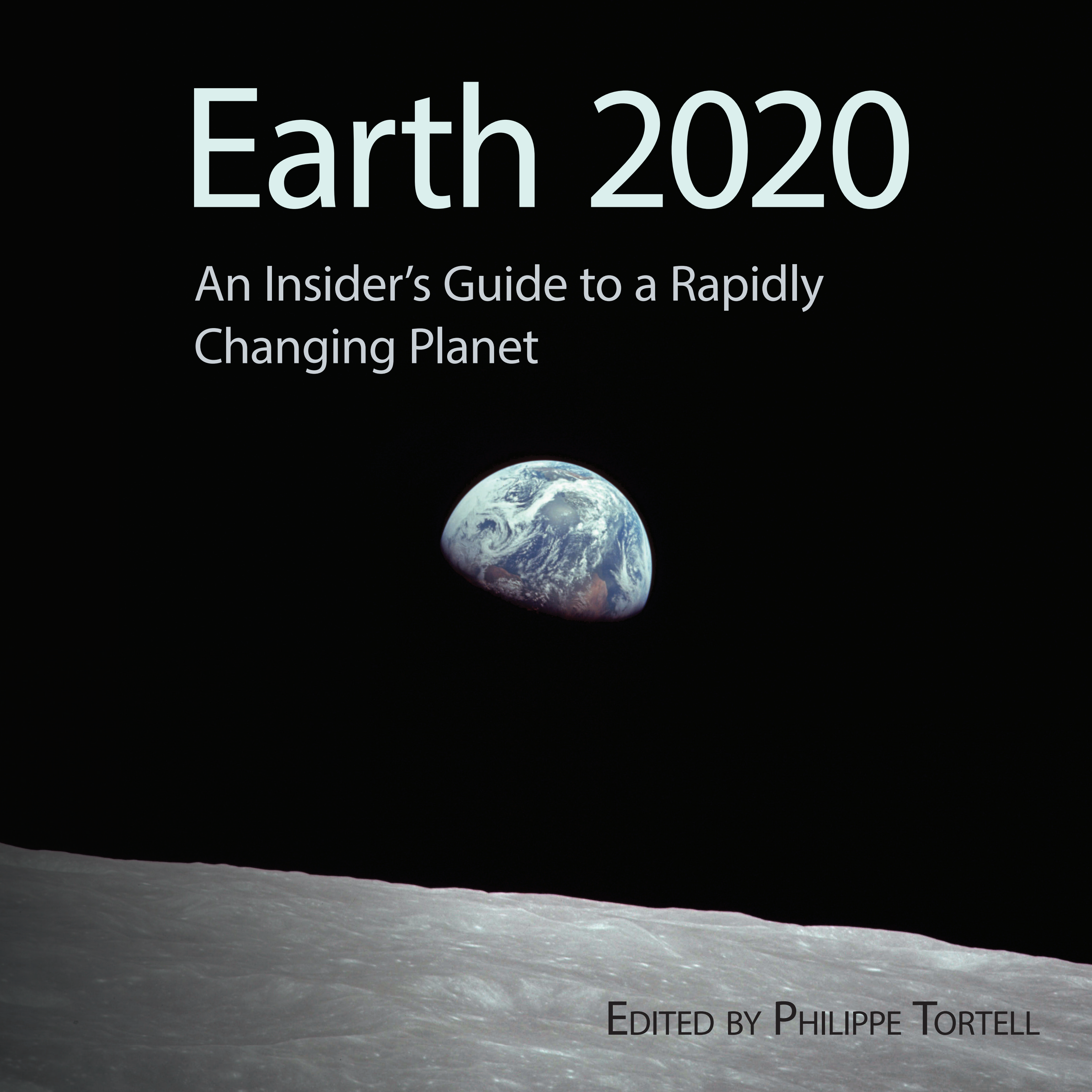
Earth 2020

An Insider's Guide to a Rapidly Changing Planet



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Space Junk

Alice Gorman

In a famous scene from the 2008 animated movie *WALL-E*, a rocket streaks up from Earth's surface, a tiny robot clinging to its side. Before reaching open space, the rocket punctures a thick layer of old satellites jostling cheek by jowl. As the layer cracks open, space junk erupts, scattering satellites like winged flies. A silver flagellated sphere gets caught in the robot's head before drifting off. The angles of its antenna are instantly recognizable; it's Sputnik 1, the first satellite ever launched, now reduced to just another piece of junk in the orbiting scrap yard. The message from this future world is clear. Just as Earth's surface has been polluted to the point where all human life has abandoned it, so too has the space surrounding Earth been choked with the endlessly circulating junk of the late industrial age.

Once upon a time, humans and their ancestors looked into the night sky to see the light of the Moon, stars, planets and galaxies, weaving them into culture through science and stories. Celestial bodies were intimate partners in the creation of a cosmos inhabited by ancestral beings and living impulses. Starting from the fifteenth century, however, new scientific methods like the telescope began to transform this intimate landscape into an infinite universe where human concerns were irrelevant.[1] This process created a distance between us and the stars that we have been striving to close ever since.

In the twentieth century, the means of creating intimacy with sterile space became material rather than visual. On October 4, 1957, the Russian satellite Sputnik 1 was propelled

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into Earth orbit. It was barely visible to the naked eye, but it made people look upwards in wonder or in fear. Sputnik 1 was blind. It carried no cameras to image the Earth whirling beneath it, but it did speak, emitting a beeping radio signal at the frequency of 20 MHz that became the sound of the Space Age. For four weeks (until the November 3 launch of Sputnik 2 with Laika the dog on board), Sputnik 1 was the only human object beyond Earth. Its successful injection into orbit was a moment of enormous consequence. It transformed Earth orbit into a buffer zone between humans and the wider solar system. In the years that followed, the formerly featureless 'orbital space' rapidly accumulated a population of robotic satellites and the junk they generated in their decay.

In the orbital space surrounding Earth, objects are in continual movement, and places are defined by velocity and height above the planet's surface. This is no longer a geography, which maps places on Earth, but an orbitography. Over the past six decades, human objects have colonized this orbital space, dividing it into zones and regions with distinct characteristics.

Low Earth orbit (LEO) ranges from around 200 km to 2,000 km above Earth's surface. Within this range, Earth observation satellites provide daily meteorological observations, environmental monitoring and military surveillance. Spacecraft in LEO are still within the outer reaches of Earth's atmosphere, which means their presence is temporary. Sparse molecules of gas exert friction on the objects, slowing them down and lowering their orbit until eventually they are drawn into the upper layers of the thermosphere. Few objects survive the ensuing blaze of re-entry into the atmosphere. Those which do make it through intact tend to have very high melting points, like the spherical titanium pressure vessels from spacecraft propulsion systems. Often, these 'space balls' are found on Earth's surface years after their re-entry, lying forgotten in fields or by lake shores.

In the first six years of the Space Age, all spacecraft were launched into LEO. The oldest space artefact still in existence is the Vanguard 1 satellite, launched by the United States in 1958. Like Sputnik 1, this satellite was also a polished silver sphere, but with six antennas as opposed to Sputnik's four. Notably, Vanguard 1 carried the first solar panels in space, providing energy to power its mission. Its orbit, tracked eagerly by people watching with binoculars and telescopes on Earth, was not a smooth curve. Wobbles in its trajectory caused by variations in Earth's gravitational pull demonstrated that Earth is not a perfect sphere; its oceans and continents hide a lumpy surface underneath. Both Sputnik 1 and Vanguard 1 were launched as part of the 1957–1958 International Geophysical Year. These early spaced-based observations proved to be a watershed in understanding the Earth system.

Earth orbit is a machine landscape, as human bodies are not adapted to the hostile conditions of the space environment.[2] Despite this, the most famous inhabitant of LEO is the International Space Station (ISS), which was launched in 1998 into an orbit around 400 km above Earth's surface. The ISS, weighing 420 metric tons, has been continuously occupied for twenty years, and is, by far, the largest artificial object in orbit, representing about 5% by mass of all human-made space materials. Inside its metal tubes, a crew of two to six people have lived in weightlessness from a few days to over a year at a time. The primary purpose of the ISS is to carry out science in microgravity, but its presence makes Earth orbit a home, a place where a new culture is being created through shared experiences of life in space.

Beyond LEO, starting at around 2,000 km above Earth's surface, is medium Earth orbit (MEO). In this region, high energy charged particles streaming from the Sun are trapped in Earth's magnetic field, enclosing the planet in protective flower-like curved petals. The high radiation levels are dangerous for satellites, potentially damaging their delicate electronics. Nonetheless, navigation satellites, vital to many facets of our everyday lives, are located in this region. The US Global Positioning Satellite (GPS), the European Space Agency Galileo and the Russian GLONASS constellations all orbit at around 20,000 km in MEO. Other MEO satellites include the 1962 commercial telecommunications satellite, Telstar 1, which inspired a raft of popular culture responses, including the design of a black-and-white hexagonal soccer ball and a chart-topping pop music hit ('*Telstar*' by the Tornados). When Telstar 1 failed in 1963, it became another piece of space junk, but one with great cultural significance.

High Earth orbit (HEO) begins about 35,000 km above Earth's surface. This is the region where telecommunications satellites, as well as the Chinese BeiDou constellation of navigation satellites, are located. At this altitude, satellites in geostationary orbits travel at the same speed as the rotation of Earth, maintaining a fixed position above a particular point on the planet's surface. The science fiction writer Arthur C. Clarke,[3] drawing on the work of the early twentieth century space theorists Konstantin Tsiolkovsky and Hermann Noordung, was the first English language writer to describe the potential of these orbits. In 1945, Clarke proposed that just three satellites in geostationary orbit could provide coverage of the entire globe. About 500 km above this orbit is a graveyard where old telecom satellites are boosted out of the way of functioning spacecraft. HEO ends where cislunar space begins, at around 150,000 km from Earth. Some spacecraft have passed through this region, like the STEREO A and B solar observatories, and it's possible that dust from satellite decay has migrated here.

For sixty years, we have been adding human materials to the space environment. These spacecraft have transformed virtually every aspect of our lives — from agriculture, environmental management and weather prediction to internet and banking. But what happens when their official mission ends? Suddenly, their status changes from an asset to a liability. They become 'space junk'.

In the first decade of the Space Age, scientists were concerned about the dangers of meteorites colliding with astronauts and spacecraft. It became apparent, however, that human debris was coming to outnumber the 'natural' objects in orbit. Instead of micrometeorites, the real problem was likely to be collisions between human materials. In 1978, Donald Kessler and Burton Cour-Palais wrote a paper which predicted a worst-case scenario, now known as the Kessler syndrome.[4] Continued debris collisions, they argued, could result in a runaway cascade where debris would be created even if no new objects were launched. In this scenario, certain regions of space could effectively become unusable, as depicted in *WALL-E*.

Today, there is significant debate about how close we are to realizing the Kessler syndrome. But there is no doubt that the risk of collision with space junk is increasing. In 1970, the year of the first Earth Day, there were an estimated 2,500 space objects distributed from LEO to HEO. Half a century later, in 2020, there are well over 30,000 pieces of debris larger than 10 cm in Earth orbit, and many millions of fragments and particles below that size. The combined total weight of human-derived space junk is estimated to be 8,400 tons (the equivalent of 4,000 adult giraffes). This includes functioning satellites, whole satellites that are no longer working, rocket bodies left abandoned in orbit after delivering their payloads, mission-related debris like the fairings that are discarded to release the satellite within, and chunks, fragments and flecks of spacecraft materials.

The density of junk is greatest in LEO. And although objects in LEO eventually get dragged back into the atmosphere where they largely disintegrate, this removal happens at a much slower rate than the creation of new debris. Over the past several decades, the space debris population has increased dramatically, as the global economy and everyday life has come to depend more and more on satellite technologies. Sometimes, catastrophic events cause a sudden increase in the amount of debris. This was the case in 2007 and 2019, for example, when China and India deliberately destroyed their own satellites using Earth-launched missiles, leading to the creation of thousands of debris objects in LEO. These actions were widely condemned by the international space community, but there's no guarantee similar tests won't occur again.

Like the accumulation of plastics on Earth, the growth of space junk poses significant problems. Satellites are a billion-dollar industry, upon which much of our modern lives depend. Collision with space junk can erode a satellite's surfaces, cause it to malfunction, or, in the worst-case scenario, explode. Each collision creates new pieces of space debris, further exacerbating the problem. The risks of space junk could prevent the emergence of the much-anticipated space tourism industry.

To date, solutions to our growing space junk problem have included guidelines to minimize the creation of debris. These guidelines recommend designing spacecraft so that there is no explosive fuel left at the end of mission life; removing spacecraft to a 'graveyard orbit'; shielding spacecraft against collision and incorporating tethers to drag them into the atmosphere. As for actively removing old debris from orbit — something that is now actively planned[5] — there are two main obstacles. First, maneuvering in orbit to capture an old satellite is extremely costly in fuel, and therefore presents a poor business case, even for the most potentially dangerous objects. More importantly, any mechanism for removing satellites from orbit could be deployed as a weapon to hobble an adversary's space capabilities, creating a host of geopolitical challenges. And so, despite increasing attention being given to space situational awareness (SSA) and space traffic management (STM), we have thus far made little progress in solving the growing problem of space junk. Time, however, may be running out.

At the same time, it may be too easy to characterize space debris as merely a problem of 'junk' that needs to be fixed. There are other ways of understanding what Earth orbit has become. One alternative approach is to consider Earth's near space environment as a cultural landscape with its own intrinsic values. When viewed through such a lens, we come to break down the distinction between natural and cultural, envisioning a new space that has resulted from the historic interactions between human and environmental factors. Here, interplanetary dust mingles with the machine dust derived from the decay of human-manufactured materials under the harsh conditions of high energy particles, micrometeorites, atomic elements and collision with other space debris. This dust mix is the archaeological signature of a space-faring species.

What counts as 'junk' is also very dependent on cultural values. Among the 4,000 defunct satellites in Earth orbit, many have heritage value in preserving legacy technologies, historic moments or processes, or through their symbolic or social significance to a nation or community. The natural setting for these artefacts is the orbital landscape, and where they do not constitute a collision risk, there is no reason to remove them. Moreover, old satellites or satellite materials can be recycled or re-used. Abandoned satellites can be repurposed for new missions such as collecting scientific data, providing they have sufficient fuel or batteries left. The metals used in spacecraft manufacture can also be used as fuel in plasma rocket engines. In future orbital manufacturing industries, space scavenging could save the enormous expense of lofting materials from Earth. Clearly, end-of-life plans for satellites have thus far not been creative enough.

Today, in 2020, we are facing a transformation of Earth's orbital landscape with the launch of proposed mega-constellations of internet telecommunications satellites. The first of these have already been launched, even though the effects of injecting tens of thousands of new objects into an already congested region of space are not fully understood. Notwithstanding the optimistic assurances of commercial operators that the satellites will quickly re-enter Earth's atmosphere, it is clear that that predictions of the onset of the Kessler syndrome will have to be revised.

No longer will people on Earth have to scan the skies systematically to pick out a lone silver sphere, as they did in 1957. Satellites sightings will become the norm, rather than the exception; they will be our constant companions whenever we look heavenwards. The burning shards of re-entering spacecraft will cease to cause fear and astonishment. And, in a few decades, the people who remember the sky before Sputnik 1 shattered its peace will be gone. Soon, the whirling graveyard of space junk punctuated by living robots will be all we have ever known.

Endnotes

1. A. Koyré, From Closed World to Infinite Universe, Baltimore: Johns Hopkins University Press, 1957.
2. A. C. Gorman, 'Ghosts in the machine: space junk and the future of Earth orbit', Architectural Design, 2019, 89, 106–11, https://doi.org/10.1002/ad.2397
3. A. C. Clarke, 'Extra-terrestrial relays', Wireless World, 1945, 305–08.
4. D. Kessler and B. Cour-Palais, 'Collision frequency of artificial satellites: The creation of a debris belt', Journal of Geophysical Research, 1978, 83, 2637–46, https://doi.org/10.1029/JA083iA06p02637
5. A new ESA mission called ClearSpace-1, with the aim of piloting space junk removal, is planned for launch in 2025. See http://www.esa.int/ESA_Multimedia/Images/2019/12/ClearSpace-1