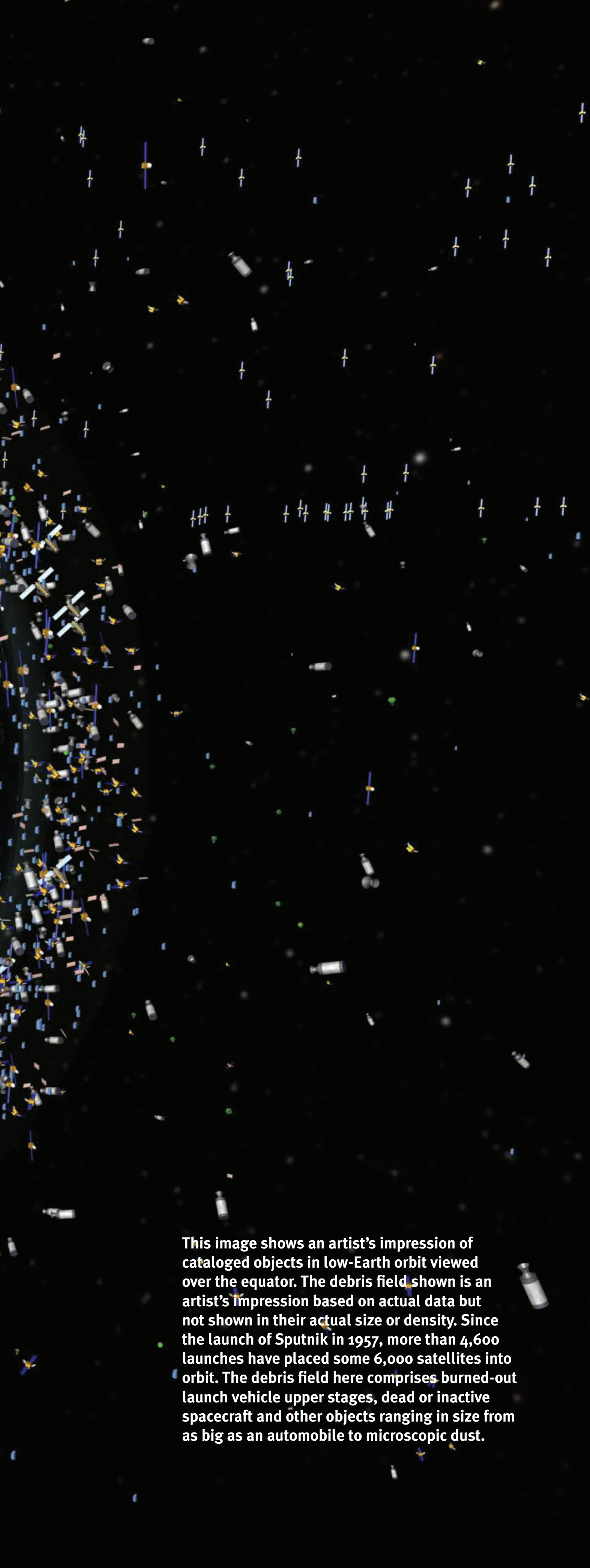
OUT OF THIS WORLD

THE 1,000 OR SO SATELLITES CURRENTLY CIRCLING THE EARTH ARE VITAL TO COMMUNICATIONS, NAVIGATION, WEATHER FORECASTING, INTELLIGENCE AND DEFENSE

BY DOUGLAS BIRCH



This image shows an artist's impression of cataloged objects in low-Earth orbit viewed over the equator. The debris field shown is an artist's impression based on actual data but not shown in their actual size or density. Since the launch of Sputnik in 1957, more than 4,600 launches have placed some 6,000 satellites into orbit. The debris field here comprises burned-out launch vehicle upper stages, dead or inactive spacecraft and other objects ranging in size from as big as an automobile to microscopic dust.

JONATHAN MCDOWELL isn't a government official but reporters from around the world turned to him in December 2012 for confirmation that the latest North Korean satellite had successfully achieved orbit. Shortly after, the media sought him out again, this time to assess reports that the spacecraft was tumbling out of control and not transmitting signals—signs that it's likely dead.

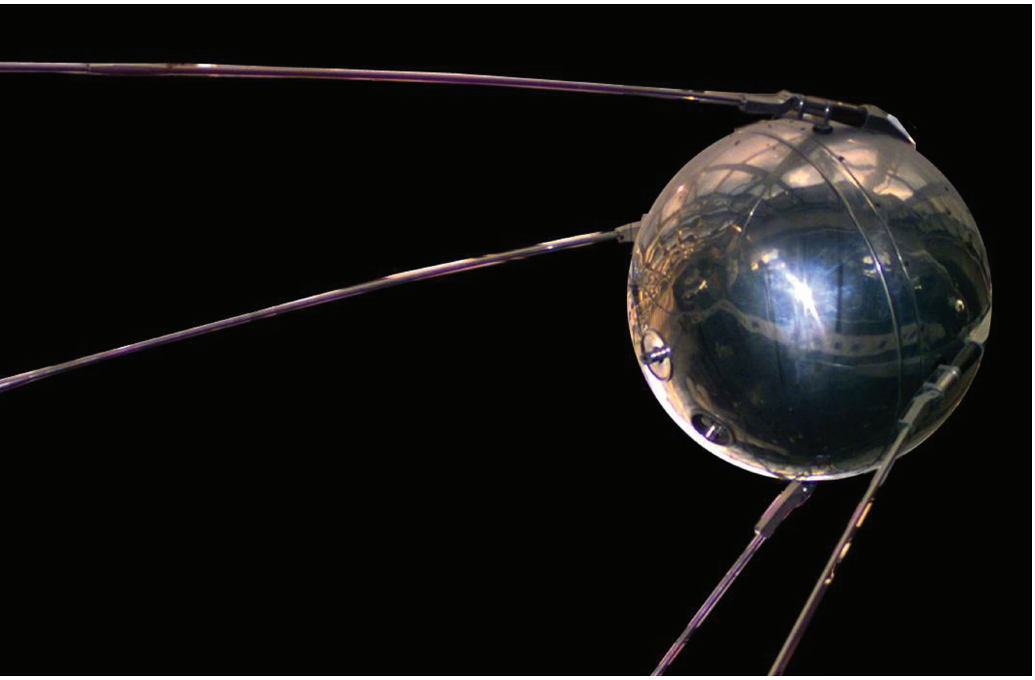
By profession, McDowell is an astrophysicist at the Harvard-Smithsonian Center for Astrophysics in Cambridge, Massachusetts, where he studies exotic objects like black holes nestled in galaxies far, far away. But the 52-year-old scientist also spends much of his spare time tracking man-made celestial objects somewhat closer to home.

From his house in Somerville, Massachusetts, McDowell publishes what he calls "the most comprehensive historical list of satellite launch information" on his website, *Jonathan's Space Home Page*. And he periodically fires off an email newsletter, *Jonathan's Space Report*, with the latest in satellite launch news.

His work has helped astronomers distinguish space junk from asteroids and comets. In 1993, the International Astronomical Union named asteroid 4589 McDowell in his honor.

McDowell is fascinated by the hidden history of the role of satellites in space exploration. "To me, it's sort of like a crossword," he says. "How do these satellites work? What do they do? How do they fit together? This is an incredibly significant era in human history; hundreds of years from now people will look back and want to know what happened in the space age."

McDowell's satellite chronicles begin with characteristic technical precision, with the Soviet Union's launch of the first satellite, Sputnik, on Oct. 4, 1957, at 19:28:34 Greenwich Mean Time. The 184-pound object, about the size and shape of a beach ball, did little in orbit besides transmitting an electronic beep. But it served as a kind of signal flare marking the start of the space age, inspiring dreams of moon colonies and space stations, and blazing a trail for thousands of spacecraft to follow.



History changed on Oct. 4, 1957, when the Soviet Union successfully launched Sputnik I, the world's first artificial satellite.

Fleets of scientific, commercial and military orbiters today play a vital role in communications, navigation, weather forecasting, intelligence and defense. By McDowell's count, there are currently just more than 1,000 active satellites, and about twice that number of defunct Earth orbiters.

Most represent investments of tens of millions of dollars and perform vital functions, like transmitting television signals, monitoring nuclear tests and transmitting the Global Positioning System data that keep millions of us from getting lost. The largest and most expensive satellite in history, the $100 billion International Space Station run by an international consortium, has hosted biomedical and materials science experiments and fostered global cooperation.

Typically these robotic spacecraft have gone about their business efficiently, as they pass silently overhead at speeds that can exceed 17,000 mph.

While the majority of these automatons don't draw much notice, the world would be a very different place without these machines pulling sentry duty.

Consider that most residents of Galveston, Texas, were blindsided by the hurricane that hit on Sept. 8, 1900, with 145-mile-an-hour winds and a 15-foot storm surge. The U.S. Weather Bureau didn't spot the monster until it had swept past Cuba, and even then no one was sure where it was headed.

First U.S. space launch: Explorer 1, Jan. 31, 1958.

About 8,000 lives were lost, making it by far the deadliest hurricane ever to hit the United States.

By contrast, residents in fall 2012 had several days warning that Hurricane Sandy was coming before it struck Atlantic City, New Jersey, with 80-mile-an-hour winds and 11-foot waves of water. Sandy still claimed more than 100 lives in the U.S., and caused an

SATELLITE MILESTONES

1903
Visionary and rocket scientist Konstantin Tsiolkovsky publishes a paper proposing the idea of a multistage rocket being used to launch a satellite into Earth orbit. He never actually builds a rocket.

1916
U.S. rocket scientist and inventor Robert Goddard writes his groundbreaking *A Method of Reaching Extreme Altitudes*. He later tells a reporter: "Every vision is a joke until the first man accomplishes it; once realized, it becomes commonplace."

1944
A German V2 rocket, developed by a team led by Wernher von Braun, is the first man-made object to reach space.

1957
The Soviet Union launches the first satellites, Sputnik 1 and 2.

1958
The U.S. makes its first successful satellite launch, of Explorer 1. Data from the flight helps lead to the discovery of the Van Allen radiation belts.

AFTER SPUTNIK THE SPACE BETWEEN THE EARTH AND THE MOON BECAME ONE OF THE MAIN PROPAGANDA, SURVEILLANCE AND INTELLIGENCE BATTLEGROUNDS OF THE COLD WAR.

estimated $65 billion in damages in New York and New Jersey. But without the help of advanced weather computers, radar systems and satellites, matters would have been far worse.

Of course, space is an arena for international competition as well, and after Sputnik the space between the Earth and the moon became one of the main propaganda, surveillance and intelligence battlegrounds of the Cold War.

Even today, space has its dark side. Satellites have been jammed, rammed and wrecked in a mid-orbit collision. There is still mystery as well. Governments, militaries and corporations often don't release critical details about the satellites they launch out of concern for national security or commercial secrets.

SPACE SPIES

Sputnik 1's flight marked the start of a period of intense innovation.

On January 31, 1958, four months after Sputnik 1 and 2, the United States answered with its first successful satellite, Explorer 1. While the German weapons scientist Wernher von Braun and his Redstone Arsenal team built the rocket, it was the brilliant James Van Allen, an Iowa native and former researcher at the Johns Hopkins Applied Physics Laboratory, who constructed Explorer 1's trailblazing scientific instrument.

Van Allen's decision to put a Geiger counter aboard led to what is arguably the first major scientific discovery using satellites: the existence of the radiation belts that bear his name. He went on to lead a team of University of Iowa rocket scientists who built scientific instruments for the Pioneer, Mariner, Voyager and Galileo spacecraft.

Most critical satellite technology was developed within the first five years of spacefaring, McDowell says: geosynchronous orbits, solar-powered communications and instruments, three-axis satellite stabilization, recoverable payloads and to some extent in-orbit maneuverability.

The year 1960 was a watershed. That's when the U.S. Navy launched the first successful communications satellite, the Courier 1B, and the first of its Transit navigation satellite fleet. That same year, the U.S. completed the successful launch of its first Corona spy satellite, which used cameras and recoverable film canisters to make detailed pictures of Soviet military installations. The launch—which came just three and a half months after the Soviets shot down the U-2 spy plane flown by Francis Gary Powers—eliminated the need for risky overflights.

William H. Pickering, James Van Allen and Wernher von Braun triumphantly raise a full-size model of the first U.S. satellite, Explorer 1, at a press conference following the craft's launch on Jan. 31, 1958.

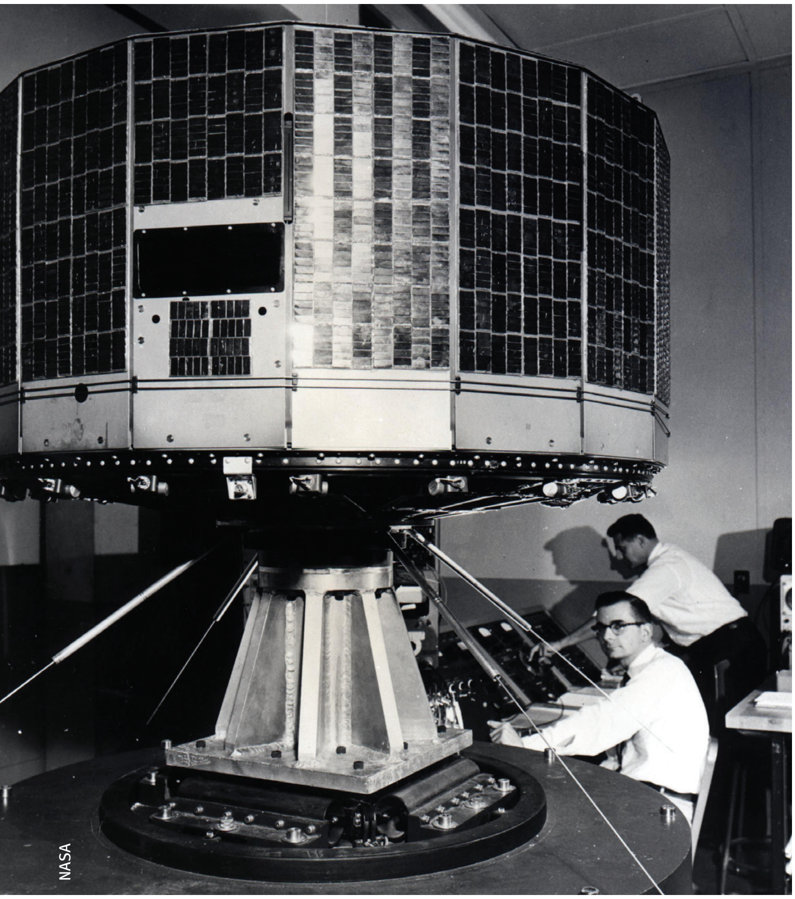
1960
The U.S. successfully launches the first active repeater communications satellite, Courier 1B, and the first weather satellite, Tiros 1.

1962
The U.S. launches Telstar 1, which carries the first live trans-Atlantic TV pictures.

1990
Launch of Hubble Space Telescope.

2000
Start of continuous habitation of International Space Station.

2012
NASA announces that Voyager 1, launched in 1977, appears to be on the last leg of its journey out of the solar system and into interstellar space. It has traveled almost 11 billion miles from the sun, farther than any other man-made object.



NASA

NASA

From left to right: The Tiros satellite, seen here undergoing vibration testing at the Astro-Electronic Products Division of RCA, was the world's first successful weather satellite. A blue and white Earth forms the background for this image (taken by crew aboard the International Space Station), which features the robotic Dragon 2 spacecraft in the grasp of the Space Station Remote Manipulator System. The Dragon spacecraft, which provides supplies, completed the first successful rendezvous with the Space Station in May 2012.

Today, the U.S. relies on its spy satellites as much as ever, not just to track other nations' nuclear arsenals but to keep an eye on militaries and militants around the globe. The program's current hardware and most other details are still cloaked in secrecy. But according to a 2013 budget document released by the National Reconnaissance Office, which runs the U.S. spy satellite program, "NRO sensors allow users to quickly focus multiple sensors on almost any point on the globe … and provide persistent, multi-INT [intelligence] coverage."

Starting in the 1960s, U.S. satellites began monitoring the frequencies and pulse periods of Soviet strategic radars. Later, more sophisticated spacecraft intercepted detailed data or "telemetry" from rocket tests. "We often had better data on Russian missile tests than they did, or at least as good," McDowell says.

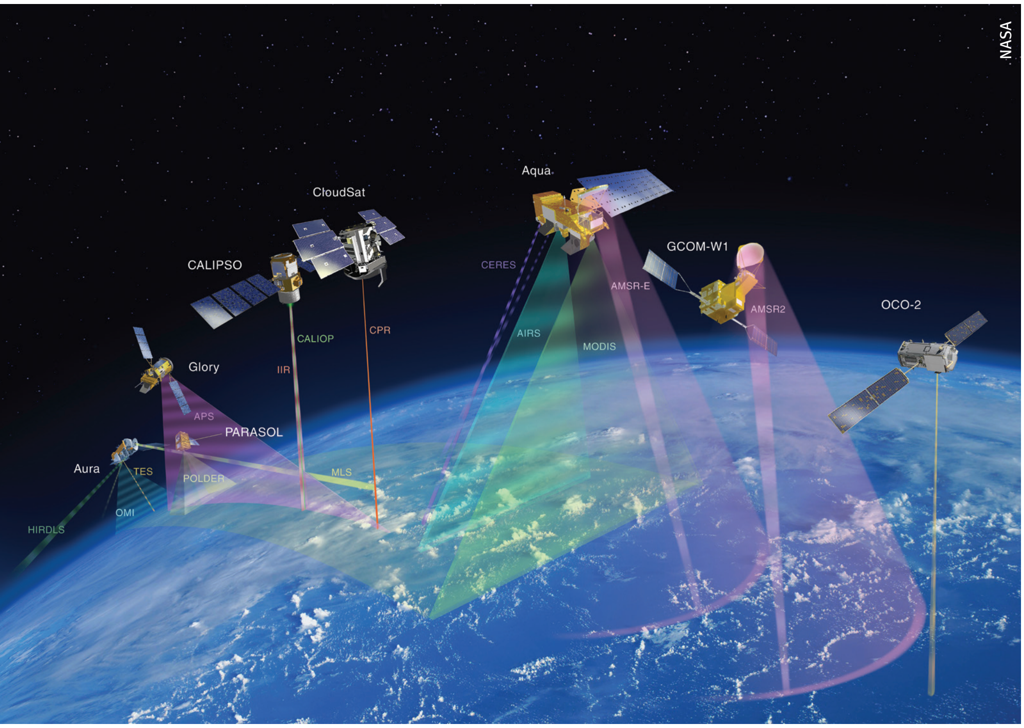
The United States also led in civilian satellite technology, orbiting the first successful weather satellite, Tiros 1, in 1960. Two Telstar communications satellites, built to relay telephone calls and television pictures across the Atlantic, were launched in 1962 and 1963.

About 30 years ago, McDowell says, the satellite business began to globalize as the Europeans and Japanese started their own space programs. "By the mid-1980s, you got away from the era of government superpower activity, with smaller nations being players as well." And the number of countries with national space agencies has continued to grow—from 40 in 2000 to about 55 in 2009, according to a report on Space.com.

While the superpowers concentrated on military and intelligence satellites, most of the recent spacefaring nations have focused on commercial and civilian orbiters. Today, McDowell estimates that roughly a third of satellites are dedicated to civilian applications, a third to military-related missions and a third to commercial programs.

Like most mature industries, the commercial satellite business has experienced its booms and busts. In the mid-1990s, there was optimistic talk that the satellite industry was poised for explosive growth, with hundreds of new communications satellites to handle voice and data networks. But these orbiters face competition from terrestrial cables and cell towers. "It didn't happen," McDowell says.

In recent years, cash, energy and enthusiasm have started pouring again into space startups. After the retirement of the aging space shuttle fleet in 2011, NASA announced that it would turn to private industry to send cargo to the



The "A-Train" convoy of satellites, which barrel across the equator each day at around 1:30 p.m., has emerged as a powerful tool for scientists who are studying the planet's changing climate. Their multisensor views chart changes in key environmental phenomenon—such as clouds or ice sheets—from numerous perspectives.

McMansion-sized $100 billion International Space Station, with the aim of controlling costs.

The agency has worked out deals with SpaceX Corp. of Hawthorn, California, and Orbital Sciences of Dulles, Virginia, to deliver 40 tons of supplies to the orbiter, which can accommodate six astronauts full time, in 20 flights, at a cost of around $3.5 billion. SpaceX's robotic Dragon spacecraft completed the first successful rendezvous with the Space Station in May 2012.

ANATOMY OF AN ORBITER

What keeps all these satellites in the sky? The Earth's thin layer of atmosphere creates "drag" or friction on everything that moves across the surface. But starting at about 120 miles up, the atmosphere thins to the point where gravity is the main force acting on an object.

When something is traveling at about 17,000 mph perpendicular to the Earth's surface, it's moving fast enough to keep from being dragged back into the atmosphere by gravity but slow enough so it doesn't zoom out of Earth's gravitational field. The result is a curving path around the planet, called an orbit.

Orbits can fly just above the atmosphere, as most manned and Earth-observing satellites do; or spin roughly 3,000 to 6,000 miles out, like most astronomical and other science satellites.

Global Positioning System satellites circle at between 6,000 and 12,000 miles out, while weather and communications satellites generally use higher, "geostationary" orbits—circling the Earth once every 24 hours at an altitude of 22,223 miles in order to stay in a fixed position relative to the surface. These satellites are relatively slow but still travel at nearly 2 miles a second.

Accelerating a large, heavy object like the space shuttle, which weighed more than 230,000 pounds loaded, to a speed of 17,000 miles an hour obviously takes a staggering amount of energy. So most satellites are built to be as light and compact as possible.

Satellites are all hand built by craftsmen, but all share the same basic design. A satellite's body is called its "bus." It contains the communications and control equipment, instruments, power and other technology. Most have solar cells and storage batteries—a few are nuclear-powered. All have computers, radios and stabilization systems, which may consist of gyroscopes, thrusters and star finders for orientation.

Usually, a given satellite will perform a few simple tasks, but because putting a satellite in orbit can cost from $50 million to $400 million, designers will use equipment that is both rugged and sophisticated to accomplish those tasks.

TODAY, MCDOWELL ESTIMATES THAT ROUGHLY A THIRD OF SATELLITES ARE DEDICATED TO CIVILIAN APPLICATIONS, A THIRD TO MILITARY-RELATED MISSIONS AND A THIRD TO COMMERCIAL PROGRAMS.

Each GPS satellite, for example, has an atomic clock on board and periodically transmits a signal relaying its location and current time. The signal is timed so that it transmits at exactly the same moment as all the other 24 or so GPS satellites. These signals arrive at the receiver at different times because some satellites are farther away than others. A GPS receiver uses the different arrival times to calculate the distance of the satellites. In turn, the receiver can use the data from at least four orbiters to calculate its location in four dimensions.

HOW GPS SATELLITES WORK

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HAZARDS ON THE HORIZON

A growing challenge for spacefarers today is space debris, which can range in size from the spent stages of old rockets to fragments smaller than nuts and bolts. Traveling at several miles a second, a screw can become a hypersonic bullet.

As space has become more crowded, the problem has worsened. A long-defunct Kosmos 2251 Russian military communications satellite collided accidentally with a U.S. Iridium communications orbiter over northern Russia in February 2009, creating two huge orbiting clouds of junk. Not all space scrap is put there by accident, either. In January 2007, China tested an anti-satellite weapon by pulverizing a 2,200-pound weather satellite, creating another orbiting scrap heap.

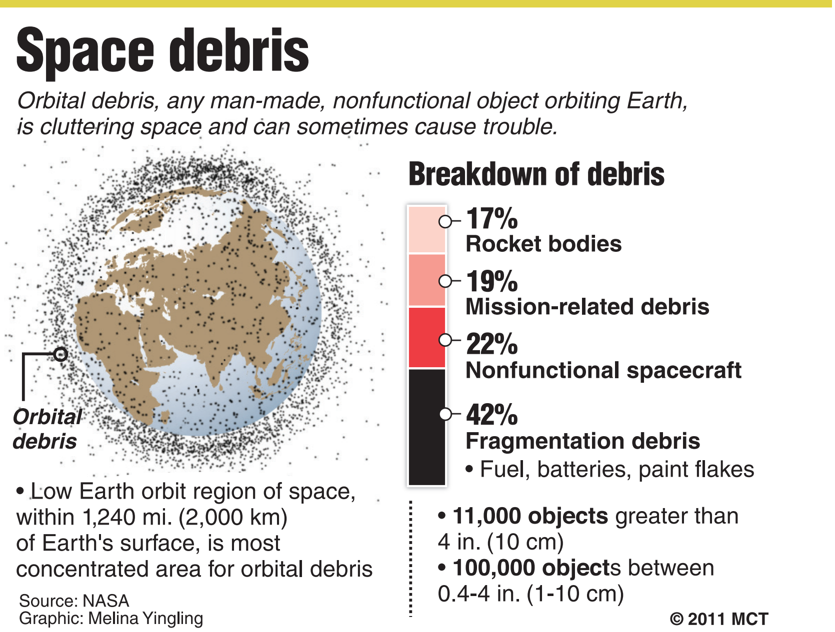
Donald Kessler, a former head of NASA's debris program, has predicted that one day there will be too much orbital trash to launch any satellites in near-earth orbit—a condition known as the Kessler syndrome.

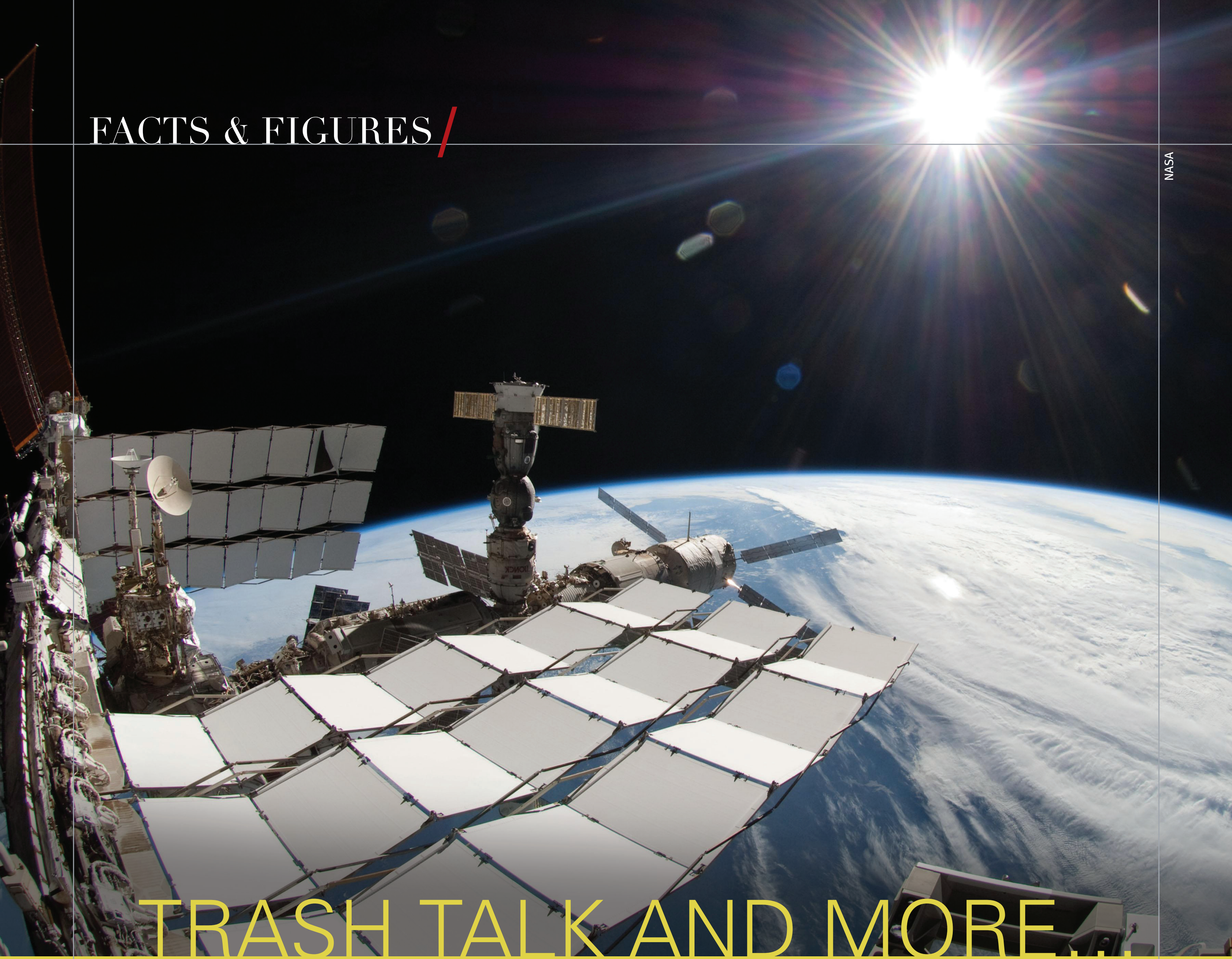
Satellite designers are making current satellites to shed fewer parts and putting smaller ones in lower orbits, where they burn up in the atmosphere sooner. And improved satellite tracking has helped avoid further mishaps. But cleaning up the mess made by previous collisions, explosions and disintegrations faces a daunting set of technical and diplomatic challenges.

McDowell worries that the biggest threat to satellite programs may simply be the ever-rising cost of putting stuff into orbit. "That's, I think, the biggest challenge that all of the space agencies face—the accounting frontier."

But there is also hope. The history of rocket science is one of overcoming obstacles. As more countries start space agencies and more businesses enter the field, competition could spur growth—and drive down costs. Increasingly, countries are talking about avoiding the overcrowded near-Earth orbits by placing communications and other working satellites beyond the moon. Nanosats—cheap orbiters—are making space more accessible to students and small science projects.

And where our robot friends go, can humans be far behind?





TRASH TALK AND MORE...

- There are more than 10,000 pieces of space debris in orbit. A piece plunges to Earth on average once a day, though so far there is no record of any ever having caused terrestrial property damage or injuries.
- Butter-fingered or just unlucky astronauts have added to space clutter over the years by losing pliers, a bag containing $100,000 worth of space tools, a glove and a camera while in orbit.
- The first earthling in space was the dog Laika, (whose name means "barker,") aboard Sputnik 2 in 1957. The first to orbit the moon was a tortoise; it flew aboard a Soviet Soyuz spacecraft on Sept. 14, 1968.
- The $100 billion International Space Station has been visited by 204 people since November 2000, according to NASA.
- Book now: Every seat for a U.S. astronaut on a Russian Soyuz spacecraft to the International Space Station now costs NASA $55.8 million. In 2014, the price will jump to $63 million.
- The Soviet Union sent up the first satellite, put the first man and woman in orbit, conducted the first spacewalk, made the first robotic soft landing on the lunar surface and launched the first space station. But the U.S. won the space race in 1969 with "one small step for man," when Neil Armstrong planted his size 9½ left boot on the moon.

The bright sun and a portion of the International Space Station and Earth's horizon are featured in this image photographed during the STS-134 mission's fourth spacewalk in May 2011. The image was taken using a fish-eye lens attached to an electronic still camera.