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Protecting the Planet or Destroying the Universe? Understanding Reactions to Space Mining

Matthew J. Hornsey [1,*], Kelly S. Fielding [2], Emily A. Harris [3], Paul G. Bain [4], Tim Grice [5] and Cassandra M. Chapman [1]

1 Business School, University of Queensland, Brisbane 4072, Australia; c.chapman@business.uq.edu.au
2 School of Communication and Arts, University of Queensland, Brisbane 4072, Australia; k.fielding@uq.edu.au
3 Melbourne School of Psychological Sciences, University of Melbourne, Melbourne 3010, Australia; harrise1@unimelb.edu.au
4 School of Psychology, University of Bath, Bath BA2 7AY, UK; pb697@bath.ac.uk
5 Square Circle, Brisbane 4000, Australia; tim@squarecircle.org
* Correspondence: m.hornsey@business.uq.edu.au

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Abstract: There is currently a surge in interest from both private and government sectors in developing technology for mining asteroids and the moon ("space mining"). One of the key benefits highlighted by advocates of space mining is that it minimizes the usual problems associated with mining on earth in terms of pollution, environmental degradation, and encroachment on human habitats. Two studies—one conducted on a 27-nation sample (N = 4819), the other conducted in the U.S. (N = 607)—provide the first test of the assumed (but never studied) notion that space mining is more palatable to the public than terrestrial mining. Both studies indicate broad support for asteroid mining: levels of support were reliably above the mid-point, and much greater than for other forms of frontier mining such as mining the ocean floor, mining Antarctica, mining the Alaskan tundra, and lunar mining. Unlike terrestrial mining, community attitudes toward mining asteroids were largely non-ideological; support was not correlated with perceptions of ecological fragility, political ideology, or individualistic/hierarchical worldviews. In summary, the current studies suggest that mining companies have a "social license to operate" for mining asteroids, but less so for lunar mining.

Keywords: space mining; asteroid mining; social license to operate; moral foundations; political ideology

1. Introduction

Valuable resources that are rare on Earth can be found in enormous quantities in space [1]. For over a century it has been speculated that humans would one day mine asteroids or the moon, but the science has lagged so far behind the aspiration that this has been traditionally considered the realm of science fiction. That has changed rapidly in the last decade. Technological advances have progressed to the point where there is serious consideration of the possibility that benefits of space mining—in terms of selling resources back on earth and/or using the resources to fuel launching pads for space exploration—may soon outweigh the costs. One of the leading benefits of space mining is the potential environmental payoff: unlike traditional mining, space mining is conducted far away from human habitats and delicate ecosystems, and therefore represents an advantage for those who are concerned about the environmental and heritage implications of resource extraction.

At the time of writing, both private companies and government-funded space agencies are exploring the possibility of extracting minerals from space. The Chinese Aerospace Science and Technology Corporation and the (now defunct) private company Planetary Resources both launched successful missions to test key technologies that might be used in space mining, while another company (Origin Space) will proceed with its space mining ambitions soon [2,3] Meanwhile, both the NASA Institute for Advanced Concepts and the

European Space Agency (ESA) funded projects to explore mining options on the moon [4,5]. In 2020, former U.S. President Donald Trump signed an executive order to stimulate private investment in space mining from U.S. companies [6], while the government of Luxembourg invested 200 million EUR in research and development associated with space mining technology and is setting up a European space mining center [7].

While there is growing interest in space mining within government and industry, academic attention is nascent. Engineers and economists have debated its feasibility [8–11] and anthropologists have discussed its heritage implications [12]. Others have discussed the political and ethical implications associated with space mining [13,14] and the challenges associated with its sustainable development [15–18].

Perhaps the greatest amount of attention, however, has come from scholars in law and international relations, who have monitored the evolution of policies and laws that make space mining possible [19–23]. In recent years, there has been growing concern regarding the pace and scope of progress in developing a legal framework sufficient to give financiers confidence to invest in space mining [24,25]. There are currently several initiatives designed to develop an international legal framework—conducted, for example, by the U.N. Committee on the Peaceful Uses of Outer Space and The Hague International Space Resources Governance Working Group—but progress is slow, resulting in significant uncertainty concerning the legal conditions under which resources in space can be mined. In the face of this uncertainty, some have made the case that private companies are turning towards alternative ways of demonstrating legitimacy and satisfying the vague conditions proposed by existing treaties such as the Outer Space Treaty [18,25,26].

One such alternative form of legitimacy is the notion of a social license to operate [25]. A social license to operate is typically interpreted as reflecting the acceptance of a company's (or industry's) practices by the broader public. The phrase emerged in the 1990s when it became clear that social and ideological opposition to mining was on the rise, and that meeting government and legal regulations alone was not always sufficient to gain legitimacy. From the perspective of the mining sector, social license to operate has emerged as a risk-management strategy, designed to reduce the potential for conflict with local communities [27].

Given this debate, it is striking that there has not yet been an empirical examination of how community members think and feel about mining in space. The primary goal of the current paper is to fill this gap: to understand community attitudes toward space mining and their psychological underpinnings. Before describing two studies examining this question, we first describe the relevant literature on how attitudes toward mining can be shaped by values, ideologies, and worldviews.

1.1. Attitudes toward Terrestrial Mining

The lack of empirical attention to what people think regarding space mining is surprising, because mining has traditionally been a highly contested and emotional enterprise, one that triggers strong moral and environmental objections [28]. Qualitative research on people's attitudes toward traditional on-earth mining has revealed a cluster of concerns: air pollution, encroachment onto residential areas, land degradation, health consequences, and noise pollution [29–32]. One of the key predictors of people's sensitivity to these potential downsides is trust: the extent to which people believe legislators, regulators, and mining companies themselves have the broader interests of the community at heart [27,33].

Over and above trust, there are a number of other psychological variables implicated in people's attitudes toward mining. Particularly relevant to this paper, there is evidence that people's attitudes toward mining sometimes assume a deontological moral quality, informed more by values and worldviews than by value-free appraisals of costs and benefits [28]; see [34–36] for related discussions of the impact of morality on climate change beliefs. Three of these worldviews are examined in this paper: the new ecological paradigm (NEP), political conservatism, and moral foundations.

The NEP is a scale that focuses in part on beliefs regarding the fragility of the environment and the importance of minimizing human impacts on the environment [37]. This construct is a powerful predictor of climate change skepticism [38] and of perceptions of environmental risk more generally [39,40]. Although the NEP has not been used as a predictor of attitudes toward mining (to our knowledge), it is a short theoretical leap to presume that endorsement of the NEP would be associated with more negative attitudes toward terrestrial mining.

Political conservatism is an outlook that encompasses a range of social and economic issues, including attitudes toward the free market. Elements of political conservatism have a central place in Kahan's theory of cultural cognition, which argues that people's attitudes toward science and innovation are shaped by culturally defined beliefs regarding power relations and the rights of individuals relative to the collective [41]. For example, if people have a strong belief in the free market and an intuitive moral suspicion of big government (as many conservatives do), then attempts to protect the environment through government regulation of business will be ideologically aversive. Similarly, if people have an intuitive moral suspicion of big business and free enterprise (as many liberals do), then emerging technologies stemming from private industry may be viewed through a lens of mistrust and concern. These basic ideological intuitions provide the motivation for people to reject certain scientific messages [42,43]. Consistent with this, various indices of political conservatism have been shown to be powerful predictors of attitudes toward climate science [38,44] and perceptions of the risks and benefits of other emerging technologies [45]. In the current study we measure political ideology both in abstract (i.e., as a measure of how "liberal" or "conservative" people are) as well as in terms of the specific dimensions of individualism and hierarchialism defined by Kahan and colleagues. Again, specific tests examining the relationship between political conservatism and support for mining are rare, but liberal attitudes have long been associated with pro-environmental activism [46] and energy-efficient attitudes [47]. On this basis, it seems reasonable to assume that liberals will be more anti-mining than conservatives.

Finally, moral foundations theory [48,49] describes the bases upon which people make moral judgments. The original theory described five foundations of morality. Two of these—*care* (in which moral judgments are based on concerns regarding care and protection of others) and *fairness* (in which moral judgments are grounded largely in perceptions of fairness and justice)—are together referred to as "individualizing" foundations. The other three are referred to as "binding" foundations: *loyalty* (based on concerns regarding group membership and loyalty to ingroups); *authority* (based on obedience and duty); and *purity* (based on the desire to preserve purity and sacredness). Notably, endorsement of these foundations is shaped by political ideology: liberals tend to prioritize individualizing foundations over binding foundations, and conservatives tend to prioritize binding foundations more than liberals do [50,51]. Furthermore, there is evidence that people with pro-environmental attitudes focus on individualizing foundations: for example, the bulk of newspaper op-eds and public service announcements designed to promote proenvironmental attitudes focus on individualizing dimensions [52]. Relatedly, the individualizing dimensions are positively associated with climate-friendly choices, whereas the binding dimensions are negatively related to climate-friendly choices [53]. However, Hang and colleagues [54] found that people respond more to corporate social responsibility efforts that are guided by binding, rather than individualizing, foundations. Furthermore, Wolsko and colleagues demonstrated that climate change appeals that canvas both the individualizing and the binding dimensions are particularly successful at encouraging mitigation efforts among people across the ideological divide [55,56].

1.2. Space Mining: An Exception to the Psychological Rule?

The research reviewed above suggests that certain ideological mindsets may predispose people to morally object to traditional (terrestrial) mining. However, it is an open question whether these same psychological orientations would also predispose people to object to *space* mining. Indeed, one of the key points made by advocates of space mining is that it is a paradigm-shifting approach to resource extraction, one that minimizes the usual problems associated with mining on earth in terms of pollution, environmental degradation, encroachment on human habitats, and so forth. This argument was encapsulated by Craig and colleagues [8], who wrote that harvesting off-earth resources has an "incalculable sustainable benefit in that they can be retrieved with absolutely no damage to earth" (p. 1039). The implications of this are somewhat utopian: a future in which humans are able to harvest a wealth of resources in a way that has no environmental cost. Furthermore, it promises a future where mining companies are not subject to the same ideological and moral concerns that people have regarding traditional mining, and therefore are unshackled from the threat of backlash.

In contrast to this notion, several scholars have pointed to the fact that space can also be considered a pristine environment, with all the ethical and environmental considerations that this implies [17,18]. It is also contestable that harvesting space resources will have no impact on earth, given that the resources will eventually be used and turn into refuse that must be disposed of. Given this complexity, it is especially important to subject to empirical scrutiny the notion that space mining companies might be exempt from the moral and ideological objections to terrestrial mining.

1.3. The Present Studies

The goal of this paper is to provide the first systematic test of people's attitudes and feelings regarding space mining. Two broad research questions are tested.

RQ1: Will people be more or less negative toward space mining than toward other examples of frontier terrestrial mining?

RQ2: Will attitudes toward space mining be correlated with the same psychological and ideological orientations that are theoretically associated with terrestrial mining?

The primary test of RQ1 is Study 1, which sampled 27 nations and compared participants' attitudes toward two types of space mining (the moon and asteroids) and two types of terrestrial mining (ocean floor and Antarctica). RQ2 is tested in Study 2, a dataset drawn from a sample of 607 Americans. Given that space mining has no direct adverse impact on humans or their immediate environments, a case can be made that people will be more positive toward space mining than toward on-earth mining (RQ1), and that attitudes toward the former will be less aligned with psychological and ideological worldviews than attitudes toward the latter (RQ2). The theoretical caveats described earlier suggest that this assumption would benefit from being subjected to empirical rigor.

2. Study 1

Drawing on participants from 27 nations, Study 1 provides the first test of whether people will be more or less negative toward space mining than to other examples of frontier mining on earth. The decision to sample from multiple nations reflected a desire to generalize our conclusions beyond the Western, educated, industrialized, rich, and democratic samples that traditionally dominate the literature [57]. Our goal was not to conduct a formal cross-cultural analysis, and we make no predictions regarding whether results will be influenced by culture. However, for the sake of thoroughness, we included nation as an independent variable in our analyses.

2.1. Material and Methods

Participants and design. We sampled 6239 participants from 27 nations across 5 continents, of which 222 dropped out before completing the first mining question. Participants were community members recruited through online access panels provided by the data collection company Survey Sampling International. We included three attention checks, and 19.9% of the sample failed at least one. To ensure the integrity of the data, we analyzed only those participants who passed all the attention checks (N = 4819), but the conclusions were the same regardless of whether or not the inattentive participants were included. The sampling strategy did not include quotas, and therefore samples were not curated to be representative of the population. Having said that, the sample was relatively balanced in terms of gender (49.5% female) and age (M = 41.85 years). Scores on education were somewhat low (M = 3.35) but scores on income (M = 3.00) were exactly at the mid-point.

Participants rated their levels of support for four types of mining: of asteroids, the moon, the ocean floor, and Antarctica. The reason we chose mining the ocean floor and Antarctica as two of our conditions was to create, as far as possible, like-for-like comparisons between space and terrestrial mining. Similar to space mining, these forms of terrestrial mining are examples of frontier resource extraction with which participants would be unlikely to have had direct experience. As such, Study 1 represents a conservative test of the notion that space mining might be perceived differently than terrestrial mining, given that our examples of terrestrial mining incorporate many of the assumed advantages of mining in space.

Measures. Questionnaires were translated into the native language of non-English speaking samples using translation/back-translation procedures.

Attitudes toward mining. Participants first read the following text:

> *Mining companies have recently begun examining the long-term feasibility of extracting minerals from areas previously considered impossible to access: Antarctica, the ocean bed, asteroids, and the moon. It has recently been discovered that certain rare and valuable minerals exist there. Previously it was not economically viable to access such remote and harsh environments. But exponential improvements in technology have raised the prospect that the financial rewards will one day outstrip the costs. Although the technology is not ready yet, most observers believe it will be possible to mine there in the future. In the next few questions we ask how you feel about the idea of mining Antarctica, the ocean bed, asteroids, and the moon.*

Participants then evaluated the four types of mining (the order of presentation of these four conditions was counter-balanced so as to eliminate order effects). Before each set of measures, participants were given a general introduction that there were "valuable minerals" to be found through that type of mining ("in Antarctica", "below the ocean's surface", "in asteroids close to earth", and "deep under the surface of the moon" depending on condition). They then read the following (with variations across conditions represented in square brackets):

> *Imagine a future in which the technology has advanced to the point that the economic gains of mining [Antarctica/the ocean floor/asteroids/the moon] are greater than the economic costs. Now rate below your thoughts and feelings about mining in [that part of the world/that part of space].*

Outcome measures. We first measured the extent to which each type of mining elicited positive and negative emotions. Participants were given the prompt "The thought of mining [Antarctica/the ocean floor/asteroids/the moon] makes me feel: "worried", "sad", "excited", "annoyed", "relaxed" and "hopeful" (1 = not at all, 6 = very much). The positive and negative items were highly correlated with each other. Consequently, we reversed the positively valenced items and combined scores into single, 6-item scales of negative affect (αs for each type of mining, calculated separately for each nation, ranged from 0.75 to 0.93).

Three items measured support (or otherwise) for the mining proposal: "This type of mining should be encouraged"; "I would support a ban on this type of mining" and "This type of mining should not be allowed" (1 = strongly disagree; 7 = strongly agree). Four additional items focused more explicitly on participants' sense that the mining company has a moral license to operate in the area: "The mining company has no right to mine minerals in this location"; "It is not fair for the mining company to extract minerals from this location"; "The mining company is entitled to mine minerals in this location", and "It is not ethically appropriate to mine minerals in this location" (1 = strongly disagree; 7 = strongly agree). Responses on the two sets of measures correlated very highly (r = 0.86).

Consequently, the negatively worded items were reversed and the items combined into a single scale of *approval* (αs for each type of mining, calculated separately for each nation, ranged from 0.87 to 0.96).

Four demographic variables were included as control variables: *age*, *sex* (0 = male, 1 = female), *income* (1 = much lower than the average national income, 5 = much higher than the average national income), and *education* (1 = less than high school; 8 = postgraduate degree). Also included were measures of participants' ideal states (e.g., ideal levels of health, IQ, wealth, longevity) and measures of desire for control. Because these measures were not relevant to the research question, they are not reported here. Further information can be obtained on request.

2.2. Results

We analyzed the data using a 27 (participant nationality) × 4 (type of mining: Antarctica, ocean, asteroid, moon) mixed ANOVA with type of mining analyzed within-subjects. We conducted analyses both before and after controlling for age, sex, education, and income. The conclusions were identical regardless of whether the demographics were controlled for or not; thus, for the sake of transparency, we report below the analyses without the covariates included. For the sake of readers who are not familiar with statistical reporting, we clarify the following abbreviations: M = mean; SD = standard devation; p = probability that the effect could have occurred by chance; α = Cronbach's alpha, a test of internal reliability of a scale; r = correlation; η^2 is an index of variance explained (effect size).

The main effects of mining type emerged for both negative affect, $F(3,4728) = 600.31$, $p < 0.001$, $\eta^2 = 0.28$, and approval, $F(3,4739) = 594.958$, $p < 0.001$, $\eta^2 = 0.27$ (see Figure 1). Levels of negative affect regarding asteroid mining ($M = 3.16$, $SD = 1.28$) were lower than regarding lunar mining ($M = 3.46$, $SD = 1.37$). Lunar mining, in turn, aroused less negative affect than ocean floor mining ($M = 3.92$, $SD = 1.37$) and mining Antarctica ($M = 4.05$, $SD = 1.39$). For approval ratings, a similar pattern emerged: asteroid mining elicited the most approval ($M = 4.36$, $SD = 1.62$), followed by lunar mining ($M = 3.88$, $SD = 1.70$), ocean floor mining ($M = 3.44$, $SD = 1.66$) and mining Antarctica ($M = 3.22$, $SD = 1.71$). All means were significantly different from each other (ps < 0.05).

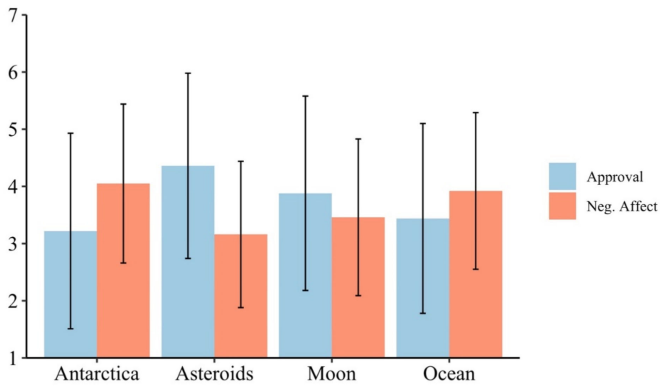

Figure 1. Mean approval and negative affect ratings for mining Antarctica, asteroids, the moon, and the ocean. Error bars represent standard deviations. Approval was measured using a 1–7 scale; negative affect was measured using a 1–6 scale.

The between-groups factor of participant nation featured a significant main effect for both negative affect, $F(26,4730) = 15.95$, $p < 0.001$, $\eta^2 = 0.08$, and approval, $F(26,4741) = 11.94$, $p < 0.001$, $\eta^2 = 0.06$. Of more relevance to the current question, these main effects were qualified by significant interactions between participant nation and type of mining (negative affect, $F(78,14190) = 5.74$, $p < 0.001$, $\eta^2 = 0.03$; approval, $F(78,14223) = 6.98$, $p < 0.001$, $\eta^2 = 0.04$). This suggests that the relative preference for the different types of mining varied across nations. As can be seen in Table 1, however, the main effect of mining type described above was quite consistent across the nations: the tendency for asteroid and lunar mining to elicit significantly more approval than the two forms of on-earth mining emerged in 21 of 27 nations, including all nations in the industrialized West. In addition, the size of the interaction effect was one-ninth the size of the main effect of mining type.

Table 1. Summary of data across nations.

		Negative Affect				Approval			
	n	**Moon**	**Asteroids**	**Ocean**	**Antarctica**	**Moon**	**Asteroids**	**Ocean**	**Antarctica**
Argentina	179	3.80_{b}	3.37_{a}	4.61_{c}	4.89_{d}	3.70_{c}	4.27_{d}	2.86_{b}	2.40_{a}
Australia	214	3.89_{b}	3.36_{a}	4.27_{b}	4.41_{c}	3.39_{c}	4.20_{d}	3.04_{b}	2.75_{a}
Brazil	180	3.27_{b}	3.17_{a}	3.70_{c}	3.93_{c}	4.30_{c}	4.63_{d}	3.95_{b}	3.62_{a}
Canada	183	3.52_{b}	3.18_{a}	4.08_{d}	3.91_{c}	3.88_{c}	4.46_{d}	3.36_{a}	3.55_{b}
Chile	188	3.41_{b}	3.10_{a}	4.16_{c}	4.53_{d}	3.85_{c}	4.48_{d}	3.19_{b}	2.73_{a}
China	158	3.00_{ab}	2.87_{a}	3.14_{b}	3.40_{d}	4.18_{b}	4.52_{c}	4.09_{b}	3.63_{a}
France	177	3.81_{b}	3.61_{a}	4.44_{c}	4.55_{c}	3.49_{c}	3.84_{d}	2.92_{a}	2.66_{b}
Germany	179	3.71_{b}	3.43_{a}	4.50_{c}	4.56_{c}	3.70_{c}	4.20_{d}	2.70_{b}	2.50_{a}
Hong Kong	155	3.53_{a}	3.54_{a}	4.31_{b}	4.38_{b}	3.64_{c}	3.86_{d}	3.03_{b}	2.85_{a}
India	136	3.07_{ac}	2.92_{a}	3.22_{bc}	3.32_{bd}	4.19_{b}	4.27_{b}	3.89_{a}	3.74_{a}
Indonesia	145	3.90_{b}	3.25_{a}	3.94_{b}	4.15_{c}	3.42_{b}	4.03_{c}	3.52_{b}	3.09_{a}
Ireland	161	3.48_{b}	3.15_{a}	4.09_{c}	4.28_{d}	3.72_{b}	4.42_{c}	3.22_{a}	3.04_{a}
Japan	176	3.06_{b}	2.99_{ab}	2.91_{a}	3.30_{c}	4.06_{b}	4.18_{c}	4.40_{d}	3.86_{a}
Mexico	184	3.34_{b}	2.96_{a}	3.85_{c}	3.97_{c}	3.95_{b}	4.46_{c}	3.38_{a}	3.19_{a}
New Zealand	184	3.77_{b}	3.21_{a}	4.34_{c}	4.56_{d}	3.54_{c}	4.35_{d}	3.06_{b}	2.70_{a}
Peru	207	3.02_{b}	2.48_{a}	3.84_{c}	3.94_{c}	4.34_{b}	4.97_{c}	3.37_{a}	3.22_{a}
Philippines	200	3.71_{b}	3.43_{a}	4.15_{d}	4.00_{c}	3.52_{b}	3.92_{c}	3.17_{a}	3.38_{b}
Poland	158	3.01_{a}	3.03_{a}	3.43_{b}	3.73_{c}	4.30_{c}	4.45_{c}	4.01_{b}	3.57_{a}
Portugal	188	3.14_{b}	2.96_{a}	3.72_{c}	3.86_{d}	4.28_{c}	4.67_{d}	3.68_{b}	3.47_{a}
Russia	193	3.02_{b}	2.81_{a}	3.49_{d}	3.36_{c}	4.72_{b}	5.06_{c}	4.11_{a}	4.30_{a}
Singapore	166	3.68_{b}	3.34_{a}	3.93_{c}	4.03_{c}	3.72_{c}	4.12_{d}	3.33_{b}	3.14_{a}
South Africa	186	3.91_{b}	3.28_{a}	4.06_{b}	4.08_{b}	3.23_{a}	4.11_{b}	3.18_{a}	3.21_{a}
South Korea	171	3.19_{b}	3.00_{a}	3.34_{b}	3.71_{c}	3.97_{b}	4.38_{c}	4.06_{b}	3.47_{a}
Spain	179	3.53_{b}	3.27_{a}	3.97_{c}	4.15_{d}	3.87_{b}	4.27_{c}	3.32_{a}	3.15_{a}
Sweden	176	3.58_{b}	3.31_{a}	4.13_{c}	4.37_{d}	3.84_{c}	4.28_{d}	3.11_{b}	2.78_{a}
UK	195	3.45_{b}	3.12_{a}	3.94_{c}	4.05_{c}	3.86_{c}	4.44_{d}	3.49_{b}	3.30_{a}
USA	201	3.53_{b}	3.22_{a}	3.89_{c}	3.79_{c}	3.97_{b}	4.58_{c}	3.64_{a}	3.74_{a}

Note: Within each measure, means that do not share a subscript are significantly different from each other ($p < 0.05$).

2.3. Discussion

Study 1 is the first test of the assumed (but never studied) hypothesis that space mining would be more palatable to community members than on-earth mining. As discussed earlier, we conducted a relatively conservative test of the hypothesis, choosing examples of terrestrial mining that shared many of the benefits of space mining, such as being geographically removed from human settlements. Even so, the pattern of responses was clear: participants were most positive regarding asteroid mining, second-most positive regarding lunar mining, and least positive regarding the two examples of terrestrial mining. This pattern was highly significant and reasonably consistent across the 27 nations. Inspection of means on *approval* relative to the mid-point shows that participants were modestly positive about asteroid mining, relatively neutral about lunar mining (in terms of the means approximating the mid-point of the scales), and clearly negative about mining the ocean floor and Antarctica.

A strength of Study 1 is that it is broad, canvassing 27 nations. However, this breadth was obtained at the expense of depth: we had no measures of the psychological and ideological correlates that could help account for why people were more positive toward space than terrestrial mining. Study 2 was designed to fill this gap by intensively examining a community sample of Americans.

3. Study 2

In Study 2 we sought to replicate the main finding of Study 1 by examining Americans' attitudes toward mining the moon, mining asteroids, and mining tundra on earth. Participants also rated their endorsement of a number of ideological constructs: the NEP, political ideology, hierachialism, individualism, and the five moral foundations as described by Haidt and Joseph [49]. In line with previous literature on proenvironmental attitudes, we predicted that approval toward the example of terrestrial mining would be associated with low scores on the NEP and scores at the conservative ends of the measures of political ideology, hierachialism, and individualism; scores at the low end of the "individualizing foundations" of Harm and Fairness; and scores at the high end of the "binding foundations" of Loyalty, Authority, and Purity.

The key question is whether these same ideological correlates would emerge with regard to attitudes toward lunar and asteroid mining. As discussed earlier, because space mining avoids some of the ecological and sustainability problems that are traditionally associated with terrestrial mining, it seems reasonable to predict that attitudes to the former may not be associated with the same cluster of ideological and political objections associated with the latter. Again, however, this prediction has never been empirically tested, and therefore predictions are necessarily tentative.

Study 2 was also designed to examine the role of trust in influencing attitudes toward space mining. We tested this in two ways. First, we measured people's pre-existing levels of trust in the integrity of mining companies, and used this as a predictor of attitudes toward the different types of mining.

Second, we manipulated whether the mining company was a member of participants' in-group (an American company) or a member of a rival out-group (a Russian company). Work towards space mining is typically not driven by national governments per se, but rather by private companies and investors. However, many private companies are associated in people's minds with particular nations, and it is evident that nations have vested interests in positioning themselves at the forefront of mining claims made in space. Furthermore, in the absence of strong international regulations, much of the work associated with policy-making and regulation with regard to space mining has (in the past) devolved into unilateral approaches taken by individual nations. This led to concerns that the cosmopolitan principles of international space law might be undermined by national interests as they compete for territory [58].

One of the most robust findings emerging from the literature on intergroup relations is that people are more likely to instinctively mistrust the motives of out-group members than in-group members [59–62]. To the extent that a particular form of mining is highly trust-sensitive, one might expect that approval would be greater when the mining was conducted by an in-group as opposed to an out-group mining company. To make the manipulation of the mining company's nationality salient, we also changed the type of mining we used as comparison conditions. Rather than evaluating proposals to mine the ocean floor or Antarctica (which are geographically neutral), participants evaluated a plan to mine the tundra of Alaska (in the American mining company condition) or Siberia (in the Russian mining company condition).

3.1. Material and Methods

Participants and design. We sampled 607 American participants using the online data collection service Mechanical Turk. Of the original sample, 48 failed an attention check. These participants were excluded from analysis, leaving 559 usable participants (53.9% male; M_{age} = 33.42 years). Participants were randomly allocated to cells of a 2 (nationality of mining company: USA, Russia) × 3 (type of mining: tundra, asteroid, moon) between-groups design.

3.2. Measures

Predictor variables. Before presenting the manipulations, we measured several indices of ideology/worldview (the order of the presentation of measures was randomized).

The *new ecological paradigm* [37] is a 15-item scale that measures a "pro-ecological" worldview. It includes items such as "The balance of nature is very delicate and easily upset" and "Humans are severely abusing the environment" (α = 0.88).

Political ideology was measured by asking participants to indicate on a 7-point scale their "political leaning" (1 = liberal, 7 = conservative).

Individualism/hierarchy worldviews were measured using the long version of the Cultural Cognition Worldview Scale [45]. The individualism/communitarianism dimension was measured via 17 items including "The government interferes far too much in our everyday lives" and "It's society's responsibility to make sure everyone's basic needs are met" (reversed). The hierarchy/egalitarianism dimension was measured using 13 items including "We have gone too far in pushing equal rights in this country" and "Our society would be better off if the distribution of wealth was more equal" (reversed). All responses were indicated on a 6-point scale (1 = strongly disagree; 6 = strongly agree) and each scale displayed adequate internal consistency (αs = 0.90 for both scales). However, the scales were highly correlated ($r = 0.65$, $p < 0.001$). Thus, to prevent these variables competing with each other for unique variance in the regression model, we combined the two scales into a single measure of individualism/hierarchy (higher scores) and communitarianism/egalitarianism (lower scores).

Moral foundations were measured using the MFQ30 [48]. This scale is split into two sections. In the first section, participants are asked "When you decide whether something is right or wrong, to what extent are the following considerations relevant to your thinking?" (1 = not very relevant; 5 = extremely relevant). Participants are provided with 15 considerations, which are theorized to tap into five underlying dimensions: *care* (e.g., "whether or not someone suffered emotionally"), *fairness* (e.g., "whether or not some people were treated differently than others"), *loyalty* (e.g., "whether or not someone did something to betray his or her group"), *authority* (e.g., "whether or not someone showed a lack of respect for authority"), and *purity* (e.g., "whether or not someone violated standards of purity and decency"). In the second section, participants are asked "Please read the following statements and rate the extent to which you personally agree or disagree with each one" (1 = strongly disagree, 6 = strongly agree). Again, the 15 subsequent items are theorized to tap into dimensions of *care* (e.g., "compassion for those who are suffering is the most crucial virtue"), *fairness* (e.g., "when the government makes laws, the number one principle should be ensuring that everyone is treated fairly"), *loyalty* (e.g., "people should be loyal to their family members, even when they have done something wrong"), *authority* (e.g., "respect for authority is something all children need to learn"), and *purity* (e.g., "people should not do things that are disgusting, even if no one is harmed"). The items were combined into reliable scales (*care*: α = 0.69; *fairness*: α = 0.68; *loyalty*: α = 0.75; *authority*: α = 0.74; *purity*: α = 0.86). Due to a clerical error, the first set of moral foundations items were measured on a 5-point scale whereas the second set of items were measured on a 6-point scale. Consequently, the scales were created using standardized scores.

Finally, three items measured participants' levels of *trust* in the integrity of mining companies generally. Participants were asked the extent to which they trusted resource extraction companies to: "act in the best interest of society", "act responsibly", and "do what is right" (1 = strongly distrust; 7 = strongly trust). Responses to these items were combined into a measure of *trust in mining companies* (α = 0.97).

Manipulations. Participants were asked to evaluate a proposal to mine (1) the moon, (2) asteroids, or (3) tundra. Furthermore, they were led to believe that the mining company was either an American or a Russian company. For example, in the moon mining condition, participants read:

> *A large [US/Russian] mining company has recently begun examining the long-term feasibility of extracting minerals from an area previously considered impossible to access:*

the moon. It has recently been discovered that certain rare and valuable minerals exist deep under the surface of the moon. These include minerals such as the magnesium-rich olivine, and ilmenite, a rare mineral that is high in titanium. Previously it was not economically viable to access such a remote and harsh environment. But sudden changes in technology have raised the prospect that the financial rewards will outstrip the costs. One advantage of mining the moon is that no humans live there, meaning that the mining is not subject to the same community Impact concerns that regular mining has. There is also no sensitive flora or fauna living in the mining zone, meaning that traditional environmental concerns do not apply. A spokesperson for the company—[John Saunders/Nikolai Ivanov]—says "The technology is not there yet. But there will definitely be mining there in the future".

In the asteroid condition, the text was identical to the above, except that it was explained that the valuable minerals "exist deep under the surface of asteroids caught in earth's orbit". In the tundra condition, the site area was described as "the remote, frozen tundra of North East [Alaska/Siberia]".

Outcome measures. We then measured approval using the same items used in Study 1, with two exceptions. First, we added a new item into the approval scale in order to provide a better balance between negatively and positively worded items ("People and governments should stay out of the way of mining companies' efforts to explore this new frontier"). Second, references to the plural ("Mining companies are entitled . . . ") in Study 1 were adjusted to the singular (e.g., "The mining company is entitled . . . "). The scale was highly consistent ($\alpha = 0.94$).

In addition to approval, we also measured participants' emotional responses to the proposal. Four of the items—worried, sad, annoyed, and hopeful—were the same as those used in Study 1. The two new items were encouraged and optimistic. After the three positive items were reversed, the six items formed a highly reliable scale of negative emotion ($\alpha = 0.88$). However, as in Study 1, these items closely correlated with approval ($r = -0.84$). Unsurprisingly, all effects found on approval were mirrored by corresponding effects on negative emotion. To avoid duplication, we focused only on the effects on approval, but full results can be obtained on request.

3.3. Results

Effects of manipulation on approval. First, we conducted a 2 (nationality of mining company: USA, Russia) x 3 (type of mining: tundra, asteroid, moon) between-groups ANOVA on approval ratings. A main effect of mining type emerged, $F(2,534) = 29.95$, $p < 0.001$, $\eta^2 = 0.10$, which is summarized in Figure 2. Approval for the asteroid proposal ($M = 5.19$, $SD = 1.36$) was well above that for the tundra mining proposal ($M = 4.43$, $SD = 1.53$), which in turn was above that for the lunar mining proposal ($M = 3.95$, $SD = 1.68$). Scores across these conditions were significantly different from each other according to Newman–Keuls post-hoc tests.

Nationality of the mining company had no influence on approval, $F(1,534) = 2.93$, $p = 0.087$, $\eta^2 = 0.005$. There was also no significant interaction, $F(2,534) = 1.02$, $p = 0.360$, $\eta^2 = 0.004$, indicating that the relative preferences for the different mining proposals did not significantly differ depending on whether the mining company was American or Russian. It should be noted that, after reading the experimental stimuli, participants were asked "What was the nationality of the mining company you read about?" and selected from the options "American", "Russian", or "other". Forty-three participants gave an incorrect response on this manipulation check. After deleting these participants from analysis, the main effect of nationality became significant, $F(1,493) = 4.43$, $p = 0.036$, $\eta^2 = 0.009$: approval was greater when the mining company was American ($M = 4.65$, $SD = 1.54$) than when it was Russian ($M = 4.40$, $SD = 1.67$). However, the interaction remained non-significant, $F(1.493) = 1.17$, $p = 0.312$, $\eta^2 = 0.005$. On this basis, we can conclude that the nationality of the mining company had no reliable effect on the relative preference for mining asteroids, the moon, or the tundra.

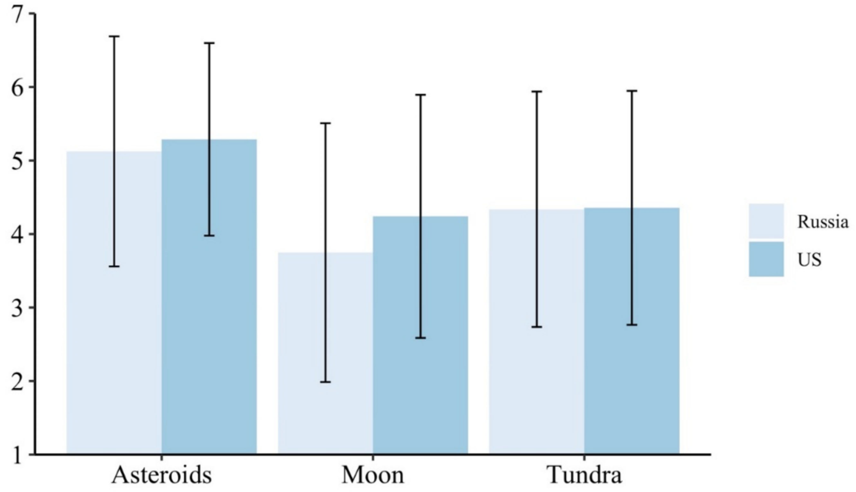

Figure 2. Mean approval ratings (1–7 scale) for mining asteroids, the moon, and the tundra in Russia and the US. Error bars represent standard deviations.

Relationship between approval and the measures of trust and ideology. We then conducted moderated multiple regression analyses to examine whether our ideological measures predicted approval, and whether the strength of these relationships differed depending on the type of mining proposal. In order for our three-level mining type variable to be included in the regression, we created two orthogonal contrast codes: one contrast comparing tundra mining to the two types of space mining (tundra = −2, moon = 1, asteroid = 1), and the other contrast comparing asteroid mining to lunar mining (tundra = 0, moon = 1, asteroid = −1).

In Step 1 of our regression we included three control variables: sex, age, and the nationality manipulation. In Step 2 we included the relevant predictor variable (centered around the mean) as well as the two orthogonal contrasts. In Step 3 we entered the product terms representing the interaction between the relevant predictor variable and each contrast. We did this nine times, each regression examining one of our nine predictors: NEP, political ideology, individualism/hierarchy worldviews, generalized trust in mining companies, and the five moral foundations.

At Step 1, there was a tendency for men to be more approving than women ($\beta = -0.11$, $p = 0.013$) but there was no effect of age ($\beta = 0.00$, $p = 0.938$). Note that, because the main effects of mining company nationality simply mirror the ANOVA reported above, they will not be reported further (this is also true of the main effects of contrast in Step 2).

At Step 2, approval was greater for people who were lower in NEP ($\beta = -0.25$, $p < 0.001$), had more individualistic/hierarchical worldviews ($\beta = 0.17$, $p < 0.001$), were more trusting of mining companies ($\beta = 0.39$, $p < 0.001$), and who had stronger moral foundations of loyalty ($\beta = 0.12$, $p = 0.005$) and authority ($\beta = 0.11$, $p = 0.005$). No significant main effects emerged as a function of political ideology, or the moral foundations of care, fairness, and purity (all *p*s > 0.10).

At Step 3, a significant interaction indicated that the relationship between the ideological predictor and approval differed in strength as a function of the type of mining proposed. Evidence for significant interactions emerged for 8 of the 9 predictors (the exception was the moral foundation of care). To break down these interactions, we summarized the pattern of correlations between approval and the predictors separately for each level of mining type (see Table 2).

Table 2. Relationship between ideological variables and mining approval as a function of mining type.

	Tundra	Moon	Asteroids
NEP	-0.39_{b}***	-0.32_{b}***	-0.11_{a}
Political ideology	0.23_{b}**	0.08_{ab}	-0.07_{a}
Individualism/ hierarchy	0.36_{b}***	0.18_{ab}*	0.00_{a}
Trust	0.53_{b}***	0.41_{ab}***	0.28_{a}***
Care	-0.07_{a}	-0.13_{a}	0.06_{a}
Fairness	-0.15_{b}*	-0.12_{b}	0.09_{a}
Loyalty	0.31_{b}***	0.11_{ab}	-0.09_{a}
Authority	0.29_{b}***	0.08_{ab}	-0.08_{a}
Purity	0.27_{c}***	0.03_{b}	-0.23_{a}***

Notes. Higher scores on political ideology indicate more conservative ideology. Correlations within rows that do not share subscripts are significantly different from each other according to Fisher's z-test, $p < 0.05$. * $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$.

As can be seen, all eight ideological variables were associated with approval for tundra mining in ways that were in line with predictions. When it came to space mining, however, ideological variables were not as predictive. Political ideology, for example, did not predict attitudes toward mining the moon or mining asteroids. Trust in mining companies was a significant predictor, but less so for mining asteroids than for mining the tundra. Although the NEP and individualistic/hierarchical worldviews remained significant predictors of attitudes toward mining the moon, they did not significantly predict attitudes toward asteroid mining. Finally, the moral foundations were not predictive of attitudes toward space mining, with one exception: among participants for whom purity was an important moral foundation, there were relatively low levels of approval toward asteroid mining (this is the opposite pattern to that found when purity was correlated with attitudes toward mining the tundra).

3.4. Discussion

Levels of approval for the asteroid proposal were well above the mid-point, and much higher than for a frontier mining proposal on earth. Combined with similar results in Study 1, it is tempting to interpret this pattern as consistent with construal level theory [63], which argues that increased psychological distance to an attitude object facilitates more abstract mental representations of that object. One consequence of this psychological distance is that gains, pro-arguments, and desirability concerns become more salient than losses, con-arguments, and feasibility concerns. Given that space mining is more hypothetical as well as more spatially and temporarily distant than terrestrial mining, it seems plausible that differences in mental abstraction might explain the relatively favorable attitudes toward space mining compared to the terrestrial alternatives.

A key caveat to this conclusion, however, is that there was much more ambivalence regarding the proposal to mine the moon than the proposal to mine asteroids. Indeed, in Study 2, approval of lunar mining was lower than for tundra mining. If we are to assume that lunar mining and asteroid mining are roughly equivalent in terms of psychological distance, one needs to turn to other (less cognitive) explanations for the pattern of results.

In that regard, examination of the ideological variables shed important light on the psychology of people's support or otherwise for the different forms of mining. Support for the proposal to mine the tundra was correlated with a predictable suite of ideological variables: it was higher among more conservative participants and those who scored highly on the binding moral foundations, while support was lower among participants who endorsed the NEP and the individualizing moral foundations more strongly. In contrast, support for space mining shared much weaker and more inconsistent relationships with the ideological variables. Strikingly, people's political ideology was not predictive of the extent to which they supported mining the moon or asteroids. Neither were the moral foundations highly predictive, with only one significant correlation out of ten possible tests. Interestingly, scores on the NEP were uncorrelated with support for asteroid mining, but negatively correlated with support for lunar mining, reflecting the increased concerns regarding environmental costs associated with the latter.

Finally, participants expressed more support for all types of mining when they had more generalized trust in mining companies. However, this relationship was weaker for space mining than for terrestrial mining. Interestingly, our American participants' responses were not reliably or consistently affected by whether the proposed mining company was an American or a Russian company.

4. Conclusions

Enthusiasm for the notion of space mining is in part based on the promise that prospectors would be freed from the backlash associated with environmentally-sensitive terrestrial mining. Two studies—one conducted on a 27-nation sample, the other conducted in the U.S.—provide the first examination of whether this optimism is well-founded.

Both studies revealed broad-based support for the principle of asteroid mining. Levels of support were reliably above the mid-point, and much greater than other forms of frontier mining that were used as frames of reference (e.g., mining the ocean floor, mining Antarctica, and mining the tundra of Alaska and Siberia). Furthermore, attitudes toward mining asteroids were largely uncorrelated with the types of ideological variables that are typically associated with terrestrial mining. Specifically, support for asteroid mining was equally strong among liberal and conservative participants, and equally strong regardless of the extent to which participants were concerned about the fragility of the Earth's ecosystem and humans' impact on it.

In contrast, proposals to mine the moon were met with a mixture of approval and disapproval. Mean scores centered at or slightly below the mid-point, which was significantly higher than support for mining the ocean floor and Antarctica (Study 1), but significantly lower than support for mining the tundra of Alaska/Siberia (Study 2). In both studies, the standard deviations indicated substantial variability, so the fact that the mean scores gravitated around the mid-point seems to reflect ambivalence across our samples rather than uniform neutrality or disinterest. A sizeable minority of people might therefore have objections to lunar mining.

As always, some caution is required in extrapolating from these results. First, although our samples were relatively balanced in terms of age and sex, they were not designed to be perfectly representative of respective countries' populations. Although we controlled for demographics in both studies, we acknowledge that online samples are typically non-representative with respect to education, under-sampling people at the very high and very low ends of education.

Second, given the vanguard nature of space mining, it is reasonable to assume that participants knew little regarding its advantages and disadvantages before completing the survey. This implies that participants may have been highly sensitized to the information we provided in advance of completing the measures. In both studies, for example, we led participants to believe that economic benefits might one day exceed the costs. In Study 2, we also emphasized that there were no sensitive flora or fauna living in the mining zone. This was necessary to provide a psychological level playing field upon which to compare the different types of mining, but it may have served the function of increasing support for the tundra proposal (where in reality environmental impacts are difficult to avoid).

Finally, we note that participants gave their immediate, first-flush response to a complex issue that they had little time to think about. It would be interesting to see the extent to which these immediate "gut" responses might change once participants had time to process a complete set of arguments for and against, particularly when these arguments are filtered through the lens of the media. One of the most interesting aspects of this paper is that attitudes toward mining asteroids (and to a lesser extent the moon) seemed broadly non-ideological, uncorrelated with political ideology or the moral foundations. However, it remains to be seen whether this would remain the case should space mining become more broadly discussed in political and media circles, where there is the potential for the issue to be drawn into the same "culture wars" that shape some other scientific issues (e.g., attitudes toward immunization; genetically modified foods; stem cell therapies; evolution; climate change [64]). As such, attitudes toward mining asteroids and the moon might be best described as "pre-ideological" rather than "non-ideological".

It is also unclear whether the relative agnosticism concerning ownership issues would remain once space mining becomes a topic for public debate. Currently, the legal battles over ownership have been conducted under the radar of the public, followed only by a small minority. This may help explain why nationality of the mining company did not feature heavily in people's concern regarding asteroid and lunar mining. Nevertheless, the "space race" of the 1950s and 1960s acts as a reminder of how quickly that can change should space mining become implicated in national pride and wrapped up in a broader conversation about economic and political supremacy. To the extent that this happens, it may be that ownership concerns—and the associated vigilance regarding international law—would increase in the future.

The current research provides the first attempt to understand attitudes toward space mining, and as such provides a benchmark for future studies. Our findings suggest that people are more positive toward space mining than terrestrial mining, and that this is especially the case for asteroid mining. Our results also suggest that space mining (especially asteroid mining) may be "pre-ideological". This suggests that space mining could provide a useful testbed for future research seeking to understand how attitudes toward market innovations can be formed, influenced, or stabilized. In a world of increasing environmental and technological change, these are critical questions to address.

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Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: Data and syntax can be found at https://osf.io/z3mq2/?view_only=8f5d3fe18225466ab7659347e9e06ea1.

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