravitational-Wave Observatory (LIGO) was a huge technical challenge because the expected amplitude of these waves is very small and must be detected at a vast distance. The effect you're looking for is like the thickness of a hair at the distance of a nearby star. Quite amazing.

Many of us thought that LIGO wouldn't find anything. Or, if it did, events would be fantastically rare, the instruments only being sensitive enough to detect collisions once a century or so. But LIGO has been more successful than any of us expected, detecting a pair of black holes about 50 times the mass of the Sun crashing together within a short time of being switched on. It was amazingly exciting and it's now detecting about one or two such events a week. It's worth celebrating for the hundreds of people who were involved with the set-up of these instruments.

The gravitational waves that LIGO observes are a short pulse of radiation of about 100 cycles per second, which is roughly the orbital period of two 50 solar-mass black holes when they merge together. But there are far bigger black holes in the centres of galaxies with masses millions of times higher than LIGO can detect. Mergers of these are much rarer, but can be detectable out to greater distances. The radiation produced, however, is at a much lower frequency.

This has to be detected by instruments that, instead of having mirrors a few kilometres apart, has mirrors a few million kilometres apart.

The ESA-led Laser Interferometer Space Antenna (LISA) is planned to launch within the next 10 years. It should detect the rare mega-cataclysms when galaxies merge and the supermassive black holes in their centres collide.

NASA'S CURIOSITY ROVER

➡ Dr Stuart Clark

Astronomer, science journalist and author
Author of *The Search for Earth's Twin*

In the kind of PR masterpiece we've come to expect from NASA, they didn't play down the difficulty of landing their Curiosity rover on Mars. Instead, they called it their "seven minutes of terror" and explained that in those 420 seconds, it had to go from a speed of close to 21,000km/h (13,000mph) to zero in order to land safely on the planet's surface.

When they achieved that, the mission's place in history was all but secured, especially since they had used an innovative 'sky crane' landing system, which guided the rover to a much more precise landing than any previous planetary mission.

Then came the science. Since 2012, Curiosity has made ground-breaking discoveries on Mars that help paint a more detailed picture of the planet's past environment, its previous habitability and even its present ability to support life.

It found chemicals and minerals in Gale Crater that indicated the past presence of liquid water, clearly a pre-requisite for life. It then found various organic molecules that serve as the building blocks for life and can be used as food by microbial organisms. While they don't prove that life existed on the planet, they at least show that the correct molecules were present.

But perhaps the rover's most tantalising discovery has been the detection of a seasonal release of methane from beneath the planet's surface. Every Martian summer, the gas has welled up from Gale Crater. While water-rock interactions could be responsible, scientists can't rule out biological activity. The next generation of Mars rovers, such as ESA's Rosalind Franklin will carry subsurface drills to investigate further.

Put together, Curiosity's longevity and its extraordinary scientific results significantly enhance our understanding of Mars, paving the way for future human missions and the search for extraterrestrial life. To seal its place in 21st-century culture, Curiosity also took a selfie (see p6).

...BUT ALSO NASA'S DART MISSION

This entry made one of the biggest impacts both figuratively and literally. On 26 September 2022, NASA's Double Asteroid Redirection Test (DART) mission smashed into the asteroid Dimorphos. The collision destroyed the spacecraft completely and shifted the orbit of the asteroid – all on purpose.

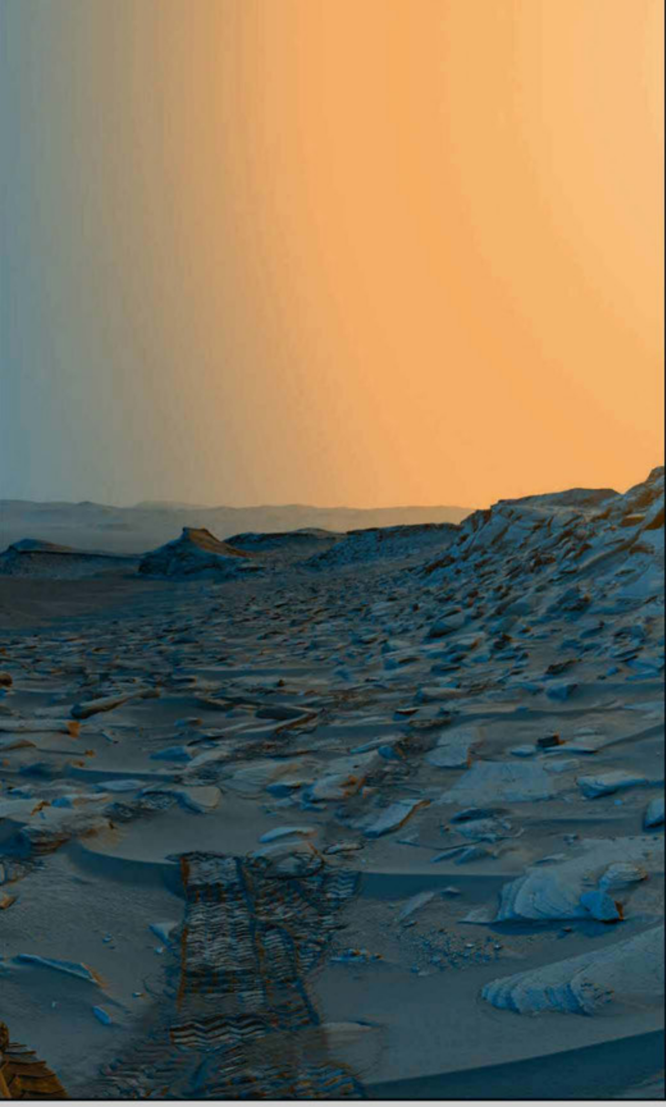
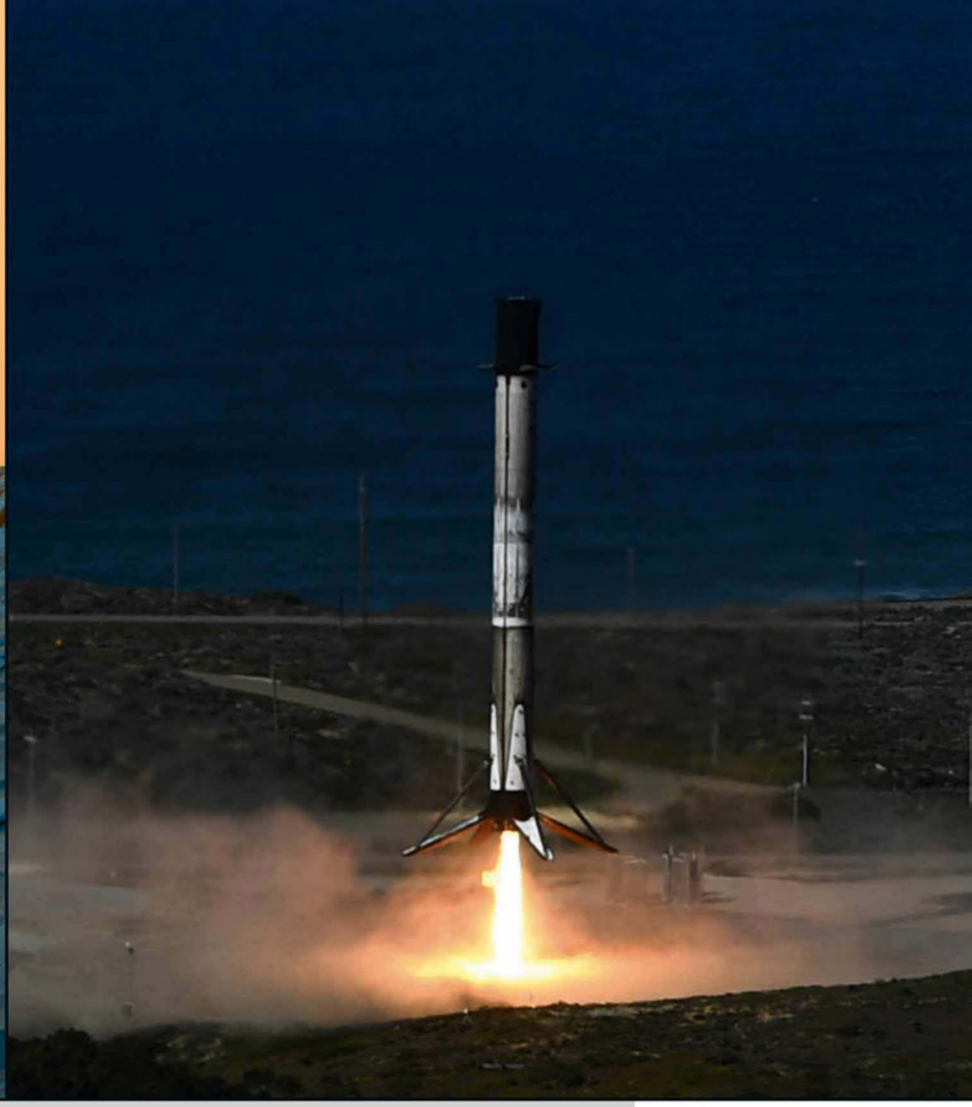
DART was a ground-breaking test of our ability to alter the orbit of a small asteroid, should we detect one on a collision course with Earth – and it succeeded spectacularly. For the first time in history, humankind changed the trajectory of a celestial object and in so doing, proved a method for averting a natural disaster.

The asteroid in question was the smaller component of a double asteroid. The larger of the two is called Didymos. Originally discovered in 1996, Didymos is a chunk of rock with dimensions of roughly 851 x 848 x 620m (2,792 x 2,782 x 2,034ft). Its companion, eventually named Dimorphos, was confirmed in 2003. With a dimension of just 177 x 174 x 116m (580 x 570 x 38ft), it was the perfect test subject for the mission.

Being locked into orbit around Didymos meant that the amount by which it had been moved would

ABOVE Curiosity looks back to capture an image of the Marker Band Valley, where it found signs of an ancient lake

ABOVE RIGHT SpaceX's reusable rockets are bringing down the costs associated with launching people and tech into space

show up in a change of the time it took to circle the larger asteroid. Before the impact, Dimorphos took just under 12 hours to orbit Didymos. After, the impact, this time had decreased by just over half an hour, showcasing a viable method for deflecting potentially hazardous asteroids from Earth.

DART's accomplishments extend beyond planetary defence, though. The mission has provided critical data on asteroid composition and impact mechanics, not to mention celestial navigation by hitting a 100m-wide (328ft) target at speeds of kilometres per second while having travelled millions of kilometres from Earth.

...AND FINALLY, SPACEX'S REUSABLE ROCKETS

For decades, the biggest roadblock to the exploration and utilisation of space has been the cost of launching objects and people into space. The enormous Saturn V, used to transport astronauts to the Moon in the 1960s and 1970s, achieved a cost of around $5,000 (about £3,950) per kilogram lofted into space, but since the 1990s, smaller disposable rockets have only managed to achieve costs of around $10,000 (approx £7.900) per kilogram.

SpaceX has blown that figure out of the water and is currently in the process of revolutionising spaceflight. The game changer was the introduction of the Falcon 9 reusable rocket in 2015. With a first stage booster that could return to Earth and land upright, the cost of launching people, supplies and technology into space started to tumble.

The reusability enabled more frequent launches, again expanding the range of commercial and scientific opportunities that space could offer. For example, it has made SpaceX's Starlink project viable. This endeavour aims to fly thousands of smaller satellites in low-Earth orbit to provide unbreakable global internet coverage.

With Falcon 9, the cost of reaching orbit is around $2,000 (£1,500) per kilogram. The giant Starship rocket that SpaceX is now test-flying is estimated to slash the cost to an extraordinary $200 (£158) per kilogram.

SpaceX's achievements have reshaped the global aerospace industry and mark a pivotal step toward humankind permanently extending its presence throughout the Solar System. But such progress doesn't come without a cost.

The ability to launch so much into space threatens to dramatically increase the amount of space debris, which imperils working satellites and interferes with astronomical observations of the night sky. Hence the innovation that these rockets allow must be understood in relation to the 'environmental damage' that it could bring to Earth's orbits and the night sky in general.

Nevertheless, SpaceX has brought us to a true watershed, not just in science but human history. **SF**

NASA/JPL, GETTY IMAGES