BJHS Themes (2024), **9**, 59–81
doi:10.1017/bjt.2024.27

RESEARCH ARTICLE

Space is the place: extraplanetary disorder in histories of science

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Abstract

What happens when we take the big picture to its spatial zenith and examine histories of science from the vantage point of outer space? The answer is somewhat messy. The satellite era launched alongside *Sputnik 1* in 1957 facilitated the extension of scientific order and control through technologies of planetary surveillance. Yet regimes of disorder and fragmentation that emerged through entanglements of anthropogenic and more-than-human natural forces at the planetary periphery prompt a reconsideration of the limits of that control. Enrolling the methodologies of envirotech and discard studies scholarship invites a generatively messy, vertical and extra-planetary view of scientific practices and politics from the ground up and back again, and a glimpse at the historiographical possibilities that emerge from an embrace of systemic disorder.

In 1966, Stewart Brand took 100 micrograms of LSD and gazed at the San Francisco skyline, waiting for a psychedelic vision to guide him towards clarity on how to promote environmental responsibility among everyday people. After envisioning the curvature of the Earth during his trip, Brand spent months making and distributing buttons asking a simple question: 'Why haven't we seen a photograph of the whole Earth yet?'[1]

The following autumn a rocket took off from Cape Canaveral, Florida. It placed a cylindrical satellite with an experimental camera aboard at an altitude of roughly 35,700 kilometres over the Atlantic Ocean. From this position, the Applications Technology Satellite 3 (ATS-3) had a clear view of the global cloud patterns that it had been designed to document. Days after its successful launch, ATS-3 transmitted a full-colour, full-disc image of the Earth to its operators on the ground below.

When NASA released the photograph, it became the first publicly available image of its kind.[2] The ATS-3 picture heralded an influx of such views of the whole Earth from the outside that inspired a shift in popular and specialist discourse as the mainstream environmentalist movement continued to build steam. Such images, including the *Blue Marble* photograph taken by Apollo astronauts returning home from the Moon, provided a technologically

1 Stewart Brand, 'Why haven't we seen the whole Earth?', in Lynda Obst (ed.), *The Sixties: The Decade Remembered Now, by the People Who Lived It Then*, New York: Rolling Stone Press, 1977, pp. 169–70.

2 The first full-colour, full-disc image of the Earth was captured by the DODGE (Department of Defense Gravity Experiment) satellite, which launched a few months earlier in 1967, but given the military status of DODGE the image taken by ATS-3 was the first to be widely available.

https://doi.org/10.1017/bjt.2024.27 Published online by Cambridge University Press

mediated but seemingly objective view of Earth as something more than a globe.[3] Against a backdrop of empty space, all visual evidence of human presence abstracted, cartographic detail obliterated, the whole Earth stands out as a fragile anomaly in a hostile, vacant cosmos – a colourful planet, lonely and remarkable and worthy of protection.[4]

The ATS-3 image provided a holistic, interconnected view of the Earth anticipated by psychedelic enthusiasts like Stewart Brand as well as by planetary scientists. It diverged from photographs taken earlier in the Space Age that glimpsed partial, crescent or gibbous Earths, some devoid of colour, from orbit or the Moon. It also challenged long-standing Western cartographic hierarchies upheld not only by two-dimensional world maps but by globes, whose vertical orientation and geometric demarcations buttressed narratives of primacy and colonial control by what is now known as the global North.[5] It conveyed a nature that is planetary rather than specific to any one region or national experience. It diverged from the twentieth-century nationalist frontier narratives of lunar conquest that spurred the production of the image in the first place, instead focusing the technological gaze back to a collective home.[6] Brand's vision bore fruit – the whole Earth would soon become an icon of the flourishing environmental movement and a metonym for nature in its entirety.[7] The ATS-3 image graced the front and back covers of the very first *Whole Earth Catalog*, the counterculture lifestyle manual published by Stewart Brand beginning in 1968 (Figure 1).

ATS-3 reached its home in geostationary orbit ten years into the satellite age. It joined some 1,400 artificial objects occupying near-Earth space at distances ranging from under two hundred kilometers above the surface to hundreds of thousands of kilometers, from Earth orbit to solar orbit – not including the many rockets, expired satellites and other artefacts that had entered space and re-entered the atmosphere in the preceding decade. Over time, the number of artificial objects continued to grow, both through intentional efforts to operate satellites at high, slow-to-decay altitudes and through unintentional anomalies like on-orbit fragmentations. Objects too small to track also multiplied, creating a vertical circumplanetary continuum of artefacts in use and in discard.[8] Yet, against the vastness of space and a much larger planet, the ever-proliferating effluent of the space industry has never been directly discernible in whole-Earth photographs. A photograph of daytime Earth from space looks much the same today as it did in 1967.[9]

3 On the complexities of the 'mechanical objectivity' of photography see Lorraine Daston and Peter Galison, *Objectivity*, New York: Zone Books, 2010.

4 Elizabeth DeLoughrey, 'Satellite planetarity and the ends of the Earth', *Public Culture* (1 May 2014) 26(2) (73), pp. 257–80.

5 Sumathi Ramaswamy, *Terrestrial Lessons: The Conquest of the World as Globe*, Chicago: The University of Chicago Press, 2017; Robert Poole, 'What was whole about the whole earth? How the earth sciences saw their subject during the Cold War and beyond', in Simone Turchetti and Peder Roberts (eds.), *The Surveillance Imperative: The Rise of the Geosciences during the Cold War*, New York: Palgrave Macmillan, 2014, pp. 213–35; Denis Cosgrove, *Apollo's Eye: A Cartographic Genealogy of the Earth in the Western Imagination*, Baltimore: Johns Hopkins University Press, 2001, p. 261.

6 Neil Maher, 'Neil Maher on shooting the moon', *Environmental History* (1 July 2004) 9(3), pp. 526–31.

7 Even as globes and maps pre-dated these pictures the proliferation of 'global' in political, environmental and general uses accelerated after the release of the first whole-Earth images. See Benjamin Lazier, 'Earthrise; or, the globalization of the world picture', *American Historical Review* (June 2011) 116(3), pp. 602–30.

8 For more on the vertical continuum of waste (and nuclearity) from Earth to space see Lisa Ruth Rand, 'Falling Cosmos: nuclear reentry and the environmental history of earth orbit', *Environmental History* (January 2019) 24(1), pp. 78–103.

9 Night-time views, however, have changed significantly. For visual and historical analysis of night-time images of Earth from space as evidence of human presence and environmental impact on a planetary scale, see Sara B. Pritchard, 'The trouble with darkness: NASA's Suomi satellite images of Earth at night', *Environmental History* (1 April 2017) 22(2), pp. 312–30.

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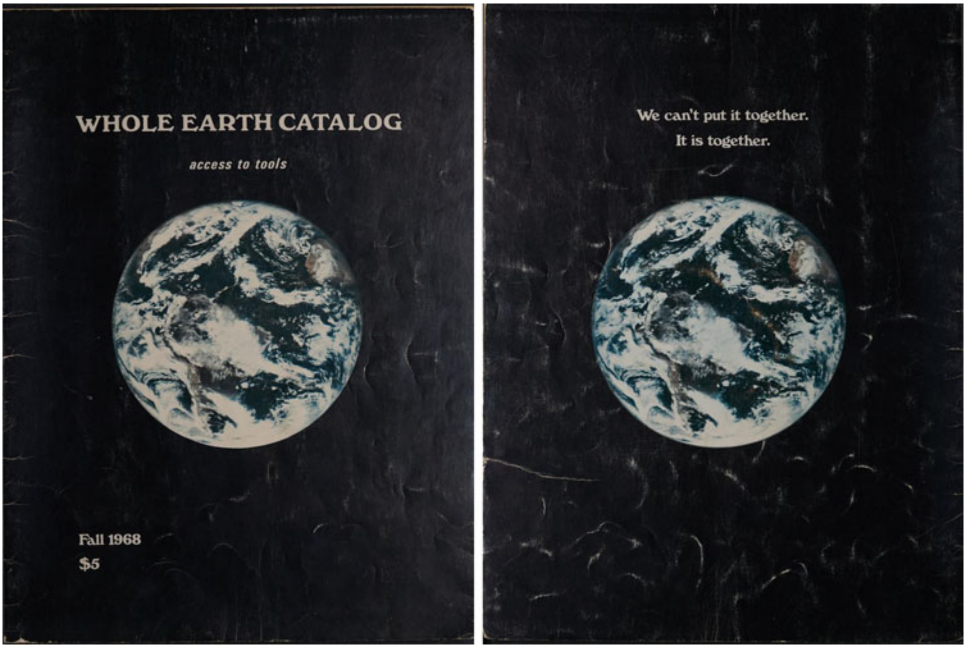

Figure 1. The first publicly available full-colour, full-disk image of the whole Earth from outer space, taken from the ATS-3 satellite in 1967, appeared on the front and back covers of the first *Whole Earth Catalog* published in the autumn of 1968. The phrase 'We can't put it together. It is together' on the back cover reflects the publishers' ideas about global unity, fracture, and fragility against the backdrop of outer space. Credit: Portola Institute.

Forty years after ATS-3 sent its novel whole-Earth image to the ground, China's space programme launched a projectile into a collision course with one of its own defunct weather satellites, *Fengyun-1C*. The two objects crashed into each other and instantly fragmented into thousands of smaller pieces. In the days and weeks that followed, specialists in orbital dynamics plotted the expected dispersal of the two rapidly spreading, intersecting plumes of high-velocity debris as they extended along the former paths of the destroyed spacecraft and threatened to converge with points representing vulnerable satellites like the International Space Station. Digital representations of the 2007 anti-satellite test showed a planet much like the one celebrated the previous century on the cover of the *Whole Earth Catalog*, on *Blue Marble* postage stamps, and on the first Earth Day flag. However, in these dynamic tableaux the whole Earth is background rather than foreground. The focus is instead drawn to a flush of bright dots enveloping a shadowy sphere. In static simulations, the Earth becomes almost entirely shrouded in arcing lines representing the dispersal and perpetual motion of debris fragments over time (Figure 2).[10]

Debris maps like those created to help observers on the ground make sense of the *Fengyun-1C* anti-satellite test provide simulated twenty-first-century views of the planet that aren't necessarily any more or less technologically mediated than the first whole-Earth images captured by robotic spacecraft or by astronauts travelling to and from the Moon. However, they reverse focus in two key ways. If whole-Earth photographs obscured evidence of human presence in favour of a pristine view of an unmarked,

10 Nicholas L. Johnson, E. Stansbery, J.-C. Liou, M. Horstman, C. Stokely and D. Whitlock, 'The characteristics and consequences of the break-up of the Fengyun-1C spacecraft', *Acta Astronautica* (August 2008) 63(1), pp. 128–35.

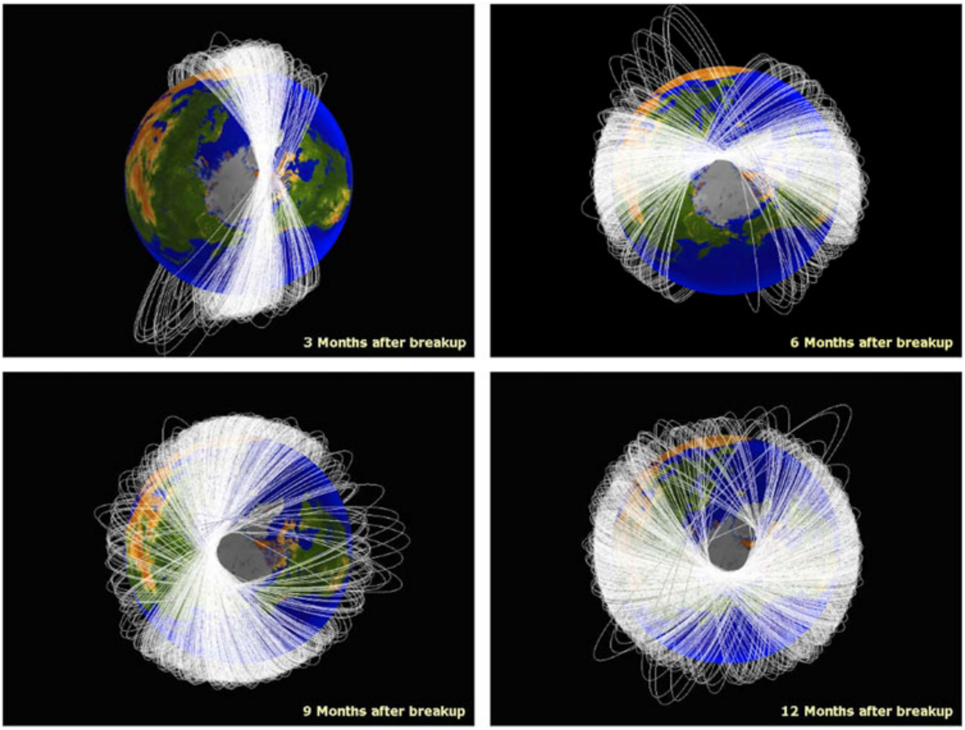

Figure 2. In January 2007 the Chinese government confirmed that the nation had conducted an anti-satellite test, destroying one of its own weather satellites using a ballistic kinetic kill vehicle. The diagrams shown here, created and released by NASA researchers eight months later, illustrate the subsequent and projected dispersal of orbiting debris created in this event. Before January 2007 the *Fengyun-1C* satellite would have been represented by a single, unremarkable point in diagrams of artificial material in orbit (see Figure 3). By the twelve-month dispersal projection, the whole Earth is largely obscured by bright lines indicating the expansive fragmentation of that single point into an uncontrollable swarm of thousands. Credit: reprinted from Nicholas L. Johnson, E. Stansbery, J.-C. Liou, M. Horstman, C. Stokely and D. Whitlock, 'The characteristics and consequences of the break-up of the *Fengyun-1C* spacecraft', *Acta Astronautica* (August 2008) 63(1), pp. 128–35, with permission from Elsevier.

unspoiled planet from outside, maps of orbital debris put discrete anthropogenic detail back into a tenuously bounded, fractured planetary picture.[11] They also bring space itself into sharper focus, not just as the hostile surroundings of a lonely, limited planet in need of stewardship but as an active, dynamic force of change over time. While citizens of the planet below envisioned, designed, launched, operated and in some cases destroyed the objects represented (in whole or in aggregate) by these points, the space environment itself also played a significant role in shaping each of these stages of technological development. Images of the whole Earth swarmed by artificial debris evoke a planet that's neither pristine nor isolated but rather part of a vast, unruly, ecosystemic – and Anthropocenic – cosmic neighbourhood.[12]

11 Programmed images of an Anthropocene whole Earth, particularly those rendered as part of climate change research, accomplish similar renderings of anthropogenic detail, though the boundaries of the planet remain sharp and details of the who/what/where of those details remain obscured. See Birgit Schneider, 'Burning worlds of cartography: a critical approach to climate cosmograms of the Anthropocene', *Geo: Geography and Environment* (2016) 3(2), e00027.

12 The so-called 'Anthropocenic turn' within the humanities provides opportunities to explore the rich conceptual dimensions of this period beyond its geophysical meanings. See Gabriele Dürbeck and Philip Hüpkes

Each uniform point in each bright swirl represents a piece of an ever-growing mass of refuse accumulated during half a century of industrial activity in orbit. Each point also represents an entanglement of nature, technology and politics that cannot be easily unravelled or tidily categorized. Over time, the proliferation of anthropogenic things moving into, through and beyond the planetary perimeter has degraded divisions between terrestrial and extraterrestrial space. It has systemically rearranged centres and peripheries of power in an era shaped by global fracture. It has broken down boundaries of expertise and corroded the scientific culture of control out of which the satellite era arose. In short, from a vantage point above and beyond a planetary Earth, the big picture of history of science gets very, very messy.

By incorporating ideas and methodologies from the interdisciplinary fields of envirotech and discard studies – which look to entanglements of natures and technologies that create, maintain and destabilize systems of order – this article invites historians of science to embrace messiness as epistemologically generative. The article begins by outlining both fields' expansive approaches to assessing the relationships between technological, social and political practices and more-than-human processes and agencies and invites rethinking order and disorder as expressions of power. It next touches upon the evolution of the orbital landscape beginning with the first orbiting artefacts, during which uneasy encounters with near-Earth space affected the expansion of the global picture, have reshaped ideas about Earth's place in the solar system, and have broadened participation in Space Age orbital regimes shaped by waste and wasting practices. The article positions such unevenness and fragmentation of the whole-Earth image and the first artificial moon as indicative of the construction of an extraplanetary envirotechnical regime, one that both replicates and resists scientific modes of mastery. Finally, viewing the history of science from an ever-shifting planetary periphery made and remade in acts of fracture and discard provides an entry point to rethink implicit or explicit imperatives of historiographical control. By saying yes to the mess, historians of science may reconsider the limits of categorization – of human and non-human, Earth and Elsewhere, specialist and amateur, just to name a few – and look beyond traditional regional, institutional and professional boundaries to gain a clearer view of the uneven contours of control shaping a more-than-human, more-than-global planetary picture.

Extraplanetary waste and hybrid landscapes: methodological interventions

Orbital debris diagrams like those created to represent the *Fengyun-1C* collision illustrate the confluence of scientific practices, politics and landscape change juxtaposed with visions of an immutable whole Earth. These simulations provide glimpses of a whole planet disrupted by the by-products of space science and industry. Their creators manipulate speed and scale to overcome the obfuscation of relativity – otherwise a piece of destroyed satellite would not visibly register against a vastly larger planet. Such renderings reconfigure what might otherwise be unremarkable, invisible objects as significant, even powerful in their ability to enshroud and obscure the entire Earth. Debris maps offer

(eds.), *The Anthropocenic Turn: The Interplay between Disciplinary and Interdisciplinary Responses to a New Age*, London: Routledge, Taylor & Francis Group, 2021. On the Anthropocene as a more-than-Earthly epoch see Valerie Olson and Lisa Messeri, 'Beyond the Anthropocene: un-Earthing an epoch', *Environment and Society: Advances in Research* (2015) 6(1), pp. 28–47; Valerie A. Olson, 'NEOecology: the solar system's emerging environmental history and politics', in Dolly Jørgensen, Finn Arne Jørgensen and Sara B. Pritchard (eds.), *New Natures: Joining Environmental History with Science and Technology Studies*, Pittsburgh: University of Pittsburgh Press, 2013, pp. 195–211; Alice Claire Gorman, 'The Anthropocene in the solar system', *Journal of Contemporary Archaeology* (22 August 2014) 1(1), pp. 87–91; Lisa Ruth Rand, 'Beyond the biosphere: expanding the limits of the human world', in John W. Kress and Jeffrey K. Stine (eds.), *Living in the Anthropocene: Earth in the Age of Humans*, Washington, DC: Smithsonian Books, 2017, pp. 66–9.

https://doi.org/10.1017/bjt.2024.27 Published online by Cambridge University Press

planetary-scale evidence not necessarily of matter out of place, as the relational categories of belonging and not-belonging that delineate waste and dirt from wanted things are described by Mary Douglas.[13] Rather, they reveal disorderly matter that reifies the vast reach of power practices on the ground below as well as the significance of more-than-human natural forces that influence human histories well beyond the familiar context of the biosphere.

Virtual renderings of debris serve as 'environing' technologies by drawing into focus the very externalities that rendered the original whole-Earth photographs so remarkable.[14] Space itself, the seeming void, the great absence, becomes an environmental actor in a hybrid technical–natural landscape in which human actions and physical forces enmesh, making it difficult to extricate clear lines of agency or intent. If the planetary is a condition in which 'there is no outside', with no distinction between nature and society in 'planetary co-participation', then the permeable boundaries of the terrestrial displayed by this landscape provoke questions about the shape of that participation – and the centres and peripheries that emerge in its wake.[15]

Research in history and science and technology studies has recently begun to un-Earth scholarly and mainstream understandings of nature and the environment, embracing cosmic places as natural actors.[16] The approach to foregrounding extraplanetary space offered here takes a step beyond examining conflations of human and non-human, a distinction that can yield misleading deterministic relationships.[17] Avoiding that pitfall requires prioritizing the tangled interstices in which these distinctions blur, revealing the scale and breadth of messy more-than-human historical processes. In offering up the epistemological promise of messiness this article suggests that historians of science look to the methods and priorities of the interdisciplinary fields of discard studies and envirotech to find expansive, if disruptive, ways of thinking about the shape, scope and limits of power in scientific contexts.

If technology is a means by which humans interpret, interact with and shape worlds – and by which those worlds also shape humans – then envirotech equally honours the role of a broadly inclusive nature in shaping those technologies from invention and use through disuse and decay. Tracing the reshaping of large socio-technical–environmental systems, such as the changing landscape of Earth orbit from the start of the Space Age through to the present moment, requires acknowledging this hybridity in a way that

13 Mary Douglas, *Purity and Danger: An Analysis of Concepts of Pollution and Taboo*, London: Routledge, 1966.

14 For more on technologies that shape conceptual framing of nature as an environment to be perceived and used see Sverker Sörlin and Nina Wormbs, 'Environing technologies: a theory of making environment', *History and Technology* (3 April 2018) 34(2), pp. 101–25.

15 Gayatri Chakravorty Spivak, *Death of a Discipline*, New York: Columbia University Press, 2003, pp. 71–6; Spivak, '"Planetarity" (Box 4, WELT)', *Paragraph* (July 2015) 38(2), pp. 290–2. On the challenges of life on a world both global and planetary see Dipesh Chakrabarty, *The Climate of History in a Planetary Age*, Chicago: The University of Chicago Press, 2021.

16 Roger D. Launius, 'Writing the history of space's extreme environment', *Environmental History*, 1 July 2010, pp. 526–32; Gorman, op. cit. (12); Valerie Olson, *Into the Extreme: U.S. Environmental Systems and Politics beyond Earth*, Minneapolis: University of Minnesota Press, 2018; Michael Rawson, 'Discovering the final frontier: the seventeenth-century encounter with the lunar environment', *Environmental History* (1 April 2015) 20(2), pp. 194–216; Olson and Messeri, op. cit. (12); Lisa Messeri, *Placing Outer Space: An Earthly Ethnography of Other Worlds*, Durham, NC: Duke University Press, 2016; Lisa Ruth Rand, 'Orbital decay: space junk and the environmental history of Earth's planetary borderlands', doctoral dissertation, Philadelphia: University of Pennsylvania, 2016; Rand, op. cit. (12); Dagomar Degroot, '"A catastrophe happening in front of our very eyes": the environmental history of a comet crash on Jupiter', *Environmental History* (1 January 2017) 22(1), pp. 23–49; Rand, op. cit. (8).

17 Sara B. Pritchard, 'Toward an environmental history of technology', in Andrew C. Isenberg (ed.), *Oxford Handbook of Environmental History*, New York: Oxford University Press, 2014, pp. 203–28.

https://doi.org/10.1017/bjt.2024.27 Published online by Cambridge University Press

does not privilege humans over other (and othered) natural actors, nor require careful drawing of boundaries around spatial or socio-technical categories.[18]

Envirotech as an interdisciplinary approach to historical scholarship accomplishes this by checking the impulse to draw deterministic relationships between technology and technical knowledge making and nature broadly writ. Drawing from history of technology and environmental history, envirotech starts from the perspective of the environment as always-already a central part of technological systems and one among many influences shaping technological change over time. Envirotechnical regimes comprising 'institutions, people, ideologies, technologies, and landscapes that together define, justify, build, and maintain a particular environmental system as normative' create and sustain envirotechnical systems even as the relationships among these entities often remain persistently uneasy.[19]

Whether in the context of established infrastructures in use or in moments of disaster, the envirotech gaze is often at its most revelatory when specific socio-technical forces of change cannot be easily disentangled from those categorized as natural.[20] Envirotech scholarship of the last two decades has demonstrated the effectiveness of this approach through examinations of the construction, maintenance and reconfiguration of energy systems, agricultural landscapes and hybrid natural–technological disasters grown out of the non-deterministic, fluid entwining of socio-technical and environmental systems.[21] As this article aims to demonstrate, embracing perspectives that elevate disorder opens pathways towards wider-ranging dimensions of change over time than might be gleaned through neater processes of categorization that assign clear lines of causality to one entity or another.

Joining envirotech methods to those of discard studies adds additional perspective to the mess.[22] The extraplanetary morass constructed in orbit during the post-*Sputnik* era confirms the vast scale and comprehensiveness of systemic inequities grown out of accelerating waste and wasting practices, including those emerging from scientific practice. The view of Earth from outer space, with the addition of data in control indicating artefacts out of control, brings into focus the scope not just of orbital debris as a symptom of industrial practice but also of the disorder that creates it as a tool of systemic – and in this case scientific – power. Examining power structures maintained and threatened by order and disorder is a central priority of discard studies scholarship.

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18 Put another way, tangling up the networks of ANT. Bruno Latour, *Reassembling the Social: An Introduction to Actor-Network Theory*, Oxford: Oxford University Press, 2005.

19 Sara B. Pritchard, *Confluence: The Nature of Technology and the Remaking of the Rhône*, Cambridge, MA: Harvard University Press, 2011, p. 23; Pritchard, op. cit. (17).

20 Martin Reuss and Stephen H. Cutcliffe (eds.), *The Illusory Boundary: Environment and Technology in History*, Charlottesville: University of Virginia Press, 2010.

21 For some examples of this scholarship see Mark Fiege, *Irrigated Eden: The Making of an Agricultural Landscape in the American West*, Seattle: University of Washington Press, 1999; Gregg Mitman, Michelle Murphy and Christopher Sellers (eds.), *Osiris* (2004) 19, *Landscapes of Exposure: Knowledge and Illness in Modern Environments*; Helen M. Rozwadowski, 'Oceans: fusing the history of science and technology with environmental history', in Douglas Cazaux Sackmanessor (ed.), *A Companion to American Environmental History*, Chichester: Wiley-Blackwell, 2010, pp. 442–61; Christopher F. Jones, *Routes of Power: Energy and Modern America*, Cambridge, MA: Harvard University Press, 2016; Etienne Benson, 'Generating infrastructural invisibility: insulation, interconnection, and avian excrement in the southern California power grid', *Environmental Humanities* (1 January 2015) 6(1), pp. 103–30; Ann Vileisis, 'Are tomatoes natural?', in Reuss and Cutcliffe, op. cit. (20), pp. 211–48; Sara B. Pritchard, 'An envirotechnical disaster: nature, technology, and politics at Fukushima', *Environmental History* (2012) 17(2), pp. 219–43.

22 Of course, anthropology also values discarded things as tools of historical inquiry, with space archaeologists beginning to take this perspective to outer-space sites. See Justin St P. Walsh, 'Protection of humanity's cultural and historic heritage in space', *Space Policy* (November 2012) 28(4), pp. 234–43; Justin St P. Walsh and Alice C. Gorman, 'A method for space archaeology research: the International Space Station Archaeological Project', *Antiquity* (October 2021) 95(383), pp. 1331–43.

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Discard studies focuses less on material waste artefacts themselves and more on discard as an act of power that supports systems predicated on the creation and maintenance of order. As Max Liboiron and Josh Lepawsky assert, maintenance of order also perpetuates the kind of power borne not through acute or sustained acts of dominion but through the myriad ways that 'unevenness' unfolds – systems in which some people, places, things and actions become valued and normalized and others unwanted and discarded. Power thus can be expressed, upheld and threatened through reordering things in and out of place, thereby rearranging the structures of such systems.[23]

Liboiron and Lepawsky argue that 'discards are necessary to hold systems together'. Unspooling the attributes of systems that generate unevenness through discard is to understand the othering of those that 'bear the burden of externalization and being made into peripheries'.[24] Examples of such entanglements certainly abound in terrestrial contexts. The effects of uneven power structures produced and maintained through discard can be traced along scales ranging from global ecosystems to individual bodies.[25] In *Pollution Is Colonialism* Liboiron examines spatial reconfiguration through disordering resulting from long-standing presuppositions of colonial access to land as a core practice of Western scientific knowledge production.[26] Discard in space, as in earthbound regimes of pollution, results from industrial and scientific wasting relationships that produce wasted people, places and natures in an extraplanetary colonial ruin built through an incremental process of decay.[27] The absence of land as typically defined does not mean an absence of appropriation through wasting relationships. Such land relations have sustained decades of global inequity in the use of space resources and exposure to space industrial effluent.

Taking a closer look at the components of these wasting relationships enacted through envirotechnical regimes unfolding at scales beyond the terrestrial systems typically highlighted in historical scholarship requires rethinking control and power in the post-*Sputnik* era. This also provides an opportunity to expand the purview of post-1945 histories of space science and technology beyond Cold War geopolitical hegemons.[28] What makes the wasted envirotechnical regime in near-Earth space compelling is its scale, its

23 Max Liboiron and Josh Lepawsky, *Discard Studies: Wasting, Systems, and Power*, Cambridge, MA: MIT Press, 2022, pp. 61–96.

24 Liboiron and Lepawsky, op. cit. (23), p. 30, 24; see also Dipesh Chakrabarty, 'Of garbage, modernity and the citizen's gaze', *Economic and Political Weekly* (1992) 27(10–11), pp. 541–47.

25 The historical and interdisciplinary discard studies literature continues to expand. Some relevant examples illustrating scalar flows of power generated and maintained through waste and discard include Simone M. Müller, 'Hidden externalities: the globalization of hazardous waste', *Business History Review* (2019) 93(1), pp. 51–74; Hannah Landecker, 'A metabolic history of manufacturing waste: food commodities and their outsides', *Food, Culture & Society* (2019) 2(5), pp. 530–47; M.X. Mitchell, 'The cosmology of evidence: suffering, science, and biological witness after Three Mile Island', *Journal of the History of Biology* (2021) 54, pp. 7–29; J. Luedee, 'Locating the boundaries of the nuclear North: arctic biology, contaminated caribou, and the problem of the threshold', *Journal of the History of Biology* (2021) 54, pp. 67–93; H. Baumann and M. Massalha, '"Your daily reality is rubbish": waste as a means of urban exclusion in the suspended spaces of East Jerusalem', *Urban Studies* (2022) 5(3), pp. 548–71; Martin V. Melosi, *Fresh Kills: A History of Consuming and Discarding in New York City*, New York: Columbia University Press, 2020.

26 Max Liboiron, *Pollution Is Colonialism*, Durham, NC: Duke University Press, 2021.

27 Lisa Ruth Rand, 'Rupture and ruination in the empyrean empire', in Asif Siddiqi (ed.), *Cosmic Fragments: Dislocation and Discontent in the Global Space Age*, Pittsburgh: University of Pittsburgh Press, forthcoming 2025. See also Marco Armiero, 'The case for the Wasteocene', *Environmental History* (1 July 2021) 26(3), pp. 425–30; Marco Armiero, *Wasteocene: Stories from the Global Dump*, Cambridge: Cambridge University Press, 2021.

28 Itty Abraham has drawn attention to the problem of defining this era as the 'Cold War' in historical analysis, noting that such periodization indulges in the superpowers' 'hegemonic fantasies' while occluding the histories of the colonial and postcolonial world and local and regional temporalities. See Itty Abraham, 'Rare earths: the Cold War in the annals of Travancore', in Gabrielle Hecht (ed.), *Entangled Geographies: Empire and Technopolitics*

comprehensiveness, its utility for encountering a Space Age rarely studied as truly global – an age unified by fragmentation.[29]

The materially and epistemologically turbulent view from space provides an opening to extend generatively messy methodologies from adjacent interdisciplinary perspectives to global and/or planetary histories of science. Anthropologist Joshua Reno describes the rise of orbital debris as a singular problem that originates from and threatens space science. Both the problem itself and efforts to solve it emerged out of 'a tendency to imagine expert knowledge and technical practice as a form of mastery, despite the fact that they lead to new and unanticipated accidents and risks'.[30] The shaping of the nearest reaches of outer space into a landscape of discard, of uneven control and risk, did not occur solely due to the actions of designers and users as emphasized in history of technology, nor producers of knowledge as prioritized in history of science. The entanglement of human efforts and natural forces beyond the human constructed uneven systems of power and control maintained through discard and wasting practices. Visual representations of the disintegration of the whole Earth into a porous planet steeped in anthropogenic debris illustrate the outsized scale of these entangled systems as well as the scholarly challenges of making sense of the persistent planetary (dis)order they create.

Control of the whole

Visions of Earth as a unified sphere did not originate with photographic images of the planet from space. Traditions around the world and across generations long accepted a spherical planetary geometry, expressed in globes, maps and words.[31] What photographs of Earth from afar did do was bring outer space into the planetary picture as a meaningful externality. Whole-Earth images like those conveyed by ATS-3 portrayed an unfathomably infinite nothingness against which the organic forms and vibrant colours of Earth stand out in sharp contrast. Without visible anthropogenic structures or the clearly delineated geographical categorizations of the cartographic globes that anticipated it, the image suggests an absence of human presence while at the same time inferring a common human experience.[32] All of humanity exists on one uninterrupted circular plane, and we are all on it together, equally imperilled and equally intrepid passengers on 'Spaceship Earth'.[33]

This sense of shared, communal precarity motivated readers of the *Whole Earth Catalog* to question global unity and mainstream environmental advocates to embrace it.[34] It underpinned burgeoning discourses of globality and global environmentality – and postcolonial resource egalitarianism – in the decade that followed the publication of the ATS-3 image.[35] However, these first satellite-produced photographs of the whole

in the Global Cold War, Cambridge, MA: MIT Press, 2011, pp. 101–24. See also Prasenjit Duara, 'The Cold War as a historical period: an interpretive essay', *Journal of Global History* (November 2011) 6(3), pp. 457–80.

29 Asif Siddiqi, 'Into the cosmic (again)', in Siddiqi, op. cit. (27).

30 Joshua O. Reno, *Military Waste: The Unexpected Consequences of Permanent War Readiness*, Berkeley: University of California Press, 2020, p. 112.

31 Peter Sloterdijk, *Globes: Spheres*, vol. 2: *Macrospherology*, Cambridge, MA: MIT Press, 2014.

32 Spivak, op. cit. (15); Chakrabarty, op. cit. (15).

33 Though Fuller is most often associated with the idea of Spaceship Earth improved by designers in positions of leadership, other thinkers of the 1960s and 1970s also thought through the idea of Earth as craft. Peder Anker, 'Buckminster Fuller as captain of Spaceship Earth', *Minerva* (2007) 45(4), pp. 417–34. See also Barbara Ward, *Spaceship Earth*, New York: Columbia University Press, 1966.

34 Andrew G. Kirk, *Counterculture Green: The Whole Earth Catalog and American Environmentalism*, Lawrence: University Press of Kansas, 2007.

35 Paul Warde, Libby Robin and Sverker Sörlin, *The Environment: A History of the Idea*, Baltimore: Johns Hopkins University Press, 2018; Paul N. Edwards, *A Vast Machine: Computer Models, Climate Data, and the Politics of Global Warming*, Cambridge, MA: MIT Press, 2010.

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Earth emerged out of an international scientific culture increasingly grounded in a quest for control and extraction at an unprecedented magnitude.[36] Greater understanding of the Earth's crust, oceans, polar regions and atmosphere supplied previously elusive intelligence on hidden activities from nuclear weapons testing to natural resource extraction to the movement of military forces – knowing a secretive enemy through knowing the Earth.[37] The International Geophysical Year (IGY) of 1957–8 accelerated out of this imperative, and the first satellites that arose during the IGY expanded opportunities for planetary surveillance and exploitation.[38] From identifying natural resources to gleaning information across vast geographical and political divides, the Cold War was truly the geoscientists' war.[39]

Whole-Earth images visually reflect this culture of control. Art historian Brooke Belisle has noted that the whole-Earth image can only be understood through 'logics of aesthetic representation' that require a specific, terrestrial way of seeing – a viewpoint grounded in photographic praxis that presents Earth as a flattened, two-dimensional, static subject crafted to match the expectations of a particular kind of Earth-bound viewer. Even the upright orientation of the North Pole in published whole-Earth images expresses cartographic ideologies of northern dominance, as the alignment in original negatives often more accurately reflect the lack of an up or down in outer space.[40] As images conveyed from space occluded distinct attributes beyond forms and weather features, satellites such as ATS-3 offered a homogeneous view of a planet that was far from unified and uniform.

ATS-3 and its contemporaries facilitated a technocratic gaze replicated in myriad practices that reach far beyond mere photographing of the planet's surface. Satellites provided useful tools through which communities of specialists in different fields could learn more about the Earth and its denizens, both organic and inorganic, through imaging, communications links and other methods of sensing. ATS-3 was designed to inform on global weather patterns, and its contemporaries and successors provided a moon's-eye view of everything from military operations to agricultural production to atmospheric changes to the movement of wildlife.[41] In the decades following the rise of whole-Earth-from-space iconography, the vertical and circumplanetary criss-crossing of information pathways between ground systems and orbiting sensors enabled the further abstraction of terrestrial features and inhabitants. Even space-assisted tracking of migratory animals travelling across vast distances – disobeying anthropocentric boundaries and order – allowed wildlife biologists to merge distinct, divergent ecosystems into a manageable

36 Sörlin and Wormbs, op. cit. (14).

37 Simone Turchetti and Peder Roberts, 'Introduction', in Turchetti and Roberts (eds.), *The Surveillance Imperative: Geosciences during the Cold War and Beyond*, New York: Palgrave Macmillan, 2014, pp. 1–19.

38 Poole, op. cit. (5); Benjamin W. Goossen, 'A benchmark for the environment: Big Science and "artificial" geophysics in the global 1950s', *Journal of Global History* (March 2020) 15(1), pp. 149–68.

39 In the introduction to *Surveillance Imperative* the volume editors make a passing reference to the Cold War as the geoscientists' war – extending the historical characterization of the First World War as the chemists' war and the Second World War as the physicists' war. Turchetti and Roberts, op. cit. (37). See also Ronald E. Doel, 'Constituting the postwar Earth sciences: the military's influence on the environmental sciences in the USA after 1945', *Social Studies of Science* (October 2003) 33(5), pp. 635–66.

40 Brooke Belisle, 'Whole world within reach: Google Earth VR', *Journal of Visual Culture* (1 April 2020) 19(1), pp. 112–36.

41 For more on the history of remote sensing as a form of environmental control and knowledge making see, for example, Etienne Benson, *Wired Wilderness: Technologies of Tracking and the Making of Modern Wildlife*, Baltimore: Johns Hopkins University Press, 2010; Soraya Boudia, 'Observing the environmental turn through the Global Environment Monitoring System', in Turchetti and Roberts, *The Surveillance Imperative*, op. cit. (37), pp. 195–212; Edwards, op. cit. (35).

https://doi.org/10.1017/bjt.2024.27 Published online by Cambridge University Press

whole.[42] In this era of scientific control broadened ever further by orbiting technologies, the Space Age Earth had become a planet composed of data – an Earth that might be programmable.[43] Even the popular Cold War concept of Spaceship Earth, which rendered the biosphere as a precious natural life support system with limited carrying capacity, also invoked the planet as a technical object that can be designed, optimized and operated to prescribed specifications should the right specialists be granted seats on the bridge.[44]

As the Space Age moved into its third full decade, national space agencies pivoting away from the concluded race to the Moon found purchase in prioritizing Earth monitoring – with the added benefit of expanding spheres of influence through information sharing.[45] NASA, the US civilian space agency, even sought to align itself with environmental politics in the post-Apollo era by directing funding and publicity towards space-based environmental research.[46] During this period, the data drawn from satellites provided new views of a not-quite-so-whole Earth. For example, orbiting satellites collected different forms of flattened planetary-scale data. Some of these data confirmed the existence and broadening of a depression in the ozone layer within mere years of scientific publications confirming the destructive effects of chlorine on atmospheric ozone. Easily interpreted, nearly real-time visualizations of the whole Earth's 'hole' supported a different kind of control manifested in the Montreal Protocol, which regulated the production and use of ozone-depleting chlorofluorocarbons (CFCs).[47] Within decades of restricting CFCs, digital representations of the whole Earth from satellite data showed signs of repair in the ozone layer depression – arguably reassurance that scientific control over the planet remained in force, plugging troubling gaps in the boundaries between Earth and an externalized elsewhere.[48]

At the same time as the ozone depression came under scientific scrutiny, concerned physicists began modelling both historical and predicted accumulation of artificial debris in orbit.[49] Like ozone diagrams such models reveal the effects of cumulative – but not comprehensive – human activity and consumption through additional layers of data

42 Etienne Benson, 'One infrastructure, many global visions: the commercialization and diversification of Argos, a satellite-based environmental surveillance system', *Social Studies of Science* (1 December 2012) 42(6), pp. 843–68.

43 Jennifer Gabrys, *Program Earth: Environmental Sensing Technology and the Making of a Computational Planet*, Minneapolis: University of Minnesota Press, 2016.

44 Sabine Höhler, *Spaceship Earth in the Environmental Age, 1960–1990*, New York: Routledge, 2016. See also Alison Bashford's analysis of the use of images of Earth from space to recall and recapitulate earlier Malthusian and eugenicist ideas about overpopulation. Alison Bashford, *Global Population: History, Geopolitics, and Life on Earth*, New York: Columbia University Press, 2014, pp. 355–64.

45 Teasel E. Muir-Harmony, *Operation Moonglow: A Political History of Project Apollo*, New York: Basic Books, 2020; Pamela Etter Mack, *Viewing the Earth: The Social Construction of the Landsat Satellite System*, Cambridge, MA: MIT Press, 1990.

46 Kim McQuaid, 'Selling the Space Age: NASA and Earth's environment, 1958–1990', *Environment and History* (May 2006) 12(2), pp. 127–63; Roger D. Launius, 'A western Mormon in Washington, D.C.: James C. Fletcher, NASA, and the final frontier', *Pacific Historical Review* (May 1995) 64(2), pp. 217–41.

47 Matthias Dörries, 'The transmutation of ozone in the early 1970s', in James Rodger Fleming and Ann Johnson (eds.), *Toxic Airs: Body, Place, Planet in Historical Perspective*, Pittsburgh: University of Pittsburgh Press, 2014, pp. 50–76. On the diplomatic efficacy of these images in fostering uptake of the Montreal Protocol see Sebastian V. Grevsmühl and Régis Briday, 'Satellite images as tools of visual diplomacy: NASA's ozone hole visualizations and the Montreal Protocol negotiations', *BJHS* (June 2023) 56(2), pp. 247–67.

48 World Meteorological Organization, *Scientific Assessment of Ozone Depletion: 2018*, Global Ozone Research and Monitoring Project, report no. 58, Geneva, Switzerland, 2018; Olson and Messeri, op. cit. (12), p. 32.

49 See, for example, D.R. Brooks, T.D. Bess and G.G. Gibson, 'Predicting the probability that Earth-orbiting spacecraft will collide with man-made objects in space', International Astronautical Federation, International Astronautical Congress, Amsterdam, 1974; T.D. Bess, *Mass Distribution of Orbiting Man-Made Space Debris*, Washington, DC: National Aeronautics and Space Administration, 1975; Donald J. Kessler and Burton

interpretation. Also like ozone layer images, the planetary maps of debris that emerged out of tables, charts and scatter diagrams highlight anthropogenic activity that would be invisible to the untrained eye without this interpretive mediation. The ozone diagrams, however, provide a generic view of the destructive consequences of human actions on an otherwise contained sphere. The chlorofluorocarbons that caused the depression, their producers and consumers, and subsequent political action are all implied rather than explicitly defined in these programmed Earths.

Debris maps and animated simulations put human materialities, with varying degrees of precision identifying which humans, visibly back into the planetary picture of a fractured Earth shaped by technopolitical assemblages in disarray.[50] Each point in these visual artefacts represents either a discrete designed object or a fractured remnant of such an object created on purpose, by chance, or often both. Diagrammed points appear and disappear over time, indicating a perpetual exchange between outer space and inner space as new artefacts reach orbit and others fall into the atmosphere in an event known as re-entry. Yet even when human operators are able to instigate and guide re-entry from afar, the geophysical nature of orbit perpetually intrudes, influencing how, where, and when the points move through space and how, where, and when they disappear. These intersecting influences disrupt conventional spherical boundaries of the terrestrial as constrained by an inviolate whole Earth.[51] The uneasily co-located technological and natural forces that gave rise to visions of a permeable, debris-swaddled planet evaded the control imperatives of post-war science that gave rise to whole-Earth images, even as the debris diagrams themselves represent scientific efforts to control the mess by mapping its past, present and future.

The data points encircling the whole Earth that make up orbital-debris simulations disclose what a particular group of specialists can know and understand about the movement of disobedient non-human subjects through an intractable extreme environment. Like wildlife or weather patterns or nuclear fallout, uncontrolled debris artefacts follow more-than-human rules in tracing paths around the planet. The causes of change over time are revealed to be more complex than the instigating moment of debris creation, such as the *Fengyun-1C* anti-satellite test or the moment at which the satellite first reached orbit eight years prior. As each bright debris dot circles around the central sphere (still abstracted but three-dimensional), moving in and out of proximity to its neighbours and changing altitude and inclination, space emerges as something much more than a vacant, oppositional background to a planetary subject. It becomes a natural environment that is both terrestrial and more than terrestrial, blurring planetary boundaries and defying the plans of designers, builders and users of satellites – and acting as one of several primary drivers of infrastructural decay. Space is neither passive nor an external, separate realm from the earthly.[52] On the contrary, space influences the shape of the artefacts that humans have built, flown and used in orbit from design through decay.[53]

G. Cour-Palais, 'Collision frequency of artificial satellites: the creation of a debris belt', *Journal of Geophysical Research* (1978) 83(A6), pp. 2637–46.

50 For more on the material and social dimensions of technopolitical assemblages see Gabrielle Hecht, 'Introduction', in Hecht, op. cit. (28), pp. 1–12.

51 Tim Ingold, 'Globes and spheres: the topology of environmentalism', in Carol Carpenter and Michael R. Dove (eds.), *Environmental Anthropology: A Historical Reader*, Malden, MA: Blackwell, 2008, pp. 31–42.

52 Olson and Messeri, op. cit. (12).

53 Viewing the challenging natural environment of outer space as playing a role in the design and use of space technology recalls James Poskett's assessment of the ways in which the unique attributes of maritime environments shaped the practices of land-based technical specialists building scientific instruments for use at sea – a complex, spatially removed environment in which the instruments would ultimately be used. James Poskett, 'Sounding in silence: men, machines and the changing environment of naval discipline, 1796–1815', *BJHS* (June 2015) 48(2), pp. 213–32.

By backgrounding the whole Earth and foregrounding the influence of a hybrid natural–-technological space environment, debris maps force a dismantling of a discrete, programmable planetary object. This does not, however, necessarily indicate a lapse of power through loss of control. As with other systems built upon wasting relationships, the disorderly envirotechnical regime of orbital space both upholds and challenges the uneven power structures from which it emerged. Historically, the superpowers maintained space dominance both through the operation of novel technologies and in the creation of disorderly debris that posed impediments to later access by less affluent nations. Such practices set a durable precedent that extended well beyond the end of the Cold War. The power to discard *Fengyun-1C*, for example, demonstrated China's growing geopolitical might as a nation with an independent space industry.[54] The hybrid technical–natural forces of the orbital environment influenced the subsequent movement of debris, threatening all satellites in the objects' paths, including those operated by the debris's creators. The material aftermath of the ASAT reflected the ongoing refashioning of centres and peripheries in global space politics, but not through clear, direct exertion of dominion or the externalization of a distinct other made in the creation of new peripheries.

The fractured-Earth picture is not so simple as human and non-human, planetary and non-planetary. Each dot in each debris map bears a technical history determined by human designers, operators and users.[55] It flows from and through scientific inquiry, technopolitics and geopolitical competition, scattered by complexities of international governance and long-standing colonial relationships.[56] The path of each point also reflects interactions with the near-Earth space environment – its material dimensions and its interactions with invisible geophysical attributes, the influence of solar activity and atmospheric particles. Each of these historical forces on their own generates physical and conceptual complexity. Combined together in a swarm of anthropogenic celestial detritus, separating deterministic causes from material outcomes becomes as challenging – and perhaps even as absurd – as the homogenization and control of an entire planet.

What does it mean for the very technologies that facilitated the accelerated, orderly unification of the Earth through surveillance and quantification to also be symptomatic of lost control? Does control require order, wholeness, unity? The view from afar, amorphous and messy, suggests that spatial and historiographical disjunction provides an opportunity to expand history of science to overlooked subjects and places. To gain this view requires understanding the Space Age from the outset as an era of generative fragmentation produced in and by a planetary-scale envirotechnical regime – a politically constructed, iteratively reconstituted, and not entirely controllable conjunction of environmental and technological systems.[57]

54 Joseph Kahn, 'China shows assertiveness in weapons test', *New York Times*, 20 January 2007; Mark Williams Pontin, 'China's antisatellite missile test: why?', *MIT Technology Review*, 8 March 2007. Critics viewed the 2019 ASAT conducted by India as an effort to demonstrate its own ascendance among Asian space powers. Ajey Lele, 'Indian ASAT: Mission Shakti should be a comma, not a full stop', *Space Review*, 27 March 2023.

55 The social construction of technology has been a crucial theoretical framework for some time, focusing not just on designers and builders but also on users as shapers of technology. Relevant foundational texts include Wiebe E. Bijker, Thomas P. Hughes and Trevor Pinch, *The Social Construction of Technological Systems: New Directions in the Sociology and History of Technology*, Cambridge, MA: MIT Press, 2012; Nelly Oudshoorn and Trevor Pinch (eds.), *How Users Matter: The Co-construction of Users and Technology*, Cambridge, MA: The MIT Press, 2005.

56 For scholarship on colonial siting of space launch infrastructure see Peter Redfield, *Space in the Tropics: From Convicts to Rockets in French Guiana*, Berkeley: University of California Press, 2000; Asif Siddiqi, 'Dispersed sites: San Marco and the launch from Kenya', in John Krige (ed.), *How Knowledge Moves: Writing the Transnational History of Science and Technology*, Chicago: The University of Chicago Press, 2019, pp. 175–200.

57 Pritchard, op. cit. (17).

Sputnik: cosmic thing

As cosmograms – representations of a universe and the myriad relationships that make it up combined into one whole – photographs of Earth from space suggested an interconnectedness between things, places and peoples within a contained globe. As a distinctly Cold War cosmogram, the whole Earth from space also conveyed a flattening of fragmented interrelationships under hegemonic fantasies of control and order that initially gave rise to these images.[58] The cosmograms divulged by orbital-debris simulations, by contrast, render visible and measurable a material and symbolic outgrowth of these fragmentations – not merely a symptom of broken practices and relationships, but central features of systemic politics and institutions of fracture.[59]

When considered as part of a messy envirotechnical regime shaped by entrenched wasting practices rather than an orderly whole, the mastered object of the Earth in the Space Age disbands into a more disorderly thing. As Bruno Latour has offered, this transformation can be catastrophic, demolishing the line between a sense of reality/fact and matters of great concern to those who seek mastery and control over technology and nature alike. Offering a fictional example of orbital ruination caused by a debris crisis in the 2013 Hollywood movie *Gravity*, Latour ruminates on the loss of outer space as a human environment and the transformation of the Anthropocene 'human' into an 'Earthbound' – one for whom escape from a rapidly transforming Earth is no longer an option.[60] The accumulation of anthropogenic debris originating from the decay of high technologies in orbit, beyond and below spurs a turning inward in moments of crisis, in a loss of control over perfectly mastered objects.

Are the orbital-debris artefacts that fracture the whole Earth into an assemblage of parts, practices and politics themselves perfectly mastered objects transformed over time into uncontrolled things? Does the orbital-debris cosmogram represent a dissolution of what was once orderly, a technological system that supported an increase in scientific control of the Earth dissolved into uncontrollable chaos? To be sure, the accumulation of debris objects has accelerated alongside the acceleration of the satellite industry that co-produced them. China did not participate directly as a major power player in the Cold War space race. Yet the *Fengyun-1C* anti-satellite test represents only one, particularly notable, act indicating the uptake of wasting practices as a requisite condition of belonging to an ever-broadening cadre of space power centres.[61] Beginning at the beginning affirms that near-Earth space in the Anthropocene has from the outset been a wasted planetary envirotechnical regime shaped as much by violent comings apart as in moments of collective achievement. And the very loss of control can itself undergird the unevenness of power upheld through regimes of discard and waste.

In his 2007 essay 'Technological world-pictures: cosmic things and cosmograms', John Tresch describes an art installation of a Volkswagen Beetle dismantled and exhibited in its component parts. The piece, named *Cosmic Thing* and reflected in the essay's title, breaks

58 John Tresch, 'Cosmic terrains (of the Sun King, Son of Heaven, and Sovereign of the Seas)', *E-Flux Journal* (December 2020) 114, at www.e-flux.com/journal/114/364980/cosmic-terrains-of-the-sun-king-son-of-heaven-and-sovereign-of-the-seas; see also Bruno Latour and Dipesh Chakrabarty, 'Conflicts of planetary proportion: a conversation', *Journal of the Philosophy of History* (19 November 2020), 14(3), pp. 419–54.

59 See Joshua Reno, 'Waste and waste management', *Annual Review of Anthropology* (2015) 44, pp. 557–72. On addressing systems rather than symptoms of discard as crucial to a 'theory of change' informed by discard studies see Liboiron and Lepawsky, op. cit. (23), p. 128.

60 Bruno Latour, 'Telling friends from foes at the time of the Anthropocene', in Clive Hamilton, Francois Gemenne and Christophe Bonneuil (eds.), *The Anthropocene and the Global Environmental Crisis: Rethinking Modernity in a New Epoch*, New York: Routledge, 2015, pp. 145–55.

61 On wasting practices, industrial and otherwise, as conditions of (often deferred) modernity and belonging see Zygmunt Bauman, *Wasted Lives: Modernity and Its Outcasts*, Cambridge: Polity, 2011; Reno, op. cit. (59).

apart an otherwise recognizable whole into pieces that, individually, contain multiple meanings and origins concealed in its former, intended, unrecognizably mastered aggregate. A mundane consumer product displayed as parts of a whole can, in Tresch's estimation, make visible the vast sweep of material, social and political relations that are otherwise obscured in a unified form most legible to the general viewer–user. Revealing an ordinary technological object as an assemblage of things 'gathers a cosmos together' into a disjointed whole, heterogeneous and manifold.[62]

The first artificial satellite to reach orbit – perhaps the first literal 'cosmic thing' – was far from being an ordinary object of its time. As much as it instigated political turbulence on the ground below, *Sputnik 1* also rearticulated cultural, scientific, and legal relations between terrestrial and celestial realms.[63] But the full dimensions of the first artificial satellite as a representational object, as a symbol, prove hard to nail down. Its iconic spherical form conceals the centrality of its designed fragmentation. As a broken thing typically represented as a mastered whole, Sputnik set the precedent for a Space Age that was and is intentionally fractured.

Sputnik 1 has been popularly remembered as a singular object, a historical moment, and the trigger of a cultural and technopolitical sea change. A product of the IGY's imperative to accelerate studies of the Earth, it gathered together a world in fracture even as it signified a new kind of planetary mastery. When the sphere with its trailing radio antennas reached orbit in October 1957, it disclosed a cosmos that seemed utterly out of order to those whose political affinities suggested that the seemingly 'backwards' Soviet Union could never reach orbit before the United States.[64] Its beeping transmission repeated on radio and television programmes the world over sounded like a cheer or a taunt depending on the political orientations of the listener. Its form – a whole, intact sphere mimicking the shape of the planet below – signified unity and shared novel experience amidst increasingly fraught, increasingly global, conflict. In popular memory, the visual appearance of the solitary satellite endures as an icon of the Space Age, its reflective surfaces and smooth curvature a visual referent for space culture and mid-century aesthetics.[65] And much as the whole Earth has come to stand in for 'the environment' writ large, *Sputnik*'s name, like the 'moonshot' it eventually inspired, has become an enduring metonym for mass collective action towards a common goal.[66]

As a 'cosmic thing' *Sputnik 1*'s material form, initially revealed in artistic representations and later photographs, of course contained a multitude of practices, labour, resources and meaning within its unbroken, polished whole. However, it also wasn't as mastered as it seemed, nor as inviolate. Much like the whole Earth, the enduring popular understanding of *Sputnik* conceals the heterogeneous nature of the satellite itself – at once a perfectly mastered object and a fragmented, concerning thing. *Sputnik 1* endures as a

62 John Tresch, 'Technological world-pictures: cosmic things and cosmograms', *Isis* (March 2007) 98(1), pp. 84–99.

63 *Sputnik 1* was the first artificial satellite to reach orbit. The Soviet Union followed this achievement by launching two more spacecraft with the same name, followed by a number. In the West, dozens of Soviet satellites and spacecraft also came to be known as 'sputnik' with an appended number, regardless of their official names. In this article, I use the name '*Sputnik*' to refer to *Sputnik 1* specifically. For more on the cultural impact of the Sputnik 1 launch see, for example, Roger D. Launius, John M. Logsdon, and Robert W. Smith (eds.), *Reconsidering Sputnik: Forty Years since the Soviet Satellite*, New York: Routledge, 2014.

64 Howard E. McCurdy, *Space and the American Imagination*, Baltimore: Johns Hopkins University Press, 2011; Steven J. Dick, *Historical Studies in the Societal Impact of Spaceflight*, Washington, DC: NASA, 2015.

65 Emily S. Rosenberg, 'Far out: the Space Age in American culture', in Steven J. Dick (ed.), *Remembering the Space Age*, vol. 2, Washington, DC: National Aeronautics and Space Administration, 2008, pp. 157–84.

66 See, for example, the naming of the first Russian COVID vaccine after the first Soviet satellite. I. Manor and J. Pamment, 'From Gagarin to Sputnik: the role of nostalgia in Russian public diplomacy', *Place Branding and Public Diplomacy* (2022) 18, pp. 44–8.

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unified object in collective memory, even as its world-shaping power grew out of being a fractured thing.

The contemporary experience and enduring memory of the first artificial satellite consolidate a *Sputnik* experience that is similarly both whole and fragmented. Moments after its initial ascent from the Kazakh steppe a unified object disbanded into no fewer than seven distinct pieces: the named satellite, the nose cone that sheltered it for the ride, and the boosters and core stage of the rocket that sent it into orbit. Rather than simply a separation of useful tool from unwanted or useless by-products, each part of the always-already expanded cosmic thing played a role in creating a *Sputnik* experienced by a geographically, politically and culturally broad sweep of humans below.

As news of the unprecedented technological feat circulated around the world, onlookers on both sides of the Iron Curtain traced the path of a bright point of light moving rapidly through the dawn and dusk sky, captivated by the sight of a new kind of moon in the heavens.[67] Depending on a variety of factors – including but not limited to level of technical expertise, access to specialized equipment and quality of regional news coverage – *Sputnik* observers viewed different components of the fragmented assemblage, knowingly or unknowingly. Those without access to optical instruments could consult their local news reports to determine where and when to spot the point of light overhead. Some may have been aware that the point of light was not the polished sphere portrayed in broadcast and print media but the much larger core of the modified R7 rocket that sent it aloft. Soviet engineers expected that the named satellite would not be naked-eye visible from the ground, so they rigged the rocket core with deployable prisms to amplify reflected light from the sun as it set beyond the horizon.[68]

The gravitational attraction between celestial bodies and the Sun's myriad physical and material influences on Earth had long been a subject of study. However, prior to *Sputnik 1*'s ascent into the cosmos physicists understood Earth as a physically isolated body within the solar system. Earth's greater-than-expected influence on its celestial neighbours came into sharp focus in the days and weeks after launch as the first human-made space artefacts moved in freefall paths around the planet.[69] As October progressed, the point of light that was the rocket core began to fluctuate in brightness, indicating a tumbling motion that intensified as time went on. By 2 December the point of light had disappeared, and researchers began to share observations that suggested the influence of drag exerted on the object by atmospheric particles at a higher altitude than was previously anticipated.[70] Separate fragments of the whole, varying in shape and mass, behaved differently while interacting with atmospheric particles at high altitude. Observers encountered difficulty in identifying objects as the space environment changed their structure and motion – for example, the previously dim nose cone, ripped sideways by friction and pressure, reflected enough sunlight to rival the reflective-by-design rocket core in brightness.[71]

By the end of the decade a cadre of newly minted space scientists had identified the contours of a topography of magnetism, radiation, energy, atmospheric particles and trapped solar particles extending outward by tens of thousands of kilometres.

67 Steven J. Dick (ed.), *Remembering the Space Age*, Washington, DC: National Aeronautics and Space Administration, 2008.

68 Asif Siddiqi, 'Iskusstvennyy Sputnik Zemli', *Spaceflight* (2007) 49, pp. 426–42.

69 Desmond King-Hele, *Satellites and Scientific Research*, London: Routledge & Kegan Paul, 1960.

70 J.D. Kraus, 'The last days of Sputnik I', *Proceedings of the IRE* (March 1958) 46(3), pp. 612–14; J.D. Kraus and E.E. Dreese, 'Sputnik I's last days in orbit', *Proceedings of the IRE* (September 1958) 46(9), pp. 1580–87.

71 Leon Campbell Jr, 'MOONWATCH observations', *Smithsonian Astrophysical Observatory Bulletin for the Visual Observers of Satellites*, March 1958, Smithsonian Astrophysical Observatory Records *c.*1954–66, Box 47, MOONWATCH Bulletins, Smithsonian Institution Archives.

As British radio astronomer Bernard Lovell commented in 1960, rather than a peripheral planet in a system of more influential bodies, 'Earth's environment' dominated its own region of the solar system to a distance of some ten Earth radii.[72] The motion of *Sputnik 1* in its fragmented, separate pieces, rather than as a single spherical object, had provided a means of gathering together a cosmos in which the Earth was perhaps more central, more physically and materially powerful, than afforded by generations of Copernican world view – and certainly less predictable.

Even as Soviet engineers designed and anticipated the fragmentation of the first satellite, the nature of extraplanetary space disrupted their full control and mastery. As a perceived whole the satellite demonstrated Soviet technological expertise and implied another dimension of potentially destructive power in the nuclear age – launched as it was atop a modified intercontinental ballistic missile. As a fractured thing it fostered unexpected unity, as scientists outside the Soviet Union and its allies celebrated the orbiting pieces as freely available scientific tools that they could use to measure the properties and dimensions of the upper atmosphere.[73] Eventually, over several months, the upper atmosphere drew the components of the *Sputnik* assemblage back to Earth. In the final moments of fragmentation, expected but not controlled, *Sputnik*'s separate pieces dissolved into even more parts upon return to their planet – rather than nation – of origin. Given the uncertainty surrounding where the pieces might fall, novel space artefacts once again consolidated Earth, this time into a resting place for a fallen moon.

Sputnik's many moments of fragmentation occurred both by design and by chance – and by nature. Identifying different elements of the orbital envirotechnical regime makes it possible to isolate certain technical or political choices, such as the planned reuse of the rocket core as a radar tracking target and an easily glimpsed signifier of Soviet achievement. Others, like the unplanned informal use of *Sputnik* fragments as free scientific instruments, decaying objects falling through the atmosphere, or the collective forgetting of *Sputnik* as fractured cosmic thing in favour of remembering it as a perfectly mastered whole, get trickier.

The breaking apart of *Sputnik*'s tangible form, the fragmentation of its meaning and use, and the motion through space that influenced those shifts in meaning and use reflected choices by Soviet engineers, interpretations by observers and interactions with the space environment. The nature of near-Earth space disclosed itself by reshaping the fragments and guiding their paths through orbit. Gravity, friction, high-altitude wind currents, solar pressure and diffuse atmospheric particles made themselves known through the motion of improvised scientific instruments meant to be broken, their effectiveness maximized in a state of disrepair.[74] That *Sputnik* overwhelmingly endures in popular memory as a unified, single object perhaps conveys the durability of a cherished triumphant narrative of human mastery over an extreme, forbidding, external environment – one that might be diminished by the reality of its disintegration.

If a broken tool reveals the world or worlds from which it emerges, making its 'referential whole' visible, the fragmentation of *Sputnik* begs the question of what a broken tool reveals if it's meant to be broken – if its scientific and political value, and its unifying potential, are contingent on breaking apart.[75] And remaining broken – not breaking

72 A.C.B. Lovell, 'The exploration of outer space', *Journal of the Royal Society of Arts* (June 1960) 108(5047), pp. 496–518.

73 Desmond King-Hele, *Observing Earth Satellites*, London: Macmillan, 1966.

74 Not the breaking down of large space instruments from a preferred functioning whole, which can have the effect of building new knowledge through the act of repairing. See Simon Schaffer, 'Easily cracked: scientific instruments in states of disrepair', *Isis* (December 2011) 102(4), pp. 706–17.

75 Tresch, op. cit. (62), p. 87. See also Joseph Masco on fallout as the 'lesser form' of the bomb in which the outcomes of nuclear violence bifurcate into the acute moment of detonation and the long-term atmospheric

https://doi.org/10.1017/bjt.2024.27 Published online by Cambridge University Press

apart as the starting and ending point of purpose, as with the violence wrought by munitions, nor as an unwanted state to be corrected through repair, but as a necessary condition of intended use. Compared to the global violence unleashed in the breaking apart of weapons technologies, especially those that shaped the global nuclear age that preceded and enabled the rise of satellite technologies, *Sputnik*'s designed and unplanned brokenness drew together a heterogeneous humanity into a unified but uneven experience known as the Space Age.[76]

Planetary peripheries

Sputnik's punctuated path of fracture, from launch, operation, use and reuse to its re-entry into the atmosphere, set off the construction of an ever-expanding landscape of fragmentation in a near-Earth space environment that both shapes and resists the intentions of space industry designers. In the decades that followed, a growing international space industry constructed an information infrastructure out of *Sputnik*'s successors. In collective memory and historical telling, satellites that made the Earth whole shrank geographical distances and facilitated programmable order on an extended planetary scale.[77] They increasingly connected Earth to its immediate celestial neighbourhood and the broader solar system through a nexus of transmissions and signals, as well as exchanges of objects and eventually animals (including people). By the 1970s the initial three or four artificial objects in motion around the planet grew into tens of thousands, then hundreds of thousands, excluding fragments too small to be detected or controlled by human observer–operators.

The objects' distances also extended further from Earth, and accordingly protracted their time in space. *Sputnik*'s relatively low-flying components all re-entered within a few months of launch, drawn into the upper atmosphere by the upper atmosphere. Its successors reached greater heights. A few months after *Sputnik* the United States sent up its second artificial satellite, *Vanguard 1*, to what's now known as middle earth orbit (MEO). Its elliptical orbit reaches a perigee of nearly four thousand kilometers, well beyond the most intense decaying influences of atmospheric particles and other geophysical forces, meaning that Vanguard will likely not re-enter for centuries. It remains indefinitely aloft, another point in the burgeoning sweep of artificial objects circling the Earth. In disuse it joins the now derelict whole-Earth-capturing ATS-3: both originated in a moment of material fracture, formerly used as scientific tools, now simultaneously historic spacecraft and space discard. Both continue to tell on the uneven technosocial systems that created, used and discarded them. These objects endure as monuments to the early satellite era as well as to a foundation for the wasting practices that both privilege and challenge the dominion of centres of space power and knowledge production.

A Space Age symbolized by the whole *Sputnik* is an age that, much like the totalizing whole-Earth image, has constrained who, what and where count as significant in historical analysis. The majority of scholarship on the history of space science and technology

events that come after – a temporal stretching of nuclear fragmentation. Joseph Masco, 'The age of fallout', *History of the Present* (2015) 5(2), pp. 137–68.

76 The R7 rocket whose pieces made up the majority of the *Sputnik* assemblage was one of the first successful test flights of the first operational intercontinental ballistic missile. It is all but impossible to separate space technology from its violent technical lineage. Michael J. Neufeld, *The Rocket and the Reich: Peenemünde and the Coming of the Ballistic Missile Era*, New York: Free Press, 1995; Asif A. Siddiqi, *Challenge to Apollo: The Soviet Union and the Space Race, 1945–1974*, Washington, DC: National Aeronautics and Space Administration, 2000; Frank H. Winter, *Rockets into Space*, Cambridge, MA: Harvard University Press, 1990.

77 Lisa Parks and James Schwoch (eds.), *Down to Earth: Satellite Technologies, Industries, and Cultures*, New Brunswick, NJ: Rutgers University Press, 2012.

focuses on a relatively small number of institutions, actors, practices and nationalist narratives – and the natural environment of space itself is either excised entirely or relegated to the periphery as adversarial or a subject of conquest rather than a primary force of change over time. Privileging the use of tools in assembled, mastered form, and the formalized use of these tools for specialized ends, constrains the historical dimensions of the post-*Sputnik* era to familiar states, institutions and individuals. It also upholds delineations of inner and outer – whether spatial (inner and outer space), professional (credentialled and amateur) or geopolitical (centres and peripheries).

These boundaries do not hold up as well in a fractured *Sputnik* Space Age. As credentialled specialists learned to use fragments of *Sputnik*, amateur specialists also wrangled knowledge production out of the satellite's disassembled parts. Amateur astronomers in the Smithsonian's worldwide network of satellite trackers, Project MOONWATCH, set early standards for knowing and understanding the ways in which objects in orbit interacted with the physical landscape of near-Earth space.[78] These same amateurs eventually took on the task of 'death watches', monitoring the further fragmentation of objects through the pressure and friction of the upper atmosphere. An international network of commercial airline personnel took on similar roles of amateur expertise, tasked by the Smithsonian with detecting, characterizing and reporting any sightings of falling fragments that might be remnants of orbiting hardware.[79] On the rare occasions when such fragments struck solid ground, local communities took on the task of identification and reporting, generating political value out of wayward, uncontrolled pieces of pieces of a whole. In many cases, those local communities lived well outside the boundaries of the tiny club of cold-warring superpowers and their industrialized allies that had, in entanglement with orbital nature, sent those fragments on their wayward paths.[80] In this way, engagement with hypermobile broken tools opened pathways to the production of scientific knowledge about the space environment by a much wider cross-section of people working outside conventional institutions of Cold War science.

The envirotechnical regime shaping orbital space expanded the breadth of engagement with the extraplanetary environment through encounters with never-quite-whole space artefacts. The effects of gravity, solar activity and friction both disobeyed and reinforced the careful delineations of a binary Cold War geopolitical order. In this regime, far-flung states, communities and environments came together through the motion of fragments under the control of more-than-human physical forces, moving through and falling from orbit. Out of this systemic fracture and discard, the visual and material contact with space artefacts produced expanded participation in space science and politics even as it bolstered centres of power constructed by and within terrestrial wasting relationships. For example, the vast majority of re-entered space hardware fragments recovered from terra firma have been found in regions of the global South.[81] From the perspective of Earth orbit, the clustering of fragments around valuable orbits oriented around the poles and equator – regions historically lacking

78 W. Patrick McCray, *Keep Watching the Skies! The Story of Operation MOONWATCH and the Dawn of the Space Age*, Princeton, NJ: Princeton University Press, 2008.

79 The Project MOONWATCH records at the Smithsonian Institution archives contain newsletters and records of data collection from these death watches, which became the primary focus of the programme after professional networks took over orbital tracking in the aftermath of *Sputnik*. They also include documentation by pilots participating in the Volunteer Flight Officers Network. Smithsonian Astrophysical Observatory Records *c.*1954–66, Box 47.

80 Rand, op. cit. (16).

81 Though no longer maintained, the Aerospace Corporation kept a log of recovered fragments, including location of recovery, through 2015. The Aerospace Corporation, 'Summary of recovered reentry debris', at www.aerospace.org/cords/reentry-data-2/summary-of-recovered-reentry-debris (accessed 15 January 2015).

https://doi.org/10.1017/bjt.2024.27 Published online by Cambridge University Press

independent space programmes and satellite users – further reflects the planetary scale and global inequality inherent in the fractured Space Age. The peripheries re-created through orbital effluence remained persistently uneven, thrown into sharp relief in moments such as when representatives of states excluded from access to crowding orbits pushed back against what they characterized as high-technology neocolonialism during the 1970s.[82]

The fragmenting power of the orbital envirotechnical regime also destabilizes the already tenuous boundaries between Earth and natures excluded from an inward, downward-facing conceptualization of the Anthropocene. A Space Age Earth in fracture broadens conceptual understandings of this epoch as one that extends well beyond the limits of a contained globe or sphere.[83] At a basic material level, matter from outer space exists within a terrestrial geology, and thanks to decades of launches matter originating from that terrestrial geology – from metals to radioactive elements – now shapes the geophysical terrain of near-Earth space.[84] The Anthropocene Earth signified by orbital-debris simulations is one that unfurls into what Valerie Olson calls an 'extended ecological heliosphere' – in the words of Latour, the Earth has transformed from a planet bounded by its atmosphere into a 'sub-lunar Gaia', an expanded realm of planetary activity and consequence that reaches far beyond the life-sustaining biosphere.[85] It challenges primal divisions between Earth and elsewhere and destabilizes the very meaning of the terrestrial as the sole locus of an increasingly foregrounded, intruding nature.[86]

In looking at digital representations of those objects – artefacts both in use and out of use, swirling around the planet neither to scale nor to speed – space and the human come back into the global picture. But depending on the breadth of the individual simulation they do so in a way that can still homogenize what it means to be a resident of Earth in the Anthropocene. Each of these bright data points indicates evidence of human activity, but which humans? When zooming out from the specific debris produced by a particular event like the *Fengyun-1C* anti-satellite test to encompass the entirety of anthropogenic stuff in orbit the dots lose specific detail, are no longer explicitly connected to their nation of origin. Orbital debris appears from this distance to be a common human problem with similarly common consequences (Figure 3).

The Anthropocene may be beyond-global in scope and affect the entire planet as a whole (or at least as represented in whole-Earth images). However, not all of humanity is living in the Anthropocene equally.[87] This reality is further confirmed by the flotsam and jetsam of the orbital landscape. While representations of debris engulf the abstracted Earth below, these maps obscure the inequalities and inequities of access to and use of near-Earth space as a natural resource. Given the historically limited number of entities

82 Nina Wormbs and Lisa Ruth Rand, 'Techno-diplomacy of the planetary periphery, 1960s–1970s', in Andreas Fickers and Gabriele Balbi (eds.), *History of the International Telecommunication Union: Transnational Techno-diplomacy from the Telegraph to the Internet*, Berlin: De Gruyter Oldenbourg, 2020, pp. 297–319; Haris Durrani, 'The Bogotá declaration: a global uprising?', *Uprising* (21 January 2018) 13(13), at http://blogs.law.columbia.edu/uprising1313/haris-a-durrani-the-bogota-declaration-a-global-uprising (accessed 17 April 2024); Siddiqi, op. cit. (56).

83 Valerie Olson and Lisa Messeri review the spatial 'othering' natures that often result from limiting this epoch to a geological/terrestrial sphere. See Olson and Messeri, op. cit. (12).

84 Rand, op. cit. (8).

85 Olson, op. cit. (12); Latour, op. cit. (60).

86 Isabelle Stengers, *In Catastrophic Times: Resisting the Coming Barbarism* (tr. Andrew Goffey), London: Open Humanities Press, 2015, p. 47.

87 Rob Nixon, 'The unequal Anthropocene', in Kress and Stine, op. cit. (12), pp. 149–60; Gabrielle Hecht, 'Interscalar vehicles for an African Anthropocene: on waste, temporality, and violence', *Cultural Anthropology* (2018) 33(1), pp. 109–41.

https://doi.org/10.1017/bjt.2024.27 Published online by Cambridge University Press

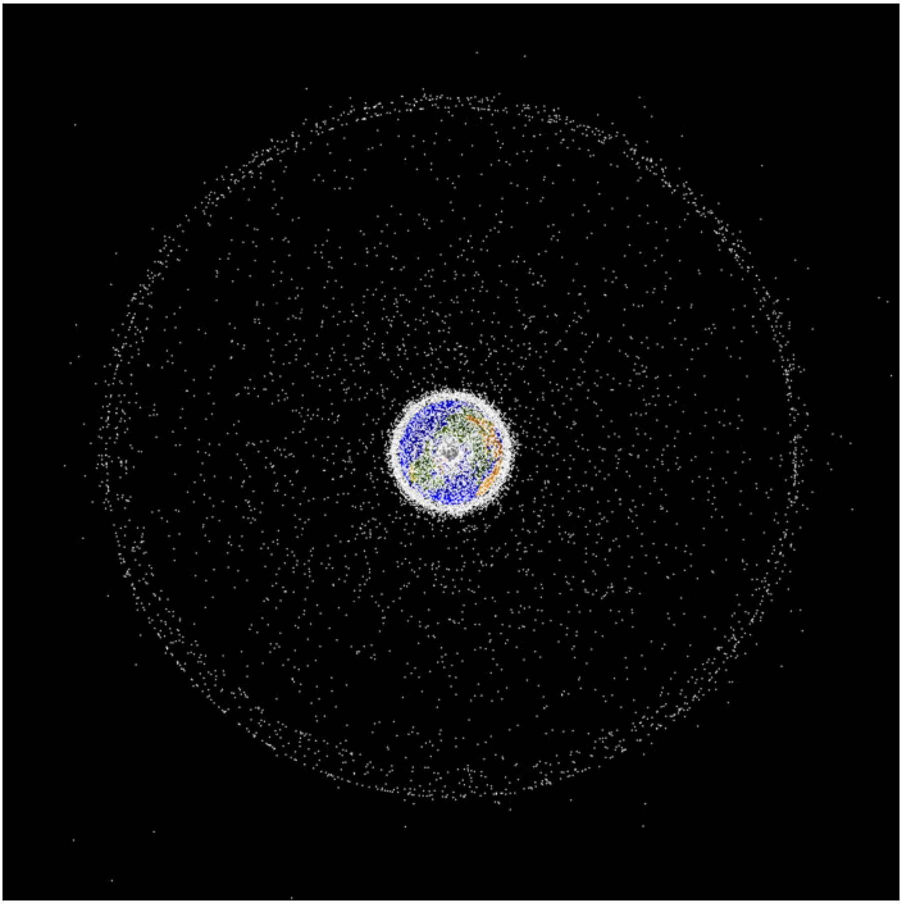

Figure 3. This static diagram shows artificial objects orbiting at a range of altitudes, current as of 1 January 2019 – a few months before the first so-called 'megaconstellation' satellites reached near-Earth space, prefiguring an exponential spike in tracked artefacts over the ensuing years. Approximately 95 per cent of the white points shown represent objects classified as orbital debris, with the remaining 5 per cent indicating functioning satellites and spacecraft. None of the dots retain identifying information, obscuring the provenance of the objects they represent and suggesting a (misleadingly) collective wasting of the orbital environment in an Anthropocene Space Age. Credit: NASA ODPO.

with the resources and capital to reach orbit, not all of humanity on the ground below can lay claim to those objects, nor to the remnants of their decay.

The exclusive study of satellites as tools in a whole, unbroken state narrows the focus of historical research on space science and technology to those regions that build, launch and operate satellites. Taken as always-already fragmented things in an envirotechnical disassemblage, however, they open up possibilities to understand and encounter the Space Age as a truly global or planetary era – not unified, homogeneous, or disciplined as conveyed by whole-Earth imagery but more expansive and inclusive than reflected in much of the period's historiography, which privileges specialists and a small geopolitical club of space-racing nations.[88] Thinking of near-Earth space as a wasted

88 Asif Siddiqi asks historians to challenge the narrative of the Cold War space race as a binary contest between superpowers in 'Competing technologies, national(ist) narratives, and universal claims: toward a global history of space exploration', *Technology and Culture* (2010) 51(2), pp. 425–43. Siddiqi has answered his own challenge by contributing scholarship on African and Asian space histories. See Asif Siddiqi, 'Science, geography, and

https://doi.org/10.1017/bjt.2024.27 Published online by Cambridge University Press

envirotechnical regime in fracture suggests not only that technologies can be multiple things at once in a cosmos that isn't the same in all places, but also that this brokenness can broaden experiences of a cosmos beyond the expected places and actors.[89]

Conclusion: say yes to the mess

Sputnik's rocket body, nose cone, polished beeping sphere and unnamed, innumerable companion fragments re-entered the atmosphere within months of their momentous, Earth-shattering and Earth-unifying ascent. The bright points of light against a dark sky that represented the fragmented whole of *Sputnik 1* no longer linger in static and animated orbital-debris diagrams. But as their descendants proliferate, tracing ever-crowded paths around a central, permeable whole Earth, they have in some ways become as mundane and overlooked as a mass-produced consumer automobile. They join a canon of technological things whose reduced wholes unify and conceal fragmented worlds. They also tell on themselves – programmed data points collected by the very same circumplanetary, extraplanetary sensing infrastructure co-located and often undifferentiated from objects broadly understood as waste.

Orbital-debris animations both reflect and destabilize the control imperatives that birthed them. They reveal expanded contours of a complex entanglement of more-than-human forces. Each point designates a snarl of colonial logics, geopolitical manoeuvring, and neocolonial technopolitics; solar behaviour, design choices, industrial growth and material decay; complexities of international governance, the uncooperative physical landscape of sublunar space and unequal access to orbit.[90] Each point in the debris map is a cosmic thing in an envirotechnical orbital regime ordered by disorder.

Attending to such tangled epistemologies may be useful towards rethinking the big picture of history of science. This approach means examining the ways in which historiographies of science replicate some of the same control imperatives and boundary work performed by the specialists that historians of science study. Adhering to an envirotech methodology requires some degree of letting go of scrupulous categorization and classification of actors, values, intellectual lineages, determinisms and myriad other ways of making sense of scientific praxis in favour of a much messier reality.

If each fragmented piece of a whole can be understood not just as gatherings of knowledge, labour and material but also as things profoundly shaped by more inscrutable intersections of agency and power, what new worlds might come into view? An invitation to embrace loss of historiographical control also invites the question of how the methods of envirotech and discard studies scholarship might open new pathways to understanding who and what influences knowledge production. It additionally brings into question the values expressed through historical order-making. Is the accumulation of debris around the planet a natural disaster? An anthropogenic disaster? Is it both? Is it even

nation', *History and Technology* (2015) 31(4), pp. 420–51 ; Siddiqi, 'Another global history of science: making space for India and China', *BJHS Themes* (2016) 1, pp. 115–43; Siddiqi, op. cit. (56).

89 On the extension of encounters with space politics and through broken materialities see Ellen Power and Arn Keeling, 'Cleaning up Cosmos: satellite debris, radioactive risk, and the politics of knowledge in Operation Morning Light', *Northern Review*, 18 October 2018, pp. 81–109; Rand, op. cit. (8); Ellen Power, 'Memories of mistrust and contamination: the legacies of Cosmos 954 and Operation Morning Light in Denendeh' (2019), master's thesis, University of Toronto.

90 This is a gesture to Sara Pritchard's framing of the Fukushima disaster as an envirotechnical disaster caused by multiple, intersecting, more-than-human influences. Pritchard, op. cit. (21); Pritchard also refers to Michelle Murphy in noting the compounding effects of these intersections into a seemingly infinite list. Michelle Murphy, *Sick Building Syndrome and the Problem of Uncertainty: Environmental Politics, Technoscience, and Women Workers*, Durham, NC: Duke University Press, 2006.

a disaster at all, and if so by whose metric?[91] From the more-than-global perspective of an Anthropocene Earth that includes the nearest regions of outer space, the big picture of history of science gets fruitfully messy, no longer as strictly bound by the consequence of clarity.

There's danger in getting too messy, perhaps – by refusing clear demarcations between actors and identities historians of science may run the risk of 'blackboxing the whole world'.[92] But rethinking the dimensions of belonging, of who and what counts as internalities and externalities that shape scientific knowledge and network building, can have the opposite effect. What historiographical practices might emerge in the wake of a point-as-debris made visible and meaningful through programmed representation, but also uncontrollable through a tangle of influences? In addition to shifting the spatial peripheries of the planetary, how might this loss of control also stimulate an expansion of historiographical outlooks? Can 'natural sciences' also be expanded beyond the usual suspects to include study of environments so extreme as to challenge standard conceptions of the natural?[93] If material breakdowns spur knowledge production in scientific research, why shouldn't the same breakdowns, whether material or discursive, similarly inspire historical knowledge production from a broader, more inclusive perspective?[94]

Isabelle Stengers has written of the twenty-first-century re-emergence of Gaia as a 'new kind of scientific being' that defies the central premise of the Anthropocene as a geological era in which humankind – undifferentiated, united, homogeneous – has become the dominant force of geochemical and geophysical change. Such a being as Gaia does not demand anything from those whose actions have shaped planetary systems, nor does it recede into the background of human affairs.[95] Even obscured by digital and material debris, Earth remains an object of concern to those seeking to reorder sublunar Gaia whether for reasons of ethics, equity or the promise of celestial capitalist extraction. Stengers notes that such concern requires that 'the dream of control or mastery be … replaced by the need to pay attention to, to care about and to learn from what we are bound to coexist with'.[96] The mess is here, has been here, and is here to stay. In relinquishing some dimensions of control or mastery to coexist with and create knowledge from and with the mess, history of science may encounter compelling new thematic and methodological horizons.

Acknowledgements. I would like to thank James Poskett for the invitation to participate in this special edition and for his generous feedback on early drafts of this article. I would also like to acknowledge commentary from two anonymous reviewers which helped me refine the article's structure and analytical framing.

Competing interests. the author declares none.

91 Scott Gabriel Knowles, *The Disaster Experts: Mastering Risk in Modern America*, Philadelphia: University of Pennsylvania Press, 2012.

92 Dániel Margócsy, 'A long history of breakdowns: a historiographical review', *Social Studies of Science* (June 2017) 47(3), pp. 307–25, 309.

93 Scholarship that examines histories and ethnographies of science in extreme environments includes Helen M. Rozwadowski, 'The promise of ocean history for environmental history', *Journal of American History* (June 2013) 100(1), pp. 136–39; Leah V. Aronowsky, 'Of astronauts and algae: NASA and the dream of multispecies spaceflight', *Environmental Humanities* (1 November 2017) 9(2), pp. 359–77; Olson, op. cit. (16); Vanessa Heggie, *Higher and Colder: A History of Extreme Physiology and Exploration*, Chicago: The University of Chicago Press, 2019.

94 On the importance of material breakdown to scientific practice see Margócsy, op. cit. (92), p. 312.

95 Margócsy, op. cit. (92), p. 312; Isabelle Stengers, 'Accepting the reality of Gaia: a fundamental shift?', in Hamilton, Gemenne and Bonneuil, op. cit. (60), 134–44; Stengers, op. cit. (86).

96 Stengers, op. cit. (95), p. 137.

Cite this article: Rand LR (2024). Space is the place: extraplanetary disorder in histories of science. *BJHS Themes* **9**, 59–81. https://doi.org/10.1017/bjt.2024.27