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Space Travelling and its Challenges: A New Scenario for Islamic Ethics?

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Abstract: In this paper, we consider the Islamic perspective on space travel. A fatwa with instructions on how to perform Muslim rites in space has been available to Muslim astronauts and aspiring ones for some years, while investments in space and its exploration by Muslim-majority countries are increasing. For some Muslim scholars, space travel can, within the framework of Islamic moral principles, be considered acceptable and, in some cases, even encouraged. However, we shall show that the project to explore or settle on other planets may require additional discussion and reflection in the field of Islamic ethics, as it is broadly understood. In this paper, we address one aspect, namely that outer space exploration – as scientists point out – might necessitate genetically modifying astronauts and ultimately altering human nature. Moreover, in a space context, sexual reproduction may be unfeasible or less advantageous than assisted reproduction technologies (in-vitro fertilization and artificial wombs). It is, then, highly likely that reflection on space travel in the Islamic religio-ethical framework should start to consider this type of problem. Further, as we shall try to demonstrate, these matters, which have already been discussed in the field of Islamic medical ethics, acquire a different sense and dimensions as soon as they are applied to space exploration, especially (but not exclusively) regarding their motivations, goals and necessity. Our conclusion is that it is important to enrich, deepen and broaden ethical reflections and the debate on this topic, both in the field of bioethics, which we have used as a case study, and with further-reaching considerations on ethical, religious, and political values related to space exploration and its purpose.

Keywords: Space travel; Islamic ethics; Islam; space; settlement of Mars; outer space exploration; transhumanism; bioethics; genome editing; assisted reproduction

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1. Introduction

The idea of space exploration has for a long time exerted great fascination on science, as well as on the imagination and creativity. Recently, space has indeed opened up to the possibilities of exploration by human beings, from satellites and probes to missions involving human crews such as the international space station, space tourism, and even the project to establish bases on the Moon and settle on Mars. Within this framework, the UN Office of Space Affairs (UNOOSA) encourages all member countries to contribute to and participate in the expansion of space-related missions and research. Their key concepts are peace and cooperation for the sake of humanity (Valluri 2024). A lot of people all around the world, including many Muslims, are interested in space, some of them directly, such as scientists, technicians, and astronauts, among others. Many countries, including those with a Muslim majority and those whose legislation and policies are based on or influenced by *sharīʿa*, are increasingly involved in this effort and contribute to this common endeavor through various types of projects. Everything seems

to suggest that interest will continue to increase and that this field will pose more and more new questions of a religious, ethical, and political nature.

Our aim is to show that, while discussions on these topics within the Islamic cultural, political, and religious context are already present, they could be further and profitably developed, given the complexity and breadth of the subject. One can observe the centrality of ethical considerations, broadly understood both in narratives related to concrete endeavors, their goals, and their benefits and also in the prevailing perspectives on the risks and challenges they entail. However, there is still a noticeable lack of either holistic treatments of the issue, addressing its multiple dimensions, or direct engagement in the specific debate on space exploration by scholars dealing with bioethical issues within the Islamic ethico-legal framework. Through our work, we aim to highlight these two possible directions of inquiry and their connections. On the one hand, we will draw attention to some key aspects that have already emerged regarding space exploration within Islamic contexts or by Muslim believers, which we believe are useful for developing a comprehensive, multifaceted view of the issue. On the other hand, we will show how the debate on space exploration can benefit from the ongoing ethico-legal discussions on major bioethical issues once the crucial difference in perspective is properly understood. This is not merely a minor adjustment that adds to existing discussions; rather, as we will see, it profoundly reshapes their meaning.

As a proposal for future lines of reflection and research, we believe that our brief analysis highlights the importance of further exploring this shift in perspective, its actual implications, and its significance for the economy, geopolitics, the improvement of human life, and the potential to ensure the survival of humankind. In other words, it seems promising as a future direction for development to revisit certain aspects and assessments and to further examine motivations and goals, as well as the scientific and technological means to achieve them, as they emerge in the discourse and practice of space exploration.

Before delving into the core of our discussion, let us recall some general aspects of Islamic ethico-legal thought. Issues relating to new technologies and applied ethics are generally among those that have not been explicitly addressed either in the sources of *sharīʿa*, namely the Qurʾān and the Sunna, or in the interpretations of past Muslim religious scholars. For this reason, they require *ijtihād* (legal reasoning) by qualified scholars of recognized authority.[1] Moreover, there is an increasing reliance on expert committees, which include scientists specializing in the technologies under consideration.[2] The plurality of individual and school positions, contexts, approaches, frameworks, and methods[3] leads to a wide range of responses and a highly nuanced debate with multiple implications. Often, in certain fields at the forefront of ethical inquiry, such as bioethics and medical ethics, there is a tendency to seek a comprehensive ethical framework inspired by a holistic vision, while also ensuring it remains accessible to healthcare practitioners and decision-makers.

In addition to the growing focus on the genre of *qawāʿid al-fiqhiyya* (Islamic legal maxims), which has long been part of the Islamic legal tradition, ongoing reflections and

[1] In general, it has to be pointed out that, 'While Islamic ethics incorporates various philosophical traditions it still holds a religious worldview and draws its resources mainly from religious texts' (Padela, 2007, 170).

[2] An interesting perspective on the historical context is provided by al-Khatib (2019). In the present day, within the field of bioethics and emerging technologies, the idea of 'collective *ijtihād*' has led to the establishment of interdisciplinary and transnational organizations, such as the Islamic Organization for Medical Science (IOMS, established in Kuwait in 1981), the Islamic Fiqh Academy (IFA, established in 1977 and based in Mecca), and the International Islamic Fiqh Academy (IIFA, established in 1981 in Jeddah) (al-Khatib 2019; Ghaly 2019a, 46).

[3] We should also consider, among other things, the internal differences in Sunni and Shia Islam, as well as those between them. It has been noted that, on certain specific bioethical issues, there are often significant similarities (Muhsin, Chin, and Padela 2024a, 5; Ghaly 2016b, 34 note 67). Additionally, contribution from different fields and approaches, such as theology, philosophy, and Sufism, should not be underestimated.It should be observed that the moral status of actions according to the *sharīʿa* is divided into five categories: the permitted, the obligatory, the recommended, the discouraged and the forbidden.

discussions are taking place on *maqāṣid al-sharīʿa* (the ultimate goals of divine Law[4]), the various dimensions of the concept of public interest (*maṣlaḥa*) and its determination, as well as on attempts to formulate a principle-based bioethics.[5] These discussions raise many questions, starting with how these concepts can be – and are – used within the general framework of Islamic law (*fiqh*) and Islamic legal theory (*uṣūl al-fiqh*) and how they relate to one another (hierarchies, differences, interconnections); in addition the central issue regarding the autonomy of certain approaches, such as *maqāṣid al-sharīʿa*.[6] Furthermore, there are other classical genres, such as the genre of virtues (*faḍāʾil* or *makārim*) and that of *adab al-ṭabīb* (practical ethics of the physician), which may open new horizons for future discussions in the fields of medical ethics and ethical thought in general (Ghaly 2016a, 37).

Without delving into the discussion and specific determination of these approaches, which goes beyond the scope of our work, we can view them as different resources available for reflecting on (and deciding) the religious, ethical, and legal dimensions of certain actions and practices.[7]

In the next section (section 2), we will see how Muslims as such relate to space travel. In addition to scientists and technicians of various kinds, there have been – and still are – Muslim astronauts or would-be ones. This is, as we shall see, important from the point of view of the possibility of performing Islamic prayer and practices in space. Moreover, some Muslim countries have begun to invest heavily in space research and exploration projects, both in economic terms and in terms of political and international prestige.

In Section 3, we will consider some general views underlying this practical approach, which function as a very general framework according to which space travel may (or may not) be accepted or even encouraged from the perspective of the Islamic religio-ethical system. We will present some references to the Qurʾān and arguments from scholarly articles dealing with this topic, not as systematic guidelines, but as conceptual tools that can help in understanding the framework. However, these should not be regarded as rigorous legal reasoning arguments, nor as part of a structured debate involving a plurality of perspectives, interpretations and rulings, as is the case, for example, in bioethics.

When reflecting on whether it is permissible for Muslims to undertake certain space missions, especially high-risk ones in outer space, it is important to consider that genetic modifications may be necessary to carry them out. Although this issue – closely linked to the debates on Bioethics and Transhumanism – has not yet emerged, in Section 4, we will explore whether genetic modifications for astronauts can be considered permissible within Islamic ethics. Since these modifications are not intended for treatment but merely to ensure survival in uninhabitable environments, their ethical justification remains uncertain.

In addition to questions about genetic modification, space exploration and settlement could raise ethical concerns about the reproductive technologies needed to build stable, self-sufficient settlements in space. For people who will therefore live in new

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[4] It relies on reflections by prominent scholars of the past, such as Abū Isḥāq al-Shāṭibī and al-Ghazālī. The five main objectives of *sharīʿa*are: the promotion and preservation of religion (*dīn*), and the preservation of life, progeny, intellect and wealth. One of the arguments supporting the use of a *maqāṣid*-based approach is that '*maqāṣid*-based frameworks represent the broader "spirit" of the Islamic revelation' (Padela 2022, 74).

[5] There are various perspectives and nuances regarding principlism and Islamic bioethics in general (Ghaly 2016; Alali, Serour, and Bagheri 2017; Chamsi-Pasha and Albar 2013).

[6] There are tendencies to consider them 'independently as the primary grounds for Islamic ethico-legal rulings'(Padela 2022, 76). See, for example, Ramadan (2018).

[7] An example of this type of procedure: 'In this quest for discernment, scholars typically engage in reasoning by either seeking analogous cases to find precedent, or (…) scrutinizing the issue through the lens of *qawāʿid* and *maqāṣid* (legal maxims and objectives of *Shariah*) to arrive at a resolution. In all instances, they perform *tawāzun*(comparative jurisprudence) between the benefits (*maṣāliḥ*) and harms (*mafāsid*) or between competing benefits or harms to determine the most comprehensive and advantageous choice'(Muhsin, Chin, and Padela 2023, 3).

settlements there, the solution might be to resort to reproductive techniques and/or artificial wombs (ectogenesis). In Section 5, we will address this issue.

Our conclusion (section 6) is that, in the current state of technological development and research, the positions of Muslim scholars on space exploration seem to require additional reflection and debate. Especially when the riskiest journeys and the settlement of other planets are involved, new reflections and perspectives emerge in the field of Islamic ethics, broadly understood, and they deserve to be (further) explored and discussed.

2. Muslims and space travel

To clarify why it is relevant to consider the Islamic perspective on space travel, we should observe that 'Islam is unique as a major religion in that it demands regular attention to the sky and geography to satisfy worship requirements' (Lewis 2013, 114). Performing Islamic rites is very important for believers, including astronauts. 'Orbiting in space calls for special adjustments to those practices, especially for geographic orientation for prayer and the observation of fasting schedules' (Lewis 2013, 114). Furthermore, the question of Islam's position regarding space exploration is relevant for Islamic countries investing in space-related projects. In Muslim-majority countries, Islam is an important source to legitimize political choices and a very important reference framework, even when it comes to countries adopting 'secular' systems and institutions.

As noted above, adjustments are needed to perform Islamic rites in space. The first Muslim astronaut, in 1985, was Sultan bin Salman, a prince and pilot from Saudi Arabia. With some sacrifices, such as not fasting for Ramadan during training and orbit around the Earth, he 'made his personal accommodations to his religion' (Lewis 2013, 110), and 'also found time to pray and to read the Koran' (Lawton and Moody 1986).[8] For Muslim astronauts who participated in missions for the former Soviet Union or Russia (on space station Mir), and for Anousheh Ansari, the first Muslim woman in space, with her self-funded mission to the International Space Station (ISS) in 2006, very little attention was paid to the religious aspect (Lewis 2013, 110–13). Only in 2007, anticipating astronaut and physician Sheikh Muszaphar Shukor's mission to the ISS, did the Malaysian government officially ask 150 Muslim jurists, scientists and astronauts for a legal opinion on guidelines regarding prayer and other Islamic practices by which Dr. Shukor would have to abide. These guidelines for missions in the ISS have been established and are an important, useful starting point for Muslims wishing to participate in space missions (A Guideline of Performing Ibadah at the International Space Station (ISS) 2007). This aspect is important because it also somehow legitimizes space travel, albeit limited to the ISS.[9]

From the point of view of the narratives and speeches accompanying this type of enterprise, we can see that the theme of modernity and progress prevails. We find nationalist views, but, as noted by Determann (2018, 15–16), these discourses are increasingly giving way to a focus on the global context and the well-being of humanity as a whole. A further aspect is the emphasis on Islam, with particular attention directed toward an audience of Muslim believers, both local and global, as seen, for example, in the media coverage of Dr. Shukor's mission (Shura TV 2009).

Identity models and narratives/representations are partly different, but partially overlap and interact with each other (for example, in many contexts 'Arab' and 'Muslim' tend to be considered synonyms): nationalisms, common religious faith and the broader reference to humanity. The idea of contributing to the good of humanity and the Earth, through the knowledge to be acquired from exploratory missions and the study of space, is a powerful argument used in favor of research in space. Particularly in an Islamic ethical context, as we shall later see in more detail, it is important to increase knowledge

[8] A slightly different description: 'Prince Sultan found a way to do everything, including fasting during Ramadan and praying three times a day' (NPR staff 2011).

[9] Regarding the importance of observance of Muslim religious rites, think also of Oktar (2023, 11), who states: 'Earth day and Martian day are almost the same, making Mars suitable for basic Islamic worship practices, such as fasting and prayer'.

of God's creation and also to develop technologies to be used on Earth, so as to promote welfare for mankind.

In this respect, the message published by the UAE after the landing of the Hope probe on Mars in 2021 is significant:

As the first Arab and Islamic probe to Mars, made up of an Emirati team who hold the highest scientific qualifications, we have become one of only five countries to successfully reach and study Mars. Not only are we immensely proud of what this means for the UAE's space on the global stage, but we are also pleased that we've been able to gather invaluable data that will give us deeper insights into solving issues on Earth, whether that be climate change or food security (Al Awadhi 2023).[10]

The idea that space research and exploration can contribute to the benefit of humanity falls within an Islamic ethical framework. On the other hand, the global horizon, understood as a 'global stage' where one can be present and recognized, may be seen as a terrain for cooperation but also for confrontation between nations and 'civilizations', to acquire scientific, cultural primacy, or bridge an alleged 'gap'. Furthermore, when viewed from a geopolitical perspective, space plays a fundamental strategic, as well as military, role. From this point of view, the reference to Islam in narratives and projects on space can take on a further aspect. As in the case, for example, of Oktar, who sees the exploration of space as a competition between religions/civilisations, thus introducing further considerations in favor of space travel and the settlement of Mars by Muslim astronauts and Muslim countries. Oktar underlines the religious aspect of previous narratives on the conquest of space, highlighting the comparison between American Protestant Christianity and Soviet atheism as the backdrop to the race to conquer space during the Cold War. In this framework, he speaks of a new technological '*jihād*', instead of the military one (although there is no agreement on the idea that *jihād* is to be understood as military): 'Muslims need to fully understand the necessities of the past, and present and understand that *jihad* is no longer armed warfare in the way of *Allah*, but through scientific and technological development' (Oktar 2023, 6).[11]

3. Space travel in the Islamic religio-ethical framework

So far, we have seen how projects and discourses on space involve Islam and Muslims (as such), and that, from this perspective, there does not seem to be a perceived conflict or a significant contradiction between the beliefs, values and rules of Islam and space exploration (as long as it does not endanger the lives of astronauts). When we shift to examining the foundations and the type of ethico-legal reasoning behind this lack of conflict, we can observe a general tendency to accept space missions and to seek solutions that allow Muslims to actively participate in them without having to forgo their religious obligations.

Knowledge and research are, in general, strongly encouraged in Islam[12], as long as they do not conflict with the religio-ethical framework of *sharīʿa*, which highlights the protection of life and the promotion of well-being and goodness. 'The principle that discoveries should contribute to the betterment of humanity is universally accepted'(Muhsin et al. 2024, 6). In general, the Islamic perspective on these points does not differ significantly from that found in other cultures, societies and religious sensibilities. Knowledge and research are encouraged and highly valued, but always within an ethical framework that balances and guides scientific progress toward the common good, with particular attention to the protection of life and human dignity.

[10] This article is titled 'The Arab world's first-ever planetary mission keeps making discoveries' (Al Awadhi 2023). The reference to the Arab world also appears in other reports: 'In 2015, the UAE announced its Mars Probe mission, which will send the Arab world's first spacecraft to the Red Planet in a scientific exploration mission that will land on planet in 2021' ("VP, Mohamed Bin Zayed Unveil 'Mars 2117 Project'" 2017).

[11] The influence of colonialist and orientalist propaganda and constructions make it necessary to emphasize what is widely recognized — namely, that Islam, both as a religion and as a civilization, is not in conflict with science and scientific research (including space exploration) but actively participates in it and contributes to it.

[12] Various passages in the sources may be recalled, such as 'Lord, increase me in knowledge!' (in Q 20:114).

Regarding space in particular, we can briefly outline some key points that may help define a framework. It should be noted that we are not engaging in rigorous legal reasoning here, but rather highlighting some relevant aspects to provide an overview of the types of arguments considered in the specific case of space exploration.

An important point that emerges concerns the inclusion of space and other planets within the horizon of revelation. Furthermore, through these and other references, the idea of the importance of exploring the universe to discover the signs of God is reinforced. There are various passages of this kind in the sources, which can, in light of the novelty of space travel, be interpreted in a new way. In Kalhoro's discussion, which summarizes some key aspects of this reflection, reference is made, for instance, to the verse, 'By His command He has made the night and day, the sun, Moon, and stars all of benefit to you. There truly are signs in this for those who use their reason' (Q 16:12). It 'highlights Allah's creation and control of the entire universe, including all of its elements, such as the stars, sun, and Moon' (Kalhoro 2023, 2) and encourages us to know the universe and recognize the signs of God.[13] Kalhoro here highlights an interpretation based on a vision of the universe which is, within the contemporary technical-scientific landscape, connected to space exploration. We can observe that the modern perspective allows for a new understanding of these (and other) references found in the sources. Kalhoro (2023, 2) emphasizes this connection, stating that, when you look at the entire universe, you see the importance of space exploration, which somehow brings humanity closer to God: 'Space exploration allows us to observe and comprehend these signs in greater depth'. The astronaut Sultan bin Salman himself spoke of his experience 'as enhancing his closeness with the Almighty' (Kalhoro 2023, 1).

Ruhaeni and Izadi (2020, 371) present a reflection that includes some of the considerations seen above and is centered on the idea of 'benefit' (maṣlaḥa) and the fact that God's commands aim to achieve prosperity and prevent harm. They explain that the concept of maṣlaḥa, 'as one of the approach methods in Islamic jurisprudence became indispensable to the development of the age, especially in the field of technology' (Ruhaeni and Izadi 2020, 372).

Ruhaeni and Izadi (2020, 371), through reference to verse Q 16:12, extend to space the idea that 'The creation of the earth with all its benefits is clearly intended for human benefit' (however, they specify the meaning thereof, by connecting it to the duties to be carried out to the fullest.) Through the developments of science and technology, humans are encouraged 'to utilize the facilities provided by God on earth' as well as 'to take advantage of what is in heaven (air space) and outer space' (Ruhaeni and Izadi 2020, 371). Furthermore, they recall the verse Q 55:33: 'Jinn and mankind, if you can pass beyond the regions of heaven and earth, then do so: you will not pass without Our authority,' and they point out that the present developments of space travel show that it requires an 'extraordinary effort in science' and 'huge expenses,' so that it can be said that 'the attempt to penetrate the sky and the earth for millions of years of light is impossible for the spirits and the human beings' (Ruhaeni and Izadi 2020, 371; see also Oktar 2023, 9).On the other hand, they highlight the aspect connected to worldly affairs. They highlight that space exploration has become 'an indispensable factor in the digital age' because of the technological development connected to it (with applications ranging from digital technology to the use of satellites for civil and military purposes). From this point of view, the development of science and technology linked to space exploration can be seen as intended for the benefit of public welfare and human life in general. They recall the *ḥadīth* 'You know more about your world,'[14] to highlight this different perspective and affirm that 'it is understandable that the exploration of heaven and earth for human benefit is not prohibited in Islam, but is strongly recommended' (Ruhaeni and Izadi 2020, 371). This is a general guideline on the perspective or criteria to be adopted: 'The

[13] 'Another of His signs is the creation of the heavens and earth, and the diversity of your languages and colours. There truly are signs in this for those who know' (Q 30:22).

[14] 'You have better knowledge (of a technical skill) in the affairs of the world.'(Ṣaḥīḥ Muslim, 2363).

development of science and technology, used in outer space exploration, (…) should be based on the concept of Benefits as Benefits is the essence of Islamic Law' (Ruhaeni and Izadi 2020, 372).

As mentioned, we refer to some highlights from these discussions to provide insights and reflections rather than elements of a rigorous ethico-legal analysis or a comprehensive examination. They are valuable in outlining the broader framework and drawing attention to specific aspects, but do not serve as definitive proofs of a thesis or as evidence of the superiority of one method or approach over another. We believe it is important to emphasize this point, as it highlights the potential for broadening the discussion and expanding the scope of inquiry.

Another important point concerns the prohibition of space travel and its underlying reasons. In fact, the projects to explore and settle on other planets are, or can be, very dangerous, and the protection of human life is a recognized priority unless there are issues of necessity and specific objectives that need to be carefully weighed up in each case. These are not merely theoretical cases: there are, as we know, projects that are already in the preparation phase, such as the important, ambitious one for the UAE to build a settlement on Mars (for 2117). This will certainly involve Arab and Muslim astronauts. In this respect, we can consider what happened regarding the Mars One project, a Dutch society, which in 2014 began recruiting aspiring astronauts for a one-way mission to Mars (which was later postponed). As the many who applied also included a large number of Muslims[15], it became necessary to question Muslim jurists for a legal opinion on the permissibility of participation in such a mission from a religious point of view. They questioned 'a fatwa committee under the United Arab Emirates' General Authority of Islamic Affairs and Endowment (GAIAE)' (Chowdhury 2014) and the opinion was negative, due to the dangerousness of the mission, which, in fact, displayed such high risks that it was comparable to suicide, which is forbidden (*ḥarām*). They pointed out that 'those who participate in the "hazardous trip" would be likely to die for no "righteous reason"' ("Mayday: Mars One Urges U-Turn on Islamic Fatwa" 2014).[16]

This legal opinion was taken very seriously by the organizers, who responded and asked for the fatwa to be withdrawn. They referred to the Qurʾān (30:22)[17], to show that it encourages one to explore and recognize God's signs; furthermore, they pointed to Ibn Battuta as an example ("Mayday: Mars One Urges U-Turn on Islamic Fatwa" 2014). They also addressed the argument about risks, on the basis that Earth exploration is also risky. Moreover, human astronauts would not be sent to Mars before a secure base was established and, above all, before intelligent (robotic) machines prepared the settlement: 'Robotic unmanned vehicles,' writes Mars One Mission, 'will prepare the habitable settlement. Water and a breathable atmosphere will be produced inside the habitat and the settlement will be operational for two years, even before the first crew leaves Earth' ("Mayday: Mars One Urges U-Turn on Islamic Fatwa" 2014; see also Fossett 2014).

With this, we have observed a type of tension that is likely to grow. In fact, over time, the risks will probably decrease (and become more controllable), making missions to other planets that may seem like 'suicide ones' today appear worth pursuing, supporting and appropriately funding. This is probably the reasoning behind the continuation of the UAE project and of the training of astronauts in Houston HERA (NASA's Human Exploration Research Analog).

However, specialists and scientists currently predict that successful exploration and settlement missions are likely to require genome editing and other practices, primarily to protect the lives of astronauts. In this framework, the question of outer space exploration

[15] 'Over 200,000 applications from 140 countries volunteered to participate in the mission, including 500 Saudis and other Arabs' ("Mayday: Mars One Urges U-Turn on Islamic Fatwa" 2014).

[16] A similar consideration has also been given toward space tourism (Kalhoro 2023, 1).

[17] 'Another of His signs is the creation of the heavens and earth, and the diversity of your languages and colours. There truly are signs in this for those who know.' (Q 30:22)

and colonization intertwines with the issue of Islamic bioethics and the debate on Transhumanism.[18] These issues are already under discussion, but they have not yet been incorporated into the perspective of space travel, which introduces further nuances and complexities. Addressing different contexts, means and goals can, at least in part, lead to different conclusions. In the following pages, we will present an example of how this discussion can be developed, starting from the ongoing ethico-legal debate in Islamic bioethics.

4. Islam and genetically modified astronauts

We have seen that there is a general tendency to admit space travel and space exploration programs as permissible or even encouraged within the framework of the Islamic religio-ethical system, under certain conditions, such as not exposing oneself to the risk of losing one's life without a righteous reason.[19] However, it remains uncertain whether such endeavors align with Islamic ethics, if we consider projects that look even further into the future, such as the building of new human settlements on other planets. This issue becomes particularly relevant given the current technological limitations in protecting astronauts from radiation, harsh climates and reduced gravity on other planets (Balistreri and Umbrello 2023; Szocik and Braddock 2019). Indeed, the risk to the life and safety of astronauts becomes very high. To address these challenges, genetic modifications for astronauts, combined with terraforming efforts, may be necessary (Szocik 2023). This raises significant ethical questions within Islam, particularly concerning genetic interventions, assisted reproduction and the potential development of embryos in artificial wombs instead of human bodies. Now we explore these ethical concerns in the context of space exploration and settlement.

4.1.Human enhancement

As we mentioned, it is likely that the longer space journeys become, the more the astronauts involved will need to undergo genetic modification interventions before departure, as our bodies are not suited to living on other planets (Balistreri 2025). However, even though initially genetic modification interventions will be conducted only on adults and thus limited to the somatic line, it can be imagined that, over time, they will also be applied to the germline (Szocik 2023), as children born in space will need protection from environmental conditions that could otherwise endanger their survival.

The mainstream position among Muslim religious scholars does not hold any principled objection to genetic modification interventions—this applies not only to somatic modifications but also to the more controversial germline modifications. In fact, the (clear) prohibition against manipulating creation must be balanced against the duty to alleviate (individuals') disease and suffering, as well as, naturally, to protect human life (International Islamic Fiqh Academy 2013; Isa, Zulkifli, and Man 2020).[20] In these terms, genome editing interventions of a therapeutic nature may constitute a 'positive' modification of creation (even though they obviously involve intervention on the human body), just like any surgical or therapeutic practice (e.g. appendectomy, tonsillectomy, etc.) (Atighetchi 2002; Ghaly 2019b). The problem arises only when the intervention goes beyond its (exclusively) therapeutic purpose and aims to produce an enhancement (i.e., to exceed the typical capacities of a human being). Therapy aims to restore or enable the achievement of a baseline level of functioning, addressing limitations or challenges,

[18] There are positions showing the possibility of coming to terms with Transhumanism by reinterpreting the doctrines and texts, while others consider them far too clear on this topic to leave any room for new, 'softer' interpretations (Bouzenita 2018; Can 2023).

[19] 'Islamic scholars consider various factors when issuing a ruling on space exploration. The intent of the journey comes first, followed by a consideration of the advantages and disadvantages for the individual. The third is to follow Islamic practises in outer space, and the fourth is to respect Allah's creation and his manifestations' (Kalhoro 2023, 2).

[20] Of course, even among Muslim scholars, the prevailing position on genome editing on the human germ line is in favour of a moratorium, at least until the technology can be considered sufficiently safe.

whereas enhancement surpasses this threshold, seeking to improve capacities beyond that which is commonly observed in human beings (Agar 2010; 2013).[21]

In this case, the prevailing position in Islamic bioethics is, in fact, that such modification can never be positive (i.e. moral), since it does not serve a therapeutic purpose and radically transforms the design of creation (International Islamic Fiqh Academy 2013; Ghaly 2019a).[22] This would, in other words, be non-essential change and at best mere 'embellishment' (Isa, Zulkifli, and Man 2020). Moreover, those defending this position argue that the human being is already perfect in the form in which it was created[23] and does not, therefore, require any further modification on our part. Indeed, due to their perfection (and the fact that they were created by God), human beings should not alter themselves, but rather preserve their 'natural' condition.[24] Furthermore, human limitations should not be altered or enhanced, as imperfection is part of the divine plan (Q4:28) and constitutes the essence of human nature (Suleman 2022). Improvement should focus on the moral aspect rather than the physical one, as perfection does not reside in the body but in character (Can 2023; Bouzenita 2024). From this perspective, any enhancement would therefore be considered a mutilation that undermines the capacity to act morally, as enhanced beings would perceive of themselves as self-sufficient and invulnerable, neglecting their concern for others (Kam 2023). Moreover, such actions would always represent an act of arrogance on the part of those who have no right to do so but wish to place themselves on the same level as God, thereby arrogating to themselves the right to create, manipulate or influence life.

According to some views, however, enhancement interventions would not be incompatible with Islamic ethics (and even transhumanism could be considered acceptable), as there would be nothing wrong with desiring to improve one's abilities or dispositions. On the contrary, resorting to enhancement could contribute to achieving personal goals, the welfare of the community and the realization of moral progress and justice. According to Kam (2023), who introduces reflections inspired by Islamic theology (*kalām*), one might argue that, if everything that happens in the world occurs with God's permission (as the Qurʾān clearly emphasizes in verses 6:59; 81:29; 92:13), then it could be more challenging to present principled reasons against human enhancement. Acting responsibly while considering the consequences of our actions on social welfare, justice and peace is appropriate, but this should not exclude the possibility of using interventions that can improve our dispositions. The idea that Islam could be compatible with a redesign of humanity is also defended by (Jackson 2020), who asserts that we have a duty to use technologies to eliminate pain, suffering, poverty and injustice (Kam 2023). Currently, however, the positions advocating the permissibility of human enhancement remain marginal in the Islamic debate, where perspectives that view transhumanist projects as incompatible with the Islamic ethical framework prevail (Kam 2023; Bouzenita 2024).

Strictly speaking, at present, the genetic modification of astronauts cannot be justified by arguing that it is necessary because it allows them to survive in an otherwise lethal environment (Balistreri and Umbrello 2022a; 2022b). Enhancement interventions designed for space missions cannot be considered absolutely necessary, as astronauts would only need to be genetically 'enhanced' if they voluntarily agreed to participate in the mission and undergo such procedures. If space programs were canceled, astronauts

[21] According to Agar (2010, 19), 'the modification of a human capacity counts as an enhancement only if it enhances beyond human norms. The norms in question are biological.'

[22] As Ghaly (Ghaly 2019a) recalls, this position has been adopted by the three transnational Muslim institutions: IOMS (The Islamic Organisation for Medical Sciences), IFA (Islamic Fiqh Academy) and IIFA (International Islamic Fiqh Academy).

[23] Here the Qur'anic passage quoted is 'Surely, we created man in the best of the molds' (Q 95:4) (Ghaly 2019a, 48; Isa, Zulkifli, and Man 2020; Serour et al. 2023).

[24] According to some Muslim scholars, the perfection of the human being should be understood as a mixture and a right balance of positive and negative elements, as in this way we can achieve our goals without falling into arrogance (Isa, Zulkifli, and Man 2020).

would not require any enhancements, as they would remain on Earth and continue to live without such modifications.

In any case, even if we were to consider the genetic modifications necessary for astronauts to survive in space as therapeutic rather than enhancing (Garasic 2021; Gouw 2020; Rappaport and Corbally 2020), we must still take into account that any genetic modification program would, in fact, initiate a process of transformation—one that could become increasingly radical over time—of our species. The result could, that is, be a radical transformation of God's creation and, therefore, a morally 'negative' modification (change) in the light of Islamic ethics (Atighetchi 2007, 237). Moreover, the radical and deliberate transformation of human nature could also represent a serious neglect of the duty to protect human life, as it may have unintended negative consequences for both those directly involved (Agar 2010; 2013) and future generations living on Earth (Balistreri 2025).

However, we can observe that the discussion has not yet addressed the issue of space exploration and settlement programs and the fact that these will be likely to require genetically enhanced astronauts. This different perspective necessitates a deeper debate and a thorough examination of ethical-legal reasoning, as fundamental elements, such as goals, motivations, technical knowledge, potential benefits and necessity, appear in a new light. Furthermore, the issue must be assessed on a case-by-case basis, considering both the specific context and broader implications. It may require increasing cooperation among various experts, including Islamic religious scholars, scientists and specialists in society, economics, politics and geopolitics. The fact that only physically, psychologically and perhaps even morally enhanced astronauts would probably be capable of enduring long-term space missions must be taken into account and weighed up alongside other significant factors and frameworks. Additionally, it is crucial to acknowledge that, without enhancements, reaching the Moon may be feasible, but constructing new settlements beyond Earth's orbit would remain forever out of reach (Szocik and Braddock 2019). For example, one could argue that, for prolonged missions beyond Earth's orbit that are considered vital (e.g., resource exploitation, military and space geopolitics or even humanity's survival), the use of pharmacological enhancement treatments or genetic modifications in space could be deemed necessary and therefore permissible. In other words, in such cases, enhancement and other practices could be justified under the principle of necessity (*ḍarūra*). This means they would fall under legal exemptions that override the ruling of something being '*ḥarām*' (forbidden) when exceptional circumstances arise. This would follow the same principle as the permissibility of eating pork in the desert if no other food is available for survival (Ilkilic 2002).

4.2. Reproduction in space

Apart from issues strictly relating to genetic modification interventions, space exploration and settlement could still rely on reproductive technologies that may be, at the very least, controversial.The new settlements that we create on other planets (or on ever larger space stations) will only be able to become stable and prosperous communities if they are capable of maintaining or increasing the number of inhabitants required to perform the various activities and functions within the community. In space, though, sexual reproduction may be unsuccessful or, in any case, less successful than assisted reproduction – regardless of the reproductive technique used (Balistreri 2025). In this case, the best scenario we can imagine is one in which people wishing to have a child in the new settlement realise this project of theirs by using their own gametes (Szocik 2023). We do not yet know, however, whether exposure to cosmic radiation and environmental conditions (e.g. the reduced gravitational pull or particularly low temperatures) on other planets could in the long run have irreversible consequences on astronauts' reproductive capabilities. It is, after all, possible that a relatively long stay on another planet reduces (or brings to zero) the possibility of having offspring with their own gametes, regardless of the technique employed (Ronca et al. 2014; Watkins 2020; Balistreri 2023). Moreover, even if the colonists retain the same reproductive capacity as they had on leaving the Earth, it is

possible that, after a long stay in space, the risk of transmitting serious genetic abnormalities increases for those wishing to have a child with their gametes (Szocik 2023).[25] In such cases, the only way to have a healthy child—rather than one with genetic abnormalities—would be to resort to assisted reproduction techniques, produce a certain number of embryos and ultimately select those that do not present genetic abnormalities. The fact that assisted reproduction techniques might need to be used in space does not pose a problem for Islamic ethics, as, from this perspective, it is permissible to use reproductive technologies when sexual reproduction is not possible: 'The overwhelming majority of Muslim religious scholars and biomedical scientists argued that ARTs should be approached as a medical means for treating infertility, making it morally neutral, or even commended' (Ghaly et al. 2020, 26). This is an important difference in comparison with the perspective of the Catholic religion, which in contrast holds a principled stance against any use of reproductive technologies (Balistreri 2025).

In space, however, the use of assisted reproduction would not be an exception (in a population where the majority of people continue to reproduce sexually) but rather a necessity for all those who wish to have a child. It is therefore legitimate to ask whether this change could alter the self-perception of individuals living on another planet and their relationship with technology, and, ultimately, influence the very concept of family and parenthood in the long term. In this case, it would represent a morally significant transformation that the Islamic perspective would also need to face and critically reflect upon.

If we hypothesize that, in space, it may — due to the risk of genetic abnormalities — be necessary to resort not only to assisted reproduction techniques but also to pre-implantation genetic diagnosis, the selection and destruction of embryos could become a problem. From the Islamic perspective, the embryo is not considered a person before ensoulment. However, this does not mean that we can do whatever we wish to with the embryo (including discarding or destroying it if it does not present certain genetic characteristics). Most jurists argue that, before the 120th day, there must be valid reasons to justify abortion, while others claim that no specific reasons are needed (Atighetchi 2007, 95). However, some jurists maintain that, even before the 120th day, abortion is not permitted because the embryo should be treated as a person from the moment of conception[26] (Muhsin, Chin, and Padela 2024).

In the case of embryo selection, no genetic modification takes place, which might suggest that this practice does not interfere with creation. However, it should be noted that the intention behind this intervention is not therapeutic but rather enhancement-focused: 'In this case, the aim of PGT-P is neither to cure genetic diseases or to prevent transmitting them to the offspring. The purpose is rather to optimize the prospective child's intelligence and other socially desirable traits' (Chin et al. 2024, 443).[27] Moreover, the use of embryo selection practices could encourage parents to rely on genetic testing and abandon sexual reproduction in favor of assisted reproduction, with the imaginable consequences for women who would have to undergo multiple IVF cycles (Chin 2022). Consequently, the Islamic legal maxim of avoiding harm (*ḍarar*) would not be upheld.

However, this issue might not arise in space, as individuals could face difficulties in reproducing sexually or might prefer not to take the risks associated with it.

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[25] The possibility of developing gametes directly from one's own somatic cells, transforming them first into induced pluripotent stem cells and then into sperm or oocytes, could be an alternative solution for people who desire a child but for some reason suffer from infertility/sterility problems and cannot have a biological one. Islamic ethics does not have any principled stance against the use of so-called artificial gametes for reproductive purposes (Serour et al. 2023), but, as we said, one can also imagine that, after long periods in space, cosmic radiation (and the extraterrestrial environment) could render both gametes and somatic cells unusable.

[26] In one *ḥadīth* (Ṣaḥīḥ al-Bukhārī, 549), the soul is blown into the fetus after 120 days, whilst another one (Ṣaḥīḥ Muslim, 2645) describes the angel shaping the fetus and determining its gender, age, livelihood and destiny after 42 nights, emphasizing God's will in creation and human fate (Muhsin, Chin, and Padela 2023, 7).

[27] In summary, it has been observed (Chin et al. 2024) that the objectives of Islamic law – preserving life, intellect, and offspring – are not fully upheld in this case, as no life is being saved, and mental retardation or birth defects are not being prevented.

Additionally, in space, embryo selection might become necessary because the risk of transmitting significant genetic abnormalities to offspring is very high. In most cases, it is also possible that the discarded embryos would not have developed successfully in any case, or that the individuals destined to be born would not be capable of surviving. In this case, the decision to screen and select embryos could be seen as a sign of moral sensitivity toward the offspring being brought into the world. Contrary to that which Chin et al. (2024) argue, the use of embryo selection does not necessarily imply that parents are incapable of loving their children (i.e., the children they might later bring into the world) unconditionally (Sandel 2007).

Other issues also arise if people living in space cannot use their own gametes to reproduce (due to radiation exposure causing uncorrectable genetic abnormalities) and must rely on donor gametes from Earth (Balistreri 2023; Balistreri and Umbrello 2022a; Szocik 2023). Receiving gametes from Earth would not pose a logistical problem, as one can imagine that the new settlement would still maintain a relationship with—and be economically, politically and technologically dependent on—the mother country, which could also ship cryopreserved gametes to the settlers along with other essential goods (Balistreri and Umbrello 2024; Garasic 2024). However, from the Islamic perspective, the use of donor gametes is not permitted. As Atighetchi (2007, 102) states, 'For Islam, the offspring, regardless of the type of fertilization, must be the fruit of the biological and legally married father and mother. Adoption is illegal.' Furthermore, Atighetchi (2007, 102) adds that interventions involving donor gametes are unacceptable, as 'any man agreeing that his wife be inseminated with another man's sperm is a despicable person, as he allows his wife's dignity to be violated'.

Resorting to reproductive technologies that do not involve the fertilization of the oocyte, such as parthenogenesis and cloning (Devolder 2022; Savulescu 1999), or those based on the production of 'synthetic' embryos (Pereira Daoud et al. 2024) would not be permitted. Such technologies are still in the experimental phase and have not yet been fully developed, but this might change in the future (Greely 2016; Horn 2023). However, the possibility of using these technologies in space could prove crucial, as we do not yet know if the fertilization of mammals is possible in space. So far, attempts conducted in low orbit have not yielded positive results. For this reason, being able to rely on reproductive technologies that do not depend on fertilization could be necessary for the long-term survival of any space mission (aiming not only to explore but also to establish new settlements). Furthermore, combining these technologies with genome editing interventions could make it easier to obtain embryos with programmed genetic characteristics, as genetic modification could be performed on a large number of cells, using only those where the intervention was successful for reproduction. In this way, it would not only be easier to bring into the world individuals with the best genetic traits to face the challenges of extremely difficult habitats (for instance, increased resistance to radiation, enhanced ability to adapt to reduced or zero gravity, and a more efficient metabolism to utilize limited resources), but it would also eliminate the need to produce a large number of embryos and then select among them, discarding those with abnormalities or those lacking the desired modification.

However, the prevailing conviction in Islamic ethics is that such technologies, which make it possible to create an embryo without fertilization, would primarily jeopardize the stability of the family as a social institution, as there would no longer be any need for a man and a woman to have a child: 'Marriage becomes unnecessary in view of procreation through cloning; the egg and the womb belong to the woman and are sufficient for reproduction to the point that the presence of the male is no longer necessary' (Atighetchi 2007, 102). There are also concerns about possible negative consequences for the well-being of the family, as this would introduce role-confusing elements, as the child coming into the world would not only be the offspring of the parent who provided the cells (whether for parthenogenesis, cloning or stem cell production), but also their twin. 'Can' – write Muhsin et al. (2024, 12) –'the stem cell donor be considered a father, mother, or sibling? (ii) Without having two parents of the

opposite sex in the form of a father and mother, who is this individual, and to which lineage does he/she belong?'.[28] There are further concerns that the use of such technologies could constitute an unacceptable manipulation of creation. According to Muhsin et al. (2024), the dignity of the child-to-be could be compromised, as there may be negative psychological and identity-related effects. Additionally, it is uncertain whether these forms of reproduction, which bypass fertilization, could be effective reproductive solutions (or more effective than sexual reproduction or assisted fertilization), as the cells used in these cases may also have been exposed to radiation and developed genetic abnormalities. In the case of parthenogenesis, egg cells would still need to be used, and these would also be necessary for performing reproductive cloning interventions.

4.3. Artificial Womb

Finally, even if the population of a new space settlement were able to reproduce without the need for donor gametes, both pregnancy and childbirth could endanger not only the unborn child but also the woman (Kendal 2022). That is, we can imagine that people living on Mars or the Moon could have children using their own gametes or by importing their cryopreserved gametes stored on Earth prior to their departure for space. However, the problem of pregnancy and childbirth would still remain (Kendal 2024). In space, with reduced or completely absent gravity, carrying a pregnancy to term or giving birth could be very risky for women.

Moreover, from the perspective of a small settlement, pregnancy would significantly limit the crew's capacity for several months, as one member would need to focus on rest and minimizing risks to the unborn child, thus reducing their active contribution to the mission. An artificial womb could therefore represent the ideal solution for reproduction in space. This technology would not only relieve women of a particularly burdensome responsibility in such an environment, but also provide greater control over reproduction (Smajdor 2007). With an artificial uterus, surgical interventions on embryos would be simpler and non-invasive for women. Moreover, an artificial uterus would enable timely genome editing of the germline during the early stages of embryonic development, as the embryo's genome could be analyzed and modified immediately after conception (Balistreri 2025).

However, in the current debate within Islamic bioethics, the artificial womb remains a highly controversial technology. The primary concern is that the artificial uterus might compromise the ensoulment of the embryo, which, according to Islamic tradition, occurs between the 40th and 120th day, or that it could in some way interfere with the natural gestational process (Ghaly 2012). However, the use of the artificial uterus can be morally justified by the principle of beneficence, as with other devices employed in medicine (Muhsin, Chin, and Padela 2023). Indeed, it 'could represent a complementary support (*ḥājiyyāt*), if not even essential (*ḍarūriyāt*), to enable motherhood for women without a functional uterus due to illness or congenital deformities, or who face severe medical risks during pregnancy, considering that surrogacy is prohibited in the Sunni tradition of Islam' (Muhsin, Chin, and Padela 2023). Moreover, the artificial uterus can help save very premature babies (by providing vital support) or assist women who are unable to have children or whose pregnancy and childbirth would pose significant risks to their health (AlJahsh 2024). Unlike in surrogacy, the artificial uterus does not involve other individuals who might compromise the sanctity of the marital bond or create confusion in familial relationships (Muhsin, Chin, and Padela 2023; AlJahsh 2024).

On the other hand, the use of the artificial womb could be incompatible with the value that Islam places on motherhood and the suffering a woman endures during pregnancy and childbirth, in a framework where the conception of motherhood is intrinsically tied to childbirth (Muhsin, Chin, and Padela 2023): no one can be considered a mother except the one who gave birth to them (Q 58:2). Moreover, as Muhsin et al.

[28] In summary, this would go against one of the five objectives of Islamic law (*maqāṣid al-sharīʿa*), which emphasizes the protection of family and lineage (Muhsin, Chin, and Padela 2023, 12).

(2023) remind us, the Qurʾān describes the woman's womb as the secure place where the child will develop (Q 23:12–14). It has also been observed (Muhsin, Chin, and Padela 2023, 8) that the potential widespread adoption of artificial wombs would affect Islamic precepts relating to the conventional heterosexual family. Once birth is no longer (biologically) tied to childbirth, even a single man or a gay couple could conceive a child.

Given these premises, it is debatable whether its use can be considered morally acceptable in space. This might indeed be permitted in situations of extreme necessity, but it does not appear morally acceptable when the woman is fertile and in perfect health:

> Our analysis suggests that its application may be contingently permissible (halal) in situations of dire need such as sustaining life and development of extremely premature newborns, for advancing fetal medicine and avoiding maternal co-morbidities during fetal treatment, and for enabling motherhood for women without functional wombs, or who face grave medical risks in pregnancy. However, its application may be proscribed (haram) for enabling healthy women to avoid pregnancy and childbirth, or to achieve parenthood equity (Muhsin, Chin, and Padela 2023, 1).

It is true that, in space, requesting an artificial womb might seem unavoidable, as the extreme conditions and health risks could endanger both the woman and the unborn child. Therefore, it would appear to be a situation of extreme necessity. Nonetheless, a healthy woman could choose to postpone pregnancy, either by completing her mission and giving birth after returning to Earth or by deciding not to pursue a life in space at all. Perhaps women born on Mars or the Moon might justifiably claim to be in a condition of necessity, as they did not choose to live in space and may not even have the option to return to Earth one day.[29] Women who come from Earth and (at least initially) have the option to return there are in a different situation and have more choices. Women from Earth, on the other hand, can decide whether to participate in a long mission or a shorter one, and they also have the possibility of returning to the planet, thus enjoying greater freedom of choice regarding motherhood and its implications.

Moreover, from another perspective, one could argue that acknowledging the moral legitimacy of using artificial wombs for healthy women in space (on Mars or the Moon) makes it increasingly difficult to justify prohibiting ectogenesis for healthy (and fertile) women on Earth. Even on Earth, women may find themselves in situations of necessity—not only due to an increased risk of illness or complications from pregnancy or childbirth, but also because of professional commitments that may be incompatible with pregnancy or conception. One could argue that, if exceptions are allowed for space, they should also be permitted for Earth. Indeed, the idea that a different moral standard could be applied in space in comparison with that accepted on Earth (Garasic 2021; 2024) would not only be inconsistent, but also a policy that would be difficult, if not impossible, to enforce (Balistreri and Umbrello 2022b). For instance, the more women in space rely on artificial wombs, the more people on Earth will become accustomed to the idea that the birth of a human being can occur without the need for a (human) body and natural gestation.

5. Conclusions

In the first part, we pointed out the development and implementation of increasingly ambitious space exploration projects by Muslim-majority countries, as well as the involvement of Muslim astronauts in several missions. We mentioned some positions and reflections that have emerged in relation to this, such as a fatwa with instructions on how to perform Muslim rites in space. We observed, very generally, that at present for some Muslim scholars, space travel can, within the framework of Islamic moral principles, be considered acceptable and, in some cases, even encouraged.

In the second part, we explored various hypotheses and demonstrated how discussions and debates could evolve in response to new challenges posed by space exploration. We did so by drawing on existing discussions and positions in the field of

[29] Indeed, if people born in space were genetically modified, they might not be biologically suited to live and survive on Earth.

Islamic bioethics, highlighting how the overall framework becomes more complex and enriched when considered from the perspective of space travel.

With regard to space travel and exploration, it can be affirmed that it is not excluded and can in some cases even be held to be encouraged within the Islamic ethical framework, under certain specific conditions. However, we have seen that space exploration can pose a major challenge to Islamic ethics, as it may require human enhancement (re-engineering human nature) and the use of new reproductive technologies that are questionable or even unacceptable from the perspective of most Muslim scholars. We believe that these issues certainly require new thinking about genome editing interventions and new reproductive technologies. This touches upon the limits of manipulating creation and humanity, as well as the very definition of what it means to be human. At the same time, the discussion on space travel should not be limited to the framework of space bioethics that has been referenced so far. The bioethical issues posed by space travel are unique and cannot simply be assimilated into the specific bioethical concerns typically discussed on Earth. In space, these concerns take on an entirely new dimension and open up unprecedented scenarios that require broader, deeper ethical reflection. Issues relating to survival, reproduction, genetic modification and human adaptation in space go beyond conventional bioethical debates and demand new analytical models that consider the long-term implications of expanding human presence beyond Earth.

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