

Human Space in Space. Considerations on the Human-Architecture's Relationship in Space Habitats

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The study of human space in architecture has always been central to the discipline, and the design of spaces which combine architectural quality with habitability is even more relevant in contexts where the host environment presents extreme conditions.

The paper aims to broaden this perspective to include architecture for harsh environments, with a particular focus on space habitats - both orbital and planetary. What is the current state-of-the-art? What measures are being taken in the design process to ensure the psycho-physical well-being of the inhabitants? What role can architects and architecture play in addressing this necessity? In the light of these questions, the intention is to investigate design proposals for orbital and planetary habitats, as well as settlements and outposts, to be able to extend the considerations to questions of urban planning and the organisation of space cities. Furthermore, is it still appropriate to refer to a city, or should it be more accurately described as an aggregation of architectures? According to this, considerations have been made as to which housing models should be applied in space, which characteristics of dwellings and terrestrial urban fabrics should be preserved, and which strategies should be implemented, given the unique and extreme conditions of the environment in which they are designed.

In conclusion, this paper aims to initiate a process of consideration of the relationship between humans and architecture in contexts beyond Earth while maintaining a bilateral relationship with it.

Nomenclature

<i>AIAA</i>	= American Institute of Aeronautics and Astronautics
<i>ASASC</i>	= Aerospace Architecture SubCommittee
<i>ASI</i>	= Agenzia Spaziale Italiana / Italian Space Agency
<i>ESA</i>	= European Space Agency
<i>HALO</i>	= Habitation and Logistics Outpost
<i>IAC</i>	= International Astronautical Congress
<i>IAF</i>	= International Astronautical Federation
<i>ICES</i>	= International Conference on Environmental Systems
<i>ISS</i>	= International Space Station
<i>LSA</i>	= Lithuanian Space Agency
<i>MHM</i>	= Minimal Habitation Module
<i>NASA</i>	= National Aeronautics and Space Administration
<i>SAS</i>	= Space Architecture Symposium
<i>STS</i>	= Space Transportation System
<i>USSR</i>	= Union of Soviet Socialist Republics

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I. Introduction

THIS manuscript presents an investigation that is part of the first authors' ongoing doctoral research project in the field of architectural design. The research project focuses on the challenges of inhabit extreme environments, with a focus on outer space. The research aims to develop an *Atlas* (i.e. catalogue) of state-of-the-art of the architectural projects beyond Earth by identifying recurring invariants and themes, as well as differences and peculiarities. The analysis and comparison of these projects will be the basis for the development of solutions for long-term habitation in space.

The main drive of this research was to understand and interpret these concepts in relation to the space sector. To start architectural design processes that favour the habitability of such places, it is useful, if not necessary, to have a clear cognitive framework of what has led to this point. Considerations will therefore be made on design parameters, such as modularity, as well as on the role of architecture and architects for space, and how this has repercussions on designing back on Earth.

Specifically, in this paper, issues regarding the concept of *inhabiting* and the *human-architecture relationships* in architectural space will be analyzed through the study and comparative analysis of the theories developed throughout history. The paper has been structured into four macro sections. Each of them investigates a specific aspect through the study of various sources, specified in the section dedicated to materials and methods, and the considerations that have emerged. The results obtained are intended to be a starting point to answer the questions raised, while opening and encouraging further discussion.

II. Material and methods

To address the questions stated in the abstract of this paper, it has been conducted an investigation has been conducted concerning the issues of *inhabiting* and architectural space in relationship with humans. In accordance with the structure of the doctoral thesis, the research topic was approached with a holistic approach. In this vein, historical treatises, dictionaries, encyclopedias, books, as well as conference and symposium proceedings, architectural journals, and doctoral dissertations were consulted with the aim of build up a concrete theoretical framework.

In addition to the theoretical aspect of the research problem, the aforementioned documents were necessary to develop a catalogue of case studies. This was done in order to proceed to a spatial-level analysis and comparisons of them, based on the graphic representations and the technical descriptions. This analysis aimed to deconstruct the architectures to bring out the adopted design choices and then highlight the human-architecture relationship between them. In order to address the questions raised in the abstract, an appropriate methodology was required to collect, select, and compare the various definitions of *space* and *habitability*, with a view to investigating how they are adapted in relation to the context in question and how they have evolved over time, with a particular focus on future developments.

It is important to note that this PhD study is still in its early stages and that some references may be missing or not considered in this particular paper. With regard to the limitations and assumptions of the thesis, greater emphasis was placed on aspects of architectural design theory, while also attempting to maintain a technical-engineering approach.

III. Human Space in Architecture

In 2017, former Italian Minister of Cultural Heritage and Activities Dario Franceschini, in an interview with *Domus* magazine Editorial Director Walter Mariotti, stated:

Architecture has the task of designing human space, building the limits of its experience and giving meaning to its contents. [...] We need to think, design and build inhabited spaces [...]. Here, cultural aggregators must constitute the new centres of a replanned city in which people travel to the outskirts to get acquainted and experiment with what's new.¹

Franceschini highlights the relationship between human beings and architectural space, emphasizing the need for citizens to reclaim their sense of community by re-appropriating public spaces. Although the concept of space could be defined in various ways, in this manuscript the focus will be on the declinations of architectural space and human space in architecture.

As early as the fourth century BCE, Aristotle focused his attention on the concept of *space* defining it *as the place occupied by bodies or the boundary adhered to the body that bounds it, including the void*. The same line of thought is taken up by the Encyclopedic Dictionary of Architecture and Urbanism,² which defines the space as

an objective reality [...]. Everything around us is physical space and we ourselves are part of it, we are a portion of it [...]. In physical space we understand everything humanly perceptible: emptiness and fullness [...]. Emptiness and fullness are therefore spatial matter.

declining it as *a advanced form, which implies the vitalizing presence of human beings as protagonists who organize space and shape it to respond to a specific purpose. [...] Architectural space corresponds to physical space, but is not identified with it* when referring to architecture and urban planning.

A great example of integrating architectural and urban space has been done by Michelangelo in the Piazza del Campidoglio (1536-1546) on top of Capitoline Hill in Rome (Figure 1),³ who was the first to do it. Andrea Palladio then clearly defined the figurative and conceptual assumptions and laid the groundwork for inserting the architectural object into the structure of the city, denying its figurative and social autonomy.⁴ On another hand, Neoclassicism is credited with recognizing the significance of this openness on the unified vision of the city and integrating it with architecture, urban structure, and nature.

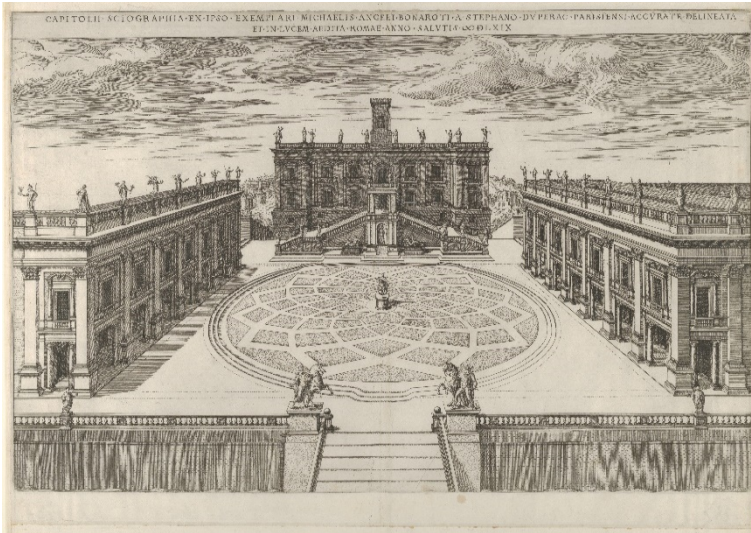


Figure 1. Dupérac, É., View of the Campidoglio as re-designed by Michelangelo Buonarroti from the ‘Speculum Romanae Magnificentiae’.

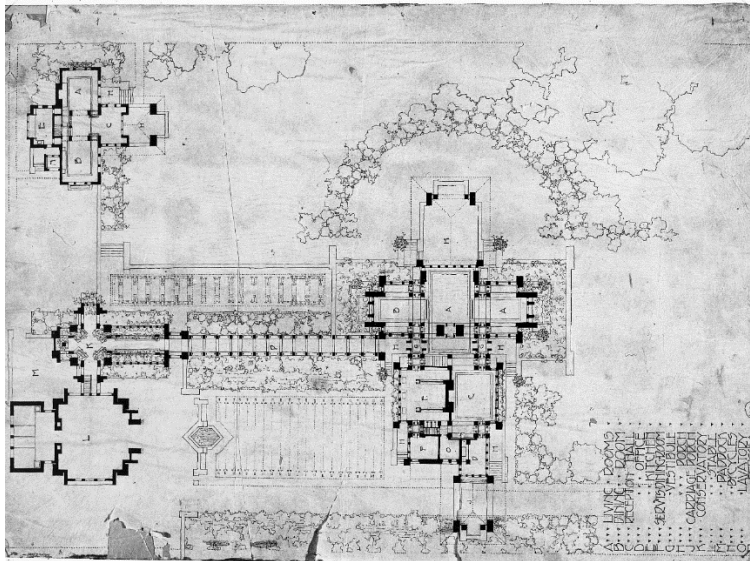


Figure 2. Darwin D. Martin House (Buffalo, New York), 1904.

Moving forward to the XX century, space became an integral part of architecture, according to F.L.Wright. This was achieved by expanding the ideographic scheme of the architectural object, specifically its modular system.⁵ A notable example of this is represented by F.L.Wright’s well-known Martin House (1903-1905) (Figure 2)⁶ in Buffalo, NY, in which he expanded the modular system with the pergola and layout of the accessory buildings. In this project, Wright concentrated on translating the client’s requirements into a living space that could accommodate them in a comprehensive manner. The layout of the rooms, the arrangement of the furniture, as well as other construction details, imparted a distinctive character to the spaces. Consequently, the architectural space, particularly in relation to people, assumes new connotations and outlines an innovative approach to design.

In architecture, human space assumes an autonomous existence, as it allows for the measurement of architectural space on a scale that ranges from small to large. The act of measuring architecture represents a complex undertaking, so much so that it can define the success, or a total failure of a project, or a space. The design of spaces on a human scale, as theorised by Le Corbusier with his Modulor (Figure 3), in the wake of Leonardo da Vinci’s Vitruvian Man (Figure 4), becomes an essential tool for the dimensioning of spaces, architectures, and even cities, so as to of (re)delivering them to citizens and making them habitable.

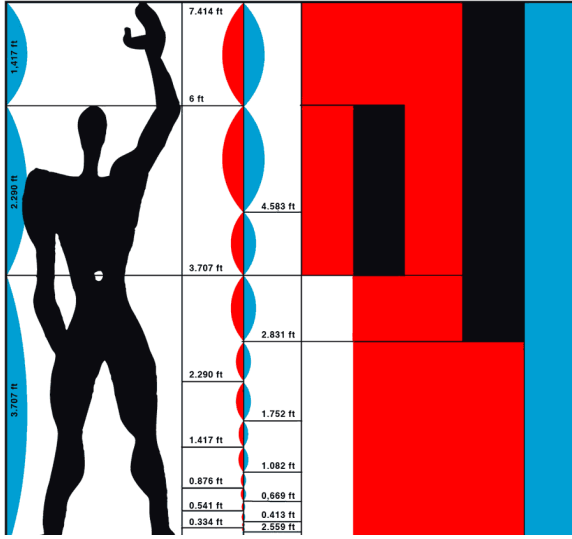


Figure 3. Le Corbusier, *The Modulor*, 1948.

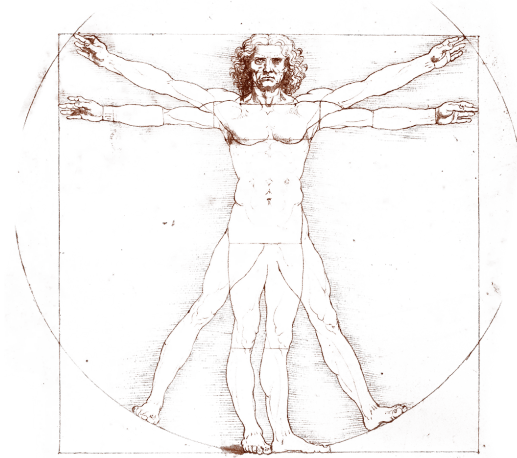


Figure 4. L. da Vinci, *Vitruvian Man*, c. 1490.

A. Inhabiting Architecture

In considering the concept of *space* in the meaning of the human space in architecture, it is essential to bear in mind also the concept of *inhabiting* it. *Owning one's dwelling and residing in a place or area* (Treccani)⁷ is frequently used to describe the act of residing in a specific place or area, but this does not mean – entirely, at least – to inhabit it. This definition is indeed connected to the etymological root of the term, from the Latin *habitare*, meaning *to hold*, and *habere*, meaning *to have*. Also expressions such as *I live in the countryside*, *I live in the city*, or *I live in an apartment* are commonly used to describe the same concept.⁸ Therefore, it is important to consider the holistic nature of inhabit a place or a space.

These phrases only provide spatial coordinates and do not fully capture the essence of living, which is a complex combination of relationships between the individual, the community, and the surrounding space. This concept can be linked to both Palladio's (Wittkower, 1964) and Franceschini's ideas (Mariotti, 2017), the first for the architectural point of view, and the second from the role of the citizens as individuals and as a community.

Inhabiting a space should mean being able to interact with it, rather than reducing spatiality to the temporality of existence.⁹ In this regard, the philosopher Martin Heidegger reports that Aristotle stated that:

[...] making space is thought of in what is proper to it, free donation of places in which the destinies of the men who live there are realized in the happiness of possessing a homeland or in the unhappiness of being deprived of it or in the indifference towards one or the other to the other possibility [...]. Making space gives the location that prepares a living from time to time.

The first who address the issue of living was Vitruvius, which in his work *De Architectura*¹⁰ postulated the need to design private homes according to the specific needs of the occupants, in relation to the culture and place to which they originally belonged, while also describing the concept of private and common rooms, the first *are those into which nobody has the right to enter without an invitation*, the others *are those which any of the people have a perfect right to enter, even without an invitation*. At the same time, he underlined the importance of *designing buildings with the right proportions, regulated by the module*, in order to guarantee the three architectural principles *Firmitas, Utilitas, Venustas*, that are: solidity, function, beauty.

Later, Leon Battista Alberti adopted the Vitruvian concepts on building and expanded them to the city, comparing and relating them in his work *De re aedificaria*. He wrote:

And if the saying of the philosophers is true, that the city is like a large house, and the house in turn is a small city, one would not be wrong in maintaining that the members of a house are themselves small dwellings.¹¹

Inhabiting becomes one of man's primary architectural experiences, deeply linked to the affective dimension of care. In the twentieth century, Le Corbusier's *Vers une architecture* focused on the problem of the house. From there, the question expands to society and architecture. The first because it depends on the time, the second because its first task is to review, adapt, renew the constituent elements of a house. On living, Le Corbusier expresses his vision of knowing how to live in architecture as a great problem:

Architecture is a fact of art, a phenomenon that arouses emotion, outside of construction problems and beyond them. Construction is for holding up, architecture is for moving. Stay? It means living, knowing how to live. Housing is the mirror of the conscience of a people. Knowing how to live is the big problem, and no one teaches people this.¹²

Inhabiting is also an anthropological question. The architectural design is essentially an abstract figure with the function of inscribing itself in a concrete, multilayered reality. According to Walter Gropius, during his time at the Bauhaus, *spatial relationships, proportions, and colors control psychological, vital, and real functions.*¹³ Therefore, the characteristics of the built space play a fundamental role in orienting the behavior of those who inhabit it. In doing so, urban space and the practices of social integration are further intertwined by describing the places that host these practices.

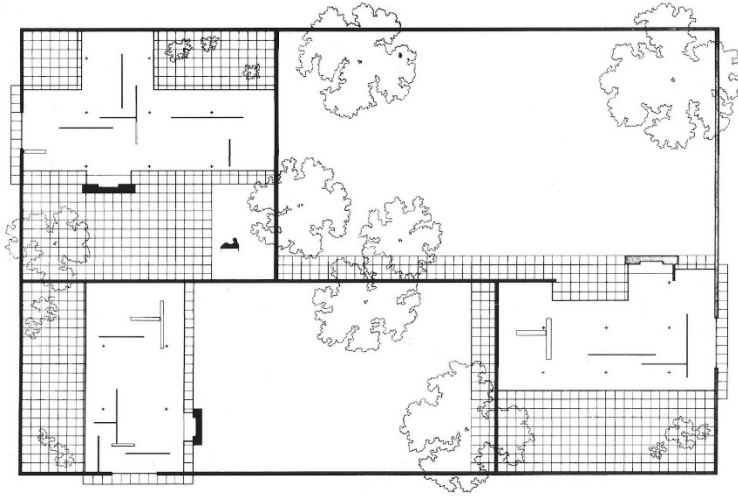


Figure 5. Plan of House with Three Courts by Mies van der Rohe, after 1938.

Another notable figure associated with the Bauhaus is Mies van der Rohe, who used modularity and proportions to enhance the qualities of his designs. In his works, it is evident how spaces assume a distinctive character, following a precise module while maintaining the qualities of both living and architecture (Figure 5).

Aldo Rossi's 1966 book, *The Architecture of the City*,¹⁴ expanded the concept of living to include the city and its architecture. Rossi's definition encompasses *not only the visible image and all of its architecture, but also the construction of the city over time.* Rossi views architecture as an integral part of civil life and society, due to its collective nature. Architecture and the city are therefore interpreted as the

means and the place in which to live, or rather *the fixed scene of man's events; full of feelings of generations, of public events, of private tragedies, of new and ancient facts.* It has been noted that the concept of living has undergone changes over time while still maintaining a *fil rouge* in certain commonalities, particularly in the relationship between humans and architecture in experiencing both public and private spaces.

Currently, a new revolution on the way to inhabit spaces and places is ongoing, both in private residences and urban areas. In occasion of the 18th International Architecture Exhibition at La Biennale di Venezia, in 2023, the British architect Norman Foster presented the *Essential Homes*¹⁵ project and stated: *the concept of living has always been in continuous evolution, proposing a new housing model of minimal residence, which encompasses the concept of affordability and speed of construction.*¹⁶

On this line, the 2024 editorial series of *Domus* has Foster as guest editor,¹⁷ who has focused it on the theme of *Futures*.¹⁸ In the issue no. 1087, Edward L. Glaeser wrote about *Recipes for Happy Cities*,¹⁹ emphasizing how they have evolved into places of both productivity and leisure, in contrast to the industrialization era.

From the above overview, which has considered some definitions and concepts of space and habitability, it can be emphasised how the relationship between human space and architectural space is crucial in achieving the parameters of habitability of spaces. Tools such as module, proportion, perception and many others can then be used to the benefit of both architecture and its inhabitants. An optimised design approach at the human scale can have a significant impact on the quality of individual units or even entire cities.

IV. Human Space in Space

As we look to the future, it is inevitable - as it should be - that the way and the concept of *inhabiting* will evolve into something new to adapt to new paradigms of living spaces and places, as well as the relationship between human and architectural space. Among contemporary perspectives becoming increasingly tangible and less a mere aspiration is the exploration and habitation of extraterrestrial realms. In such a context, it is reasonable to contemplate the relationship between humanity and architectural design and the implications of the concept of *inhabit* in these new settings.

A. Inhabit Extreme Environments

The capacity of humanity to inhabit places in extreme and variable conditions is a phenomenon that has been observed throughout history. This ability has enabled humans to extract those qualities that are conducive to life, as evidenced by their presence in deserts and Antarctica.^{20,21} The capacity to inhabit ‘the uninhabitable’ has driven humans to overcome increasingly complex frontiers. This has been driven by the desire to explore new worlds beyond planet Earth, in orbit and on other celestial bodies such as the Moon and Mars.

In 2011, Felipe Gómez defines extreme environments as follows: *extreme environment as a habitat characterized by harsh environmental conditions, beyond the optimal range for the development of humans [...]. Basically, all inhospitable conditions for life.*²²

However, Olga Bannova notes that the term *extreme* is relative and that on Earth extreme environments are often associated with geographical location rather than the objective conditions of the place.²³

Inhabiting extreme environments presents ongoing challenges due to adverse climatic conditions and the need to consider design parameters that ensure comfort and safety. Therefore, the design approach to such contexts depends on specific environmental conditions and the needs of inhabitants, and, according to Bannova, it could be possible to extend this design approach to space habitats.

B. Inhabit Outer Space

Designing architectures in extreme environments, such as temporary shelters or semi-permanent structures, requires multidisciplinary skills to ensure safety, self-sufficiency, and comfort, which are achieved by continuing to develop and experiment with the latest technologies in the field. The discipline that deals with designing architectural space beyond Earth is Space Architecture, which pursues an holistic and multidisciplinary approach, as defined by the *Millennium Charter Manifesto*.²⁴ To date, numerous designs of space habitats have been designed, but only few have been implemented in space programs worldwide.

Since the late 1950s, when the two rival superpowers – the USSR and the USA – initiated the Space Race, the objective of conquering space, and especially landing on the Moon, has become a tangible reality. This unprecedented challenge has led to the establishment of space programmes, the development of advanced technologies, and, last but not least, humanity's expansion beyond the Earth. The Soviet Union was the first to achieve this goal, sending the first satellite into orbit, Sputnik 1, in 1957, and the first human into orbit, Yuri Gagarin, only four years later, in 1961, aboard the Vostok 1 capsule. Additionally, the USSR developed spacecrafts such as Voskhod and Soyuz designed by the Russian architect and designer Galina Balashova,²⁵ but also among the first orbital space stations such as Salyut (a programme running from 1971 to 1986) and Mir (1986-2001), the first modular space station that operated in low Earth orbit. The United States' space exploration history also includes several notable projects, including Project Mercury (1961-63), which placed the first American in suborbital flight; Project Gemini (1965-66); and the more widely known Apollo Project (1967-72), whose primary mission was to send humans to the Moon, explore it, and bring them safely back to Earth.

On July 20th 1969, Italian television journalist Tito Stagno famously stated: *Ha toccato! Ha toccato il suolo lunare!*²⁶ That was the announcement of the Apollo 11 moon landing. Shortly thereafter, astronaut Neil Armstrong would pronounce the phrase that marked a new era:

*one small step for (a) man, one giant leap for mankind*²⁷

The Apollo 11 landing fulfilled the dream of an entire generation, of millions of people, a win for the entire humanity. Following this milestone event, the Americans also placed into orbit their first space station: Skylab (1973-79), which was characterised by a modular configuration and a crew of up to three people at a time. A few years later, they developed the Space Transportation System (STS), better known as the Space Shuttle, which operated from 1981 to 2011. In 1975, the first international space mission was developed, with an American and Soviet crew, as part of the Apollo-Soyuz mission. This mission featured the Apollo spacecraft and the Soyuz capsule.

These experiences have provided a corpus of knowledge and tangible examples of what it could mean to *inhabit outer space*. How the human body behaves in microgravity conditions, what advantages and disadvantages result from this, what design requirements must be put in place to make space habitats comfortable, and at the same time highly functional.

Currently, the International Space Station, permanently inhabited since 2nd Nov. 2000,²⁸ and the Chinese Space Station Tiangong,²⁹ are orbiting the Earth.³⁰ At this time, plans are underway to develop and replace the ISS – which will be deorbited by 2030 – with other orbiting space stations around the Earth.³¹ The data collected by these orbiting stations is of great value in enabling the continuous improvement of the quality of spaces, both human and

architectural, in these contexts. We have learned a great deal about the adaptability of the human body in microgravity conditions from this nearly 30-year experience, but maybe it is worth to bear in mind that any definition of habitability, related to places beyond Earth, in this moment could only be an approximation. Regarding planetary architectures, simulations such as analogue missions can only provide speculative information. Only by inhabiting these places will we have the necessary data to build upon. Nevertheless, it is also true that analog missions provide some initial information and are essential to build an apparatus of ideas and data on which to build.

Historically, the design of space missions has often prioritized factors other than habitability. Today, the importance of habitability remains a topic of debate (Häuplik-Meusburger & Bannova, 2016). In space, *habitability* can be defined as:

a general term to describe the suitability and value of a built habitat (house or spacecraft) for its inhabitants in a specific environment (Earth or Space) and over a certain period of time. Set into the space context, habitability can be understood as the measure of how well the (built) environment supports human health, safety and well-being to enable productive and reliable mission operation and success.³²

Having defined the concepts of *inhabiting* extreme environments and outer space, the next step is to do an overview of projects and proposals for habitats and settlements beyond Earth. This will enable an examination of the architectural space in which the inhabitants will live, and the formulation of assessments.

In 2002, the members of the Aerospace Architecture SubCommittee (ASASC) of the American Institute of Aeronautics and Astronautics (AIAA), during the Space Architecture Symposium (SAS), in occasion of the *World Space Congress* in Houston, developed the following mission statement about the discipline of Space Architecture:

*Space Architecture is the theory and practice of designing and building inhabited environments in outer space*³³

In line with the doctoral research, there have been considered two main categories of Space Architecture: orbital and planetary. These categories have subcategories that are characterized by the site or the functions that the architecture must perform. It is important to note that these two branches are closely connected to the site and have specific characteristics that refer to site-based design. Orbital architecture is concerned with designs that can orbit the Earth, moons, other planets, or asteroids. On another hand, planetary architecture is more focused on designing settlements,³⁴ landing bases, and space cities. Both aim to ensure livability parameters that guarantee the survival and comfort of occupants.

1. Orbital Architectures

By analyzing the structure of the ISS (Figure 6), it is possible to observe that it develops with a narrow and long configuration, obtained from the assembly of 16 pressurized modules distributed along a main axis and lateral extensions. The diameter of the modules ranges from a minimum of 1.9 m (6 ft 3 in) to a maximum of 10.7 m (35 ft),

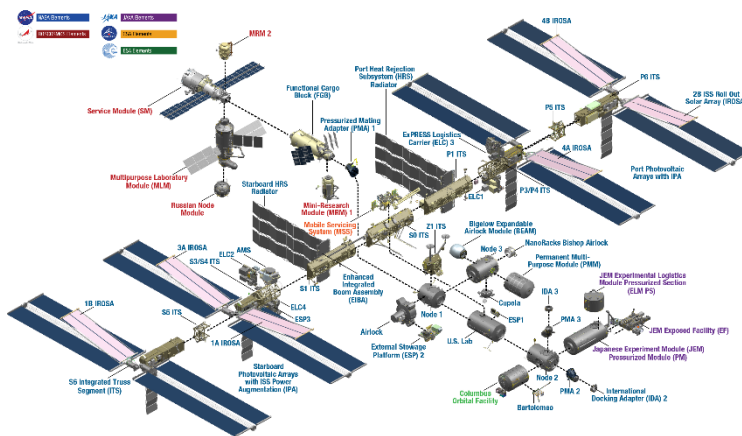


Figure 6. NASA.gov, ISS blowout, update 2023, <https://www.nasa.gov/wp-content/uploads/2023/05/iss-blowout-updated-view-2023-300.png>

with the habitable ones having an average diameter of ca. 4.3 m (14 ft).³⁵ The living space inside is significantly limited due to the various types of equipment covering the external walls. The module gives the occupant the sensation of being in a long and narrow corridor, which can feel claustrophobic at times.³⁶ Perhaps for this reason, by the evidence collected from astronauts, it can be said that the favorite module of astronauts is the *Cupola*: a small module equipped with seven windows, which offers to astronauts also a privileged view of Earth and the celestial bodies,³⁷ designed for the observation of operations outside the station such as robotic activities, the approach of vehicles, and spacewalks.³⁸

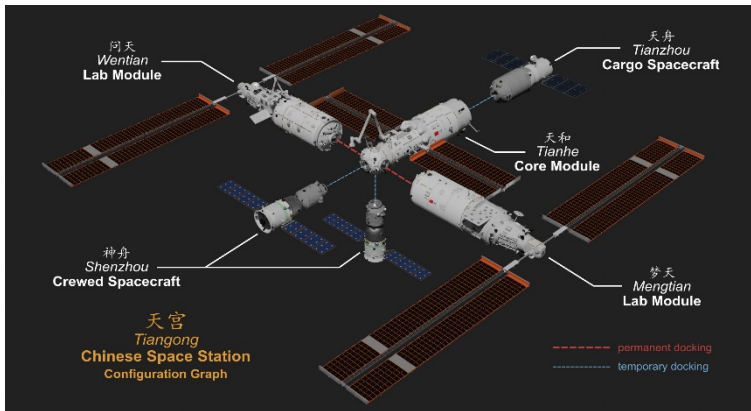


Figure 7. Tiangong Space Station, Configuration 2022, By Shujianyang - Own work, CC BY-SA 4.0, <https://commons.wikimedia.org/w/index.php?curid=125241236>

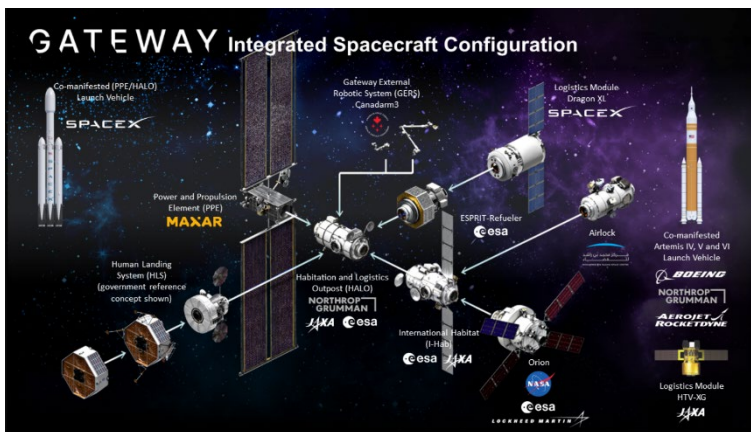


Figure 8. NASA.gov, Lunar Gateway, Integrated Spacecraft Configuration, <https://www.nasa.gov/wp-content/uploads/2023/06/microsoftteams-image-17.png>

The Tiangong Space Station (Figure 7), which is of more recently construction and based on similar design principles of ISS, is characterized by a T-shaped structure, divided into two large cylindrical sections with respective diameters of 4.2 m (14 ft) and 3.5 m (11 ft 6 in).³⁹ It is not present a module that allows for outside scrutiny, as there are no windows of any kind. In contrast to the ISS, the space of the Tiangong station appears more compact and claustrophobic.

The construction of new orbiting stations, both public and private, is planned for the near future. One of these stations is the Lunar Gateway,^{40,41} also known as Gateway (Figure 8), which will orbit near the Moon as part of the Artemis program.⁴² The station's structure will be similar to previous examples but adapted for future technology. Among the modules that will compose it, this text will focus on the Habitation and Logistics Outpost (HALO), also known as the Minimal Habitation Module (MHM). HALO is a scaled-down habitation module measuring 6.1-7 m (20-22.9 ft) by 3-4.4 m (9.8-14.4 ft). It is designed based on the Cygnus module and mainly performs life-support and habitability functions.^{43,44}

In regards to human space and architecture in microgravity contexts, it is worth to cite the Pavilion of Lithuania at the 17th International Architecture Exhibition of La Biennale di Venezia was titled *Planet of People*.⁴⁵ It is a study of a hypothetical artificial planet composed of human bodies, combining artistic and scientific elements.⁴⁶ Lithuanian Space Agency (LSA) explores the requirements for realizing the architectural fiction of Planet of People and raises questions about its sociopolitical implications. The Founder of LSA, Julijonas Urbonas, in an interview with STIRworld, regarding the idea at the base of the Pavilion project, stated:

Take a large population of humans, strip them of all social, racial, cultural, sexual, political, and economic constructs and bring them together so that they stay in close proximity for a substantial amount of time. That would be the ultimate revision of human architecture.⁴⁷

The installation outlined how the human body behaves in microgravity conditions, focusing solely on the body's movement in space.

In a nutshell, from an architectural perspective, a common trait of this kind of habitat is the highly compacted and dense available space, which leaves little room for the inhabitants to move around. Moving inside the space station could be difficult due to the high amount of equipment on the walls. At the same time, the private pods result in being very different from the ones we are used to having at home. Indeed, the astronauts used to sleep "standing up". Nevertheless, it is worth bearing in mind that the dimensions of the modules are limited in the first instance by the launch constraint, and then by the equipment required to fulfill mission goals.

2. Planetary Architectures

Planetary architectures share similarities and requirements, yet differ from orbital structures. Parameters such as location, light availability, gravity, structure and material types, and aggregation strategies (analyzed in greater detail in the papers presented at the 2023 editions of ICES⁴⁸ e IAC⁴⁹) hold distinct significance in this type of architecture. For instance, while the internal layout and architectural space of orbital structures differ from those on Earth, they share some similarities.

By citing projects such as the Moon Village⁵⁰ (designed by Skidmore Owings & Merrill – SOM for the European Space Agency – ESA), MARSHA⁵¹, Lunar Master Plan⁵² (designed by Hassell Studio for ESA), and Nüwa Mars City,⁵³ it is possible to discuss about design approaches and how internal architectural space changes in relation to the above-mentioned parameters. First of all, it is worth bearing in mind that these projects are designed for Moon and Mars, so they responds to different requirements. The study presented in this paper intents to concentrate only on spatial arrangements, i.e. vertical and horizontal circulation and base expansion strategies. Another point to consider is that some of the case studies refers to habitats while others to settlements. However, the choice has been made specifically to demonstrate how internal organization could vary when considering multi-scale systems. These cases serve an illustrative function and are considered by the authors as best-practices in the space architecture sector.

The architectural space among these projects would seem to be organized mainly along two axes: vertical and horizontal. Moon Village (Figure 9) and MARSHA (Figure 10) are examples of beacon structures that develop vertically, organizing internal environments on multiple levels and assigning each level a specific functional purpose, such as differentiating between common and private areas.

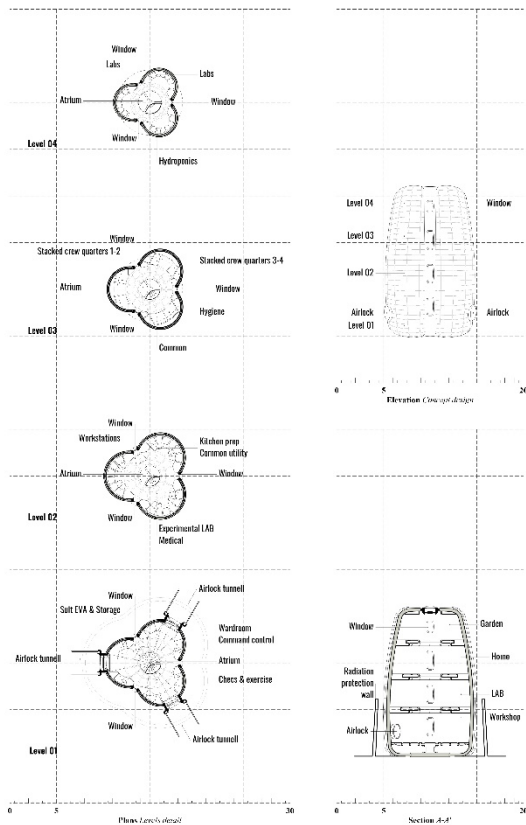


Figure 9. Re-interpretation, drawings and analysis of Moon Village by SOM, 2021.

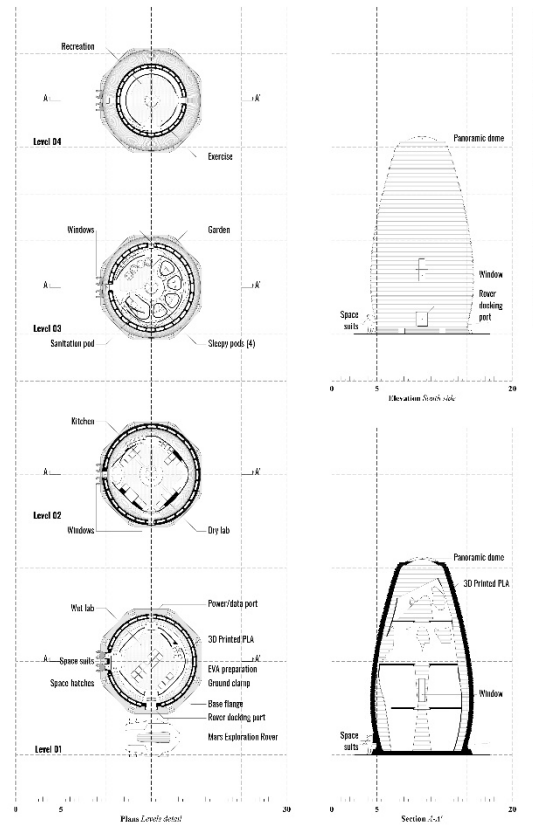


Figure 10. Re-interpretation, drawings and analysis of MARSHA by AISpaceFactory, 2021.

In contrast, the Lunar Master Plan and Nüwa Mars City projects (Figure 11) adopt a horizontal development of spaces, which, while maintaining a functional characterisation, facilitates greater connectivity. From a spatial perspective, the areas are sized to ensure the safety and comfort standards required for the long-term permanence. In wider settlements like these, there is more room for facilities beyond the strictly necessary. Indeed, there are areas

designated for culture and leisure, such as digital/virtual museums or conservatories, in Nüwa Mars City. Furthermore, the strictly required areas are better distributed in the general layout of the settlement. This allows for a more appropriate layout to be provided for private areas and common areas, as well as for labs and energetic areas. Thinking in the large scale of the settlement allows for a different kind of quality to be provided even at the smallest scale of its parts.

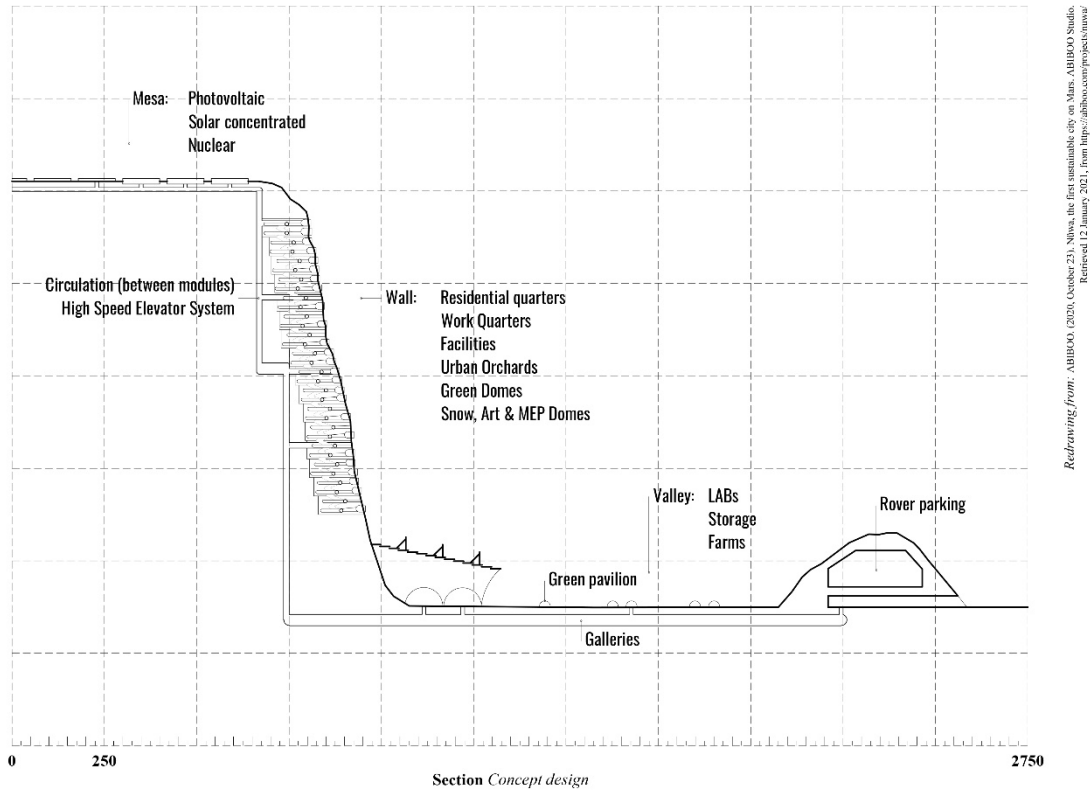


Figure 11. Re-interpretation, drawings and analysis of Nüwa Mars City, 2021.

In addition, as previously stated in Chapter III, it is crucial to consider the aspect of modularity when designing architectures for outer space. Technical and practical requirements, which are also established by international standards, promote the use of a module-based design approach. This standardisation, particularly in the case of docking modules and other connections, serves to establish a connection point between projects. With regard to the relationship between modules and human space and architecture, it is pertinent to cite again the studies on proportion and measurement developed by Leonardo da Vinci and Le Corbusier, such as the Vitruvian Man and the Modulor. Consequently, the architectural design for space, in a manner analogous to terrestrial architecture, should be founded upon human needs and scaled to a human scale.

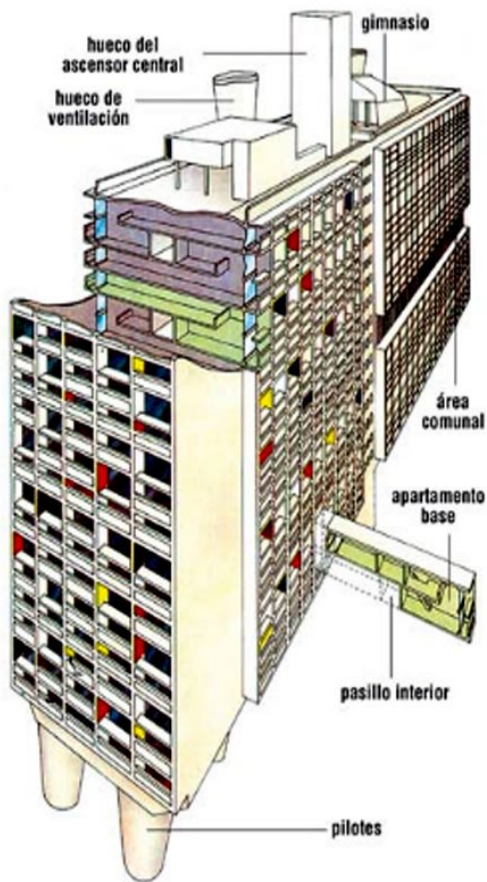
Finally, it is necessary to highlight the interconnection between orbital and planetary architectures. The most prevalent attribute of habitable structures in space is the necessity for their pressurisation in order to provide a habitable atmosphere. This necessitates the utilisation of airtight structures and the maximisation of equal internal pressure distribution, which consequently dictates the structural geometries.

C. Inhabit the Future

In accordance with Rod Jones, a first consideration regarding the living models of the future and the possibilities for designing architecture in systems beyond Earth is that such architectures should be considered as adaptive and constantly evolving models. The ISS has provided a thirty-year experience where astronauts have made additions and modifications to adapt to their needs.⁵⁴

Norman Foster also writes about the concept of adaptability and reappropriation of space, in the sense of customization based on personal and/or shared needs. In the editorial of Domus 1087, which is dedicated to the issues

of the future of urbanization, he writes about how human beings are in a phase in which they are inclined to reclaim spaces and how models of compact cities can be effective both from a social point of view and from the point of view of sustainability.⁵⁵



Esquema de una de las unidades de habitación de Marsella.

Figure 12. Scheme of Unite d'habitation by Le Corbusier, <http://architecture-history.org/architects/architects/LE%20CORBUSIER/OBJECTS/1952,%20The%20Cit.html>

It is assumed that these considerations could also be extended to space, as an adaptive, compact, and constantly evolving environment not only facilitates social dynamics, which in extreme contexts become fundamental for the success of missions but also favors the saving of resources. When settling on other celestial bodies, it has been questioned whether defining such places as *cities* is still appropriate. The term *city* has Indo-European roots, originating from the Latin word *civitas* (or *urbs*, if referring to a walled city in Ancient Rome). It encompasses several meanings, including *citizenship*, *urban center*, and *built environment*.⁵⁶ However, a city is not merely a physical space, but a product of human habitation. It is believed that a city cannot exist without inhabitants. In the context being considered, beyond Earth, this concept can be extended, providing an answer to the question above.

The habitats, the settlements, and the cities of the future will therefore not be mere agglomerations of constructions built for their own sake, but inhabited places that will constantly evolve as such. They will not be mere agglomerations of buildings for their own sake but will be inhabited places that are constantly evolving as such, places where social and environmental barriers could be overcome in the pursuit of a common goal. In conclusion, for the above-mentioned reasons, it is believed that it is correct to consider such places as cities.

In consideration of the studies and analyses presented in the text, it can be posited that a compact city model, akin to that proposed by Le Corbusier for the Unité d'Habitation in Marseille, France (Figure 12), may be a suitable framework for space habitats and space cities. This exemplifies an architectural approach wherein design is based on the human scale, enabling the integration of social and other functions within a single edifice, while maintaining the quality of the spaces and their liveability. It also serves as an exemplary illustration and case study with respect to the two-way relationship between terrestrial and extraterrestrial design.

It is evident that a single housing or city model is insufficient for the task at hand. A multiplicity of additional models should be employed in space, while maintaining the objective of achieving a balanced relationship between architectural space and human space. In accordance with the aforementioned concept of maintaining the compact nature of future cities, it is beneficial to consider the 15-minutes city model,^{57,58} which allows inhabitants to become "owners" of the available space and places. On another hand, the city-community of Arcosanti,^{59,60} Arizona, designed by Paolo Soleri, can be regarded as a model of best practice in which architecture becomes a new ecology. A heritage that may be regarded as epitomising the most profound aspects of humankind's predicament, the act of experimentation represents an attempt to create new universes that, in a cyclical manner, can be viewed as a 'return to the Earth'.

V. Architecture and Architects for Space: What Role?

In 2011, Bannova and Bell⁶¹ argue for the importance of incorporating architectural principles into aerospace engineering education. They begin by highlighting the traditional role of architects as designers who prioritize functionality in their creations. While imperfect structures can survive on Earth, space and extreme environments demand a more rigorous approach. In the paper then they contrasts the established role of architects on Earth with the more complex role of a space architect. The authors note that the aerospace field is traditionally focused on engineering and machinery, often viewing humans as operators or mechanics. They propose that integrating architectural education into aerospace engineering curriculums would be a natural evolution, offering students a broader perspective on problem-solving and preparing them for a wider range of professional applications.

In 2014, on the occasion of AIAA Space Conference and Exhibition, Brand N. Griffin wrote the following about the relationship between engineers and architects: *Engineers think architects make things prettier, difficult to build, and more expensive. Some can, but space architects are different. They analyze like an engineer and synthesize like an architect.*^{62,63}

Griffin's statement indicates that space architects, due to their multidisciplinary training, possess a unique set of skills that allows them to combine various professions into one. This is not solely due to their close connection with engineers in the space sector. The discipline of space architecture is based on the principle of multidisciplinary and collaboration among professionals to pursue the aforementioned mission statement of the Millennium Charter. This approach is a significant factor in the success of space architecture.

The recent growth of interest in the discipline, driven in part by a new wave of interest in and awareness of space, has led to exponential growth in recent years. This growth has been coupled with international space exploration programmes, such as Artemis, which have helped to strengthen the field. As a result, more and more architects are choosing to specialise in it. The high demand has led to the establishment of ad hoc courses of study at all levels, as well as the promotion of numerous design competitions and calls for ideas for permanent bases on the Moon or Mars. In order to ensure the continued evolution of design and living beyond the Earth, it is essential that architecture and architects play a pivotal role in the pursuit of the principles that have already been established for these two roles. However, it is also crucial to consider the potential variations that they can take in the context of the space sector.

On December 2023, the authors hosted a PhD seminar titled "Space in Space" as part of the PhD course in Architecture at the University Mediterranea of Reggio Calabria. The objective was to disseminate knowledge and experiences regarding the field of space architecture to the local academic community in occasion of the 3rd Italian National Space Day. The lecturers presented their research and shared their thoughts on the role of architecture and architects in the space sector. The principal outcome of this event was that, in the context of future human settlements on celestial bodies, architecture should play a significant role as part of a multidisciplinary design team, with the objective of ensuring the comfort of the inhabitants. Regarding the role of Space Architects, it has been outlined how research is a key point in the professional development, but just like "terrestrial" ones. It is of the utmost importance to identify the most optimal solutions to address the specific needs of a given project. Moreover, despite the fact that the majority of individuals employed in the field of space are engineers, space architects are able to exert a greater influence in terms of numbers than typical engineers.

Space architects are tasked with addressing challenges that were once considered utopian. They have the opportunity to exercise their imagination while experimenting with and testing new architectural concepts and living arrangements in a way that would have been impossible on Earth. However, they also bear a significant responsibility with respect to ensuring the survival of the inhabitants of space and meeting their needs for comfort and well-being, which are necessary for long-term permanence beyond our planet. The training of the space architect is undoubtedly multidisciplinary and should be accompanied by a holistic approach, so as to ensure that the individual in question is a professional figure as complete and varied as possible in terms of knowledge and skills.

VI. Conclusion

In summary, this paper explores the relationship between *inhabiting* and architectural space, examining how humans have influenced and been influenced by their environments throughout history and into the future of space exploration. The focus is on the dynamic interplay between humans and their environments, which has evolved in concert with human understanding of the universe and its place within it. However, it is worth noting that there has been one fascinating constant: the human-centered approach to architectural design. Throughout history, architects have attempted to create spaces that prioritize comfort, safety, and well-being, using scale and modular proportions to ensure that these basic needs are met. This focus remains essential in both terrestrial and space architecture.

The paper tries to outline a bilateral correspondence between Earth and Space architectural design approach. Architectural knowledge gained on Earth has served as a springboard for innovation in space, and conversely, discoveries made in space have fueled advances on our home planet. This mutual progress highlights the interconnectedness of these seemingly different environments. By examining the role of architects in the space sector, the research sheds light on common challenges and unique considerations. While the fundamental principles of design remain constant, innovative approaches and specialized expertise are necessary to meet the extreme conditions of space. An understanding of these similarities and differences is central to the creation of sustainable and functional habitats beyond Earth.

In conclusion, this research aims to serve as a starting point for discussion, inviting further exploration of the dynamics and issues surrounding architecture in space. As humanity explores deeper into space, the connection between humans and their constructed surroundings will inevitably transform, requiring inventive solutions and reflective discussion.

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References

- ¹Mariotti, W., “Redesigning human space and making its content meaningful. A conversation with the Italian Minister of Cultural Heritage and Activities and Tourism for the launch of the renewed Domus website.”, *Domusweb*, 2017. [Interview]. <https://www.domusweb.it/en/opinion/2017/10/06/redesigning-human-space-and-making-its-content-meaningful.html>
- ² *Dizionario Enciclopedico di Architettura e Urbanistica*, Collana di dizionari enciclopedici di cultura artistica, Istituto Editoriale Romano, Rome, Italy, 1968-1969.
- ³ Dupérac, É., “View of the Campidoglio as re-designed by Michelangelo Buonarroti from the ‘Speculum Romanae Magnificentiae’,” Etching and engraving, *Metropolitan Museum of Art*, NYC, USA, 1569. URL: <https://www.metmuseum.org/art/collection/search/395099>
- ⁴ Wittkower, R., *Architectural Principles in the Age of Humanism*, 2nd ed., Einaudi, Turin, Italy, 1964.
- ⁵ Zevi, B., “F. L. Wright and the Conquest of Space”, *Magazine of Arts*, No. 5, May 1950, pp. 186-191.
- ⁶ Wright, F.L., *Darwin D. Martin House (Buffalo, New York)*. 1904. Avery Architectural and Fine Arts Library, Columbia University, *JSTOR*, <https://jstor.org/stable/community.28483531>.
- ⁷ “Abitare”, *Enciclopedia Treccani*, n.d. https://www.treccani.it/vocabolario/abitare_res-ec03dde3-000b-11de-9d89-0016357eee51/
- ⁸ Buonavoglia, S., “Alla ricerca dell’abitare ideale. Le geometrie celesti del Mantegna, La corona di pietra di Federico II di Svevia”, Ph.D. Dissertation, Architecture Dept., University of Florence, Florence, IT, 2012-2015, pp. 25-28.
- ⁹ Heidegger, M., *L’Arte e lo Spazio / Art and Space*, italian ed., Angelino, C. (curated by), Melagnolo, Genoa, Italy, 1979.
- ¹⁰ Vitruvius Pollio, M., *De Architectura*, italian ed., Corso, A., & Romano, E. (curated by), Vol. VI, Einaudi, Turin, Italy, 1997.
- ¹¹ Alberti, L. B., *L’Architettura. De re aedificatoria*, italian ed., Orlandi, G. (curated by), Edizioni Il Polifilo, Milan, Italy, 1966.
- ¹² Le Corbusier, *Verso una architettura / Vers un architecture*, italian ed., Cerri, P., & Nicolini, P. (curated by), Longanesi, Milan, Italy, 1979.
- ¹³ Argan, G., *Walter Gropius e la Bauhaus*, Einaudi, Turin, Italy, 1988.
- ¹⁴ Rossi, A., *L’Architettura della Città*, 3rd ed., CittàStudiEdizioni, Milan, Italy, 1995, pp. 9-11.
- ¹⁵ “Essential Homes Research Project”, Norman Foster Foundation, 2022. <https://normanfosterfoundation.org/project/essential-homes-research-project/>
- ¹⁶ Benetti, A., “Norman Foster’s tiny dwelling as the evolution of the minimal house”, *Domus*, no. 1080, EcoWorld supplement, Editoriale Domus S.p.A., Rozzano, Milan, Italy, June 2023.
- ¹⁷ Mariotti, W., “Norman Foster named Domus Guest Editor for 2024”, *Domus*, 30th Nov. 2023. <https://www.domusweb.it/en/norman-foster-named-domus-guest-editor-for-2024.html>
- ¹⁸ Foster, N., “Futuri / Futures”, *Domus*, no. 1086, Editoriale Domus S.p.A., Rozzano, Milan, Italy, Jan. 2024, pp. 1-3.
- ¹⁹ Glaeser, E. L., “Recipes for happy cities”, *Domus*, no. 1087, Editoriale Domus S.p.A., Rozzano, Milan, Italy, Feb. 2024, pp. 4-9.

- ²⁰ Buono, F., & Vlahovljak, M., “Dalla Terra allo Spazio”, in: Fallacara, G., & Netti, V., *Abitare Marte. Architettura oltre il pianeta Terra. Hive Mars: progetto di un insediamento, di classe ibrida, sulla superficie marziana*, 1st ed., Gangemi Editore, Rome, Italy, Chap. 2, 2021, p. 10-19.
- ²¹ Bannova, O., “Designing for Extremes: A methodological approach to planning in Arctic regions”, Ph.D. Dissertation, Architecture Dept., Chalmers University of Technology, Gothenburg, Sweden, 2016. ISBN 978-91-7597-461-3, ISSN 0346-718X
- ²² Gómez, F., “Extreme Environment”, in: Gargaud, M., *et al. Encyclopedia of Astrobiology*, Springer, Heidelberg, Berlin, 2011. DOI https://doi.org/10.1007/978-3-642-11274-4_566
- ²³ Bannova, O., *Space Architecture. Human Habitats Beyond Planets Earth*, DOM Publishers, Berlin, Germany, 2021, p. 41.
- ²⁴ AIAA ASASC – Aerospace Architecture Subcommittee, “The Millennium Charter. Fundamental Principles of Space Architecture,” *AIAA Space Architecture Symposium & Workshop*, World Space Congress, Houston, Texas, USA, 10-12 October 2002, p. 3. <http://spacearchitect.org/wp-content/uploads/2020/06/The-Millennium-Charter.pdf>
- ²⁵ Meuser, P., Galina Balaschowa: Architektin des sowjetischen Raumfahrtprogramms, german ed., DOM Publishers, Berlin, Germany, 2014.
- ²⁶ [ENG: It touched! It touched the lunar surface!]. *L'uomo sulla Luna 1969 – Ore 22:17 : “Ha toccato!”*, original video from Jul. 1969, RayPlay, 2019. [Video] <https://www.raiplay.it/video/2019/06/Luomo-sulla-Luna---Ore-2217-Ha-toccato-b270a655-8943-47b1-b019-09180e61aebb.html>
- ²⁷ NASA Video, *One Small Step, One Giant Leap*, 2013. Restored footage of Neil Armstrong's first steps on the lunar surface during the Apollo 11 mission in July 1969. [Video] Youtube. <https://youtu.be/xSdHina-fTk?si=ozhzU4U1oWwdMU5P&t=40>
- ²⁸ “International Space Station facts and figures”, NASA, n.d. <https://www.nasa.gov/international-space-station/space-station-facts-and-figures/>
- ²⁹ Jones, A., & Dobrijevic, D., “China’s space station, Tiangong: A complete guide”, *Space.com*, Aug. 2023. <https://www.space.com/tiangong-space-station>
- ³⁰ Häuplik-Meusburger, S., & Bannova, O., “Space Architecture and Habitability: An Asset In Aerospace Engineering And Architectural Curricula,” *ActaFutura*, no. 10, Zenodo, 2016, pp. 6-22. DOI <https://doi.org/10.5281/zenodo.202149>
- ³¹ NASA, “The International Space Station Transition Plan”, *NASA.gov*, Sept. 2023. <https://www.nasa.gov/faqs-the-international-space-station-transition-plan/>
- ³² Häuplik-Meusburger, S., *Architecture for Astronauts: An Activity-based Approach*, Springer, Vienna, Austria, 2011. ISBN 978-3-7091-1936-5. DOI <https://doi.org/10.1007/978-3-7091-0667-9>
- ³³ *Op. cit.* AIAA ASASC, “Space Architecture Mission Statement”, p. 1
- ³⁴ “Settlement: group of permanently inhabited habitats installed near each other, possibly interconnected.”, International Astronautical Federation (IAF), “IAF: Space Habitats Committee”, n.d. [Definition] <https://www.iafastro.org/about/iaf-committees/technical-committees/space-habitats-committee.html>
- ³⁵ “Reference Guide to the International Space Station”, *NASA*, Utilization ed., NASA NP-2015-05-022-JSC, Sept. 2015.
- ³⁶ NASA Johnson, “Everything About Living in Space”, Oct. 2016. [Video] Youtube. <https://www.youtube.com/watch?v=ouDKD9G9jOE>
- ³⁷ ASI, “The Cupola is the International Space Station’s window”, *ASI.it*, n.d. <https://www.asi.it/en/life-in-space/international-space-station/cupola/>
- ³⁸ NASA, “Cupola”, *NASA.gov*, n.d. <https://www.nasa.gov/international-space-station/cupola/>
- ³⁹ Barbosa, R. C., “China preparing to build Tiangong station in 2021, complete by 2022”, *NASASpaceFlight*, Mar. 2021. <https://www.nasaspacespaceflight.com/2021/03/china-preparing-to-build-tiangong-station-in-2021-complete-by-2022/>
- ⁴⁰ NASA, “Gateway News Releases”, *NASA.gov*, n.d. <https://www.nasa.gov/gateway-space-station/>
- ⁴¹ NASA, “Gateway: A Deep Space Home, and So Much More”, *NASA.gov*, Oct. 2022. <https://www.nasa.gov/missions/artemis/gateway-halo-a-deep-space-home/>
- ⁴² National Aeronautics and Space Administration, “ARTEMIS PLAN. NASA’s Lunar Exploration Program Overview”, NASA, Sept. 2020. https://www.nasa.gov/wp-content/uploads/2020/12/artemis_plan-20200921.pdf?emrc=f43185
- ⁴³ Fuller, S., Lehnhardt, E., Zaid, C., & Halloran, K., “Gateway Program Status and Overview”, *IAF Space Exploration Symposium, Moon Exploration – Part 2, 72nd International Astronautical Congress (IAC)*, International Astronautical Federation (IAF), Paris, France, 2021. IAC-21,A3,2B,13,x66240
- ⁴⁴ Fuller, S., Lehnhardt, E., Connell, D., Zaid, C., & Halloran, K., “Gateway Program Status and Overview”, *IAF Human Spaceflight Symposium, 73rd International Astronautical Congress (IAC)*, International Astronautical Federation (IAF), Paris, France, 2022. IAC-22,B3,1,8,x69484
- ⁴⁵ “Lithuanian Pavilion at the Biennale Architettura 2021”, *ArchDaily*, 2021. <https://www.archdaily.com/961370/lithuanian-pavilion-at-the-biennale-architettura-2021>
- ⁴⁶ “Pavilion of the Lithuania. Planet of People”, *17th International Architecture Exhibition of La Biennale di Venezia*, La Biennale di Venezia, Venice, Italy, 2021. https://images.adsttc.com/submissions/events/pdf_file/7427/LSA_-_Press_Release_-_EN.pdf?utm_medium=website&utm_source=archdaily.com

- ⁴⁷ Shah, D., & Ahuja, A., “STIRring Together: Julijonas Urbonas and Jan Boelen on Lithuania’s ‘Planet of People’”, *STIRworld.com*, 2021. [Interview] <https://www.stirworld.com/inspire-people-stirring-together-julijonas-urbonas-and-jan-boelen-on-lithuania-s-planet-of-people>
- ⁴⁸ D’Amico, G., & Tornatora, R.M., “Atlas of Habitats Beyond Earth. Architectural Solutions for Space Applications”, *ICES502: Space Architecture, 52nd International Conference on Environmental Systems (ICES)*, Texas Tech University, Lubbock, Texas, USA, July 2023. ICES-2023-270, <https://ttu-ir.tdl.org/handle/2346/94692>
- ⁴⁹ D’Amico, G., & Tornatora, R.M., “From the Earth to Space: Notes for a Planetary Space habitat Catalogue”, *34th IAA Symposium on Space and Society, 74th International Astronautical Congress (IAC)*, International Astronautical Federation (IAF), Paris, France, October 2023. IAC-23,E5,2,4,x78614
- ⁵⁰ Petrov, G., Inocente, D., Haney, M., Katz, N., Koop, C., Makaya, A., Arnhof, M., Lakk, H., Cowley, A., Haignere, C., Messina, P., Sumini, V., Hoffman, J., “Moon Village Reference Masterplan and Habitat Design”, *ICES502: Space Architecture, 49th International Conference on Environmental Systems (ICES)*, Texas Tech University, Lubbock, Texas, USA, July 2019. ICES-2019-280, <https://hdl.handle.net/2346/84487>
- ⁵¹ Montes, J., Botham, C. J., Earle, J., Coleman, J., Riedel, D., “Prototyping MARSHA: Discoveries, Surprises and Lessons in Additive Habitat Construction”, *30th IAA Symposium on Space and Society, 70th International Astronautical Congress (IAC)*, International Astronautical Federation, Paris, France, 21-25 Oct. 2019. IAC-19-E5.1A.9
- ⁵² “Hassell | Lunar Master Plan: Hassell and European Space Agency launch pioneering habitat concept”, *Hassell*, 2024. <https://www.hassellstudio.com/news-event/lunar-master-plan-hassell-and-european-space-agency-launch-pioneering-habitat-concept#0>
- ⁵³ Destrell, G., Muñoz, A., Banchs-Piqué, M., Anglada, G., Hartlieb, P., Sureda, M., “Nüwa, a Self-Sustainable City State on Mars – Development Concept, Urban Design and Life Support”, *ICES502: AIAA LS&S - Space Architecture, 50th International Conference on Environmental Systems (ICES)*, Texas Tech University, Lubbock, Texas, USA, July 2021. ICES-2021-225, <https://hdl.handle.net/2346/87195>
- ⁵⁴ Jones, R., “Performance of the International Space Station Interior”, in Howe, A.S., & Sherwood, B. (edited by), *Out of this world: the new field of space architecture*, American Institute of Aeronautics and Astronautics (AIAA), Reston, Virginia, USA, 2009, PP. 31-43. ISBN 9781563479823
- ⁵⁵ Foster, N., “The future of urbanization”, *Domus*, no. 1087, Editoriale Domus S.p.A., Rozzano, Milan, Italy, Feb. 2024, pp. 1-3.
- ⁵⁶ *Op. cit.* Dizionario Enciclopedico di Architettura e Urbanistica, “Città”, Cinema-Gotico, pp. 7-17.
- ⁵⁷ Moreno, C., *Droit de cité: De la “ville-monde” à la “ville du quart d’heure”*, Editions de l’Observatoire, Paris, France, 2020.
- ⁵⁸ Moreno, C., *The 15-Minute City: A Solution for Saving Our Time & Our Planet*, John Wiley & Sons Inc, New York, USA, 2024.
- ⁵⁹ Doglio, F. & Tosoni, P., *Paolo Soleri. Paesaggi energetici. Arcologie in terre marginali*, LetteraVentidue, Syracuse, Italy, 2013.
- ⁶⁰ Sicilia, A., *Le architetture di Paolo Soleri. Un viaggio in Arizona*, Malcor D’ edizione, Catania, Italy, 2015.
- ⁶¹ Bannova, O., & Bell, L., “Space architecture education as a part of aerospace engineering curriculum”, *Acta Astronautica*, Vol. 69, Issues 11-12, Elsevier, Amsterdam, Netherlands, 2011, pp. 1143-1147. ISSN 0094-5765, DOI <https://doi.org/10.1016/j.actaastro.2011.06.011>
- ⁶² Griffin, B. N., “Space Architecture: The Role, Work and Aptitude”, *AIAA SPACE 2014 Conference and Exposition*, San Diego, CA, USA, 4-7 August 2014. DOI <https://doi.org/10.2514/6.2014-4404>
- ⁶³ *Cit.* Häuplik-Meusburger, S., “Architecture for Astronauts”, p. 12