RESEARCH ARTICLE

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Beyond the Blue Dot: Mars as the Next Step in Human Civilization and Public Readiness for Multiplanetary Migration

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Abstract

Human history is marked by migration, exploration, and adaptation. This article argues that permanent settlement on Mars should be understood not as an escape from Earth, but as a long-horizon extension of evolutionary and civilizational strategies for resilience, innovation, and continuity. We pair a conceptual synthesis of literature on human dispersal, cultural evolution, technological revolutions, existential risk, space resources, and governance with an exploratory online survey of 519 respondents in China examining attitudes toward Mars migration over a 200-year horizon. The survey is used as a hypothesis-generating case study illustrating how questions of feasibility, fairness, and social legitimacy may condition public readiness for multiplanetary futures. We propose a historical framework in which successive technological revolutions expand the operational radius of civilization: the first great migration made *Homo sapiens* a multicontinental species, industrial-era infrastructure enabled durable transoceanic societies, and AI-enabled autonomy may prepare human systems for interplanetary distances. A single-planet civilization remains exposed to correlated risks, while off-world settlement could create scientific, economic, institutional, and resilience-related benefits if pursued responsibly. Survey results indicate cautious optimism: 66.5% of respondents believe a first Martian base is likely within 200 years, and 61.1% expect net positive effects. However, concerns about fairness and inequality are substantial; many believe Mars migration could widen gaps between rich and poor and marginalize those remaining on Earth. We argue that the legitimacy of Mars settlement depends not only on technical feasibility, but also on transparent governance, equitable access, planetary protection, and continuing stewardship of Earth. Mars should be framed as a cooperative, ethically governed project of long-term human development, not as conquest or abandonment.

Keywords: Mars settlement, public attitudes, human migration, space governance, planetary protection, multiplanetary civilization.

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1 Introduction

Throughout its history, humanity has never been a stationary species. Survival, progress, and cultural flourishing have repeatedly emerged not from remaining within familiar boundaries, but from the willingness to cross them. Fossil and genetic evidence indicates that *Homo sapiens* originated in Africa before dispersing across continents and adapting to radically different climates and ecological conditions [1, 2]. These migrations were not incidental to human history; they were central to survival through climatic instability, population bottlenecks, and environmental stress [3].

The question, therefore, is not simply whether humans will one day live on Mars, but why history suggests that spatial expansion, when ethically governed, is a recurring mechanism of resilience. Civilizations that endure are those that adapt to changing conditions, diversify their habitats and institutions, and invest in long-range capacity rather than short-term equilibrium [4]. At a planetary scale, Earth itself is a finite system, bounded by ecological limits and increasingly exposed to systemic risks arising from both natural processes and human activity [5, 6].

A distinctive contribution of this article is to connect deep-time migration, technological revolutions, and public readiness within a single framework: the expanding operational radius of civilization. Human expansion has repeatedly accelerated when technologies reduced the cost, risk, and uncertainty of long-distance movement. The Industrial Revolution was a decisive inflection point in this pattern. Steam power, railways, telegraphy, improved navigation, metallurgy, medicine, and later electrification enabled people, goods, information, and institutions to cross oceans and continents at unprecedented scale [7, 8]. This transformation helped consolidate and integrate multicontinental societies across North America, South America, and beyond, while also producing colonial violence, displacement, and ecological damage that must not be romanticized. The historical lesson is therefore double-edged: technology can enlarge civilization, but legitimacy depends on whether expansion is governed by justice and stewardship rather than extraction.

Today, humanity stands at the threshold of a comparable transformation in space. The maturation of artificial intelligence as a general-purpose technology — encompassing autonomous systems, advanced robotics, high-fidelity simulation, and automated scientific discovery [9] — is beginning to reduce the cognitive and operational barriers that once made sustained activity beyond Earth prohibitively difficult, as demonstrated by recent applications in space exploration [10, 11]. Much as industrial-era infrastructure prepared humans to operate across oceans, the AI-enabled information revolution may prepare human systems to operate across interplanetary distances, where communication delays, limited resupply, local autonomy, and system reliability become defining constraints.

Mars occupies a unique position within this technological and historical context. It is not the nearest destination beyond Earth, since the Moon is closer, but it is among the most plausible long-term settlement targets because it has a substantial geological record, accessible water-ice resources in some regions, a CO_2-rich atmosphere, a surface gravity stronger than the Moon's, and a diverse mineral inventory that can support in-situ resource utilization in principle [12–15]. These facts do not make Mars easy or automatically habitable. They make it scientifically and strategically important as the first realistic planetary-scale test of whether human civilization can become self-sustaining beyond Earth. This focus on Mars should not be read as a claim that Mars is the only plausible path beyond Earth. Human activity in space has already separated into machine and human branches: robotic spacecraft, orbiters, rovers, and autonomous systems extend human scientific reach long before people arrive. Nearer destinations such as the Moon, cislunar space, free-floating orbital habitats, and asteroid-adjacent infrastructure may precede or accompany Mars settlement because they involve shorter communication delays, shallower gravity wells, or easier access to particular resources. Mars is used here as a focal case because it is the nearest planet with substantial in situ resources and a planetary surface capable of sustaining a long-term settlement experiment, not because other expansion scenarios are unimportant.

Framing Mars settlement as humanity's next step does not imply abandoning Earth. On the contrary, it reframes responsibility toward Earth by expanding humanity's capacity to safeguard life, knowledge, and civilization against existential and catastrophic risks. In engineering, biology, and information systems, redundancy is a foundational principle of resilience; extending human presence to multiple worlds applies that principle at a civilizational scale [16, 17]. The same capabilities needed for Mars, including closed-loop recycling, careful energy management, autonomous maintenance, and ecological discipline, are also relevant to living more sustainably on Earth.

This article develops the argument through a conceptual synthesis accompanied by an exploratory empirical component. The first part synthesizes evidence from human evolution, cultural evolution, resilience theory, space policy, technological spillover, and governance to explain why Mars settlement can be understood as a rational extension of long-term human adaptation. The second part presents descriptive survey findings from China, not as a decisive test of this thesis, but as an early indication of the social conditions under which publics may view Mars migration as legitimate. In this structure, the empirical findings refine the governance implications of the conceptual argument by highlighting fairness, affordability, selection criteria, and emotional ambivalence as constraints that any future settlement program would need to address.

2 Humanity's First Great Migration: From Africa to the World

The earliest and most consequential expansion in human history was not the spread of empires or the opening of oceanic trade routes, but the much older dispersal of Homo sapiens from Africa into the rest of the world. This "first great migration" was a long, uneven process rather than a single event, yet its logic is clear: a species that can move, learn, and adapt is better positioned to survive environmental volatility than a population confined to one narrow habitat. The significance of this analogy is not that prehistoric migration makes Mars settlement inevitable; rather, it reveals a general resilience pattern. Mobility can reduce correlated risk while opening new domains of learning, cooperation, and cultural invention.

2.1 Origins in Africa

Fossil and genetic evidence converge on Africa as the primary origin region for *Homo sapiens*, with early remains and archaeological signatures distributed across the continent and a particularly deep genetic diversity among African populations [1, 2]. The earliest genetic reconstructions that popularized the "recent African-origin" model drew on mitochondrial DNA (mtDNA). Cann et al. [18] showed that mtDNA lineages in their global sample traced back to an African root and that non-African populations carried a subset of that diversity, an early quantitative signal consistent with expansion from Africa into Eurasia. Subsequent population-genetic work using broader markers reinforced this picture at higher resolution. A robust empirical pattern is that neutral genetic diversity decreases with geographic distance from Africa, consistent with serial founder effects during stepwise range expansion [19, 20]. Taken together, these lines of evidence support a view of early *Homo sapiens* as initially concentrated within Africa—highly capable, but still vulnerable to localized environmental shocks. A geographically constrained population faces a fundamental risk: when the entire species depends on the stability of one region, drought cycles, resource collapses, disease outbreaks, or ecological disruption can threaten its long-term continuity.

2.2 The Cost of Staying Still

In ecology, restricted geographic range size is one of the most consistent predictors of elevated extinction risk. Across many taxa, species with small ranges are disproportionately vulnerable because they have fewer "escape routes" when climate, predators, pathogens, or habitat conditions shift [21]. This general principle applies naturally to early humans: before the emergence of large-scale agriculture and global trade, a regional climatic downturn could translate directly into starvation, conflict over scarce resources, and demographic collapse.

Pleistocene Africa was not climatically static. High-resolution paleoclimate records indicate that eastern Africa experienced repeated episodes of hydroclimate stability punctuated by abrupt and extreme perturbations over the last several hundred thousand years, conditions that likely shaped both biological and cultural change in hominin populations [22]. For early *Homo sapiens*, remaining confined to a narrow region would have concentrated existential risk: a severe multi-decade drought, the contraction of freshwater corridors, or persistent ecosystem shifts could have produced population bottlenecks with no alternative refugia.

A counterfactual thought experiment highlights the stakes while also revealing the limits of the analogy. If early *Homo sapiens* had never expanded beyond Africa, many regional or continent-scale contingencies would have remained closer to species-level threats. Epidemics, rapid climate transitions, or catastrophic events could have had much greater consequences if all populations were concentrated in a single ecological region. Geographic dispersal did not eliminate all extinction risks, and truly global catastrophes could still have affected widely dispersed populations, but it reduced the probability that any one local or regional collapse would become final.

The modern world adds a second layer to this "cost of staying still." Today, humans inhabit nearly every terrestrial biome, yet our ecological footprint fragments and transforms the very landscapes that sustain complex life. Global analyses of human impact show that low-disturbance areas now represent only a minority of the terrestrial biosphere, with the most productive and biodiverse biomes facing the greatest conversion pressure [23] — evidence that even a species distributed across the entire planet can degrade the single habitat on which it depends. While technology allows us to buffer many local stresses, it does not eliminate the underlying fragility of a civilization confined to one biosphere.

These considerations motivate a crucial analogy: at the planetary scale, modern humanity remains geographically "narrow," not within one valley or continent, but within one world. Earth is an extraordinary refuge, but it is still a single habitat exposed to both internal shocks and external hazards. A long-term resilience strategy therefore mirrors the logic of early migration: diversify habitats. Mars is relevant here not because it is easy, but because among nearby worlds it offers an unusually practical combination of accessibility and resources. Although interpretations of recurring slope lineae have shifted over time, later analyses support dry granular flows as a dominant mechanism in many locations, while abundant evidence for subsurface ice continues to point to practical pathways for water access in a settlement context [13, 24].

In parallel, Mars is not a barren rock in geochemical terms. A systematic survey of confirmed and plausible Martian minerals indicates substantial mineral diversity and multiple formation pathways, implying the availability of sulfates, oxides, phosphates, and other resource-relevant phases that would support construction, manufacturing, and chemical processing in a settlement context [14]. NASA technology assessments have also emphasized that bioregenerative or hybrid food systems are plausible in principle, with on-planet production pathways that could include high-efficiency biomass sources such as mushrooms, insects, cyanobacteria (e.g., spirulina), and duckweed [25]. These are not claims that Mars settlement will be easy, but evidence that the basic resource grammar of survival, including water, energy, and usable chemistry, exists in some form beyond Earth.

2.3 Becoming a Multicontinental Species

Human expansion beyond Africa was gradual and likely occurred in multiple pulses, shaped by climate windows, coastal and inland corridors, and technological innovations in subsistence and toolmaking. While details remain debated, a major dispersal event is often placed around ~60,000 years ago, when modern humans spread rapidly through parts of Eurasia [3]. Archaeological and genetic syntheses also emphasize that earlier dispersals may have occurred, with later expansions contributing most strongly to present-day non-African ancestry [26, 27].

Regardless of the exact timing and route, the long-term outcome was unambiguous: *Homo sapiens* became a multicontinental species. As populations moved into the Levant, Arabia, Europe, Asia, and eventually Oceania and the Americas, they encountered new pathogens, seasonal cycles, diets, and ecological constraints. Each transition demanded adaptive problem-solving—new clothing, shelter strategies, hunting technologies, social coordination, and knowledge transfer. Genetic data record this expansion as a series of founder events and demographic branchings, with diversity patterns that still preserve the signature of movement outward from Africa [19, 20].

The key insight for the broader argument of this manuscript is that mobility and survival are inseparable. Once humans became distributed across multiple continents, no single drought, volcanic winter, or regional ecological collapse could plausibly extinguish the entire species. In resilience terms, the species had created redundancy across habitats. Figure 1 summarizes this logic and the analogy to a future multiplanetary civilization. This evolutionary pattern does not make Mars settlement inevitable or ethically simple, but it suggests that expanding the "habitable footprint" of civilization follows a deep historical principle: when the costs of staying confined rise, societies that can explore and adapt gain a long-term advantage. The next section turns to the cognitive and civilizational consequences of this dynamic, showing how exploration does not merely protect a species, but can also amplify intelligence, innovation, and cultural flourishing.

The analogy to Mars is therefore structural rather than literal. Prehistoric migration was undertaken

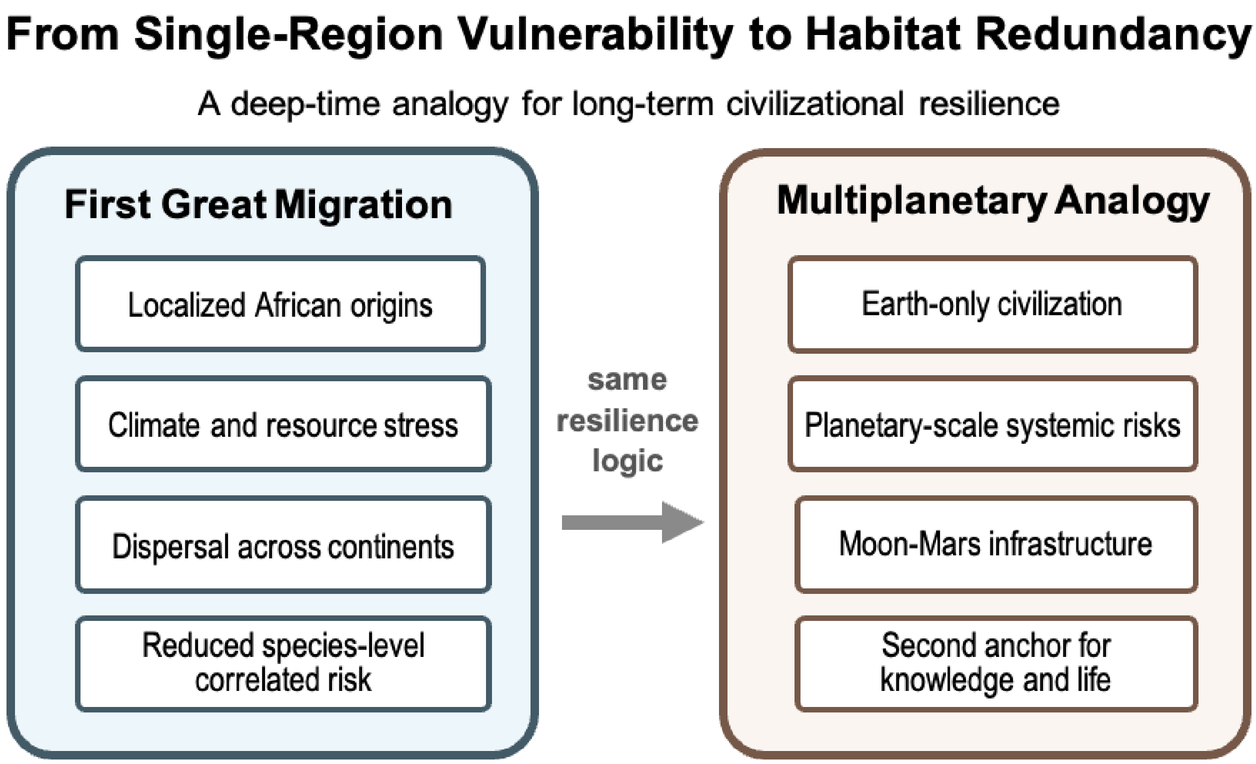


Figure 1. Conceptual model of migration as risk diversification. Human dispersal from a geographically concentrated origin in Africa to multiple continents reduced correlated environmental risk; the same resilience logic motivates the argument for a future transition from a single-planet civilization to a responsibly governed multiplanetary one.

by individuals and small groups without states, corporations, prior planetary reconnaissance, or engineered life-support systems. Many terrestrial destinations were difficult but ultimately survivable once reached, whereas Mars is hostile at every stage and would require continuous technological mediation. These differences matter for governance, ethics, selection, and risk. The analogy is useful for the resilience logic of diversification, but it should not be used to treat Mars settlement as a simple replay of prehistoric dispersal.

3 Exploration as the Engine of Intelligence and Civilization

Human exploration is often discussed as a logistical challenge or a geopolitical project, but at a deeper level it is also a cognitive engine. Crossing into unfamiliar environments repeatedly confronts individuals and groups with uncertainty, novelty, and high consequences for error. These pressures reward foresight, experimentation, cooperation, and the accumulation of shared knowledge. Over evolutionary time, exploration helped shape traits associated with human intelligence; over historical time, it helped generate the institutions that make complex civilization possible. In this section, we argue that the same dynamic applies to space: building an enduring presence on Mars would not only diversify humanity's habitat, but also accelerate the growth of collective intelligence and technological capability if the project is open, cooperative, and scientifically grounded.

3.1 Selection for Curiosity, Risk-Taking, and Adaptability

Migration is rarely a purely random process, but evidence from modern mobility should be applied to prehistory with caution. In modern societies, people who choose to relocate can differ, on average, from those who remain. Longitudinal evidence from the United States suggests that personality traits such as openness to experience (and, in some contexts, extraversion) predict internal migration, while economic studies indicate that risk attitudes can influence migration decisions [28, 29]. These findings do not demonstrate that the same psychological mechanisms drove Pleistocene dispersals, nor do they justify claims that migrants are inherently superior. They more modestly suggest that mobility often involves tolerance of uncertainty, learning, and adaptive decision-making—traits that future off-world programs would need to support institutionally rather than assume biologically.

Once migration begins, the environment itself becomes a teacher. Groups entering new ecologies must quickly learn unfamiliar seasonal cycles, food sources, hazards, and social landscapes. In such settings, the value of flexible learning increases, and the cost of rigid reliance on a single local tradition rises. A major body of work in cultural evolution argues that humans occupy a "cultural niche," in which social learning is essential because it allows individuals to acquire locally adaptive practices far faster than genetic evolution alone could produce [30]. From this perspective, exploration does not merely select for individual cleverness; it increases the payoff to high-fidelity transmission, teaching, and institutionalized knowledge storage. The cultural brain hypothesis formalizes this logic by linking the expansion of human cognitive capacity to the advantages of acquiring, storing, and selectively deploying cultural information in variable environments [31].

Importantly, the "intelligence" that enables exploration is not confined to any single brain. Large-scale coordination—sharing routes, pooling food, caring for children and injured members, and maintaining trust—requires social cognition and group-level organization. The social brain hypothesis proposes that cognitive capacity is constrained and shaped by the demands of managing relationships in complex social groups [32]. When populations expand and interact across wider spaces, the density and diversity of social ties increase, creating larger networks for learning and cooperation. In this way, exploration helps build what Muthukrishna and Henrich call "collective brains," in which innovation emerges from social connectivity, transmission fidelity, and the recombination of ideas across many minds [33].

3.2 Civilizations Born from Movement

At the scale of civilizations, movement creates contact zones, ports, caravan cities, river junctions, and borderlands, where ideas travel alongside goods. Trade routes did not merely distribute resources; they distributed techniques, stories, and scientific practices. UNESCO's historical overview of the Silk Roads, for example, highlights how papermaking knowledge diffused westward through interregional exchange, contributing to new administrative and intellectual capacities in societies that adopted it [34]. Similarly, maritime exploration has repeatedly driven advances in navigation, timekeeping, and observational astronomy, because long-distance travel makes accurate orientation a matter of survival.

Recent cognitive-science syntheses of traditional navigation underscore how demanding exploration can be in practice: successful wayfinding often involves integrating multiple cues — stars, winds, ocean swells, and ecological signals — through embodied skill and shared cultural training that must be explicitly transmitted across generations [35]. These cases illustrate a broader principle: the cognitive demands of exploration create a persistent pressure to formalize, teach, and institutionalize knowledge.

Exploration also expands the demographic and network conditions that make cumulative innovation possible. Cumulative cultural evolution refers to the process by which tools and practices become more complex over time because each generation can build on the discoveries of earlier generations [36]. Models and empirical syntheses suggest that population size and connectivity matter: when groups are too small or too isolated, complex skills can be difficult to maintain and may even be lost [37], whereas larger and better-connected populations are more likely to sustain and ratchet up technological complexity [38]. Seen through this lens, migrations and trade networks did more than spread humans across geography; they enlarged the "effective population" of learners, making civilization's knowledge base more robust.

This relationship between connectivity and innovation remains visible in modern quantitative patterns. In contemporary urban systems, measures associated with economic productivity and knowledge creation often scale superlinearly with city population size, consistent with the idea that denser networks of interaction accelerate idea generation and diffusion [39]. Although cities are not the same as migrating bands, they are a continuation of the same underlying process: movement concentrates diverse people and skills, producing social environments where recombination of ideas becomes easier and more frequent.

3.3 Mars as a New Evolutionary Frontier

Mars settlement would extend these dynamics into a new domain. Like early terrestrial frontiers, Mars would impose intense constraints: hostile conditions, limited supplies, and deep isolation. Yet Mars also introduces a uniquely modern challenge: communication delay. NASA's Human Research

Program emphasizes that crews traveling far from Earth may face communication delays up to about 20 minutes one way, alongside heightened risks from equipment failures and medical emergencies, making self-sufficiency a mission requirement rather than a preference [40]. In practical terms, this means that settlers must develop local autonomy in decision-making, maintenance, medicine, and crisis response.

These constraints are precisely the conditions that historically generate bursts of innovation. A functioning Mars settlement would demand reliable closed-loop life support, high-efficiency recycling, resilient energy production, local manufacturing, precision health systems, and robust governance under extreme scarcity and delayed outside assistance. It would also amplify the value of advanced robotics and artificial intelligence systems that can operate with limited human oversight and limited real-time guidance from Earth [10, 11]. Rather than being an isolated outpost, a Martian community could become an intensive laboratory for sustainability technologies, systems designed not for convenience, but for survival.

Just as earlier migrations expanded humanity's collective brain by widening networks of exchange, a second planet would expand it again, adding new environments, new scientific data streams, and new institutional experiments. The long-run significance is not that Mars settlers would somehow be "better" humans, but that the project of settlement would push civilization to develop higher levels of planning, cooperation, and systems thinking. Figure 2 summarizes this feedback loop. In this way, Mars becomes a new evolutionary frontier in the broad sense: a frontier that selects for robust cultures and technologies, returns knowledge to Earth, and provides a second anchor for human continuity.

4 The Limits of a Single-Planet Civilization

Even if humanity achieves remarkable technological sophistication, the basic architecture of our civilization remains fragile: all people, critical infrastructure, and accumulated knowledge are concentrated on one planet. In risk-management terms, Earth is a single point of failure. This section explains why the finiteness of Earth's life-support systems and the existence of low-probability, high-consequence hazards make a single-planet civilization structurally vulnerable, and why a self-sustaining settlement on Mars functions as a rational form of redundancy rather than an act of escapism.

4.1 Earth as a Finite System

Earth's biosphere is not an unlimited warehouse of resources; it is a delicately balanced life-support system. Modern civilization depends on stable climate, predictable hydrological cycles, fertile soils, biodiversity, and biogeochemical processes that operate within particular ranges. The planetary boundaries framework and the concept of a "safe operating space for humanity" formalize this dependence: the Earth system has limits beyond which abrupt or irreversible changes become more likely [5, 6].

This framing is important because it shifts the discussion from simple scarcity to system stability. Some limits can be negotiated through substitution or efficiency (e.g., improving energy technologies), but other limits involve nonlinear feedbacks in coupled climate–ecological systems. When pressures on the Earth system accumulate, through greenhouse gas emissions, habitat conversion, or disrupted nutrient cycles, risk can rise faster than our intuitive linear expectations. In other words, the question is not only how much the planet can provide, but how resilient the planetary system remains under stress [5, 6].

History provides smaller-scale analogs for this dynamic. Societies that overshoot ecological constraints or fail to adapt to changing conditions can enter rapid decline, even when they possess sophisticated institutions for their time [4]. Today's global civilization is technologically advanced, but also tightly coupled: food systems, energy grids, supply chains, and public health networks are interconnected in ways that allow local disruptions to cascade. Although strong governance and scientific stewardship can reduce risk, a single biosphere still represents a hard constraint: there is no alternative Earth that can absorb errors, shocks, or long-term drift.

4.2 Single-Point Failure in Human Survival

In engineering, avoiding "single-point failure" is a core principle: if one component can end the entire system when it fails, the system is brittle. At a civilizational scale, humanity currently violates this principle. All humans and almost all of our accumulated cultural and technological capacity remain located on one planet. Bostrom [16] describes existential risks as threats that could cause human extinction or permanently and drastically curtail humanity's long-term potential; Ord [17] similarly emphasizes that the stakes are not merely the loss of current lives, but the loss of the vast future

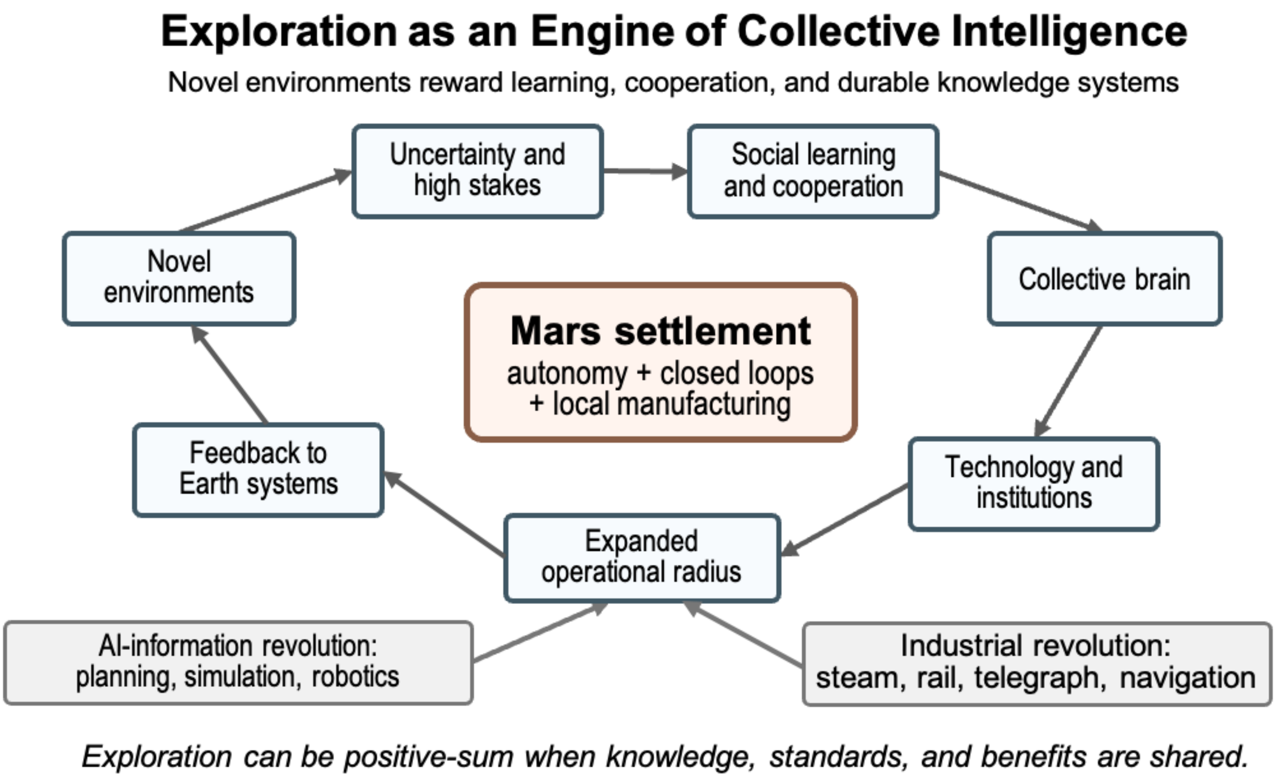


Figure 2. Exploration as an engine of collective intelligence. New environments increase the demand for learning, cooperation, and durable knowledge systems; Mars settlement would intensify this loop through autonomy, closed-loop life support, local manufacturing, and sustainability technologies that can feed back to Earth.

that a flourishing civilization could create.

The specific hazards vary, but the structural problem is the same: when all critical assets are colocated, many risks become perfectly correlated. Natural events such as large asteroid or comet impacts, supervolcanic eruptions, or rare solar-related disruptions may be low probability in any given year, yet they are not zero [43, 44]. Over centuries and millennia, even small annual probabilities accumulate into meaningful risk. At the same time, the modern era introduces powerful anthropogenic hazards, including nuclear conflict, engineered or highly transmissible pandemics, runaway climate change, and failures in managing transformative technologies. The details and likelihoods of each scenario are debated, but the relevant commonality is that they could destabilize or collapse a single-planet civilization in ways that are global rather than local [16, 17].

A multiplanetary presence is best understood as risk diversification. Diversification does not guarantee safety, and it does not remove the ethical responsibility to reduce risks at their source on Earth. However, it can reduce the chance that any one catastrophe ends the story entirely. Just as distributed backups and redundant infrastructure increase the recoverability of critical systems, physically separated human populations increase the probability that civilization can persist, rebuild, and continue its trajectory even after severe disruption. The key requirement is genuine independence: redundancy only works when the secondary system can operate when the primary system fails.

4.3 Mars as a Second Anchor for Civilization

Mars offers one important candidate for true physical separation at a planetary scale, but it is not the only possible anchor for human expansion beyond Earth. The Moon, orbital habitats, asteroid-supported infrastructure, and machine-led exploration may all play major roles in building a solar-system civilization. Mars remains distinctive because it is a separate planet with a substantial atmosphere, accessible water ice, a day length close to Earth's, and a diverse geological record; nevertheless, the resilience argument is not dependent on Mars being first or exclusive. Because Mars is a different world, many threats that could devastate Earth, including pandemics, global war, cascading ecological collapse, or certain climate tipping pathways, would not automatically propagate there in the same way.

However, Mars can only serve as a "second anchor" if it can support long-term autonomy. The planet's value is not comfort but capability: it offers resources that can be transformed into the necessities of survival. Mars has a rich geological history with diverse terrains and materials, implying broad opportunities for construction and resource extraction [12]. Water is essential for drinking, agriculture, and industrial chemistry, and evidence for subsurface ice in the Martian mid-latitudes suggests a practical pathway for local water access [13]. In addition, Mars' CO_2-rich atmosphere provides feedstock for chemical processing and fuel synthesis, while also indicating constraints on terraforming ambitions that clarify what must be engineered rather than assumed [41].

Resource autonomy also requires a materials base. The documented diversity of Martian minerals, including sulfides, phosphates, oxides, and other phases, suggests that a settlement could, in principle, develop industrial chains for metals, ceramics, glass, and chemical reagents over time [14]. On the biological side, in-situ resource utilization concepts and bioregenerative life-support studies point to feasible approaches for local food production and recycling, including high-efficiency biomass sources that could complement conventional crops [25].

Mars autonomy is not simply a technical aspiration; it is imposed by distance. Communication delays and the inability to rely on rapid resupply mean that critical systems must be robust, maintainable, and capable of independent operation [40]. Long-duration habitation also raises nontrivial human health challenges, including radiation exposure, confinement stress, and performance degradation, that must be addressed in mission design and settlement planning [42]. These constraints sharpen the central point: Mars does not offer an easy refuge, but it does offer a pathway to build a second, independent platform for human continuity.

Framed properly, this is not an argument for abandoning Earth. It is an argument for applying mature resilience thinking to civilization itself. A second habitat can preserve knowledge, culture, and technical capacity against catastrophes that would otherwise end our future. At the same time, the discipline required to live on Mars, including closed-loop recycling, efficient energy use, and careful system management, aligns with the capabilities needed to live within Earth's own planetary boundaries. The next section therefore turns from "why" to "how": if exploration and redundancy are rational strategies for long-term survival, what does this imply about the way modern societies allocate resources between competition and constructive exploration [5, 6, 16, 17]?

A staged pathway may therefore be more realistic than a single leap. Robotic systems can prepare infrastructure and characterize risks; lunar and cislunar operations can mature life-support, power, and governance models; asteroid-resource missions can test off-world extraction; and Mars can serve as the first planetary-scale test of settlement under deep separation. Recognizing these alternatives makes the argument more robust: the underlying goal is not Mars for its own sake, but a responsible transition from a single-planet civilization toward a more distributed human and machine presence in the solar system.

5 Competition, Exploration, and Leadership in the Space Age

5.1 The Modern Resource Allocation Dilemma

Modern societies face a resource-allocation dilemma that is rarely framed in civilizational terms. SIPRI reports that world military expenditure reached $2.887 trillion in 2025, the eleventh consecutive annual increase, while OECD estimates put government space budgets at roughly $75 billion in 2022 [45, 46]. This comparison is illustrative rather than a claim that defense and civil space budgets can be traded one-for-one. Defense spending, deterrence, social welfare, climate adaptation, and exploration serve different political and institutional functions. The more limited point is that budgetary choices reveal how much collective capacity is absorbed by rivalry relative to long-horizon public goods.

This is not an argument that defense is unnecessary. States have legitimate security obligations, and deterrence can reduce some near-term risks. It is also important to distinguish SIPRI's empirical expenditure data from SIPRI's policy-normative argument that high military spending may divert resources from social and sustainable-development priorities [47]. The present article adopts a narrower claim: when rising shares of national wealth are absorbed by arms races and rivalry, the opportunity cost is not merely financial but imaginative. The institutions, laboratories, workers, materials, and political attention devoted to competition could also help build resilience-oriented capabilities in energy, health, climate adaptation, space infrastructure, and international science.

5.2 Limits of Zero-Sum Strategies

Arms races often have zero-sum features because their logic is comparative rather than cumulative: one side's gain is frequently interpreted as another side's loss, and success is measured by relative advantage rather than by the enlargement of humanity's total stock of knowledge or capability. Even when deterrence prevents war, it can lock societies into cycles of insecurity that require continuous reinvestment simply to preserve relative position. By contrast, scientific exploration can generate non-rival knowledge and shared technical standards, although space activity can also become competitive or militarized if poorly governed. The distinction is therefore not that exploration is automatically peaceful, but that it creates institutional opportunities for positive-sum cooperation.

For the same reason, dominance in conflict does not automatically translate into lasting civilizational leadership. Durable influence rests on a broader foundation: productive capacity, institutional credibility, scientific achievement, and the ability to attract cooperation [48]. Nye's concept of "soft power" is relevant here, because societies shape the behavior of others not only through coercion or payment, but also through achievements and norms that others find legitimate and worth joining [49]. In this sense, the societies that matter most in history are not merely those that can defeat adversaries, but those that expand the horizon of what humanity can build.

5.3 Exploration as a Positive-Sum Path

Exploration operates differently when designed around shared scientific goals, interoperability, and transparency. Its benefits are often positive-sum because new scientific knowledge, technical standards, and operational experience can diffuse across borders and sectors. The history of the International Space Station demonstrates this possibility. NASA describes the ISS as the most politically complex space exploration program ever undertaken and as a partnership among the United States, Russia, Europe, Japan, and Canada [50]. Such cooperation has limits and can be disrupted by terrestrial conflict, but it shows that space projects can create durable channels for technical collaboration even among states with broader strategic differences.

Exploration also produces material returns on Earth. OECD analyses show that public space investment helps sustain wider industrial ecosystems, while NASA's Spinoff program continues to document commercial applications derived from agency technologies [46, 51]. The critical point is not that exploration is free of competition, but that its most valuable outputs are cumulative and shareable. A nation or coalition that leads through exploration gains prestige not by threatening others, but by creating knowledge, infrastructure, and norms that enlarge the possibilities available to everyone. That form of influence is more compatible with a stable and plural human future than leadership based primarily on coercive superiority.

5.4 The Historical Significance of "Firsts"

History repeatedly assigns unusual weight to "firsts" because first achievements redefine what later generations regard as normal. The first transoceanic crossings linked previously separated human worlds, redrew maps, and initiated enduring exchanges of crops, diseases, technologies, and institutions across oceans [52, 53]. The first artificial satellite did something similar at a planetary scale: NASA's historical account describes Sputnik's launch in October 1957 as the event that began the space age and led directly to the creation of NASA [54]. The first Moon landing had an equally transformative symbolic force. The Smithsonian notes that Apollo 11 made Armstrong and Aldrin the first humans to set foot on another celestial body before a global television audience [55].

What makes such "firsts" historically important is not only priority, but precedent. A first crossing, first orbit, or first landing compresses the distance between imagination and reality. It alters public expectations, reorganizes national ambitions, and generates institutional follow-through: new research programs, new industries, new educational aspirations, and new legal questions. In this sense, the first durable human presence beyond Earth would matter not as a publicity milestone, but as a redefinition of the scale at which civilization can operate.

5.5 Lunar and Martian Settlement as Civilizational Milestones

That is why lunar and Martian settlement would mark a civilizational threshold. Short missions demonstrate reach; sustained habitation demonstrates continuity. NASA's Moon to Mars architecture frames lunar operations as a build-up toward Mars missions, and the National Academies of Sciences, Engineering, and Medicine (2026) emphasizes high-priority science, planetary evolution, the search for life, and preparation for sustained exploration [15, 56, 57]. A sustained settlement, even if initially small and fragile, would mean that humanity had crossed from episodic exploration to extraterrestrial habitation.

Such a transition should be understood as a shared human achievement rather than a replay of terrestrial imperial competition. The legal and ethical foundation already exists in space law. The Outer Space Treaty states that outer space shall be explored for the benefit of all countries and as the province of humankind, while more recent cooperative frameworks such as the ISS partnership and the Artemis Accords emphasize transparency, interoperability, scientific openness, and mutual assistance [50, 58, 59]. If Mars is to become a new chapter in civilization, it should begin with institutions that reward stewardship and cooperation.

5.6 A Forward-Looking Scenario

If any society or coalition becomes the first to establish a permanent lunar or Martian settlement, the consequences will extend far beyond prestige. Early leaders will help define operational norms for traffic management, rescue obligations, data sharing, resource use, environmental protection, and the relationship between public institutions and private firms. In other words, they will not simply occupy a frontier; they will help write the constitutional culture of human activity beyond Earth [58, 59].

Properly understood, this is a form of leadership distinct from domination. The most consequential leader in the space age will be the actor that contributes the most to humanity's common future: by lowering barriers to participation, sharing knowledge, setting safe and interoperable standards, and demonstrating that expansion into space can strengthen rather than divide civilization. A permanent settlement on the Moon or Mars would therefore be remembered not primarily as a national victory, but as a moment when one society helped humanity take responsibility for life beyond a single world. Leadership of that kind derives its legitimacy from creation, not conquest.

6 Mars Settlement as an Engine for Economic and Human Advancement

6.1 Technological Spillover

Space exploration is not only a destination-oriented enterprise; it is also a generator of technologies that return to Earth in altered and often unexpected forms. Long-duration missions require advances in power systems, water recycling, closed-loop life support, autonomous robotics, miniaturized sensors, advanced materials, and medical monitoring, precisely the kinds of technologies that have wide terrestrial application. NASA's Spinoff program and related human spaceflight reports document how space-driven research diffuses into commercial products, industrial processes, health technologies, and environmental monitoring tools [51, 60]. Research on the International Space Station has likewise produced Earth-facing benefits in areas such as remote sensing, disaster response, and biomedical research [61]. Mars-focused development would intensify this pattern because interplanetary settlement imposes stricter efficiency requirements than most terrestrial systems: every watt, kilogram, and liter must be used with exceptional care. The resulting technologies are therefore likely to be especially valuable for sustainability challenges on Earth.

6.2 A New Economic Frontier

Mars exploration will also test new economic models. Recent U.S. budget request materials frame Mars investment as part of a broader Moon-to-Mars architecture: the FY 2026 request introduced more than $1 billion in new Mars-focused technology investments, and the FY 2027 request continued to emphasize Artemis and Mars-focused capabilities as part of an $8.5 billion exploration portfolio [62, 63]. These figures should be interpreted cautiously because budget requests are proposals subject to congressional appropriation, agency trade-offs, and changing federal priorities; they are not guaranteed long-term commitments. At the same time, NASA's Commercial Crew Program was designed to achieve safe, reliable, and cost-effective access to low Earth orbit through partnership with private industry, while the agency's Communications Services Project is using commercial awards and agreements to help build a market for relay services [64, 65]. These examples suggest that public missions can function as anchor demand for private innovation rather than as purely state-run projects.

This does not remove the need for public scrutiny. Large exploration programs require substantial public investment, and their returns are often indirect, distributed, and long term. Yet that is true of many foundational infrastructures, from railways to the internet, that later became engines of economic growth. The relevant question is not whether every Mars dollar yields an immediate consumer payoff, but whether such spending helps create capabilities, markets, and technical competencies with durable value. Viewed in this way, Mars exploration is less like a one-off spectacle than like frontier infrastructure: expensive to establish, but potentially catalytic once in place [66].

6.3 Inspiration for Future Generations

Exploration matters not only because it produces technologies, but also because it shapes aspirations. The International Space Exploration Coordination Group reported that Apollo-era achievements were followed by increases in doctoral degrees in engineering and the physical sciences in the United States, suggesting that visible exploration milestones can influence educational choices and technical ambition [60]. Mars could play a similar role for a new generation by connecting planetary science, artificial intelligence, climate engineering, biology, materials science, and ethics within a single public project. The inspirational value of Mars exploration is therefore not ornamental. It helps enlarge the future scientific workforce, creates shared cultural symbols of constructive achievement, and reminds societies that long-term problems can be met with imagination rather than resignation.

7 Public Expectations and Social Readiness for Mars Migration

The civilizational case for Mars settlement does not eliminate a basic political question: will publics regard such a project as legitimate, desirable, and fair? To address that question, this manuscript incorporates an exploratory survey study focused on contemporary expectations about Mars migration. The survey is not a representative measure of global opinion and is not designed to test the conceptual claims in Sections 2–6. It is included as a hypothesis-generating empirical component that helps identify social concerns—especially fairness, affordability, selection, and emotional ambivalence—that should inform any governance framework for settlement.

7.1 Study Design and Sample

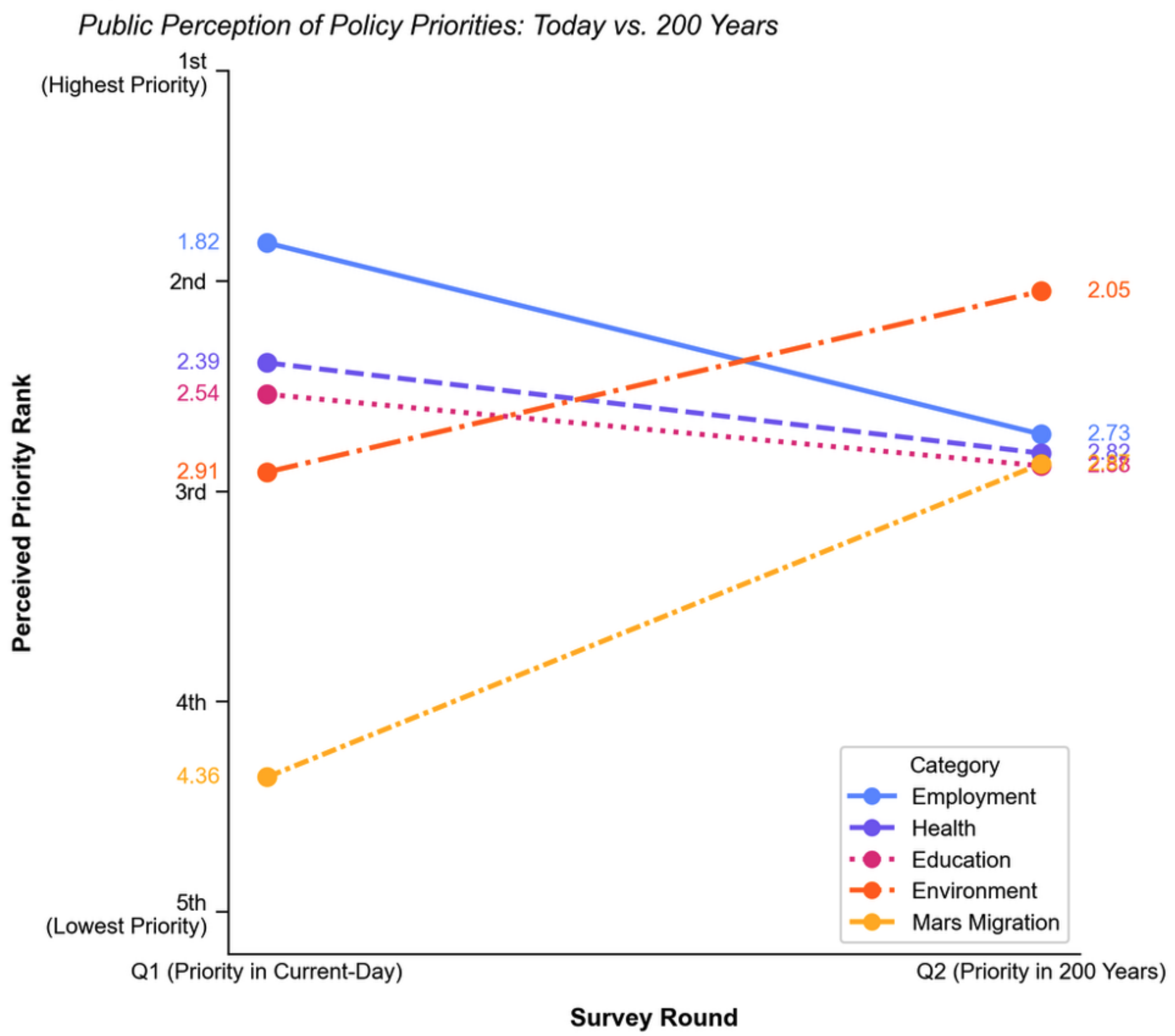
The empirical component used a self-administered online questionnaire containing 28 items, distributed in Chinese through major online platforms including WeChat, Xiaohongshu, Weibo, and Wenjuanxing. A total of 519 valid responses were retained (Table 1). The original survey draft reports 39% male and 61% female respondents, an age range from under 18 to over 60 years ($M = 33.18$, $SD = 7.32$), and responses from all provinces of China except Tibet, Hong Kong, Macau, and Taiwan. The survey included demographic items, ranking tasks, single-choice and multiple-response questions, and 5-point Likert-scale items. The source materials state that participation was voluntary and that informed consent was obtained. Because recruitment occurred online within one national context, the results should be interpreted as exploratory and hypothesis-generating rather than statistically representative. The English questionnaire is provided in Appendix A.

Table 1. Survey sample characteristics.

Valid responses	519
Gender	39% male; 61% female
Age	Under 18 to over 60 years ($M = 33.18$, $SD = 7.32$)
Geographic coverage	All provinces in China except Tibet, Hong Kong, Macau, and Taiwan
Survey mode	Self-administered online questionnaire in Chinese
Distribution platforms	WeChat, Xiaohongshu, Weibo, and Wenjuanxing

Note: *Although the source report describes the sample as randomly drawn from the general public, the observed recruitment method is best interpreted as an online volunteer sample; results should therefore be treated as exploratory rather than nationally representative.*

The sample composition matters for interpretation. Recruitment through Chinese social-media channels means that the survey is not generalizable globally. The platforms used in this study (e.g., Xiaohongshu, Weibo) probably overrepresent respondents who are younger, more digitally connected, more urban, and more educated than the national population; the gender distribution also differs from national demographics. These features may inflate optimism about science and technology, or alternatively heighten concerns about inequality and opportunity. As a limited sensitivity check, responses were compared across age groups. The results revealed a statistically significant difference in perceptions of the benefits of Mars migration; however, no significant differences were found in respondents' perceived likelihood or perceived importance of Mars migration. Findings that show mixed emotions and fairness concerns are likely to be broadly informative, because such concerns appear across many contexts in technology governance. More precise estimates of support, expectations about the timing of a Martian base, and cost-allocation preferences should be treated as especially tentative until replicated with probability samples, demographic weighting, and cross-national comparison.



Note. Priority rankings were derived from respondents' self-reported ordering of policy areas by perceived importance. A weighted mean rank was calculated for each category using the formula: $\Sigma(\text{rank}_i \times \text{frequency}_i) / n$, where lower mean values indicate higher perceived priority. Participation in each item was voluntary; respondents were not required to rank all options. As a result, the number of valid responses varies across categories and survey rounds (Q1 n ≈ 489; Q2 n ≈ 489).

Figure 3. Weighted mean priority rankings for selected issues — employment, health, education, environment, and Mars migration — under present conditions (Q1) and a 200-year horizon (Q2). Elderly care and mental health items from the original ranking task are omitted from this figure for clarity. Lower scores indicate higher priority.

7.2 Future Priorities and Perceived Necessity

Two survey items asked participants to rank six issues — employment, elderly care, mental health, environmental protection, Mars migration, and an open-ended "other" category — under present conditions and under a 200-year horizon (Figure 3). For clarity, Figure 3 presents only the five items most directly relevant to the article's themes; elderly care and mental health rankings are omitted from the figure but were included in the original task. Lower scores indicated higher priority. The mean ranking for Mars migration shifted from 4.36 in the present to approximately 2.88 in the future, while environmental protection also rose in priority. Because the survey changed the time horizon but did not experimentally manipulate a resilience frame, the result cannot establish why respondents ranked Mars migration higher in the 200-year condition. One plausible interpretation is that respondents associated Mars migration with long-term environmental or existential stress; another is simply that they viewed Mars as a distant issue more appropriate to a distant future. The finding should therefore be read as evidence of temporal conditionality, not as proof that resilience framing alone increases support. Socioemotional selectivity theory offers an additional potential explanation: when time is perceived as open-ended, individuals tend to prioritize future-oriented, knowledge-based goals over emotionally immediate ones [67]. The 200-year horizon may therefore have led respondents to underweight emotional and relational costs—such as severed social bonds—that would realistically accompany interplanetary migration. Consequently, these findings may overestimate acceptance of Mars migration under more personal or near-term framings.

7.3 Fairness, Selection, and Cost Allocation

Questions on migration selection criteria probed what respondents think would happen and what they believe should happen. Table 2 shows that adaptability received the highest importance in both frames, while the weight assigned to wealth or power fell in the normative version of the question. Interest also increased modestly. These results do not test a governance model, but they do refine one: they suggest that legitimacy would depend on selection criteria perceived as transparent, merit-based, and humanly relevant rather than driven by elite status. This finding directly informs Section 8, where fairness, selection, and public accountability are treated as central design requirements rather than secondary public-relations concerns.

Cost questions reveal a similar pattern of conditional support. When hypothetical migration costs fell from CNY 10 million to CNY 1 million and further to CNY 100,000, the share of respondents who believed individuals should bear responsibility rose progressively from 59.64% to 79.96%, while support for government and private-sector responsibility declined correspondingly. Respondents therefore appear willing to accept greater individual burden when migration becomes financially imaginable, but they treat very high costs as a public or collective issue. In policy terms, this indicates that perceived affordability and the structure of cost-sharing may be as important for legitimacy as the technical success of the mission itself.

Table 2. *Mean rankings of criteria in the perceived and preferred selection process for Mars migration.*

Criterion	Q6: Perceived criteria	Q7: Preferred criteria	Difference
Adaptability	4.55	4.61	+0.06
Education level	2.96	3.04	+0.08
Wealth or power	2.93	2.79	−0.14
Interest	2.87	2.96	+0.09

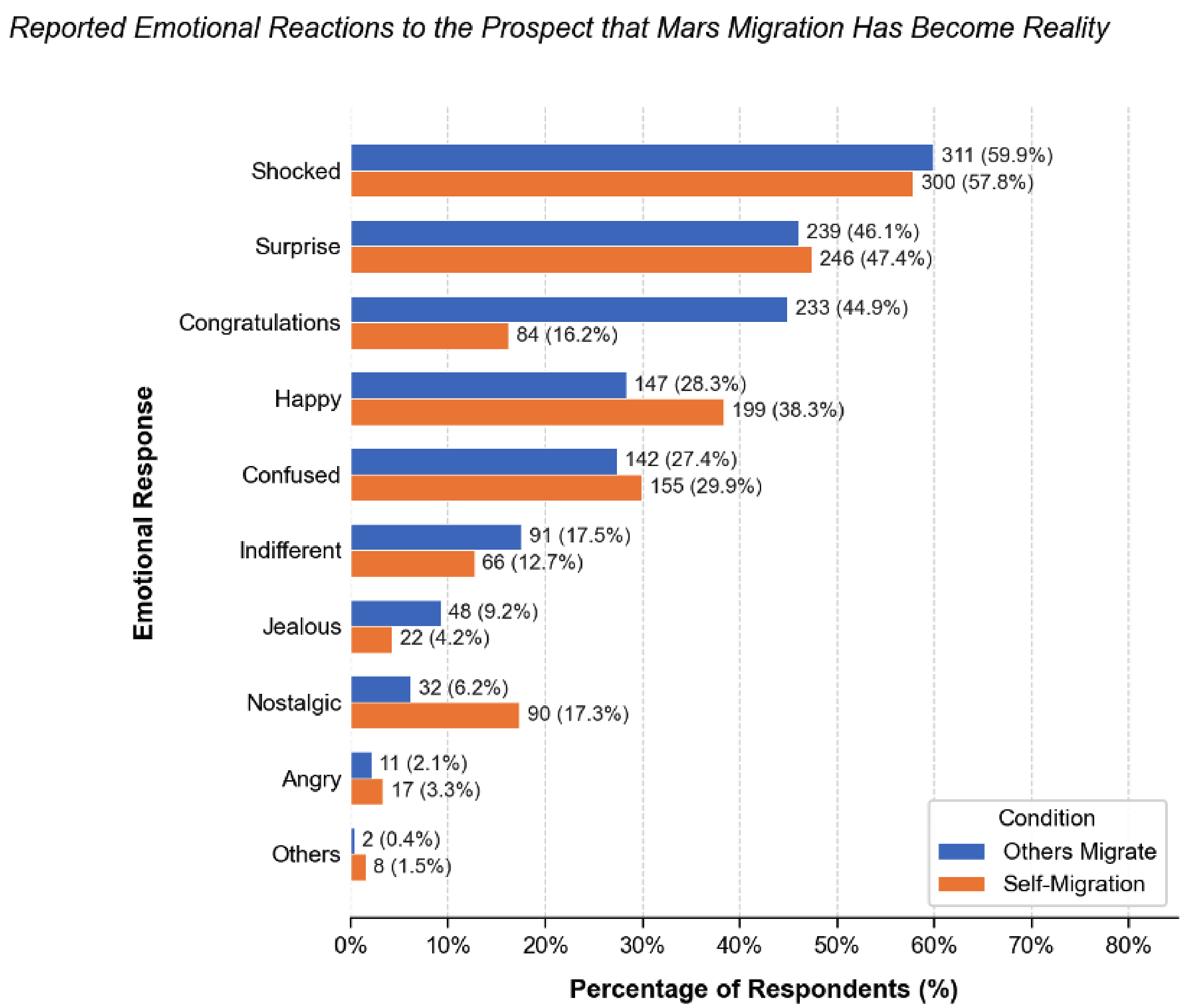
Note: *Original ranking items used 1 = most important and 5 = least important. For ease of interpretation, values in this table were reverse-coded onto a 1–5 scale, with larger numbers denoting greater importance. Question 6 asked what respondents believed would happen in practice; Question 7 asked what they believed should happen.*

7.4 Emotional Reactions and Perceived Social Consequences

Attitudinal items revealed a mixed but mostly positive emotional landscape. Most respondents reported neutral or positive views of Mars migration overall, and only 14.45% expressed outright opposition. In a separate item, 66.5% believed that building the first Martian base within 200 years was likely or very likely, while 61.1% believed Mars migration would bring more positive than negative effects. At the same time, concerns about distributive justice were strong: 67.82% believed Mars migration could widen the gap between rich and poor, and 55.49% believed it could marginalize people remaining on Earth. Optimism about technical feasibility therefore coexists with significant anxiety about social stratification.

Emotional reactions became even more layered when respondents imagined the event becoming real. Figure 4 shows that hearing that Mars migration had become reality elicited shock, surprise, congratulations, happiness, and confusion in both scenarios, while nostalgia rose when respondents imagined that they themselves, not merely others, could migrate. The pattern suggests that public responses to settlement will not be reducible to simple enthusiasm or opposition. Mars appeals simultaneously to aspiration and attachment: people may welcome the opening of a new frontier while still experiencing grief at the idea of leaving Earth, family networks, and familiar social worlds behind.

Additional exploratory findings reinforce this picture. Among respondents with religious beliefs, 46% said religion and interplanetary migration could complement one another, while 14.9% saw them as contradictory, suggesting that cosmological commitments may shape adaptation differently across groups. The survey also found that respondents who perceived the selection process as being driven more



Note. Condition 1 (Others Migrate): respondents reported their emotional reactions upon learning that other individuals may have the opportunity to migrate to Mars (n = 519). Condition 2 (Self-Migration): respondents reported their emotional reactions upon learning that they themselves may have the opportunity to migrate to Mars (n = 519). Respondents were permitted to select more than one emotional response; therefore, percentages do not sum to 100% within each condition. Raw frequencies are shown in parentheses.

Figure 4. Reported emotional reactions to the prospect that Mars migration has become reality, comparing responses when others may migrate and when respondents imagine migrating personally.

by wealth or power were more pessimistic about the feasibility of a Martian base, whereas science-fiction readers were markedly more optimistic. Even if these relationships are provisional, they suggest that cultural narratives and perceived fairness can shape future public support.

7.5 Limitations and Implications

This survey evidence should be interpreted with caution. The questionnaire was distributed online within China, the sample is not nationally representative, and several items used forced-choice, ranking, or multiple-response formats that likely constrained the range of possible responses. For example, the priority-ranking items required respondents to order a fixed set of policy areas; the emotional-response items offered predefined categories; and the cost-allocation items used specific hypothetical price points rather than open-ended willingness-to-pay measures. The results are therefore not a direct measure of global public opinion and should not be used to infer population-level support without further sampling. Nevertheless, the findings are useful for the present article because they illuminate an often-neglected dimension of Mars settlement: social legitimacy. The data suggest that support for Mars is real but conditional. Respondents are most receptive when the project appears feasible, fair, and collectively beneficial, and most skeptical when it appears to privilege wealth, power, or national rivalry. Future work should extend this survey cross-nationally, use demographic weighting and preregistered instruments, test alternative framings experimentally, and track how attitudes change over time. Core analyzed survey items are listed in Appendix A; the complete questionnaire and de-identified data are available from the corresponding author and may be supplied as supplementary material where journal policy permits, subject to privacy and ethical constraints.

8 Ethical, Social, and Governance Dimensions

The survey evidence highlights that the challenge of Mars settlement is not only whether humans can survive there, but how the project should be governed. Ethical evaluation must therefore integrate astronaut health, distributive justice, planetary protection, and obligations to future communities. A technically successful settlement that lacks legitimacy, safeguards, or moral restraint would still represent a civilizational failure.

8.1 Human Factors and Psychosocial Adaptation

Human factors remain fundamental. Deep-space crews will face isolation, confinement, communication delays, and the psychological burden of separation from Earth. NASA's human research literature emphasizes that medical emergencies, equipment failures, and long communication delays make far-from-Earth missions uniquely demanding, while longer-term habitation raises radiation, performance, and mental-health concerns [40, 42]. The survey's finding that nostalgia rises when respondents imagine themselves migrating reinforces the point that Mars settlement is not merely a transportation problem. It is a life-world transition that will require durable systems of mental-health support, family policy, education, conflict mediation, and meaningful consent.

The same applies to reproduction and multigenerational settlement. Early Martian communities will almost certainly be small, demographically constrained, and exposed to biological conditions unlike those on Earth. Questions about reproductive health, developmental monitoring, genetic diversity, and the rights of Mars-born children therefore cannot be deferred until after settlement begins [71]. An ethically serious Mars program must treat these issues as core design requirements rather than as afterthoughts to engineering.

8.2 Justice and Inclusion

Justice is equally central. One of the clearest messages of the survey is that people worry Mars migration will privilege wealth or power and intensify inequality. Those concerns are not peripheral; they go to the legitimacy of the entire enterprise. A settlement program that functions as an off-world exit option for elites would undermine the argument that Mars serves humanity as a whole. Transparent selection criteria, public accountability, pathways for broad participation, and protections for those who remain on Earth are therefore ethical requirements, not public-relations accessories.

8.3 Planetary Protection and Scientific Stewardship

Planetary protection raises two related but distinct obligations. The first is biological: preventing forward contamination of Mars by terrestrial organisms, especially in environments where Earth microbes might survive or where indigenous Martian life, if it exists, could be obscured or damaged. Article IX of the Outer Space Treaty requires states to avoid harmful contamination, and the COSPAR planetary protection framework provides the main international standard for translating that obligation into mission categories, documentation, bioburden controls, and special-region considerations [58, 68–70]. For settlement, these concerns become harder rather than easier, because habitats, waste streams, agriculture, drilling, and surface mobility all increase the number of pathways by which terrestrial biology could enter Martian environments.

The second obligation is scientific and archival. Even if Mars is lifeless, its rocks, ice deposits, atmospheric history, and possible prebiotic chemistry constitute a record of planetary evolution that has intrinsic scientific value. Protecting that archive is not identical to preventing biological contamination: it may require zoning, protected scientific reserves, sample-handling rules, limits on industrial activity near high-value sites, and transparent international oversight. Treating Mars as an archive as well as a potential habitat helps avoid a false choice between exploration and preservation. Responsible settlement would need both:

strict biological safeguards for potentially habitable environments and stewardship rules that protect the planet's geological and historical record for future science.

8.4 Responsibility to Future Persons and Civilizational Heritage

Finally, Mars settlement raises obligations to future persons and to civilization itself. The purpose of becoming multiplanetary is not simply to extend extraction into a new environment, but to preserve and enlarge the conditions under which life, knowledge, and culture can endure. Early settlements will make choices about governance, education, archives, language, law, and memory that could shape human development for generations. They should therefore be designed to preserve scientific openness, cultural plurality, and institutional self-correction rather than reproduce the most exclusionary features of terrestrial history.

In this sense, responsibility extends in two directions at once: backward toward Earth, whose ecosystems and societies still deserve care, and forward toward the communities that may one day live beyond it. A morally mature spacefaring civilization would treat Mars not as a substitute for Earth, but as a second site of stewardship. It would use extraterrestrial settlement to diversify risk, safeguard knowledge, and broaden human possibility while remaining accountable to the principle that expansion in space should strengthen, rather than fracture, the common future of humankind.

8.5 Fiscal Responsibility and Public Legitimacy

Fiscal responsibility is therefore part of the ethical framework, not separate from it. Public budgets are finite, and respondents' own priority rankings show why Mars cannot be framed as an unlimited claim on present-day resources: employment, health, education, and environmental protection remain immediate priorities, while Mars migration gains salience primarily over a 200-year horizon. A defensible funding model should therefore distinguish near-term social obligations from long-horizon resilience investment. Government spending on Mars is easiest to justify when it creates public goods such as safety standards, scientific data, open infrastructure, planetary-protection protocols, sustainability technologies, and international norms, rather than merely subsidizing private exit options for a narrow elite. In fiscal terms, Mars settlement should be presented not as a blank check or a substitute for social investment on Earth, but as a staged infrastructure program with transparent accounting, independent review, international cost-sharing, measurable milestones, and demonstrable Earth-facing returns [46, 63].

At the individual level, affordability matters because it shapes legitimacy. The survey's cost-allocation items suggest that respondents become more willing to assign responsibility to individuals when hypothetical migration costs fall, but they treat extremely high costs as a collective issue requiring public and private participation. This pattern points toward a practical principle: public investment should lower barriers, create shared capabilities, and prevent elite capture, while individual or commercial participation can expand once costs decline and safety standards mature. A future in which only the wealthiest can leave Earth would undermine the claim that settlement serves humanity. A more credible pathway would separate participation from migration: most citizens could benefit through education, open data, remote science, public consultation, commercial spin-offs, and ecological technologies even if they never travel to Mars. The ethical question is therefore not simply who pays for rockets, but who receives the benefits of the knowledge, resilience, and technologies those rockets help produce.

9 Conclusion

Human survival has always depended on the willingness to move beyond familiar ground. The dispersal of *Homo sapiens* out of Africa, the expansion of trade and exploration across oceans, the Industrial Revolution's transformation of long-distance mobility, and the ongoing AI-information revolution each reflect a deeper pattern: when environments change and horizons widen, societies that learn, adapt, and venture outward gain resilience. Mars settlement should be understood in this same tradition. It is not a rupture with human history but a continuation of one of its oldest strategies—diversifying habitats, extending knowledge, and building new forms of collective capacity.

For that reason, the central choice before modern civilization is not simply whether Mars is technically reachable. It is whether humanity will continue to devote its greatest energies to forms of rivalry that consume resources without enlarging our common future, or whether it will redirect a larger share of its intelligence toward creation. A sustained human presence on Mars would not solve Earth's problems automatically, nor would it excuse neglect of the planet that made us. But it would expand the margin of safety for life, accelerate technologies relevant to sustainability, and affirm a civilizational ethic built on exploration, stewardship, and responsibility.

The survey evidence incorporated here adds an important constraint to this vision and clarifies why the empirical component is best read as exploratory rather than confirmatory. Many respondents can imagine Mars settlement as feasible and even beneficial, but their support appears conditional on whether it is governed transparently, financed credibly, and organized in ways that do not simply export terrestrial inequality into space. The path beyond the blue dot will therefore be judged not only by rockets and habitats, but by institutions: whether humanity can build a Mars program that is cooperative, equitable, scientifically serious, and worthy of the future it claims to protect. Future research should test these attitudes with representative and cross-national samples, compare Mars with lunar, orbital, asteroid, and machine-led scenarios, and examine how different governance frames influence public support.

Data Availability Statement

The de-identified survey data, coding information, and questionnaire materials used in this exploratory study are available from the corresponding author upon reasonable request, subject to appropriate privacy and ethical considerations. The original Chinese questionnaire is also available from the corresponding author upon reasonable request. De-identified item-level responses can also be provided upon reasonable request, with respondents anonymized and coded numerically.

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Conflicts of Interest

The authors declare no conflicts of interest.

AI Use Statement

The authors declare that no generative AI was used in the preparation of this manuscript.

Ethical Approval and Consent to Participate

This study used an anonymous, voluntary online survey on public attitudes toward Mars settlement and migration. No personally identifiable information was collected, and no sensitive personal or medical data were requested. Participants were informed of the purpose of the study prior to participation, and completion of the questionnaire constituted informed consent. The authors consider this study to represent minimal-risk survey research; formal prospective institutional ethics review was not obtained prior to data collection.

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Appendix

Survey Questionnaire

Before you begin: This questionnaire explores public perceptions regarding interplanetary migration. Please be assured that all of your responses will be used solely for research purposes and kept confidential. If you feel uncomfortable answering any question, please feel free to withdraw from the survey at any time or skip that question. Thank you for your participation.

Q1. Based on current social conditions, please rank the following issues according to how much attention you believe society should give them. (Smaller numbers indicate higher priority.) [*Ranking*]

A. Employment
B. Elderly care and/or childcare
C. Mental health
D. Environmental issues and sustainable development
E. Interplanetary migration (e.g., Mars migration)
F. Other (please specify)

Q2. Now imagine the year is 200 years in the future (i.e., 2225). Please rank the following issues according to how much attention you believe society should give them. (Smaller numbers indicate higher priority.) [*Ranking*]

A. Employment
B. Elderly care and/or childcare
C. Mental health
D. Environmental issues and sustainable development
E. Interplanetary migration (e.g., Mars migration)
F. Other (please specify)

Q3. If migration to Mars became a reality, which of the following would you most like to be? [*Multiple-answer question*]

A. An astronaut (one of the first people to land on Mars; highly recognized but not necessarily living there permanently)
B. A pioneer (one of the first settlers to live and establish a community on Mars)
C. A migrant (moving to Mars only after several generations have demonstrated that long-term life there is feasible)
D. I would prefer to stay on Earth.

Q4. (Shown only if Q3 = D) Why would you prefer to stay on Earth? [*Multiple-answer question*]

A. My family and friends are here.
B. Migration to Mars is not feasible and carries significant risks.
C. My age or physical condition would prevent me from migrating.
D. I prefer Earth's environment.
E. I simply don't want to move.
F. I don't think there is any need to migrate to Mars.
G. Other (please specify)

Q5. If the timeline were 200 years in the future, how would you answer Question 3? [*Multiple-answer question*]

A. An astronaut
B. A pioneer
C. A migrant
D. I would still prefer to stay on Earth.

Q6. In your opinion, how do you think the first group of Mars settlers would actually be selected? (Smaller numbers indicate greater importance.) [*Ranking*]

A. Adaptation to the Martian environment (e.g., physical ability)
B. High education degree
C. Wealth and/or political influence
D. Level of interest
E. Other (please specify)

Q7. In your opinion, how should the first group of Mars settlers be selected? (Smaller numbers indicate greater importance. Note that this question asks what *should* happen, unlike the previous question.) [*Ranking*]

A. Adaptation to the Martian environment (e.g., physical ability)

B. High education degree

C. Wealth and/or political influence

D. Level of interest

E. Other (please specify)

Q8. If the cost of sending one person to Mars were RMB 10 million (approx. 1.4 million dollars), who should pay? (Select up to two options.) [*Multiple-answer question*]

A. The government

B. The individual (those who want to migrate should pay themselves)

C. Society (e.g., philanthropic donations or public crowdfunding)

D. Other (please specify)

Q9. If the cost of sending one person to Mars were RMB 1 million (approx. 140,000 dollars), who should pay? (Select up to two options.) [*Multiple-answer question*]

A. The government

B. The individual (those who want to migrate should pay themselves)

C. Society (e.g., philanthropic donations or public crowdfunding)

D. Other (please specify)

Q10. If the cost of sending one person to Mars were RMB 100,000 (approx. 14,000 dollars), who should pay? (Select up to two options.) [*Multiple-answer question*]

A. The government

B. The individual (those who want to migrate should pay themselves)

C. Society (e.g., philanthropic donations or public crowdfunding)

D. Other (please specify)

Q11. Overall, what is your attitude toward migration to Mars? [*Single-answer question*]

A. Neutral / No strong opinion

B. Oppose

C. Support

Q12. (Shown only if Q11 = A) Why are you neutral about migration to Mars? [*Multiple-answer question*]

A. I probably won't live long enough to see it happen.

B. It is unrealistic and unlikely to become a reality.

C. Even if it became possible, I wouldn't go.

D. Other (please specify)

Q13. (Shown only if Q11 = B) Why do you oppose migration to Mars? [*Multiple-answer question*]

A. There are other issues that deserve greater attention from society and the government.

B. The government should not spend taxpayers' money on what I see as an unrealistic endeavor.

C. I probably won't live long enough to see it happen.

D. It could lead to contact with extraterrestrial life, which may not be beneficial.

E. Other (please specify)

Q14. (Shown only if Q11 = C) Why do you support migration to Mars? [*Multiple-answer question*]

A. Humanity needs to find a new home because Earth cannot sustain us indefinitely.

B. It is important for our country to become a leader in interplanetary exploration.

C. Research on Mars migration can drive scientific and technological advancement.

D. It could lead to the discovery of extraterrestrial life.

E. Other (please specify)

Q15. If you heard that someone else was able to migrate to Mars, how would you feel? [*Multiple-answer question*]

A. Excited
B. Congratulatory
C. Surprised
D. Jealous
E. Indifferent
F. Happy
G. Confused
H. Angry
I. Nostalgic
J. Other (please specify)

Q16. If you heard that you yourself were able to migrate to Mars, how would you feel? [*Multiple-answer question*]

A. Excited
B. Congratulatory
C. Surprised
D. Jealous
E. Indifferent
F. Happy
G. Confused
H. Angry
I. Nostalgic
J. Other (please specify)

Q17. If migration to Mars became a reality, which of the following outcomes do you think would be most likely? [*Multiple-answer question*]

A. It would widen the wealth gap on Earth.
B. It would create new opportunities for equality.
C. It would marginalize those who remain on Earth.
D. Other (please specify)

Q18. Two hundred years from now, remaining on Earth would most likely be viewed as: [*Single-answer question*]

A. A conservative but secure choice
B. An outdated mindset lacking a spirit of exploration
C. A demonstration of loyalty to Earth
D. Other (please specify)

Q19. If migration to Mars required 30% of Earth's scientific research budget, what would your attitude be? [*Single-answer question*]

A. Support
B. Oppose
C. It would depend on Earth's circumstances at the time.
D. Other (please specify)

Q20. Do you practice a religion? [*Single-answer question*]

A. No religion
B. Buddhism
C. Islam
D. Protestant Christianity
E. Catholicism
F. Other (please specify)

Q21. (Shown only if Q20 $\neq$ A) What do you think is the relationship between religion and interplanetary exploration? [*Single-answer question*]

A. No particular relationship
B. They are in conflict.
C. They complement each other.
D. Other (please specify)

Q22. What types of books do you usually read? [*Multiple-answer question*]

A. I rarely or never read books.
B. Academic books
C. Romance fiction
D. Science fiction
E. Other (please specify)

Q23. Do you think migration to Mars is likely to become possible within the next 200 years (i.e., establishing a permanent base on Mars after the first astronauts land there)? [*5-point Likert Scale*]

A. Definitely impossible
B. Probably not
C. Unsure
D. Probably yes
E. Definitely yes

Q24. How important do you think migration to Mars will be 200 years from now? [*5-point Likert Scale*]

A. Not at all important
B. Unimportant
C. Neutral
D. Important
E. Very important

Q25. I believe discovering extraterrestrial life would be a good thing. [*5-point Likert Scale*]

A. Strongly disagree
B. Disagree
C. Neutral
D. Agree
E. Strongly agree

Q26. I believe the benefits of pursuing migration to Mars outweigh the drawbacks. [*5-point Likert Scale*]

A. Strongly disagree
B. Disagree
C. Neutral
D. Agree
E. Strongly agree

Q27. What is your gender? [*Single-answer question*]

A. Male
B. Female
C. Non-binary

Q28. What is your age group? [*Single-answer question*]

A. Under 18
B. 18–25
C. 26–30
D. 31–40
E. 41–50
F. 51–60
G. Over 60

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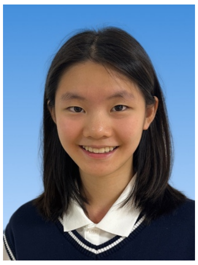

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