# Transforming outer space transportation through immersive technologies: a SWOT analysis

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**Abstract:** This study provides a SWOT analysis of immersive technologies, specifically Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR), in relation to space transportation. Immersive technologies have completely transformed astronaut training, spacecraft design, and public involvement in space. They provide notable benefits such expanded simulation capabilities, cost-effective training, and improved safety and efficiency. Notwithstanding these advantages, obstacles such as substantial implementation expenses, technological constraints, and user opposition persist. The study highlights favorable prospects for innovation and global cooperation, while also acknowledging possible hazards such as cybersecurity vulnerabilities, information saturation, and the swift obsolescence of technology. Organizations involved in outer space affairs may improve mission effectiveness and safety by strategically utilizing the strengths and potential of immersive technology, while also addressing their shortcomings and risks. This will promote further progress in space exploration. This research highlights the crucial significance of immersive technology in determining the future of space exploration.

**Keywords:** Immersive technologies, Virtual Reality (VR), Augmented Reality (AR), Mixed Reality (MR), SWOT Analysis.

# Transformarea transportului spațial prin tehnologii imersive: o analiză SWOT

**Rezumat**: Acest studiu oferă o analiză SWOT a tehnologiilor imersive, în special Realitatea Virtuală (VR), Realitatea Augmentată (AR) și Realitatea Mixtă (MR), în legătură cu transportul spațial. Tehnologiile imersive au transformat complet pregătirea astronauților, designul navelor spațiale și implicarea publicului în domeniul spațial. Ele oferă beneficii notabile, cum ar fi extinderea capacităților de simulare, antrenamente mai eficiente din punctul de vedere al costurilor și îmbunătățirea siguranței și eficienței. În ciuda acestor avantaje, există obstacole, precum costurile semnificative de implementare, constrângerile tehnologice și opoziția utilizatorilor. Studiul subliniază perspective favorabile pentru inovație și cooperare globală, dar, în același timp, recunoaște și posibilele pericole, cum ar fi vulnerabilitățile cibernetice, saturația informațională și obsolescența rapidă a tehnologiei. Organizațiile implicate în afacerile spațiale pot îmbunătăți eficiența și siguranța misiunilor, prin utilizarea strategică a punctelor forte și a potențialului tehnologiilor imersive, abordând. totodată. deficiențele și riscurile acestora. Aceasta va promova un progres continuu în explorarea spațială. Cercetarea evidențiază semnificația crucială a tehnologiilor imersive în modelarea viitorului explorării spațiale.

**Cuvinte cheie**: Tehnologii imersive, Realitate Virtuală (VR), Realitate Augmentată (AR), Realitate Mixtă (MR), Turism spațial, Explorare spațială, Antrenament pentru astronauți, Designul navelor spațiale, Analiză SWOT.

## 1. Introduction

This paper considers how some of the applications of immersive technologies — such as mixed reality (MR), augmented reality (AR), and virtual reality (VR) – can be used to improve space transportation, including human spaceflight. Through a comprehensive SWOT analysis, the paper elaborates on the strengths, weaknesses, opportunities and threats of these technologies. By discussing these aspects that immersive technologies present for space exploration, this study contributes to a better understanding of how they can be integrated within it. Although VR has revolutionized public outreach, spacecraft engineering and astronaut training already, AR/MR is set

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to provide fresh and distinctive possibilities when it comes to safety procedures in orbit, the preparation of astronauts for these tasks, as well as the space tourism experiences. SpaceX, for example, utilizes virtual reality (VR) when designing spacecraft to improve safety and expedite development practices (Craig, 2020). The “Pilote” study by the ESA and CNES incorporates VR, haptic interfaces to teleoperate arms used on space vehicles at a distance, as well as workspace ergonomics for future missions (NASA, 2021).

This allows the developers of AR applications to set digital information over objects in real life, which improves data gathering and decision-making amongst many disciplines, such as tourism and environmental protection; for instance, applications like CapeOutdoors3D which expand the Earth Observation capabilities and improves real-time navigation data (ESA, 2017). These technologies are essential to managing wildlife parks, wildfires, as well as visitor experiences in national parks, but also health care and emergency response (Spacewatch Europe, 2024).

Companies in the field of space tourism use virtual reality as well, allowing people to participate such experiences like a virtual 360º VR Space Safari which helps facilitate the interest for outer-space exploration and missions (Ørsted, 2024). These VR experiences expose children to space exploration and inspire a new generation of explorers.

Applications of immersive technologies in critical space infrastructure help to improve different processes such as planning, design and maintenance, monitoring and diagnostics. To simulate the harsh conditions in space for training, immersive technologies allow astronauts to practice difficult maneuvers without risking their safety (NASA, 2024). AR allows for real-time equipment maintenance instructions, leading to fewer mistakes and keeping systems operational (ESA, 2024). MR allows for the collaborative participation of ground teams and space crews in real-time, combining virtual elements with reality to achieve improved training coverage and operational efficiency (Paré, 2022).

For routine environment scanning and field operations, NASA uses VR for simulation training and repair practice on the International Space Station (ISS), while the ESA uses VR for mission planning and crew training, improving overall space operations effectiveness (ESA, 2024; Hille, 2024). Industries that use VR and AR, including SpaceX and Blue Origin, are promoting both safety and innovation in space telemetry. These are the virtual/augmented realities and immersive technologies that take space exploration into yet another bold phase in human history, revolutionizing not just the operations that take place in outer regions of space, but also the participating experience for public audiences, as well as facilitating training advances, and public design participation alongside operations, whereas enhancing mission’s efficiency and safety.

Given that space tourism evolved from a theoretical idea into a booming business, one might argue that it is just an extension of traditional space flight. Historically, the primary goals of space missions have been exploration, research, and national defense. On the other hand, by providing the general people with access to orbital and suborbital space travel experiences, space tourism is altering this paradigm. Contrarily, space tourism is redefining this paradigm, by giving the general public access to orbital and suborbital space flight experiences. This emerging sector modifies rocket launch vehicles and spacecraft, among other fundamental technologies used in conventional space transportation, to meet the demands of civilian passengers (Chang, 2020; Schweinsberg & Fennell, 2024).

Space tourism is a rapidly growing sector which comes with both opportunities and challenges. Immersion technologies such as mixed reality (MR), augmented reality (AR) and virtual reality (VR) offer both new exciting ways to train astronauts and potential safety procedure improvements in space humans' experience. These tools can offer basic training in run up to real missions that replicate the unique conditions associated with space travel (Bingham et al., 2024; Nilsson et al., 2023). Thus, as an extension of space transportation, framing space tourism highlights the critical role that immersive technologies will play in shaping the future of commercial space travel and broader space operations.

Section 2 delves into the use of immersive technologies in space transportation, highlighting the applications of VR, AR, and MR in astronaut training and mission planning. Section 3 provides a detailed SWOT analysis, outlining the strengths, challenges, and opportunities these technologies present within the context of space exploration. In Section 4, the key aspects and implications of these technologies for future space operations are discussed. Finally, Section 5 concludes the paper by emphasizing future research directions and the critical role of international collaboration in integrating immersive technologies into space transportation.

## 2. Immersive technologies in space transportation

While immersive technologies have demonstrated added value in several business sectors, their use within the operations context is rather new when taking into account the outer space. Space operational immersive systems are of interest due to their proposed benefits, yet little scientific, technical and behavioral research has been presented.

The Prototype Immersive Experiences (PIE) effort led by NASA seeks to design, assess and prototype operations concepts. In 2023, the lab designed a new set of programs named Digital Lunar Exploration Sites and Lunar Assessment with VR Assets that was tested for using Unity, Unreal Engine, DOUG Engine (real-time visualization tools) (Garcia, 2023).

One of the primary ways that immersive technologies will be used in space transportation is for training astronauts. Astronaut training is typically conducted using physical simulators and real-world analogs. VR/AR solutions can be more flexible, economical and scalable. By simulating mission scenarios, VR allows astronauts to rehearse tricky maneuvers, such as docking and extravehicular activities (EVAs) or emergency procedures, without the restrictions of physic-based sims. These simulations depict zero-gravity environments and spacecraft layouts in exacting detail, making the practices virtually indistinguishable from real events.

AR is also being tested to expedite real-time decision making and efficient operations at the time of missions. This type of data overlay is key when astronauts are performing hands-on tasks, as AR headsets can display instructions on how to do things – repairing a system step by step; diagnosing issues within any given mechanical or electrical system onboard the spacecraft in real time and closely monitoring health indicators directly onto wearables like rings. This ability helps people reduce the time they need to think about decisions and prevent human errors during a difficult task. For instance, AR could be used during ISS maintenance to provide reference material and warnings for individual components of complex procedures.

In other words, immersive technologies have reached a point where they can add tremendous value in the spaceship design and prototyping process. For example, companies like SpaceX and Blue Origin heavily utilize VR/AR in their design workflows. Thanks to these capabilities, engineers can view parts of spacecraft in a virtual world and find errors or determine an ideal configuration before anything ever gets physical built. This method of work speeds up the design process and leads to more secure, reliable spacecraft, because they can be put through simulated tests thousands or millions of times.

And, more than that, enhanced by the emerging technologies of tele-presence performance in space, VR platforms enable researchers, technicians and mission planners in different countries to operate together within a single virtual realm. It is especially useful in multinational missions, as communication and coordination are vital for success. Through virtual spaces, teams can conduct simulations together, simply review mission plans and collaborate in a decision-making process more effectively than through regular teleconference methods.

However, despite these advances, there are a number of continuing challenges. While drift toward immersion continues, high cost to develop and implement these technologies can be the stumbling block for a lot of organizations. Low-latency visuals, and high-res displays that require heavy-duty computing hardware to run the simulations obviously present their own set of technical red tapes. Furthermore, long term use of VR and AR can lead to mystical discomfort or vertigo, hence the need of studies for deeper behavioral adaptation.

Cybersecurity is also a major problem, just like this use of immersive technologies within space operations adds new aspects to cyberattacks. As a result, being able to secure the data and communications channels in these systems is critical to ensuring that sensitive mission information stays safe and space operations integrity can be maintained.

In short, applying immersive technologies in space transportation is still very immature, but may have impactful benefits. To date, ongoing research and development by entities such as NASA's PIT Laboratory are facilitating the broader adoption of VR/AR applications for space exploration. As these technologies continue to develop, it is anticipated that they will have a substantial impact on the way astronauts are trained, as well as on has how spacecrafts are designed and missions planned – all of which (and more) play an important part in future space mission success and safety.

## 3. SWOT analysis

The SWOT analysis of immersive technologies in space transportation (Figure 1) comprehensively evaluates the strengths, weaknesses, opportunities, and threats associated with their deployment. This analysis is pivotal for discerning the strategic potential and inherent challenges that virtual reality (VR), augmented reality (AR), and mixed reality (MR) technologies present in augmenting space missions. The SWOT specifically evaluates the deployment of immersive technologies in space transportation, focusing on internal factors such as technological capabilities (Strengths and Weaknesses) and external influences, including industry trends and security threats (Opportunities and Threats). By systematically identifying these factors, space organizations can leverage their strengths, address their weaknesses, capitalize on emerging opportunities, and mitigate potential threats more effectively. This clear distinction between internal and external factors forms the basis of informed decision-making and strategic planning, thereby ensuring the successful integration of immersive technologies in future space endeavors.

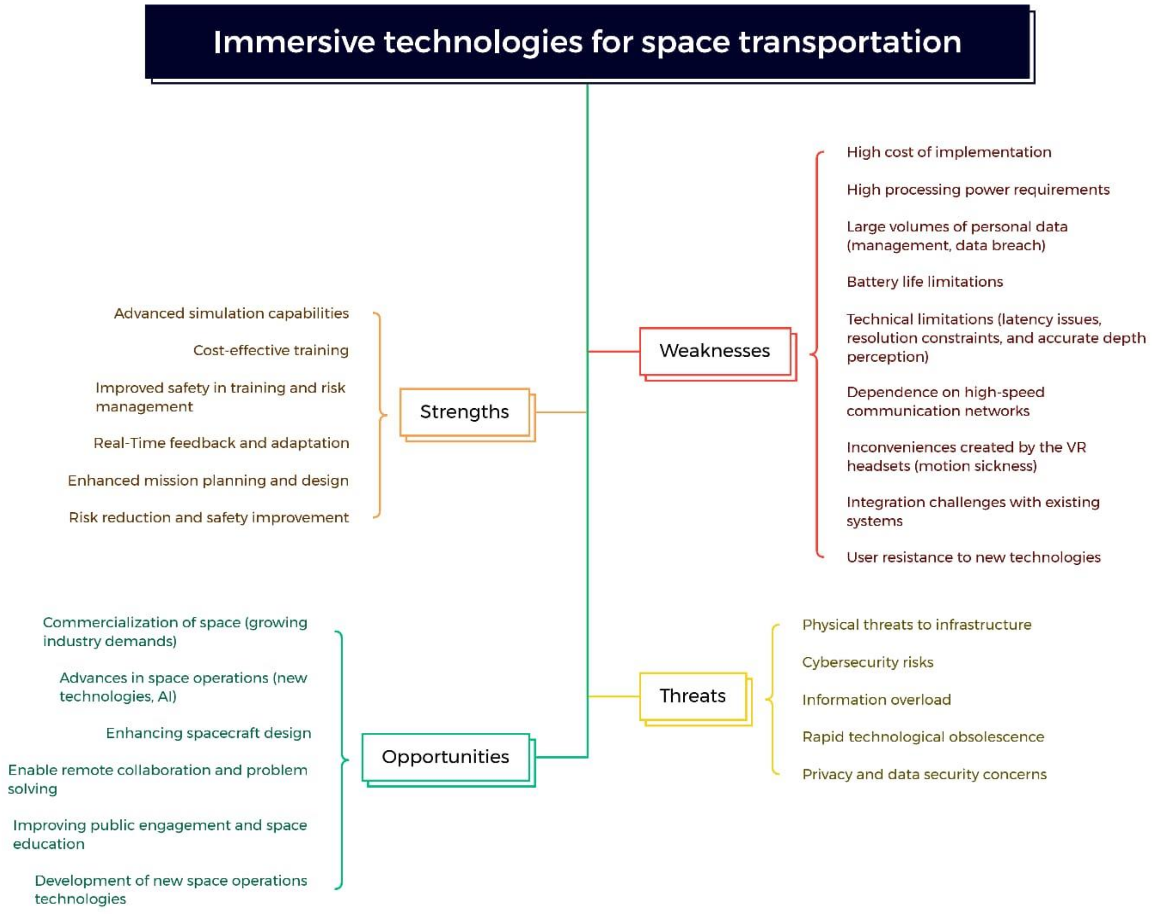


**Figure 1.** SWOT analysis overview

## 3.1. Internal factors

### 3.1.1. Strengths

These new immersive technologies offer a few very powerful advantages which represent the main arguments for adoption. The implementation of VR in simulation contexts allows for the development of advanced skills for conducting high-risk activities in later scenarios characterized by a high degree of danger (Engelbrecht, Lindeman & Hoermann, 2019). Moreover, extended reality technologies are useful for handling unique space transportation needs, including astronaut training and mission planning, enabling high-end simulations to minimize risks and improve operational productivity. They provide engineers and astronauts with immersive environments to simulate and experience mission scenarios, integrated spacecraft systems and operational procedures, in a controlled environment, before actual deployment. They will be prepared for no gravity environments with variations not just on time, but also on speed and trajectory, which helps improve all-round preparation before a take-off. Advanced simulation capabilities and cost savings in training are especially crucial, as space flights increasingly encompass both utilitarian components and the emerging field of space transportation. Immersive technology presents significant strengths for encouraging and conducting these activities under optimal conditions, with many specific elements paralleling those in the hospitality industry (Kulakoğlu-Dilek, Kızılırmak & Dilek, 2018). Safety in training and behavior modeling in a danger-free environment is one of the most critical strengths of any simulator, and even more so for space simulators (Zhang et al., 2022). VR can be particularly beneficial for training individuals involved in space flights, enabling them to visualize in 3D, identify errors more easily, and optimize their projects, before construction begins.

One of the most challenging variables in space transportation is the cost of training for spacecraft operators and travelers. From this perspective, immersive technologies can offer substantial assistance. Although the initial investment in virtual simulators is considerable, it is significantly lower than the cost of traditional preparation for space transportation and tourism. Moreover, many modeling and real-time rendering tools are now freely available, making the technology more accessible. However, budget cuts for training are often targeted during financial crises (Buckman, 2005), which can jeopardize the entire space tourism endeavor.

The high initial cost of an immersive training simulator for space flights will gradually be amortized, as the same infrastructure can be repurposed to train individuals in different contexts and high-risk scenarios. The ability to record data during training sessions constitutes a valuable resource, enabling continuous adaptation and improvement. Additionally, the continuous connection with computerized databases and the provision of real-time feedback, built on data using machine learning and artificial intelligence, provide a compelling argument for the use of VR in space contexts (Vaughan, Gabrys & Dubey, 2016). This capability allows better adaptation to the unknown and challenging environment of space throughout the journey. This technology uses photo-realistic virtual environments to allow the visual exploration and interaction with virtual spacecraft models, mission terrains, and complex operational tasks. These technologies can be used to uncover potential design flaws, operational pitfalls, and safety issues, which, in return, provide insights valuable for risk reduction as well as for mission efficiency and effectiveness (Bingham et al., 2024). The feedback information is based on the replication of the surrounding environment, which, although synthetic, can be seamlessly integrated with the real environment. The databases used to construct the virtual environment are highly complex and predominantly visual, but mature technologies such as haptic feedback, sound, and smell are also employed (Xie et al., 2021). The continuous evaluation of user needs, specifically those of space travelers, ensures that the technology remains relevant and effective (Kim, Rhiu & Yun, 2020). Various technologies and applications, including artificial intelligence, machine learning, and remote systems, are designed to meet these needs.

In the event of technical or other issues during the flight, immersive technologies allow for the remote intervention of recognized experts to resolve problems quickly and cost-effectively. Guided instructions are employed for inspecting and repairing components on space stations using AR, thus reducing risks to crew members, but also ensuring operational efficiency. This capability is another undeniable quality of using VR, as it facilitates communication between geographically dispersed individuals (Li et al., 2021). Additionally, in emergencies requiring complex decision-making under time pressure, augmented reality can provide critical data on equipment status, safety protocols, and evacuation procedures (Molka-Danielsen et al., 2018), thus improving decision-making (Cilluffo et al., 2023; Ruff, Urban & King, 2005).

### 3.1.2. Weaknesses

While the cost of training is reduced by the immersive technologies, their implementation is very expensive (Creed et al., 2024; Perceived, 2023) and represents a significant concern for many organizations, as the development and deployment of these technologies require substantial investments in specialized hardware, software, and skilled personnel. For instance, high-end VR headsets, powerful computing resources, and advanced sensors can increase the budget above an acceptable threshold for many enterprises.

When considering the computing needs, the high processing power required to run complex immersive applications can be a serious drawback, especially in field settings where access to powerful computing resources may be limited. Many specialized systems require high-end graphics cards, processors, and memory to function smoothly, which can be difficult to provide in remote or challenging environments, such in the context of space transportation.

Emerging technologies often involve the aggregation and examination of large volumes of personal data, including geographic location, biometric information, and user preferences. These practices raise significant privacy and security concerns, potentially fostering skepticism among users towards the technology and implementing entities. Data breaches can expose critical information about advanced space technologies and mission plans, damaging trust and loyalty. Currently, no technology guarantees the identity of users controlling avatars in the metaverse, presenting challenges for identification and associated activities. Misuse of captured personal data using various techniques, such as posture tracking and eye movement analysis, can lead to unauthorized access to intellectual property (Dissanayake, 2018).

Short battery life can also be a significant weakness, particularly in space transportation applications requiring extended field use, as the battery capacity limitations may restrict the complexity and richness of the virtual environments that can be created and explored (Baker et al., 2023). Headset devices rely on battery power to function, and the high processing demands of these technologies need ample power resources and can quickly drain batteries (Wang & Zhao, 2022). Consequently, as the users may need to pause their work to recharge devices, this can disrupt workflows and negatively affect productivity. In space missions, where continuous operations are crucial, such interruptions can pose serious operational risks. To address these concerns, developers of immersive applications for space missions often face trade-offs between quality of experience, such as visual fidelity or interactivity, and battery life, potentially compromising the effectiveness of the immersive experience.

Other technical limitations, such as latency issues (Awan et al., 2023) and resolution constraints (Spagnolo et al., 2023), can also impact the success of immersive technologies. For example, a high latency between a user's action and the virtual environment response may break the illusion of being in a virtual space. Furthermore, the graphical resolution is of paramount importance for high quality user experience, as the images need clarity and high level of detail. Moreover, accurate depth perception is essential for understanding spatial details in a virtual environment (Yin et al., 2023). If users cannot accurately perceive the spatial arrangement of objects, it can lead to errors and misjudgments, especially in scenarios that require precise spatial awareness, and it can significantly influence the use of immersive technologies in applications that demand accuracy, such as training simulations for space missions.

Immersive technologies rely on the availability and reliability of high-speed communication networks, and, while this may not be an issue in large cities or certain locations, it still can be a challenge in remote or poorly connected areas, where digital infrastructure may be lacking or unreliable (Mhlanga, 2024). Furthermore, any disruption in digital services, such as network outages or server failures, can significantly hinder the use of AR/VR/MR applications.

Another shortcoming of immersive technologies is related to the inconveniences created by the VR headsets which may provoke symptoms specific to motion sickness, such as nausea, dizziness, headaches, disorientation, user desensitization, fatigue, and other health issues that may affect the performance of astronauts and technical personnel. Cyber sickness, often exaggerated online, could compromise adoption.

The use of unlicensed, unproven technologies for training and daily applications raises further concerns. Potential litigation, injuries, and other issues stemming from improper use of immature Extended Reality (XR) technology highlight the need for careful development and deployment. Ergonomic shortcomings make immersive technologies uncomfortable for long-term use, particularly in microgravity environments, posing health and safety risks. Continuous use of VR and AR can also lead to social isolation and alienation. These health and well-being issues can be particularly problematic for space transportation applications where users need to wear headsets for long duration. Virtual experiences often lack authenticity, making it difficult to convey genuine emotions and creating a disconnect between users and the experience. This emotional and psychological detachment can reduce user engagement. Unrealistic or exaggerated representations can create unmet expectations, leading to disappointment and skepticism about future interactions. Additionally, compatibility and integration issues between immersive and traditional technologies can cause operational errors and interruptions.

The digitalization and automation of services through VR and AR can lead to a loss of personalized human interaction, particularly problematic in industries like tourism and hospitality that rely on personal attention. The absence of authentic human interaction can reduce customer satisfaction and the quality of service-client relationships.

## 3.2. External factors

### 3.2.1. Opportunities

Opportunities for immersive technologies in space transportation are shaped by the external environment, which includes advances in space operations, growing industry demands, new technologies, international cooperation and funding availability. Given the shifting landscape of space industry development, which has continued to accelerate in recent years and diversified beyond traditional applications, into a range of specialized services, there seems ample scope for immersive technologies at different stages or aspects within space missions.

This includes a high level of investment by government and commercial space sectors, both known for their readiness to develop groundbreaking technology.

The VR/AR simulator for space transportation and tourism can be significantly optimized by incorporating new content from ongoing experiments or as underlying technologies advance. New advanced motion tracking systems and bespoke virtual environments will also be used to collate data for the improvement of training protocols, development of complex procedures, and optimization human-robotic interactions required by future spaceflight missions. VR and AR could have loads of fulfilment when implemented for exploring space, in terms of virtually training new crewmembers, supporting the development designs and helping astronauts aboard spacecraft. Also, artificial intelligence or new disrupting materials that may appear can be embedded in immersive technology for better results and sooner adoption and dissemination.

Opportunities for using immersive technologies are vast: from developing possible solutions in space operations, to innovating existing processes. VR may be a very useful tool in controlling robotic systems on the space stations, thereby testing remotely operations and even more, without risk for real astronauts to go outside the station, hence promoting new technologies innovation ideas into space stations.

In addition, the development of immersive technologies for space transportation may be strongly influenced by international cooperation in the area, such as different treaties which may be signed or new space laws which may have an impact on accelerating space commercialization in terms of new satellites, new resources exploitation and space tourism.

A new interest for space education could stimulate curiosity and inspiration for innovation in out-of-this-world dimensions of exploration, within planetary science. Alongside plans to increase space transportation infrastructure, there are opportunities for applications of immersion tech adapted towards designing future missions and optimizing planning, by improving on operational efficiency and enhancing safety via better simulation and testing environments.

Additionally, application of VR and AR in space education has the potential to not only captivate, but also motivate and bring a portion of attention to future generations that can cultivate further interest into aspiring young minds for careers, within innovative aspects related to outer space exploration. Being able to visualize and interface with space missions in a 3D virtual environment has tremendous potential for aiding in understanding the challenges that are faced on these types of endeavors.

The introduction of these emerging technologies brings in an enormous opportunity for exploring the space together with novel ways and improvements and showcases the immense possibilities of immersive technologies in transforming space operations and enabling further technological advancements for future missions to explore new horizons.

### 3.2.2. Threats

The outer space environment is becoming increasingly crowded, contested, and competitive, presenting a myriad of challenges and threats that could impact the functionality and safety of space operations (European Commission, 2022).

Immersive technologies, including AR, VR, and MR, face several threats that could hinder their adoption and effective use in space transportation and other sectors.

Traditional physical threats, such as the destruction of platforms incorporating XR technologies, remain a significant concern. Kinetic attacks using anti-satellite missiles can cause substantial economic losses, without directly harming human lives, making them less condemnable in the eyes of the public (Georgescu et al., 2019). These systems become targets of opportunity for actors who wish to avoid escalating armed conflicts while still disabling critical infrastructure. Laser attacks, electromagnetic pulses, and other forms of electronic warfare can also disrupt communication links essential for space operations. An example is the jamming of GPS signals, which can mislead terrestrial receivers (Lews, 2022).

Intentional threats, including jamming, laser attacks, and cyberattacks, further complicate the safety landscape of space transportation. Jamming can disrupt spacecraft communications, potentially interfering with navigation and life-support systems. Laser attacks can damage or disable sensors and other components, while cyberattacks pose insidious threats by aiming to disrupt operations or gain unauthorized control over space transportation assets (Botezatu, 2023; Botezatu & Vevera, 2024; Ciuperca, Stanciu & Cîrnu, 2021).

AR interfaces are susceptible to malicious code injections that can alter or corrupt the visual content seen by users. Man-in-the-middle and denial-of-service (DoS) attacks can disrupt applications, misleading users with potentially severe consequences. Immersive technologies rely on sophisticated data and communication networks, often handling substantial personal data vulnerable to phishing attacks, unauthorized access, malware, and ransomware. These cyber threats can compromise sensitive data and gain malicious control over critical equipment. Frequent cyberattacks, such as data falsification and sniffing, undermine the reliability of content, even if it originates from legitimate sources. Additionally, hackers can record user actions in AR environments and threaten to expose the data unless a ransom is paid (Qamar, Anwar & Afzat, 2023).

One of the main issues with immersive technologies, particularly in the metaverse, is the potential for information overload. Users with little prior experience may be overwhelmed by the numerous options and interactions in virtual environments, leading to negative experiences and an inability to focus on their objectives. Adequate measures must be implemented to ensure that information overload does not diminish service quality or communication efficiency.

The integration of immersive technologies with external existing systems and workflows in the space transportation infrastructure sector can be a complex and time-consuming process (Pappas, 2023). Many organizations in this field rely on established software, databases, and protocols that may need to be compatible with these specialized systems. In this situation, it may be necessary to disrupt existing workflows to adapt these legacy systems to work seamlessly with immersive applications. Converting and preparing the data for use in AR/VR/MR applications can be a laborious task and require specialized skills and tools. Also, to create content for immersive environments, developers need expertise with a broad range of technologies, such as 3D modeling software, and experience with many specialized tools (Andalib & Monsur, 2024). Moreover, these skills and knowledge need to be continuously updated, as the pace of technological change in this space is very high. Therefore, the pool of capable developers is limited and can impact the widespread adoption and implementation.

The lack of comprehensive education in XR technologies is a result of several factors, including the poor performance of mentors from academic initiatives, insufficient interest from educators, and inadequate experience among professionals offering XR support. Additionally, XR startup directors often have limited business experience, leading to post-investment diversification that detracts from technological development. Resistance to change within educational institutions exacerbates this issue, with high costs and fragmented training programs further undermining thorough preparation in XR.

Poorly placed investments and inefficient fund allocation, driven by hype and dramatic failures, can undermine investor and customer trust in XR technologies. Hygiene concerns, especially post-COVID, and the failure of Location-Based Entertainment (LBE) centers have exacerbated this issue. The rapid obsolescence of technology also poses a financial and operational challenge, as investments quickly become outdated.

Not least, resistance to new technologies is a general problem in modern societies, particularly regarding the adoption and use of virtual environments and immersive experiences. Users may be hesitant to embrace these new technologies, especially if they are unfamiliar or uncomfortable with them (Fonarov, 2024).

## 4. Discussions

The integration of immersive technologies like VR, AR, and MR into space transportation is a major engineering and astronautics breakthrough. This SWOT analysis clarifies these technologies' pros and cons, revealing their potential influence on space missions.

Immersive technologies revolutionize training, design, and operations. They enable extremely realistic simulations that prepare humans for space travel, iterative design procedures that improve spacecraft safety and dependability, and remote cooperation for real-time problem-solving. Continuously capturing and analyzing training data allows these systems to adapt to space missions' changing demands, enhancing mission results and safety.

Immersive technologies have high prices, technological constraints, and a steep learning curve, limiting their use. The cost of expensive technology and software and the necessity for specialist expertise are major obstacles for smaller companies. Latency, resolution restrictions, and high computing power might also limit these applications. These technologies also face human resistance and motion sickness, making their incorporation into space operations difficult.

Immersive space transportation systems have great potential for innovation and improvement. These technologies can improve astronaut training, spaceship design, and international collaboration, by creating a virtual environment for scientists and engineers. Immersive experiences may excite the public and recruit fresh space exploration talent. Moving forward, VR, AR, and MR technologies will minimize space mission dangers and improve mission efficiency and safety.

However, various concerns might hinder immersive technology uptake and utilization. Physical and cyber dangers, such as XR platform damage and data breaches, represent serious concerns. XR implementation is complicated by information overload and a lack of knowledge. Privacy, security, identification, and investor and consumer distrust are also major difficulties. Rapid technological obsolescence and the lack of a harmonized regulatory framework further endanger space operations' continuing incorporation of these technologies.

## 5. Conclusions

In conclusion, immersive technologies hold immense potential for transforming space transportation. For this potential to be realized, major challenges need to be tackled by using strengths and opportunities effectively, but also with an appreciation of weaknesses and threats. Further research, investment and the cooperation of nations will be required if the power of VR/AR/MR technologies, in the realm of space exploration, is to be properly harnessed. As these technologies continue to evolve, they will certainly be a crucial part of the effort for human civilization venture out into and settle in the cosmos.

Additionally, immersive technologies have the potential to support space exploration, by providing better training methods, safer practices and technological advancements that engage a broader audience with these opportunities. Continually improving these technologies is essential for again taking humans further in space. Through kindling the curiosity in our hearts and bolstering perpetual mission protocol enhancement, immersive technologies are playing a colossal role in propelling space exploration advance sustainably. The (hopefully) brighter future of VR, AR and MR in the space industry reveals their importance to take people into an era expecting bolder objectives at each successful turn!

Going forward, more research is needed, mainly about how immersion technologies can be integrated into space transportation, especially in astronaut training and mission simulation, as well as in upcoming businesses like space tourism. The next steps are to further evaluate the effects of AR, VR and MR technologies on crew performance (both in training scenarios, but also while executing mission plans) as well as how these can be used for long term health monitoring during spaceflight, while taking into account cybersecurity risks along with technological limitations. To that end, partnerships with industry members are also taken into account, for tailored immersive solutions, which would allow spacecraft operations to benefit from more effective missions. Moving forward, experiments and tests in the field will be conducted based on the theoretical insights presented here, to significantly help research contribute towards further development of space transportation technologies.

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