ABSTRACT

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| Title of Thesis: | NEO-FUTURE: Envisioning the Transformation of the Human Environment Through Space Architecture |
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| Thesis Directed By: | James W. Tilghman, the Professor of the Practice, School of Architecture, Planning, and Preservation |

This thesis envisions human environments beyond the current Earth-bound limitations of architecture, extending into Low Earth Orbit and Lunar Orbit. It seeks to transform our traditional understanding of architecture and shape a more sustainable future for human habitation. The proposal is a space-based habitat that transcends pure functionality. It fosters a symbiotic relationship between humans and their extraterrestrial environment, addressing not only physiological challenges but also the psychological well-being of its occupants. By deepening our understanding of the human-environment interaction, this research works to create a framework for sustainable habitation beyond Earth while simultaneously enriching our understanding of human centered design and sustainability applicable to terrestrial contexts. The design explores innovative solutions such as artificial gravity mechanisms, sustainable life support systems, community-oriented design, modular assembly, and automated construction. Furthermore, this thesis investigates strategies for creating a nurturing environment in the harsh expanse of space through principles of biophilic design and communal spaces conducive to resilience and social cohesion. By synthesizing insights from various disciplines including

architecture, aerospace engineering, psychology, and human physiology, the aim of this research is to act as a first step to propel humanity towards a future where the line between terrestrial and extraterrestrial life begins to dissolve. Ultimately it seeks to catalyze a shift in mindset—one that harmonizes the relationship between our human species, the environments we design, and the cosmos around us.

# NEO-FUTURE: Envisioning the Transformation of the Human Environment Through Space Architecture

by

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of the requirements for the degree of
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# Preface

Since the dawn of human civilization, the history of space exploration has been a testament to humanity's enduring curiosity for discovery and desire to connect with the universe around us. Humanity's relationship with the cosmos began long before the first rockets—rooted in ancient cultures that studied the stars for navigation, agriculture, and spiritual meaning. This timeless fascination eventually evolved into scientific pursuits where in the 20th century, pioneers like Konstantin Tsiolkovsky, Robert Goddard, and Hermann Oberth were laying the foundations of modern rocketry[1]. The Space Age officially began with the Soviet Union's launch of Sputnik 1 in 1957, the first artificial satellite, and just a few years later Yuri Gagarin became the first human in space in 1961[2]. The United States' Apollo program culminated in the historic Apollo 11 moon landing in 1969 which marked a significant milestone in human achievement. In the following decades, space exploration became a truly global endeavor with the United States and the Soviet Union (later Russia) were joined by other nations as Europe formed the European Space Agency (ESA) in 1975 and countries such as China and India established their own national space programs, while astronauts from multiple countries conducted long-duration missions aboard orbital stations like the Soviet Mir and the International Space Station (ISS)[3]. In recent years, private companies like SpaceX, Blue Origin, and Virgin Galactic have emerged as key players in spaceflight, pioneering innovations such as reusable rockets that have dramatically reduced

[1] (HISTORY.com 2010)
[2] (Logsdon 2025)
[3] (Logsdon 2025)

launch costs[4]. Advancements in technology and plans for crewed missions to Mars signal an exciting new era in space exploration, where both government agencies and private enterprises collaborate to push the boundaries of human exploration beyond Earth's orbit.

As humanity continues to expand its presence beyond Earth, the need for designers of human environments within the space travel industry becomes increasingly vital. Unlike any other environment, space presents unique challenges such as microgravity, radiation exposure, and limited resources. Designers specializing in human environments play a crucial role in ensuring the safety, comfort, and well-being of astronauts during their missions. They are tasked with creating habitats that can sustain life for extended periods, optimizing living spaces for efficiency and functionality, and addressing psychological factors like isolation and confinement. As space tourism and long-duration missions become more prevalent, the demand for innovative and ergonomic designs tailored to human needs becomes even more pronounced. In essence, designers of human environments are essential in shaping the future of space exploration, enabling humanity to thrive in the inhospitable environment beyond our planet.

In the space travel industry, the architect plays a pivotal role in shaping the built environments that enable human exploration and habitation beyond Earth. Their responsibilities extend far beyond traditional architectural practices, encompassing the design of spacecraft interiors, habitats, and infrastructure for space missions.

[4] (Gundersen and Hammond 2024)

Architects must address unique challenges such as microgravity conditions, radiation protection, and resource management while creating functional, ergonomic, and safe living and working environments for astronauts. They collaborate closely with engineers, scientists, and space agencies to integrate advanced technologies, optimize spatial layouts, and ensure the sustainability and efficiency of space habitats. Moreover, architects contribute to the development of future space settlements and habitats, envisioning innovative designs that accommodate long-term human habitation on celestial bodies like the Moon and Mars. In essence, the architect's role in the space travel industry is crucial for advancing human exploration beyond our planet and creating sustainable environments for spacefarers to thrive.

As architects define their role within the space industry, one fundamental question emerges: Why is architecture needed in space? While engineers and scientists drive the technical systems that make space missions possible, architects bring an equally critical perspective that is rooted in the human experience. Their training encompasses far more than constructing shelters, architects deeply understand how environments shape behavior, culture, and well-being. In the context of space exploration, this insight becomes indispensable. Architects specialize in creating spaces that foster comfort, identity, and cohesion. These qualities are vital for supporting mental health and social stability during long-duration missions in isolated, confined, and extreme environments. They are equipped to design for communal living, mediate private and shared zones, and create spatial rhythms that reduce stress and monotony. Moreover, their ability to think holistically allows them

to integrate sustainability, material efficiency, and life support infrastructure into environments that still feel humane and intuitive.

Architecture also offers a cultural lens to space exploration, recognizing that as we build beyond Earth, we are not just constructing functional habitats, but laying the foundations for future communities and societies. In this way, architects contribute to shaping not just space shelters, but space culture. They draw upon centuries of knowledge about the built environment, from vernacular traditions to cutting-edge innovations, to imagine settlements that respect both human needs and planetary constraints. By embedding human-centered design into the foundation of extraterrestrial architecture, architects ensure that our next great leap as a species is not only technologically advanced, but also emotionally, socially, and ethically grounded.

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# Chapter 1: Why Architecture in Space Matters

## *An Issue of Sustainability*

Designing for space inevitably brings us face-to-face with one of the most urgent and complex challenges of our time: the sustainability of the human species. The issue of sustainability of the human species on Earth is one of the most pressing discussions of our generation. In architecture, the term sustainability is frequently a buzzword, but we must not lose sight of its true meaning. At its core, sustainability is not a fixed outcome but a continuous commitment to meeting present needs without compromising the ability of future generations to meet theirs.

While sustainability is a multifaceted problem that requires a coordinated effort from all of mankind for a long period of time, we have already made significant strides in improvement. Humans have enacted sustainable policy initiatives, improved societal attitudes towards a more sustainable world, advanced the utilization of sustainable technologies, and transformed the building industry with sustainable design strategies. These advancements are critical but there is much more progress to be made before the human species can be considered sustainable.

The challenge of sustaining life in space, where resources are scarce, waste must be minimized, and every system must be efficient, forces us to confront sustainability in its true form. Lessons learned from designing resilient and effective closed-loop habitats beyond Earth offer not only a testing ground for innovation but also a reflection of how far we still must go here on Earth. In this way, space exploration becomes more than a scientific frontier, it becomes a lens through which

we can critically examine and reimagine our relationship with our environment, resources, and community. As we look towards building the future both in orbit and on Earth, the principles of space architecture challenge us to rethink what it truly means to live sustainably.

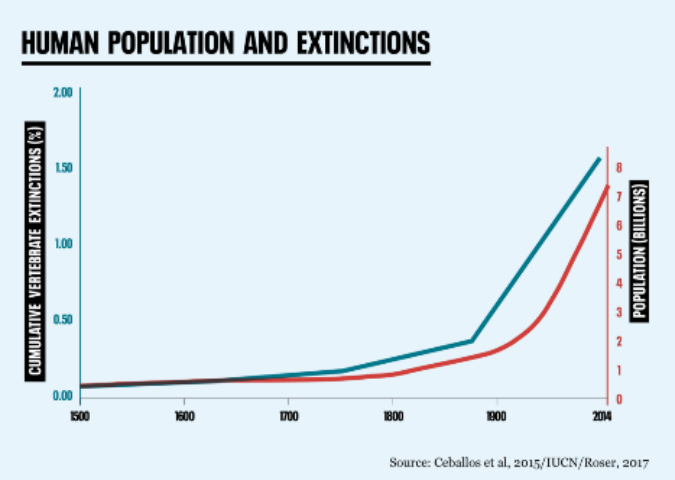


*Figure 1: Human Population Increase Correlation with Increase in Extinctions (Sources: Ceballos et al, 2015/IUCN/Roser, 2017)*

The lack of sustainability of the human species has greatly damaged the natural environment and human communities all around the globe. Rapid industrialization, unchecked resource extraction, and high consumption lifestyles, amplified by a growing human population, have led to extensive environmental degradation.[5] More than 75% of Earth's land area has been significantly degraded and deforested or converted for agriculture undermining ecosystems and driving widespread species extinction.[6] These impacts disrupt delicate ecosystems, jeopardize wildlife habitats, and threaten the stability of essential ecosystem functions. Scientists report that vertebrate species are disappearing at rates tens to hundreds of times

[5] (Leahy 2018)
[6] (Leahy 2018)

higher than natural background levels, indicating that a human-driven sixth mass extinction is already underway.[7] This loss of biodiversity disrupts pollination, water purification, and climate regulation which are critical functions that support life on Earth.[8]

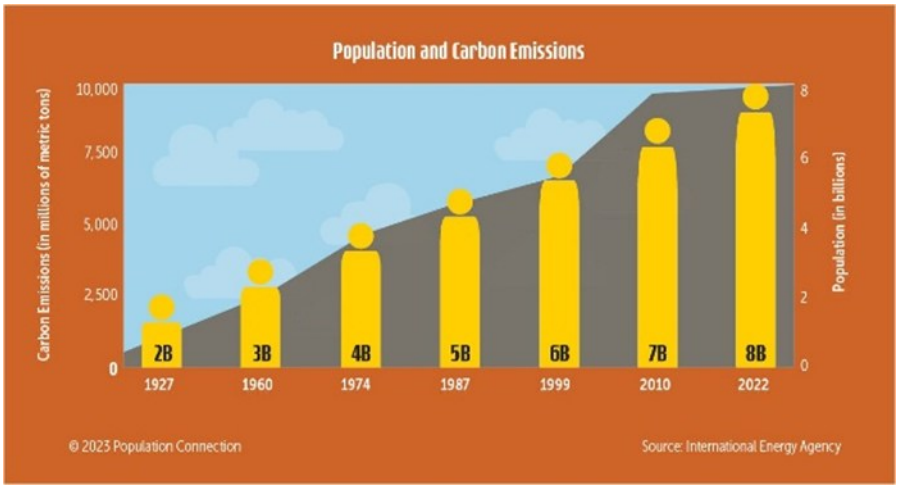


*Figure 2: Human Population Increase Correlation with Carbon Emissions (Source: International Energy Agency, 2023)*

Human communities, specifically those in vulnerable regions, are also feeling the consequences of an unsustainable human presence on Earth. Unsustainable human activities are destabilizing the climate as greenhouse gas emissions from burning fossil fuels and deforestation have reached record levels, "choking our planet and putting billions of people at immediate risk," as the UN Secretary-General states.[9] The impact of these unsustainable human activities is intensifying climate change, exacerbating environmental stresses and has already exposed millions of people to acute food and water insecurity through more frequent extreme weather.[10] The lack of

[7] (Ceballos, et al. 2015)
[8] (Leahy 2018)
[9] (Jana 2022)
[10] (The Intergovernmental Panel on Climate Change (IPCC) 2023)

sustainability also contributes to social inequalities, disproportionately affecting marginalized populations who lack resources and resilience to cope with environmental challenges. Urgent action is needed to address these interconnected issues and transition towards a more sustainable and equitable future for all.



*Figure 3: Plastic Pollution Flooding the Negro River and Adjacent Community in Manaus, Amazonas state. Brazil*
*(Source: VOA News, 2022)*

Contrary to the perception that considering space exploration may divert attention from the sustainability issues outlined previously, the development of human habitats in space offers a vital opportunity to confront sustainability head-on. In fact, space architecture demands the most extreme form of sustainable design, where survival is based entirely on resource efficiency, closed-loop systems, and environments that support both physical survival and social well-being. Understanding the advancement of space technology as a transformative force in sustainable development underscores its significance in informing the design of efficient and resilient human environments across both extraterrestrial and terrestrial contexts. Space architecture works to explore ways to design sustainably out of

necessity as environments in space do not afford the amenities we are familiar with on Earth.

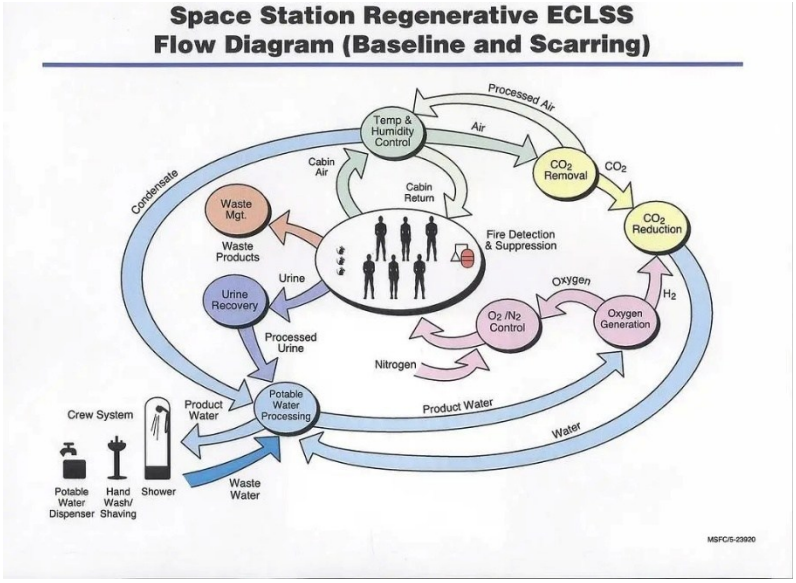


*Figure 4: Diagram of the ISS's regenerative ECLSS, recycling water and oxygen through its water recovery and oxygen generation systems.*
*(Source: NASA, 2017)*

Unlike Earth, space offers no natural abundance of air, water, or raw materials and every element must be carefully managed, recycled, and optimized. Each kilogram of material must be maximally utilized due to the significant cost associated with transporting materials to space which emphasizes the necessity for innovative approaches to reuse and recycle, especially concerning water, as the water supplied onboard must undergo purification processes to enable its reuse in various capacities.[11] The same concept is utilized when talking about air. On Earth, we take for granted the air we are provided but in space this precious resource for life needs to be carefully recycled and purified in order for humans to continue breathing out in

[11] (Wormald 2023)

deep space.[12] This attitude is translated to every component of the designed space and creates a closed-loop system that takes into account the entire lifecycle of everything onboard. Designing a human environment in space creates a sustainable way for the human species to live that can be directly translated into more resilient human environments on Earth.

Designing for space pushes us to rethink how we live, consume, and design which encourages a mindset rooted in necessity, resilience, and long-term thinking, essential to the sustainability of our species on Earth. Advancements in space technology have led to innovations in renewable energy, resource management, and environmental monitoring that can be applied to address pressing sustainability challenges on our planet. In this way, space settlements become a model for the sustainable technologies supporting the self-sufficient, zero-waste communities we aim to build on Earth. This approach has already yielded direct benefits on our planet. NASA's decades-long development of Controlled Ecological Life Support Systems (CELSS) to sustain astronauts led to breakthroughs in indoor farming and resource recycling technologies that are now helping communities achieve food and water self-sufficiency on Earth.[13] Additionally, the development of sustainable human habitats in space requires efficient resource utilization, recycling technologies, and closed-loop life support systems, which can inspire and inform sustainable design on Earth. For example, NASA's Sustainability Base, featured in *ArchDaily*, exemplifies how space technology can transform terrestrial design. The building integrates systems

[12] (Wormald 2023)
[13] (NASA 2022)

originally engineered for the International Space Station (ISS), including forward-osmosis water recycling and smart environmental sensors, resulting in one of the most resource-efficient buildings ever constructed.[14] The project demonstrates how principles of resilience, closed-loop thinking, and high-performance design that are developed under the constraints of space can inform more sustainable built environments on Earth.[15] Applications of these practices can aid in mitigating food and water scarcity, dealing with air pollution, and managing waste on Earth. Further applications can lead to the transformation of the way architects design sustainable human habitats and provide a critical testing ground for the technologies, strategies, and mindsets needed to thrive within terrestrial and extraterrestrial boundaries.

Sustainable technology and strategies are key components that inspire architectural design and, with the growth of these technologies due to space habitation and exploration, will come an evolution of sustainable architecture. Many organizations are currently working on space habitats that have an immediate application for structures here on Earth. The architecture studio SAGA Space Architects is working on a lunar space habitat called LUNARK which works to support the physical and mental well-being of occupants in extreme environments and has been field tested in Northern Greenland.[16] This structure is extremely space efficient as it is foldable and designed to fit into the cargo hold of a rocket ship. The architects are integrating LED light panels to replicate Earth's sensorial stimulation, simulating circadian rhythms, and incorporating living organisms like algae into the

[14] (ArchDaily 2012)
[15] (Palca 2015)
[16] (Cutieru 2022)

design to convert carbon dioxide into oxygen, while also providing a rapid source of proteins, vitamins, and minerals.[17] Another space project that displays application to habitats here on Earth is the Aquarius Reef Base which works to study the habitation of life underwater as it can inform habitat requirements for life on Mars. Nineteen meters below the coast of Key Largo, Florida, a small habitat hosted six aquanauts for 16 days as part of the 21st installment of the NASA Extreme Environment Mission Operations (NEEMO) project, during which they conducted equipment tests and simulated spacewalks on the seabed, potentially offering invaluable insights for future low-gravity missions to Mars and beyond.[18] These projects, while testing for human environments in space, are shaping the way sustainable design can exist on Earth and embody the human will to explore and live in vastly different places. The ability to explore and inhabit space leads to advancements that can directly impact our capacity to explore and inhabit various regions on Earth sustainably. Space exploration also fosters international collaboration and innovation, encouraging the sharing of knowledge and resources to tackle global sustainability issues together as a species. By leveraging the expertise and technologies developed for space exploration and habitation, we can create a more sustainable and far-reaching future for the generations of humanity to come.

[17] (Cutieru 2022)
[18] (Gearin 2017)

*Transcend the Understanding of Humans and their Environment*



*Figure 5: Photograph taken of astronaut Ed White performing the first U.S. spacewalk in 1965*
*(Source: James McDivitt, 1965)*

Creating human environments in space represents a monumental leap forward in our understanding of the human environment, transcending our current limitations and opening new frontiers of exploration and innovation for the next generations of humanity. By venturing beyond Earth, we confront unique challenges and opportunities that force us to reevaluate our relationship with our surroundings. These space habitats require sustainable design principles, closed-loop systems, and advanced life support technologies, prompting us to rethink resource management, energy efficiency, and environmental stewardship on a cosmic scale. Through the pursuit of designing space environments, we uncover profound insights into the interplay between humanity and its environment, creating a deeper appreciation for

the delicate balance that sustains life and the creativity required to thrive in extreme conditions.

The creation of human environments in space holds the promise of unlocking new possibilities for the human species, inspiring a new era of exploration, colonization, and discovery. Beyond serving as temporary outposts for scientific research and exploration, these space habitats represent stepping stones towards permanent settlements on other celestial bodies. These extraterrestrial habitats serve as testbeds for innovative technologies, economic models, and social systems, offering valuable lessons that can be applied to address pressing challenges on Earth and inspire a more sustainable and equitable future for the human species. This works to establish sustainable human colonies beyond Earth that not only expand the horizons of human civilization but also safeguard against existential threats and ensure the long-term survival of our species.

*The Security of our Species*

Humanity faces a plethora of existential threats, ranging from climate change, pandemics, asteroid impacts, and nuclear warfare, which could have catastrophic consequences if left unaddressed. As our population grows and our technological capabilities advance, so too do the risks associated with these threats, amplifying the urgency for proactive measures to safeguard the future of our species. However, many of these threats are inherently planetary in nature, meaning that they pose global risks that cannot be mitigated solely through terrestrial solutions. Without the diversification of our species beyond Earth, we remain vulnerable to the possibility of

a single catastrophic event, such as an asteroid impact or global environmental collapse, that could render our planet uninhabitable and jeopardize the survival of humanity.

Space exploration and the establishment of human habitats beyond Earth offer a compelling solution to mitigate the existential threats facing humanity. By venturing beyond, humans not only expand the horizons of human civilization but also ensure the long-term survival of our species. Space habitats provide a safety net against planetary-scale disasters, offering refuge for humanity in the event of a catastrophic event on Earth. By exploring and inhabiting other celestial bodies, such as the Moon or Mars, we establish a resilient, multi-planetary civilization that is better equipped to withstand and recover from existential threats. In this way, space exploration serves as a survival mechanism for the future of humanity and space architectural design will facilitate this.

# Chapter 2: Maintaining Culture and Terrestrial Connections

## *The Importance of Human Culture*



*Figure 6: ESA astronaut Thomas Pesquet and his crew mates held the very first space Olympics as the Olympic Games started in Tokyo. For crew cohesion and fun, they put together a friendly competition between the Soyuz team and the Dragon team. (Source: ESA/NASA–T. Pesquet, 2021)*

Culture plays a vital role in the existence of human environments in space. As humans, much of our identity and essence stem from the richness of culture which has evolved over human history on Earth. As our species ventures out into space, humans will encounter environments that lack familiarity to our home planet and are devoid of human presence. This fact will require our species to think about solutions to ensure the environments we design will facilitate the expression and nurturing of our culture rather than suppress it. This becomes especially important in such an environment as deep space exploration as, in the midst of the unknown, we are creating a sense of connection to our species that transcends the distance put between explorers and their home planet. Accomplishing this connection not only aids in sustaining life in communities within deep space but also cultivates the flourishing of

diverse cultural expression that creates a sense of belonging and unity to our human heritage.

The reason why culture is so important within the human environment is because it is central to the unity of our species. Space architects and human-centered designers must recognize that the environments we build off-world must nurture the culture that binds us together as humans. Culture, which is the shared values, practices, arts, and traditions of our species, is more than just a social ornament, it is a central pillar of human identity and a powerful tool for adaptation.[19] By consciously designing space habitats that preserve and celebrate terrestrial heritage, we ensure that as humans adapt to alien conditions, we remain fundamentally human, connected to each other and to our home planet.



*Figure 7:The 'Earthrise' image, taken by the crew of Apollo 8 in 1968 (Source: Bill Anders/NASA, 1968)*

Culture offers a collective memory and value system to our environments that transcend any one individual. In the extreme isolation of space, such a shared cultural

[19] (Harris 1994)

framework will be essential for uniting diverse crew members and settlers. The implementation of culture creates common ground, mitigates feelings of otherness, and reinforces the idea that we are one human family, even as we form new communities in an unfamiliar environment. Astronauts who have viewed Earth from orbit often report a profound "global consciousness" or a realization of humanity's unity despite the triviality of the divisions between us.[20] This overview effect speaks to the power of cultural identity on a planetary scale as leaving Earth can heighten our awareness that all humans share the same fragile home and heritage. Preserving culture in space isn't just a sentiment, but a strategy for sustaining human unity and cooperation when we are far from home.

When thinking about culture in space, it is also important to recognize that humans are a highly adaptable species, capable of adjusting physically and socially to radically new environments. This potential for change is important to consider with the design of human environments as it is universally favorable that humanity keeps its unity across the species despite any physiology, cognition, or even social organization as we respond to low gravity, confined habitats, and artificial ecosystems. A shared concern for this topic is expressed by Sergey Krichevsky, Doctor of Philosophical Sciences, and Vladimir Levchenko, Doctor of Biology, in their article, "Human Life and Evolution in Biospheres on Earth and Outer Space: Problems and Prospects". It is mentioned that fundamental characteristics distinguish human beings and must be safeguarded throughout their ongoing evolution, both on

[20] (Gaines 2015)

Earth and in space. This preservation is essential in the pursuit of becoming cosmic individuals while maintaining their humanity, ensuring they do not transform into cyborgs, cyborg-robots, or other speculative entities. Krichevsky and Levchenko even go on to ask “But is it possible? What does it mean to be and remain human in the process of evolution?”.[21] The element that works to unify the human species and provide a sense of belonging is culture. Through the conscious consideration of this fundamental aspect of humanity, designers can create an environment for humans that will support the expression and nourishments of culture within the environment of space.

For successful space exploration, innovative design solutions need to be implemented to create human environments that work to support culture and its expression. By prioritizing cultural sensitivity and inclusivity, space habitats can become more than just functional living quarters. They can serve as dynamic platforms for the celebration and continuation of diverse cultural traditions. This type of international dynamic is seen on the current International Space Station and it serves as a place of peace amongst a highly divided world. Additionally, Incorporating elements such as adaptable interior spaces and customizable recreational areas can facilitate meaningful cultural exchanges among crew members from different backgrounds. Establishing interactive communication platforms from space back to Earth can also create a sense of unity amidst the vastness of space. Embracing these innovative design solutions that prioritize cultural enrichment can

[21] (Krichevsky 2021)

allow space exploration endeavors to transcend mere scientific exploration, becoming transformative journeys that celebrate the richness and diversity of human culture along with our terrestrial origin on a cosmic scale.

*Biophilia Hypothesis*

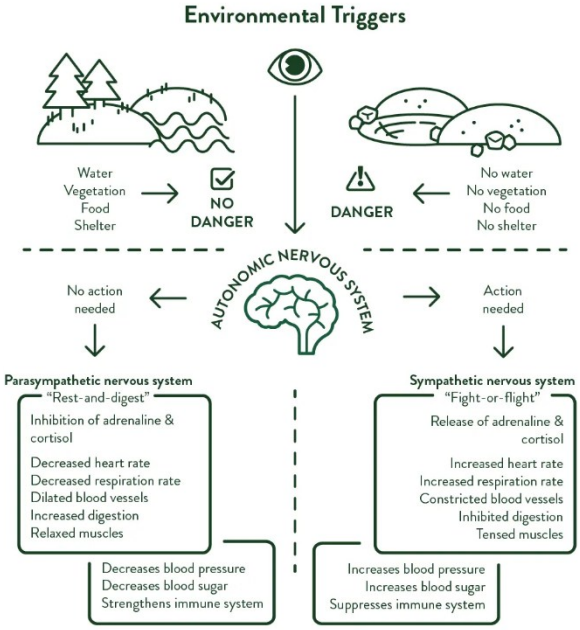


*Figure 8:Diagram Showing how Environmental cues Activate the Nervous System, Triggering Either a Relaxed or Stress Response Based on Perceived Safety or Danger.*
*(Source: Selenay Koç/Medium, 2023)*

Alongside culture, another fundamental element that makes us human is our shared connection to our home planet. Earth, the environment that humans and all biological species we know of evolved to exist in, is a vital part of our humanity. It is even hypothesized that the presence of natural elements within the human environment is critical for our health and well-being. This is called the biophilia hypothesis. The basis of this hypothesis suggests that humans have the innate tendency to seek connections with nature and other life. With this hypothesis in mind,

it is important to think about how this translates to a human environment in space and how leveraging this innate trait can offer an opportunity to craft spaces that not only evoke a connection to our terrestrial origins but also contribute to the overall health and well-being of astronauts in a biophilic atmosphere.

Through further study of the Biophilia hypothesis, it is apparent how fundamental it is to our human environments. The term was introduced by Edward Osborne Wilson (E.O. Wilson) in his book Biophilia published in 1984. E.O. Wilson interprets biophilia to be an evolutionary trait that offers an explanation for why humans are fascinated by life and tend to affiliate with life and life-like forms emotionally. Giuseppe Barbiero and Rita Berto, authors of the article "Biophilia as Evolutionary Adaptation: An Onto- and Phylogenetic Framework for Biophilic Design", dive into the fascination aspect of biophilia within their work. They claim that nature holds a captivating allure for humans, evoking an attraction that effortlessly captures their attention. This phenomenon, known as fascination, forms the cornerstone of the Attention Restoration Theory (ART). Studies indicate that exposure to natural environments elicits involuntary attention, allowing individuals to replenish their directed attention resources and alleviate mental fatigue. Nature serves as a preferred and compelling stimulus, offering a restorative sanctuary for both adults and children.[22] Barbiero and Berto continue their analysis into the affiliation aspect of biophilia by saying that affiliation with nature involves forming emotional connections with specific life forms, rooted in our capacity for empathy and shared

[22] (Berto 2021)

emotional experiences. While empathy is typically associated with human interactions, it extends to relationships with animals and nature, contributing to stress reduction and emotional well-being. Contact with domesticated animals, in particular, offers opportunities for empathic engagement, leading to faster recovery from stress. These findings underscore the therapeutic benefits of affiliating with nature and highlight the importance of nurturing emotional bonds with the natural world for human health and resilience.[23] The authors of this article also work to try and explain how this possibly could have been the result of natural selection favoring individuals inclined to explore and settle in environments offering ample resources while avoiding those with higher risks or poorer resources. This phylogenetic perspective suggests that the learning mechanisms associated with biophilia may have become ingrained in the human gene pool, enhancing our species' adaptation to the environment by guiding behaviors that promote survival and well-being.[24] With the understanding of biophilia being such a fundamental part of human psychology, it is vital to include this consideration within human environments in space.

While biophilic environments are easier to encounter on the surface of Earth, human environments in space are completely void of these experiences and require implementation in order to alleviate the stressors of long-duration spaceflight activities. In an article called “Can the Biophilia Hypothesis Be Applied to Long-Duration Human Space Flight? A Mini-Review”, written collaboratively by Brittany N. Neilson, Joseph A. Vance, Curtis Craig, Martina I. Klein, George Altman, and

[23] (Berto 2021)
[24] (Berto 2021)

Alexandra Travis, it dives into the discussion around strategies that can be utilized to combat the psychological effects of long-duration spaceflight with biophilic principles. One of the strategies discussed is the implementation of virtual reality (VR). The article says VR offers a feasible method for recreating natural settings in space, providing astronauts with a much-needed break. Preliminary studies indicate that virtual natural spaces can evoke similar positive effects as real outdoor environments and research from NASA supports this kind of implementation, showing its potential to reduce stress and anxiety.[25] Another strategy proposed by the authors is the incorporation of vegetation within the vessel. They say that NASA is investigating the possibility of adding vegetation, like potted plants or indoor gardens, to spacecraft interiors. This could mitigate stress, promote social interaction, and enhance attentional capacity for astronauts during missions.[26] While this solution would be considered ideal, the primary issue would surround cost and storage limitations that would discourage potted plants in the environment of space. The authors take these concerns into consideration by proposing a solution of digital media implementation. They say digital nature images are cost-effective and show that they can significantly reduce stress. Given the potential similarity in isolation and stress levels between astronauts and participants in the studies analyzed by the authors, digital media featuring nature could serve as a promising method for stress reduction. Additionally, research indicates that certain natural images combined with sounds have a greater impact on mood and performance which may enhance the

[25] (Brittany Neilson 2021)
[26] (Brittany Neilson 2021)

restorative effect for astronauts.[27] These strategies show promising results in these studies and have the potential to transform the way human environments exist in space. Following these principles to support humans in this unfamiliar environment also works to create a unifying presence for the human species within the cosmos. Part of this presence will also include the overall design of space architecture which has the potential to reinforce this terrestrial unification through biomimetic design.

*Biomimetic Design*

Biomimetic design or Biomimicry is the practice of drawing inspiration from nature to solve human challenges, and holds immense potential for enhancing human environments in space exploration. Evolution has had billions of years of trial-and-error to produce species finely adapted to their environments and, by emulating biological systems and processes, biomimicry offers innovative solutions to address the unique challenges of space habitats. In fact, many traits crucial for biological survival such as adaptability, resilience, light weight structures, efficient use of energy, and self-regeneration are exactly what we need in sustainable human habitation beyond Earth.[28]

One of the foremost challenges in space habitation is creating life support systems that provide air, water, and food with minimal resupply and here biomimicry offers a clear advantage by emulating Earth's self-regulating ecosystems. For instance, researchers have looked to the self-regulating systems found in ecosystems

[27] (Brittany Neilson 2021)
[28] (Banken and Oeffner 2023)

to design closed-loop life support systems capable of recycling waste and producing essential resources like water, oxygen, and food. For example, the European Space Agency's *MELiSSA* project is demonstrating a nearly 100% closed-loop life support system – essentially a miniature self-sustaining ecosystem that ideally requires no resupply from Earth.[29] These systems use microbes and plants to scrub carbon dioxide, recycle water, and even produce food, closely mirroring the recycling networks of terrestrial ecology. By biomimicking these natural cycles, future Moon or Mars bases could continuously regenerate vital resources like oxygen, drinking water, and fresh food from astronaut waste, enabling long-term habitation independent of Earth.

Biomimetic materials inspired by the resilient structures of organisms such as shells, mycelium, or even spider silk could be used to create lightweight, durable space habitat components. Spider silk, in particular, has a tensile strength comparable to high-grade steel while remaining highly elastic and energy-absorbing.[30] Mimicking these behaviors of organisms and organic structures adapted to extreme environments on Earth also may inform the design of resilient habitats capable of withstanding cosmic radiation, temperature extremes, and microgravity conditions. Certain microbes and fungi, for example, produce protective pigments like melanin that absorb harmful ultraviolet and ionizing radiation. Synthetic melanin-based coatings inspired by these organisms are being investigated for spacecraft radiation shielding.[31] By harnessing efficiency, adaptability, and sustainability inherent in

[29] (European Space Agency (ESA) 2009)
[30] (Rising 2024)
[31] (Banken and Oeffner 2023)

natural systems, biomimicry has the potential to revolutionize space habitat design. This can make human exploration of the cosmos safer, more sustainable, and more successful.

In addition to materials innovations, biomimetic design helps maintain a vital connection to Earth for the occupants of these space habitats. Long-duration space missions risk isolating humans from the natural environment that our minds and bodies have evolved to thrive in. Incorporating living elements and Earth-like cues into space habitats is therefore more than aesthetic preference, but also therapeutic. For instance, astronauts aboard the International Space Station (ISS) have tended small gardens of lettuce, flowers, and herbs as part of research into bioregenerative life support. Beyond the nutritional boost, the psychological benefits have been profound. “These plants are a connection to Earth. The look, feel, taste, and smell all remind us of life on Earth,” said one astronaut, emphasizing how caring for living plants improved crew mood and mental health.[32] By mimicking the rhythms and forms of Earth’s ecosystems, we not only solve technical problems of sustainability but also nurture the explorers’ well-being. These biomimetic space habitats become a living extension of Earth, keeping humans psychologically grounded even as we venture farther from our home planet.

[32] (White 2022)

# Chapter 3: Psychological Needs in Space

*Psychological Needs in Space*

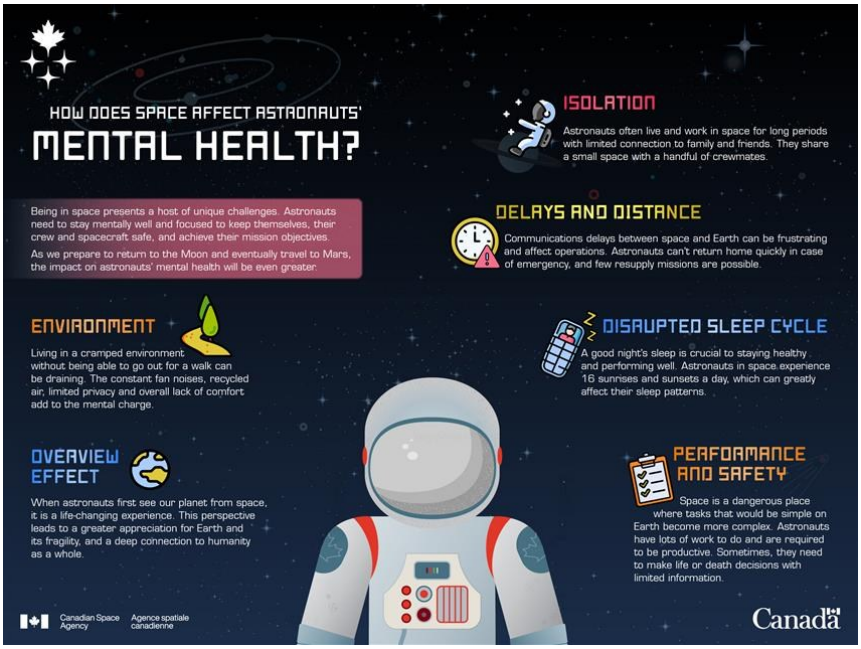


*Figure 9: Infographic showing the ways that space can impact mental health (Source: Canadian Space Agency, 2022)*

Designing environments that provide psychological support is essential for human habitats, and it becomes critically important in the unique and challenging conditions of outer space. To design environments that offer this vital psychological support, it's crucial to understand how space habitats can negatively impact human well-being. Numerous factors in the space environment contribute to stress, ranging from isolation and confinement to the lack of Earth's conditions, natural sounds, and landscapes. This environment tests the mental resilience of astronauts, necessitating space habitats that serve as sanctuaries. These habitats must bolster mental health and facilitate social interaction, creating a sense of normality and comfort. Designing space environments that support psychological well-being requires a collaborative

effort across disciplines. Architects, psychologists, and space professionals must work together to create habitats that safeguard physical health while nurturing the mind and spirit. These habitats must aim to mitigate space travel risks by reducing stress, enhancing mood, and designing for cognitive support. For long-duration space missions to be successful, it's essential not only to survive in space but also to thrive mentally and emotionally in the cosmic expanse. Understanding psychologically supportive human environments on this level will not only inform habitats in space but also revolutionize the way we design environments on Earth.

*Psychological Impacts of Space*

There are numerous negative psychological impacts that astronauts experience when in the environment of space. One of the most prominent psychological issues related to long-term human spaceflight is the stress associated with isolation within the vast cosmic unknown. This topic is explored within the article "THE BURDEN OF SPACE EXPLORATION ON THE MENTAL HEALTH OF ASTRONAUTS: A NARRATIVE REVIEW", written in collaboration by Alessandro Arone, Tea Ivaldi, Konstantin Loganovsky, Stefania Palermo, Elisabetta Parra, Walter Flamini, and Donatella Marazziti. The article analyzes the effects of long-term spaceflight on astronauts and notes that the lack of diversity in the space crew, the crew's size, ethnic origins, languages, and roles all could lead to tensions and communication challenges. Furthermore, the extended separation from family and familiar Earth routines poses a mental health threat to astronauts. This risk is compounded when living in close quarters with the same individuals. Additionally, the monotony arising from isolation can be dissected into three categories: spatio-temporal, sensory, and social isolation,

all of which can negatively impact the mission's success.[33] The article goes on to analyze specifically how these conditions could psychologically impact the astronauts. It includes that studies on space analogues indicate that these factors could lead to various symptoms such as exhaustion, sleep issues, and cognitive deficits. Additionally, the spacecraft's characteristics, referred to as "habitability", are crucial for space missions and extend their role beyond mere transportation. These features could also contribute to the stress affecting astronauts' overall well-being.[34] The article emphasizes the importance of understanding the psychological burdens of space exploration and highlights how these factors can exacerbate mental health challenges for astronauts. It demonstrates that the intricate dynamics of isolation, crew diversity, and spacecraft habitability are pivotal in understanding and mitigating the adverse psychological impacts on astronauts which emphasizes the need for comprehensive mental health strategies in long-term space missions.

The psychological impacts of long-duration spaceflight can also be attributed to the foreign environment conditions of space and the deprivation of Earth-like characteristics. One of the impacts associated with the absence of Earth-like conditions is the disruption of sleep schedules. This can significantly contribute to astronaut stress due to alterations in circadian rhythms on the spacecraft. Circadian rhythms are internal processes that regulate the sleep-wake cycle, synchronized with the light patterns on Earth. Unlike Earth, where humans have adjusted to a 24-hour light-dark cycle, the lighting conditions in space differ considerably, affecting sleep

[33] (Alessandro Arone 2021)
[34] (Alessandro Arone 2021)

patterns. Within an article titled “Headspace: How Space Travel Affects Astronaut Mental Health”, written by David Dezell Turner, this topic is discussed further with references to experiment results conducted on the International Space Station (ISS). The article says astronauts on the ISS witness 16 sunrises and sunsets daily, disrupting their sleep due to rapid changes in natural light and extended exposure to artificial blue light, which inhibits melatonin production and sleep onset. This disruption, coupled with the effects of chronic sleep deprivation, can impair cognitive functions and mental health, affecting their ability to perform critical tasks in space.[35] The space environment, characterized by irregular light cycles and artificial lighting on the ISS, contrasts sharply with Earth's natural rhythm which poses significant challenges for astronauts' sleep and well-being. The article referenced in the previous passage, “THE BURDEN OF SPACE EXPLORATION ON THE MENTAL HEALTH OF ASTRONAUTS: A NARRATIVE REVIEW”, emphasizes concerns related to the impact of sleep disturbances by noting that during space missions, disturbances or interruptions in sleep can lead to fatigue, concentration difficulties, and could even lead to life-threatening situations.[36] The research evidence and potential risks associated with the changing of light-dark cycles is motivation for serious consideration around how well these astronauts are adapting to this new environment. Another major change in this environment is the introduction of microgravity conditions. With the absence of gravity, humans are posed with the difficulty of adapting to a new way of interacting and moving through their

[35] (Turner 2019)
[36] (Alessandro Arone 2021)

environment which can result in cognitive issues. “THE BURDEN OF SPACE EXPLORATION ON THE MENTAL HEALTH OF ASTRONAUTS: A NARRATIVE REVIEW” also notes these issues and brings in evidence gathered within an experiment conducted on the ISS. The article states that microgravity can lead to cognitive challenges, with declines in motor skills like multitasking, motion perception, and manual coordination documented after six months on the ISS.[37] These deficits typically resolve within four days post-landing. This finding comes from a small study involving only eight astronauts, which may limit the conclusiveness of the results. Some research may even suggest that microgravity might enhance cognitive abilities in non-stressful conditions, indicating that stress, rather than microgravity itself, could be the main factor in cognitive decline; however more research is needed to hint at this conclusion. These foreign conditions in space and their associated negative psychological impacts highlight the need for ways to address these environmental stressors. Earth-like conditions that typically aid in alleviating stress, like views of natural landscapes, sounds of nature, and biophilic environments, are absent within this environment. Adaptable strategies to manage the unique conditions faced in space to maintain astronauts' health and operational efficiency is crucial for defining the success of human habitation in space environments.

*Proposed Solutions*

To address the psychological challenges of long-duration spaceflight, integrating biophilic design principles can be highly beneficial. The biophilia

[37] (Alessandro Arone 2021)

hypothesis (mentioned in chapter 2), which posits that humans have an inherent affinity for nature, can be leveraged to create environments that mitigate stress and enhance cognitive function. Proposed within the article "Can the Biophilia Hypothesis Be Applied to Long-Duration Human Space Flight? A Mini-Review", virtual reality (VR) systems can be a solution that simulates natural environments, offering astronauts immersive experiences that help reduce feelings of isolation and confinement.[38] These VR environments can include forests, oceans, and other calming settings, providing a psychological respite from the artificial surroundings of a spacecraft. Additionally, incorporating green design elements, such as living walls or hydroponic gardens, can significantly enhance the living conditions within spacecraft. These natural elements provide visual and sensory stimulation, crucial for maintaining mental health. Research within the article has demonstrated that exposure to natural elements can improve mood, reduce stress, and enhance overall well-being. By embedding these biophilic features, space habitats can create a more supportive environment, helping astronauts cope with the psychological demands of extended missions.

Another method to mitigate the psychological impacts of long-duration space travel is through architectural design in space stations that can incorporate principles from neuroarchitecture. This field of study works to show how architectural elements influence brain activity and emotional states. Research within the article "Walking through Architectural Spaces: The Impact of Interior Forms on Human Brain

[38] (Brittany Neilson 2021)

Dynamics" has shown that the form of interior spaces significantly affects human brain dynamics and emotional responses.[39] For instance, spaces with curved forms are generally preferred over rectilinear forms and are associated with increased activity in the anterior cingulate cortex (ACC), a brain area involved in emotional regulation and decision-making. Integrating these insights, space station designs could prioritize curved and naturalistic forms over harsh, angular geometries to create more psychologically supportive environments. Using virtual reality (VR) and mobile brain/body imaging (MoBI), designers can simulate and evaluate the impact of various architectural forms on astronauts' brain activity before construction. This approach allows for the creation of spaces that not only fulfill functional needs but also promote mental well-being by reducing stress and enhancing mood through thoughtfully designed environments. Incorporating varied interior forms and providing opportunities for natural movement and exploration can enhance the spatial experience for astronauts. This includes designing spaces that allow for different perspectives and interactions with the environment, facilitating a sense of discovery and engagement. By addressing the cognitive and emotional needs of inhabitants through strategic architectural design, space habitats can better support the mental health and overall well-being of astronauts during extended missions.

[39] (Banaei , et al. 2017)

# Chapter 4: Physiological Needs in Space

*Physiological Needs in Space*

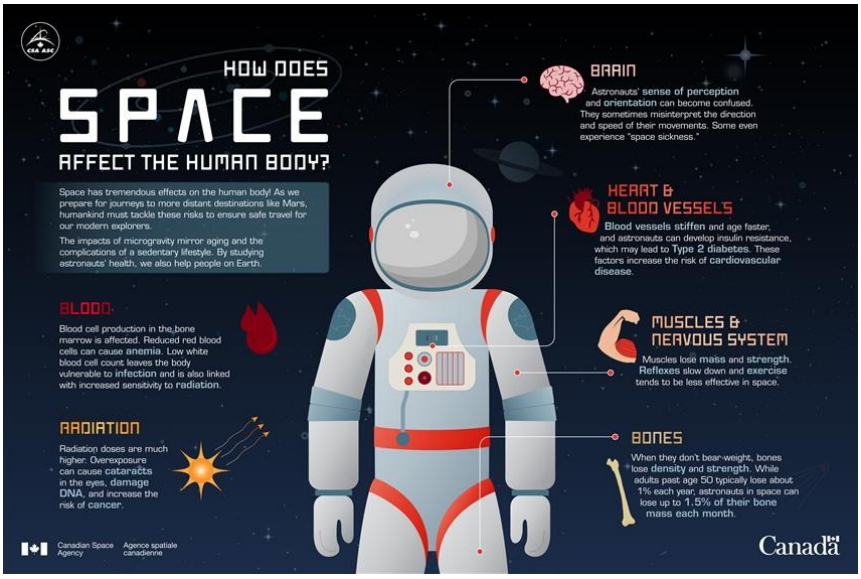


*Figure 10: Diagram showing the physiological impacts of space on humans (Source: InnovaSpace.org, Rohan Krishnan, 2022)*

While designing a psychologically supportive environment for humans in space is critical for cosmic habitats, the significance of also tailoring these environments to meet human physiological needs cannot be overlooked and must be considered in order to ensure that this environment can support human habitats over long-duration spaceflight missions. Addressing the challenges associated with human physiology in the extraterrestrial realm is vital to ensuring the health and safety of those who will live and work in these off-world communities. One of the primary challenges in space habitation is combating the effects of microgravity, or weightlessness. This condition poses significant health risks by contributing to the deterioration of the muscular and skeletal systems among other physiological complications. The exposure to cosmic radiation further intensifies the potential for

severe health risks, emphasizing the urgent need for innovative solutions. Currently, the strategies employed for astronaut habitation in space are basic and fall short of providing the comprehensive protection and support required for long-duration spaceflight. There is a pressing need for advanced solutions, such as the development of artificial gravity systems and enhanced radiation shielding technologies. These innovations are crucial for a path toward a safe and healthy expansion of humanity into space. This outlines the importance of investing in and focusing on this groundbreaking field. Engaging with and understanding these challenges and solutions is not just about the survival of astronauts, it is also about taking the necessary steps toward the future of human exploration and settlement in the vast cosmos along with understanding what it means to create a supportive environment for human needs.

*Physiological Effects of Spaceflight*

In order to create a physiologically supportive environment in space, it is important to understand the ways that gravity impacts the human body. It is important to consider that the human body is highly adaptive to stressors of the physical environment and will work to adapt accordingly. On Earth, humans along with all other organisms that we know of have evolved and adapted to the gravitational field of 9.81 $m/s^2$ and the protective atmosphere that supports all life on Earth. In the article “Human Pathophysiological Adaptations to the Space Environment”, written in collaboration by Gian C. Demontis, Marco M. Germani, Enrico G. Caiani, Ivana Barravecchia, Claudio Passino, and Debora Angeloni, the implications of physiological adaptation to Earth are discussed. It is mentioned that the transition

from aquatic to terrestrial life within human evolution significantly influenced the need for ancestral organisms to evolve intricate systems to manage stability, fluid balance, gravity perception, and movement. This evolutionary pressure led to the development of mechanisms where every cell potentially detects gravitational shifts, transforming mechanical stimuli into biochemical signals.[40] This adaptation is significant when considering the condition of microgravity, which occurs due to the lack of gravitational pull. This change in condition results in human physiology quickly changing in order to optimize functioning in that environment. This leads to several issues relating to deconditioning of the cardiovascular system, atrophy of muscles, decreasing bone mineral density, and altering fluid distribution within the body.

The condition of microgravity within the space environment has a number of problematic influences on the human body, especially when considering the possibility of long-duration spaceflight. In the article mentioned above, the authors write about the missions that have been done through the history of human spaceflight which provide evidence of physiological adaptations when exposed to microgravity. The article refers to Skylab missions completed in the 1970s. They lasted 28, 56, and 84 days respectively and involved three astronauts each, providing substantial data that laid the groundwork for space physiology.[41] The initial findings from these missions included issues like negative calcium balance leading to decrease in bone density, muscle atrophy, cardiovascular and blood changes, as well as

[40] (Gian Demontis 2017)
[41] (Gian Demontis 2017)

disruptions in metabolism, endocrine functions, and sleep patterns. This led space medicine experts to believe that astronauts experienced accelerated aging in space. However, this notion was reconsidered when it was observed that astronauts regained their health after returning to Earth indicating that the changes were not permanent. The similarity in symptoms and the potential for more severe effects from longer space missions continue to make accelerated aging a topic of keen interest within ongoing research in space medicine.[42] These impacts of microgravity pose a unique challenge to respond to when designing human habitats within space, yet the concerns extend beyond this to include the dangers of cosmic radiation as well.

Cosmic radiation, in addition to microgravity, significantly affects human physiology in space especially on long-duration spaceflight missions to the Moon or Mars. The extent that humans have studied radiation has revealed risks associated with long-term exposure that can lead to serious disease and even lethal outcomes. In the article mentioned previously, the author describes the exposure to radiation that astronauts could experience and the physiological impacts that they would likely experience in this environment. It is mentioned that astronauts of long-term missions to the Moon or Mars would face exposure to solar particle events (SPE) and galactic cosmic radiations (GCR), which contribute to both acute and late morbidity respectively.[43] The maximum acceptable risk of radiation-induced death for space missions has been set at 3%, a threshold that Mars missions are predicted to exceed. These predictions are based on data from Earth-based studies and might lack

[42] (Gian Demontis 2017)
[43] (Gian Demontis 2017)

accuracy. Moreover, the effects of high atomic number and energy (HZE) particles, which cause more severe DNA and cellular damage, are not fully understood. Radiation exposure can lead to both acute conditions, like radiation sickness, and long-term consequences, including cancer. Experiments on mice have shown that radiation exposure can decrease survival and induce various forms of cancer. In space, the reduced capability for DNA repair, compounded by factors like isolation and disrupted circadian rhythms, creates a complex health risk for astronauts.[44] Understanding the physiological risks associated with long-duration spaceflight such as effects of radiation exposure and the degradation of the human body due to microgravity, necessitates the development of solutions tailored to these harsh conditions of space to sustain human life in the extraterrestrial habitat.

*Current Solutions*

One of the current solutions practiced in order to mitigate the impacts microgravity has on human physiology are exercise programs before, during and after spaceflight missions. Incorporation of resistance training as part of spaceflight missions works to act as a countermeasure for the lack of forces experienced in microgravity environments. The article "Human Pathophysiological Adaptations to the Space Environment" mentions that various equipment used in order to facilitate these exercise programs. The various devices for exercise, including a bicycle ergometer, treadmill, bungee cords, and the Advanced Resistive Exercise Device (ARED). Incorporation of this equipment shows comparable results to Earth-based

[44] (Gian Demontis 2017)

free-weight training in terms of muscle strength and other physical parameters. ARED is now used on the International Space Station (ISS) to enhance astronauts' cardiovascular and musculoskeletal health. Additionally, advancements in treadmill technology have led to the creation of the Zero-Gravity Locomotion Simulator (ZLS). This technology effectively simulates the ground resistance force experienced during running on Earth.[45] While this technology is effective in acting as a countermeasure for microgravity, it depends upon the time an astronaut would take out of their busy schedule to incorporate this exercise program. The article mentions some additional technology that has potential in mitigating these physiological impacts. The technology includes the Low Body Negative Pressure (LBNP) chamber which is a tool that can counter the upward fluid shift in space, working by creating a negative pressure around the legs to enhance blood and fluid circulation downward. Its use has shown promising results in maintaining fluid balance without affecting foot venous pressure. Space activity suits, like the SkinSuit, are another solution, applying steady pressure on the body to mitigate spinal elongation and potentially reduce back pain and disc injury risks for astronauts. Additionally, research on whole-body vibrations (RVE) indicates potential benefits for musculoskeletal health, with experiments showing improved conditions in both human and animal models, suggesting these methods could be effective in counteracting the adverse effects of prolonged exposure to microgravity.[46] These technologies are fairly new and still in development however

[45] (Gian Demontis 2017)
[46] (Gian Demontis 2017)

show a lot of promise. They even show potential applications on Earth as they can aid in issues related to the deterioration of human physiology from aging.

Alongside solutions to mitigate impacts of microgravity, there are also strategies to mitigate radiation exposure risks during prolonged space missions. Shielding the spacecraft with materials that absorb or deflect radiation can provide a physical barrier against space radiation. Developing advanced spacecraft materials, possibly incorporating elements like hydrogen-rich compounds or alloys, could enhance this protective layer. Additionally, pharmacological strategies can play a major role in radiation risk mitigation. The article mentioned previously outlines this potential for pharmacology by saying that the pharmacological approach involves using antioxidants and other substances to neutralize reactive oxygen species (ROS) caused by space radiation. The article references studies that have shown that a combination of antioxidants, including L-Selenomethionine, sodium ascorbate, N-acetylcysteine, α-lipoic acid, vitamin E succinate, and coenzyme Q10, can improve the total antioxidant status (TAS) in living organisms exposed to radiation. The Bowman-Birk Inhibitor (BBI), a protease inhibitor derived from soybeans, has been particularly effective in restoring TAS. In addition to antioxidants, growth factors like granulocyte colony stimulating factor (GCSF) have been used to enhance neutrophil production and counteract lymphopenia caused by radiation.[47] It is mentioned that further research is needed in order to properly implement these strategies into spaceflight programs.

[47] (Gian Demontis 2017)

*Proposed Solutions*

A promising solution to mitigate physiological effects of microgravity is the creation of artificial gravity. This concept, often seen in science fiction, involves generating a force that mimics Earth's gravity to counteract the adverse impacts of microgravity on the human body. Artificial gravity can be achieved through centrifugal force. For example, rotating space habitats, such as the proposed O'Neill cylinder, Stanford Torus, and Bernal Sphere create gravity by spinning. These massive structures, envisioned by physicists, consist of large cylinders or spherical objects rotating and creating centrifugal force. Although practical implementation of such large-scale designs is distant, they offer a blueprint for future space habitats that can house millions of people. Within the article ”Artificial Gravity: Definition, Future Tech and Research” researchers are exploring smaller-scale solutions, such as rotating systems within spacecraft.[48] These systems use a centrifuge to generate Earth-like gravity, allowing astronauts to experience periods of normal gravity. This could help mitigate bone density loss and muscle atrophy, common issues in microgravity. One innovative design is a rotating vehicle with a crew compartment and a nuclear reactor at opposite ends, creating gravity through rotation. However, engineering challenges have so far prevented its practical application. A notable project aiming to implement artificial gravity is the Voyager space hotel, developed by the Orbital Assembly Corporation. Scheduled to begin construction in 2025, this rotating wheel space station will generate artificial gravity for its occupants. The station will not only serve scientific purposes but also cater to space tourists,

[48] (Lea 2022)

providing a unique environment where gravity can be controlled and studied. The first step in this ambitious project involves creating a prototype gravitational ring to demonstrate the viability of artificial gravity. This ring will generate gravity roughly equivalent to 40% of Earth's, similar to the gravity on Mars. In conclusion, while microgravity poses significant challenges to human physiology during space missions, innovative solutions like artificial gravity offer promising ways to mitigate these effects. As technology advances, these concepts could revolutionize space travel, making long-duration missions safer and more feasible.

# Chapter 5: Artificial Gravity and Life Support Systems

## *Artificial Gravity*

When looking for solutions to mitigate the harmful effects of microgravity within the environment of space flight, it is useful to consider environments that feature artificial gravity (previously mentioned in chapter 4). Artificial gravity is a simulated gravitational force created within a spacecraft, space station, or other cosmic environment to mimic the effects of gravity found on Earth. This force can be generated using rotational methods, where the centrifugal force resulting from spinning the habitat or spacecraft provides a gravity-like effect outward toward the perimeter. This technology can transform space living by providing a stable gravitational environment that preserves human health and reduces risks like muscle atrophy and bone loss. Key considerations include structural design, habitability, technological integration, psychological well-being, sustainability, and community dynamics. Addressing these aspects allows for the creation of supportive, efficient, and sustainable space habitats, facilitating growth and a sense of belonging in space communities.

Current research on centrifuge technology for the International Space Station (ISS) focuses on developing systems with automatic balancing and intelligent fault tolerance. These advancements are crucial for creating artificial gravity environments to mitigate the adverse effects of microgravity on astronauts' health. The research, as detailed in the article "Automatic Balancing and Intelligent Fault Tolerance for a Space-Based Centrifuge," outlines innovative approaches to maintaining equilibrium

within space-based centrifuges. The automatic balancing system utilizes existing sensors and actuators to ensure stability. This system relies on a maximum likelihood theory for fault detection and isolation (FDI), an approach similar to Kalman filters but designed for greater simplicity and robustness.[49] The technology can identify imbalances without complex dynamic modeling, making it adaptable to various failure scenarios. By integrating sensor data from strain gauges, counterweights, and rotational measurements, the system estimates net force and torque, enabling efficient diagnosis and correction of imbalances. On the ISS, these centrifuge systems play a pivotal role in simulating gravity for biological experiments and astronaut training. Maintaining a balanced and fault-tolerant centrifuge ensures consistent and reliable artificial gravity, essential for studying the effects of gravity on biological samples and human physiology. This research enhances our understanding of the physiological impacts of long-term spaceflight and provides valuable data for future missions. The implementation of centrifuge technology on the ISS is a significant step towards more advanced artificial gravity systems for future space habitats. These systems will be vital for long-duration missions to Mars and beyond, where maintaining astronaut health and performance is critical. The research outlined in the article provides a foundation for developing sustainable artificial gravity environments, essential for the success of extended human presence in space.

Current research on modern centrifuge systems is also being studied alongside their impacts on humans. The research on this artificial gravity technology and its

[49] (Wilson and Mah 2005)

impact on human physiology is highlighted in the study "Hemodynamic and Neuroendocrinological Responses to Artificial Gravity." The study involved ten male participants exposed to continuous and intermittent artificial gravity at 2 Gz. Significant changes were noted in hemoglobin levels and peripheral blood pooling during continuous exposure, indicating that sustained artificial gravity affects blood distribution.[50] Intermittent artificial gravity showed better tolerance, with normalized hemodynamic values during rest periods, suggesting breaks in exposure can mitigate some physiological impacts. Heart rate and blood pressure remained below levels experienced during moderate exercise, indicating artificial gravity might be a less stressful alternative for cardiovascular training in space. No significant changes in neuroendocrine markers were observed, suggesting short-term exposure may not significantly impact stress-related hormones. The study offers valuable insights but has limitations. The small sample size (ten male participants) and short duration of exposure might not fully represent long-term impacts or account for variations in responses due to gender or individual differences. Moreover, the study focuses on immediate physiological responses, leaving the long-term effects of artificial gravity on human health less understood. Future research should include larger, more diverse cohorts and extended exposure periods to provide a comprehensive understanding of artificial gravity's impact on human physiology.

Advancing artificial gravity research is crucial for ensuring safe and effective human life in space. Specific needs in technological development is outlined within

[50] (Schneider, et al. 2020)

the article “Artificial Gravity for Humans in Space: Philosophical and Methodological, Historical, Technological, and Futurological Aspects” saying that improving the design and implementation of artificial gravity systems, such as short-arm centrifuges and rotating habitats, ensuring they provide necessary gravitational forces without adverse effects on the human body.[51] Biomedical research must investigate long-term physiological and psychological impacts, including mitigating muscle atrophy, bone density loss, cardiovascular health issues, and mitochondrial stress observed in studies like the NASA Twins Study.[52] Integrating artificial gravity with space habitats to support daily activities and long-term health is essential, creating environments resembling Earth’s conditions. This integration is vital for the feasibility of long-duration missions and permanent space settlements.[53] Interdisciplinary approaches combining insights from physics, biology, engineering, and social sciences are necessary to address the complex challenges of living and working in space.[54] Additionally, international collaboration through initiatives like an International Center for Artificial Gravity Research can facilitate knowledge and resource sharing, accelerating the development and implementation of artificial gravity technologies and promoting safer human space exploration.

*Sustainable Life Support Systems*

Designing sustainable life support systems for long-duration space travel is crucial for the success and safety of space missions. The article "Greenhouse Module

[51] (Krichevsky 2021)
[52] (Krichevsky 2021)
[53] (Krichevsky 2021)
[54] (Krichevsky 2021)

for Space System: A Lunar Greenhouse Design" emphasizes the importance of creating integrated systems that allow astronauts to grow their own food, thereby reducing dependency on resupply missions from Earth.[55] The greenhouse design includes an inflatable outer structure with a rigid inner core, maximizing efficiency and space utilization. This system not only provides fresh produce but also supports air and water recycling, contributing to a closed-loop life support system essential for long-term space habitation. Sustainable life support systems are important as they ensure a continuous supply of food and essential resources, reduce mission costs, and enhance overall independence and resilience of space missions. Developing such systems is critical for enabling human settlement on other celestial bodies, as it addresses the logistical challenges of supplying crews on long-duration missions.[56] Sustainable designs also promote environmental stewardship and the efficient use of resources, which are vital principles for space exploration and habitation.

Current research on life support systems for other planets is exemplified by the study "Can Plants Grow on Mars and the Moon: A Growth Experiment on Mars and Moon Soil Simulants." This study explores the feasibility of cultivating plants in Martian and lunar soil simulants. Various plant species, including tomatoes, wheat, and cress, were tested for their ability to germinate and grow in these simulants. The findings revealed that plants could indeed grow, with better results on the Martian soil simulant compared to the lunar soil.[57] The implications of this research are significant for future space missions. Demonstrating that plants can grow in extraterrestrial soil

[55] (Zeidler, et al. 2017)
[56] (Zeidler, et al. 2017)
[57] (Wamelink, et al. 2014)

simulants supports the development of sustainable life support systems that incorporate agriculture. This would allow for food production on Mars and the Moon, significantly reducing the need for resupply missions from Earth. Moreover, growing plants in space habitats can aid in air and water recycling, contributing to a closed-loop life support system. This research paves the way for more advanced studies on optimizing soil conditions, selecting suitable plant species, and developing efficient agricultural practices for space environments.

Understanding how to support life in deep space exploration is also crucial for envisioning humans in long-duration spaceflight missions. The study detailed in the article "Closed Biotechnological Cycles for Transport Life Support Systems in Deep Space Exploration" focuses on integrating closed biotechnological cycles into life support systems (LSS) for autonomous transport systems (ATS) used in deep space missions. The research investigates biotechnological cycles of methane and carbon dioxide, aiming to achieve high efficiency in closed circulation and create nature-like features. Specifically, the study explores processing ATS crew waste, using methane for oxygen generation, and employing biosynthesis for food protein production.[58] This integrated approach aims to create sustainable ecosystems necessary for long-duration space missions and planetary settlements. The significance of this research lies in its potential to revolutionize life support systems for long-duration space flights and human settlements in space. By developing self-sufficient ecosystems that recycle waste and produce essential resources like oxygen and food, this study

[58] (Kabashkin and Glukhikh 2023)

addresses the critical challenge of resource dependency on Earth. The use of biotechnological cycles enhances sustainability and reduces the logistical complexity of resupply missions. Moving forward, this research could evolve into more sophisticated systems that incorporate advanced biotechnologies and automation, further improving efficiency and reliability. This progress is crucial for the viability of long-term human presence on Mars and other celestial bodies, enabling sustainable living conditions and supporting the broader goal of space exploration and colonization.[59]

[59] (Kabashkin and Glukhikh 2023)

# Chapter 6: Modular Design and Lunar Construction

*Modular Design*

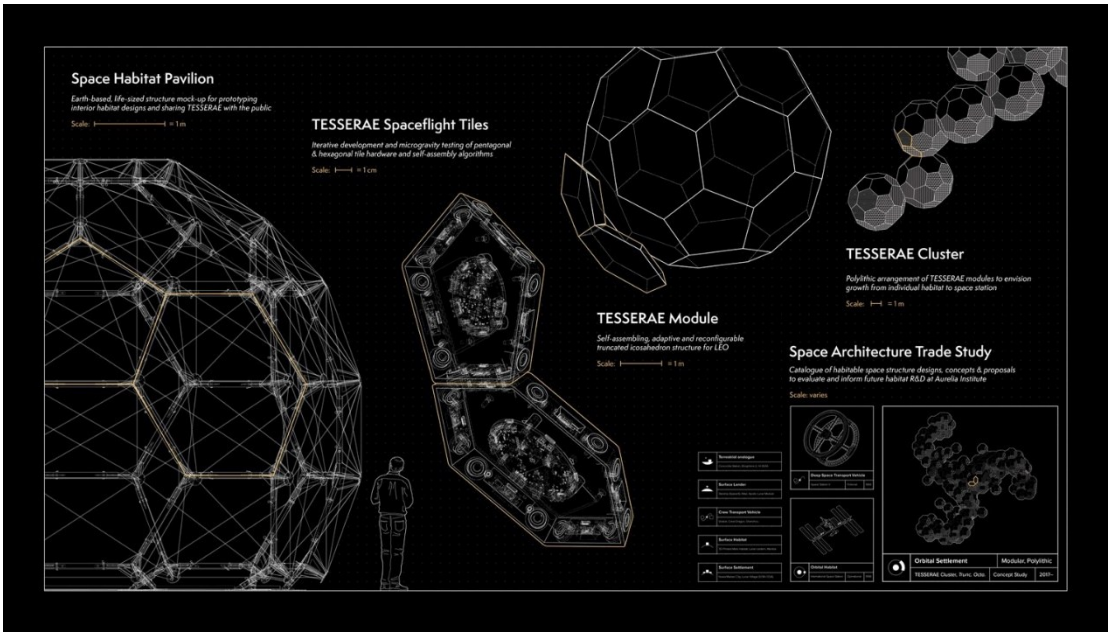


*Figure 11: TESSERAE module technical drawings created by Aurelia Institute (Source: Aurelia Institute, 2025)*

The TESSERAE (Tessellated Electromagnetic Space Structures for the Exploration of Reconfigurable Adaptive Environments) project, led by Aurelia Institute, focuses on developing self-assembling, adaptive, and reconfigurable structures for space habitats. This innovative approach, which began as a PhD thesis by Ariel Ekblaw at MIT, aims to revolutionize space habitation by reducing payload weight and assembly complexity through in-space manufacturing. The project has already seen successful tests, including on the Ax-1 mission to the ISS. Future tests will continue to refine the technology, pushing toward full-scale space station designs.

TESSERAE's design leverages a unique combination of magnetism and smart materials to enable its modules to autonomously connect and form stable structures. This approach allows for a high degree of adaptability, making it possible to create various configurations suited to different missions or needs in space. The project's success so far has set the stage for more ambitious goals, including the development of large-scale space stations that could support long-term human habitation.

The technology behind TESSERAE is not just about creating space habitats; it also has broader implications for in-space manufacturing and assembly. By minimizing the need for human intervention in the construction of space structures, TESSERAE could significantly lower the costs and risks associated with space exploration. As the project advances, it continues to explore new materials and techniques to improve the robustness and functionality of these self-assembling habitats, with the aim of making space more accessible for sustained human presence.

*Lunar Construction*

The lunar surface offers a wealth of resources that can significantly support human exploration and habitation. Regolith, which covers the Moon's surface, is rich in minerals like silicon dioxide, iron oxide, and aluminum oxide. These materials can be utilized for construction purposes, such as creating sintered blocks, concrete, and glass. Additionally, regolith contains oxygen, which can be extracted and used for life support systems and as an oxidizer in rocket fuel, reducing the dependency on Earth-supplied resources.

Water ice, found in the permanently shadowed craters at the lunar poles, is another critical resource. This ice can be split into hydrogen and oxygen, essential for both sustaining human life and serving as rocket propellant. The availability of water on the Moon could enable the Moon to function as a refueling station for deeper space missions, significantly lowering the cost and increasing the feasibility of such missions.

Metals like iron, aluminum, and titanium found in the lunar regolith are crucial for constructing infrastructure on the Moon. These metals can be processed to manufacture structural components, machinery, and other necessary equipment. Silicon, another abundant element, can be used to produce solar cells, providing energy for lunar bases and other installations.

Helium-3, a rare isotope embedded in the lunar regolith by solar wind, holds promise for future energy production through nuclear fusion. Although the technology is still in development, helium-3 could become a valuable resource for generating clean and efficient energy, making lunar mining operations highly desirable.

Utilizing these lunar resources effectively can dramatically reduce the need for transporting materials from Earth, making sustained lunar exploration and habitation more feasible and economically viable. Furthermore, the Moon could serve as a crucial hub for deeper space exploration, providing essential resources like life support and fuel, and laying the groundwork for long-term human presence beyond Earth.

# Chapter 7: What Does This Mean for the Future?

## *The Future of Design and Academia*

The pursuit of space architecture is not simply about engineering survival in orbit—it is about expanding the role of architecture into the domain of planetary stewardship and human evolution. Designing habitats for space demands more than structures; it demands systems that sustain life independently of Earth. This necessity pushes architecture beyond aesthetics or function into the realm of integrative, regenerative design. It requires architects to think like ecologists, psychologists, and theorists. In doing so, space architecture becomes a lens through which we reevaluate our assumptions about how humans live, interact, and thrive. It poses a fundamental question: "if we had to design the ideal conditions for human life, what would we prioritize?" The answers are surprisingly applicable to Earth as psychological well-being, community structure, resource efficiency, and environmental harmony are all fundamental to all of our human environments. These are not just needs for spacefarers, they are universal needs for humanity.

This thesis proposes that the effort to build sustainable human environments in space is inseparable from the work of healing and sustaining life on Earth. The innovations developed for space, such as closed-loop ecological systems, modular adaptable habitats, automated manufacturing, artificial gravity simulations, and bio-integrated environments, are prototypes for a new way of living, both in orbit and in our cities. These technologies, born from constraint, encourage us to reimagine Earth not as an unlimited provider, but as a shared vessel that requires conscious and

intelligent design. Through the design of space communities, we are testing methods of resource conservation, social organization, and psychological support that can inform how we build homes, neighborhoods, and institutions on Earth. The environmental ethic at the core of space architecture is not about escape, it is about return and bringing back ideas, systems, and mindsets that can transform the future of human settlement across any environment.

The exploration of space architecture offers profound implications not only for the future of design but also for academia. By addressing the challenge of creating human habitats in space, this field encourages a multidisciplinary approach, blending engineering, biology, psychology, and architecture. Viewing this challenge through an architectural lens uncovers the fundamental human needs required for survival in extraterrestrial environments—such as protection from harsh conditions, psychological well-being, and efficient resource utilization. This understanding can lead to innovative designs on Earth that prioritize sustainability, adaptability, and long-term human well-being. Integrating space architecture into academic curricula opens the door to teaching architecture not as an isolated practice, but as a shared, human-scale response to planetary-scale questions. It encourages future architects, engineers, artists, and scientists to view their work not just as disciplinary expression, but as vital contributions to humanity's adaptive survival.

The insights gained from designing for space exploration can significantly influence academic curriculum, inspiring institutions to integrate space architecture into their programs. This inclusion would foster a generation of architects and

designers who are not only technically proficient but also deeply attuned to humanity's best interests. These future professionals would be equipped to tackle global challenges such as climate change, resource scarcity, and sustainable development, applying principles learned from space architecture to create environments that support life on Earth and beyond.

Furthermore, this effort marks a pivotal step toward breaking away from humanity's dependence on Earth's biosphere and natural resources. By developing technologies and strategies for sustainable living in space, we can also advance our capabilities for sustainable living on Earth. The goal of space architecture is to create a 100% sustainable human presence, a vision that can transform not only our future in space but also how we live on our home planet.

Incorporating space architecture into academic studies could revolutionize how we approach design, encouraging a shift towards more holistic, sustainable practices. This shift has the potential to influence a wide range of disciplines, from urban planning to environmental science, ultimately guiding humanity toward a future where we thrive in harmony with the environment, both on Earth and in space. This thesis works to envision architecture and human environments that are no longer limited to the Earth’s surface and become a medium for constructing empathy, resilience, and continuity across generations and worlds. Space becomes a mirror through which we learn to value what is sacred about Earth, and a testing ground for how we might do better. In proposing new ways to live in space, this thesis ultimately proposes a new ethic of design which is one that is generous, regenerative, and

grounded in the belief that our survival is not just a technical achievement but a cultural, ecological, and deeply human one.

# Chapter 8: Program

*Defining the Space*

This thesis envisions a habitat within Earth's orbit as a dynamic living, learning, researching, and teaching environment with an emphasis on symbiotic human-environment relationships to enhance occupants' well-being. Rooted in human-centered design, the habitat incorporates advanced life support systems, artificial gravity, biophilic design, and modular construction to support long-term, sustainable habitation. Flexible and adaptable spatial configurations foster both privacy and social cohesion, while communal areas promote collaboration and psychological well-being. Drawing from biomimicry and biophilia, the habitat reconnects occupants with their terrestrial heritage, helping preserve a sense of identity and ecological awareness even in orbit.

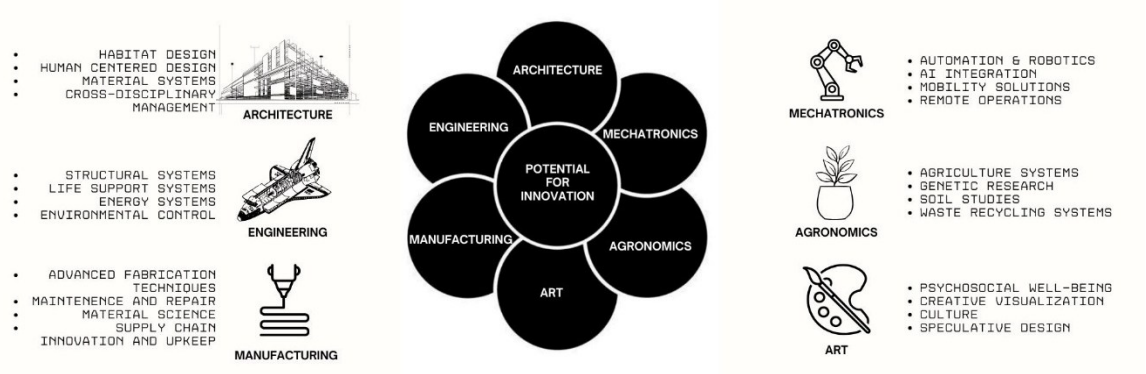


*Figure 12: Diagram displaying disciplines within the proposed program and their expertise within the specified fields.*
*(Source: David Fischetti, 2025)*

The interdisciplinary work practiced here aims to reach a nexus between technology, architecture, and the human environment. Programmatically, the station functions as a micro-civilization composed of six disciplines being architecture,

engineering, manufacturing, mechatronics, agronomics, and art. Each of these discipline communities contributes vital knowledge and innovation to the collective mission. The mission being to operate as a collaborative think tank, using space as a testing ground for advancing solutions to humanity's greatest challenges related to sustainability and overall advancement as a species.

The goal of this thesis is to, not only explore and adapt to extraterrestrial living, but to refine technologies, mindsets, and strategies that can return to Earth and be scaled for global benefit. By integrating sustainability, automation, social well-being, and adaptive design, this thesis envisions a future where the boundaries blur between terrestrial and extraterrestrial habitats, fostering harmonious coexistence between humanity, the environment around us, and the cosmos, ultimately enriching sustainable, human-centered design both in space and on Earth.

*Case Study: Orbital Reef*

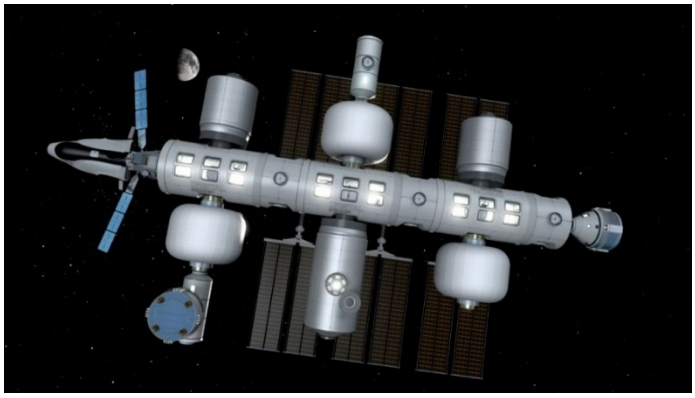

*Figure 13: Orbital Reef Project designed by Blue Origin to be the first business park in space in 2027.*
*(Source: Blue Origin, 2021)*

While there is no precedent for a design like this currently, there are projects that will be emerging within the next 5 years that will accomplish a design very

similar. Blue Origin's Orbital Reef project aims to create a commercially owned and operated space station, envisioned as a “mixed-use business park” in low Earth orbit, providing a shared infrastructure where research institutions, industrial manufacturers, international space agencies, and commercial ventures can all establish an address in orbit.[60] The projects is to begin operations in the late 2020s and is emerging as a strong precedent for a commercially operated, mixed-use space habitat.

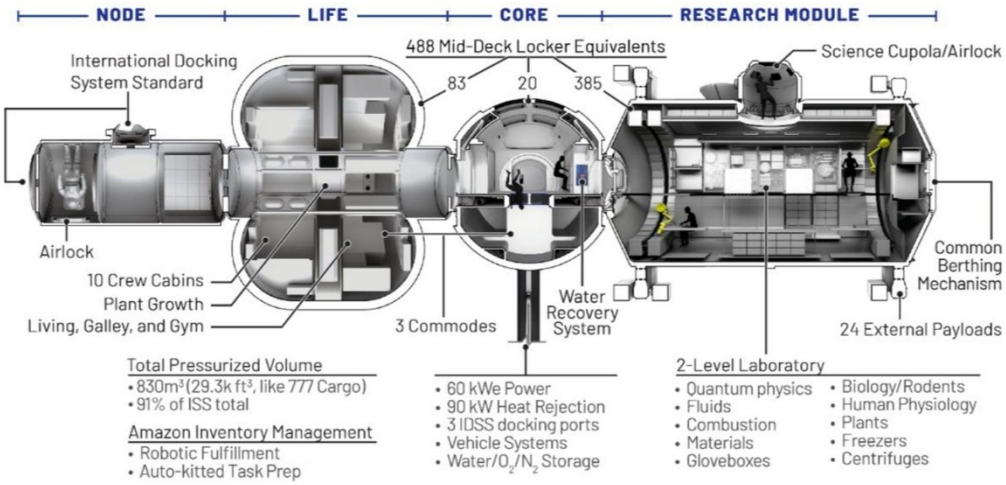


*Figure 14:Orbital Reef’s modular elements including the Node, LIFE, Core, and Research Module from Mosher & Kelsey*
*(Source: Mosher & Kelsey, 2023)*

The design includes several modules, each with specific functionalities, enhancing the versatility of the station. Key components include the LIFE Module (an expandable living module offering 300 m³ of habitable volume), capable of housing 10 crew members with dedicated living and working spaces, the Research Module equipped with internal and external payloads for scientific experiments, and the Core Module (~250 m³ volume), which provides essential utilities and life support

[60] (Blue Origin 2021)

systems.[61] The Node Module (~40 m³ volume) connects different parts of the station and includes vehicle ports for visiting spacecraft. The Energy Mast supports solar arrays providing 100 kWe power, and the single-person spacecraft allows for suitless EVAs. The modules measure approximately 12 meters in diameter, with additional stowage spaces and various anti-microbial facilities for exercise, hygiene, and food preparation. Overall, Orbital Reef's fully assembled configuration will deliver roughly 90% of the International Space Station's internal volume (~830 m³) and accommodate a permanent crew of ten.[62]

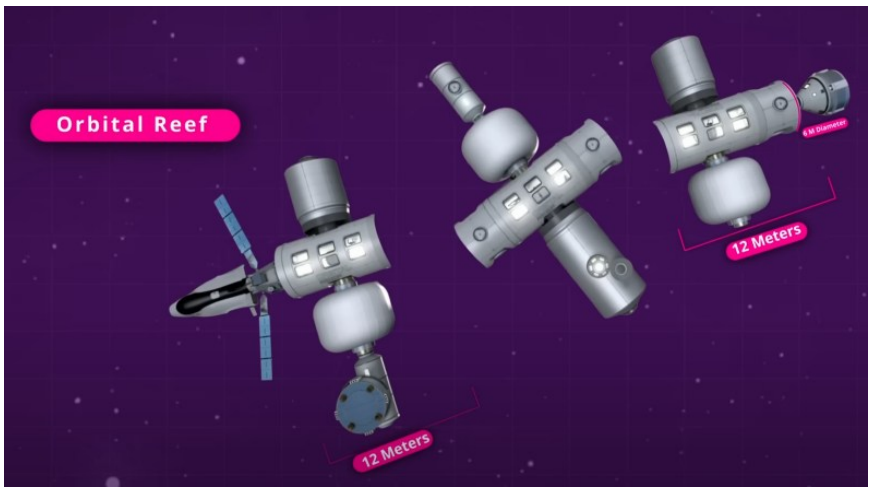


*Figure 15: Orbital Reef Structure segmented into parts.*
*(Source: The Space Race, 2023)*

Notably, Orbital Reef's design emphasizes crew accessibility and comfort. The business model is intentionally open and multi-user as Orbital Reef will offer "end-to-end" services (transportation, habitation, operations) at competitive rates to lower the barriers of entry for new users.[63] Brent Sherwood of Blue Origin highlights its human-centered architecture with "big volumes, big hatches, a sky canopy of huge

[61] (Zea, et al. 2024)
[62] (Davenport 2021)
[63] (Blue Origin 2021)

windows facing Earth, a central thoroughfare between modules, and a safe, easy way to do excursions outside".[64] By providing these amenities and utilities, plus a crew on board to assist, the station lowers complexity for users. For example, manufacturers could use microgravity to produce exotic materials, researchers can conduct experiments in biology or physics, and space tourists might simply enjoy the view.[65] This multipurpose, multi-tenant approach is aimed at stimulating a vibrant Low Earth Orbit (LEO) economy beyond what the ISS has enabled.

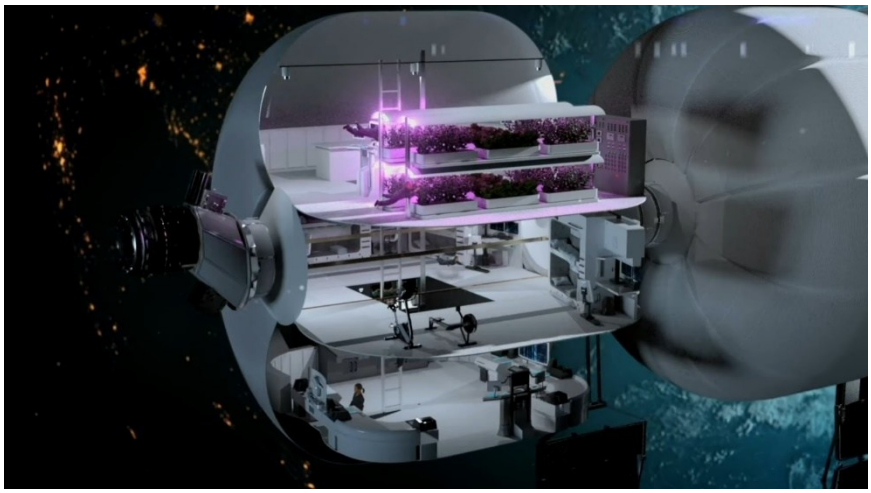

*Figure 16: 3D section of one of the modules showing off the living spaces on the interior.*
*(Source: The Space Race, 2023)*

Orbital Reef serves as a powerful proof-of-concept for modular commercial space habitats, demonstrating how private industry and partnerships can create a multi-use orbiting community. This thesis proposal uses Orbital Reef as a springboard but pushes the concept further with new innovations in gravity, sustainability, crew wellness, and inclusivity. The thesis design places a heavier emphasis on closed-loop life support and renewable on-site resource utilization. The proposed design also

[64] (Clark 2021)
[65] (REDWIRE 2021)

recognizes the health challenges of long-term microgravity. The thesis proposes incorporating rotating living environments to generate artificial gravity which mitigates issues like bone density loss and muscle atrophy, enabling longer stays and improved crew health and comfort for a broader range of occupants. The design also goes further in supporting the mental and emotional health of its residents. It integrates biophilic elements and community spaces far beyond the amenities of Orbital Reef. For instance, the habitat interior features simulated natural lighting cycles, small gardens, and recreation areas to combat stress and isolation. The layout is conceived to maximize open, communal volumes creating a sense of neighborhood in space. In contrast to Orbital Reef's commercial model, the thesis project envisions a space habitat with a strong educational and inclusive mission. It is designed to be accessible to a global and diverse community of students and mentors, not just elite astronauts or wealthy space tourists. This results in a vision of a future space habitat that not only accommodates research, but also fundamentally reimagines long-term living in space and on Earth as more self-sufficient, more humane, and more accessible to all.

*Community-Centered Design*

To envision an environment like this, it is necessary to think about the community itself and how it will be composed. Future space habitats must be designed with human social cognition in mind. Anthropological research by Robin Dunbar suggests there is a cognitive limit (around 150 people) to the number of

individuals with whom one can maintain stable, meaningful relationships.[66] [67] Leveraging Dunbar's number within the design of these orbital habitats will focus on creating community-sized environments that promote familiarity and form the kind of tight-knit bonds essential for trust and cooperation in extreme environments.

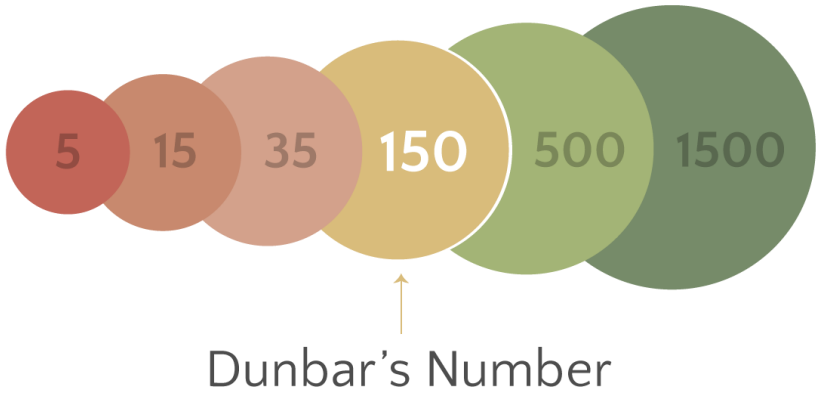


*Figure 17: Diagram demonstrating the groupings of people leading up to Dunbar's Number*
*(Source: Robin Dunbar, 2021)*

By structuring the habitat into smaller interconnected modules, the habitat fosters a sense of familiarity and trust among its inhabitants. Each person can develop a support clique (perhaps their immediate crewmates or roommates) and a sympathy group within their module, while the entire habitat population remains within the 150-person active network limit.[68] Designing for Dunbar's number is fundamentally about humanizing the habitat. Long-duration missions in extreme isolation (whether orbital habitats, lunar bases, or even on Earth) face risks of loneliness, stress, and group tension. By structuring the environment into intimate communities, this thesis design aims to replicate the psychosocial benefits of a small town or tight-knit research

[66] (Hyde 2022)
[67] (Dunbar and Spoors 1995)
[68] (Dunbar and Spoors 1995)

community. Each person has a place and a role where they feel known and valued – which is vital for mental health when far from home. Strong social ties have been shown to buffer stress and improve well-being, while in contrast, anonymity and social isolation can erode trust and performance.[69] These communities will be a supportive social fabric and cooperative atmosphere that mirrors the close-knit communities found on Earth.

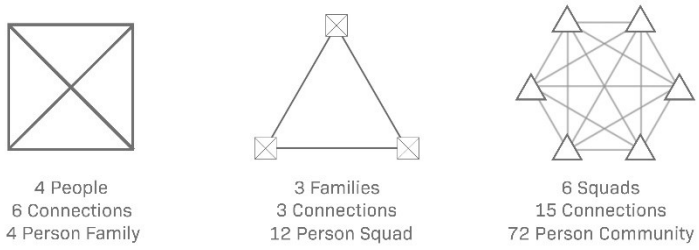


*Figure 18: Breakdown of Community Sized Modules based on Dunbar's Number (Source: David Fischetti, 2024)*

These community-sized modules will be designed to be self-sustaining units that, if any disconnection to the whole community occurs, are resilient to change. As humanity's presence in space grows, new habitats can be established as extensions of this model rather than simply crowding more people into one settlement. Much like historical towns or campus colleges, once a colony approaches the limits of cohesion, it can branch into another module cluster – maintaining inter-community links but preserving the manageable size of each unit. In this way, Dunbar's number not only guides the initial design of an orbital habitat but also informs a sustainable growth pattern for space societies. By designing with our social brains in mind, we ensure

[69] (Novotney 2019)

that even in the most extreme environment, humans can continue to do what we evolved to do best: live and work together in thriving, cooperative communities.

Within these close-knit communities, there will be a program of spaces that will work to create a dynamic living, learning, researching, and teaching environment designed for people of a wide background including professional mentors alongside students. The composition of this program will contain the following list of spaces:

- **Residential/Living Zones (6 modules at 12,800 sq. ft. per module)**
    - Living Units
    - Living/learning Collaboration Areas
    - A Communal Courtyard
    - Exhibition Space for Innovations
- **Research and Learning Zones (6 modules at ~4000 sq. ft. per module)**
    - Classrooms/Research Labs
    - Facility Management
    - Mission Control Areas
    - Collaborative Workspaces
- **Resupply Zones (6 modules at ~700 sq. ft. per module)**
    - Resupply Docking Ports
    - Transitionary Space Between Communities
- **Community Expression Zone (1 module at ~7500 sq. ft.)**
    - Social/Event Space
    - Community/Cultural Expression Area
    - Docking/welcoming areas

Each of the modules within the overall community will contain these spaces in order to support a close-knit community while also having a distinction between each module in order to encourage the interaction of people across the community as a whole. Each module will be uniquely themed or specialized, providing a distinct identity that creates a sense of pride and belonging among its residents. For example, one module might focus on artistic endeavors, offering studios, galleries, and performance spaces, while another might emphasize scientific research with state-of-the-art laboratories and conference rooms. This thematic distinction not only caters to diverse interests and talents but also motivates residents to explore and engage with other modules, promoting an interconnected community.

The modular design will also incorporate flexible communal support spaces within each module, allowing for a range of functions based on the evolving needs and desires of its occupants. By integrating these shared spaces, the habitat ensures that residents have ample opportunities to socialize, share knowledge, and build relationships beyond their immediate module. These flexible environments can support collaborative work, informal gatherings, recreational activities, or quiet reflection all working to empower inhabitants to shape their surroundings to suit both personal and collective rhythms. This structure mirrors the dynamics of small towns or neighborhoods on Earth where people can enjoy the intimacy of their local community while still being part of a larger and more interconnected society.

The module's orientation and integration will be strategically informed by the habitat's artificial gravity system. A comparative analysis of visionary structures,

such as the Stanford Torus, the O'Neill Cylinder, and the Bernal Sphere, will guide the spatial layout and draw inspiration from scientific theory. This fusion of speculative architecture and engineering will determine how gravity, movement, and human experience shape the architecture of orbital life.

*The Stanford Torus Model*

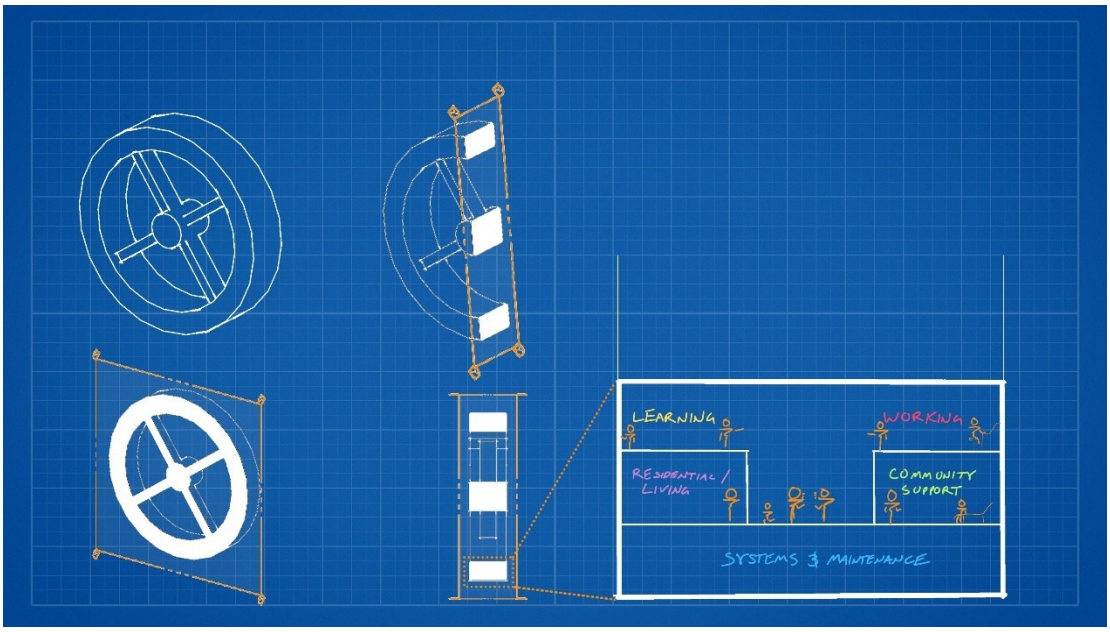


*Figure 19: Blueprint showing a 3D axon, 3D sections, and 2D sections for a Stanford Torus Model of a community in space.*
*(Source: David Fischetti, 2024)*

The Stanford torus model envisions a large, ring-shaped space habitat designed to support a community in space. The programmatic layout includes distinct zones for residential living, learning, working, community support, and systems maintenance, effectively creating a self-sustaining ecosystem. At the center of the torus, the hub is dedicated to essential systems and maintenance, ensuring the smooth operation of the habitat. Surrounding this core, residential areas provide private and communal spaces for inhabitants, fostering a sense of community and home. Adjacent

to the residential zones are learning and educational spaces, promoting continuous personal and professional development. Working spaces are strategically placed to facilitate productivity and collaboration among inhabitants. Additionally, community support areas offer essential services and recreational facilities, enhancing the overall quality of life.

The positives of this model include its integrated living environment, which supports a balanced lifestyle with designated areas for living, learning, and working. The torus design provides artificial gravity through rotation, potentially mitigating the health issues associated with long-term weightlessness. Furthermore, the extensive use of in-situ resources and advanced autonomous construction methods could enhance sustainability and reduce reliance on Earth. However, there are also challenges. The initial construction and maintenance of such a habitat are highly complex and costly. The isolation from Earth, despite the self-sufficient design, could pose psychological challenges for residents. The habitat must also ensure robust protection against space hazards, such as radiation and micrometeorite impacts. Despite these challenges, the Stanford torus represents an innovative and comprehensive approach to long-term human habitation in space, offering a blueprint for future space communities.

*The O'Neil Cylinder Model*

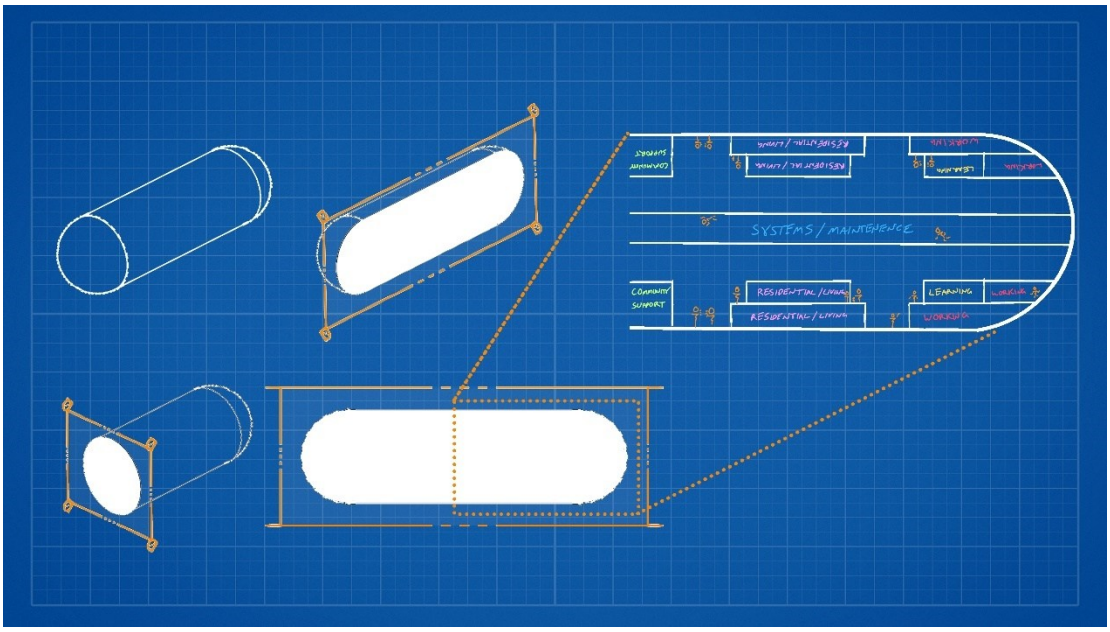


*Figure 20: Blueprint showing a 3D axon, 3D sections, and 2D sections for a O'Neil Cylinder Model for a community in space.*
*(Source: David Fischetti, 2024)*

The O'Neill Cylinder model envisions a long, cylindrical space habitat designed to support a large community in space. According to the blueprint, the programmatic layout includes sections for residential living, learning, working, community support, and systems maintenance. The core of the cylinder is dedicated to systems and maintenance, ensuring the habitat's essential operations are well managed. Surrounding this core are extensive residential areas providing ample living space for inhabitants, designed to create a comfortable and homelike environment. Learning areas are strategically positioned to foster education and continuous development, while working zones are spread throughout the habitat to encourage productivity and ease of access to various job functions. Community support areas are integrated to provide essential services, recreational facilities, and social spaces to enhance the quality of life.

There are many positives of the O'Neill Cylinder model. The extensive residential areas offer ample room for inhabitants, reducing the feeling of confinement often associated with space habitats. The rotation of the cylinder creates artificial gravity, potentially mitigating the health issues linked to long-term exposure to microgravity. The inclusion of systems maintenance and community support areas promotes a self-sustaining environment, minimizing dependency on Earth for resources. Additionally, the strategic placement of working and learning spaces ensures efficiency and fosters a balanced lifestyle for the inhabitants. However, there are also significant challenges. The high initial costs and advanced technology required for constructing such a large and complex habitat are substantial. Ensuring the safety and well-being of inhabitants in the face of space hazards, such as radiation and micrometeorite impacts, adds another layer of complexity. Despite these challenges, the O'Neill Cylinder represents an innovative and comprehensive approach to long-term human habitation in space, potentially also providing a detailed blueprint for future space communities.

*The Bernal Sphere Model*

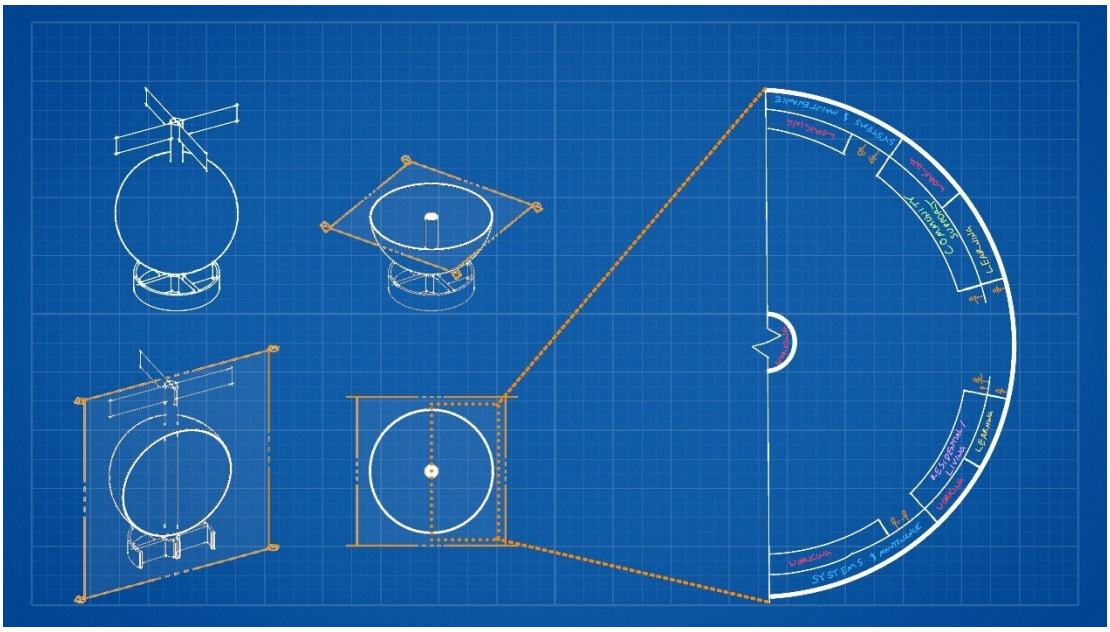

*Figure 21: Blueprint showing a 3D axon, 3D sections, and 2D sections for a Bernal Sphere Model for a community in space.*
*(Source: David Fischetti)*

The Bernal Sphere model envisions a large, spherical space habitat designed to support a community in space, with a focus on creating a balanced environment for living, learning, and working. According to the blueprint, the programmatic layout includes distinct zones for residential living, learning, working, community support, and systems maintenance. The central axis of the sphere is dedicated to systems and maintenance, ensuring the essential operations of the habitat are efficiently managed. Surrounding this central core are areas designated for working and residential living, providing inhabitants with easy access to both their homes and workplaces. Learning areas are strategically positioned to foster continuous education and development, while community support zones offer essential services and recreational facilities, enhancing the overall quality of life.

The positives of the Bernal Sphere model include its compact and integrated design, which promotes efficient use of space and resources. The spherical shape allows for uniform distribution of artificial gravity, created by the rotation of the sphere, which can mitigate the health issues associated with long-term exposure to microgravity. Additionally, the inclusion of dedicated areas for systems maintenance and community support ensures a self-sustaining environment, minimizing dependency on Earth for resources. However, this model also faces significant challenges. The high initial costs and advanced technology required for constructing such a large and complex habitat are substantial. Ensuring the safety and well-being of inhabitants in the face of space hazards, such as radiation and micrometeorite impacts, adds another layer of complexity. Furthermore, the Bernal Sphere is considered the least feasible of the three models (Stanford Torus, O'Neill Cylinder, and Bernal Sphere) due to its design and engineering challenges. Despite these hurdles, studying the Bernal Sphere's dynamics with space remains important as it provides valuable insights into the potential for human habitation in space and contributes to the advancement of space habitat designs.

# Chapter 9: Site Selection

## *Defining the Vision*

The site location of the Neo-Future thesis should not only work to support the convenience and safety of the human environment in space but also act as a source of inspiration for all that experience this environment. In envisioning the ideal site, it must serve as a sanctuary amidst the vastness of space while also being close enough to our home planet to act as a bridge to the cosmos. It should emphasize security and safety to support the delicate habitat for inhabitants to thrive in. It should also offer a mesmerizing panorama to the cosmos while also acting as a constant reminder of our place in the universe. This location should evoke a sense of wonder and awe that ignites the imagination and inspires current and future generations' exploration. The chosen site must not only meet practical needs such as radiation mitigation and proximity to home but also serve as a beacon of inspiration, inviting humanity to embrace the boundless possibilities of our cosmic journey while also paying respects to our home planet.

## *Earth*

Establishing an orbital community around Earth's orbit presents a mix of potential positives and negatives. The proximity to Earth offers a significant advantage in terms of reduced travel costs and shorter travel times, enhancing the feasibility of frequent trips and resupply missions. This close proximity also allows residents to maintain a visual connection with Earth, which can be psychologically beneficial. The ability to autonomize construction using robotic technologies could

reduce human labor and associated risks during the building phase. However, challenges include high initial construction costs and the need for advanced technology to ensure sustainability and safety. Radiation exposure levels in orbit are higher than on Earth's surface, necessitating robust shielding solutions to protect inhabitants. While the community could serve as a strategic platform for cosmic exploration, supporting families might be challenging due to the confined living spaces and potential long-term health effects of microgravity. The potential for danger from space debris and the complexity of continuous resupply logistics also pose significant risks. Despite these challenges, an orbital community could be an innovative leap for humanity, fostering new advancements in space habitation and expanding our reach into the cosmos.

*The Moon*

Locating an orbital community around lunar orbit or on the lunar surface offers distinct positives and negatives. The increased distance from Earth results in higher travel costs and longer travel times, complicating transportation and resupply logistics. The visibility of Earth from the lunar surface or orbit can provide a unique and inspiring view, though less frequent visual contact might affect psychological well-being compared to Earth’s orbit. The overall feasibility is challenging due to the harsh lunar environment including significant radiation exposure and extreme temperature fluctuations. This will require advanced shielding and habitat technologies. However, the Moon's proximity to Earth compared to deeper space destinations makes it a strategic stepping stone for cosmic exploration. Additionally, constructing and launching space vehicles from the lunar surface is more economical

than from Earth due to the lack of atmospheric friction and the Moon's lower gravitational pull. The low gravity environment of the Moon poses both opportunities and challenges for human health, potentially complicating the feasibility of long-term habitation. Autonomous construction using robotics and on-site resources could mitigate some of these difficulties making the project more sustainable and less labor-intensive. The potential for danger from lunar dust, micrometeorite impacts, and the absence of a protective atmosphere adds to the risk factors. Despite these challenges, establishing a community on or around the Moon would be a groundbreaking achievement, driving innovation in space technology and paving the way for future interplanetary habitation.

*Mars*

Locating an orbital community around Mars' orbit or on the Martian surface presents numerous positives and negatives. The cost of travel is significantly higher due to the vast distance from Earth, resulting in long travel times and substantial logistical challenges for transportation and resupply. The visibility of Earth from Mars is minimal, potentially impacting psychological well-being due to the sense of isolation. The overall feasibility is complex, requiring advanced technologies to address the high radiation exposure levels and extreme environmental conditions on Mars. However, Mars offers a unique opportunity for cosmic exploration, serving as a potential base for further missions into the outer solar system. The feasibility of raising a family is uncertain, with concerns about the long-term health effects of Mars' lower gravity and the confined living conditions. Autonomous construction using Martian resources could significantly enhance the sustainability and cost-

effectiveness of building habitats. The potential dangers include Martian dust storms, micrometeorite impacts, and the lack of a protective atmosphere, all of which necessitate robust safety measures. Despite these challenges, establishing a community on or around Mars would represent an extraordinary leap for humanity, pushing the boundaries of space exploration and innovation.

*The Matrix*

| Criteria | Location & Rating (1 - 5) | | | | |
|---|---|---|---|---|---|
| | Earth's Orbit | Lunar Orbit | Lunar Surface | Mars' Orbit | Mars' Surface |
| Cost of Travel | 1 | 2 | 3 | 4 | 5 |
| | $10 million/person | $70 million/person | $750 million/person | $500 Billion | $500 Billion + |
| Proximity to Earth | 1 | 2 | 2 | 3 | 3 |
| | 1,200 Miles | 238,900 Miles | | 140,000,000 Miles | |
| Visibility of Earth | 1 | 2 | 2 | 3 | 3 |
| |  |  | |  | |
| Difficulty of Transportation | 1 | 2 | 3 | 4 | 5 |
| | Duration: 10 mins - several hours | Duration: 3 days - several weeks | | Duration: 6-9 months | |
| Difficulty for Resupply | 1 | 2 | 3 | 4 | 5 |
| Feasibility | 1 | 2 | 3 | 4 | 5 |
| | >330 manned missions completed | 9 manned missions completed | 6 manned missions completed | >50 unmanned missions completed | 10 unmanned missions completed |
| Radiation Exposure | 1 | 3 | 5 | 4 | 2 |
| | 0.08 millisieverts per day | 0.366 millisieverts per day | 1.369 millisieverts per day | Similar to Lunar Surface | Less than Lunar Orbit |
| Support for Cosmic Exploration | 5 | 3 | 4 | 1 | 2 |
| Practicality for Raising a Family | 1 | 3 | 2 | 5 | 4 |
| Other Orbital Dangers | 3 | 2 | x | 2 | x |
| Innovtion for Humanity | 5 | 4 | 3 | 2 | 1 |
| Autonomous Assembly Potential | 3 | 2 | 1 | 2 | 1 |
| Total Score (Lowest = Most desirable) | 24 | 29 | 31 | 38 | 36 |
| | Winner | | | | |

*Figure 22: Matrix of all potential site locations for an orbital community that are scored based on key criteria.*
*(Source: David Fischetti, 2024)*

This vision makes clear that there are certain requirements that must be met along with possibilities that could transform initial limitations of the thesis. Maintaining that view to Earth is important to this proposal so locations such as Mars' orbit and surface are not as relevant. This also is due to the proximity and practicality of traveling to such a far place. However, orbits around Earth and the Moon could serve as optimal sites, offering proximity to Earth while also providing the overview effect and a stunning backdrop of the cosmos. These locations would not only fulfill practical needs but also enhance the overall experience, working to

turn current limitations into opportunities for innovation and inspiration. Envisioning this project in terms of a network of structures happening along multiple sites is also a strong direction, as it allows for a more holistic approach. This works to create that connection between humans and the cosmos along with fulfilling both practical and inspirational aspects of the vision.



*Figure 23: Photograph taken from Apollo 8 mission named "Earthrise" that is looking back at the Earth from lunar orbit showcasing the "overview effect" (Source: Bill (William) Anders, 1968)*

*The Direction of Choice*

With all of the criteria in mind, it becomes clear that in order to fully capture the experience of space travel alongside bridging the physical limitations humans have on Earth that a network of structures across multiple orbits is the most compelling choice as it follows all of the criteria listed in the matrix along with opening up for the opportunity to tell a story through the journey one takes through space. Adopting a multi-site approach significantly benefits the overall thesis by transforming initial constraints into opportunities for innovation. By envisioning a

network of structures across various orbits, primarily around Earth and the Moon, the project leverages proximity to our planet while providing the awe-inspiring overview effect and a stunning cosmic backdrop. This strategy not only addresses practical requirements, such as ease of travel and communication, but also enriches the space experience, turning limitations into inspirational milestones. A multi-site network fosters a holistic connection between humans and the cosmos, allowing for diverse interactions and perspectives that a single location cannot offer. It creates a compelling narrative of space exploration which integrates practical solutions with the profound emotional and psychological impacts of space travel. Ultimately, this approach aligns with the thesis criteria, presenting a robust and comprehensive vision that enhances both the practical and inspirational dimensions of human presence in space.

# Chapter 10: Convergence into Experience

*Defining the Narrative*

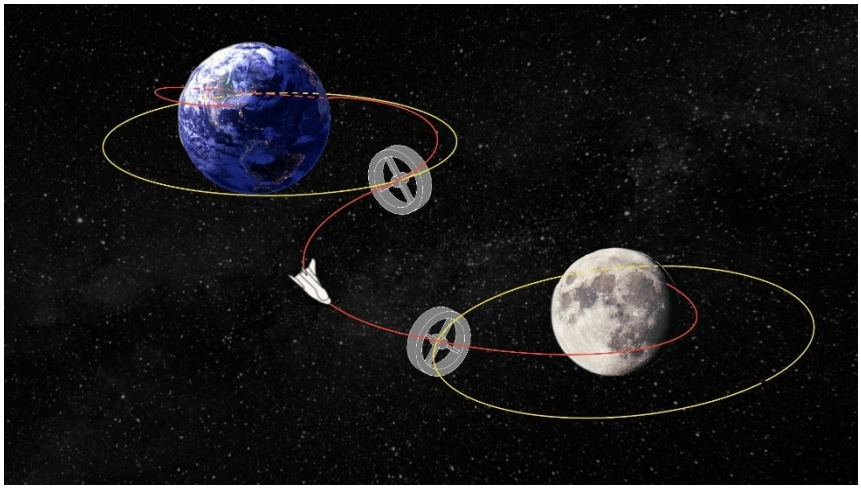

*Figure 24: Diagrammatic map of multi-orbital network.*
*(Source: David Fischetti, 2024)*

ASTRIAH (Astral Innovation for the Advancement of Humanity) is a visionary space architecture thesis that imagines a transformative journey through orbit as both a literal and symbolic vehicle for advancing human knowledge, resilience, and unity. The project centers on a spacefaring school for interdisciplinary innovation & global advancement composed of two orbital habitats, one being in Low Earth Orbit (LEO) and another in Lunar orbit. Students and mentors from six diverse disciplines, being architecture, engineering, manufacturing, mechatronics, agronomics, and art, embark on a semester-long residency aboard the Earth Bound ASTRIAH habitat. While here they are immersing themselves in interdisciplinary research, communal living, and collaborative problem-solving. After fifteen weeks, the cohort transitions to the Moon Bound ASTRIAH habitat, engaging with new environmental challenges, gravitational differences, and research frontiers. This

cyclical academic pilgrimage is not only an educational experience but a narrative of perspective-shifting. As these learners descend from orbit, they carry with them technologies, insights, and strategies designed to address Earth's most pressing challenges from sustainability and health to community resilience.

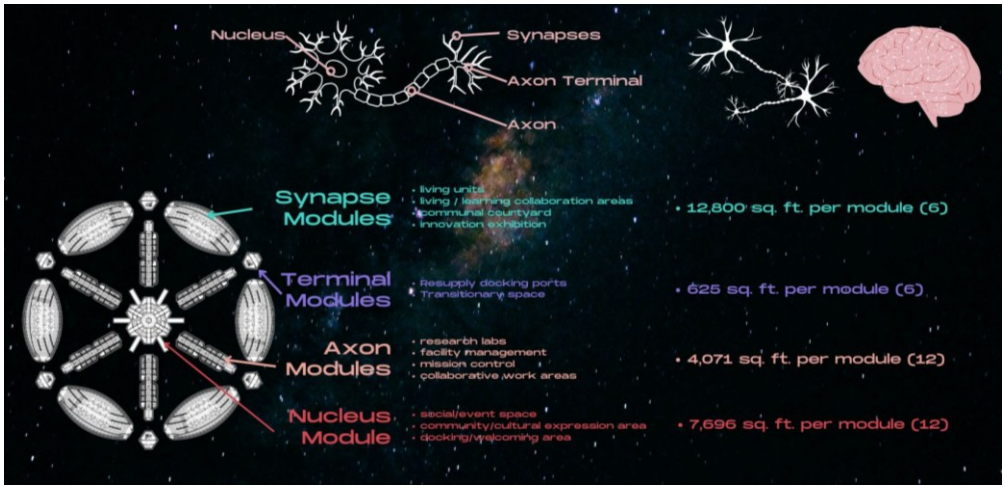


*Figure 25: Breakdown of Program as it relates to the various modules of the ASRIAH community and how its naming convention mirrors that of a neuron in the human brain*

*(Source: David Fischetti, 2025)*

The spatial organization of ASTRIAH is more than functional, it is metaphorically and biologically inspired, drawing directly from the structure of neurons in the human brain. Just as neurons transmit signals to power thought, ASTRIAH is designed as a vessel for intellectual connectivity, innovation, and cultural transmission. The modular habitat mirrors neural anatomy. The Synapse Modules act as the living and learning units holding spaces for interaction, collaboration, and exchange. This is much like synapses where signals pass between neurons. These large, open modules are where most of the communal life unfolds. The Axon Modules serve as the connective workspaces: research labs, mission control, and collaborative facilities that carry the signal of innovation outward

through purposeful activity, much like the axon transmits impulses in the brain. At the center lies the Nucleus Module which functions as both a literal and symbolic brainstem that houses social and cultural events, shared rituals, and welcoming ceremonies that reinforce a shared identity. Connecting all of the Axon and Synapse Modules are the Terminal Modules which are the transitional ports for docking, resupply, and circulation between modules. These spaces maintain exchange and movement, much like axon terminals form junctions with other neurons. This neuron-based spatial framework embodies the thesis' deeper mission to construct a living, thinking, and evolving brain in orbit. This works to enable humanity to think collectively, learn together, and return home with the tools to rewire society for a more sustainable future.

*The Journey of ASTRIAH*

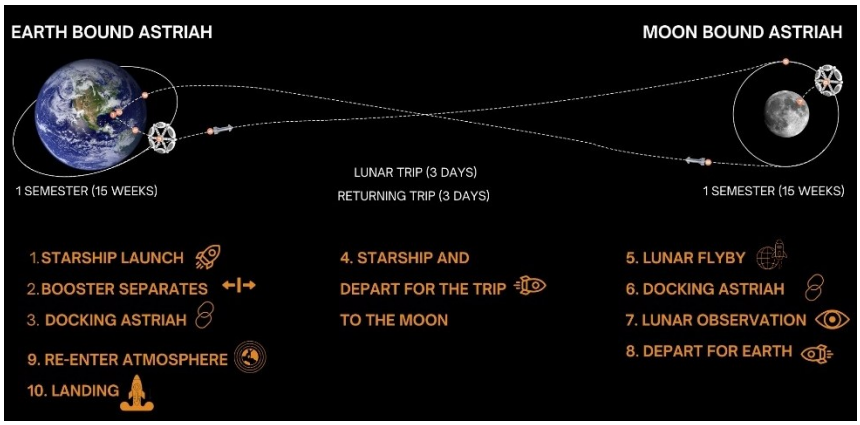


*Figure 26: Detailed journey diagram of the experience traveling between ASTRIAH habitats*
*(Source: David Fischetti, 2025)*

Embarking on the ASTRIAH journey is a transformative experience that mirrors the stages of human growth, exploration, and reintegration. It begins on Earth, where a selected internationally diverse group of students and mentors from diverse

disciplines, including architecture, engineering, agronomics, mechatronics, manufacturing, and art, prepare for departure. Their vessel for departure is SpaceX's Starship which is a fully reusable spacecraft designed for deep space missions.

The journey commences with the launch of Starship, propelled by the Super Heavy booster. Upon reaching orbit, the booster separates and returns to Earth, while Starship continues its ascent. Once in LEO, the crew docks with the Earth Bound ASTRIAH habitat. Here, they spend a semester (15 weeks) living and working in modular communities structured around structures around social cohesion, creating close-knit relationships and interdisciplinary collaborations.

After 15 weeks, the cohort prepares for the next phase to transition to the Moon Bound ASTRIAH habitat. The Starship departs from Low-Earth Orbit (LEO), performing a series of propulsive maneuvers to enter a trans-lunar trajectory. Upon reaching the Moon, it executes a lunar orbit insertion, settling into a near-rectilinear halo orbit (NRHO), a stable and energy-efficient path around the Moon and towards the orbiting ASTRIAH community.

Docking with the Moon Bound ASTRIAH habitat, the crew embarks on another semester (15 weeks) of research and living in a collaborative interdisciplinary environment. The unique vantage point offers an unparalleled view of Earth, often leading to the "Overview Effect" creating a cognitive shift in awareness that fosters a profound sense of connection to humanity and the planet. This perspective reinforces the mission's purpose of gathering knowledge and insights that can benefit Earth.

Concluding their lunar residency, the crew boards the Starship for the return journey. The spacecraft departs lunar orbit, re-enters Earth's atmosphere, and lands at a designated site. Upon return, the students and mentors reintegrate into their home communities, sharing the knowledge, technologies, and experiences gained. This dissemination aims to address Earth's challenges of sustainability and inspire future generations.

The ASTRIAH journey, facilitated by SpaceX's Starship, exemplifies a holistic approach to space exploration. The journey emphasizes personal growth, interdisciplinary collaboration, and the betterment of humanity overall through the fusion of space-based experiences and Earth-bound applications.

*Life Aboard ASTRIAH*



*Figure 27: Rendering of SpaceX's Starship Approaching Earth Bound ASTRIAH (Source: David Fischetti, 2025)*

Every journey through ASTRIAH begins with a departure, both physical and symbolic. As the SpaceX Starship clears Earth's atmosphere and drifts into space, the blue planet we call home shrinks behind and is replaced by the anticipation of the

unknown ahead. It is here, in this moment of weightless ascent, that a sense of collective purpose takes hold. Onboard are students and mentors from around the globe, each carrying with them a piece of their home, their culture, their knowledge, and the shared hope of shaping humanity for the greater. As the ship glides toward the orbital habitat, ASTRIAH emerges into view. The structure suspended in the void, like a mind in motion waiting for activity. Its neuron-inspired form is a symbol of connectivity, of intention, of innovation. With every kilometer drawn closer, the crew begin to understand they are not just arriving at a space station, but they are entering a living community designed to think, grow, and evolve. The approach is filled with optimism and awe along with the realization that this marks the beginning of a new kind of experience rooted in collaboration, discovery, and the advancement of humanity.

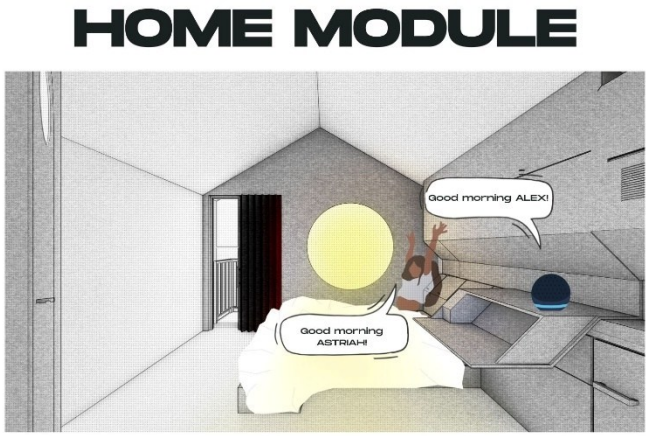


*Figure 28: Interior Rendering of experience within ASTRIAH's Home Module (Source: David Fischetti, 2025)*

Each morning aboard ASTRIAH begins within the serenity of the Home Module which is a private refuge designed to balance autonomy with connectivity. As

the glow of the module's circular window simulates a rising sun, it gradually synchronizes with the occupant's circadian rhythm, gently waking them in harmony with their internal clock. The onboard AI assistant offers a cheerful greeting, learning your name, habits, and preferences to personalize your routine. This interaction sets the tone for the day, encouraging a sense of support.

The Home Module is more than just a sleeping quarter, it is a compact, self-sustaining environment equipped with all the essentials. A closed-loop life support system recycles air, water, and waste with efficiency. A small kitchenette provides tools for personal meals, and a sleek workstation supports focused creativity or quiet reflection. The bathroom and shower offer the comforts of privacy in the vastness of space. Sliding open the door to your balcony, you're met with the view of your personal microgreens growing in railing planters and a shared courtyard below that connects you to the greater community. From this vantage point, you witness the quiet stirrings of your neighbors and the emerging pulse of ASTRIAH's living ecosystem. Each day works to begin not in isolation, but as part of a network of innovations and your fellow community of diverse thinkers ready to begin on their journey of discovery together.

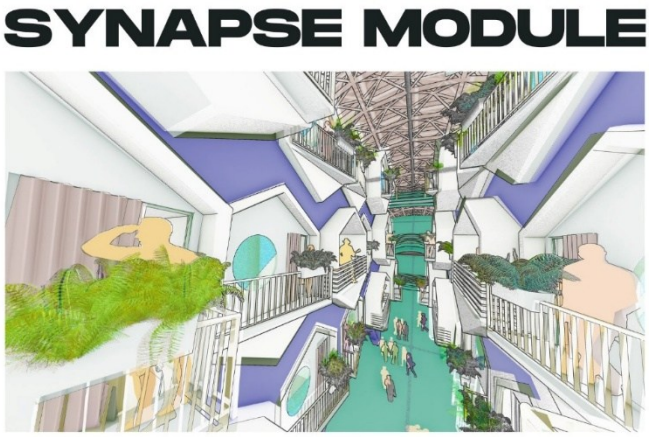


*Figure 29: Interior rendering of experience within the Synapse Module communal courtyard*
*(Source: David Fischetti, 2025)*

The Synapse Module is the heart of community interaction aboard ASTRIAH acting as an open and adaptive environment where creativity, culture, and innovation converge. Stepping into this space, one is met with a sense of possibility as a shared courtyard wrapped in green planters where residents peer out from their private quarters and descend into the commons. Here, international cohorts from across disciplines gather not only to work, but to engage in collaborative play and transform the act of problem-solving into a form of social connection. Flexible zones throughout the module allow for the exhibition of prototypes, ideas, and artistic expressions, sparking spontaneous dialogue and cross-pollination between architecture, art, robotics, engineering, agriculture, and more. The space is sustained by its own closed-loop life support system, ensuring environmental self-sufficiency through the continual recycling of air, water, and waste. Expansive viewports line the periphery of the module, offering breathtaking glimpses of either Earth or the Moon (depending on whether one is aboard the Earth Bound or Moon Bound ASTRIAH) reminding everyone of the mission to why they are here and innovating in this

environment. Within the Synapse Module, culture and innovation are not hidden in labs or studios, but they are lived and shared in the open. This works to display innovation as a celebration of what humanity can achieve when it comes together to build, dream, and evolve as one.




*Figure 30: Interior rendering of experience within the Terminal Module as one transitions from one module to another*
*(Source: David Fischetti, 2025)*

The Terminal Module is the connective tissue of ASTRIAH acting as a threshold space where movement, transition, and unexpected connection converge. As the place where residents leave their communal Synapse Modules and step into the collaborative momentum of the Axon research modules, it serves as both a physical and symbolic crossing point. It is where individuals from different backgrounds, disciplines, and starting points within the habitat might encounter one another in the flow of their day. In these transitional encounters, spontaneous conversations, ideas, or collaborations may ignite. Functionally, the Terminal Module also plays a crucial role as, when ASTRIAH is paused in rotation, this is the port of access where resupply vessels dock, offloading vital cargo and replenishing the

Synapse Modules with fresh space food, tools, or experimental materials. The Terminal Module is more than a hallway, it is a shared space of possibility, acting as both artery and spark within the living system of ASTRIAH.




*Figure 31: Interior rendering of Axon Module group seating and vertical garden space*
*(Source: David Fischetti, 2025)*

The Axon Module is the intellectual engine of ASTRIAH, being a space designed for disciplinary specific work and innovation. Within the 6 of these modules across the ASTRIAH community, each field onboard (architecture, engineering, agronomics, manufacturing, mechatronics, and art) has their dedicated areas for study, prototyping, and experimentation. Stretching vertically through the module is a core of vertical gardens, providing not only a renewable food source but also a constant connection to nature, instilling a calming biophilic presence that grounds the occupants during rigorous research.

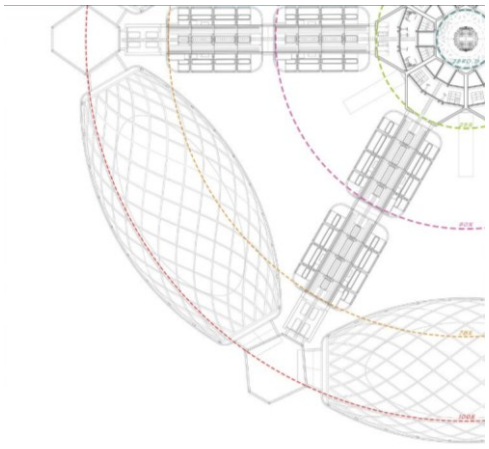

*Figure 32: Diagrammatic section cutting through the ASTRIAH community displaying the varying levels of gravity as one ascends to the center of the artificial gravity structure*
*(Source: David Fischetti, 2025)*

As one ascends the levels of the Axon Module, they move closer to the central axis of ASTRIAH's rotational structure where gravity gradually lessens. This gradient creates a dynamic testing environment, enabling projects and experiments to be trialed across varying gravitational conditions from near-Earth-like weight to almost weightlessness. Integrated facility management levels throughout the module house the Axon's closed-loop systems, seamlessly recycling air, water, and waste to support the sustainability of the space. With windows framing the cosmos beyond, the Axon Module becomes more than just a laboratory, it is a sanctuary for inquiry, experimentation, and breakthrough ideas that may one day change the trajectory of life on Earth and beyond.

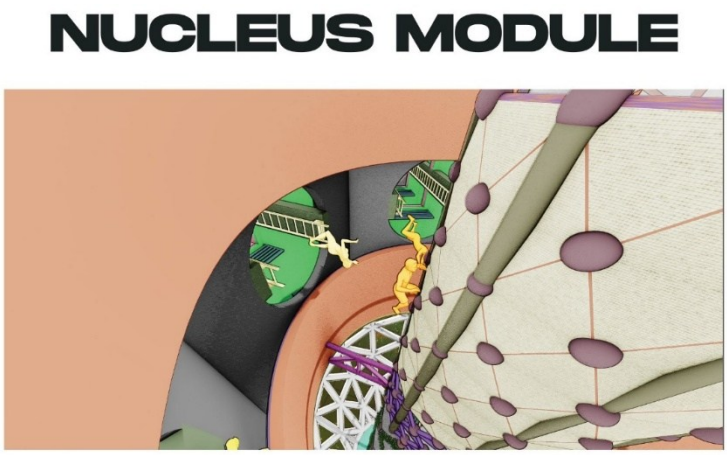


*Figure 33: Interior rendering of Nucleus Module transitioning between the artificial gravity zone to the microgravity zone*
*(Source: David Fischetti, 2025)*

The Nucleus Module marks the center of gravity and imagination within ASTRIAH. In the first stage of entering this space, inhabitants experience a carefully choreographed transition from the rotating zones of artificial gravity into microgravity. This unique shift occurs through a vertical circulation shaft outfitted with a playful yet purposeful design. A ladder leads to the threshold, where users can leap onto the central Velcro-clad structure using specially designed gloves or socks (an homage to the invention of Velcro for early space missions). This soft, tactile interface transforms the act of moving between gravity zones into an almost ceremonial moment. It is a spatial gesture that reminds inhabitants they are no longer Earth-bound and they are in a domain of possibility, where the rules of gravity, routine, and reality are gently bent in service of something greater.

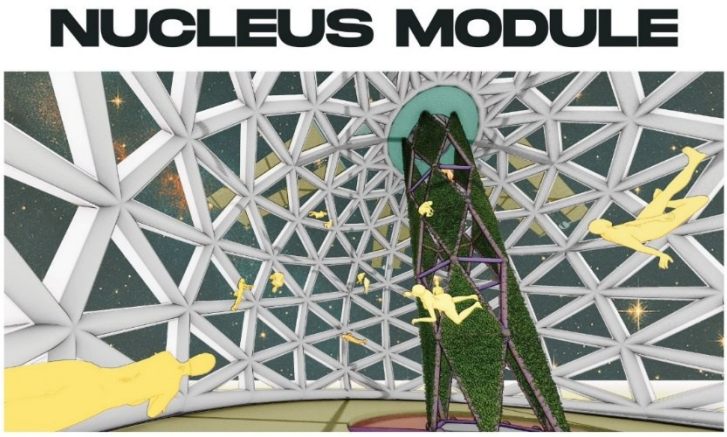


*Figure 34: Interior rendering of Nucleus Module exhibition space operating in microgravity and featuring grow panels for a biophilic atmosphere*
*(Source: David Fischetti, 2025)*

Once within the microgravity dome, the space opens into a celestial exhibition/event space. This large, open area reveals the core of the Nucleus Module being a floating exhibition hall, biophilic garden, and collective commons all in one. This zero-gravity environment encourages free movement, spontaneous gathering, and innovative collisions among disciplines. Along the vertical core, panels of greenery line the structure offering a sense of grounding through nature even while floating in microgravity. Around the dome's periphery, wide observation portals frame the surrounding cosmos displaying views of Earth, Moon, or stars depending on orbital position, reaffirming the broader context of the community's mission. This is where innovation takes flight as inhabitants can display research, prototypes, or artistic works, inviting interdisciplinary feedback and collaboration. Events, celebrations, and shared milestones are held here and reinforce ASTRIAH's identity as both a school and a global culture node. As the welcoming point for any new

spacecraft, resupply vessels, or future ASTRIAH extensions, this dome acts a portal for integration and the ongoing evolution of humanity's presence in space.

# Chapter 11: Conclusion

*Synthesis*

ASTRIAH is not just a space habitat, it is a mirror through which we reflect our deepest hopes for humanity. This thesis has traced a path from our earliest celestial curiosities to the development of orbital communities designed for sustainability, interdisciplinary collaboration, and human-centered living. In doing so, it redefines architecture as not only a discipline of form and function, but one of foresight, empathy, and planetary responsibility. By proposing a journey that lifts students from the Earth to Low Earth Orbit and onward to Lunar Orbit, then returns them to their communities with new insight, ASTRIAH symbolizes a cyclical transfer of knowledge, resilience, and global unity. It shows us how architecture can act as a vessel for not just survival, but for cultural preservation, psychological well-being, and cross-disciplinary innovation.

And so, the question arises: What's next? The answer lies in how we choose to bring these insights home. The real work begins as we take what we've learned from space about closed-loop living, sustainable systems, and shared human identity and apply it to our cities, institutions, and relationships on Earth. The future of architecture will not be limited by gravity or geography. It will be shaped by those willing to imagine beyond limitations, to build bridges between disciplines, and to design futures that elevate us all. ASTRIAH marks the beginning of this new chapter.

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