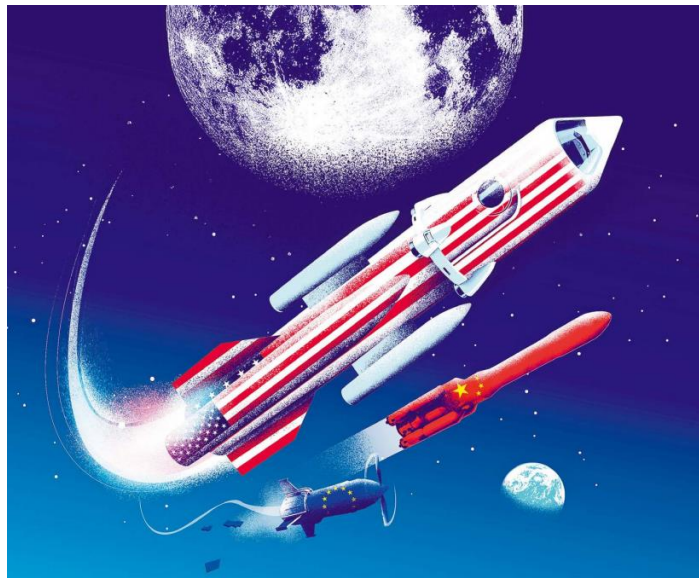


Space Travel

Reaching for the Stars

Long considered an expensive dream, the race to space is now becoming reality. A new billion-dollar market is emerging - fueled by the U.S. government as well as start-ups and billionaires from America. Their visions have the potential to change our world.



Pittsburgh and its homegrown space robotics company, Astrobotic – an anchor for an emerging space cluster opportunity in the region – are featured in this article about a new era of commercial and private space travel. See page 3.

**Felix Holtermann, Thomas Jahn. Pittsburgh, New York, Düsseldorf
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Only a few night owls witnessed the spectacle shortly before midnight. Last Monday, a Falcon 9 rocket from SpaceX thundered into the sky at ten times the speed of sound and loaded with 15 satellites. It released the satellites into Earth orbit. Less than ten minutes later, the main stage landed back on a floating platform off the California coast.

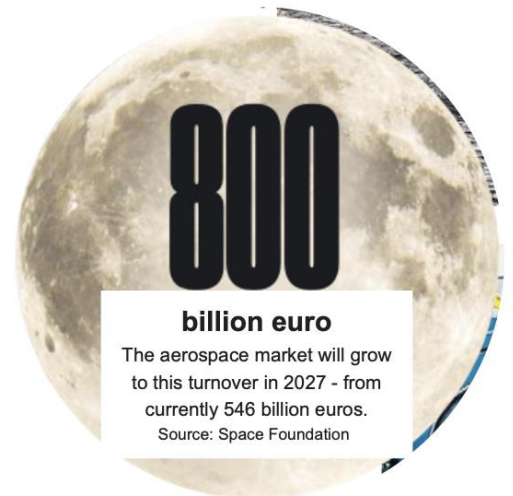
This rocket is called "Of Course I Love You" and runs fully automated. After landing, a robot anchors the red-hot, towering booster. A tugboat brings the platform back to the Port of Long Beach. There, the main stage is unloaded, overhauled, and soon lifts off again.

The landing platform is often underway, just like its sister ships on the U.S. East Coast named "Just Read The Instruction" and "As Shortfall of Gravitas." The names are inside jokes from SpaceX founder Elon Musk and come from spaceships written by science fiction author Iain Banks.

Meanwhile, the process under California's skies no longer have anything to do with fiction. The rockets are launched almost every day and are considered technical masterpieces. Earlier rockets were disposable machines whose boosters burned up after launch. The Falcon 9s are largely reusable. This makes space travel much cheaper - and cements America's technological lead.

Musk's vision is becoming reality - day by day. SpaceX has already launched nearly 5,000 satellites into space for its Starlink satellite network, and it could launch as many as 42,000. "You want to wake up in the morning and believe that the future is going to be great," Musk says. For him, Earth orbit is just an interim goal. Humanity needs to go out to the stars and become an "interplanetary civilization," he dreams. Many Americans are dreaming along with him.

The last time humans were on the moon was in 1972, and then interest in space waned: Mother Earth, it seemed, had other problems. But ever since nations like China and India started reaching for the stars, the U.S. has been making a comeback. In contrast to the Cold War, space travel is now less about prestige and more about tangible economic interests. According to estimates by the Space Foundation, the space industry will grow from the current \$546 billion to \$800 billion over the next five years. The major bank Goldman Sachs and the consulting firm McKinsey even see a trillion-dollar market in the coming decade.



"In the future, space will become an economic zone where completely new economic dimensions will open up, both on the moon and in Earth orbits," says Josef Aschbacher, head of the European space agency Esa, in an interview with Handelsblatt. He knows Europe is flying behind the developments. Aschbacher calls for more competition - and a greater role for startups. The role model is clear: America.

There, startups, the state, and billionaires have powerfully set a flywheel in motion that will change the sky - and all our lives. Handelsblatt spoke with several dozen entrepreneurs, experts and researchers. Seven visions emerge that are driving the new space economy.

Vision 1: A start-up in space

The man who helped spark the new race to space lives in rural Oklahoma. Jim Bridenstine once spied on terrorists as a reconnaissance pilot in Afghanistan, sat in the U.S. Congress, and became head of the space agency Nasa in 2017. Bridenstine found an untenable state of affairs there: After the space shuttle program ended in 2011, U.S. astronauts could only be launched into space on Russian Soyuz rockets. "That was a problem,"



Bridenstine recalled in an interview with Handelsblatt. "Our goal as Americans should be to not be dependent on partners." But Nasa's own developments had been severely delayed. That was the core problem: "Governments have a tendency to preserve the status quo," says the 48-year-old. After all, they have to think about their constituents, about jobs, and so they mainly continue to write existing programs.

An apt description of the state of the European space program today. According to space analyst Phil Brunkard, it's strikingly similar to the space shuttle program that was discontinued 12 years ago: "That was highly political. There were manufacturers all over America building parts of the shuttle. Orders went to whoever had the best political contacts. Everything was expensive and cumbersome."

The new Nasa chief, Bridenstine, accelerated collaboration with startups and private companies. "In contrast, the private sector has a strong incentive to do things faster, better and cheaper," Bridenstine says. Rather than the government buying, owning and operating hardware, he says, it should order services from private companies to bring "as much innovation as possible to the space ecosystem."

With success: since 2020, SpaceX's "Dragon 2" has been the only U.S. spacecraft flying humans to the International Space Station (ISS). Brunkard, a space analyst, also believes that connecting government and startups is crucial. The Europeans should emulate it. The most important space player today is SpaceX, Brunkard says. "By reusing rockets, SpaceX has solved the cost problem."

Yet a decade ago, the company was known only to absolute experts. In the meantime, he says, the sheer size of the company has massively diminished its importance. Take Boeing, for example: In 2014, Nasa commissioned the aerospace company to develop the "Starliner" manned spacecraft - for a fixed price of five billion dollars. Today, the costs are 1.5 billion dollars above plan. At the same time, Boeing had to repeatedly postpone the first manned launch due to technical problems.

Vision 2: Return to the moon

Another push from Bridenstine: In 2017, he launched the Artemis program. This is intended to bring people back to the moon and "create an infrastructure there from which commercial companies can profit," says Bridenstine. The Earth satellite would thus become a gateway to space.

If John Thornton, head of Astrobotic, has his way, the return to the moon can't happen fast enough. "We know there is water on the moon." You can't just drink it. Water can be used to produce oxygen for breathing and, more importantly, rocket fuel. "Water on the moon is like oil on Earth."

Astrobotic is from Pittsburgh, the old steel town. There are no more steaming smokestacks. The last steel mill closed in 1998, and the city was on the verge of becoming a second Detroit. Now, visitors to Pittsburgh experience an up-and-coming metropolis. This is made possible by the tech sector that has settled around Carnegie Mellon University and the University of Pittsburgh. One important component: space start-ups.

Astrobotic is also a university spin-off. With the start of the Artemis program, the company has grown rapidly in the past five years, from 20 to 220 employees, Thornton says. Nasa has already awarded Astrobotic \$500 million in contracts.

The first flight is scheduled for December: The "Vulcan," an advanced Atlas V rocket, is to take Astrobotic's lander "Peregrine" to the moon. This will cost around \$100 million, Thornton reveals, "a historically low price." Then in 2024, the second, much larger shuttle is scheduled to land, called "Griffin." This contains the 450-kilogram Nasa rover "Viper," which is to drill for water. That should make the first lunar colonies possible, Thornton believes: "The moon will become a gas station."

Astrobotic is focusing on unmanned flights - and hopes to do good business: the market for lunar transportation alone is expected to be worth around \$79 billion in 2040, according to a PwC study.

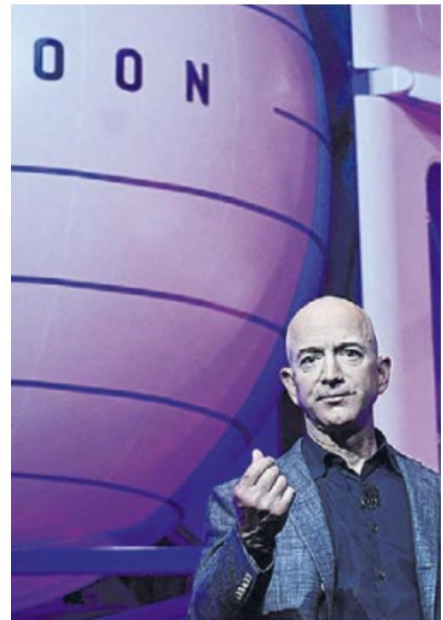
Nasa is now planning the first manned Artemis flight for 2026, when humans will set foot on another celestial body for the first time since 1972. Private companies such as SpaceX, Lockheed Martin and Blue Origin, which are to build parts of the necessary capacities, will again play an important role. There are still many challenges, he said, aside from the extreme temperatures and lack of atmosphere. "Lunar dust is razor sharp," says space analyst Brunkard, "if it gets on your hand or in your lungs, it's deadly."

Vision 3: Orbital Stations

Almost every kid in America knows about the ISS: Even "Sesame Street" has switched to the outpost in space. Soon, the stars of the series, Elmo and company, will have to choose a new destination: After 24 years, the days of the ISS are numbered. Besides the ISS, only the Chinese space station "Tiangong" ("Heavenly Palace") is currently orbiting the Earth.

But a replacement has been found. By the end of the decade, six stations could already be orbiting the Earth, plus one more orbiting the moon: the "Lunar Gateway," planned by Nasa, and Esa, planned by the Japanese and Canadians, whose core module is scheduled for launch in November 2024.

The reason for the activity: not only scientific experiments can be carried out in weightlessness. The first business models are also based on microgravity. Government stations could soon be in the minority. More and more companies are planning their own outposts. Supported by Nasa is "Orbital Reef," which could be operational by 2030. Behind it are Blue Origin, the space company of Amazon founder Jeff Bezos, Sierra Space from Denver, and Boeing. The "Starlab Space Station" of the start-up Nanoracks and Airbus could be launched as early as 2028, also with the help of Nasa funds. Their goal: "Advance research and promote industrial activities in microgravity."



Blue Origin, Jeff Bezos: The Amazon founder's start-up is building the Blue Moon moon landing rocket for NASA, which could be used in 2029 at the earliest.

They are considered a big growth market. "Microgravity can help with many production processes," says Christine Kretz, former head of the partnership program at the National Lab in Florida, which is responsible for the U.S. portion of the ISS. One example: printing ultra-thin membranes. According to Kretz, by 2022, "more than \$260 million in private sector investment has flowed to teams that have used the ISS National Lab." And that was just the first test run.

Metals could be made in zero gravity, without debris, vibration or convection, that are stronger and more durable. Pharmaceutical companies could grow new kinds of cell structures to find drugs faster. Chip companies could squeeze more and more transistors onto an ever-smaller surface area - after all, there are no interfering gas molecules in a vacuum. The result would be tiny superchips.

Space travel itself will also promote production in space. After all, every kilogram that has to be brought up from Earth remains expensive, despite all the advances in rocket technology. 3D printers could be used to manufacture devices in space. Mitsubishi Electric has already unveiled a technique for printing satellite antennas in space, based on resin and solar energy.

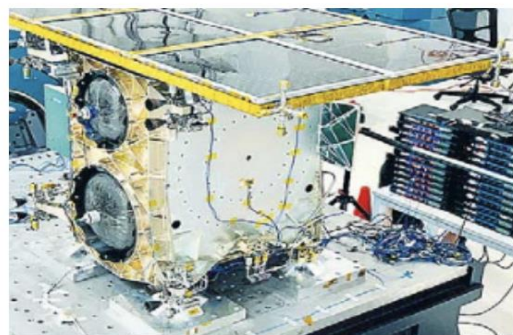
One day, spacecrafts will be built directly in space and refueled on the moon, which should significantly reduce launch costs for ambitious missions. Yet it is clear that the new space factories will hardly be populated by humans - too risky and too expensive. Most of the work will be done fully automatically - by robots.

Vision 4: Space robots

Jeremy Grimmatt looks almost lovingly at the shoebox-sized device next to him. It is a model of "Laura," the first space robot from his New Hampshire-based startup Rogue Space. "Laura" is designed to survey malfunctioning satellites and is equipped with sensors to do so, including spectral cameras, lidar, and radar sensors. Rogue Space's second spacecraft no longer fits on a desk: "Fred" is two meters tall, or more than 17 meters with solar panels extended, and has four robotic arms.

"Take a satellite that's not working properly," Grimmatt explains. "Laura can visually inspect it. Fred can grab it and fix it," deploying stuck solar panels, for example. And if none of that does any good? "Then Fred can pull the satellite into a lower orbit, where it burns up." The first mission is scheduled to launch in October 2023.

Rogue Space has already secured a major customer: the U.S. Space Force. In total, the U.S. government has already transferred three million dollars to Rogue Space as part of its development funding. The use of their robots should make human repair missions in space unnecessary.



Impulse Space Mira: The start-up of former SpaceX rocket boss Tom Mueller wants to build a cargo service for space.

Tom Mueller, a member of SpaceX's founding team, also believes in robots. His start-up, Impulse Space Propulsion, has developed "Mira." It is a kind of fully automated "space tug" - a vehicle that covers the proverbial last mile in space. Once "Mira" reaches orbit with a rocket, it penetrates various orbits there and drops off individual satellites.

If Mueller has his way, a glorious future lies ahead for his space taxi service: "We have achieved cost-effective access to space through reusable rockets. In the future, there will be a lot of things to transport in space. And we want to be the company that gets them there."

The fact that robots have been developed primarily to take care of satellites so far is no coincidence: the business with artificial Earth satellites is already flourishing.

Vision 5: Satellite networks

In the past, a satellite launch was something special. Onlookers camped out at the Cape Canaveral spaceport, and TV broadcasted live. Today, a satellite launch is an everyday occurrence, as the example of SpaceX shows. According to the consultancy Euroconsult, around 2,500 satellites are launched into the sky each year, 40 times more than two decades ago. In their latest report, BCG analysts predict a new "record pace": between 2023 and 2030, "at least 24,000" if not 40,000 satellites would be launched. Setting the pace here, too: the United States.

The reason for the many launches are the novel satellite constellations "Starlink" from SpaceX and "Kuiper" from Amazon, which flood the orbit with thousands and thousands of satellites. But China and the EU are also building new constellations with "Guowang" and "Iris2." These networks are orbiting in the lower earth orbit, the so-called LEO ("Low Earth Orbit").

Whereas satellites used to cost up to a billion dollars apiece, LEO satellites can be had for \$100,000 or less. Their use provides "new data that we get from AI-powered low-Earth orbit satellite imagery of our planet," says analyst Brunkard. They also provide Internet to the world's most remote places: Planes, ships, mines. Telecom companies in Australia or New Zealand buy capacity from "Starlink" to supply rural areas, thus saving themselves the expensive construction of lines.

According to the U.S. analysis firm Grand View Research, the market for satellite Internet will grow by almost 12 percent annually to around 20 billion dollars by 2030. Until now, users have needed a receiver. But in the fall, Apple introduced the first iPhone that can connect directly to a satellite in emergencies.

There are many niche applications for this. Black Sky is a subsidiary of industry pioneer Spaceflight Industries, which operates twelve of its own satellites and is launching a new generation with unprecedented resolution into space for the U.S. Army. They are needed in the Ukraine war, for example. Satellite data could help shorten or mitigate armed conflicts, Black Sky CEO Brian O'Toole told Handelsblatt. Customers would be the first to know about new developments - and could act all the sooner. "I'm not so confident to say we can prevent wars. But creating transparency, insight and awareness can make a difference."

The skies above are changing. Astronomers are already complaining about "Starlink" satellites disrupting long-term images. "It's going to become like a highway at rush hour in a snowstorm, where everyone is speeding," fears astrophysicist Jonathan McDowell of Harvard University. In ten years, he says, there will be up to 100,000 satellites - by which time the upper limit will have been reached, and the probability of collisions will be too high.

Will orbit become a junkyard? Not necessarily: LEO satellites fall back into the atmosphere over time. Only at altitudes of 1,000 kilometers and above does junk whiz around the Earth practically indefinitely. Then only robot cleaning crews can help.

Satellites or robots: But nothing inspires the dreams of space fans like the prospect of new manned flights.

Vision 6: Space tourists

Dennis Tito was the first space tourist. But his 2001 trip to the ISS wasn't enough for him. Together with his wife Akiko Tito, the 82-year-old bought two seats for a lunar orbit from SpaceX. The launch date has not yet been set, nor has the ticket price been announced. For his first trip, the former Wall Street executive paid more than \$20 million; a flight to the ISS costs \$55 million at SpaceX.

Space travel costs a lot of money. So it makes sense to target a particularly affluent clientele: super-rich space tourists. Currently, two other U.S. companies besides SpaceX are able to fly paying passengers into space: Blue Origin, which travels to near-Earth, suborbital space, and Virgin Galactic, owned by billionaire Richard Branson.

Estimates put the revenue potential of space tourism at three to twelve billion dollars in 2030. But the business is still small and risky. After aborting an unmanned test flight in the fall of 2022, Blue Origin had to pause its program.

Instead, Virgin Galactic's first successful commercial flight made headlines at the end of June. The demand is there. Virgin Galactic has sold around 800 tickets since sales began ten years ago, initially at a cost of \$200,000 and now \$450,000. Soon, experts say, prices should fall, due to more competition and cheaper rocket launches.

There will also be new forms of space tourism. How realistic Space Development's plans are remains to be seen. The start-up from the U.S. wants to open two space hotels in a few years, the "Pioneer" and "Voyager" stations. Both look like gigantic wheels with four spokes with space for 28 and 400 guests. Partners are lacking so far.

Jeff Bezos' plans are more serious with the "Orbital Reef" station. It is to accommodate not only researchers, but also tourists. Bezos has dreamed of space all his life. In 2021, he flew into space himself with his "New Shephard" rocket. In his high school graduation speech, the "Star Trek" fan spoke of his dream to colonize Mars.

Vision 7: Mars colonization

The long-term goal is the "final frontier" that has characterized the TV series "Star Trek": the colonization of alien worlds. Nasa does not yet give a date for a Mars mission. There are too many unknowns in the equation. Ex-Nasa chief Bridenstine expects settlements on Mars before the end of this century. But cautions, "On Mars, gravity is only one-third." This weakens the immune system, bone mass is reduced, and at the same time cranial pressure increases, which can lead to hallucinations.



Nevertheless, one person remains an optimist: Elon Musk. He wants to go to Mars as soon as possible with "Starship. According to his vision, Mars could one day be made life-friendly through "terraforming," which would give humanity a second home, a kind of back-up to Earth. Musk is convinced that the first manned mission to Mars could start in 2029.

All science fiction? When President John F. Kennedy announced in 1962 that he would send a man to the moon by 1970, 58 percent of Americans didn't believe it would happen, according to a Gallup poll.

On July 20, 1969, Neil Armstrong walked on the moon.