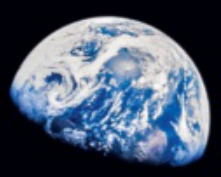
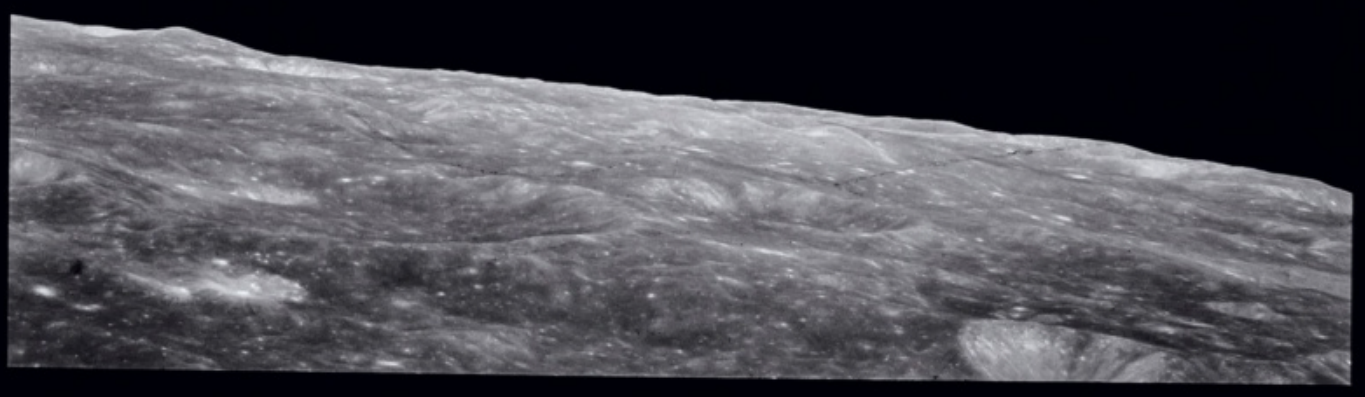
07.2019

NATIONAL GEOGRAPHIC

The Moon and Beyond

A NEW ERA OF SPACE TRAVEL IS HERE





"The moon is the proving ground; Mars is the horizon goal."

JIM BRIDENSTINE
NASA ADMINISTRATOR


APOLLO 11
BUZZ
ALDRIN

THE FIRST WATCH WORN ON THE MOON

On the 50th anniversary of the first lunar landing, OMEGA is reflecting on the golden moments that defined that iconic day. Nobody remembers it quite like Buzz Aldrin, who wore an OMEGA Speedmaster when he stepped onto the dusty surface and left his footprints in history.

#MOONWATCH

OMEGA

Exclusively at OMEGA Flagship Boutiques and selected retailers worldwide

COUNTDOWN TO A NEW ERA

IN SPACE

Astronaut Harrison Schmitt bounds toward the lunar rover during the Apollo 17 mission in December 1972, the last time humans set foot on the moon.

EDITOR'S NOTE: This image is part of a panorama that NASA created from 18 photos. To show how the lunar landscape looked to the astronauts, NASA removed lens flare from sunlight by blacking out the sky.

NASA/LUNAR AND PLANETARY INSTITUTE

Fifty years ago this month, astronauts walked on the moon for the first time. Apollo 11's success—just 66 years after the Wright brothers' first flight—showcased humankind's moxie and ingenuity. Now the moon is in our sights again, for a generation that will test where science meets profit.

00:0

:05	:04	:03
PIONEERS	GETTING THERE	WHERE WE WENT

ABOVE: Documenting the small steps of Apollo 11 astronauts, Buzz Aldrin took these photographs of his boot print.

T MINUS

0:06

:02	:01	:00
WHAT WE TOOK	IN POP CULTURE	WHAT'S NEXT

T MINUS

PIONEERS

LEFT: John Glenn wore this space suit, made with 27 zippers to ensure a tight fit, when he orbited Earth on February 20, 1962.

ANIMALS WERE OUR FIRST SPACE TRAVELERS, CLEARING THE WAY FOR ASTRONAUTS WHO BECAME FAMOUS—AND FOR LESSER KNOWN HEROES.

BY NADIA DRAKE

PHOTOGRAPHS BY DAN WINTERS

Yuri Gagarin, Alan Shepard, John Glenn, Neil Armstrong—the first wave of space travelers—were military-trained astronauts thought to have the "right stuff" for risky missions.

But early spaceflight wasn't the exclusive province of men—or even humans. Fruit flies, monkeys, mice, dogs, rabbits, and rats flew into space before humans.

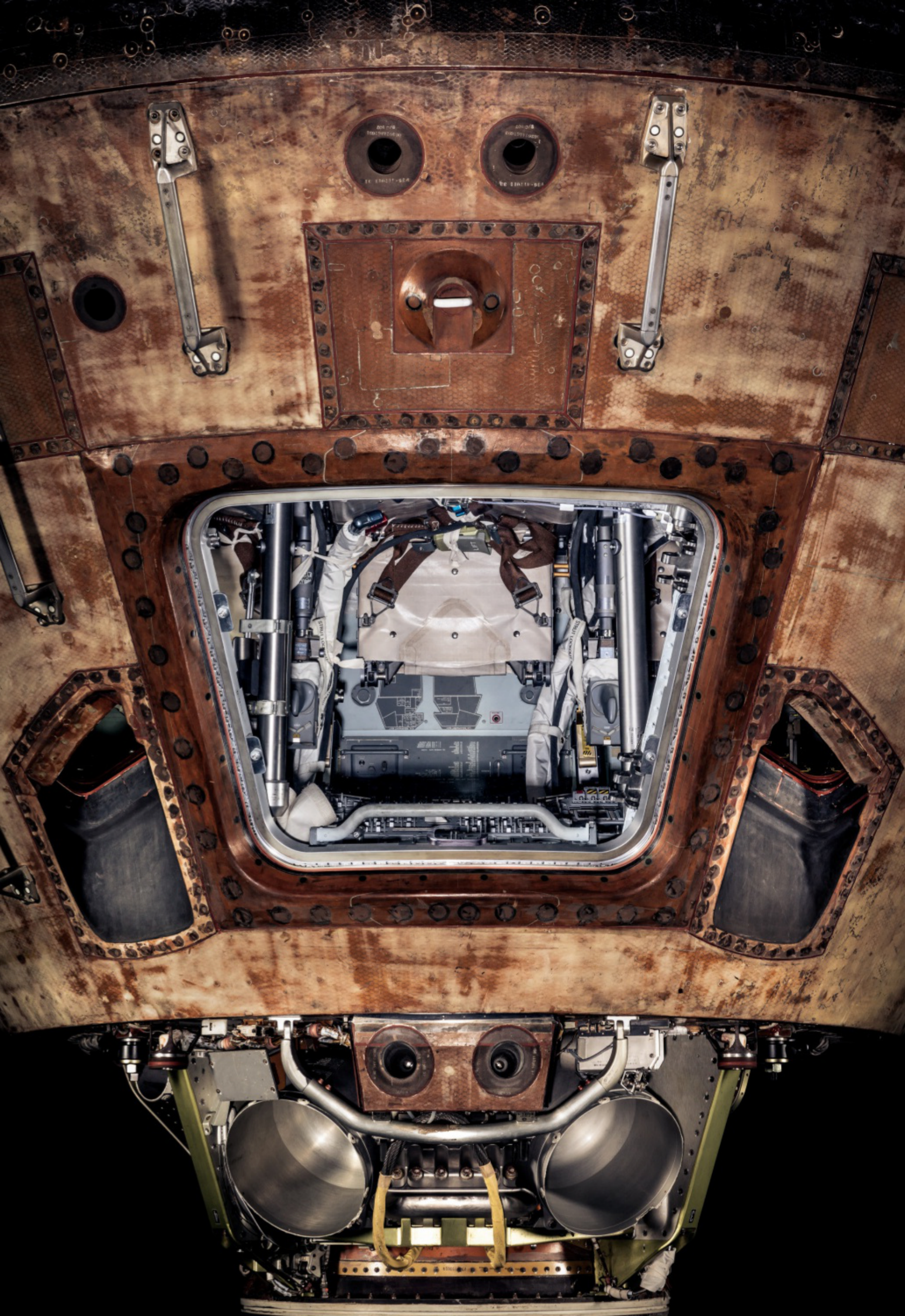
More than three years before Gagarin became the first human in space with his April 1961 journey around Earth, the Soviets famously—or perhaps infamously—sent up a stray dog. Laika was the first animal to orbit Earth but died during her flight. The United States launched a chimpanzee named Ham into space. Happily, he survived, clearing the way for Shepard to became the first American in space in May 1961.

Despite discrimination, women were also pioneers. Some, such as mathematician Katherine Johnson—who hand-calculated the details of the trajectory of the flight that would make Glenn the first American to orbit the Earth in 1962—stayed behind the scenes. Valentina Tereshkova, an early cosmonaut, became the first woman in orbit in 1963. It wasn't until two decades later that Sally Ride flew on the space shuttle *Challenger* to become the first American woman to reach space.

TOP
Sputnik's launch on October 4, 1957, was covered on television, a relatively new and increasingly popular medium. The Soviet Union's surprise success at putting the first human-made object in space shocked the U.S. and triggered the superpower space race.
PHOTO ILLUSTRATION

ABOVE
Strelka shot into space in a Soviet craft on August 19, 1960, along with another dog, Belka; a rabbit; 40 mice; two rats; flies; and some plants and fungi. The menagerie made it back to Earth. The preserved dogs, hailed as heroes, are displayed in a Moscow museum.
MUSEUM OF COSMONAUTICS

RIGHT
The Apollo 11 crew, including the first astronauts to land on the moon, were carried into space on July 16, 1969, in this command module, the *Columbia*. The three men returned to Earth in the capsule, which splashed down southwest of Hawaii.
MUSEUM OF FLIGHT, SEATTLE



T MINUS

GETTING THERE

LEFT: Using old but still reliable technology, Russia launches a Soyuz rocket in March from its Baikonur Cosmodrome in Kazakhstan.

EARLY ROCKETEERS FIGURED THAT A MULTISTAGE LAUNCHER COULD PROPEL HUMANS TO THE MOON. THE SATURN V DID THAT—AND SET THE STAGE FOR THE FUTURE.

A bespectacled, bearded Russian recluse fond of science fiction, Konstantin Tsiolkovsky believed humanity's destiny lay among the stars. By the early 1900s, he had worked out the equation for humans to slip beyond Earth's gravitational pull. He also imagined how moon-bound rockets would work: using a mix of liquid propellants and igniting multiple stages.

Independently, Hermann Oberth and Robert Goddard reached similar conclusions. By 1926, Goddard, an American, had built and launched the first liquid-fueled rocket. About that time, Oberth, who lived in Germany, determined multiple stages are crucial for long journeys.

Four decades later, the trio's ideas roared to life in the enormous Saturn V rockets that thrust Apollo crews into space. Measuring 363 feet tall and fueled by liquid hydrogen, liquid oxygen, and kerosene, the Saturn V was the most powerful rocket ever built. Engineered by Wernher von Braun—a Nazi Germany rocket scientist who relocated much of his team to work for the U.S. after World War II—the Saturn V had three stages that fired in sequence. Rocketry is still governed by Tsiolkovsky's equation. But no rocket has yet eclipsed the Saturn V, which propelled humans closer to the stars than ever before.

FAR RIGHT

Five bell-shaped engines powered the initial stage of the Saturn V rocket, which shot most of the Apollo missions beyond Earth's orbit and eventually carried astronauts to the moon. Together the five engines generated as much energy as 85 Hoover dams.

NASA KENNEDY SPACE CENTER VISITOR COMPLEX

1950

1955

1960

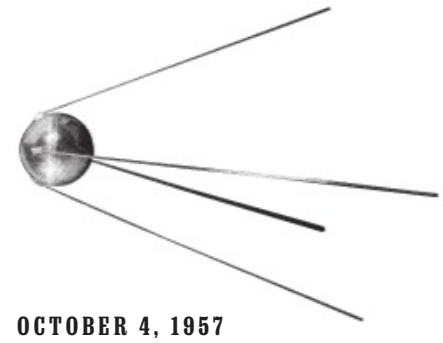
1965

1970

1975

RUSSIAN MILESTONES

JULY 22, 1951
Soviet Union begins suborbital flights with dogs as passengers.



OCTOBER 4, 1957
The Sputnik satellite is the first human-made object to orbit Earth.

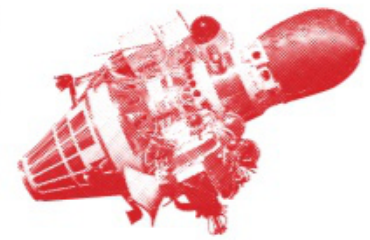
NOVEMBER 3, 1957
Sputnik 2 carries the first animal, a dog named Laika, into Earth orbit.

APRIL 12, 1961
Yuri Gagarin flies in Vostok 1, becoming the first human to reach space and orbit Earth.

JUNE 16, 1963
Vostok 6 is launched with Valentina Tereshkova, the first woman to reach space.

MARCH 18, 1965
Alexei Leonov conducts the first space walk.

FEBRUARY 3, 1966
Luna 9, an uncrewed spacecraft, achieves the first soft landing on the moon.



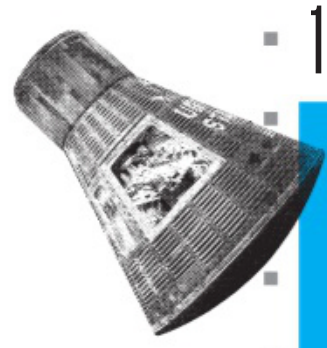
JULY 15, 1975
The Apollo-Soyuz Test Project becomes the first international partnership in space, between the U.S. and Soviet Union.

U.S. MILESTONES

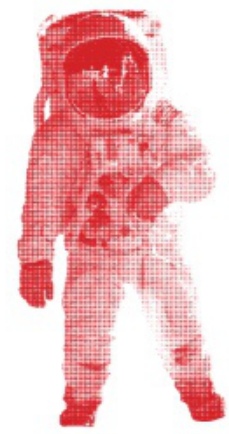
JANUARY 31, 1958
Explorer 1 becomes the first U.S. satellite to reach space.

MAY 5, 1961
Freedom 7 is launched with Alan Shepard, the first American to make a suborbital flight.

FEBRUARY 20, 1962
John Glenn becomes the first American to orbit Earth, piloting *Friendship 7*.



JULY 20, 1969
Apollo 11's Neil Armstrong and Buzz Aldrin are the first to walk on the moon.



PHOTOENGRAVINGS: SOVFOTO/UNIVERSAL IMAGES GROUP/SHUTTERSTOCK (SPUTNIK); OMIKRON/SCIENCE SOURCE/GETTY IMAGES (EXPLORER); GENE J. PUSKAR, AP/SHUTTERSTOCK (CAPSULE); SPUTNIK/SCIENCE PHOTO LIBRARY (LUNA 9); NASA (ALDRIN)

SOVIETS IN SPACE

The Soviets' Vostok ("East" in Russian) launched the first human, Yuri Gagarin, into one orbit around Earth.

The R7 was first used for space-flight to launch Sputnik. A third stage was added later; modified versions are still in use.

Spacecraft
VOSTOK 1
1961

Launch vehicle
R7
1957-present

Third stage

Second stage

First stage, four boosters

First stage

Launch vehicle
SPACE SHUTTLE
1981-2011

Orbiter
COLUMBIA
1981-2003

Parachutes

First stage

Solid rocket boosters could be refurbished after use if no damage was discovered.

Cargo bay

In-orbit fuel

First stage (reusable)

Landing legs open

FERNANDO G. BAPTISTA, KAYA BERNE, EVE CONANT, NGM STAFF; RONALD PANIAGUA
SOURCES: NASA; SMITHSONIAN'S NATIONAL AIR AND SPACE MUSEUM; SPACEX; *THE SOYUZ LAUNCH VEHICLE*, BY CHRISTIAN LARDIER AND STEFAN BARENSKY

Numbers are averages for specific vehicles above.

TOTAL WEIGHT

0.58 million lb

Fuel (%) 88% Spacecraft

PAYLOAD (crew and cargo) 11,000 lb (to low Earth orbit)

6.5 million lb

91%

250,000 lb

100,000 lb (to lunar orbit)

4.5 million lb

84%

63,500 lb

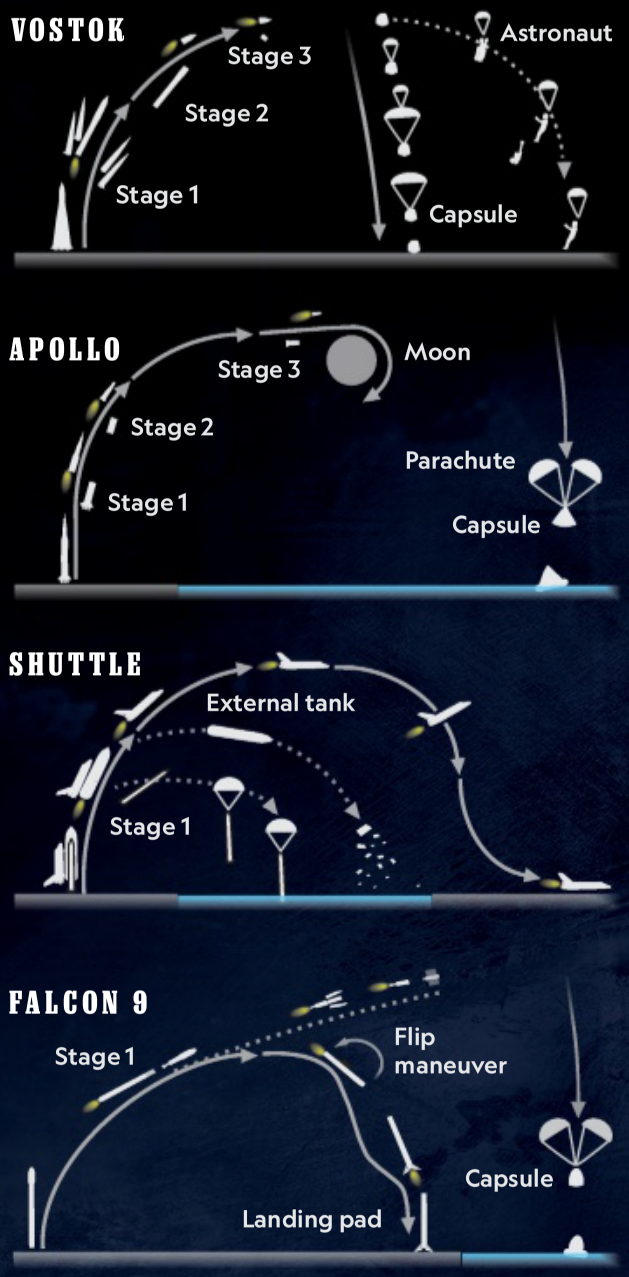
1.2 million lb
(proportions not available)

50,000 lb

LIFTING OFF

Rapid advancements in spaceflight occurred during the space race between the U.S. and the Soviet Union. Ballistic missiles for warfare evolved into rockets destined for exploration. Now commercial space companies are also building spacecraft and selling tickets for future tourist flights.

GETTING THERE AND BACK

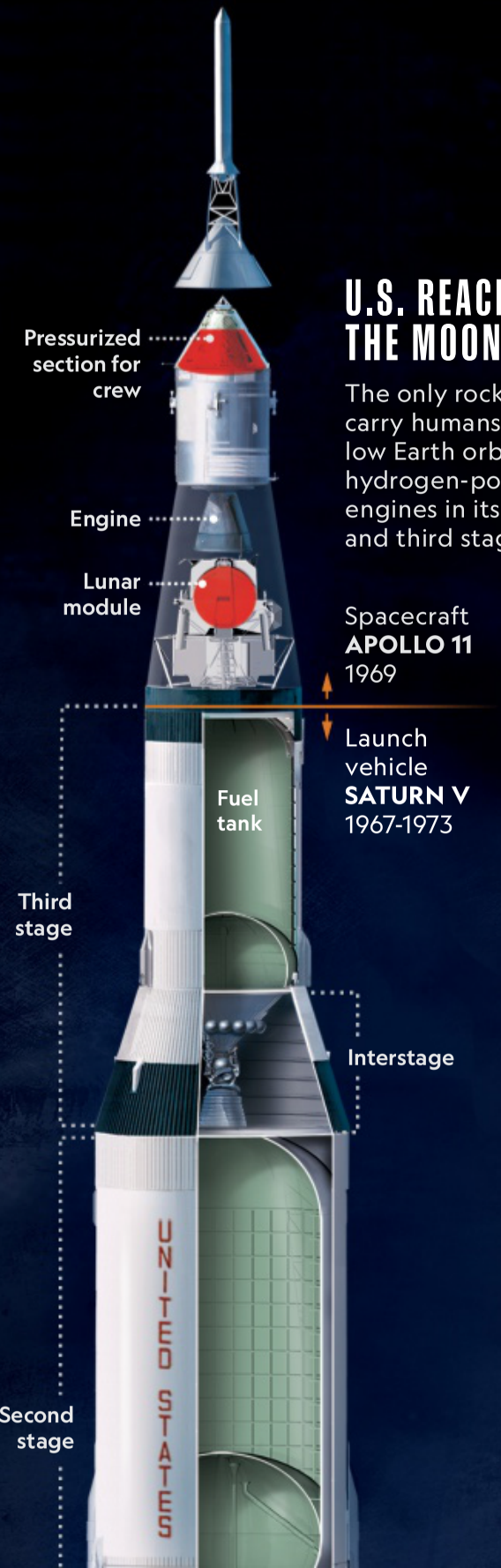


U.S. REACHES THE MOON

The only rocket to carry humans past low Earth orbit had hydrogen-powered engines in its second and third stages.

Spacecraft
APOLLO 11
1969

Launch vehicle
SATURN V
1967-1973

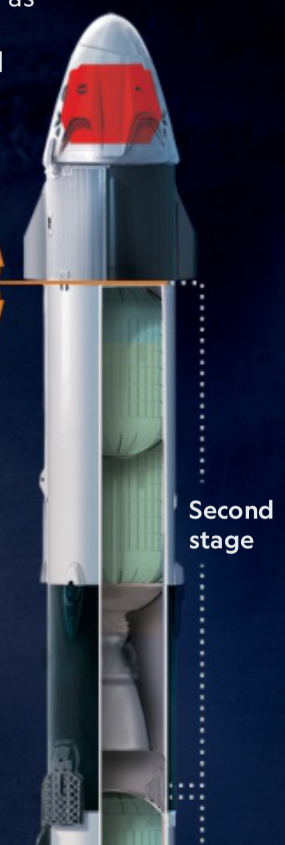


U.S. GOES COMMERCIAL

NASA has contracted with SpaceX to bring astronauts as well as cargo to the International Space Station.

Spacecraft
CREW DRAGON
2019

Launch vehicle
FALCON 9
2010-present



ROUND-TRIP TICKET

The world's first reusable spacecraft to carry humans into orbit could transport up to eight passengers.

A Soyuz spacecraft is towed to a launch-pad this past March at the Baikonur Cosmodrome. Developed by the Soviet Union in the 1960s, the durable design is still used by Russia's space program. Since the last space shuttle was retired in 2011, U.S. astronauts have hitched rides to the International Space Station on the Soyuz.

SUITING UP

Space suits—designed to provide oxygen and consistent atmospheric pressure—have evolved from pressure suits for pilots in high-altitude planes to ones that can keep astronauts alive in the near-vacuum conditions of space.

DESIGNED FOR SURVIVAL

Extravehicular Activity (EVA) Space Suits (E)

EVA suits allow for work outside spaceships. They protect against threats such as extreme temperatures, debris, and radiation.

Intravehicular Activity (IVA) Space Suits (I)

IVA suits are an emergency system for cabin contamination or decompression. Proper pressure keeps body fluids from boiling.

Intra/Extravehicular Activity (IEVA) Space Suits (IE)

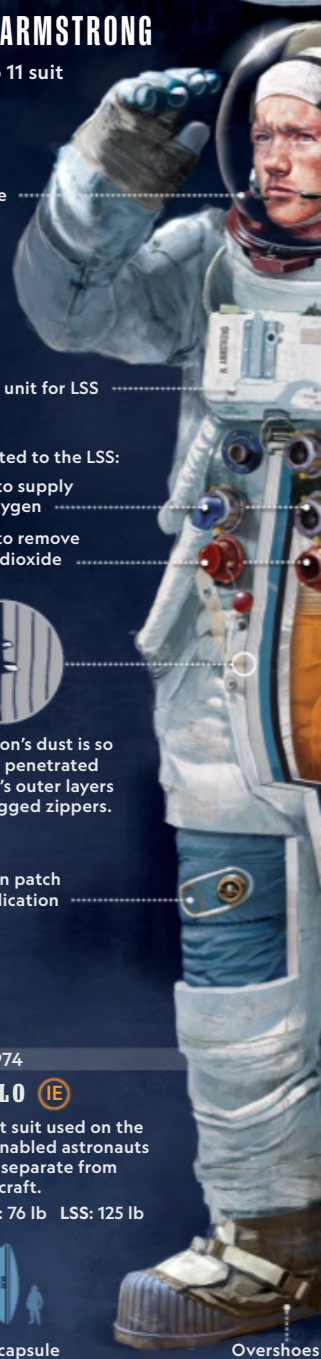
IVA suits accessorized to work outside, or IEVAs, eliminate the need for two separate suits and reduce cargo weight.

Suits shown pressurized

LUNAR EXTRAVEHICULAR VISOR ASSEMBLY
Two visors, one gold coated, shield user from the sun's rays and heat.

NEIL ARMSTRONG

Apollo 11 suit



1934-1935 (years worn)

WINNIE MAE (I)

Wiley Post designed the first pressure suit, made of cotton and rubber, and flew nearly 50,000 feet high in it.

Weight: not recorded

Lockheed Vega *Winnie Mae*

1959-1968

X-15 (I)

The suit was used on the first rocket-powered craft to hit the edge of space, 62 miles above sea level.

Weight: 25 lb

North American X-15

1961-1963

MERCURY (I)

This suit took on water in one landing; later Mercury suits had survival gear with flotation devices.

Weight: 22 lb

Mercury capsule

1965-1966

GEMINI (IE)

The first suit worn outside a vehicle was attached by an oxygen and tether line.

Weight: 34 lb **VCM:** 8 lb

Gemini capsule

1969-1974

APOLLO (IE)

The first suit used on the moon enabled astronauts to fully separate from a spacecraft.

Weight: 76 lb **LSS:** 125 lb

Apollo capsule

FERNANDO G. BAPTISTA, KAYA BERNE, EVE CONANT, NGM STAFF; JOSE DANIEL CABRERA PEÑA
SOURCES: KENNETH S. THOMAS; NASA; SMITHSONIAN'S NATIONAL AIR AND SPACE MUSEUM; RICHARD D. WATSON; AMY J. ROSS

UNDERGARMENTS

1. Liquid cooling garment prevents overheating
2. Urine-collection assembly

SPACE SUIT LAYERS

3. Comfort liner
4. Neoprene-coated nylon to retain pressure
5. Nylon restraint layer
6. Protective layers include thermal-regulating aluminized polymers and fire-resistant fabric

LIFE-SUPPORT SYSTEM (LSS)

7. Portable life-support system (up to six hours)
8. Emergency oxygen (30 minutes)

1983-today

SHUTTLE/ISS (E)

Suits, once customized, now have generic, swappable parts that fit men and women on the International Space Station.

Weight: 122 lb **LSS:** 187 lb

Shuttle

T MINUS

WHERE WE WENT

RIGHT: In 1966 and 1967 five orbiters photographed the moon, helping to identify sites where Apollo missions would land.

APOLLO MISSIONS FOCUSED ON THE MOON'S NEAR SIDE. NOW UNCREWED PROBES ARE REVEALING MORE ABOUT THE MOON AND BEYOND.

COUNTDOWN TO A NEW ERA IN SPACE | PAGE 62

NASA IMAGE COLLECTION/ALAMY STOCK PHOTO (TOP); NASA/U.S. GEOLOGICAL SURVEY/LUNAR AND PLANETARY INSTITUTE (2)

NEW PHASE OF EXPLORATION

National Geographic has always been at the forefront of lunar mapping. As the Apollo program closed in on its goal, cartographers relied on photos from 1966 and 1967 orbiter missions to create the February 1969 hand-painted map—considered the best reference at the time. Our newest version uses a mosaic of some 15,000 images and detailed height measurements from NASA's Lunar Reconnaissance Orbiter, which has surveyed the entire surface. The moon is peppered with probes and landers, the legacy of human efforts to explore it.

***A larger version of this map can be purchased at:* natgeo.com/spacemaps.**

Lunar missions

- Landing
- Crash or impact

Country or agency

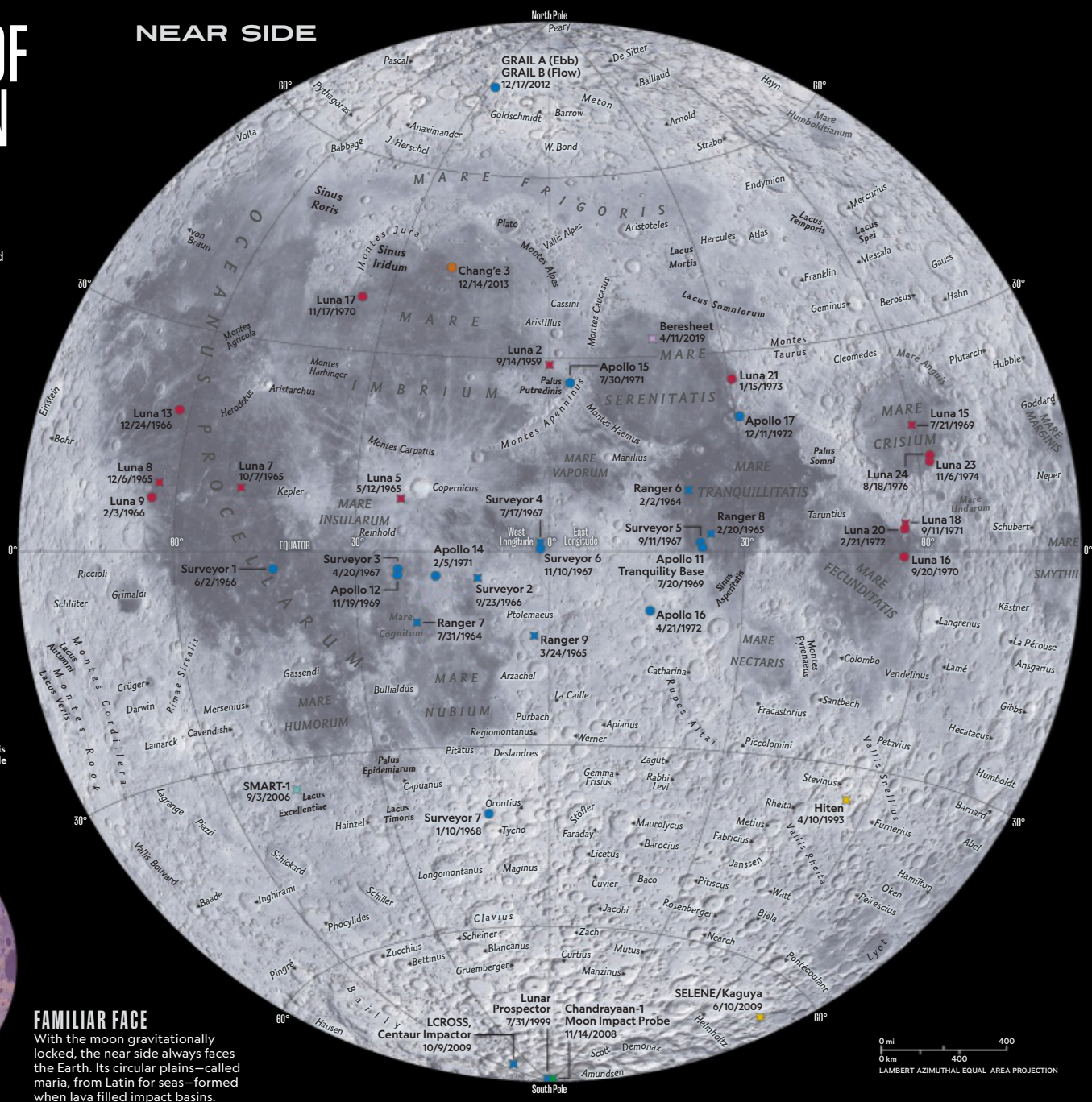
- United States (U.S.)
- Soviet Union (U.S.S.R.)/Russia
- China
- Japan
- European Space Agency (ESA)
- India
- Israel

Lunar topography (in feet)

30,000
15,000
0*
-15,000
-30,000

***As the moon has no sea level, zero is set where a sphere with a 1,079-mile radius would intersect the surface.**

NEAR SIDE



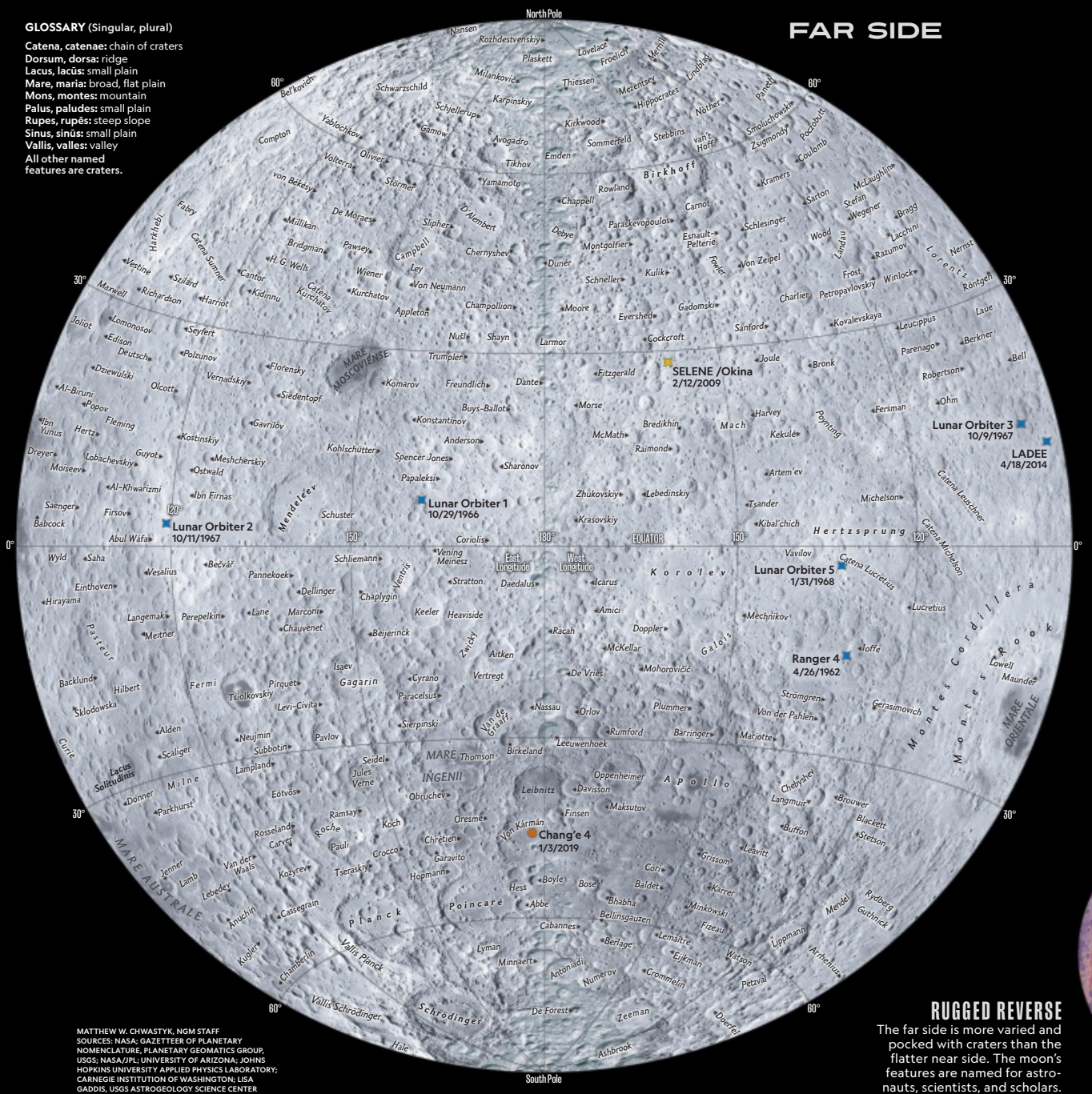
FAMILIAR FACE

With the moon gravitationally locked, the near side always faces the Earth. Its circular plains—called maria, from Latin for seas—formed when lava filled impact basins.

GLOSSARY (Singular, plural)

Catena, catenae: chain of craters
Dorsum, dorsa: ridge
Lacus, lacūs: small plain
Mare, maria: broad, flat plain
Mons, montes: mountain
Palus, paludes: small plain
Rupes, rupēs: steep slope
Sinus, sinūs: small plain
Vallis, valles: valley
All other named features are craters.

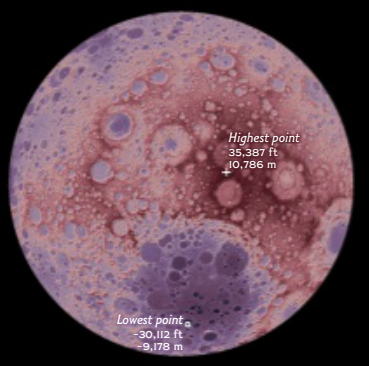
FAR SIDE



MATTHEW W. CHWASTYK, NGM STAFF
SOURCES: NASA; GAZETTEER OF PLANETARY NOMENCLATURE, PLANETARY GEOMATICS GROUP, USGS; NASA/JPL; UNIVERSITY OF ARIZONA; JOHNS HOPKINS UNIVERSITY APPLIED PHYSICS LABORATORY; CARNEGIE INSTITUTION OF WASHINGTON; LISA GADDIS, USGS ASTROGEOLOGY SCIENCE CENTER

TO THE MOON OR BUST

The prize of the space race—landing humans on the moon and returning them home safely—fueled the rivalry between the U.S. and Soviet Union in the 1960s. Now robotic missions are determining whether the moon could be a stepping-stone for human ventures deeper into the solar system.



RUGGED REVERSE

The far side is more varied and pocked with craters than the flatter near side. The moon's features are named for astronauts, scientists, and scholars.

AFTER APOLLO

Nearly half a century has elapsed since humans last visite
But we never stopped exploring. We've inhabited research
(right) and sent robotic craft (below) to venture even far
selfies on Mars, plunge into Jupiter, and investigate our s

In the 1960s our moon was still very much a mystery. To learn the most from the Apollo visits, NASA selected landing sites in a variety of lunar terrains, including the dark, flat plains sculpted by vanished lava oceans and highlands formed by meteor impacts.

From 1969 to 1972, U.S. astronauts landed at six sites, each chosen for different scientific objectives. All of them were on the moon's mottled near side, where the terrain had been studied extensively by lunar orbiters and Mission Control could remain in direct contact with the astronauts.

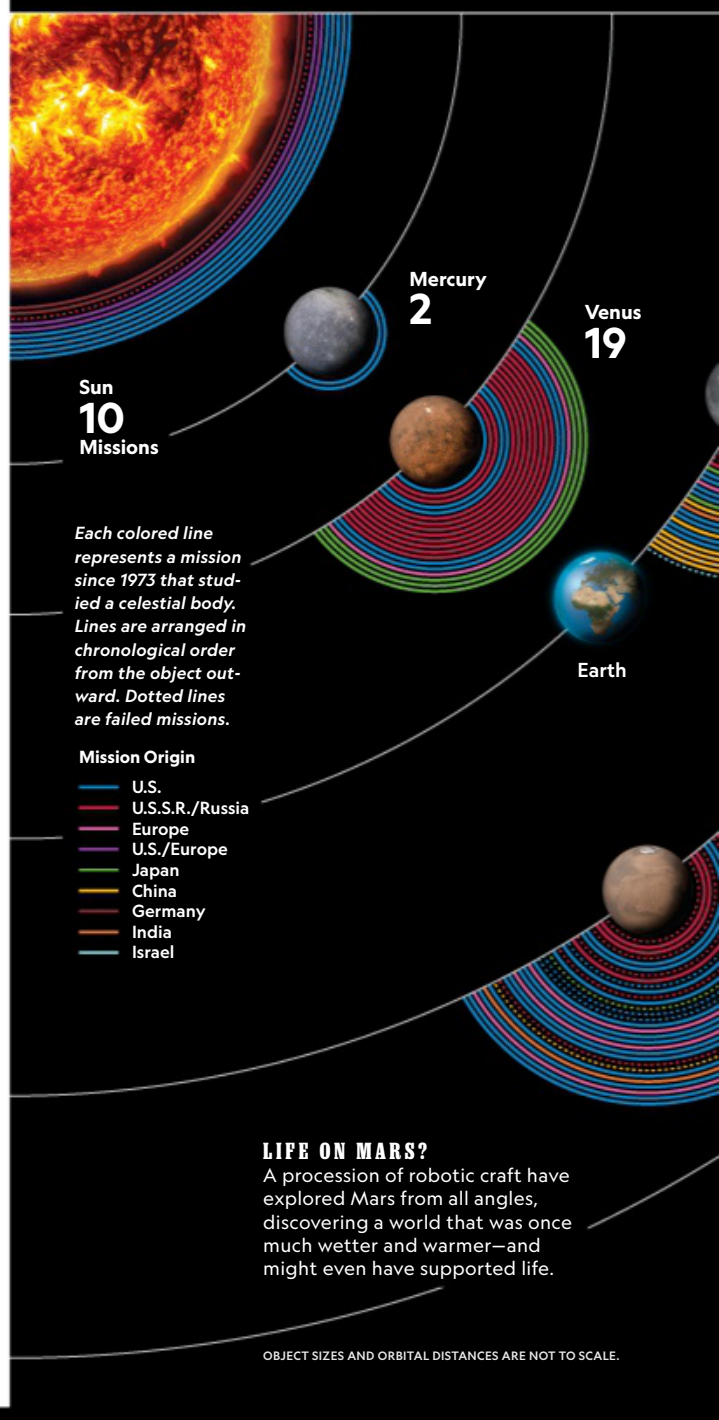
Space agencies have sent probes, with no people on them and thus no need to worry about human safety, to visit far-flung places in the solar system. Spacecraft have explored 60 other moons and even set down on one, Saturn's Titan. On our own moon, robotic rovers have left tracks at four sites.

China made history earlier this year by setting its Chang'e 4 lander on the moon's far side.

The first private lander to reach the moon crashed in April, but the Israeli nonprofit behind it quickly announced plans to try again.

Not to be outdone, the U.S. intends to send a series of landers with technology to lay the groundwork for astronauts to return.

INNER SOLAR SYSTEM



LIFE ON MARS?

A procession of robotic craft have explored Mars from all angles, discovering a world that was once much wetter and warmer—and might even have supported life.

OBJECT SIZES AND ORBITAL DISTANCES ARE NOT TO SCALE.

ed the moon in 1972.
stations orbiting Earth
ther into space to take
solar system up close.

LIVING AND WORKING WHILE ORBITING EARTH

International crews have continued to conduct research on Earth-orbiting stations, while for 30 years NASA's reusable space shuttles carried crew and cargo on a variety of missions.

ASTEROID BELT

OUTER SOLAR SYTEM

THE MOON AND ITS PROSPECTS

Space companies are determining whether there's money to be made on Earth's nearest neighbor through projects like mining, commercial travel, and colonization.

Moon 25

Deimos

Phobos 6

Mars 30

Asteroids 11

ASTEROID ENCOUNTERS

Filled with protoplanetary bodies, the asteroid belt holds clues to how our solar system and planets formed. Probes have visited and collected samples from asteroids.

TURBULENT JUPITER

The first missions to the planet revealed a ball of violent, swirling gases. Some of Jupiter's moons have been studied for the potential to harbor life.

Callisto 4
Ganymede 5
Europa 5
Io 5
Thebe
Amalthea 3
Metis
Adrastea

Jupiter 8

Saturn 4

Pan
Daphnis
Atlas 2
Prometheus 2
Pandora 2
Epimetheus 2
Janus 2
Mimas 3
Methone
Pallene
Enceladus 3
Tethys 3
Telesto 2
Calypso 2
Dione 3
Helene 3
Rhea 3
Titan 4
Hyperion 3
Iapetus 3
Phoebe 2

Uranus 1

Cordelia
Ophelia
Bianca
Cressida
Desdemona
Juliet
Portia
Rosalind
Belinda
Puck
Miranda
Ariel
Umbriel
Titania
Oberon

Neptune 1

SATURN SOJOURN

Few missions have visited the planet, but Cassini arrived in 2004 and explored for 13 years; data are still being processed.

KUIPER BELT

Reaching the most distant bodies in our solar system, the New Horizons spacecraft was the first to visit Pluto; it then flew on to explore Ultima Thule.

Naiad
Thalassa
Despina
Galatea
Larissa
Proteus
Nereid
Triton

Pluto 1

Charon
Styx
Nix
Kerberos
Hydra

Ultima Thule 1

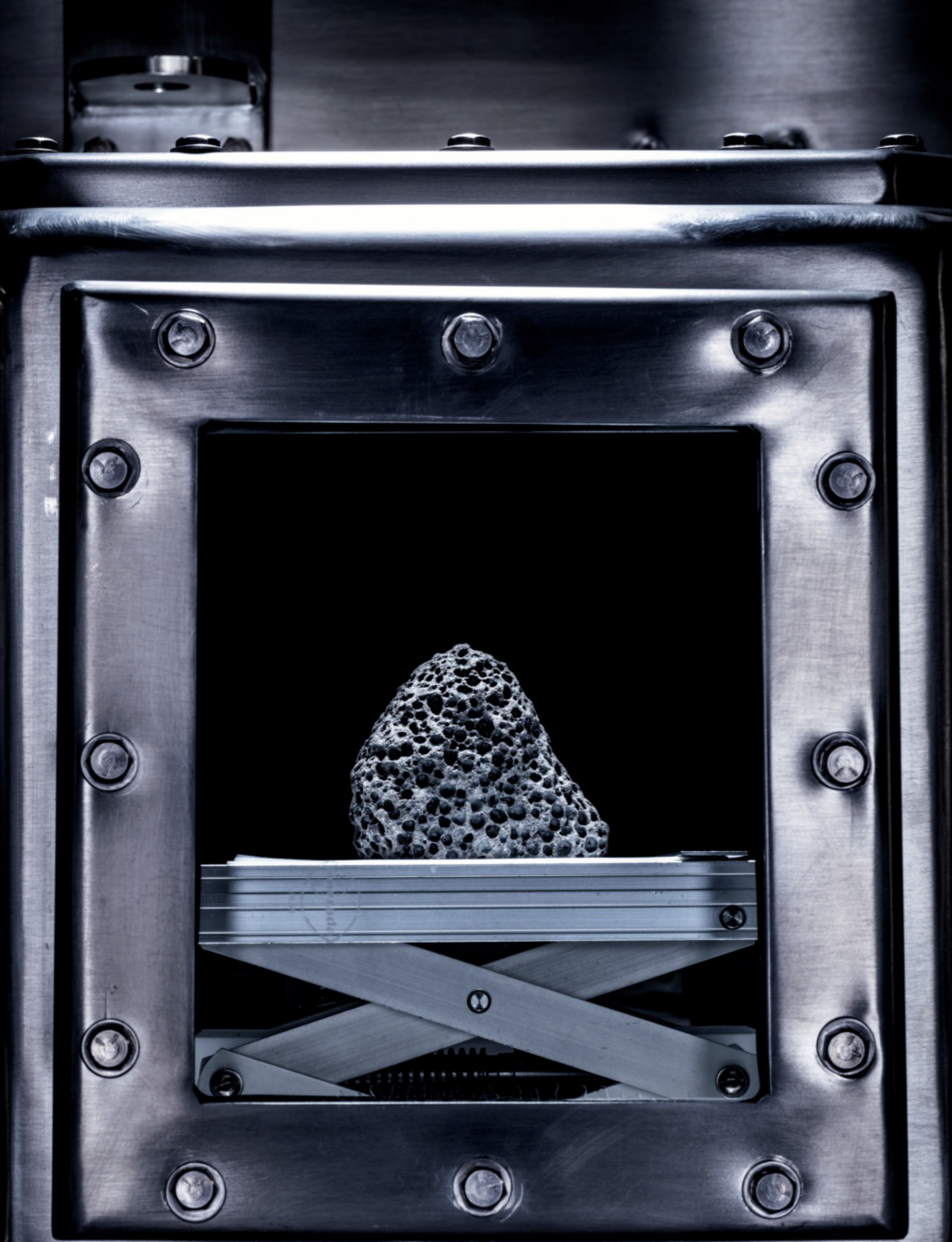
HALLEY'S COMET

On an eccentric orbit that travels past Neptune, Halley returns to the inner solar system every 76 years. Various craft studied its last visit, in 1986.

Halley's comet 5

Comets 11

NGM ART. MATTHEW TWOMBLY; ALEXANDER STEGMAIER. SOURCES: NASA; ASIF SIDDIQI, FORDHAM UNIVERSITY; JONATHAN McDOWELL, HARVARD-SMITHSONIAN CENTER FOR ASTROPHYSICS; USGS ASTROGEOLOGY SCIENCE CENTER



T MINUS

WHAT WE TOOK

LEFT: A piece of Lunar Sample 15016, a form of basalt, is preserved in a stainless steel cabinet filled with flowing, purified nitrogen gas.

ASTRONAUTS COLLECTED ROCKS, PEBBLES, SOIL, AND DUST. THEY ALSO TOOK PERSONAL ITEMS TO SPACE THAT REFLECTED THEIR INTERESTS, BELIEFS, AND PASSIONS.

NASA JOHNSON SPACE CENTER

Over four years, NASA astronauts hauled 842 pounds of moon rocks back to Earth. But the most profound souvenirs weigh nothing: images of Earth. Apollo 8 astronaut William Anders snapped an iconic one on Christmas Eve in 1968, showing our blue planet suspended in darkness near the moon's sterile, cratered horizon.

Astronauts didn't just take photos and collect moon rocks, they also carried an array of objects from Earth into space with them.

John Young (Gemini 3) notoriously smuggled aboard a corned beef sandwich and shared it with Gus Grissom, his crewmate. Grissom pocketed it when crumbs began to float around the cabin.

Buzz Aldrin (Apollo 11) took wine, bread, and a chalice to celebrate Communion. His crewmate Neil Armstrong carried a piece of the Wright Flyer's wooden propeller. Alan Shepard (Apollo 14) used a sock to hide a six-iron clubhead, which he attached to a tool handle to hit two golf balls on the moon. Charles Duke (Apollo 16) packed a family photo and left it in the Descartes highlands.

Perhaps the most poignant memento on the lunar surface is a small aluminum human figure, placed there by David Scott during Apollo 15. It rests near a placard bearing the names of 14 fallen astronauts and cosmonauts.

One of NASA's most requested space photos, this view of Earth, known as Blue Marble, was taken in 1972 from about 18,000 miles away, as Apollo 17 was traveling to the moon.

NASA JOHNSON SPACE CENTER

TOP LEFT

Aboard Gemini 6, Walter Schirra tootled "Jingle Bells" on this harmonica as Thomas Stafford shook sleigh bells, making the first music in space on December 16, 1965.

SMITHSONIAN'S NATIONAL AIR AND SPACE MUSEUM

BOTTOM LEFT

After landing on the moon, Buzz Aldrin drank consecrated wine from this three-inch goblet, which is still used by his former church near Houston.

WEBSTER PRESBYTERIAN CHURCH

T MINUS

IN POP CULTURE

RIGHT: In 1967 Mattel introduced Major Matt Mason, one of the first realistic space action figures. His suit was based on a prototype.

FROM TV SHOWS TO MOVIES, TOYS, FOOD, AND THE WAY WE EXPRESS OURSELVES, SPACE CONTINUES TO HAVE A HOLD ON OUR IMAGINATION.

As the space race boomed, it catapulted its aspirations into the zeitgeist—and transformed the way we live.

Sputnik inspired replicas and songs. *Life* magazine published exclusive stories on the lives of the celebrated Mercury Seven, the United States' first astronauts. Seattle built the Space Needle for the World's Fair. Stanley Kubrick created *2001: A Space Odyssey*. The space age flourished in movies, TV, music, architecture, and design, where the sleek, aerodynamic lines of rockets inspired the look of cars and trains.

Space is still lodged in popular culture. The NASA logo appears everywhere, from tattoos to Vans high-tops. We've had *Star Trek*, *The Jetsons*, *Mork & Mindy*, *Star Wars*, and the current spate of Mars movies and space-themed TV shows. Also: the Houston Astros and the Houston Rockets, Space Camp, antigravity ballpoint pens, astronaut ice cream, the moonwalk, and Space Mountain.

Concepts like "the right stuff," "moon shot," and "light-years" figure into everyday conversation. Your first day back after vacation might be filled with "reentry" problems. Your craft-brewed IPA might taste like "rocket fuel" or even use those words as its name. And, on discovering a distressing situation, you might calmly say, "Houston, we have a problem."

LEFT

The January 10, 1967, issue of *Look* magazine featured this Norman Rockwell painting of how it might look when Neil Armstrong set foot on the moon. Rockwell, a stickler for accuracy, consulted experts and collaborated with a space artist to create this vision.

© 1967 ARTWORK COURTESY THE NORMAN ROCKWELL FAMILY AGENCY/SMITHSONIAN'S NATIONAL AIR AND SPACE MUSEUM

RIGHT

In Russia cosmonauts are often depicted on memorabilia. This poster, headlined "World's First," heralds the 20th anniversary of Valentina Tereshkova's solo flight in 1963, when the 26-year-old former textile worker and skydiver became the first woman in space.

DAVID POLLACK, GETTY IMAGES

LEFT

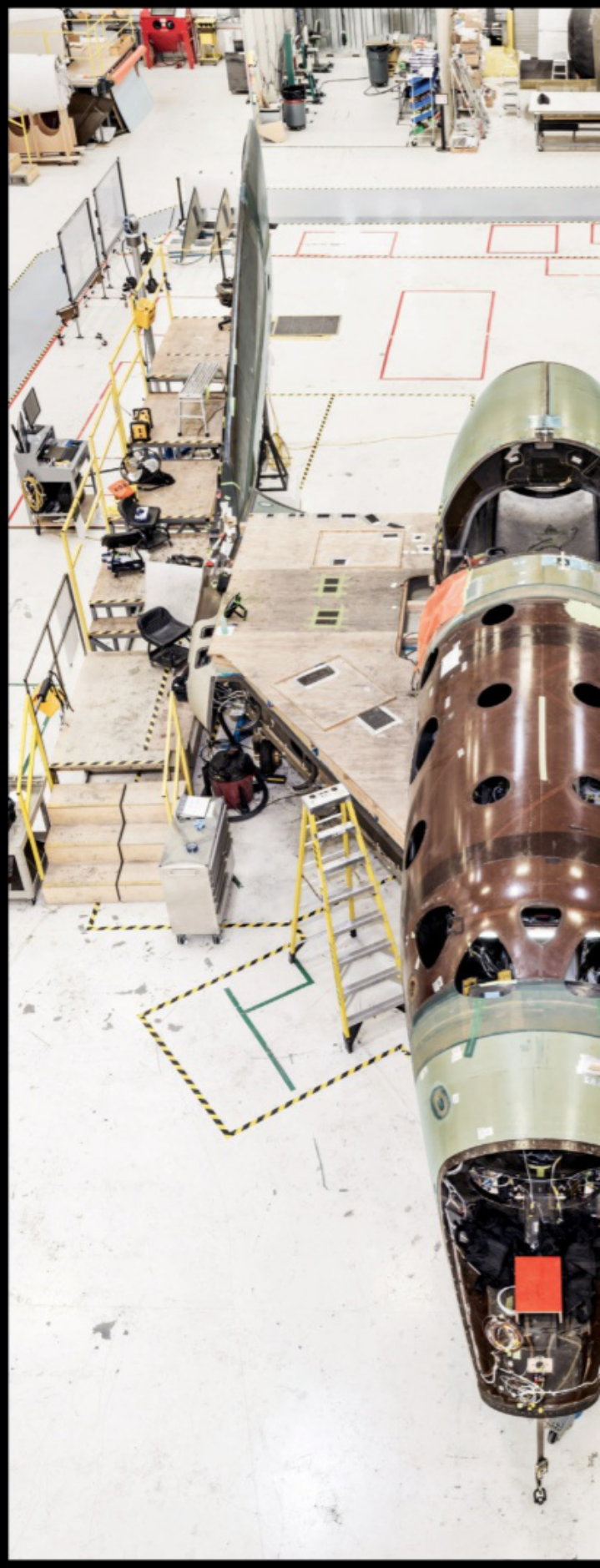
Project Mercury, which rocketed U.S. astronauts to space six times from 1961 to 1963, inspired many objects that celebrated the historic achievement. This metal lunch box shows an accurate cutaway view of the cone-shaped, single-seat Mercury capsule.

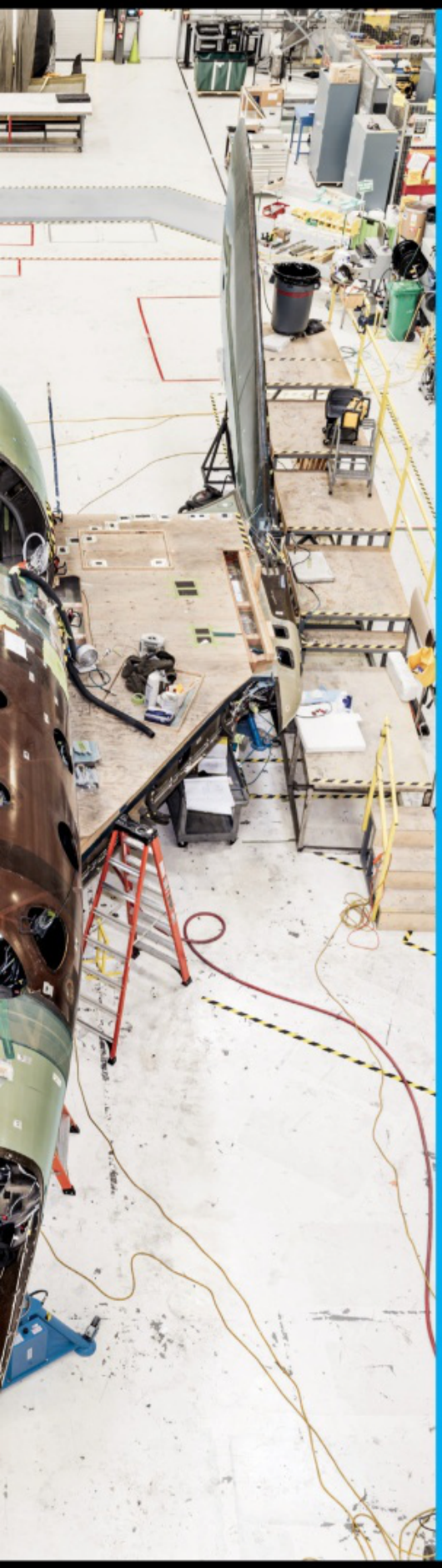
PRIVATE COLLECTION OF SUSAN N. FREEMAN

ABOVE

Billed as "the first space age–inspired car," the Firebird III, built by General Motors, was powered by a gas turbine engine and sported seven fins. The 1958 concept car had a computer, electronic controls, and a joystick to accelerate, brake, and steer.

GENERAL MOTORS HERITAGE CENTER





LIFTOFF!

WHAT'S NEXT

LEFT: Virgin Galactic's VSS *Unity,* shown in 2015, has flown higher than 50 miles, the distance NASA considers the beginning of space.

IT MAY SEEM AS IF WE'VE BEEN GOING NOWHERE FOR DECADES. BUT A NEW AGE OF SPACE TRAVEL IS COMING, MIXING EXPLORATION WITH A RACE FOR PROFITS.

BY SAM HOWE VERHOVEK

PHOTOGRAPHS BY DAN WINTERS

hen human beings stepped on the moon 50 years ago this month, it was one of history's most astounding moments, and not just because our first visit to another world was among humanity's greatest scientific achievements or because it was the culmination of an epic race between two global superpowers, though both were true. The *New York Times* put a poem by Archibald MacLeish on the front page, and newscaster Walter Cronkite, "the most trusted man in America," would come to say that people living 500 years in the future would regard the lunar landing as "the most important feat of all time." ¶ The ultimate significance, however, was not that the race had ended or even that a once unimaginable milestone had been attained. ¶ This achievement was really just the beginning. ¶ The beginning of a new era in humanity's vision of its horizons, of the places we could explore and might even inhabit. Having started as a landfaring species, expanded our reach to the entire planet when we became seafaring, and conquered the atmosphere above Earth when powered flight made us skyfarers, we were now destined to be pilgrims in a vast new realm. We were spacefarers—and soon, as this seminal triumph helped us get over what celebrated scientist and writer Isaac Asimov called our "planetary chauvinism," we would become an extraplanetary species. "Earthlings" would no longer be sufficient to describe who we were. ¶ All this is what was widely expected, amid the euphoria and wonder on July 20, 1969, when *Eagle,* Apollo 11's lunar module, touched down on the moon's surface. The greatest journey starts with a single step. A small step for one man; a giant leap for all of humankind. ¶ The head of the U.S. National Aeronautics and Space Administration, Thomas O. Paine, was soon aiming for Mars, and not just as a someday goal but with a detailed itinerary laid out in *National Geographic*. Depart: October 3, 1983. Crew of 12, split between two 250-foot-long spacecraft fired by nuclear rockets. Enter Mars orbit: June 9, 1984. Eighty days of exploration on the Martian surface. Return to Earth orbit: May 25, 1985. ¶ The very act of reaching the moon somehow exalted the human race, yielding confidence that we would indeed push deeper into space. "Wherever we went, people, instead of saying, 'Well, you Americans did it,' everywhere they said, 'We did it!'" recalled Michael Collins, the pilot of Apollo 11's command module. "We humankind, we the human race, we people did it."

The weather on Mars can vary dramatically, requiring a space suit that makes it possible for astronauts to venture out into temperatures as low as minus 80°F and as high as 70°F. Under development by a lab at the University of North Dakota with funding from NASA, this experimental suit is made from 350 components.

NASA KENNEDY SPACE CENTER

Sunrise is still a few hours away, and as the bus cuts a lonely path through miles of remote steppe in southern Kazakhstan, its headlights occasionally illuminate for the briefest of moments a giant faded mural or a chipped tile mosaic. These stylized works of art show the ravages of baking summers and bitter winters. They adorn huge, rusting, abandoned buildings, and they celebrate the decades-old glories of a space program in a nation that no longer exists: the Soviet Union.

Finally, after miles of this *Twilight Zone* landscape of Cold War detritus, the bus makes a sudden turn down a gated lane and arrives at a giant, banged-up structure that is definitely not abandoned. Well-armed Russian and Kazakh security officers in camouflage gear seem to have the place surrounded, and it's bathed in floodlights. Inside this hangar is a gleaming new rocket ship.

I've come to the Baikonur Cosmodrome because, just shy of the 50th anniversary of the moon landing, it's the only place on the planet where I can watch a human blast off to space. In turn, the only place in the universe these people can fly to is the International Space Station, some 250 miles above Earth, which is barely one-thousandth of the distance to the moon.

For the past eight years, ever since NASA retired the space shuttle, the only way it has been able to get an American astronaut to the space station has been to hitch a ride with its Russian counterpart, known as Roscosmos, at roughly $82 million for a seat up and back down.

Fifty years on from the moon landing, this is where we are in space, if by "we," we mean human beings. Which sure sounds like basically nowhere, at least as measured by the yardstick of 1969's great expectations. Twelve people—all Americans, all men—have stepped on the moon, none since 1972, and other than on Earth-orbiting space stations, no human has set foot anywhere else in the universe.

Measured another way, of course, we're doing extraordinary things in space.

We've sent uncrewed probes to explore all the other planets in our solar system, yielding astonishing photographs and troves of data. The twin Voyager spacecraft have literally sped across the solar system and into interstellar space, the first human-made objects ever to do so. They're more than *11 billion miles away* and still communicating with us.

Because the Voyagers could travel forever into the void and both the sun and the Earth have an expiration date (don't worry, it's a ways off), it's conceivable that one day these sedan-size eternal sojourners will be the only evidence that we ever existed. Yet it's also conceivable that a successor species to us will have long gone interstellar by then, hopefully granting us some recognition for their feat.

And if they do, they may well point to this moment in time—the late 2010s, the early 2020s—as the "inflection shift," which is how Jim Keravala, a physicist who has overseen satellite launches on Russian, European, and U.S. rockets, characterizes the frenzy of activity in the commercial space industry today.

We are, Keravala says, at the dawn of "the true beginning of the era of space settlement and humanity's future off-world." (Keravala now heads OffWorld, a company that intends to deploy millions of robots to turn the inner solar system into a "better, gentler, greener place for life and civilization.")

Keravala's intriguing prediction is highly debatable, in part because that old industry chestnut—"space is hard"—happens to be true; setbacks and delays are virtually always part of the march to progress.

But it's undeniable that something big is going on in space. Two U.S. companies, SpaceX and Boeing, are moving closer to certification of their spaceship models, putting NASA "on the precipice of launching American astronauts on American rockets from American soil," in the words of NASA administrator Jim Bridenstine. These ships—which are to Apollo's cramped modules as a Boeing 787 Dreamliner is to a prop-driven airliner of the 1950s—may carry out crewed missions by late this year or early next year.

Meanwhile, spacecraft built for two other private companies, Virgin Galactic and Blue Origin, have also made major strides, bringing us ever closer to a novel era of space tourism. To begin, they will shoot well-heeled customers up to an elevation of 60-odd miles, to the edge of outer space, where the clientele will experience zero-gravity weightlessness and see the black void of the universe and the blue curvature of the Earth. All this can be yours for a mere $200,000 or so at present—though both companies say prices will drop rapidly and options expand as they bring more rocket ships on line.

GETTING INTO ORBIT

In the 1950s the Soviet Union and the U.S. built the first launch sites. Other countries followed in the 1970s. Today Rocket Lab has the only private site, but others are under construction. Many of the 22 active ports are in the southern regions of countries because Earth's surface rotates faster near the Equator, giving launches a boost.

Blue Origin is also shaking up the race to put humans back on the moon, announcing in May that it's building a lander named Blue Moon. The robotic vehicle will be able to haul up to seven tons of cargo and could put astronauts on the lunar surface by 2024.

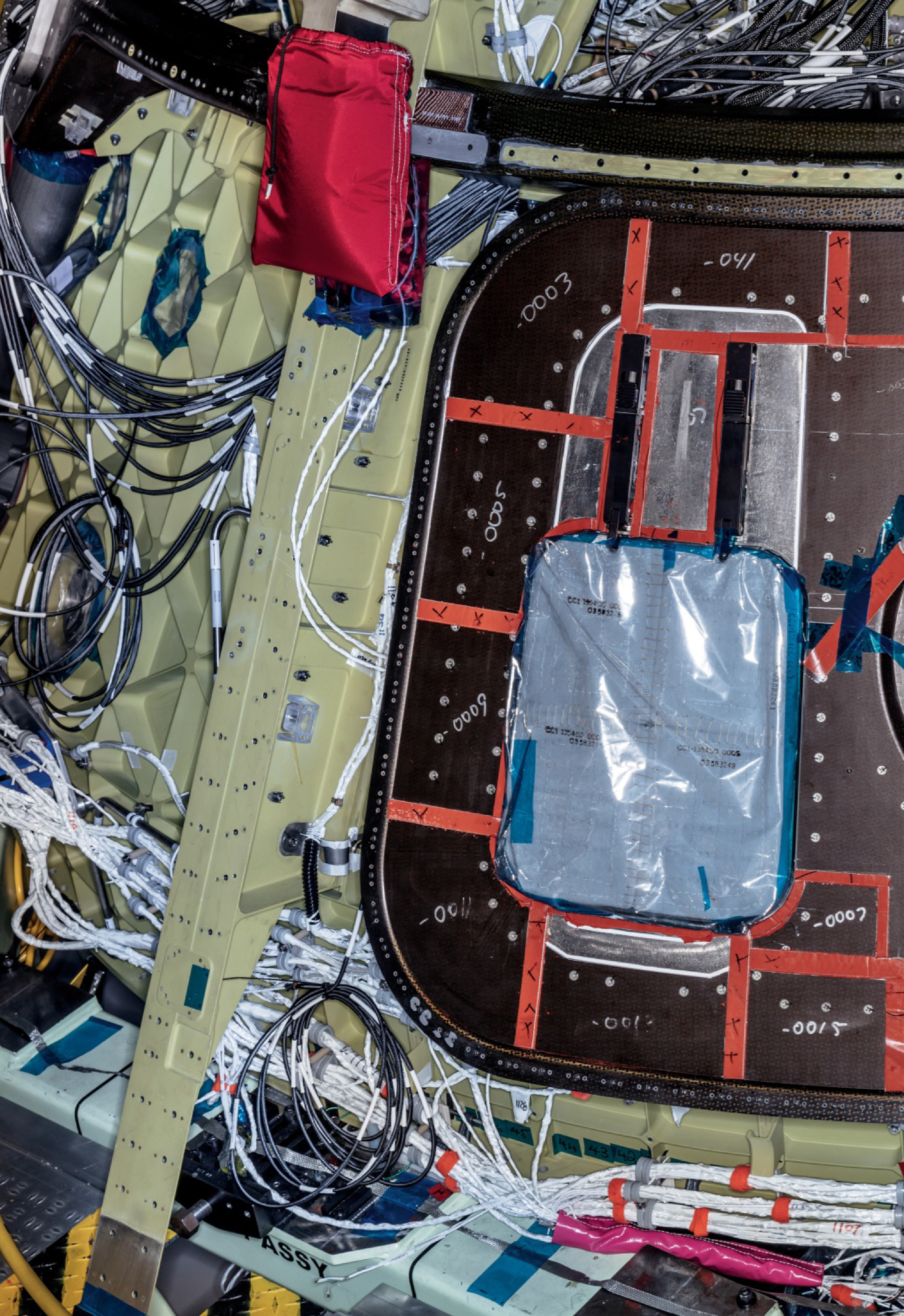
The action in space is hardly confined to American companies or Russia's program. In January, China boasted that it "opened a new chapter" in lunar exploration by soft-landing an uncrewed spaceship on the far side of the moon, the first time a vehicle had ever touched down there. That spacecraft deployed a rover bearing a "mini-biosphere," designed to test whether fruit flies and a variety of plants and seeds can work together to create food in lunar conditions. China announced in April that it intends to build a research station on the moon's south polar region within the next decade, although the nation's space agency remains mum about how soon it might try to land "taikonauts," as its astronauts are known, on the lunar surface.

In Israel, which sees itself as a plucky "start-up nation," there were both cheers and tears in April, when a nonprofit consortium called SpaceIL made history as the first private concern to orbit the moon. But its bid to make Israel the fourth country to soft-land an object there had a hard ending: SpaceIL's small spacecraft called Beresheet (Hebrew for Genesis, or "in the beginning") instead crashed on the lunar surface and

NEXT PHOTO

A technician installs components on the CST-100 Starliner, a new capsule engineered by Boeing that can carry as many as five passengers to the International Space Station. Designed to set down on the ground, rather than on water, it has parachutes to brake its descent and airbags to cushion its landing. Each capsule will be able to be used up to 10 times. Boeing plans a crewed test launch within a year.

ACTIVE PORTS WITH AT LEAST ONE ORBITAL SPACE LAUNCH BETWEEN 2008 AND 2018 SHOWN.
SOREN WALLJASPER, NGM STAFF. SOURCE: THOMAS G. ROBERTS, CSIS AEROSPACE SECURITY PROJECT



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lost contact with mission control.

In remote New Zealand, from a launchpad adjacent to a giant sheep pasture, a company called Rocket Lab is sending innovative, low-cost rockets bearing satellites into low Earth orbit.

At the edge of Dubai, where Emirates airline has forged a massive global crossroads for air travelers out of once empty desert, an entirely new and even more colossal airport under construction is being billed as the world's first "cosmotropolis." Authorities say it will be capable of handling rocket ships and hyper- and supersonic aircraft as well as conventional jet airliners.

And in Japan, JAXA, the official space agency, announced in March that it was working with Toyota to develop a crewed moon rover that would enable astronauts to travel 6,000 miles on the lunar surface.

Much of today's rocketry is fueled by an intense competition among a few superbillionaires whose ambitions (and egos) appear to be out of this world.

Their spacecraft are different from yesteryear's because they are not being developed purely for scientific exploration. These spacecraft are intended to make money by fulfilling the expensive wishes of wannabe astronauts or harvesting valuable resources through mining on asteroids; by flying people quickly between any two points on Earth; and indeed, as Keravala suggests, by ultimately making us a multiplanetary species.

Many of these space titans have a clear vision of where they're taking the rest of us, but collectively we have barely begun to discuss the ethics—or wisdom—of it all. If, as the relentless evangelist for space and commerce Jeff Bezos has insisted, the solar system can easily support "a trillion humans," among whom we would have "a thousand Einsteins and a thousand Mozarts," should we then heed the Amazon founder's call to go forth and multiply in the firmament? (And if so, will Amazon Prime deliver?)

At the same time, there is something very curious about the lofty slogans, visions, and mission statements that private space companies feature in their promotional materials: Many contend that going to space is actually about … saving the Earth—and making it a better place.

"We open space to change the world for good" (Virgin Galactic, founded by billionaire Richard Branson). "To preserve Earth … we must go to space to tap its unlimited resources and energy" (Blue Origin, Bezos's company). "We open access to space to improve life on Earth" (Rocket Lab). "Imagine most journeys taking less than 30 minutes, with access to anywhere in the world in an hour or less" (SpaceX, brainchild of billionaire Elon Musk, who says space travel will make such Earth-to-Earth trips feasible).

Why are we in space? Fifty years ago, it was easy to answer the question. To reach the moon! Sure, discovery, generally; and national prestige, specifically. To issue a grand proclamation of goodwill: "We came in peace for all mankind." Everybody knew the point was to step on the moon, return safely, and crow about it.

Ask that question today, however, and you may get any of a dozen answers. These are worth examining, because you can't explore whether we should be in space without a sense of what we are doing there—or aiming to do.

Outside the hangar in Kazakhstan, I step off the bus along with the rest of my group—a large crop of reporters, mostly Russians and a few Canadians. We stand around and stomp our feet for a while, as it's cold on this early December day—seven degrees Fahrenheit with a rattling wind that has a well-below-zero feel to it.

We are at the edge of a security barrier—my group on this side, wielding cameras and notebooks, the security guys on the other side, gripping guns and speaking purposefully into walkie-talkies tucked into the shoulders of their uniforms. The rocket ship is on its side on a flatbed railcar, four conical boosters at the base of a white cylinder, with a brightly painted Russian flag at the top. As it sounds a low whistle, the train slowly pulls out, headed to the launchpad a few miles away.

There's some drama to the launch because the previous one, in October, was aborted just 57 miles up when a sensor malfunction prompted the crew capsule to separate from the rocket and booster assembly. NASA astronaut Nick Hague and Russian cosmonaut Alexey Ovchinin averted disaster with a harrowing emergency landing.

"The crew was lucky," Anne McClain, an Army lieutenant colonel, Iraq war veteran, and helicopter pilot, explained in a NASA-TV news conference. "But every crew that makes it to orbit is lucky. Spaceflight's not easy."

McClain should know: A NASA astronaut,

Much of today's rocketry is fueled by an intense competition among a few superbillionaires whose ambitions are not purely scientific: Their spacecraft are intended to make money.

she's on the launch I'm at the Cosmodrome to see.

Now Roscosmos says the problem is fixed and this Soyuz rocket launch will be trouble free. And indeed, from behind a glass wall in a special quarantine zone, McClain and the other two crew members are telling us—in English, in Russian, and in French—that they share that faith. Thumbs-up all around. A Russian Orthodox priest, as is customary these days, blesses the crew and the ship with holy water in two brief but solemn ceremonies; he even blesses the assembled reporters, a touch I cannot help but appreciate in this era of relentless attacks on the free press.

At Baikonur, reporters witness a launch from a distance of just under a mile, which is significantly closer than at Cape Canaveral, where they are kept about three miles away. It's a mesmerizing and profound spectacle: the huge burst of orange flame at the rocket's base on ignition, the engine roar, the rumbling, shaking ground. The awe I feel is intensified by the knowledge that at the very tip of the ship, three of my fellow human beings are trusting that all will be well as they are shot straight up into the sky.

The number of human beings living in space is about to double—from three to six. In less than three weeks the three already at the space station would come home, and the human census beyond Earth's atmosphere—on the moon, on all the other planets in the solar system, on all those other moons, on asteroids, and in or on the many things that humankind has built and launched into orbit over six decades—would drop back down to three. The other 7.6 billion or so of us? We're still earthbound.

Soon, however, the United States could have not one but two American-made options for getting astronauts to space, finally severing NASA's sole dependence on Russian Soyuz rockets. These new spaceships are a first step toward much longer range missions: to the moon, to asteroids, and even to Mars.

And so, a few months after the surprisingly moving, even mystical experience of watching the Soyuz liftoff, I find myself some 170 feet above the ground on a gorgeous blue-sky Florida day, the Atlantic Ocean sparkling a half mile away.

I'm at Cape Canaveral Air Force Station, atop Space Launch Complex 41, whose history dates to 1965, when it began launching Titan rockets for the space programs that preceded Apollo. It's eventually going to launch Boeing's CST-100 Starliner capsule, which will carry as many as five passengers at a time to the International Space Station.

The first thing I notice after stepping off the elevator are four parallel zip lines leading to the ground at the very edge of the launch complex.

"If you're an astronaut, you really, really don't want to be taking that ride," says Tony Taliancich, director and general manager of launch operations for ULA, a launch alliance that is a joint venture of Boeing and Lockheed Martin. Taliancich, imposingly built but perpetually smiling during my tour of his bailiwick, explains that these 1,300-foot-long zip lines are a critical part of the escape system, in case a last-minute explosion, fire, or other emergency provokes an abandon-ship order.

They bring to mind the fire that erupted in the cabin of the Apollo 1 spacecraft in January 1967, a tragedy that quickly claimed the lives of three astronauts at Launch Complex 34 near here, now a memorial site honoring the men "who made the ultimate sacrifice so others could reach the stars."

They're also a useful reminder: Despite the strides NASA has made in its perpetual quest to make spaceflight safer, it's still a dangerous business. Our astronauts are essentially stepping on top of a bomb whenever they climb into the capsule of a spacecraft, a bomb they trust will go off in a controlled manner.

Of the 135 space shuttle flights, two ended in disaster, claiming seven lives each. If we

accepted that failure rate in the commercial airliners we rely on in this country, we'd be tolerating more than 500 crashes *every day*.

Taliancich, who spent much of his career in Air Force space-launch operations, shows me where the Starliner crew capsule will fit and points out the entryway into a sealed chamber that will ensure the cabin remains pristine when the astronauts enter it.

I'd seen a Starliner an hour or so earlier in a nearby assembly plant. More accurately, I'd seen the upper and lower halves of the conical capsule without their outer heat-shielding shells, revealing the mind-boggling spaghetti mix of tubes, wires, and electrical cables that go into a spacecraft.

With improved seats and larger windows, as well as interior LED "mood lighting," this spacecraft's cabin is clearly a 21st-century upgrade from an Apollo capsule. While the lighting feature sounds a bit whimsical, it's anything but. Eventually, advanced lighting may help regulate astronauts' circadian rhythms and sleep cycles as well as their emotions, one of several critical challenges that must be overcome before NASA or any other space agency can send humans on the months-long trip to Mars.

Thomas O. Paine, NASA's chief in 1969, thought we'd have set foot on Mars and the moons of Jupiter by now. His prediction still may come true—by the 100th anniversary of Apollo 11.

Just when will that Mars trip finally occur?

NASA does not have a specific timeline for human exploration of the red planet. In the meantime, the focus is on sending astronauts back to the moon as a way to test both human and spacecraft capabilities.

"The moon is the proving ground; Mars is the horizon goal," NASA's Bridenstine said in March during a presentation at Cape Canaveral unveiling the space agency's proposed budget.

To establish a presence on the moon, astronauts will need to look at ways of extracting water, oxygen, and helium—as fuel for human and machine alike. (Helium-3, a gas thought to exist in significant quantities there, could be used for future nuclear fusion–propelled rockets.) The moon could also wind up as a staging ground for launches to elsewhere: Since it has only one-sixth of Earth's gravity, much less energy is needed to send a ship beyond the moon's pull than here on our planet.

Space-exploration advocates are unhappy with the budget, saying it provides for a too-slow timetable for getting to Mars. Bridenstine counters that it incentivizes private industry to speed up capabilities for a crewed landing, and he frequently invokes the frenemy of comic character Charlie Brown to make his case that the path to Mars is genuine: "This is not Lucy and the football anymore," he says. The Starliner—or the SpaceX version, called Crew Dragon, or both—may well be the future of human space exploration.

Still, let's return to Earth and reiterate a few things about where we are today.

We're manifestly not where many thought we'd be 50 years on, and certainly not where NASA's Paine said we could be, which was not only Mars but also the moons of Jupiter and who knows where else. We're not even back on the moon. Paine, who died in 1992, believed that thousands of us would be enjoying lunar vacations in his lifetime.

"There's no question we can reduce the cost of travel to the moon to the cost of traveling through air today," Paine told *Time* magazine shortly before the Apollo 11 landing.

It's certainly possible that the big predictions of 1969 will come true—but closer to the 100th anniversary of the lunar landing, with this half-centennial milestone marking the beginning of Space Age 2.0.

Musk, who says he intends to move to Mars someday, is the most aggressive on a time frame. He's pegged 2024 for a crewed SpaceX spaceship to land on Martian soil, a projection widely dismissed as hopelessly—or recklessly—optimistic. In April a U.S. government–mandated

independent analysis concluded that it was "infeasible under all budget scenarios and technology development and testing schedules" for NASA to send humans to Mars before 2034. Other Mars advocates say the early 2040s is more like it.

Landing and exploring: doable. But, to be clear, many experts consider bold projections of celestial living to be, pardon the pun, lunacy.

I ran into Bill Nye, the popular and pithy Science Guy of television fame and CEO of the Planetary Society, at a space conference last year in Washington, D.C., and he rolled his eyes at the idea that Mars will eventually be "terraformed" for human habitation.

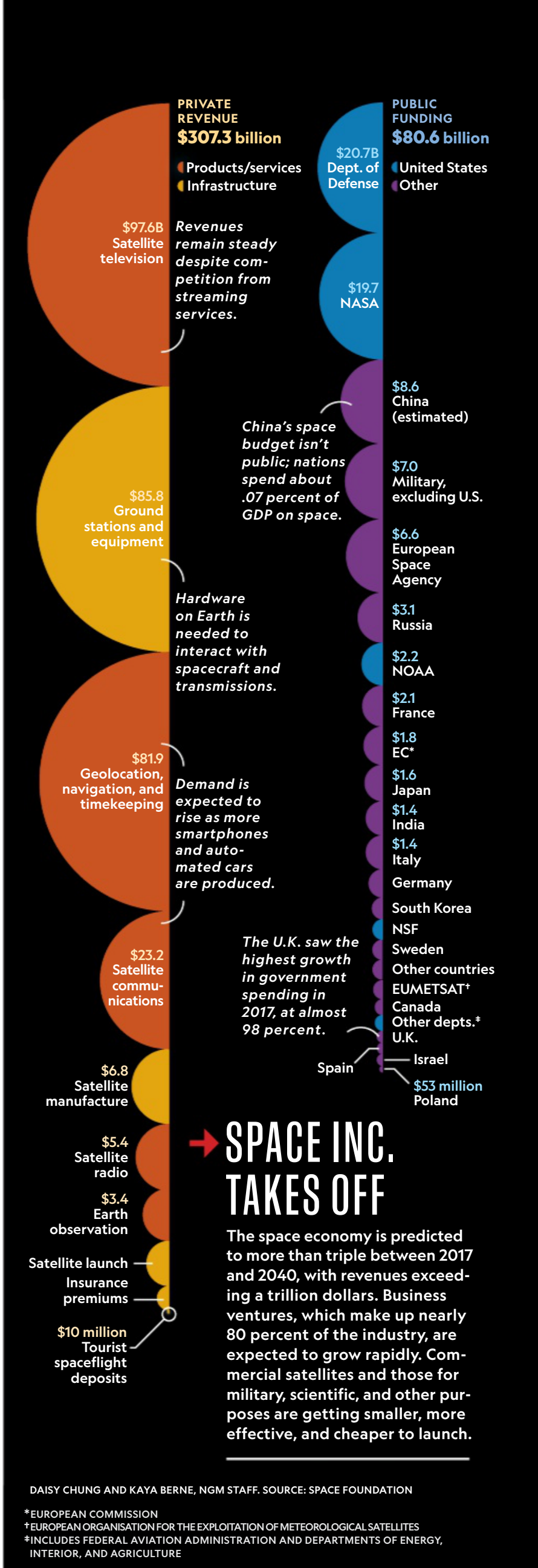
"It's incredibly cold, there's hardly any water, there's no food, and by the way, there's nothing to breathe," Nye said. "And the smell in your space suit—bring all the Febreze you can pack, because you're going to be craving it on Mars." (Nye does favor missions to the red planet, just not permanent habitation.)

The other thing to reiterate: Anything we can do, our robots can do better (in space, that is), with the exception of capturing the majesty of what's there as only an artist or poet could. We've done amazing things in space without sending people there, and not just because we've launched all those satellites into orbit that have propelled quantum leaps in how we communicate, navigate, prognosticate—on the weather, anyway—and do countless other things here on Earth.

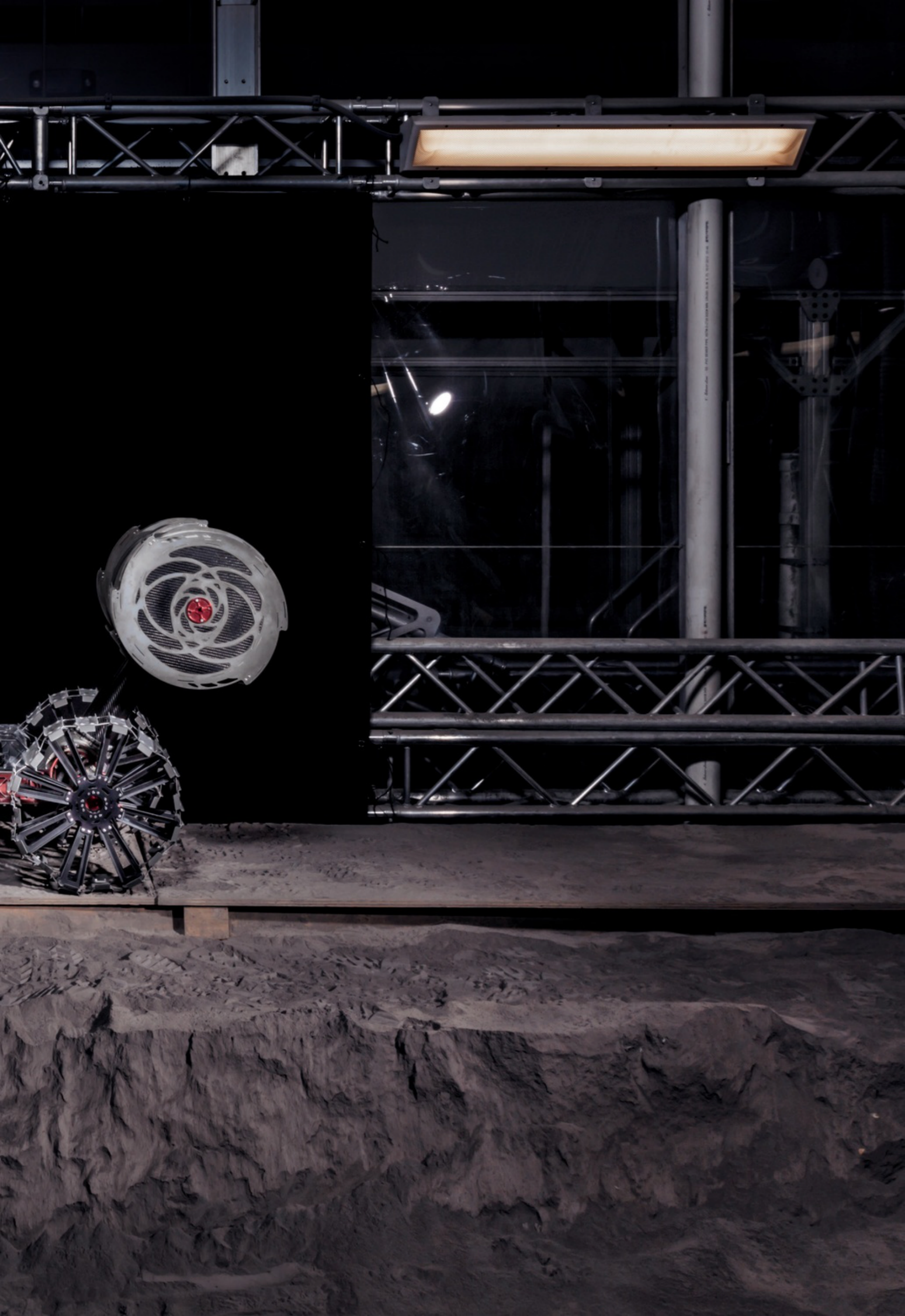
Probes keep sending back detailed images, and soon we will be launching a telescope into space so powerful that it will enable us to peer at faraway objects whose light originated billions of years ago. This may help us answer questions about the early universe and perhaps even locate life elsewhere in the cosmos.

Those remarkable twin Voyager probes, launched in 1977 and fueled by tiny nuclear-powered generators, are still returning data about the environment around them, sent by a radio transmitter that uses about as much power as a standard light bulb. That makes for a faint signal, but here on Earth we can "hear" what the Voyagers have to say because we've developed antennas sensitive enough to pick up the signal.

"Amazing" strikes me as far too limited a word to describe our most far-flung emissaries, which indeed are diplomats in that they each carry the legendary "Golden Record" of earthly sounds,



To excavate, haul, and dump the layer of dust and rocks found on the surface of the moon, NASA designed a mobile robotic platform called RASSOR, shown here at the Kennedy Space Center. To operate in a low-gravity environment, it has counter-rotating bucket drums that are not dependent on traction or weight.



music from around the world, and greetings from Jimmy Carter (the U.S. president at launch time) to inform and entertain any sentient aliens that might encounter them.

That the Voyagers are still hurtling through the heavens illustrates a serious point.

Humans simply couldn't make this trip. With our nettlesome need for air and food and water, protection from cosmic radiation or solar flares, not to mention stimulation so we don't go mad on the long journey to wherever, it's worth asking: Why go at all? Why go, especially when there is basically nothing to be done that a robotic probe cannot do more efficiently, quickly, cheaply, and safely than a human being? Let's face the truth: From mining asteroids for rare materials to snapping photos of other planets, uncrewed probes are better suited to the job.

Yet this raises the question of whether it's important for us to explore. No uncrewed journey—even one of billions of miles—will ever generate quite the thrill, suspense, or awe of a man putting the first footprint on our nearby moon—or a woman doing so someday on Mars. (The next American to step on the moon, Bridenstine says, will likely be a woman.) If members of the human species are driven to scale Mount Everest or slog to the poles, isn't there an inevitable urge onward to Mars and beyond? It's ... you know ... what we do.

"There's a fundamental truth to our nature: Man must explore," Apollo 15 commander David R. Scott radioed in 1971 to ground control in Houston from his spot near Hadley Rille, a valley on the moon. "And this is exploration at its greatest."

There's also the matter of what some futurists call an "insurance policy" for the survival of the species and others call our Plan B in case Earth itself were to become uninhabitable. That could happen through a force beyond our control, like the asteroid that seems to have annihilated the dinosaurs, or by our own folly, through nuclear war or drastic derangement of our climate.

We've been worried about Plan A, and that's a good thing, because it's by far the best plan we have, and it may be the only one. As the environmental activist and author Bill McKibben puts it, the least hospitable patch of Earth is still far more hospitable to human life than any reachable spot we have found anywhere else.

The central irony of the first space age was that the most iconic images it yielded were not those of the moon or the other planets, but the ones of our own planet. "Earthrise," our serene-looking blue orb swaddled in swirling clouds over the moon's horizon, is the most famous. These photographs galvanized the environmental movement, spurred new laws to clean our water and air, and prompted a lot of people to ask a simple question: "Shouldn't we be spending all that money to fix our own problems first?"

The "all that money" part referred to the space program, which in some years consumed 4.5 percent of the federal budget. (Today NASA's budget is half of one percent.) Getting men and women to Mars before now could easily have cost at least that much, so there's a pretty good case to be made that we've been right to take a pass so far.

We're now entering that second space age, in which relentless innovations such as reusable rockets are driving down the cost of getting there. It will surely prove much less expensive to get to Mars in another decade or three than it would be today, and certainly less than it would have been in the 1980s. That's a good bargain, even if those of us who watched Neil Armstrong kick up a little moondust never dreamed that it would take that long.

How much longer remains the wild card.

A serious accident or tragedy in any space venture tends to set back all of them, sometimes by years. Funding is hardly bottomless: For the moment, for instance, plans for asteroid mining seem to have stalled a bit. It may or may not be true that (as the industry's cheerleaders contend) there's a trillion dollars or more to be harvested from rare minerals out in space, but what if it takes $100 billion or $200 billion to develop the technology to try to find out? That's a lot of money to wager that your unicorn will come in.

Finally, space has a dark side, and not just the vast empty blackness that astronauts who have been through it describe. With the United States, China, and Russia all developing space weaponry (for defensive purposes, all three insist), we could find ourselves fighting a future war in space, launching missiles, destroying satellites, and training powerful laser weapons on earthbound targets, including people.

On my way to the Soyuz rocket launch in Kazakhstan, I stopped first in Moscow to meet with a few cosmonauts and visit some museums, because it's hard to

We're entering a second space age, in which innovations such as reusable rockets are driving down the cost of getting to Mars. The wild card: How much longer will it take to get there?

appreciate how NASA's astronauts got to the moon without understanding the challenge posed by the Soviet space program that spurred them there.

Americans tend to view the push to the lunar landing as they would, say, a football game. Nobody really remembers or cares who was ahead during most of the contest; the important thing is who won, even if they had to come from three touchdowns behind to do it. By that score, the U.S. triumphed. End of story.

But in Russia, where Soviet-era cosmonauts are national icons, you come away with a Bizarro World view of a completely different space race.

In the Russian telling, the whole thing was more of a track meet, and they killed on points, even if the Americans bagged a prestige event at the end.

The list of Soviet firsts in space is indeed impressive, from the first satellite, dogs, man, and woman in space to the first multiperson crew and space walk. It's enough to make any American appreciate the magnitude of our national humiliation in space at the hands of our Communist adversaries at the height of the Cold War and why President John F. Kennedy's pledge to land astronauts on the moon and return them to Earth by the end of the 1960s was such a brilliant gambit to recoup prestige on the global stage.

Interestingly, the cosmonauts I met in Russia seemed to share two perspectives with their American counterparts. First, their time in space made them profoundly more interested in protecting the Earth. (Indeed, two cosmonauts gave me books they had written—not on space, but on protecting our environment.) Second, even while strongly favoring human space exploration, they think the idea of permanent, widespread human colonization of space is bonkers.

"It's not … pleasant, actually," Viktor Savinykh said after a long pause when I asked him about living in space.

Savinykh, 79, is famous in Russia for his role in the daring repair of a crippled, ice-encrusted, and dangerously out-of-orbit Salyut space station in 1985. "You get disoriented so easily, you can't remember things up there," he continued. "It's really hard on the brain. All that sun in your eyes. It's hard to describe. Your body weakens."

Still, he acknowledged that Bezos's vision could come to pass someday.

"I don't have the answers to this," Savinykh told me. "The new generation and then the next and then the next—they will get to decide. We did our part."

Those generations are certainly going to ask intriguing questions. Toward the end of the space conference I'd attended in Washington, a panel of U.S. astronauts fielded videotaped queries sent in by schoolkids from around the world.

"Is it possible," a five-year-old boy from Baltimore named Braith Ortenzi wanted to know, "to get from galaxy to galaxy?"

"I'm glad he's thinking big!" replied Chris Ferguson, a veteran of three space shuttle missions who's slated to be on the first Boeing Starliner trip to the space station. "We're going to have to master this whole light-speed thing," he added as the audience broke into laughter, "before we get galaxy to galaxy."

"He'll develop the technology to do it!" interjected Victor Glover, an astronaut slated for the first SpaceX Crew Dragon flight.

"Please take us," said Nicole Stott, a retired astronaut and veteran of two trips to the space station. "Take us with you!"

Glover, nodding with a huge grin, had the final word: "It's on you, brother!" □

Sam Howe Verhovek really did stare long and hard at the moon on July 20, 1969, thinking he might spot the Apollo 11 lunar module. As a boy, **Dan Winters** wanted to be an astronaut; now he revels in chronicling humankind's explorations in space. **Nadia Drake** has dreamed of dancing on the moon for as long as she can remember.