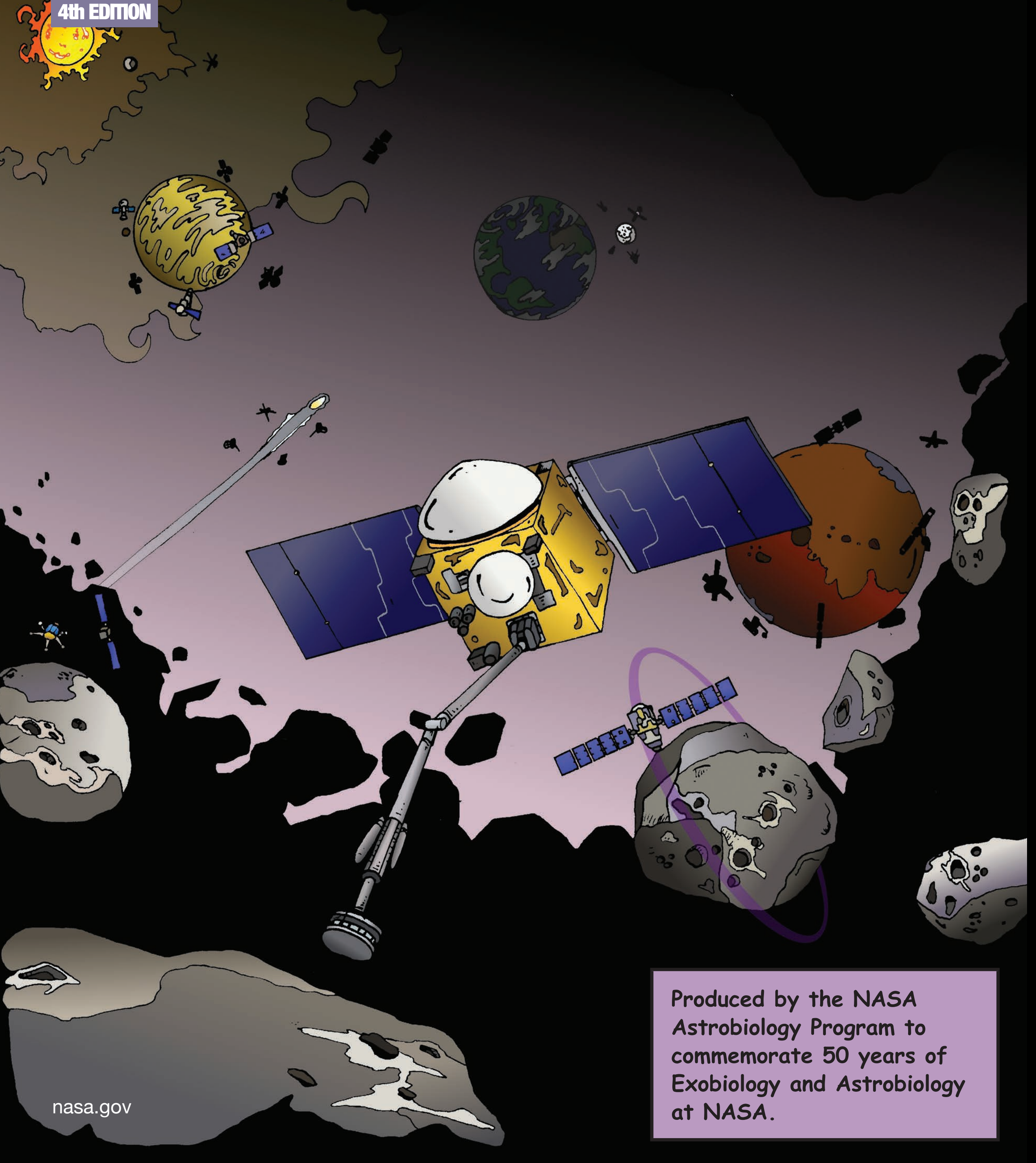
National Aeronautics and Space Administration

Issue #3

4th EDITION

ASTROBIOLOGY

The Story of our Search for Life in the Universe



Produced by the NASA Astrobiology Program to commemorate 50 years of Exobiology and Astrobiology at NASA.

nasa.gov

Astrobiology

A History of Exobiology and Astrobiology at NASA

This is the story of life in the Universe — or at least the story as we know it so far. As scientists, we strive to understand the environment in which we live and how life relates to this environment. As astrobiologists, we study an environment that includes not just the Earth, but the entire Universe in which we live.

The year 2010 marked 50 years of Exobiology and Astrobiology research at the National Aeronautics and Space Administration (NASA). To celebrate, the Astrobiology Program commissioned this graphic history. It tells the story of some of the most important people and events that have shaped the science of Exobiology and Astrobiology. Beginning shortly after the establishment of NASA, this field is relatively young. However, as you will see, the questions that astrobiologists are trying to answer are as old as humankind.

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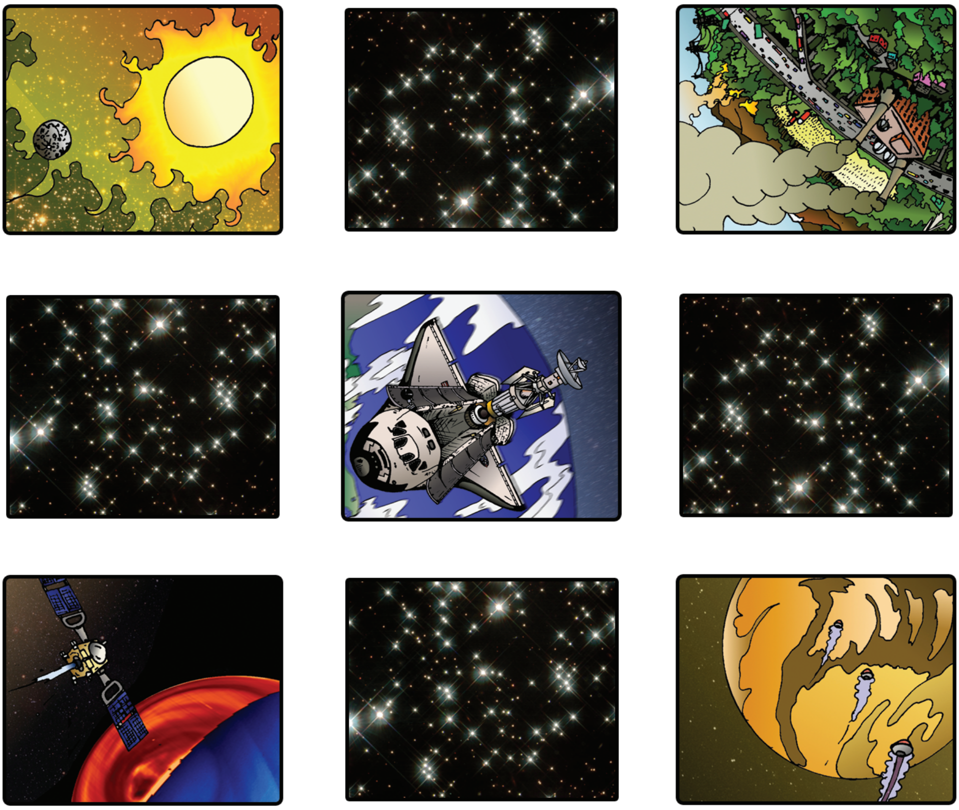
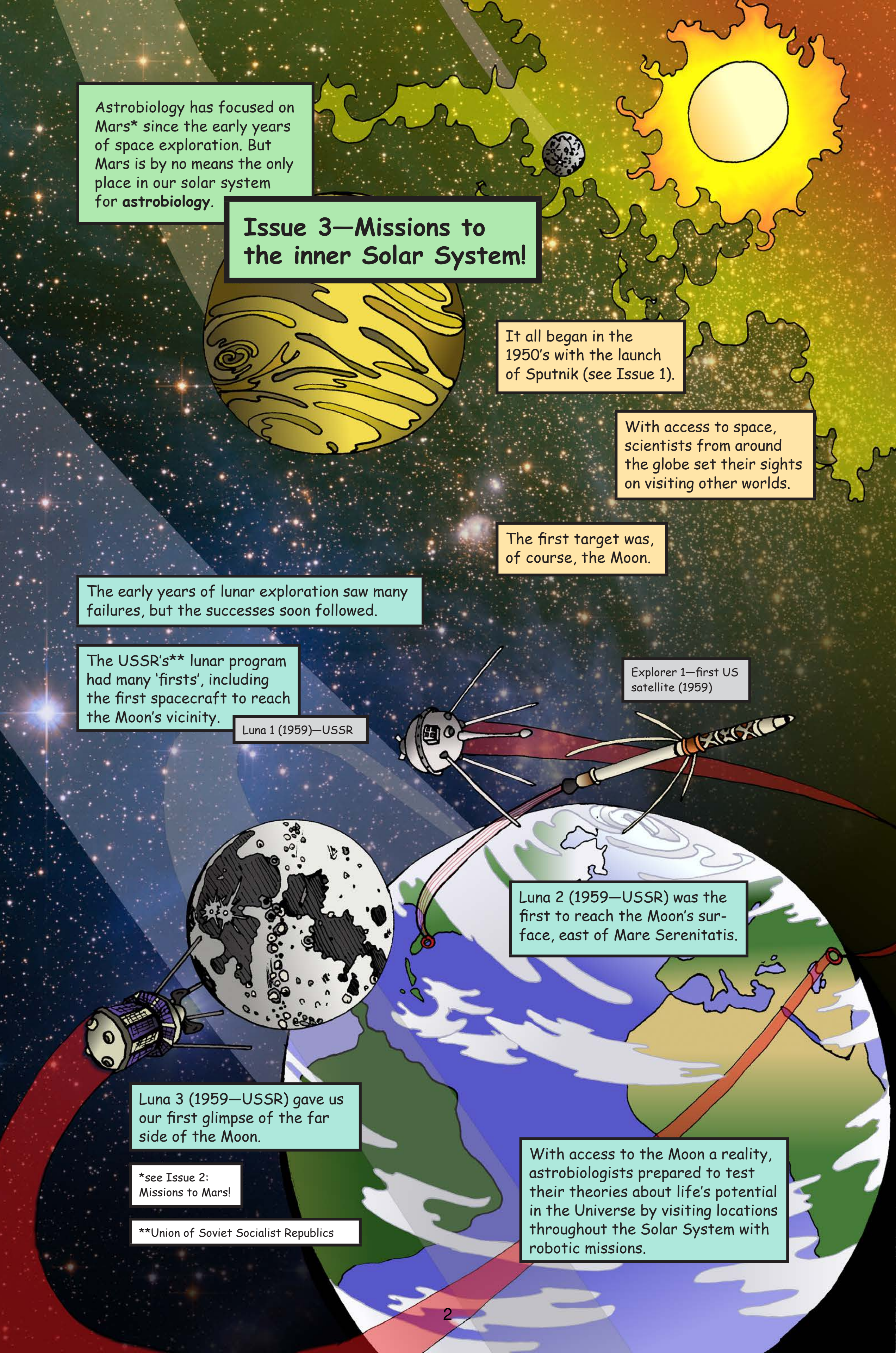
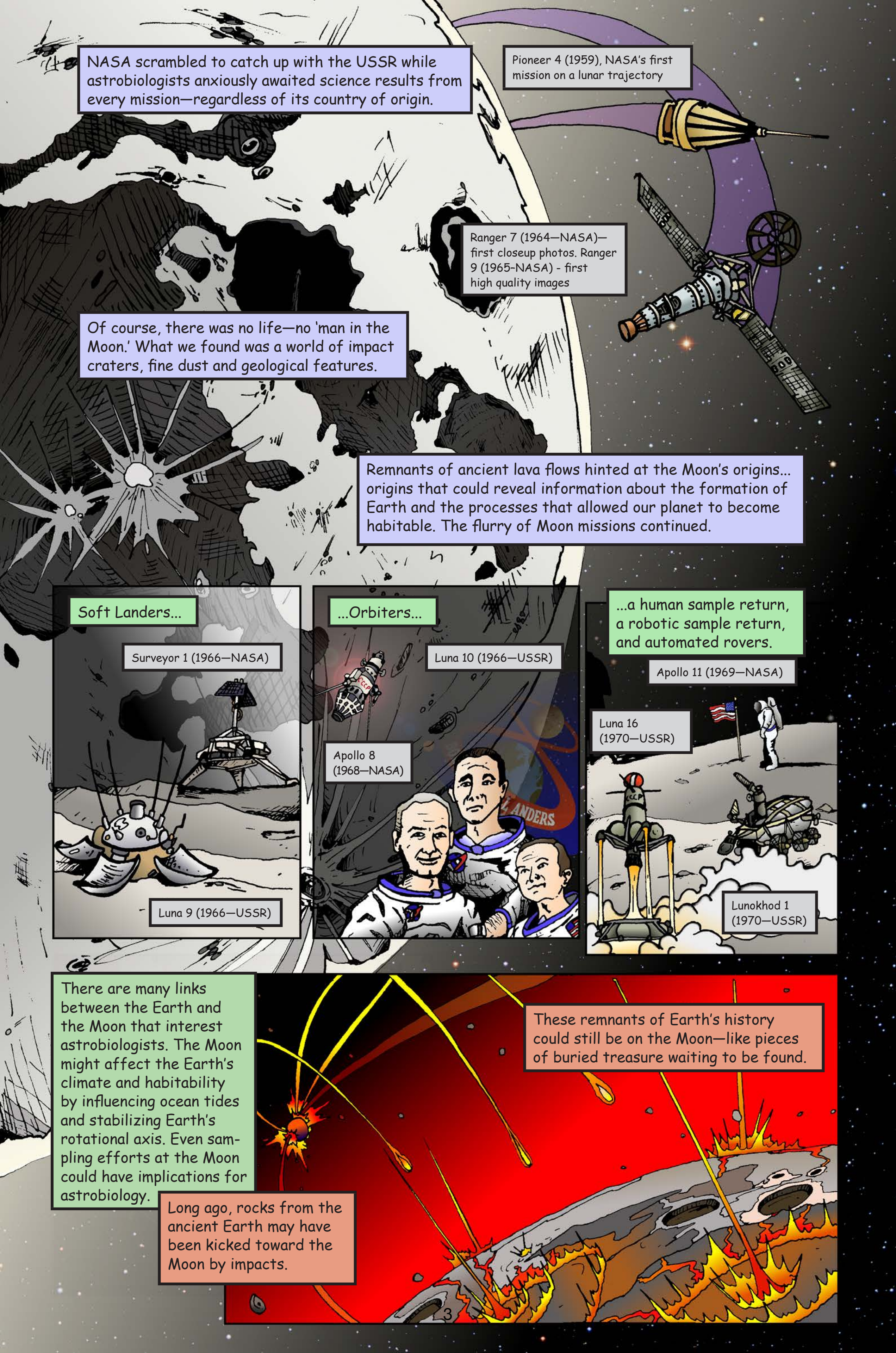
Issue #3
Missions to the inner Solar System!



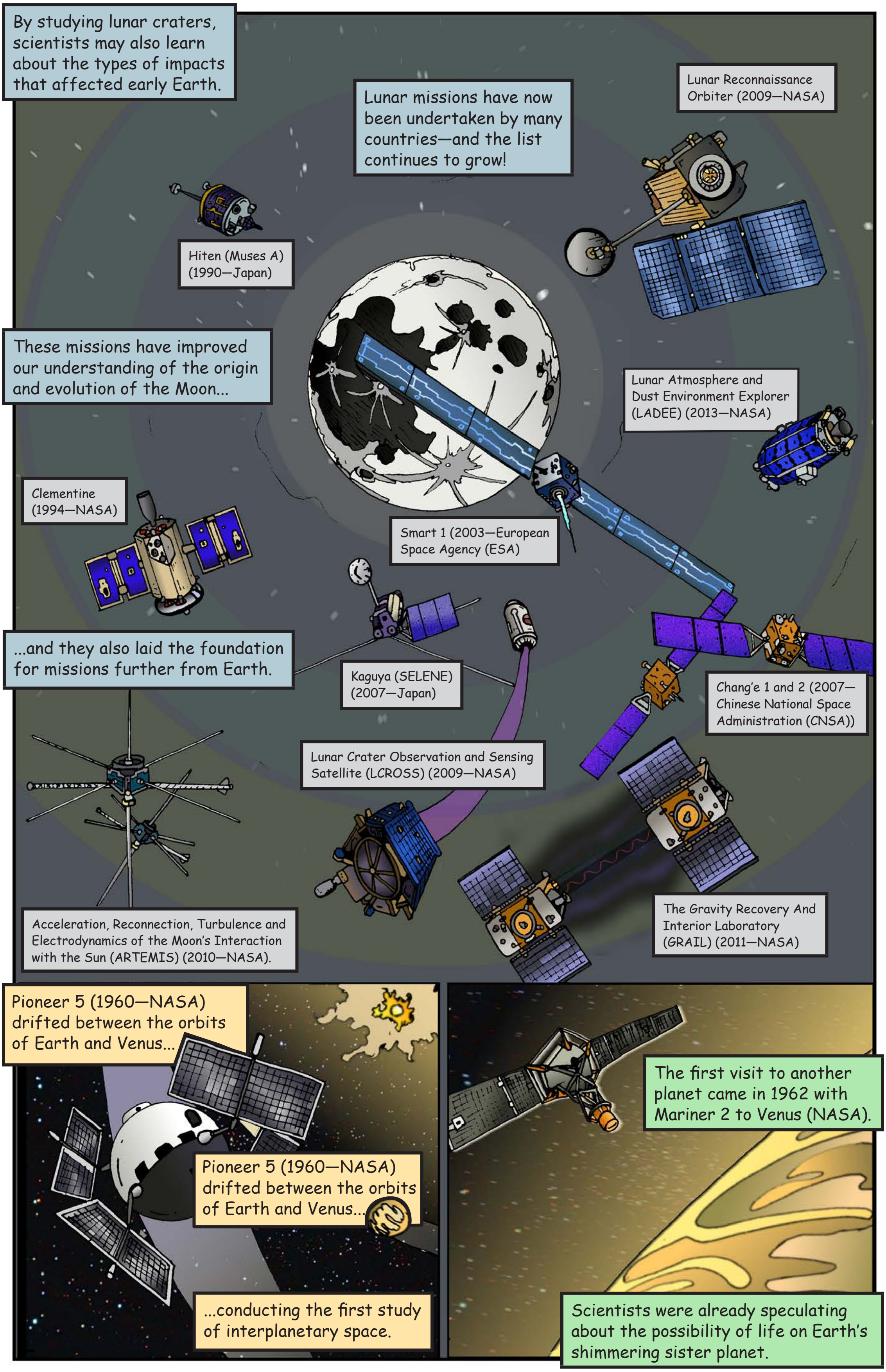
The year 2010 marked the 50th anniversary of NASA's Exobiology Program, established in 1960 and expanded into a broader Astrobiology Program in the 1990s. We are telling the story of how this field developed and how the search for life elsewhere became a key component of NASA's science strategy for exploring space. This issue is the sixth in a series of graphic history books. Though not comprehensive, the series has been conceived to highlight key moments and key people in the field as it explains how Astrobiology came to be.

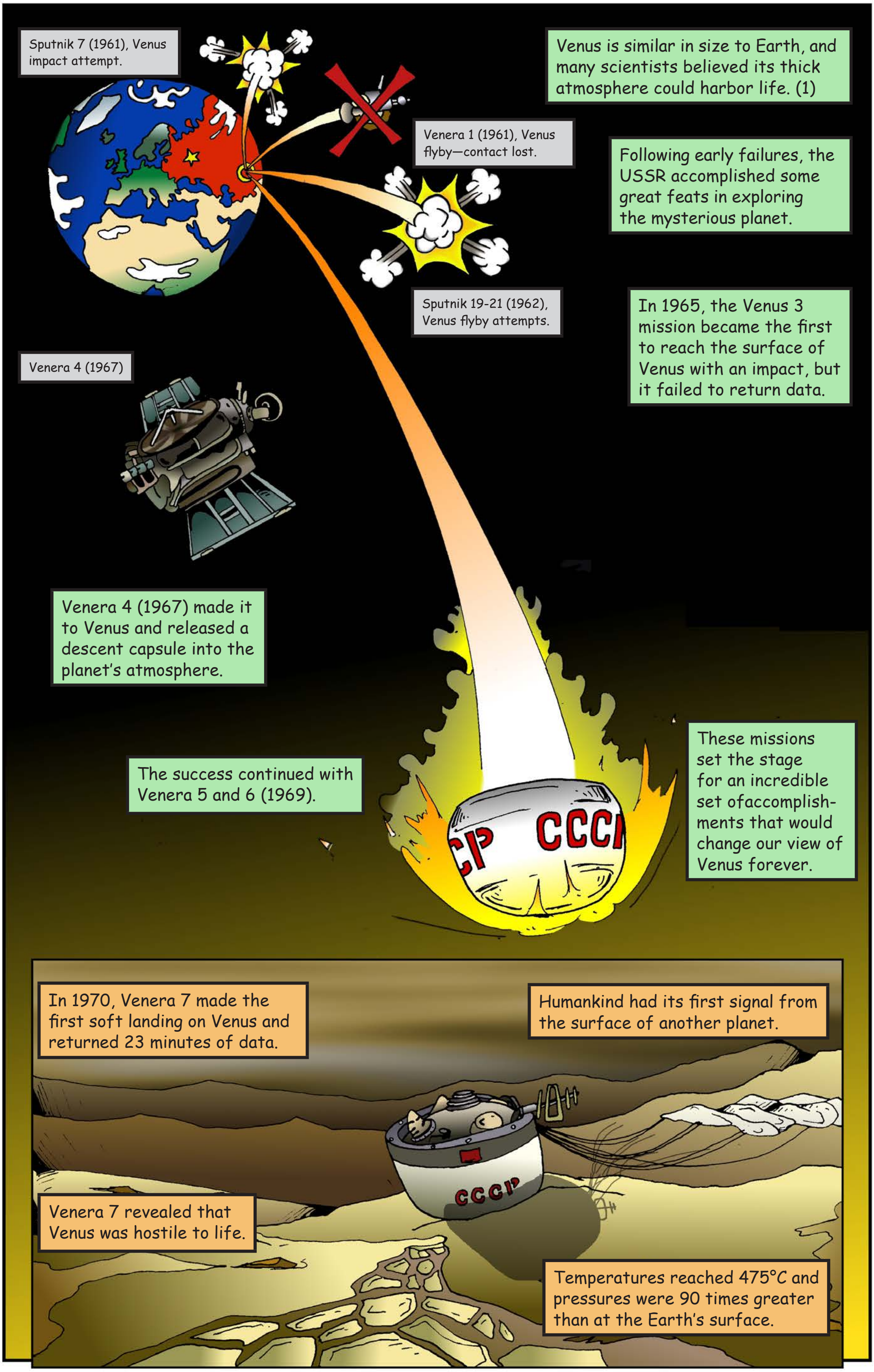
-Linda Billings, Editor


Astrobiology has focused on Mars* since the early years of space exploration. But Mars is by no means the only place in our solar system for **astrobiology**.
Issue 3—Missions to the inner Solar System!
It all began in the 1950's with the launch of Sputnik (see Issue 1).
With access to space, scientists from around the globe set their sights on visiting other worlds.
The first target was, of course, the Moon.
The early years of lunar exploration saw many failures, but the successes soon followed.
The USSR's** lunar program had many 'firsts', including the first spacecraft to reach the Moon's vicinity.
Luna 1 (1959)—USSR
Explorer 1—first US satellite (1959)
Luna 2 (1959—USSR) was the first to reach the Moon's surface, east of Mare Serenitatis.
Luna 3 (1959—USSR) gave us our first glimpse of the far side of the Moon.
*see Issue 2: Missions to Mars!
**Union of Soviet Socialist Republics
With access to the Moon a reality, astrobiologists prepared to test their theories about life's potential in the Universe by visiting locations throughout the Solar System with robotic missions.

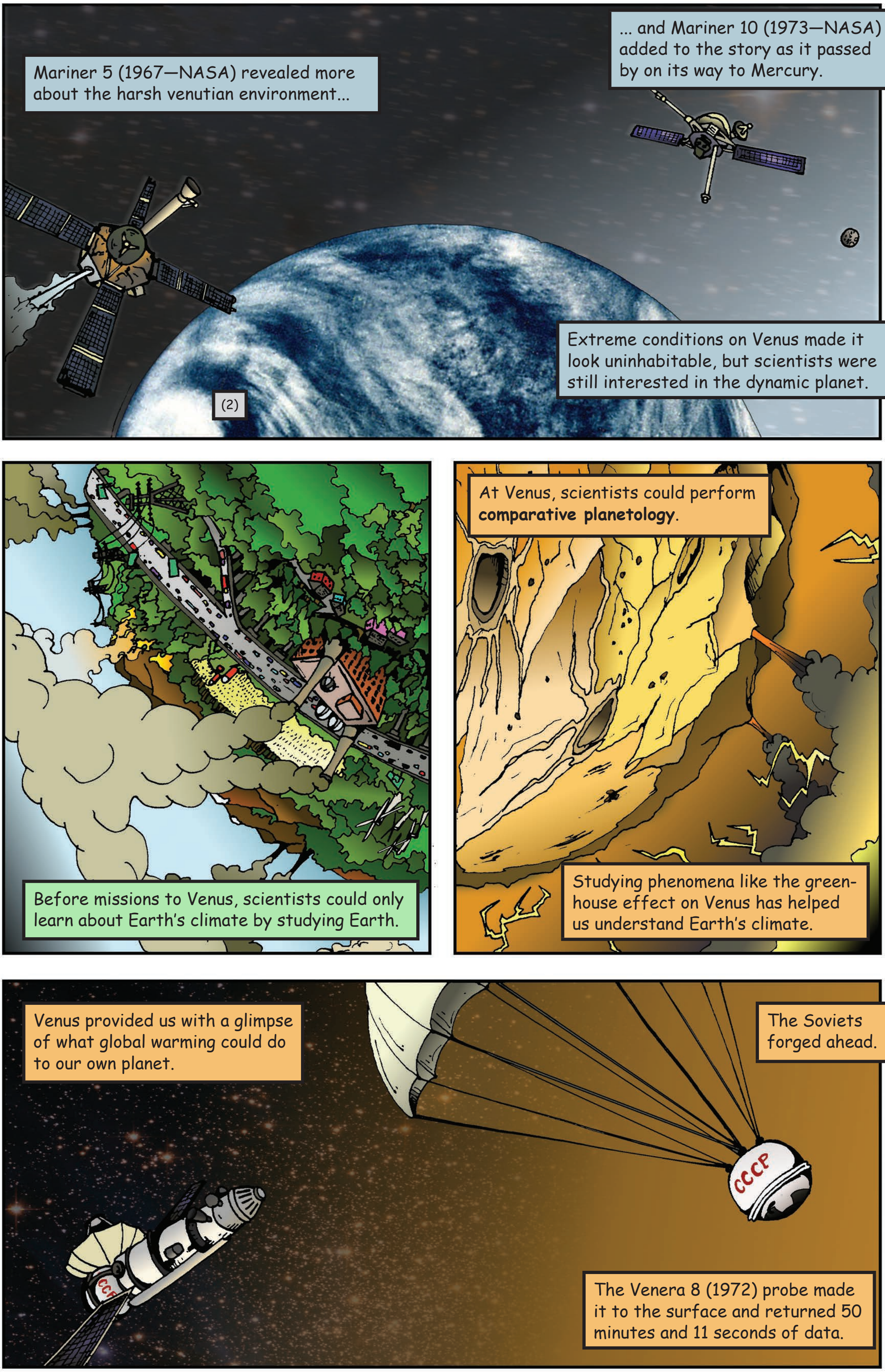


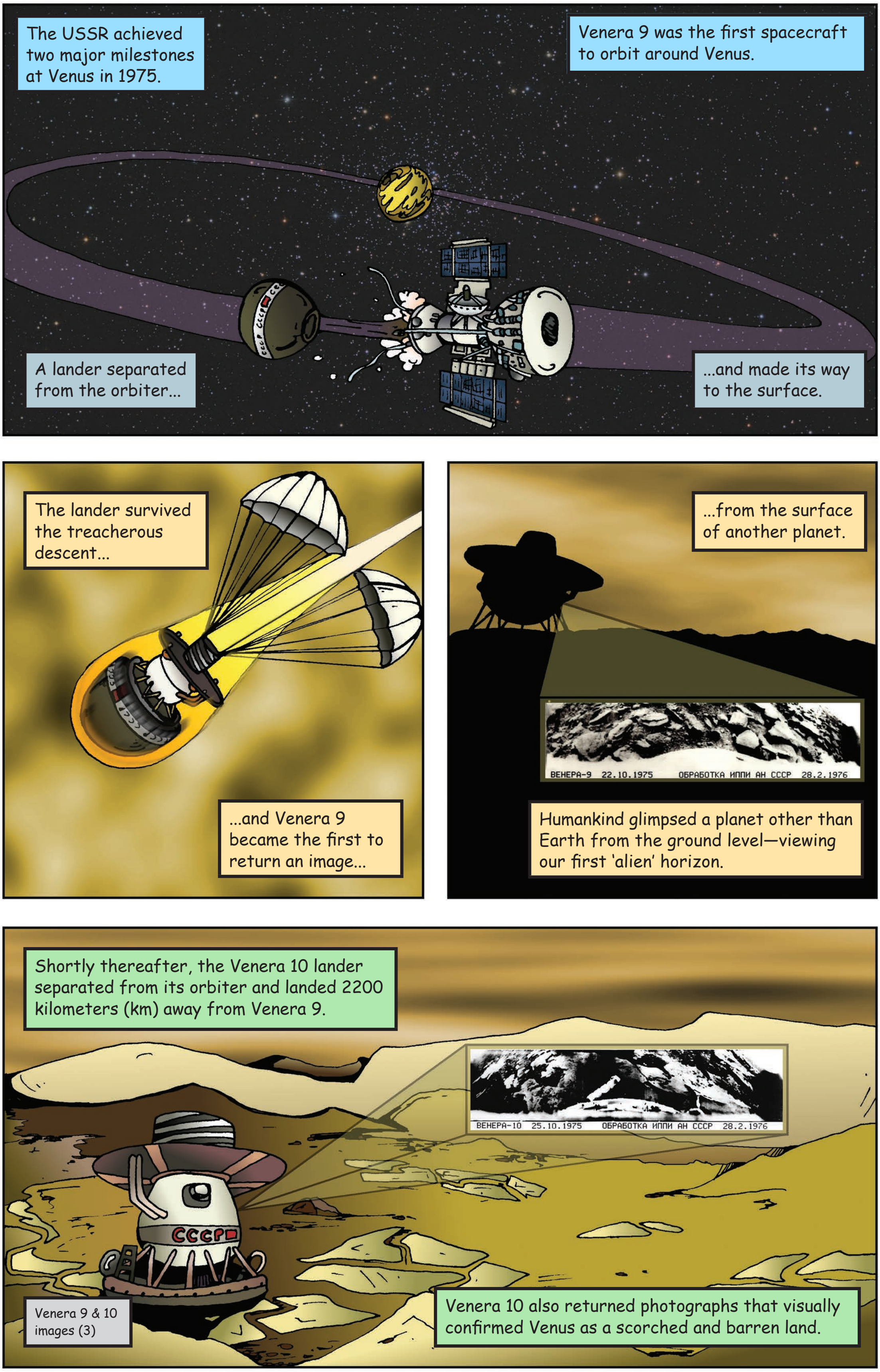
NASA scrambled to catch up with the USSR while astrobiologists anxiously awaited science results from every mission—regardless of its country of origin.
Pioneer 4 (1959), NASA's first mission on a lunar trajectory
Ranger 7 (1964—NASA)—first closeup photos. Ranger 9 (1965-NASA) - first high quality images
Of course, there was no life—no 'man in the Moon.' What we found was a world of impact craters, fine dust and geological features.
Remnants of ancient lava flows hinted at the Moon's origins... origins that could reveal information about the formation of Earth and the processes that allowed our planet to become habitable. The flurry of Moon missions continued.
Soft Landers...
Surveyor 1 (1966—NASA)
Luna 9 (1966—USSR)
...Orbiters...
Luna 10 (1966—USSR)
Apollo 8 (1968—NASA)
ANDERS
...a human sample return, a robotic sample return, and automated rovers.
Apollo 11 (1969—NASA)
Luna 16 (1970—USSR)
Lunokhod 1 (1970—USSR)
There are many links between the Earth and the Moon that interest astrobiologists. The Moon might affect the Earth's climate and habitability by influencing ocean tides and stabilizing Earth's rotational axis. Even sampling efforts at the Moon could have implications for astrobiology.
These remnants of Earth's history could still be on the Moon—like pieces of buried treasure waiting to be found.
Long ago, rocks from the ancient Earth may have been kicked toward the Moon by impacts.


By studying lunar craters, scientists may also learn about the types of impacts that affected early Earth.
Lunar missions have now been undertaken by many countries—and the list continues to grow!
Lunar Reconnaissance Orbiter (2009—NASA)
Hiten (Muses A) (1990—Japan)
These missions have improved our understanding of the origin and evolution of the Moon...
Lunar Atmosphere and Dust Environment Explorer (LADEE) (2013—NASA)
Clementine (1994—NASA)
Smart 1 (2003—European Space Agency (ESA)
...and they also laid the foundation for missions further from Earth.
Kaguya (SELENE) (2007—Japan)
Chang'e 1 and 2 (2007—Chinese National Space Administration (CNSA))
Lunar Crater Observation and Sensing Satellite (LCROSS) (2009—NASA)
Acceleration, Reconnection, Turbulence and Electrodynamics of the Moon's Interaction with the Sun (ARTEMIS) (2010—NASA).
The Gravity Recovery And Interior Laboratory (GRAIL) (2011—NASA)
Pioneer 5 (1960—NASA) drifted between the orbits of Earth and Venus...
Pioneer 5 (1960—NASA) drifted between the orbits of Earth and Venus...
...conducting the first study of interplanetary space.
The first visit to another planet came in 1962 with Mariner 2 to Venus (NASA).
Scientists were already speculating about the possibility of life on Earth's shimmering sister planet.

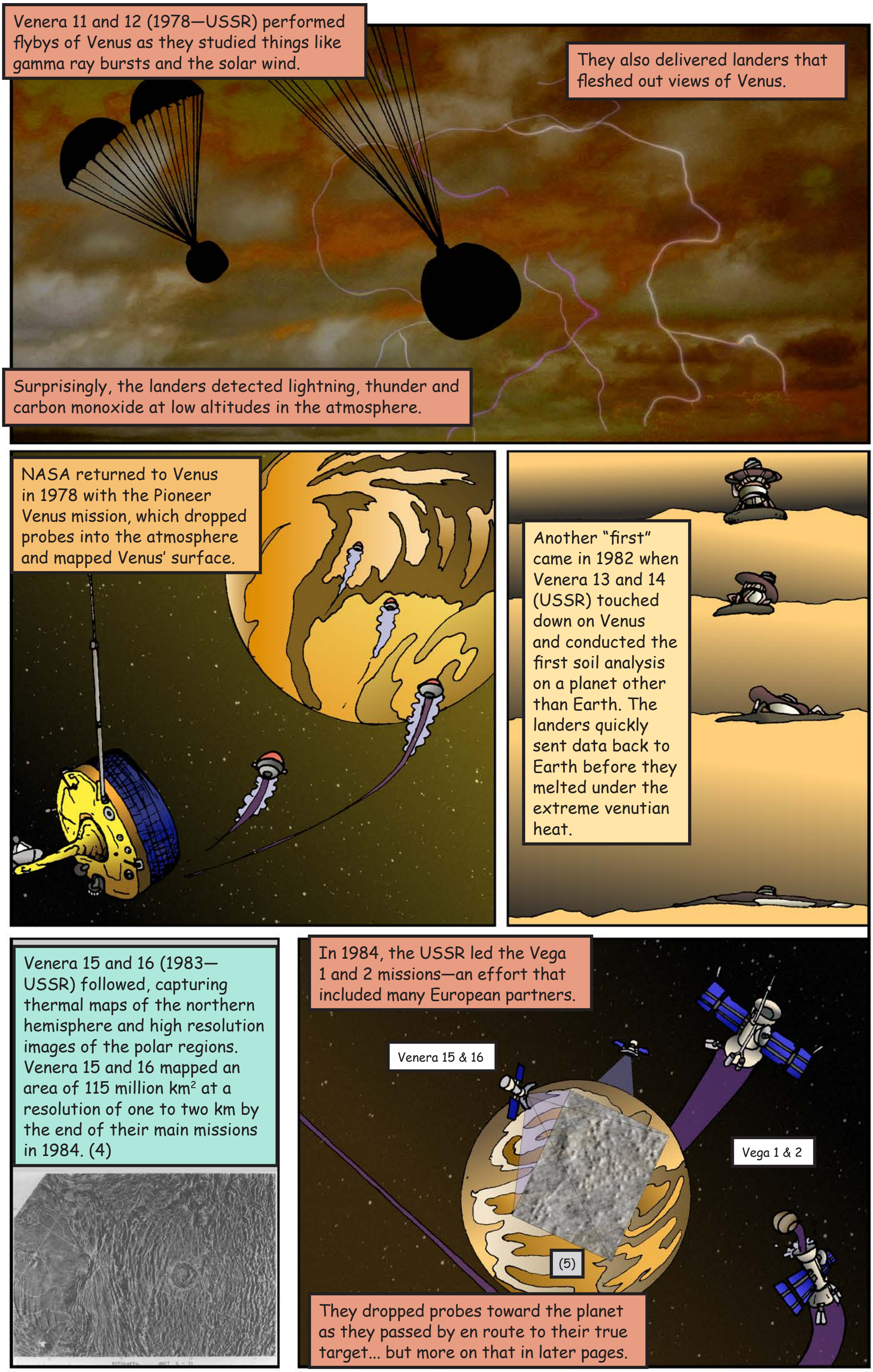


Sputnik 7 (1961), Venus impact attempt.
Venus is similar in size to Earth, and many scientists believed its thick atmosphere could harbor life. (1)
Venera 1 (1961), Venus flyby—contact lost.
Following early failures, the USSR accomplished some great feats in exploring the mysterious planet.
Sputnik 19-21 (1962), Venus flyby attempts.
In 1965, the Venus 3 mission became the first to reach the surface of Venus with an impact, but it failed to return data.
Venera 4 (1967)
Venera 4 (1967) made it to Venus and released a descent capsule into the planet's atmosphere.
The success continued with Venera 5 and 6 (1969).
CCCP
These missions set the stage for an incredible set ofaccomplish-ments that would change our view of Venus forever.
In 1970, Venera 7 made the first soft landing on Venus and returned 23 minutes of data.
Humankind had its first signal from the surface of another planet.
CCCP
Venera 7 revealed that Venus was hostile to life.
Temperatures reached 475°C and pressures were 90 times greater than at the Earth's surface.

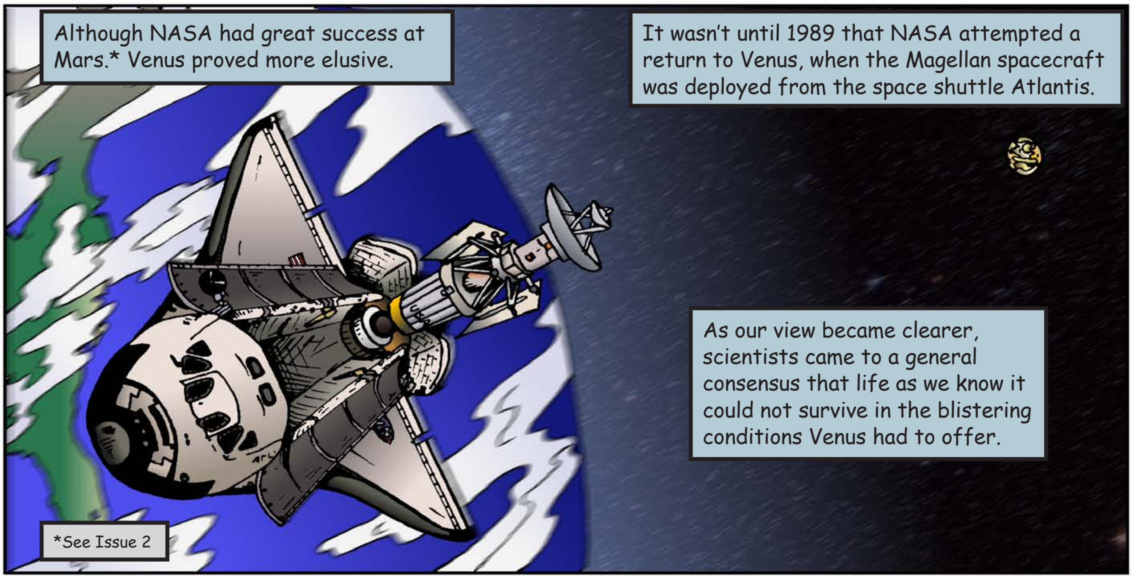

Mariner 5 (1967—NASA) revealed more about the harsh venutian environment...
... and Mariner 10 (1973—NASA) added to the story as it passed by on its way to Mercury.
Extreme conditions on Venus made it look uninhabitable, but scientists were still interested in the dynamic planet.
(2)
Before missions to Venus, scientists could only learn about Earth's climate by studying Earth.
At Venus, scientists could perform **comparative planetology**.
Studying phenomena like the greenhouse effect on Venus has helped us understand Earth's climate.
Venus provided us with a glimpse of what global warming could do to our own planet.
The Soviets forged ahead.
CCCP
The Venera 8 (1972) probe made it to the surface and returned 50 minutes and 11 seconds of data.

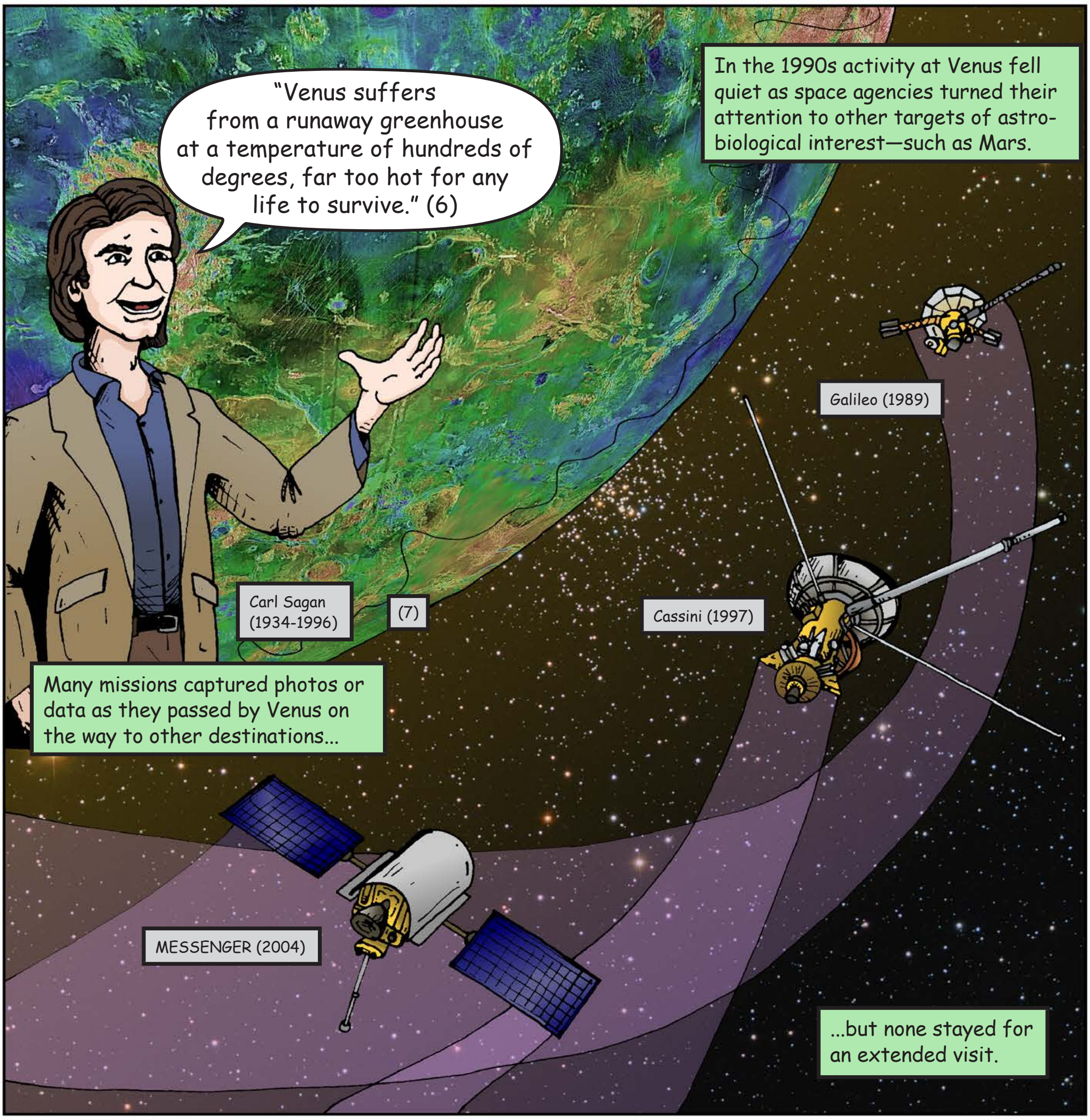


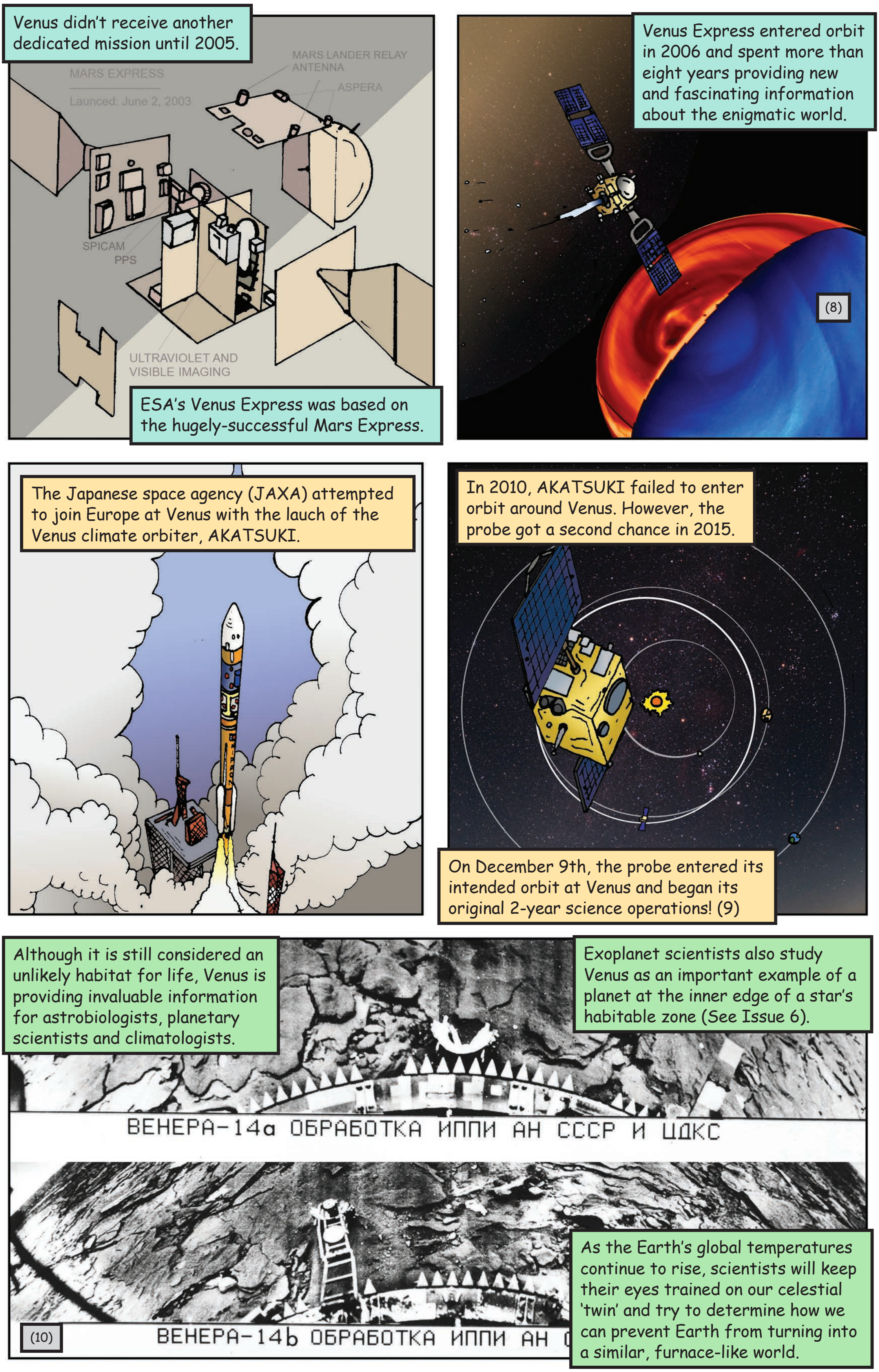
Venera 9 & 10 images (3)

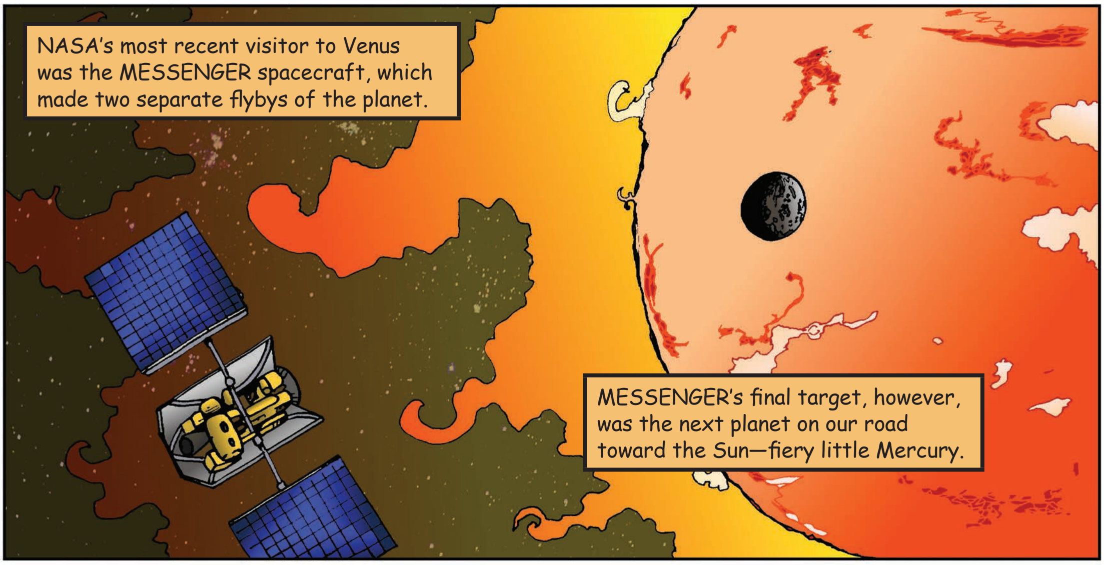


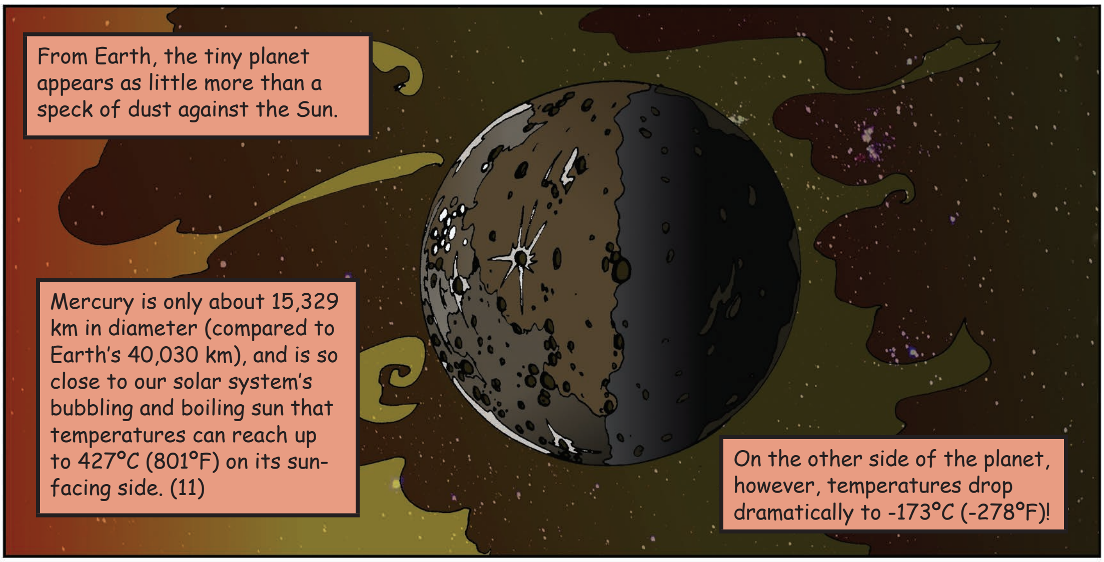
Venera 11 and 12 (1978—USSR) performed flybys of Venus as they studied things like gamma ray bursts and the solar wind.
They also delivered landers that fleshed out views of Venus.
Surprisingly, the landers detected lightning, thunder and carbon monoxide at low altitudes in the atmosphere.
NASA returned to Venus in 1978 with the Pioneer Venus mission, which dropped probes into the atmosphere and mapped Venus' surface.
Another "first" came in 1982 when Venera 13 and 14 (USSR) touched down on Venus and conducted the first soil analysis on a planet other than Earth. The landers quickly sent data back to Earth before they melted under the extreme venutian heat.
Venera 15 and 16 (1983—USSR) followed, capturing thermal maps of the northern hemisphere and high resolution images of the polar regions. Venera 15 and 16 mapped an area of 115 million km² at a resolution of one to two km by the end of their main missions in 1984. (4)
In 1984, the USSR led the Vega 1 and 2 missions—an effort that included many European partners.
Venera 15 & 16
Vega 1 & 2
(5)
They dropped probes toward the planet as they passed by en route to their true target... but more on that in later pages.

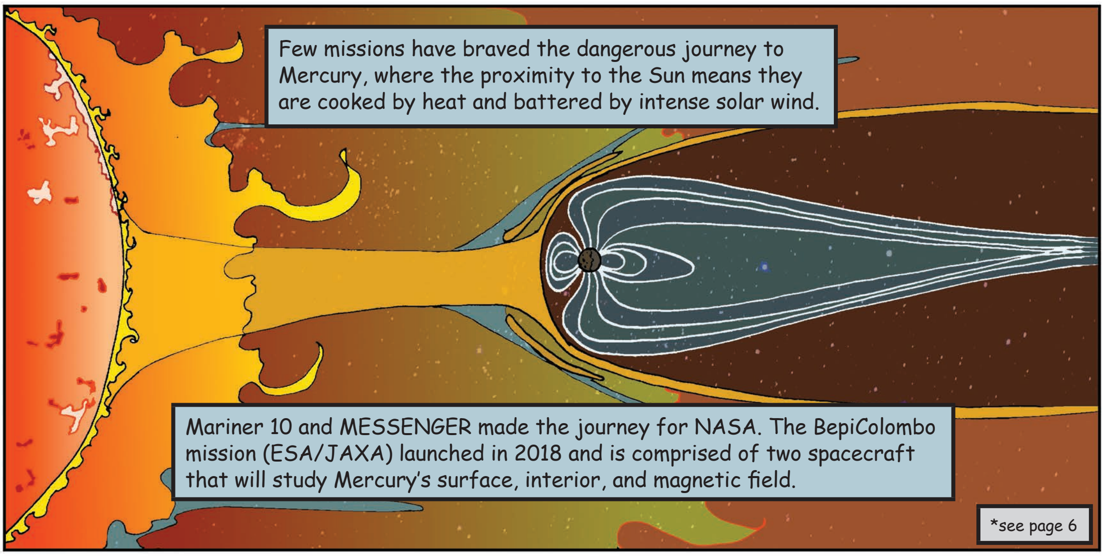

Although NASA had great success at Mars.* Venus proved more elusive.
It wasn't until 1989 that NASA attempted a return to Venus, when the Magellan spacecraft was deployed from the space shuttle Atlantis.
As our view became clearer, scientists came to a general consensus that life as we know it could not survive in the blistering conditions Venus had to offer.
*See Issue 2

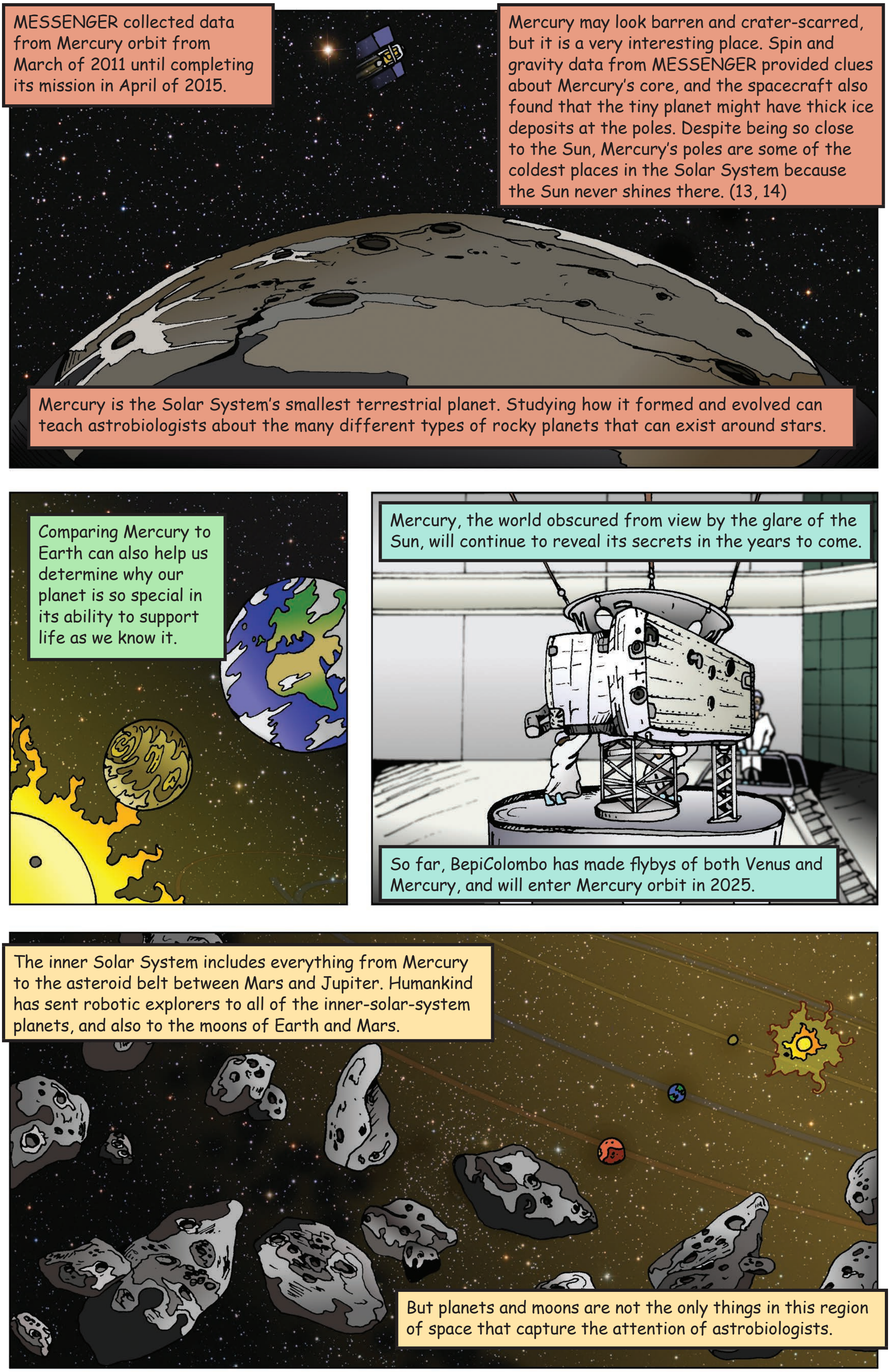

"Venus suffers from a runaway greenhouse at a temperature of hundreds of degrees, far too hot for any life to survive." (6)
In the 1990s activity at Venus fell quiet as space agencies turned their attention to other targets of astro-biological interest—such as Mars.
Galileo (1989)
Carl Sagan (1934-1996)
(7)
Cassini (1997)
Many missions captured photos or data as they passed by Venus on the way to other destinations...
MESSENGER (2004)
...but none stayed for an extended visit.


Venus didn't receive another dedicated mission until 2005.
MARS EXPRESS
Launced: June 2, 2003
MARS LANDER RELAY ANTENNA
ASPERA
SPICAM
PPS
ULTRAVIOLET AND VISIBLE IMAGING
ESA's Venus Express was based on the hugely-successful Mars Express.
Venus Express entered orbit in 2006 and spent more than eight years providing new and fascinating information about the enigmatic world.
(8)
The Japanese space agency (JAXA) attempted to join Europe at Venus with the lauch of the Venus climate orbiter, AKATSUKI.
In 2010, AKATSUKI failed to enter orbit around Venus. However, the probe got a second chance in 2015.
On December 9th, the probe entered its intended orbit at Venus and began its original 2-year science operations! (9)
Although it is still considered an unlikely habitat for life, Venus is providing invaluable information for astrobiologists, planetary scientists and climatologists.
Exoplanet scientists also study Venus as an important example of a planet at the inner edge of a star's habitable zone (See Issue 6).
ВЕНЕРА-14а ОБРАБОТКА ИППИ АН СССР И ЦДКС
ВЕНЕРА-14b ОБРАБОТКА ИППИ АН
(10)
As the Earth's global temperatures continue to rise, scientists will keep their eyes trained on our celestial 'twin' and try to determine how we can prevent Earth from turning into a similar, furnace-like world.

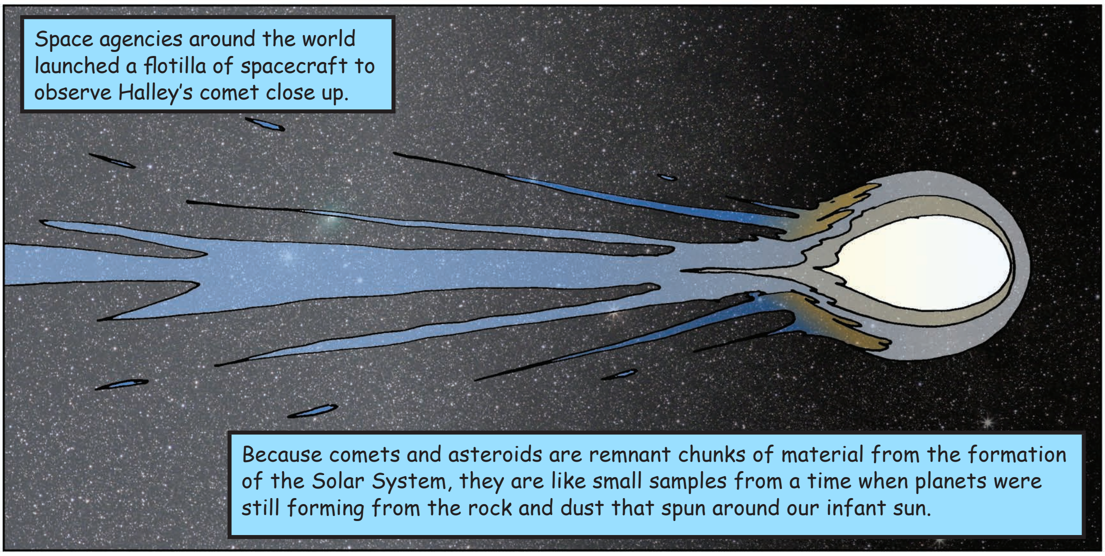

NASA's most recent visitor to Venus was the MESSENGER spacecraft, which made two separate flybys of the planet.
MESSENGER's final target, however, was the next planet on our road toward the Sun—fiery little Mercury.

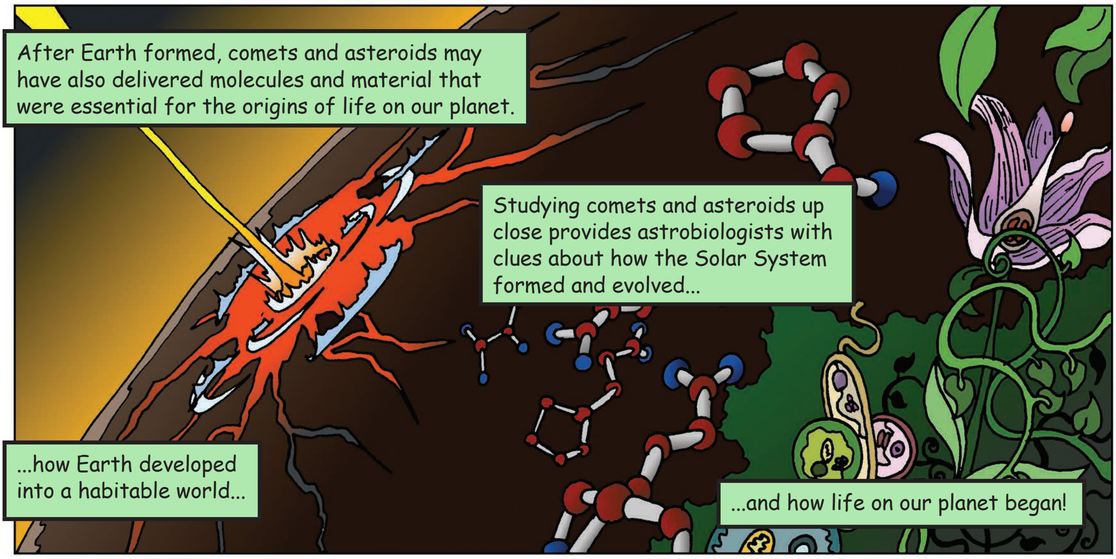

From Earth, the tiny planet appears as little more than a speck of dust against the Sun.
Mercury is only about 15,329 km in diameter (compared to Earth's 40,030 km), and is so close to our solar system's bubbling and boiling sun that temperatures can reach up to 427°C (801°F) on its sun-facing side. (11)
On the other side of the planet, however, temperatures drop dramatically to -173°C (-278°F)!

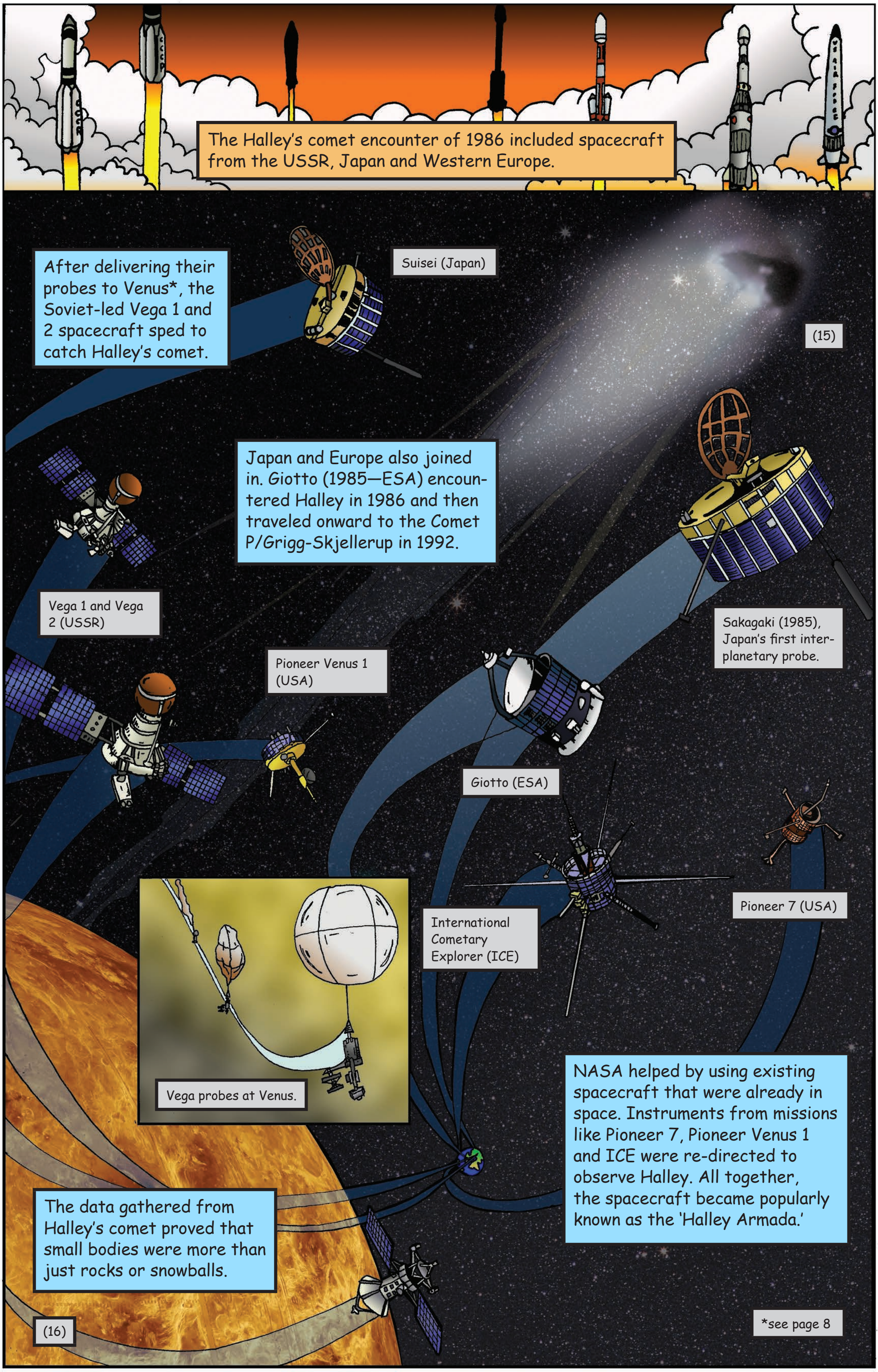

Few missions have braved the dangerous journey to Mercury, where the proximity to the Sun means they are cooked by heat and battered by intense solar wind.
Mariner 10 and MESSENGER made the journey for NASA. The BepiColombo mission (ESA/JAXA) launched in 2018 and is comprised of two spacecraft that will study Mercury's surface, interior, and magnetic field.
*see page 6

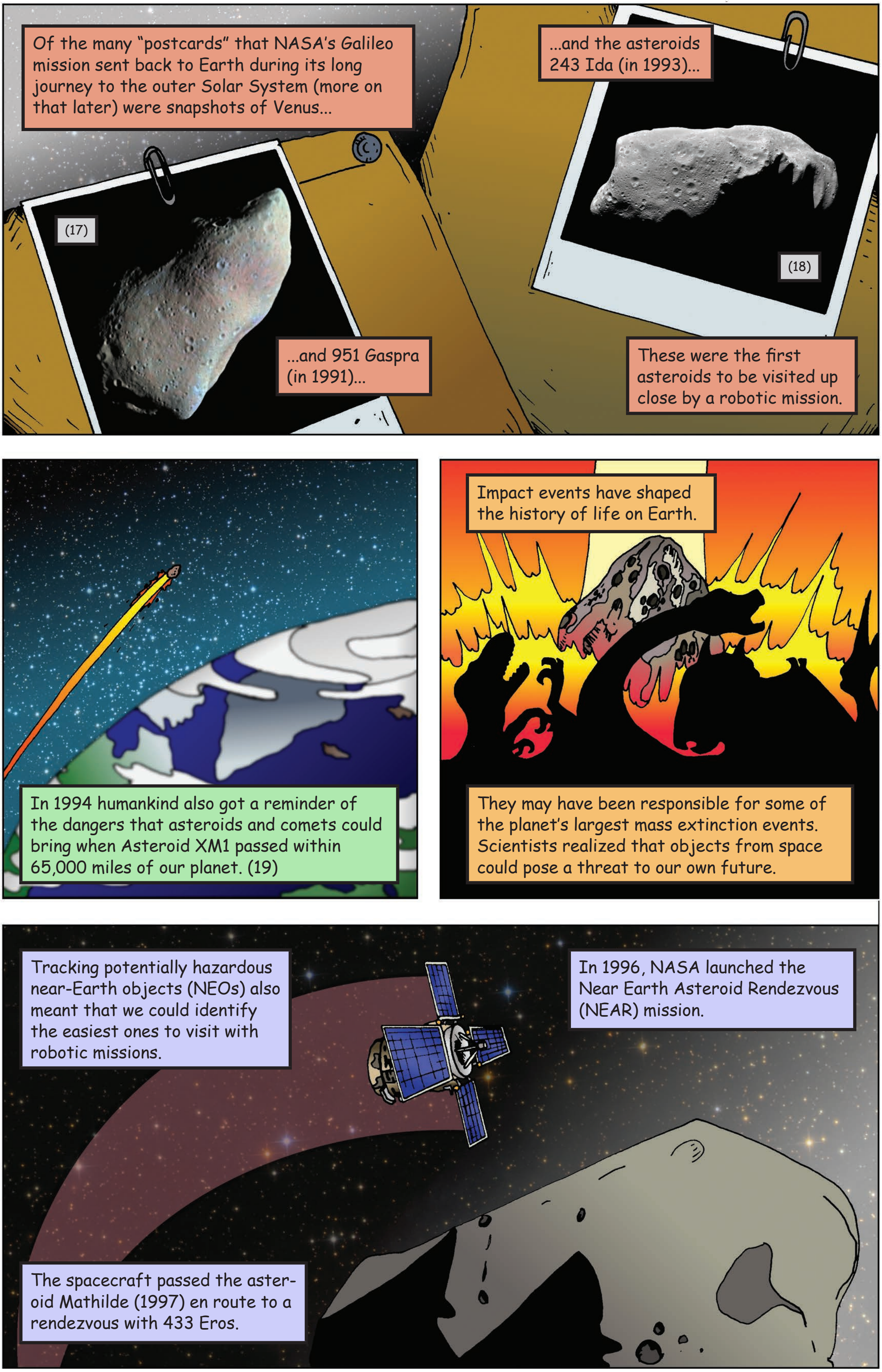

MESSENGER collected data from Mercury orbit from March of 2011 until completing its mission in April of 2015.
Mercury may look barren and crater-scarred, but it is a very interesting place. Spin and gravity data from MESSENGER provided clues about Mercury's core, and the spacecraft also found that the tiny planet might have thick ice deposits at the poles. Despite being so close to the Sun, Mercury's poles are some of the coldest places in the Solar System because the Sun never shines there. (13, 14)
Mercury is the Solar System's smallest terrestrial planet. Studying how it formed and evolved can teach astrobiologists about the many different types of rocky planets that can exist around stars.
Comparing Mercury to Earth can also help us determine why our planet is so special in its ability to support life as we know it.
Mercury, the world obscured from view by the glare of the Sun, will continue to reveal its secrets in the years to come.
So far, BepiColombo has made flybys of both Venus and Mercury, and will enter Mercury orbit in 2025.
The inner Solar System includes everything from Mercury to the asteroid belt between Mars and Jupiter. Humankind has sent robotic explorers to all of the inner-solar-system planets, and also to the moons of Earth and Mars.
But planets and moons are not the only things in this region of space that capture the attention of astrobiologists.

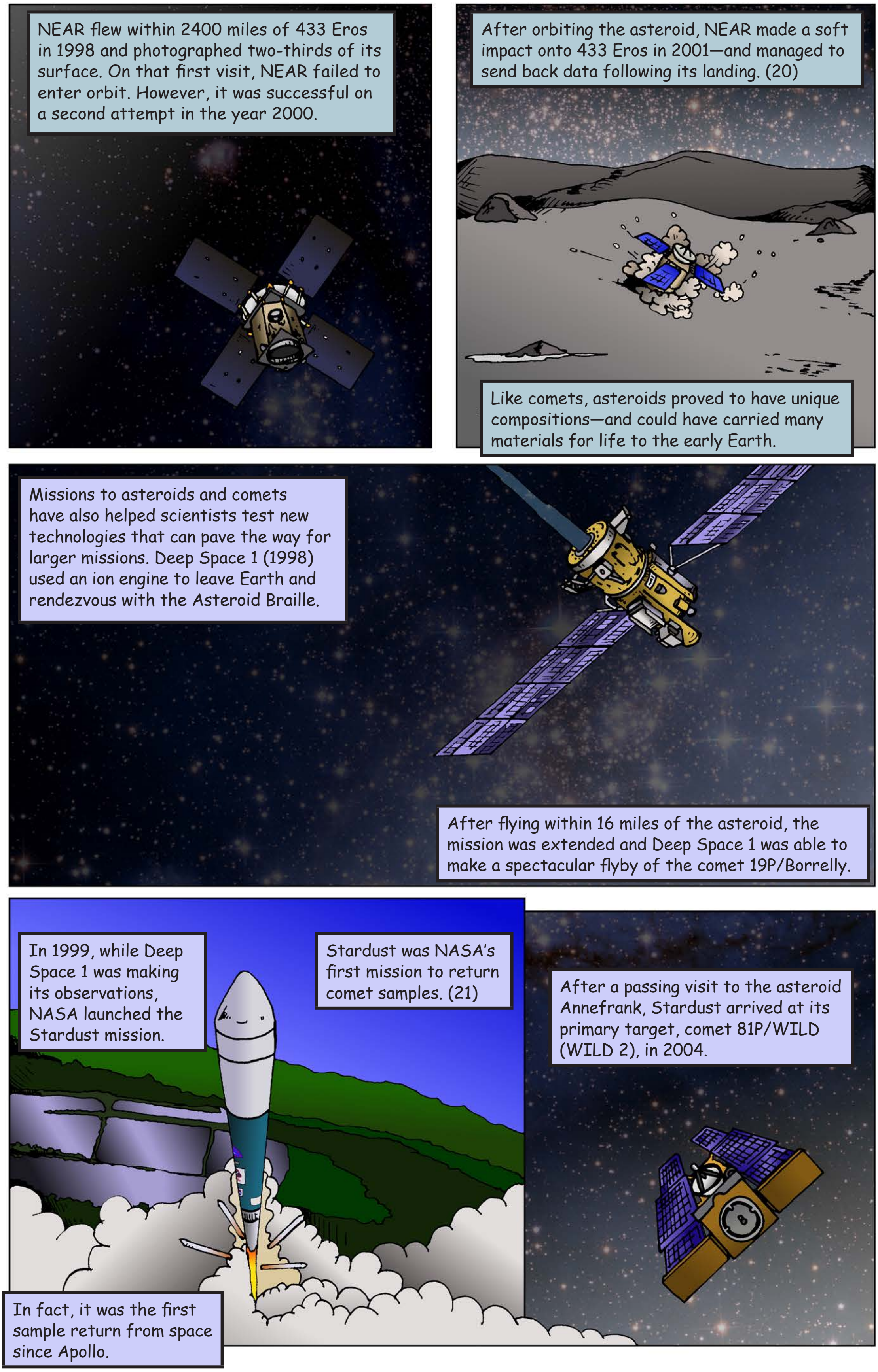

Asteroids and comets also move through the inner Solar System. Occasionally, they come close enough to Earth to visit with dedicated spacecraft.
In the mid 80s, as it journeyed around the Sun, the majestic Halley's comet made a rare visit to the inner Solar System.
(15)

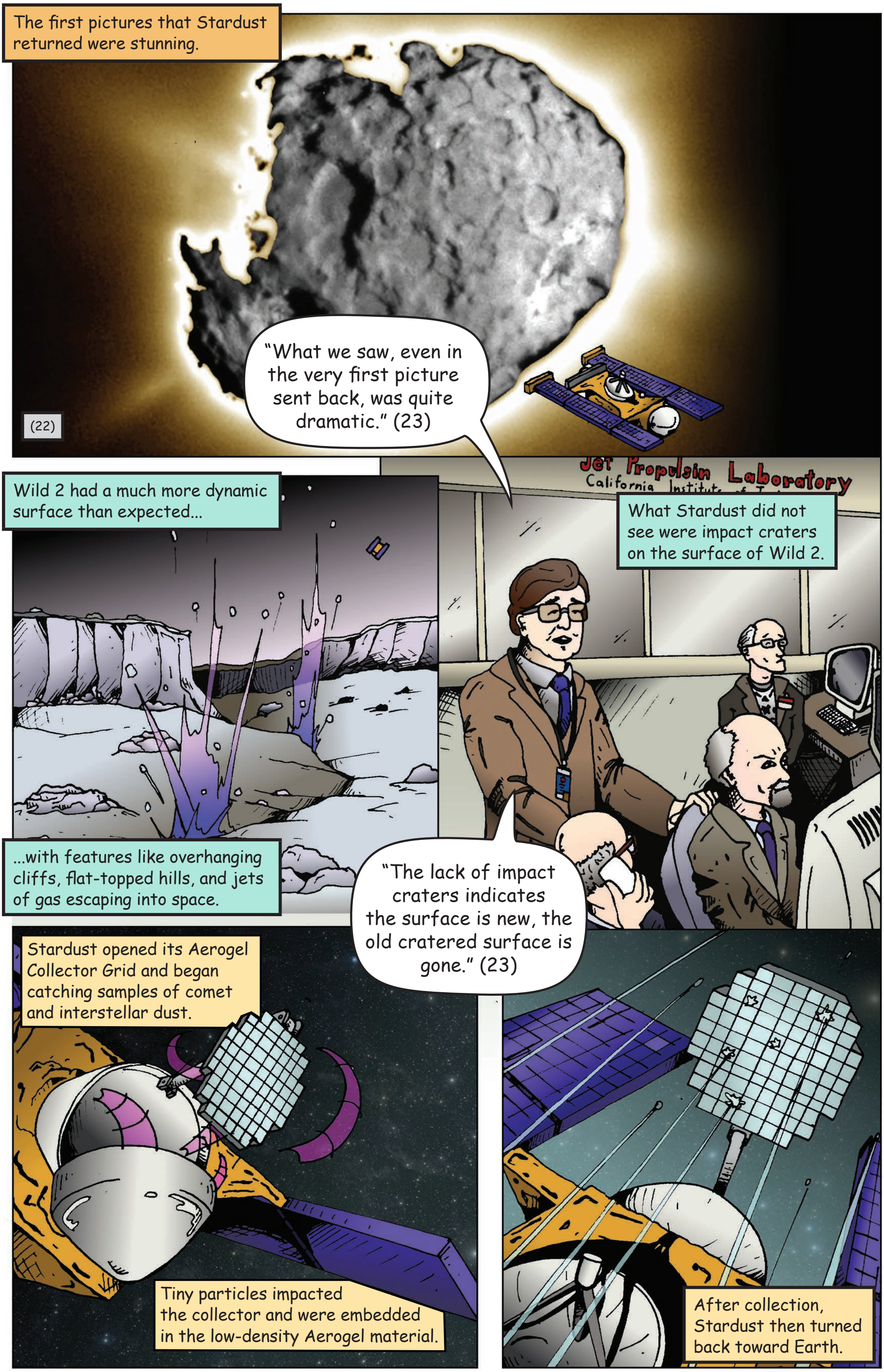

Space agencies around the world launched a flotilla of spacecraft to observe Halley's comet close up.
Because comets and asteroids are remnant chunks of material from the formation of the Solar System, they are like small samples from a time when planets were still forming from the rock and dust that spun around our infant sun.


After Earth formed, comets and asteroids may have also delivered molecules and material that were essential for the origins of life on our planet.
Studying comets and asteroids up close provides astrobiologists with clues about how the Solar System formed and evolved...
...how Earth developed into a habitable world...
...and how life on our planet began!

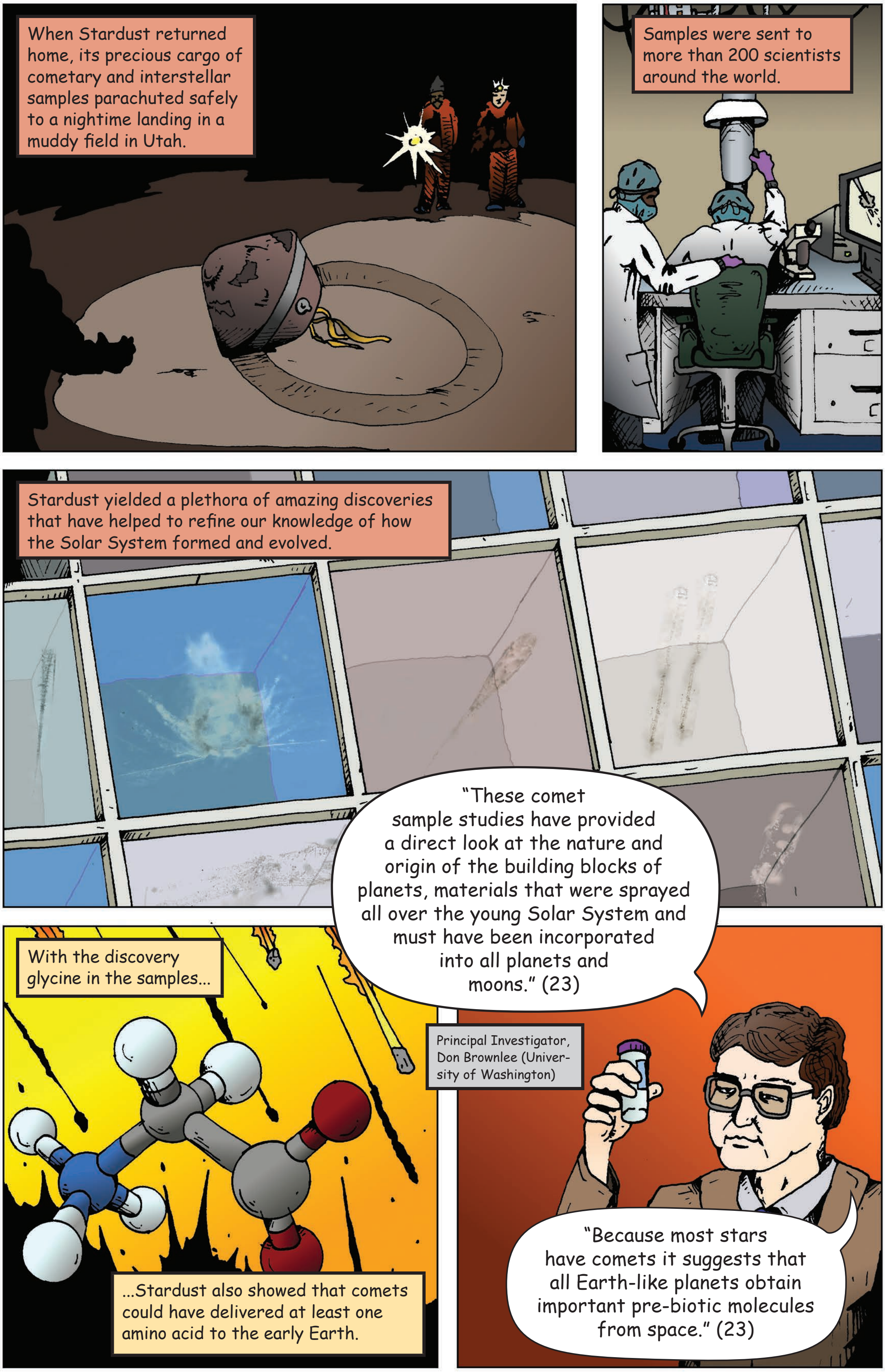

The Halley's comet encounter of 1986 included spacecraft from the USSR, Japan and Western Europe.
After delivering their probes to Venus*, the Soviet-led Vega 1 and 2 spacecraft sped to catch Halley's comet.
Suisei (Japan)
(15)
Japan and Europe also joined in. Giotto (1985—ESA) encountered Halley in 1986 and then traveled onward to the Comet P/Grigg-Skjellerup in 1992.
Vega 1 and Vega 2 (USSR)
Sakagaki (1985), Japan's first interplanetary probe.
Pioneer Venus 1 (USA)
Giotto (ESA)
International Cometary Explorer (ICE)
Pioneer 7 (USA)
Vega probes at Venus.
NASA helped by using existing spacecraft that were already in space. Instruments from missions like Pioneer 7, Pioneer Venus 1 and ICE were re-directed to observe Halley. All together, the spacecraft became popularly known as the 'Halley Armada.'
The data gathered from Halley's comet proved that small bodies were more than just rocks or snowballs.
(16)
*see page 8

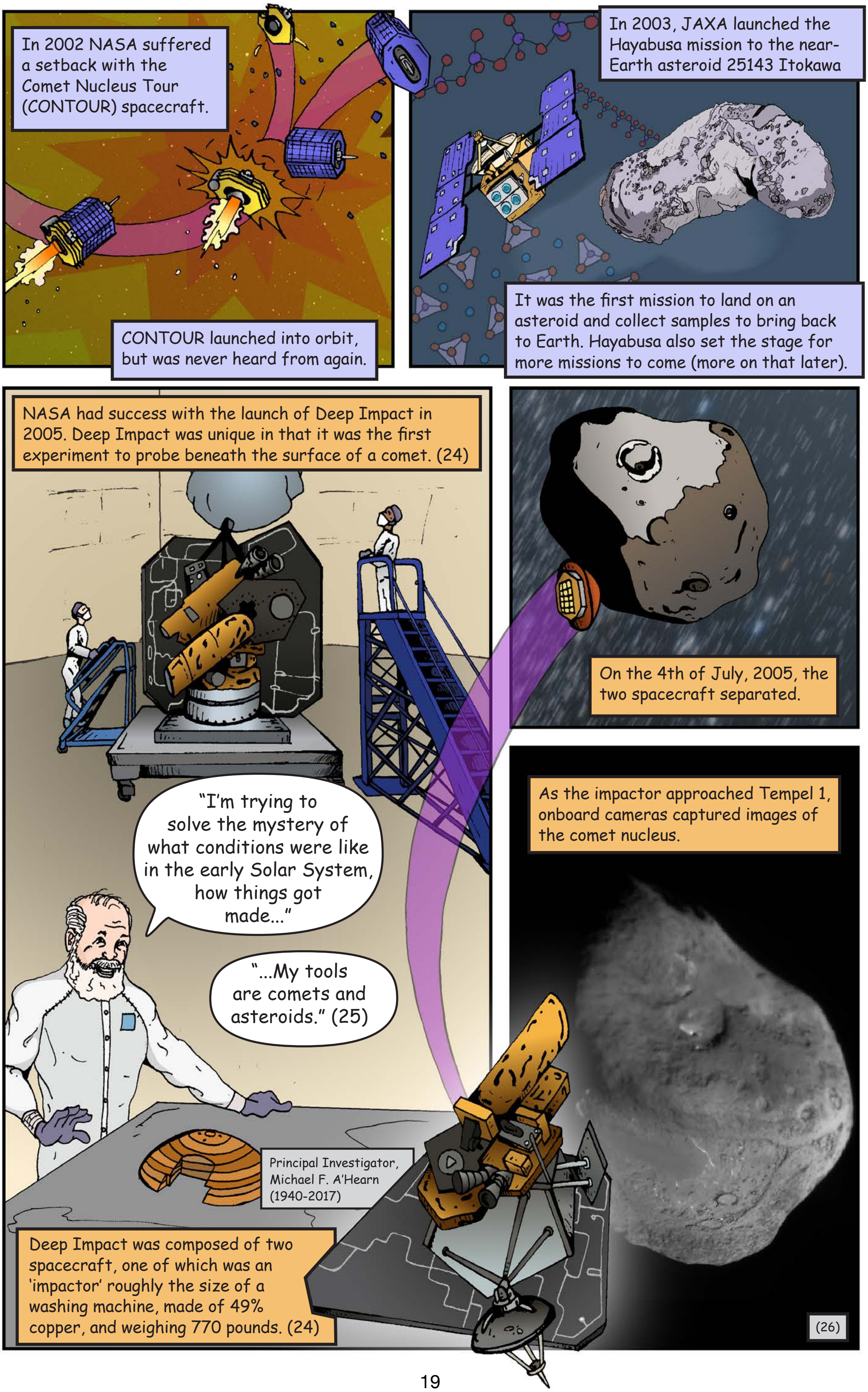

Of the many "postcards" that NASA's Galileo mission sent back to Earth during its long journey to the outer Solar System (more on that later) were snapshots of Venus...
(17)
...and 951 Gaspra (in 1991)...
...and the asteroids 243 Ida (in 1993)...
(18)
These were the first asteroids to be visited up close by a robotic mission.
In 1994 humankind also got a reminder of the dangers that asteroids and comets could bring when Asteroid XM1 passed within 65,000 miles of our planet. (19)
Impact events have shaped the history of life on Earth.
They may have been responsible for some of the planet's largest mass extinction events. Scientists realized that objects from space could pose a threat to our own future.
Tracking potentially hazardous near-Earth objects (NEOs) also meant that we could identify the easiest ones to visit with robotic missions.
In 1996, NASA launched the Near Earth Asteroid Rendezvous (NEAR) mission.
The spacecraft passed the asteroid Mathilde (1997) en route to a rendezvous with 433 Eros.

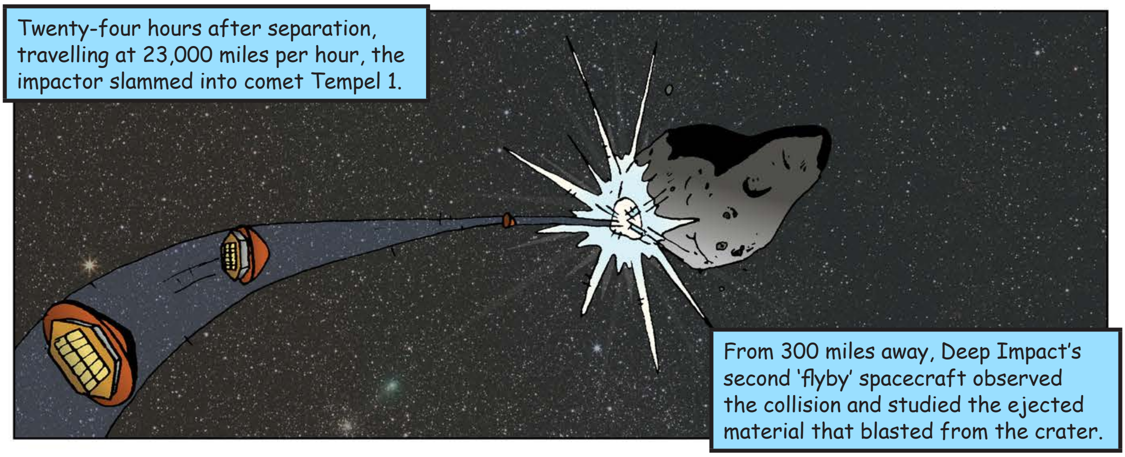

NEAR flew within 2400 miles of 433 Eros in 1998 and photographed two-thirds of its surface. On that first visit, NEAR failed to enter orbit. However, it was successful on a second attempt in the year 2000.
After orbiting the asteroid, NEAR made a soft impact onto 433 Eros in 2001—and managed to send back data following its landing. (20)
Like comets, asteroids proved to have unique compositions—and could have carried many materials for life to the early Earth.
Missions to asteroids and comets have also helped scientists test new technologies that can pave the way for larger missions. Deep Space 1 (1998) used an ion engine to leave Earth and rendezvous with the Asteroid Braille.
After flying within 16 miles of the asteroid, the mission was extended and Deep Space 1 was able to make a spectacular flyby of the comet 19P/Borrelly.
In 1999, while Deep Space 1 was making its observations, NASA launched the Stardust mission.
Stardust was NASA's first mission to return comet samples. (21)
In fact, it was the first sample return from space since Apollo.
After a passing visit to the asteroid Annefrank, Stardust arrived at its primary target, comet 81P/WILD (WILD 2), in 2004.

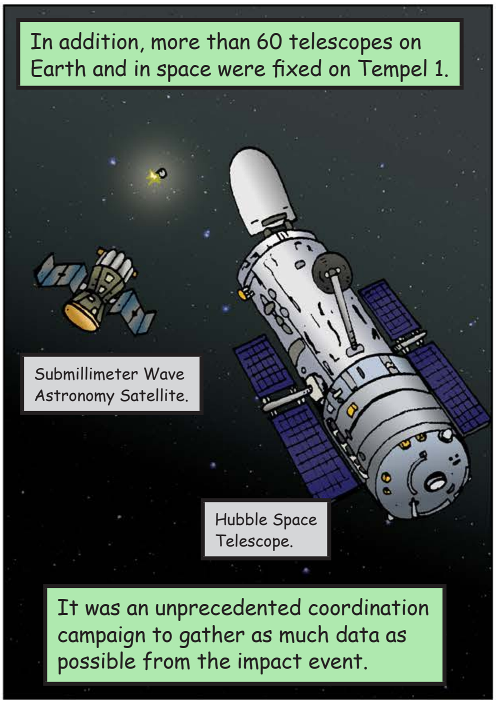


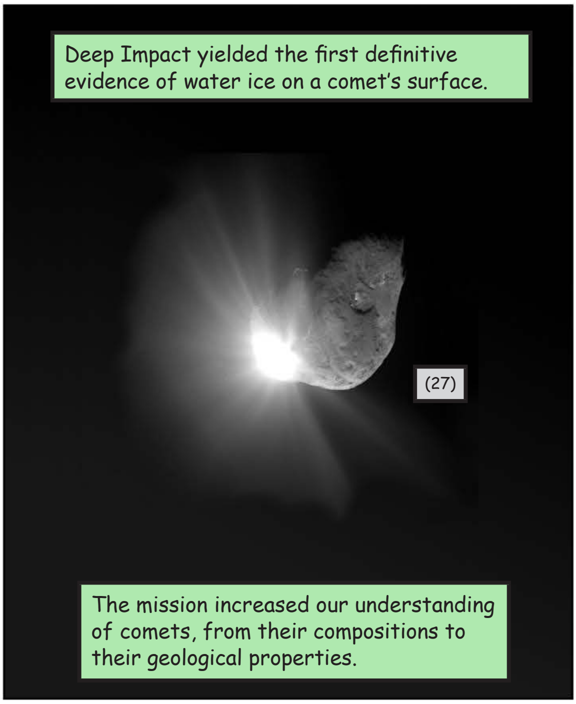
The first pictures that Stardust returned were stunning.
(22)
"What we saw, even in the very first picture sent back, was quite dramatic." (23)
Wild 2 had a much more dynamic surface than expected...
...with features like overhanging cliffs, flat-topped hills, and jets of gas escaping into space.
Jet Propulsion Laboratory
What Stardust did not see were impact craters on the surface of Wild 2.
"The lack of impact craters indicates the surface is new, the old cratered surface is gone." (23)
Stardust opened its Aerogel Collector Grid and began catching samples of comet and interstellar dust.
Tiny particles impacted the collector and were embedded in the low-density Aerogel material.
After collection, Stardust then turned back toward Earth.

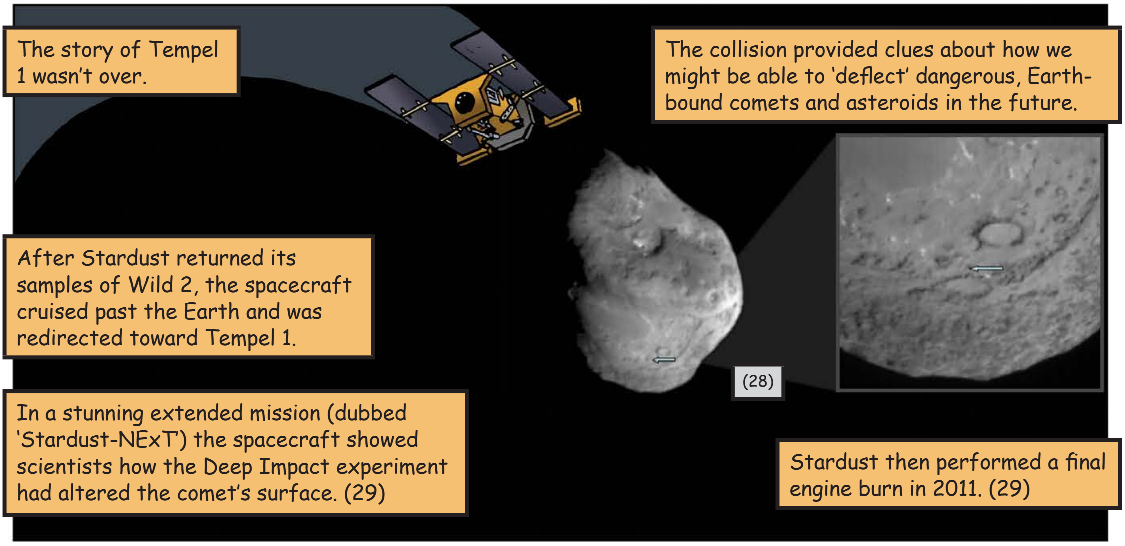

When Stardust returned home, its precious cargo of cometary and interstellar samples parachuted safely to a nightime landing in a muddy field in Utah.
Samples were sent to more than 200 scientists around the world.
Stardust yielded a plethora of amazing discoveries that have helped to refine our knowledge of how the Solar System formed and evolved.
"These comet sample studies have provided a direct look at the nature and origin of the building blocks of planets, materials that were sprayed all over the young Solar System and must have been incorporated into all planets and moons." (23)
With the discovery glycine in the samples...
...Stardust also showed that comets could have delivered at least one amino acid to the early Earth.
Principal Investigator, Don Brownlee (University of Washington)
"Because most stars have comets it suggests that all Earth-like planets obtain important pre-biotic molecules from space." (23)

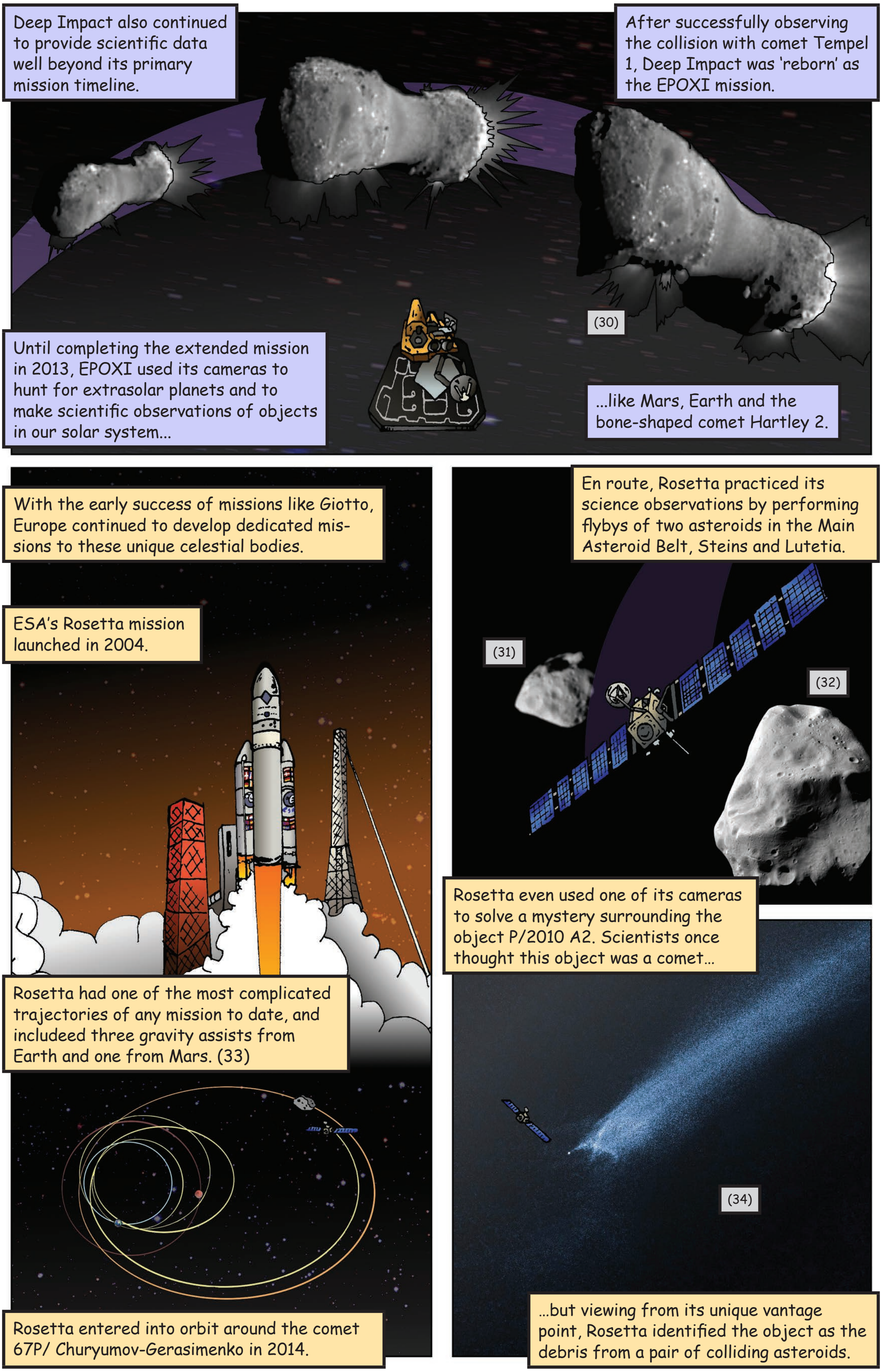

In 2002 NASA suffered a setback with the Comet Nucleus Tour (CONTOUR) spacecraft.
CONTOUR launched into orbit, but was never heard from again.
In 2003, JAXA launched the Hayabusa mission to the near-Earth asteroid 25143 Itokawa
It was the first mission to land on an asteroid and collect samples to bring back to Earth. Hayabusa also set the stage for more missions to come (more on that later).
NASA had success with the launch of Deep Impact in 2005. Deep Impact was unique in that it was the first experiment to probe beneath the surface of a comet. (24)
"I'm trying to solve the mystery of what conditions were like in the early Solar System, how things got made..."
"...My tools are comets and asteroids." (25)
Principal Investigator, Michael F. A'Hearn (1940-2017)
Deep Impact was composed of two spacecraft, one of which was an 'impactor' roughly the size of a washing machine, made of 49% copper, and weighing 770 pounds. (24)
On the 4th of July, 2005, the two spacecraft separated.
As the impactor approached Tempel 1, onboard cameras captured images of the comet nucleus.
(26)

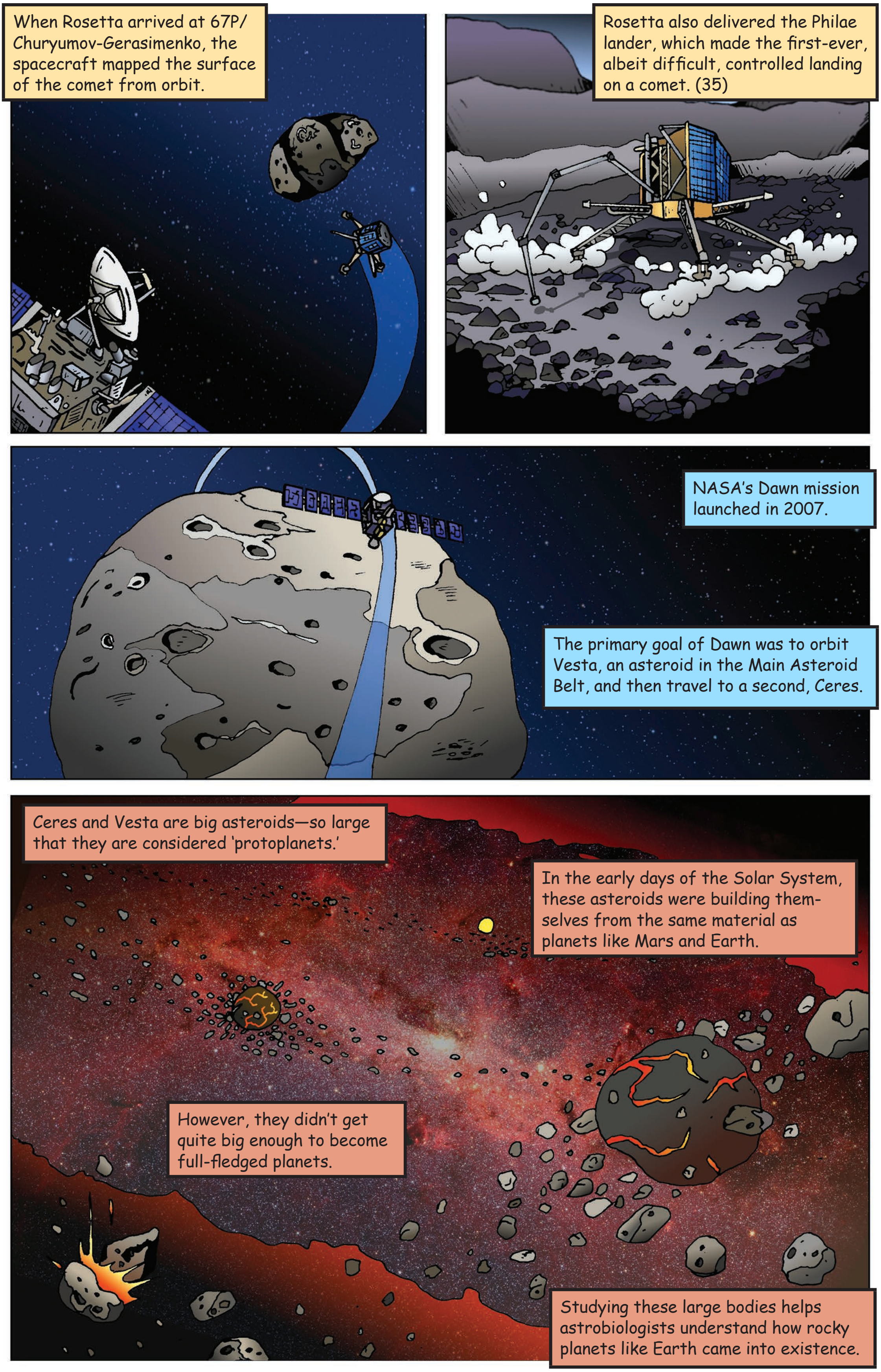

Twenty-four hours after separation, travelling at 23,000 miles per hour, the impactor slammed into comet Tempel 1.
From 300 miles away, Deep Impact's second 'flyby' spacecraft observed the collision and studied the ejected material that blasted from the crater.

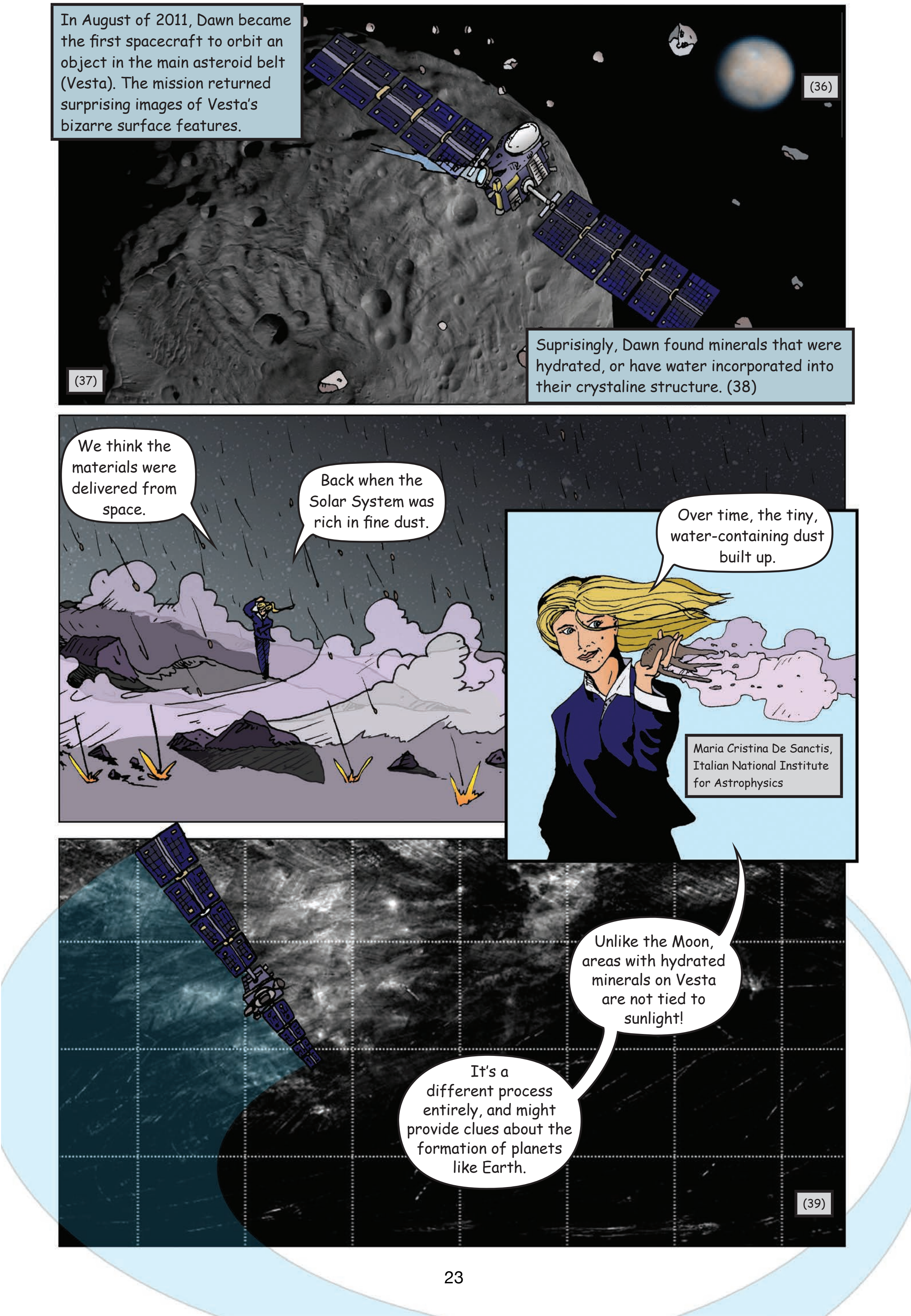

In addition, more than 60 telescopes on Earth and in space were fixed on Tempel 1.
Submillimeter Wave Astronomy Satellite.
Hubble Space Telescope.
It was an unprecedented coordination campaign to gather as much data as possible from the impact event.

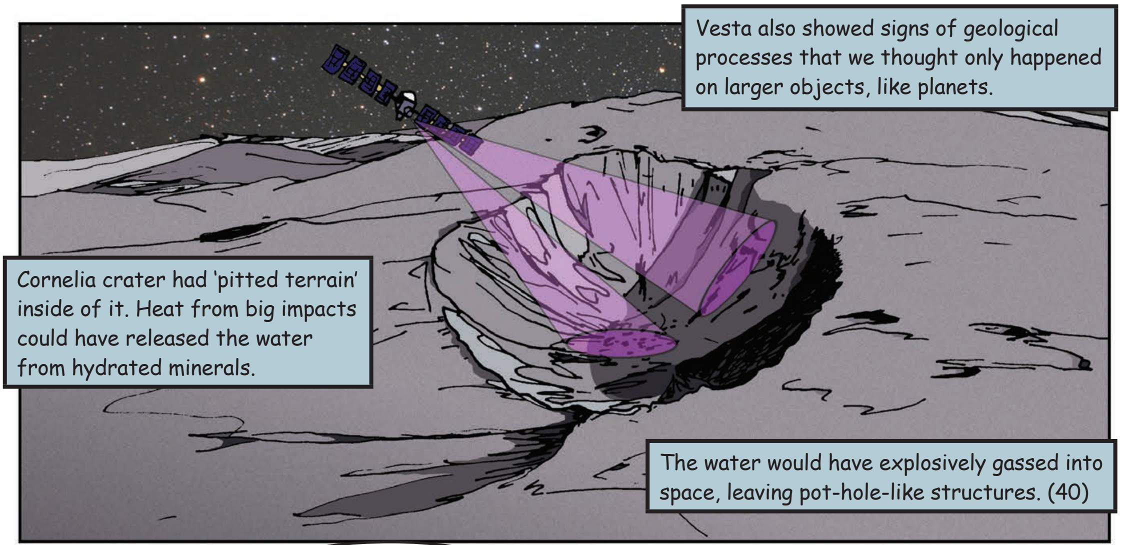

Deep Impact yielded the first definitive evidence of water ice on a comet's surface.
(27)
The mission increased our understanding of comets, from their compositions to their geological properties.

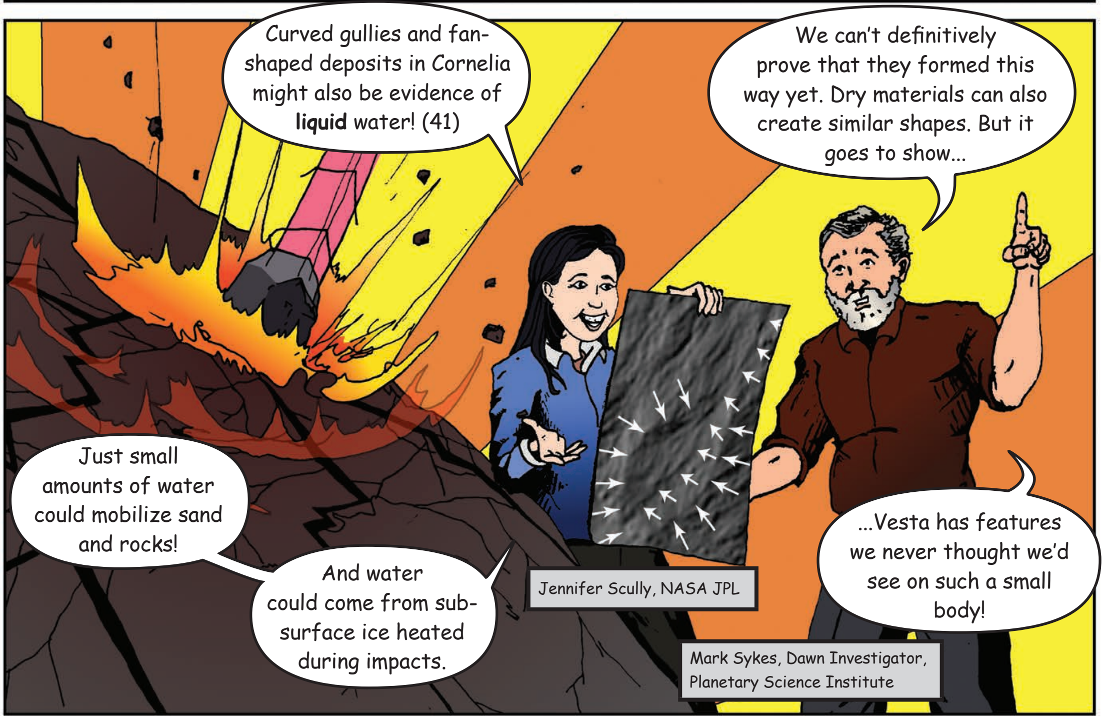

The story of Tempel 1 wasn't over.
The collision provided clues about how we might be able to 'deflect' dangerous, Earth-bound comets and asteroids in the future.
After Stardust returned its samples of Wild 2, the spacecraft cruised past the Earth and was redirected toward Tempel 1.
(28)
In a stunning extended mission (dubbed 'Stardust-NExT') the spacecraft showed scientists how the Deep Impact experiment had altered the comet's surface. (29)
Stardust then performed a final engine burn in 2011. (29)

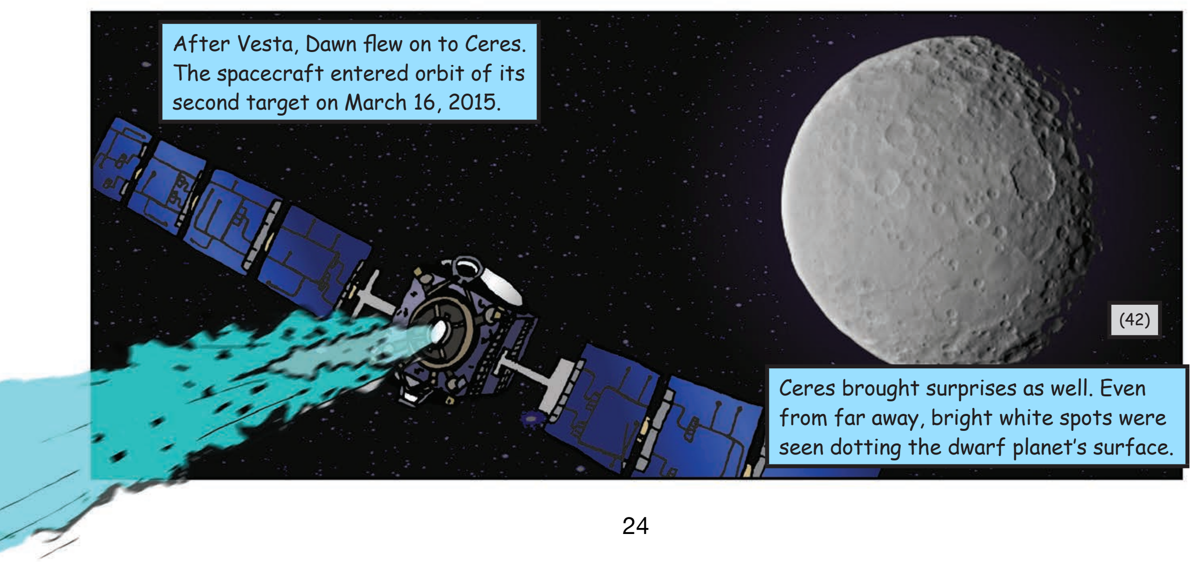

Deep Impact also continued to provide scientific data well beyond its primary mission timeline.
After successfully observing the collision with comet Tempel 1, Deep Impact was 'reborn' as the EPOXI mission.
(30)
Until completing the extended mission in 2013, EPOXI used its cameras to hunt for extrasolar planets and to make scientific observations of objects in our solar system...
...like Mars, Earth and the bone-shaped comet Hartley 2.
With the early success of missions like Giotto, Europe continued to develop dedicated mis-sions to these unique celestial bodies.
ESA's Rosetta mission launched in 2004.
Rosetta had one of the most complicated trajectories of any mission to date, and includeed three gravity assists from Earth and one from Mars. (33)
Rosetta entered into orbit around the comet 67P/ Churyumov-Gerasimenko in 2014.
En route, Rosetta practiced its science observations by performing flybys of two asteroids in the Main Asteroid Belt, Steins and Lutetia.
(31)
(32)
Rosetta even used one of its cameras to solve a mystery surrounding the object P/2010 A2. Scientists once thought this object was a comet...
(34)
...but viewing from its unique vantage point, Rosetta identified the object as the debris from a pair of colliding asteroids.

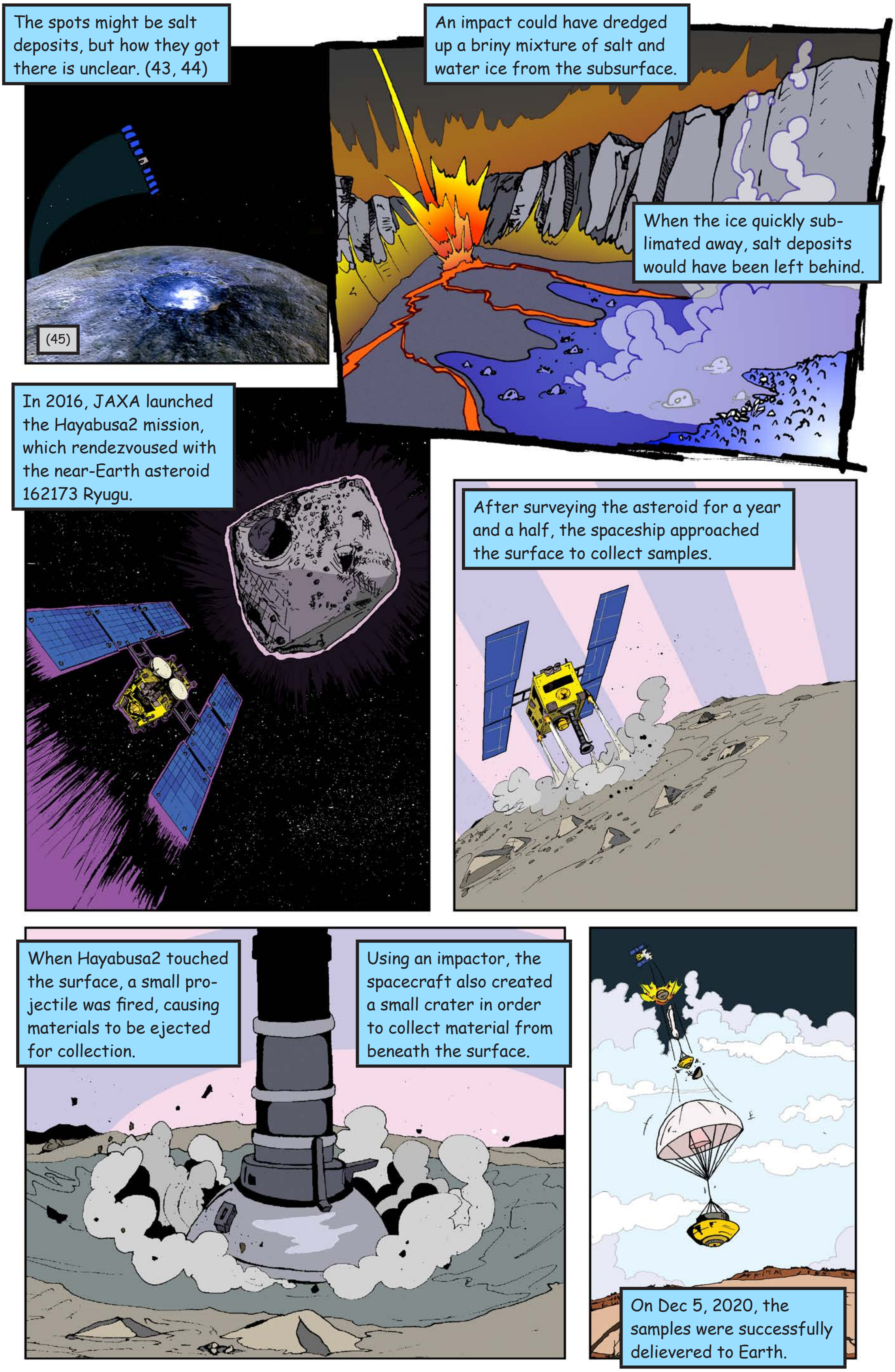

When Rosetta arrived at 67P/ Churyumov-Gerasimenko, the spacecraft mapped the surface of the comet from orbit.
Rosetta also delivered the Philae lander, which made the first-ever, albeit difficult, controlled landing on a comet. (35)
NASA's Dawn mission launched in 2007.
The primary goal of Dawn was to orbit Vesta, an asteroid in the Main Asteroid Belt, and then travel to a second, Ceres.
Ceres and Vesta are big asteroids—so large that they are considered 'protoplanets.'
In the early days of the Solar System, these asteroids were building themselves from the same material as planets like Mars and Earth.
However, they didn't get quite big enough to become full-fledged planets.
Studying these large bodies helps astrobiologists understand how rocky planets like Earth came into existence.

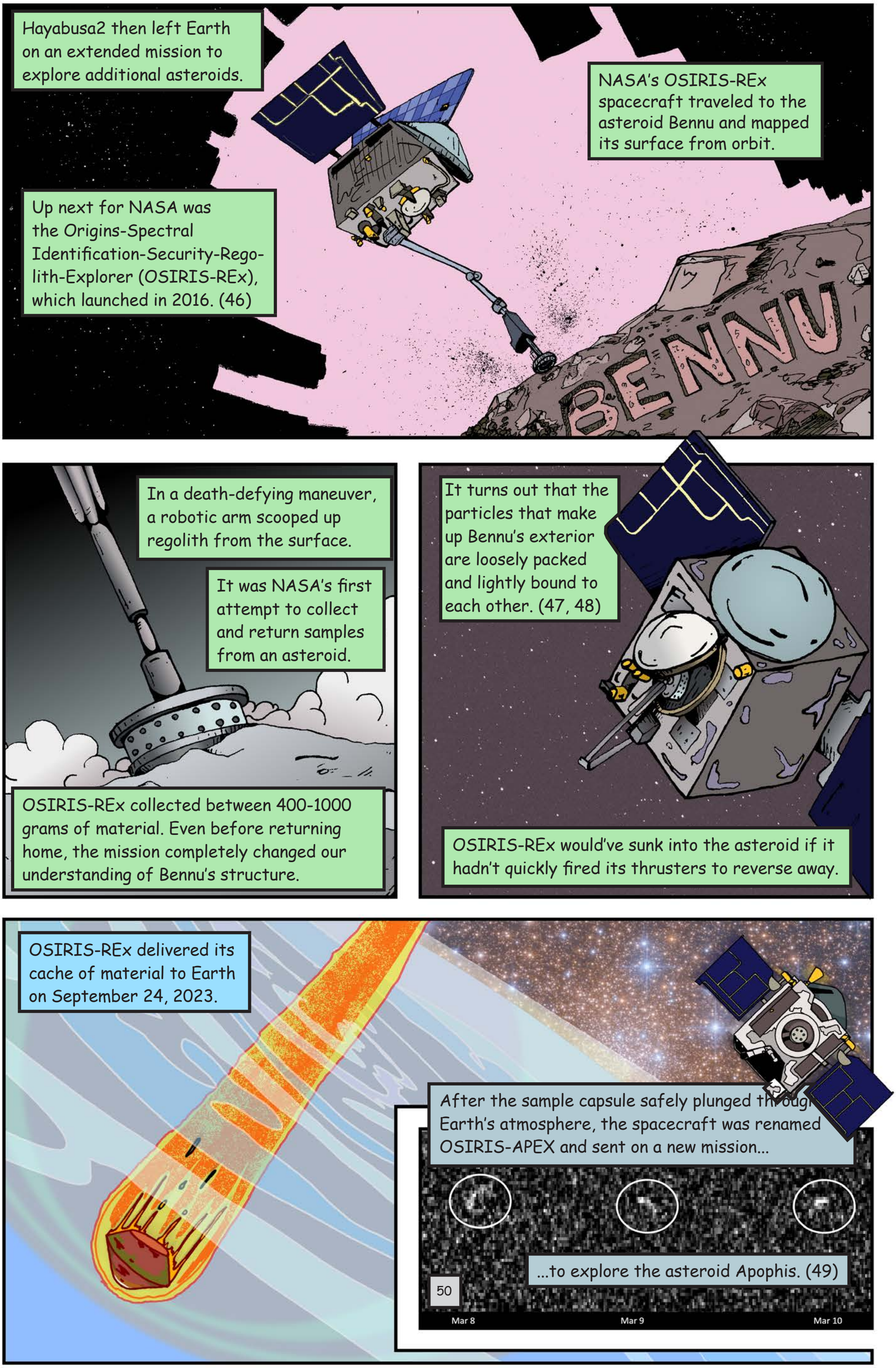

In August of 2011, Dawn became the first spacecraft to orbit an object in the main asteroid belt (Vesta). The mission returned surprising images of Vesta's bizarre surface features.
(36)
(37)
Suprisingly, Dawn found minerals that were hydrated, or have water incorporated into their crystaline structure. (38)
We think the materials were delivered from space.
Back when the Solar System was rich in fine dust.
Over time, the tiny, water-containing dust built up.
Maria Cristina De Sanctis, Italian National Institute for Astrophysics
Unlike the Moon, areas with hydrated minerals on Vesta are not tied to sunlight!
It's a different process entirely, and might provide clues about the formation of planets like Earth.
(39)

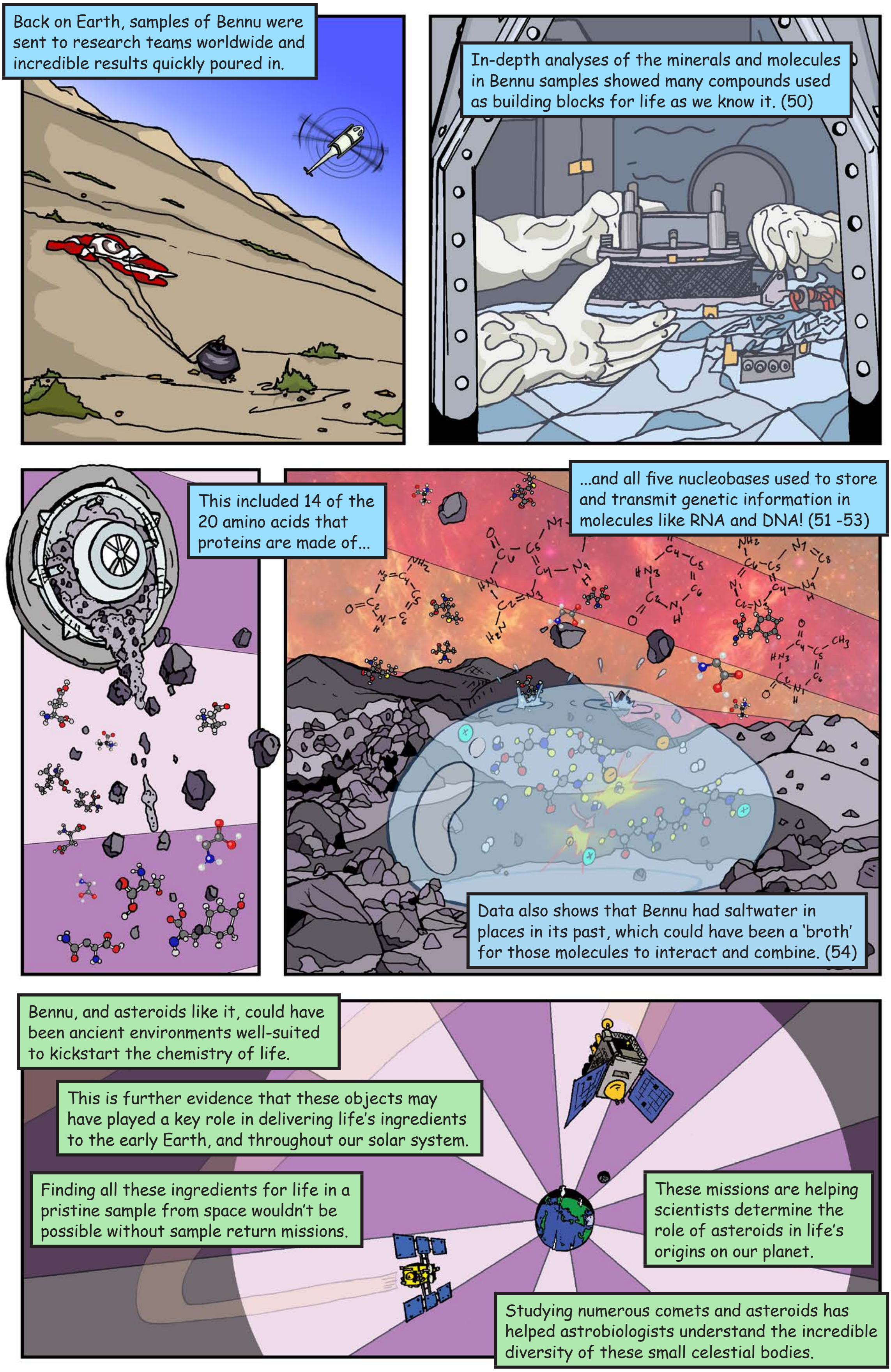

Vesta also showed signs of geological processes that we thought only happened on larger objects, like planets.
Cornelia crater had 'pitted terrain' inside of it. Heat from big impacts could have released the water from hydrated minerals.
The water would have explosively gassed into space, leaving pot-hole-like structures. (40)

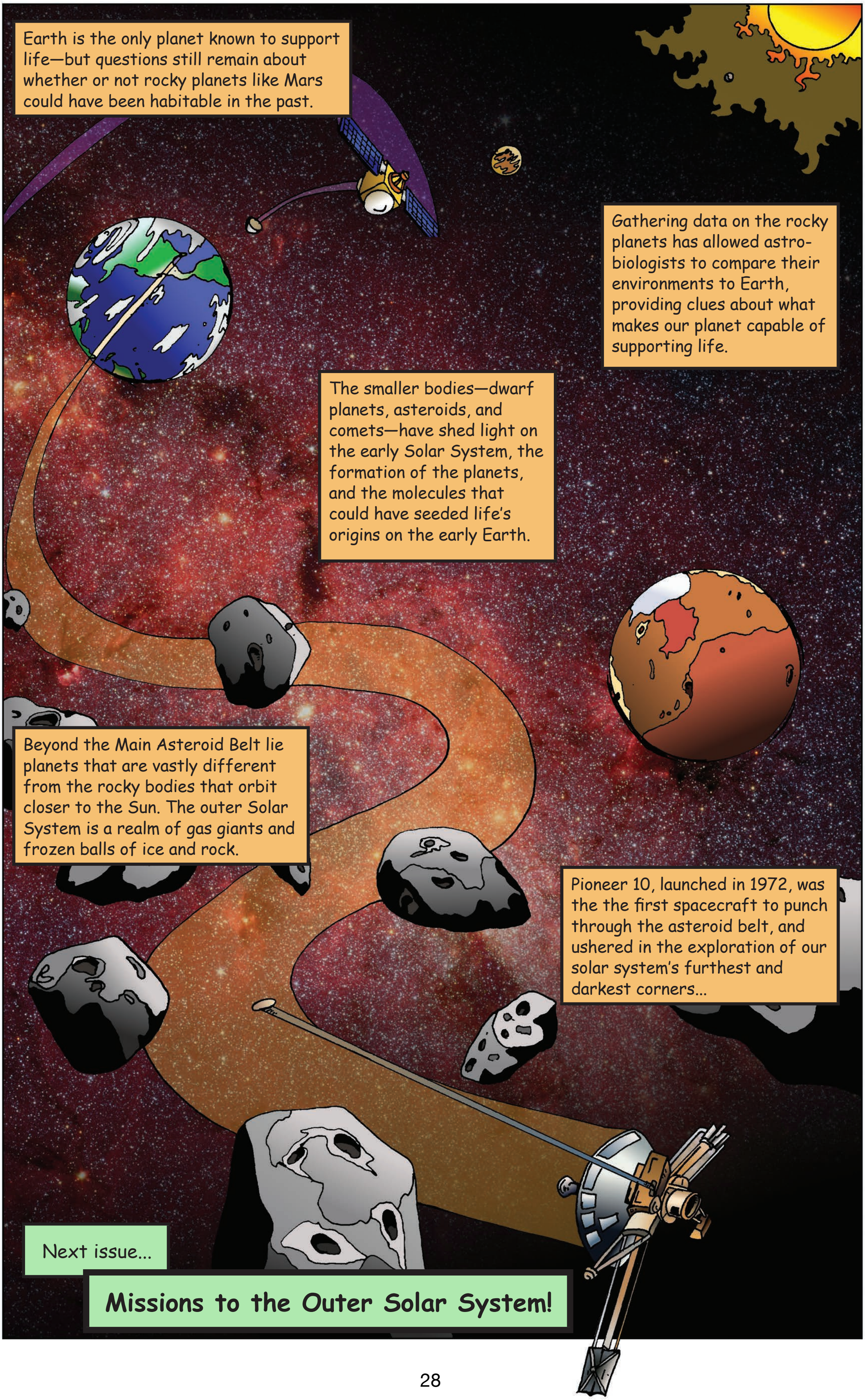

Curved gullies and fan-shaped deposits in Cornelia might also be evidence of **liquid** water! (41)
We can't definitively prove that they formed this way yet. Dry materials can also create similar shapes. But it goes to show...
Just small amounts of water could mobilize sand and rocks!
And water could come from sub-surface ice heated during impacts.
Jennifer Scully, NASA JPL
...Vesta has features we never thought we'd see on such a small body!
Mark Sykes, Dawn Investigator, Planetary Science Institute


After Vesta, Dawn flew on to Ceres. The spacecraft entered orbit of its second target on March 16, 2015.
(42)
Ceres brought surprises as well. Even from far away, bright white spots were seen dotting the dwarf planet's surface.


The spots might be salt deposits, but how they got there is unclear. (43, 44)
(45)
An impact could have dredged up a briny mixture of salt and water ice from the subsurface.
When the ice quickly sub-limated away, salt deposits would have been left behind.
In 2016, JAXA launched the Hayabusa2 mission, which rendezvoused with the near-Earth asteroid 162173 Ryugu.
After surveying the asteroid for a year and a half, the spaceship approached the surface to collect samples.
When Hayabusa2 touched the surface, a small pro-jectile was fired, causing materials to be ejected for collection.
Using an impactor, the spacecraft also created a small crater in order to collect material from beneath the surface.
On Dec 5, 2020, the samples were successfully delievered to Earth.


Hayabusa2 then left Earth on an extended mission to explore additional asteroids.
Up next for NASA was the Origins-Spectral Identification-Security-Rego-lith-Explorer (OSIRIS-REx), which launched in 2016. (46)
NASA's OSIRIS-REx spacecraft traveled to the asteroid Bennu and mapped its surface from orbit.
BENNU
In a death-defying maneuver, a robotic arm scooped up regolith from the surface.
It was NASA's first attempt to collect and return samples from an asteroid.
OSIRIS-REx collected between 400-1000 grams of material. Even before returning home, the mission completely changed our understanding of Bennu's structure.
It turns out that the particles that make up Bennu's exterior are loosely packed and lightly bound to each other. (47, 48)
OSIRIS-REx would've sunk into the asteroid if it hadn't quickly fired its thrusters to reverse away.
OSIRIS-REx delivered its cache of material to Earth on September 24, 2023.
After the sample capsule safely plunged th
Earth's atmosphere, the spacecraft was renamed OSIRIS-APEX and sent on a new mission...
...to explore the asteroid Apophis. (49)
50
Mar 8
Mar 9
Mar 10


Back on Earth, samples of Bennu were sent to research teams worldwide and incredible results quickly poured in.
In-depth analyses of the minerals and molecules in Bennu samples showed many compounds used as building blocks for life as we know it. (50)
This included 14 of the 20 amino acids that proteins are made of...
...and all five nucleobases used to store and transmit genetic information in molecules like RNA and DNA! (51 -53)
Data also shows that Bennu had saltwater in places in its past, which could have been a 'broth' for those molecules to interact and combine. (54)
Bennu, and asteroids like it, could have been ancient environments well-suited to kickstart the chemistry of life.
This is further evidence that these objects may have played a key role in delivering life's ingredients to the early Earth, and throughout our solar system.
Finding all these ingredients for life in a pristine sample from space wouldn't be possible without sample return missions.
These missions are helping scientists determine the role of asteroids in life's origins on our planet.
Studying numerous comets and asteroids has helped astrobiologists understand the incredible diversity of these small celestial bodies.


Earth is the only planet known to support life—but questions still remain about whether or not rocky planets like Mars could have been habitable in the past.
Gathering data on the rocky planets has allowed astro-biologists to compare their environments to Earth, providing clues about what makes our planet capable of supporting life.
The smaller bodies—dwarf planets, asteroids, and comets—have shed light on the early Solar System, the formation of the planets, and the molecules that could have seeded life's origins on the early Earth.
Beyond the Main Asteroid Belt lie planets that are vastly different from the rocky bodies that orbit closer to the Sun. The outer Solar System is a realm of gas giants and frozen balls of ice and rock.
Pioneer 10, launched in 1972, was the the first spacecraft to punch through the asteroid belt, and ushered in the exploration of our solar system's furthest and darkest corners...
Next issue...
Missions to the Outer Solar System!

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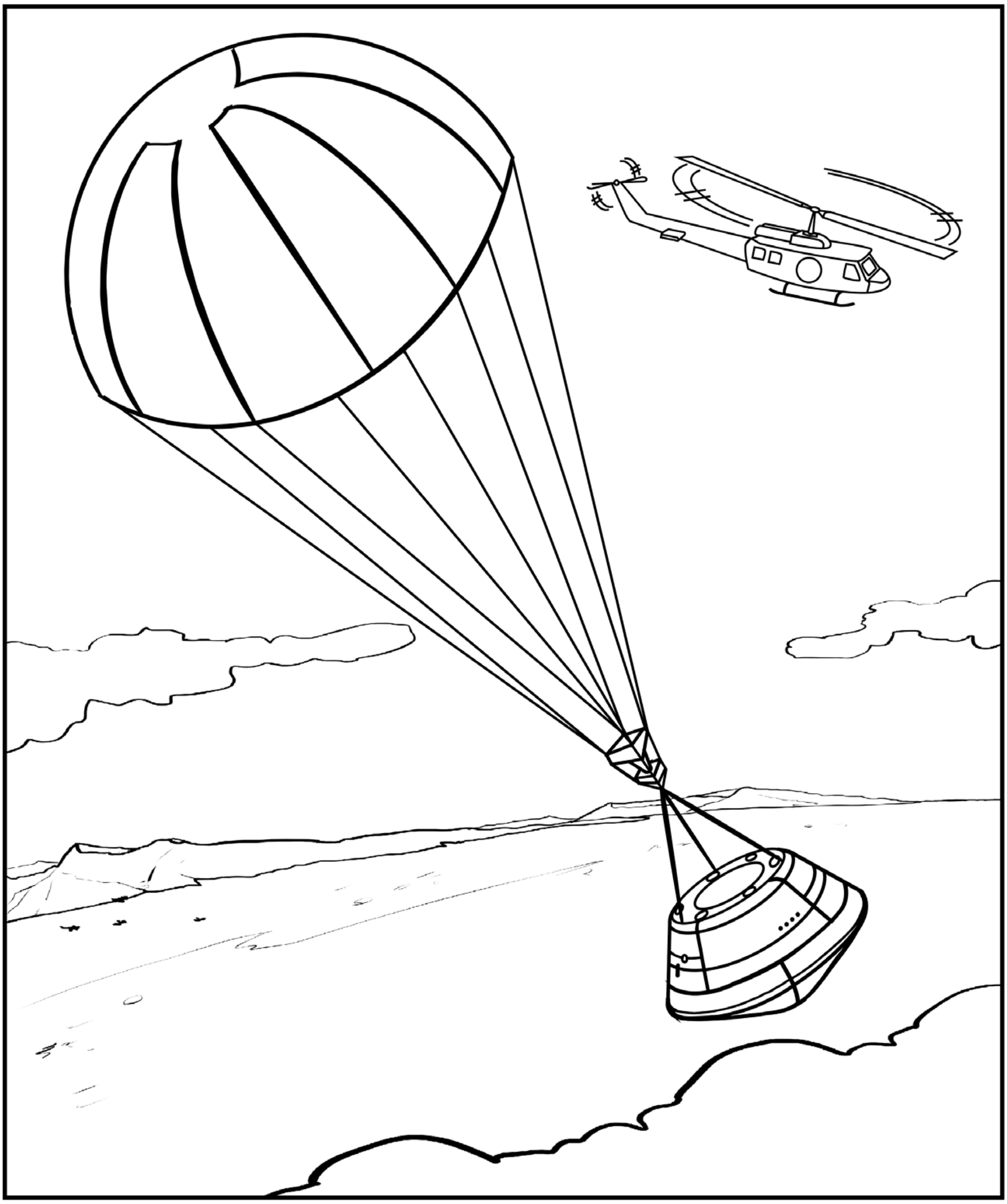
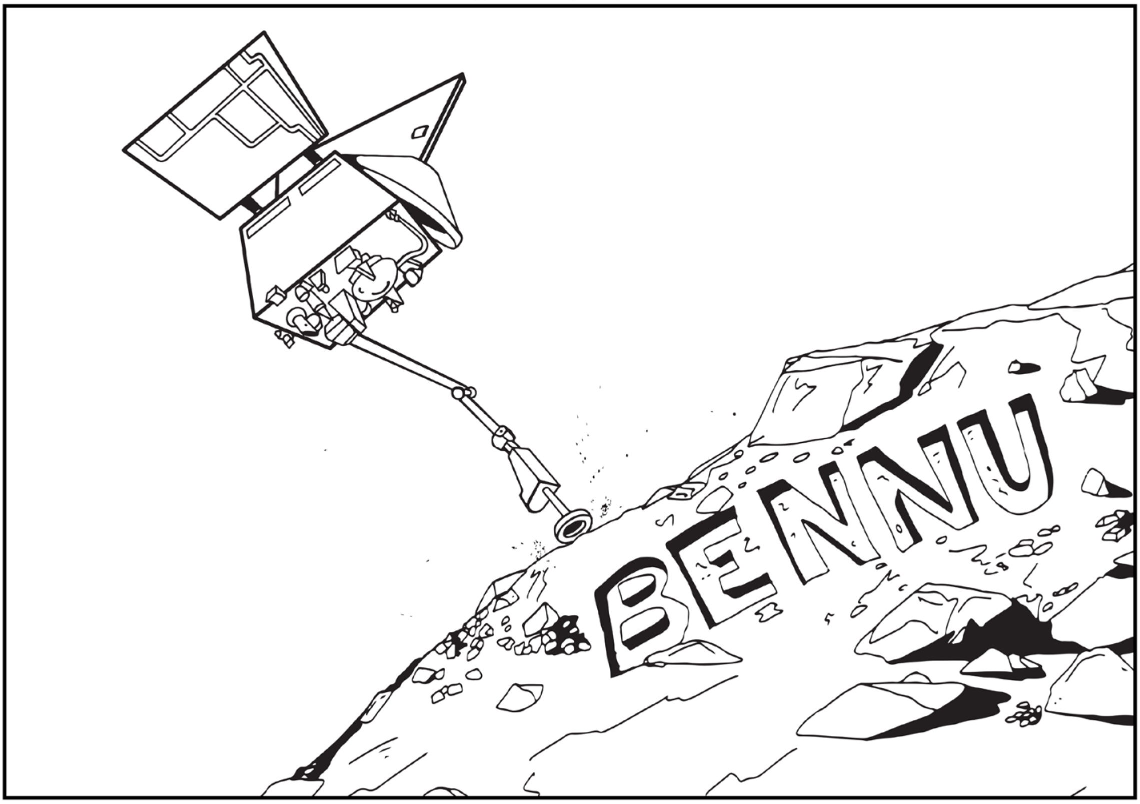
Astrobiology Coloring Page: OSIRIS-REx



NASA's Origins, Spectral Interpretation, Resource Identification, Security, Regolith Explorer (OSIRIS-REx) returns to Earth on Sept. 24, 2023. Here, the sample capsule descends to Utah desert with its precious cargo. Scientists on Earth will study the material in order to learn about the formation of the Sun and planets about 4.5 billion years ago.

Astrobiology Coloring Page: OSIRIS-REx



The Origins, Spectral Interpretation, Resource Identification, Security, Regolith Explorer (OSIRIS-REx) was the first NASA mission to collect samples from an asteroid. The spacecraft gathered pieces of the asteroid Bennu in October of 2020, and then began its journey back home to deliver the samples to scientists on Earth.

Visit **science.nasa.gov/astrobiology/** to learn all about Astrobiology at NASA!

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