Out of Place in Outer Space?

Exploring Orbital Debris through Geographical Imaginations

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■ **ABSTRACT:** Increasing human activity in orbital space has resulted in copious material externalities known as “orbital debris.” These objects threaten the orbital operations of hegemonic stakeholders including states, corporations, and scientists, for whom debris present a significant problem. We argue that the geographical imaginations of powerful stakeholders shape conceptions of orbital debris and limit engagement with these objects. By engaging with interdisciplinary literature that considers orbital debris and geographical imaginations of outer space, we encourage a more capacious approach to orbital debris that goes beyond hegemonic narratives focused on functionality. We explore the connections between debris and injustice, arguing that these objects must also be considered in relation to terrestrial power and ecology. We then contemplate the possibilities that counter-hegemonic framings present when considering speculative futures of orbital space. In these ways, we explore how and why debris are variously engaged with as pollutants, risks, opportunities, or otherwise.

■ **KEYWORDS:** capitalism, collision, colonization, critical geography, debris, orbital space, pollution, space junk

In October 2020, the space community sounded an alarm. Ground-based radars were tracking two defunct objects in Earth's lower orbit, Cosmos 2004—a 1989 Russian satellite—and CZ-DEB—the body of a 2009 Chinese rocket launcher. The objects were projected to pass within 12 meters of each other, and if they were to collide, the ensuing production of material debris in orbital space would be massive (Mack 2020). As this event lit up the Internet, there were various preoccupations with this potential collision. In online forums, scientists, both amateur and professional, disagreed over the risk of collision, with some wondering whether debris could pose a threat to the International Space Station (Pueo 2020). Amateur astronomers debated the consequences of debris production clouding their observation (u/neotek 2020). Those only just learning about orbital debris wondered whether these objects could hit Earth, while others speculated about whether resulting debris clouds would impact existing satellites and future space travel (u/Sauvignon_Arcenciel 2020). Media outlets jumped on the issue to debate the perils of “space junk” (Mack 2020). United States Space Command confirmed that they had been watching the objects closely but were not concerned about collision (Wattles 2020). On 16 October, the objects passed each other without incident.

Although this close encounter sparked concern, it was far from clear what had been at stake. Everyone watching this potential collision incident had different perspectives of debris¹ and their impact. Incidents like this are not uncommon. Orbital space is increasingly a place of

national, capitalist, cultural, and scientific possibility and accumulation. As human engagements with outer space intensify, the crowding of orbital space has prompted anxieties about the increasing probability of orbital objects colliding with one another. Collisions have the potential to fundamentally transform the place of orbital space, thus becoming a matter of significant geographical interest.

Orbital space is a site enmeshed in flows of sociocultural relations with specific conceptions and expectations that construct it as a meaning-laden place (Agnew 2011). One's conception of orbital space is informed by their specific geographical imaginations that shape their relationship to this place, what it is, and what it should be (Cresswell 1996, 2004; Massey 2006). To use a simplified metaphor for complex place-making processes, everyone approaches orbital space with a selection of different camera lenses and tools that they use to interpret and shape engagements with this place. Some of these may be widely shared, such as hegemonic narratives that provide lenses and tools in the shape of colonial thought or capitalist accumulation. Others may be less ubiquitous, for instance an environmentalist might find a lens with the label "pollution" most fitting to apply to the increasing human-made material in outer space, while an anthropologist might find a lens with the label "artifact" more apt. Throughout this article, we use the framework of geographical imaginations as a method of orienting our investigation of interpretations of orbital debris. A foundational concept for critical geographers concerned with place, power, and representation, the framework of geographical imaginations allows us to explore some of the core sociospatial narratives that construct orbital space and objects within it (Gieseke 2016).

A growing body of critical work considers geographies of outer space (e.g., Cosgrove 1994; Dunnett et al. 2019; MacDonald 2007; Messeri 2016; Olson and Messeri 2015). This includes influential work considering near-Earth space as a place of geopolitics, capitalist endeavor, environment, and culture (Klinger 2019; Parks 2005, 2012; Rand 2016). As geographers, we engage with this literature to critically consider orbital debris, calling attention to the geographical imaginations that shape these objects. We consider various interpretations of debris and orbital space as they are represented in both critical literature and science, government, and industry documents. We first present a brief background of orbital debris and how they are commonly understood as problems. Next, we introduce the concept of geographical imaginations, and what it can offer to the study of orbital debris. We argue that core stakeholders' engagements with debris reveal underlying judgments of what orbital space "should be." Recognizing the power-laden and limiting nature of these core imaginations, we then explore how alternative approaches offer unique insights into the "problem" of orbital debris, and different engagements with orbital space more generally. Throughout this article, we apply the framework of geographical imaginations as a device to help us to reveal the sociospatial framings that underlie dominant narratives of orbital debris, and to illuminate and encourage more capacious approaches. As geographers whose own work focuses on matter and knowledges sometimes considered "out of place," we are interested in drawing attention to alternative perspectives, counter-hegemonic possibilities, and speculative futures in the exploration of orbital debris.

Orbital Debris

Since Sputnik 1 was launched in 1957, an increasing number of objects have entered orbital space—spy satellites, navigational systems, space stations, and more. This has resulted in a rapidly growing body of both operational objects and nonoperational material externalities (Brearley 2005; Gorman 2005; Rand 2016). The latter, known as orbital debris, are created through various deliberate and anomalous events in a spacecraft's lifetime, and their scale can range from

entire defunct satellites to paint chips (Brearley 2005; Gheorghe and Yuchnovicz 2015). There are currently an estimated 34,000 debris objects larger than 10 centimeters, as well as 900,000 objects between 1 centimeter and 10 centimeters and 128 million objects from 1 millimeter to 1 centimeter in orbital space, far exceeding the 3,700 functioning satellites in orbit (European Space Agency 2021).

There are several principally defined areas of orbit. The various speeds and positions of each offer differing advantages for particular operational objects, and high-value orbital positions are limited (Collis 2009; Gheorghe and Yuchnovicz 2015). Although human activities within them vary, debris affect all regions of near-Earth orbit. The long lifespans of defunct objects in orbital space are central to debris accumulation. The “end” of a satellite’s lifespan typically comes when its operations cease and efforts are made to move it out of usable orbit. This can happen through “graveyarding,” where the satellite is placed in a higher orbit (Radtke et al. 2015). Or, they can be placed in a disposal orbit where atmospheric drag will eventually cause earthbound reentry and the satellite’s disintegration (Gheorghe and Yuchnovicz 2015). Larger objects may not disintegrate fully during reentry and fragments may return to Earth (De Lucia and Iavicoli 2019). Despite regulation requiring post-mission disposal plans for new satellites, many objects lack sufficient fuel or disposal capabilities to be actively removed from orbit (Pelton 2015). Thus, they may rely on natural orbital decay to fall to the atmosphere (Rand 2016). This can take anywhere from months to millennia, depending on orbital position (Gorman 2009).

As the number of objects in orbital space increases, so too does the probability of them colliding (Kessler et al. 2010). Orbital objects may generate debris intentionally as part of their mission (e.g., rocket launchers), accidentally from anomalous events like failure and collision, be decommissioned, or be deliberately destroyed (Gheorghe and Yuchnovicz 2015). When orbital objects collide, their fragments have the potential to collide with other objects, generating further debris. In 1978, Donald J. Kessler and Burton G. Cour-Palais described a possible scenario, since dubbed the “Kessler syndrome,” where collisions could cascade exponentially until entire areas of orbit become “unusable” due to the density of debris objects (Kessler et al. 2010). High-profile incidents have cemented concerns about this phenomenon, such as the collision of the defunct Cosmos 2251 Russian military satellite with the functioning Iridium 33 American commercial satellite in 2009, which produced “more than 2,000 trackable debris objects” (Gheorghe and Yuchnovicz 2015: 361). Even with no new launches, a number of catastrophic collisions could still occur over the next 200 years from existing orbital material (Liou and Johnson 2006). The mitigation and disposal of orbital debris have thus become critical to space stakeholders and an increasing concern for the general public.

Geographical Imaginations and Orbital Debris

Outer space and Earth are not detached, but deeply interconnected by flows of meaning and matter that interrelate through zones of designation such as orbital space. Though they may seem removed from everyday consciousness, orbital space and debris are not abstract concerns for many people. Whether materially involved in outer space endeavors, reliant on the flows of data allowed by orbital objects, or connected by personal, cultural, or spiritual meanings and engagements, most people have some sort of relation to outer space (Bawaka Country et al. 2020; Cosgrove 1994; Klinger 2019; MacDonald 2007; Parks 2012). Outer space is a vital part of geographical consideration not only physically, but also because its sociospatial production relies upon and potentially amplifies terrestrial inequalities and power relations (Beery 2016, 2017; Dunnett et al. 2019; MacDonald 2007; Parks 2005).

To understand how different actors consider orbital debris, we can investigate their underlying geographical imaginations. Geographical imaginations are framings, informed individually and collectively, that shape relational understandings of places and how they are known (Daniels 2011; Gregory 1994; Howie and Lewis 2014). Though individuals have unique “geographic minds” that inform their ideas and attitudes, these are not separate from broader entanglements of place, meaning-making, geographic narrative, and power (Giesekeing 2016; Massey 2006). Geographical imaginations inform and are informed by partisan motivations within systems of education, capital, global power, and colonization (Daniels 2011; Howie and Lewis 2014; Massey 2006). Plainly said, everyone has their own meaning-laden understandings of places that inform their relations with them. Physical access or tangible connections are not required for people to develop strong senses of place (Cresswell 2004). There are strong geographical imaginations that inform beliefs about the place of orbital space, what belongs there, who should engage in and with it, and how (Cresswell 2004). Orbital debris objects are thus multifariously defined by the geographical imaginations that frame their meaning. As geographers, we emphasize the importance of understanding objects in the context of their spatial relations. For orbital debris, this means turning our attention to how debris objects are understood in relation to geographical imaginations of the place of orbital space.

All beings on Earth can be considered to “hold a stake” in orbital space. Even so, core interest groups are particularly engaged with orbital debris including states, corporations, and lawmakers. These actors hold particular power to shape orbital space not only in their own disciplines but also in crafting public narratives. For our purposes, we call these powerful entities stakeholders. Exploring their core narratives and engagements, both shared and disparate, can reveal judgments of orbital objects and the differing geographical imaginations that underlie their social construction as debris. Through policing what belongs in orbital space, these hegemonic stakeholders have great power to define its boundaries and uses.

Stakeholders engage with orbital space and debris in different ways: politically, economically, scientifically, and ontologically. Multiple interest groups share a preoccupation with orbital space and the potential impacts of orbital debris, but do not necessarily share the same concerns. Engagements with orbital debris and outer space are sociospatially informed by what is considered “in” or “out of place” depending on specific geographical imaginations of orbital space (Cresswell 1996). An object that may be “in place” (e.g., belonging, useful, or correct) for one may be “out of place” (e.g., polluting, hazardous, or wrong) for another (Cresswell 1996; Douglas 1966). Stakeholders have specific framings of orbital debris, which may be constructed as particular kinds of problems requiring particular kinds of solutions. Hegemonic stakeholders create and perpetuate powerful narratives about what “belongs” in orbital space, which in turn inform their relationship with debris objects. Accordingly, they strategize various ways to reduce, remove, or control debris objects. In this way, their engagement with debris reveals their geographical imaginations of orbital space and what belongs there. Thus, orbital debris can be better understood in the context of the place-based expectations that inform how these objects are perceived and engaged with.

Geographical Imaginations of Outer Space

Outer space is a site of intense imagination and creative speculation (McCurdy 2011). At the same time, certain orbital locations are accessed so routinely that they may be considered banal rather than awe-inspiring (MacDonald 2007). The breadth of geographical imaginations of outer space are beyond the scope of this article. We focus here on some of the key geographical

imaginings that underpin engagements in Earth's near space. Exploring hegemonic stakeholders' framings of and engagements with outer and orbital space allows the examination of dominant geographical imaginings and the ways they define orbital debris. In particular, ideas of "empty space" and "purity" have shaped conceptions of orbital space, what it "should be" for, and how it might be inhabited, exploited, or protected.

One consequential geographical imagination is the framing of outer space "as an empty vessel, or, more accurately, one with profound but specific forms of both absence and possibility . . . awaiting purposeful inscription by the human species" (Kearnes and Van Dooren 2017: 182). This imagination has inspired and legitimated hegemonic engagements with orbital space, particularly by state actors. Julie Klinger understands this imagination as one in which "the environments of outer space are recast as strategic assets that must be instrumentalized to increase state power and authority" as part of the "nationalist performativity" of outer space endeavors (2019: 3, 13; see also MacDonald 2007). The term "frontier" is embedded in scientific, state, and popular narratives of outer space exploration, with roots in the "final frontier" narrative of the Cold War (Rand 2016; McCurdy 2011). Daniel Sage (2008) argues that US politicians and NASA continue to legitimize their extraterrestrial exploits with the idea of outer space as a frontier that must be explored and exploited to fulfil the geographical imagination of American manifest destiny. "Frontier" has origins in the violent colonization of the American West (Benjamin 2003; Sage 2008; Messeri 2016; Rand 2016). It evokes extraterrestrial places as sites that demand intervention, with evident colonial logics that work to legitimate expansion and exploitation (Bawaka Country et al. 2020; Gorman 2005). Scholars have recognized the troubling parallels between terrestrial colonialism and state expansion into outer space, in which "both interplanetary space and the lands of 'primitive' people are [considered] terra nullius, empty wildernesses, or moral vacuums, into which civilized sea-faring or space-faring nations can bring the right moral order" (Gorman 2005: 99; see also Genovese 2017; Kearnes and Van Dooren 2017; Klinger 2019; MacDonald 2007; Rand 2016; Sage 2008; and Sutch and Roberts 2019).² A formative article from the Bawaka Collective makes it clear that expansion into outer space is a direct act of colonization and "the extension of earth-based colonization into space disrupts and colonizes the plural lifeworlds of many Indigenous people who have ongoing connections with and beyond the sky" (Bawaka Country et. al. 2020: 1).³ Colonial logic is globally pervasive, and just as it informs terrestrial place-making, so too does it foundationally inform exploitation in outer space.

This "empty space" imaginary is also prevalent within NewSpace private enterprises, for whom outer space at-large is a site of capitalist endeavor and unlimited growth. NewSpace is a term collectively referring to contemporary engagements with "space as a free market frontier" (Burwell 2019: 41). NewSpace enterprises, like SpaceX, Blue Origin, and Virgin Galactic, engage in extraterrestrial capitalist endeavors that contribute to the privatization of outer space, such as space tourism (Genovese 2017), satellite communication (Radtke et al. 2017), and private contracts with state space agencies (Sage in Dunnett et al. 2019). Taylor Genovese argues that these ventures reveal how "outer space is being imagined as a site of capitalist accumulation" (2017: 129), where "the imaginary for outer space shifts from a place in need of exploration to a place in need of exploitation" (2017: 129–130). David Valentine (2012) argues that NewSpace actors are not only motivated by financial opportunity, but also a utopian future of free market extension into outer space as an "exit strategy" from the constraints of Earth. Others describe the latter as "charismatic accumulation" (Shammas and Holen 2019: 4), whereby the spectacle of NewSpace ventures obscures the financial gains of elite individuals and the uneven labor geographies of the space industry under the guise of universal human achievement or necessity (Genovese 2017; Sage in Dunnett et al. 2019; Shammas and Holen 2019). Victor Shammas and

Tomas Holen have related NewSpace pursuits to David Harvey's (2001) concept of the spatial fix, wherein "blank spaces" (2019: 5) are appropriated and exploited by capitalism and its expansionist underpinnings. NewSpace activities are similarly legitimized through colonial narratives of outer space as "empty" and available for exploitation. If orbital space is conceived only as a void within which stakeholder endeavors occur, then orbital debris can only be understood in relation to the risks or opportunities they pose to these; the "blank space" imaginary does not allow otherwise.

Not all core stakeholders consider outer space to be empty. Scientists, for instance, may not consider outer space a site for explicit exploitation, but rather a place of knowledge production and perhaps extraterrestrial life. Lisa Messeri argues that Mars and exoplanet scientists' searches for other inhabitable planets are world-building projects that "are populating the 'emptiness' of space with planetary places . . . replacing outer space with outer place" (2016: 23). Further, Lisa Ruth Rand notes that even "the nearest reaches of outer space support an abiotic ecosystem consisting of energy exchanges, radioactivity, natural rocky objects and energetic plasmas, and gravitational forces" (2016: 8)—and thus it is not a blank space at all. As Valerie Olson found in interviews with scientists concerned with near-Earth objects, outer space is a dynamic "political ecological space" (2012: 1030) that can be considered "in environmental and ecological terms" (2012: 1029), for instance, in activists' efforts to mitigate the threat of asteroids to terrestrial life (Olson 2012, 2013, 2018) or scientists' efforts to theorize life in extraterrestrial environments (Helmreich 2012; Messeri 2016). In this imaginary, outer space is not empty or even separate, but rather "a crowded and unpredictable environment" (Olson 2013: 198) of serious human-environmental significance that demands both management and scientific study.

In this consequential fullness, objects such as orbital debris may be considered in terms of their interaction with other materials or processes in space (e.g., asteroids or orbital weather), as well as their effect on research (Rand 2016; Reno 2018). For instance, astronomers have expressed concerns that both satellites and debris may impede their ability to collect data (e.g., Hainaut and Williams 2020; McNally and Rast 1999). Shammas and Holen argue that astronomers' "outrage" at such objects is grounded in "the idea of a material, concrete, visible object polluting 'pure' scientific data" (2019: 3). Here, human-made objects are "unnatural" against a scientific ideal of outer space as an untouched fieldsite in which excessive human material presence is out of place (see, e.g., Cameron and Matless 2011; and Hennessy 2018). Of course, scientists do not all conceive of this place in the same way; an amateur astronomer and a government resource geologist will certainly have differing perspectives. Different actors' objectives and knowledges of outer space fundamentally transform how they might engage with orbital debris.

Although this overview is limited, particularly given its focus on actors and theorists in the Global North, it is clear that different communities and stakeholders hold specific geographical imaginations that affect their engagement with orbital space and orbital objects. Orbital debris are flexibly defined (Rand 2016; Reno 2020). Such objects are not static but understood in relation to sociospatial framings. We use the term "debris" in this article to echo the language of scientific, corporate, and governmental discourse and to avoid making judgments about these objects. However, either implicitly or explicitly, debris may be deemed "space junk" or "pollutants" (Gorman 2019; Klinger 2019; Rand 2016). Though the stakeholders we address may not always use these latter terms, they often engage with debris *as if* they are pollutants: things that are transgressive or out of place within specific expectations of the place of orbital space (Cresswell 1996; Douglas 1966). This is particularly apparent in stakeholders' attempts to control perceived transgressions through the management, ordering, and removal of debris (Damjanov 2017; Johnson 2004; Liou et al. 2010). This stems from the desire to control or maintain a specific sense of place and its purpose. We can thus understand engagements with debris as

place-defining interventions where stakeholders attempt to construct or return orbital space into an apparent ideal state (Douglas 1966).

Orbital Debris: Risk and Mitigation

Powerful stakeholders such as states, scientists, and corporations share a core geographical imagination of orbital space where debris are risks to certain objects and functions, which must be mitigated. The framing of what is at risk, by what, and how varies among stakeholders and contexts, shaping their engagement with debris objects (Klinger 2019). One core preoccupation of this risk and mitigation focus is the economic impact of debris. Satellites are integral to the information flows of late capitalism, enabling the consumption and exchange of the vast data that defines our epoch (Damjanov 2017). The potential disruption to satellite-enabled technologies and communications from collision could adversely impact the global economy, and particularly affect rural areas and low-income regions (OECD 2020). The mitigation of risks that debris pose to orbital functions and investments includes costly strategies such as insurance, predictive modeling, and satellite repositioning (Parks 2012). In these engagements, the place of orbital space is imagined predominantly as a vessel for operational activities (Kearnes and Van Dooren 2017). Orbital debris, as objects that threaten functionality, are viewed as out-of-place hazards that must be mitigated.

Though existing in nonterrestrial space, orbital debris are not removed from questions of responsibility and equality. Certain risk-based narratives frame orbital debris not as neutral or natural risks, but as politically charged objects that restrict equal opportunities in outer space. For example, the proposed 1976 Bogota Declaration attempted to address concerns that nations in the Global South would be unable to access valuable orbits before they were appropriated for the activities of national and corporate superpowers (Agama 2017; Collis 2017). Other literatures have specifically addressed the risks that orbital debris—generally produced by nations in the Global North (Union of Concerned Scientists 2021)—pose to outer space access for the Global South (Ferreira-Snyman 2013). Klinger (2019) argues that powerful actors have degraded orbital space, limiting access for developing space powers while allowing those with existing access to remain unaccountable. Here, orbital debris are framed as threats to opportunity based on imaginations of outer space as a place that should provide universal prospects for national endeavor and economic gain (Collis 2017; MacDonald 2007).

Orbital debris are also risks in military imaginations of outer space. Orbital space has become integral to the modern military strategy of many nations (Hildreth and Arnold 2014; MacDonald 2007). For instance, the US military relies on satellite data for communications, surveillance, and weaponry deployment (Hildreth and Arnold 2014). Thus, the potential compromise of satellites via collision damage is considered a major threat to military operations, such that debris may be regarded as national security risks (Bowen 2014). Indeed, China's deliberate destruction of its own satellite in 2007 to demonstrate antisatellite weaponry is often foregrounded in militaristic American narratives regarding the dangers of debris (e.g. Hildreth and Arnold 2014; Imburgia 2011). Here, orbital debris are transformed into a foreign security concern—an antagonistic threat to the safety of US troops and citizens (Imburgia 2011). This threat is cast in relation to an outer space that has been imaginatively denied significance beyond strategic value (Klinger 2019). In these militaristic and legislative narratives, orbital debris are again considered in relation to the risk they pose to expected and desired operations in orbital space. It becomes clear that risk is constructed in ways relative to different actors' imaginations of what "should be" or "should happen" in orbital space.

Preoccupations with risk are also focused on the danger that debris pose to future exploration and endeavor. Beyond the aforementioned issues of uneven access, scholars have raised concerns about an imminent “economic Kessler syndrome” in which debris accumulation will render certain orbits “unprofitable” (Adilov et al. 2018). Orbital debris have also cast doubt on some speculative NewSpace endeavors, such as space tourism (Gorman 2020). Katarina Damjanov argues that the anxious mitigation of debris through legislation or a proposed “antiwaste arsenal” of “nets,” “lasers,” and “robots” (2017: 179) attempts not only to secure current assets, but also to “preserve the possibility of our extraplanetary expansion” (2017: 180). In this way, orbital debris are not only considered threatening in imminent concerns of collision in orbital space, but also present a risk to potential futures in outer space.

Further hegemonic preoccupations with orbital debris focus on the risk they may pose to the ability to access or study spaces beyond orbit. Scientists have expressed concerns about how increasing orbital objects may impact astronomical observation. This is not a new concern, nor one that is restricted to defunct objects. As Rand notes in her analysis of Project West Ford—a US Cold War communications “experiment that culminated in the launch of hundreds of millions of tiny copper needles into space” (2016: 29)—astronomers have long been concerned with the ways that “industrial products and byproducts” (2016: 106) can obscure optical and radio observations of outer space. Recently, astronomers have spoken against the launch of mega-constellations by NewSpace corporations, which could increase the threat of collision and disrupt astronomical observations (Hainaut and Williams 2020; Radtke et al. 2017). This could “imperil scientific progress and humanity’s access to dark skies” in the name of “technological and socio-economic advancements” (Massey et al. 2020). In these narratives, astronomers consider debris as just one part of their concern with the crowding of orbital space and its impact on scientific endeavor. This remains a question of risk and mitigation, but one that asks which orbital objects count as “polluting” within a geographical imagination of outer space as a crucial more-than-human fieldsite. Here, functional objects may be considered as polluting as debris.

Inequality and Orbital Debris

Despite their occurring “out there,” many materially impactful activities in orbital space—such as satellite launches, spaceflight, and space-based astronomical observation—produce social and environmental inequalities. Engagements with debris are inextricably linked to the modern market economy, rely upon racial capitalism, and perpetuate transnational environmental inequalities (Pellow 2007; Pulido 2017). The creation and management of debris objects and the placement and operation of their associated industries contributes to global economic, racial, and environmental injustices (Klinger 2019). In turn, these inequalities shape knowledge production and inform imaginations of orbital space and debris. The idealistic imagination of space as a common resource for humankind (UNOOSA 1967) is waylaid by global political economy and racial capitalism such that orbital space and debris cannot be removed from a consideration of the inequalities inherent in terrestrial life (Collis 2017; Pulido 2017). Many outer space activities require access to an upper echelon of capital and power, where stakeholders craft core narratives that shape contemporary engagements with orbital space and debris objects around hegemonic ideologies (Genovese 2017). If we wish to understand orbital debris in their entirety beyond such narratives, we must consider orbital debris in relation to geographies of global power.

The reentry of Cosmos 954, a Soviet intelligence satellite that fell over the Great Slave Lake area of the Northern Territories in Canada in 1978, has been well studied (e.g., Parks 2012;

Power 2018; Power and Keeling 2018; Rand 2016, 2019) and is a revealing case when it comes to considering inequality and orbital debris. Though no one was directly harmed by the initial impact, the satellite's nuclear reactor prompted a governmental effort to recover and dispose of the potentially radioactive debris scattered over 30,000 square miles (Parks 2012). Despite official reports claiming that the debris posed no significant risk to humans or nature, Ellen Power's (2019) interviews with Dene and Métis communities in the vicinity of the crash reveal that they have ensuing fears about lingering satellite debris and radioactivity. This has impacted their traditional use of the land, as "the Dene fish and trap in almost every square mile of this area . . . there is no place where the debris fell which is not used by the Dene" (Erasmus 1980, in Power 2019: 41). One interviewee explained that she still "washed all the berries she picked before she ate them, just in case there might still be debris resting on the plants" (Power 2019: 49). Such anxieties are compounded by an understandable mistrust of Southern authority and a lack of follow-up after the initial cleanup operation (Power 2019). The background contamination of the crash site, caused in part by routine toxic externalization into this region (see Hird 2016), has made it difficult to discern the exact source of increased levels of illness since the crash (Power 2019).

Considering orbital debris in the context of reentry (i.e., not just debris *in orbit*, but that *have been in orbit*), reveals how they are defined in relation to place. Though Cosmos 954 fragments were seen as a potential threat to humans and animals by the Canadian government, this risk was downplayed due to the colonially imagined "emptiness" of the Canadian North (Hird 2016; Rand 2019). Official reports and media presented satellite fragments as somewhat "in place" in the Northern Territories—somewhere that "stoically and harmlessly absorbed the nuclear detritus of Cosmos 954" (Rand 2019: 90). Though these reentered debris did not fall in the Pacific Ocean—the usual destination for earthbound orbital objects (De Lucia and Iavicoli 2019)—the Arctic, the deep sea, and outer space are similarly imagined through colonial logics as empty and lifeless (Collis 2017; Klinger in Dunnett et al. 2019; Rand 2016, 2019). The impact of this colonial geographical imagination on the perfunctory American–Canadian cleanup effort was well summarized by a community member who asked, in Chipewyan: "Would the government have done more if the satellite had fallen in the middle of Toronto?" (Knight 1978, in Rand 2019: 90). For these communities, debris are not innocuous or trivial, but deeply out of place and ongoing threats to their lives and land (Power 2019). Responses to Cosmos 954 demonstrate how different actors carry their geographical imaginations into practice, as well as how these imaginations can perpetuate inequalities.

Reentry events also draw attention to other externalities of the space industry (Gorman 2011). The material externalities of orbital objects are not limited to orbital space, and the terrestrial burden of outer space activities is not equally shared. For instance, scholars have noted the unequal geographies of rocket launch sites, which are often placed in areas inhabited by marginalized communities (Gorman 2005; Klinger 2019; Kopack 2019; Redfield 2000). The people and environments in the proximity of launch sites are at risk from toxic and material fallout, and the placement of such operations often follows the strategic, racist geographies of sacrifice zones (Klinger 2019). This refers to the geographical "pattern of environmental injustices in which low-income and minority populations are at greater risk of being exposed to health destroying toxic chemicals" (Lerner 2010: 297), often the toxic fallout of corporate or state activities. For example, the land that surrounds the Baikonur Cosmodrome in Kazakhstan is in ecological crisis following thousands of rocket launches, something that Robert A. Kopack argues "continue[s] [the] historical disposability" (2019: 560) of this landscape and its inhabitants. Additionally, Daniel Sage (in Dunnett et al. 2019) has highlighted the uneven labor geographies of the space industry, in which private commercial endeavors such as SpaceX rely on

an increasingly nonunionized, precarious workforce. Understanding the externalities of outer space industries in the context of power and injustice is essential for postulating a departure from hegemonic considerations of orbital debris and their impacts.

Imagining Orbital Debris Differently

Dominant preoccupations with the operational capacity of orbit and collision risk place their focus on functionalist paradigms of orbital space and debris objects. The narratives created here—often both produced by and reproducing hegemonic geographical imaginations of orbital space—limit how debris are engaged with. We now highlight a selection of more capacious geographical imaginations of orbital space to offer inspiration for how scholars and stakeholders might (and do) engage with orbital debris differently. We hope that such expanded and creative engagements may better reflect the diversity of relationships between the terrestrial and extra-terrestrial, as well as the unfathomable time scales of orbital objects.

Space archeologist Alice Gorman suggests an alternative imagination by arguing for a more heterogeneous view of orbital debris wherein outer space is considered a cultural landscape (Gorman 2005, 2009, 2019, 2020). This approach goes beyond human–nature dichotomies, recognizing places as co-created through human–environment interaction (Gorman 2005). Gorman embraces the cultural significance and complexity of near-Earth space, and she argues that terms like “wilderness” and “final frontier” are outdated given the now-multifaceted interactions between “the space environment and human material culture” (2005: 86). Through this, Gorman liberates space objects from risk and mitigation frameworks that regard all debris as out of place, assessing orbital matter instead through its “social, historical, aesthetic, and scientific significance” (Gorman 2009: 382). Considering the still-orbiting 1958 Vanguard 1 satellite, Gorman (2009) questions how attempts to “solve the space junk problem” could inadvertently destroy the cultural heritage of outer space, as defunct historic satellites are technically debris. She suggests that “the natural setting for these artefacts is the orbital landscape, and where they do not constitute a collision risk, there is no reason to remove them” (2020: 244). Gorman (2009) does not disregard the serious consequences that may result from debris-based collision events, but rather argues that the cultural heritage value of debris objects should also be considered and perhaps protected in the management of orbital space. This cultural landscape approach provides one possible alternative to narrowly functionalist paradigms of orbital space.

We might also consider how an environmentalist geographical imagination of orbital space could offer alternative understandings of orbital debris. Outer space as “environment” or “ecology” has been well established by a number of critical space scholars (e.g., Beery 2016; Klinger 2019; Olson 2013; Olson and Messeri 2015; Rand 2016). As noted above, scholars have been concerned with the negative, often unjust, environmental impact of space activities on Earth. However, the environmental impact of debris *on orbital space* is much trickier to articulate. Rand observes that outer space is often portrayed as “the opposite of verdant green-and-blue nature” (2016: 8). The lack of charismatic megafauna makes it challenging to argue the grounds for environmental protection of outer space outside of the risk that debris pose to human endeavors (Rand 2016). Even so, ideas of “space environmentalism” and “astroenvironmentalism” have been proposed. Ryder W. Miller (2001) suggests that the environmentalist project be extended upward to regard “space and the celestial bodies [as] pristine wildernesses that need to be protected rather than frontiers to conquer.” This includes calls for the creation of guidelines, ethics, and legal power that would safeguard space from unilateral control based around nation or corporation, and which is concerned with the environmental future of outer-spaces (Miller

2001). Others question what it would mean for the collective good to extend the concept of sustainable development beyond terrestrial boundaries (Wallacher et al. 2019). In these arguments, however, much attention is still given to current and future *human* entanglements with this environment, including the impact of orbital debris on satellites, rather than more-than-human environmental considerations.

How, then, can we think of the environmental protection of outer space beyond anthropocentrism? Critical geography now widely recognizes more-than-humans as social actors and place-making agents (Haraway 2008; Whatmore 2006). However, this scholarship rarely recognizes its debt to Indigenous ontologies and thinkers who, as noted by Kim TallBear, “have never forgotten that nonhumans are agential beings engaged in social relations that profoundly shape human lives” (in Muñoz et al. 2015: 234; see also Belcourt 2015; and Todd 2016). Environmental geographical imaginations of orbital space must consider what is more-than-human and more-than-machine, and how these beings and entanglements might offer new perspectives on orbital debris beyond functionalist paradigms. As mentioned above, many scientists do not understand space as empty, but rather as a complex fieldsite full of energy, matter, and forces (Olson 2013; Rand 2016). Many embrace the probability of life beyond Earth (Messeri 2016), pointing to the fact that lively places like hydrothermal vents in the deep ocean were similarly once thought to be barren (Helmreich 2012). Here, outer space is not an “empty vessel” (Kearnes and Van Dooren 2017: 182) or purely a space for knowledge production and capitalist endeavor, but a natural ecosystem potentially containing “other sensitive biological systems with the prerogative to exist” (Klinger 2019: 22). This point raises the question of whether this “nature” should be protected against human-machinic “contamination,” whether by debris or functional objects.

This issue of safeguarding is partially addressed by the planetary protection protocols of the Outer Space Treaty (UNOOSA 1967). These were designed in part to prevent the “contamination” of outer space by terrestrial microbes brought along by spacecraft (European Space Agency 2014), which might harm the existence or emergence of extraterrestrial life forms (Klinger 2019) as well as the ability of scientists to “discover” them (Cheney et al. 2020). However, Klinger (2019) notes that spacefaring powers, particularly private enterprises, have either disregarded these protocols altogether or have shifted from protection to preservation due to the inhibiting nature of the protection protocols to their endeavors. “Preservation” here follows the “logic of Earthly conservation regimes” (2019: 22), where outer space could become segmented “into spaces of acceptable and unacceptable contamination” (2019: 22). This could create interstellar preserves shielded from the apparent imperatives of colonial capital destruction (Klinger 2019). In terrestrial nature preserves, places become protected for their ecological or cultural importance (Dudley et al. 2010). If these preservationist practices were applied upward, orbital space could be framed as a protected wilderness area—a pure “nature” that must be shielded from the polluting interventions of humans (Cockell and Horneck 2006; Miller 2001). However, orbital space seems to lack the speculative and charismatic biodiversity that planetary protection protocols seek to protect (Rand 2016). To evoke the protection of orbital space as nature, the cultural-ecological significance and uniqueness of certain processes, exchanges, forces, and orbital objects would need to be identified by heterogeneous interest groups (Tavares et al. 2020). Whole orbital trajectories could be designated as extraterrestrial parks with strict rules about satellite traffic and orbital littering, or human-made objects could be banned from certain locations altogether (Cockell and Horneck 2006). In this vision, any orbital matter could be considered polluting, regardless of its functionality or collision potential with other human-made materials. However, this parks model could give free rein for the degradation of non-protected areas (Klinger 2019), or project problematic human–nature divides into outer space (Gorman 2005; Klinger 2019).

To draw attention to less dominant framings of orbital space, we are compelled to consider alternative ethics to those evident in hegemonic geographic imaginations of orbital space. Matthew Kearnes and Thom van Dooren offer the “ethics of interstellar flourishing” (2017: 180) as an alternative to frontier logics that frame space as empty and thus limit ethical demands. They explain that the concept of “‘worlding,’ ask[s]: What kind of worlds are we helping to produce and with what consequences for whom?” (2017: 186). This question allows a consideration of ethics in relation to both human and nonhuman actors in outer space. It asks whether abiotic asteroids, future Martians, and seemingly empty spaces might also be of ethical importance (Kearnes and Van Dooren 2017: 186). Critically, this ethic discards imaginations of outer space as an empty void waiting to either be occupied or protected. Instead, if “space is already full of meaning and value; the very stuff of ethics” (2017: 186), then our ethics must be attentive to the entangled and unknowable nature of outer space. By “holding ‘the good’ open, under question” (2017: 188) a living, inclusive ethic of extraterrestrial extension might better account for the diversity of outer space actors, objects, and unknowable futures (Kearnes and Van Dooren 2017). By demanding attention to the “diversity within categories like humanity, the nonhuman, the abiotic, and ‘space’” (Kearnes and Van Dooren 2017: 186), interstellar flourishing pushes beyond imaginations of extraterrestrial extension as a “biological imperative” (Gorman 2005: 103) of a homogeneous human race, who all benefit or are harmed equally by these endeavors (Kearnes and Van Dooren 2017). This connects with a call by Frank Tavares and colleagues (2020) for a reevaluation of planetary protection measures to reject the expansion of colonial practices onto other planets. They argue, for instance, that “agency and moral consideration” (Tavares et al. 2020: 2) needs to be extended to existing and potential microbial life and that potential lifeforms matter beyond their relative “intelligence” (2020: 4). Thus, a “multiplicity of epistemologies” (2020: 1) must be considered to decenter colonial logics in discussions of extraterrestrial expansion.

Speculative Futures of Orbital Debris

Predicting the impacts of debris that will remain in orbit for thousands of years is not easy (Kearnes and Van Dooren 2017; Tavares et al. 2020). The time scale of cause and effect here is staggering: how can we know how future generations, beings, or worlds may be affected by orbital debris? Perhaps debris may be held up as invaluable cultural artifacts of humanity’s complex interactions with orbital space or as scrapheaps that future spacefarers scavenge for parts (Gorman 2020). Curious alien species could be contaminated by biohazards that survive on orbital materials (Nicholson et al. 2009), or passing asteroids might carry debris into new space environments with different possibilities for collision and encounter. We might even imagine a future in which orbital debris are widely embraced as beings that not only affect other lively beings and processes (see Damjanov 2017) but are *themselves* lively agents with their own lifeworlds. Thinking through such speculative futures allows us to move away from narrow functionalist paradigms of orbital space that perpetuate colonial logics and terrestrial inequalities. If we are to hope for a future with heterogeneous, meaningful entanglements between humanity and orbital space, we must decenter hegemonic narratives about orbital debris and the geographical imaginations that underlie them.

In looking to more expansive considerations of orbital debris, it is imperative to recognize that alternative imaginations of the place of outer space and its relations are not new. In this article, we have largely engaged with limited Euro-Western literatures to investigate hegemonic

narratives. If we are looking for insight into how to conceive of human–space relationships and considerations of the more-than-human, how might we learn from non-hegemonic ways of knowing such as Indigenous ontologies, which have articulated their own long-standing frameworks for human–environment relations (Todd 2016)? To engage with the topic of outer space or orbital debris, and propose alternative imaginings of these environments, objects, and relations without acknowledging ways of knowing that already have expertise in engaging in relational ways of thinking would be a form of ontological colonization (Todd 2016). We think it is essential not only to theorize how dominant geographical knowledge production normalizes colonial thought, but also to encourage orbital scholars and stakeholders to practically make room for non-hegemonic knowledges (De Leeuw and Hunt 2018).

Dominant considerations of orbital debris are largely attentive to the interests of the global elite. Diverse geographical imaginations not encumbered by the human–nature divides of colonial capitalist thought can provide different understandings of orbital space and debris (Watts 2013). Critical scholarship has looked not only at ways in which environmental relations can be conceived outside of dominant ontologies, but has also framed human interactions in orbital space within narratives of colonial violence, sovereignty, environmental ethics, and questions of who the future of outer space is for (Bawaka Country et al. 2020; Cornum 2015; Oman-Reagan 2017). Domains of speculative science fiction literature⁴ such as Afrofuturism or Indigenous Futurism have considered the forms future human activity in outer space might take from non-hegemonic, anticolonial, or anticapitalist perspectives (Yaszek 2006). Considering speculative futures allows not only reflection on what lies ahead—what may happen, who will benefit or be harmed—but also the examination of present inequalities and decisions that will affect potential futures. We thus encourage a critical decentering (see Roy 2016) of discussions of orbital debris, so that the narration of speculative futures, of humankind's actions in orbital space, and of the differentiated impact of these actions, may be diversified. Making room for non-Euro-Western geographical imaginations of orbital space would allow for a more complete interrogation of how orbital debris interrelate with global systems of capitalist and colonial logics of consumption and extraction, and how orbital space matters beyond its operational capacity.

Through our exploration of literatures related to orbital space and debris, we have offered geographical imaginations as a concept that can help explain how framings of debris vary. We have observed that dominant core narratives may limit considerations of debris objects and engagements with them. We do not intend to disregard the impacts of collision, but rather emphasize how else debris might be considered. Recognizing the limitations of dominant narrations might allow counter-hegemonic possibilities in future considerations of orbital space and debris. The nature of speculative thinking is centered on unknowability, and thus there is no tidy way to tie up a consideration of what a future with orbital debris may bring. We have sought to encourage more capacious approaches that complicate debris by drawing attention to the different ways they may be viewed outside hegemonic risk and mitigation frameworks. How might acknowledging the vast entanglements of orbital debris and terrestrial life, alongside a multiplicity of imaginations of outer space, change how humankind engages with orbital space? This opens pathways toward potential futures where debris might be created and addressed differently: might this mean full and appropriate consultation practices in the establishment of orbital objects? Thorough environmental consideration? Embracing debris as lively actors? Radical restructuring of industry and power? Such possibilities might allow orbital debris to be more than hazards—that is, to be lively and complicated objects with risks, responsibilities, and opportunities universally shared.

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■ NOTES

1. We employ the plural to avoid coalescing debris as a singular abstracted “issue,” to draw attention to the specificities of singular objects and their production.
2. Terrestrial and extraterrestrial colonialism are not separate. For instance, see Iokepa Casumbal-Salazar's (2017) work on the Kanaka 'Ōiwi (Native Hawaiian) struggle against the proposed Thirty Meter Telescope construction on Mauna a Wākea (Mauna Kea) and Peter Redfield's (2000) study of the French government's placement of a space center in the former penal colony of French Guiana.
3. See also Maryboy and Begay (2010) on Indigenous knowledge and astronomy.
4. For example: *How Long Til' Black Future Month?* By N. K. Jemisin (2018) or *Binti* by Nnedi Okorafor (2015).

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