

Extended summary

DOCTORAL DISSERTATION

Architecture in Extreme Conditions:

*The Problem of Self-Sufficiency in Space Architecture and Its Impact
on Sustainable Development*

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1. Scope and Objectives

1.1. Introduction

The dissertation begins with the observation that technologies developed for space missions have, for decades, been a significant driver of technological and scientific development on Earth. This phenomenon is described in literature and practice as spin-off, understood as the adaptation of space solutions for terrestrial applications, and spin-in, the reverse process, meaning the implementation of terrestrial technologies in space missions¹ [Fig. 1].

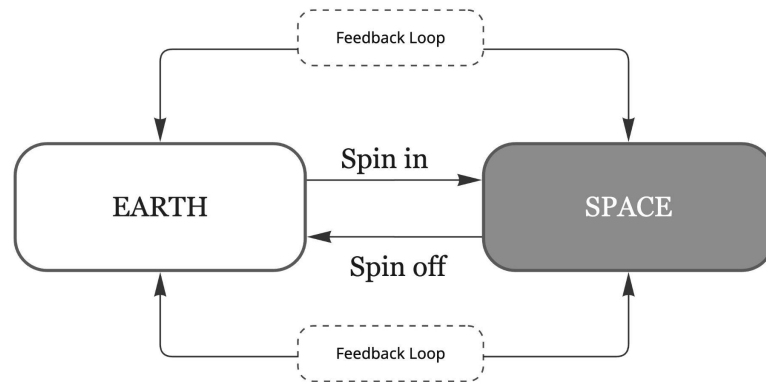


Fig. 1. Modified model of knowledge transfer between outer space and Earth (author's elaboration based on: Schlacht, 2016).

If solutions developed for space missions prove effective in such diverse fields, it is reasonable to assume that a similar transfer potential also exists in architecture. This particularly concerns issues related to self-sufficiency, which in space architecture constitutes a condition for the functioning of inhabited environments².

¹ Schlacht, I., Foing, B., Bannova, O., Blok, F., Mangeot, A., Nebergall, K., Ono, A., & Schubert, D. (2016a). *Existing and new proposals of Space analog, off-grid and sustainable habitats with Space applications. 46th International Conference on Environmental Systems.*

² Dziadula, W., & Fross, K. (2022). *About architecture in extreme conditions. How can space and extreme environment help architects design better? 73rd International Astronautical Congress (IAC) Proceedings, International Astronautical Federation (IAF), Paris, France*

The space context and other extreme environments (such as polar, underwater, and desert environments) can be analysed within a single coherent research perspective because they share characteristics defined by conditions that deviate from optimal ones. These environments are classified as ICE (*Isolated, Confined, Extreme*)³ [Fig. 2].

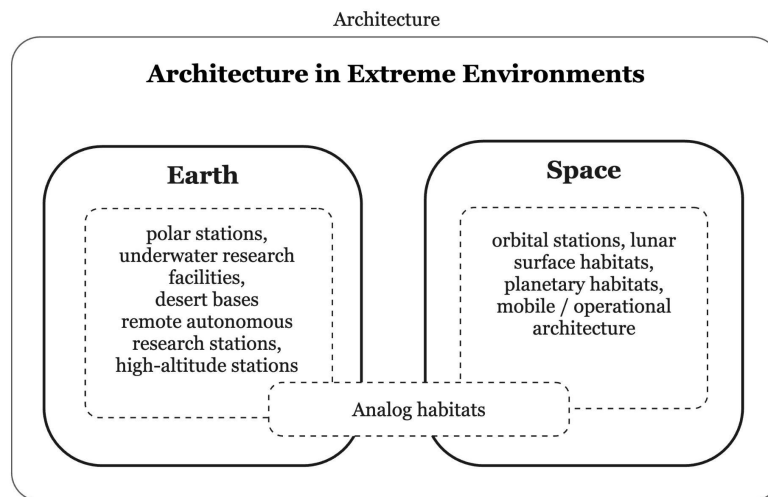


Fig. 2. Classification of environments and types of extreme architecture, including facilities operating on Earth, in outer space, and analog habitats as a connecting element between both research domains (adapted from: Dziadula & Fross, 2022).

Therefore, extreme environments characterised by high levels of constraint may provide a context for developing solutions that address key challenges of contemporary terrestrial architecture, such as the rational management of limited resources, the optimisation of energy consumption, and the increasing resilience of the built environment to variable and extreme external factors.

1.2. Research Gap

The development of space architecture as a scientific research field began only at the beginning of the 21st century, when the discipline's definition and objectives were officially formulated at the International Astronautical Congress⁴. Since that moment,

³ Suedfeld, P., & Palinkas, L. A. (2021). Psychosocial issues in isolated and confined extreme environments. *Neuroscience and Biobehavioral Reviews*, 126, 413–429. 10.1016/j.neubiorev.2021.03.032

⁴ Team 11. (2002). *THE MILLENNIUM CHARTER*. spacearchitect.org. <https://spacearchitect.org/wp-content/uploads/2020/06/The-Millennium-Charter.pdf> (accessed: 04 February 2026).

space architecture has developed as a highly interdisciplinary field, originating from aerospace engineering while remaining strongly connected with psychology⁵, environmental engineering, materials science, and robotics⁶. This topic is primarily present in English-language literature, within aerospace engineering, systems science, environmental psychology, and research on confined environments. In Polish-language literature, the scope of research remains limited.

An important theoretical background for considering architecture as a system is provided by concepts of systems thinking and the perception of the built environment as a closed life-support system, present among others in the works of R. Buckminster Fuller and in the development of ecological design, demonstrating the transition from architecture as an object to architecture as an environmental system⁷. Despite the consolidation of these ideas in literature, they have not yet resulted in the development of coherent analytical tools enabling the assessment of the impact of space architecture and extreme environment experiences on terrestrial architecture. Experiences from space architecture and extreme environments provide unique data regarding the functioning of closed environmental systems, management of limited resources, and the long-term impact of space on users, including self-sufficient operation. **The identified research gap concerns the lack of tools enabling the organisation and analysis of knowledge developed within space and extreme architecture in the context of its potential significance for terrestrial architecture.**

1.3. Research Problem and Objectives

The dissertation addresses the problem of insufficient identification of key factors of architectural self-sufficiency and their relationship with terrestrial architecture, as well as the lack of tools enabling their comparison and evaluation in the context of diverse operational conditions. As a result, the methodological identification of directions and

⁵ Häuplik-Meusburger, S., & Bannova, O. (2016). *Space Architecture Education for Engineers and Architects: Designing and Planning Beyond Earth*. Springer International Publishing.

⁶ Häuplik-Meusburger, S., & Bishop, S. (2021). *Space Habitats and Habitability: Designing for Isolated and Confined Environments on Earth and in Space*. Springer International Publishing.

⁷ Fuller, R. B. (2008). *Operating Manual for Spaceship Earth* (J. Snyder, Ed.; Original published 1969 ed.). Lars Müller Publisherscategorise.

needs for transferring solutions from space architecture to the terrestrial context remains limited, particularly in relation to architecture operating under conditions of resource deficit, system isolation, and operational autonomy.

The main aim of the dissertation is to identify and categorize solutions that ensure self-sufficiency in extreme environments and, on this basis, to develop an integrated model for the assessment and development of autonomous, resilient, and independent architecture.

Specific Objectives:

1. To examine the relationship between the characteristics of extreme environments and the degree of integration of self-sufficiency systems in space architecture and in buildings operating under extreme terrestrial conditions.
2. To identify and analyse technological and design solutions developed in the context of extreme architecture.
3. To indicate directions for the transfer of knowledge and technologies between space/extreme architecture and terrestrial architecture, in terms of spin-off and spin-in processes.
4. To identify and distinguish factors of architectural resilience and self-sufficiency (*ARF - Architectural Resilience Factors*), forming a basis for the analysis of solutions applied in extreme environments.
5. To develop an original scale for the assessment of architectural self-sufficiency - the *Self-Sufficiency Readiness Level (SSRL)*, based on ARF and adapted to a multidimensional evaluation of architectural self-sufficiency.
6. To formulate guidelines and recommendations for the development of future self-sufficient architecture, based on experience from space architecture and the results of the ARF and SSRL analyses.

Theses of the Dissertation:

Thesis 1. Space architecture, analog space missions, and buildings in extreme environments constitute a key source of design, technological, and operational knowledge that can be directly applied to the development of self-sufficient architecture on Earth.

Thesis 2. Architectural Resilience and Self-Sufficiency Factors (ARF) constitute a tool for the systematic assessment of the degree of integration of autonomous systems both in architecture operating under extreme environmental conditions and in buildings designed for everyday use under standard terrestrial conditions.

Thesis 3. The author's Self-Sufficiency Readiness Level (SSRL) scale is an effective tool for the multidimensional assessment of the level of self-sufficiency of buildings, enabling comparison, classification, and the identification of potential directions for the development of technologies and design strategies.

Thesis 4. Technologies and design strategies developed for the needs of space architecture play an important role in shaping future models of sustainable development and in increasing the resilience of terrestrial architecture to future challenges.

2. Research Methodology

The dissertation applies a qualitative research approach using literature analysis, case studies, and synthesis of obtained results. It includes literature analysis, the author's empirical experience, and comparative analysis of architecture operating in ICE environments (Isolated, Confined, Extreme), both in the context of the space environment and extreme terrestrial environments [Fig. 3].

In the first stage, conceptual and methodological frameworks of the dissertation were defined, including issues of space architecture, ICE environments (Isolated, Confined

and Extreme), and self-sufficiency. Literature analysis allowed the formulation of theoretical foundations concerning architectural design in extreme conditions. The author’s empirical experience complemented theoretical analyses, enabling the connection of design considerations with real environmental and operational constraints.

The next stage involved comparative analysis (case study) of facilities operating in different extreme environments, including space architecture, analog space habitats, and selected terrestrial facilities. This analysis aimed to identify common design, technological, and spatial strategies influencing the level of architectural self-sufficiency.

Based on the results of the analyses, Architectural Resilience Factors (ARF) were identified and then examined through comparative analysis using heatmaps. The obtained results formed the basis for the development of an original, multidimensional scale for evaluating architectural self-sufficiency – the Self-Sufficiency Readiness Level (SSRL).

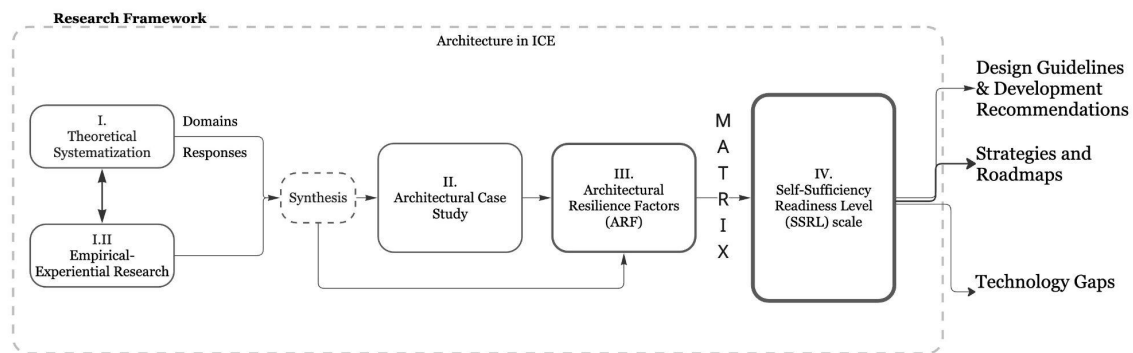


Fig. 3. Logical structure of the research framework (author’s elaboration, 2025).

The application of the SSRL scale in the analysis of selected case studies had a pilot character. It enabled the evaluation of its usefulness as a comparative and interpretative tool in the context of transferring solutions from space architecture and extreme environments to terrestrial architecture.

3. Synthesis of Research

3.1. Literature Analysis - Theory of Architecture in Extreme Environments

Based on the literature analysis, an original set of key design domains was identified, forming a framework for the theory of design in extreme environments and organising the main areas of architectural challenges. The dissertation identifies four fundamental design domains that overlap and create a dynamic system of interdependencies [Fig. 4]:

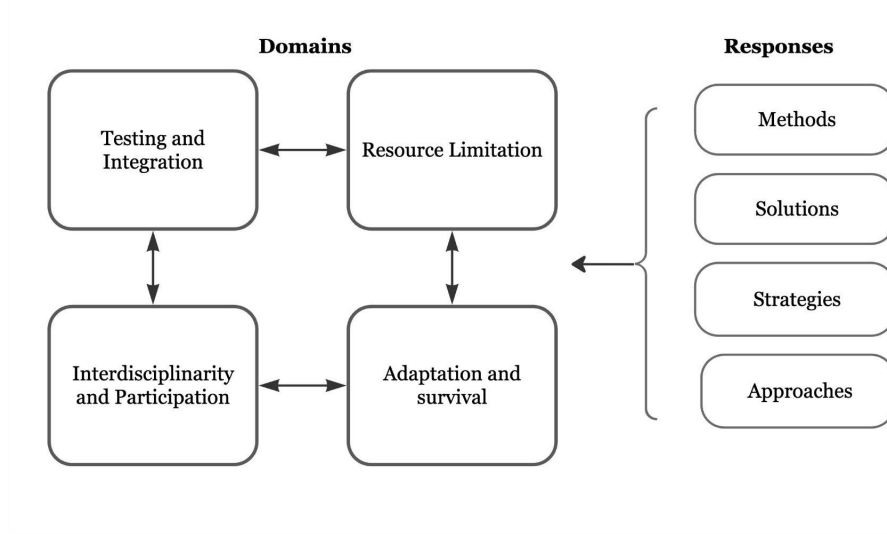


Fig. 4. Identified design domains in extreme environments (author's elaboration, 2026).

Interdisciplinarity and Participation. Design in space and extreme environments requires close cooperation between architecture, engineering, biology, space medicine, and environmental psychology. The architect performs the role of an integrator of technical and humanistic systems. This domain emphasises the importance of design models enabling parallel work of multiple disciplines and involving future users in the design process, which reduces the risk of errors and supports the development of feedback loops.

Testing and Iteration. The design process in extreme environments is cyclical and iterative. Architectural solutions are repeatedly verified through simulations, testing, mock-ups, and research conducted in analog environments. Architecture functions here as a testing tool, enabling system integration and evaluation of their performance under conditions similar to target environments.

Resource Limitation. Space and extreme environments are characterised by a lack of access to resources and limited possibilities for their replenishment. Architectural design in this domain focuses on the creation of self-sufficient systems, closed-loop cycles of matter and energy, minimisation of material consumption, and maximum use of local environmental conditions.

Adaptation and Survival. Architecture must support long-term human functioning under conditions of isolation, hazard, and limited contact with the natural environment. This domain includes issues related to habitability, ergonomics, spatial use, sensory perception, and psychological well-being. It emphasises that elements previously considered secondary (aesthetics, lighting, colour, contact with vegetation) have key importance for user safety and operational efficiency.

These domains form a system of interdependencies, as each influences the others, generating a dynamic design process. Their presence and characteristics affect design decisions, the selection of appropriate methods, strategies, and approaches.

3.2. Empirical Experience

An important complement to theoretical analyses and literature studies are the author's own experiences gained through research, design, and experimental activities conducted in the context of space architecture and extreme environments. The author participated in simulated space missions, research projects, and design workshops carried out at the Faculty of Architecture of the Silesian University of Technology and in cooperation with the analog space habitat Lunares Research Station, addressing issues of habitability, spatial organisation, privacy, ergonomics, and psychosocial well-being in confined environments.

These experiences were complemented by conceptual work on space and extreme habitats (including Lunae Abyssis, APA Mission MARS), participation in research on bioregenerative systems (Space Volcanic Algae), and participation in the PANDA

analog space mission⁸. An additional source of observations was students' research projects conducted within the SIRIUS (2022), HESTIA I (2023), and PEGASUS (2024) missions, carried out with reference to the concept of supportive design.

The author's own experiences constituted the empirical context of the dissertation and supported the interpretation of literature analyses, case studies, and syntheses conducted in the development of ARF factors and the SSRL scale; however, they did not independently determine the results of the dissertation.

3.3. Case Study

The case study includes selected architectural facilities operating in space, analog, and terrestrial environments, selected due to the presence of environmental constraints, isolation, and an increased level of operational autonomy (ICE environments). The analysis aims to identify recurring design issues and strategies for their resolution, forming the basis for further synthesis and conclusions.

- Polar environments are represented by the Halley VI and FMARS facilities, operating under extreme climatic and logistical conditions.
- Desert environments include analog Martian habitats, MDRS – Mars Desert Research Station and D-MARS, used for research on isolation and operational autonomy.
- Underwater environments are analysed through the Tektite and Aquarius Reef Base projects, enabling research on long-term human habitation in closed environmental systems.
- The microgravity environment (LEO – Low Earth Orbit) includes the analysis of Skylab and the International Space Station (ISS) as real orbital habitats.

⁸ Fross, K., Orzechowski, L., Dziaduła, W., & Mintus, A. (2022). *The Panda Space Program in the LunAres habitat - research on needs and behavior during isolation*. w B. Komar, K. Fross, & B. Urbanowicz (Redaktorzy), *Multifaceted research in architecture*. Vol. 2, Architecture against the challenges of the future – smart architecture (s. 22–33). Wydawnictwo Politechniki Śląskiej, 22-33.

- The lunar environment is analysed through conceptual projects such as Moon Village.
- The Martian environment is represented by the Martian Habitat (NASA 3D Printed Habitat Challenge), a conceptual design of a Martian base.

Each analysed facility represents a response to a different set of environmental, technological, and operational conditions resulting from both the nature of the environment and the mission objectives and duration.

The comparison of case studies confirms that there is no single universal architectural or technological solution ensuring complete self-sufficiency. None of the analysed facilities achieves full environmental, technological, and logistical autonomy simultaneously. The functioning of habitats - even under the most extreme space conditions - is based on partial closed-loop systems that reduce dependence on external supply but do not eliminate it, particularly in relation to water, air, and energy cycles. Self-sufficiency, therefore, does not appear as an absolute goal but as a gradable variable dependent on the configuration of design, operational, and environmental factors. At the same time, the analysed projects confirm the existence of recurring design mechanisms independent of scale and level of implementation. Architecture in extreme environments operates as an integrated safety system combining spatial, technological, and operational solutions to protect life and ensure stable conditions for human functioning. Of key importance are the integration of technical systems with spatial organisation, strategies of closed resource cycles and the use of local resources, as well as modularity and flexibility enabling adaptation to changing operational conditions.

The analysis of case studies also revealed the significant role of habitability issues. Spatial organisation, functional division, level of privacy, and strategies supporting users' psychological well-being have a direct impact on the long-term and safe functioning of habitats under conditions of isolation.

Based on the conducted analyses, it was assumed that for the purposes of comparison and the development of a universal self-sufficiency scale, it is essential to move beyond

the description of individual technologies toward the identification of overarching architectural strategies and capabilities resulting from the main challenges of design in extreme environments. The Design Challenges and Design Factors identified in the analysis were subjected to a process of synthesis and generalisation, leading to the identification of characteristics describing the ability of architecture to respond to changing environmental conditions, resource limitations, and user needs.

4. The Results

4.1. ARF Factors

Based on the conducted analyses, a set of Architectural Resilience Factors (ARF) was developed as a tool for evaluating the ability of architecture to function in a self-sufficient manner. ARF factors describe key properties of the built environment that determine its resilience, safety, and adaptability. It should be emphasised that the proposed Architectural Resilience Factors (ARF) do not refer to specific technical solutions or technologies. They focus on architectural objectives and capabilities. Each identified ARF factor includes a set of sub-factors (sub-ARF), which specify its scope and enable operational analysis of architecture in different environmental contexts. The implementation of individual ARF factors may vary and depend on specific design conditions such as environmental context, facility scale, function, duration of use, and resource availability. ARF, therefore, constitutes an analytical framework enabling the evaluation of architecture independently of applied technical means.

As a result, seven ARF factors were identified, representing the main categories of architectural capabilities:

ARF 1. *Resource autonomy and metabolism.* This factor concerns the ability of architecture to independently obtain, process, store, and recirculate basic resources necessary to sustain life and facility operation under conditions of isolation.

ARF 2. *Atmospheric and internal environment stability.* This factor concerns the ability of architecture to maintain physical conditions enabling safe and long-term human presence in a closed environment.

ARF 3. *System resilience and safety.* It refers to the ability of architecture to maintain operational continuity in conditions of failure, disturbances, and unforeseen situations without immediate loss of user safety.

ARF 4. *Structural, constructional, and material adaptability.* The ability of architectural structures to adjust their form, construction, and materials to changing environmental, logistical, and operational conditions.

ARF 5. *Spatial and functional organisation.* The ability to provide a clear, logical, and flexible spatial layout supporting efficient operational functioning.

ARF 6. *Psychosocial well-being.* The ability to support the long-term psychological and social stability of users.

ARF 7. *Operational autonomy.* The ability of architecture to function operationally under conditions of limited or delayed external support.

A comparative analysis of sub-ARF was conducted using heatmaps, enabling the transition from qualitative description to the hierarchy of their impact on architectural self-sufficiency. The analysis was based on three criteria corresponding to successive levels of built environment stability: survival, operability, and well-being. The results revealed transition points in the significance of individual factors, demonstrating that as the environment develops, the dominant set of requirements changes from factors critical for survival, through operational stability, to aspects related to user well-being. This analysis enabled the description of self-sufficiency as a gradual process rather than

a final state and formed the basis for the development of the Architectural Self-Sufficiency Scale.

4.2. Self-Sufficiency Scale

For the dissertation, an original definition of architectural self-sufficiency was adopted [Fig. 5], understood as the ability of the built environment to support long-term human functioning based on the integration of technological, spatial, and psychosocial solutions, enabling stable relationships between humans, the interior of the facility, and the external environment under limited external support. Based on the results of the ARF factor analysis, an original Self-Sufficiency Readiness Level (SSRL) scale was developed. The scale has a descriptive and qualitative character rather than a computational one and defines self-sufficiency as a gradual process rather than a final state. Its structure reflects the discontinuous transition between successive states of facility operation and changing relationships between architecture, resources, environment, and users.

Subsequent levels of the SSRL scale describe an increasing degree of integration of environmental, technical, and user-related processes. At lower levels, architecture functions mainly as a recipient of resources and a stabiliser of basic operational conditions. Intermediate levels include partial regeneration, local environmental regulation, and system integration. At the highest levels, architecture operates as an integrated, adaptive, and self-regulating system capable of long-term functioning under conditions of isolation while simultaneously supporting users' psychosocial well-being.



Fig. 5. The SSRL scale illustrates qualitative thresholds of architectural self-sufficiency, from infrastructure-dependent buildings to fully self-sufficient habitats (author’s elaboration, 2025).

An important assumption of the SSRL scale is its non-normative character. The scale does not indicate a universal “target” level of self-sufficiency but constitutes an analytical, design, and scenario-based tool enabling the comparison of facilities of different scales, functions, and locations, as well as the assessment of the transfer of solutions developed in space architecture to terrestrial applications. The primary value of the scale lies in the identification of qualitative thresholds between successive stages of architectural maturity rather than the maximisation of individual technical parameters. The SSRL scale was verified through a pilot qualitative comparative analysis of selected architectural facilities operating in different functional contexts.

4.3. Interpretation of the SSRL Scale in the Context of Sustainable Development

The Self-Sufficiency Readiness Level (SSRL) scale aligns with systemic approaches to sustainable development by enabling the evaluation of architecture through the functioning of the built environment rather than solely through individual technical

solutions. In this perspective, sustainable development is understood not only as the reduction of negative environmental impact but primarily as the ability of architecture to function in a stable and long-term manner under changing resource, environmental, and social constraints. The SSRL scale links the concept of sustainability with levels of autonomy, resilience, and system integration, moving beyond the binary distinction between “sustainable” and “unsustainable” solutions.

The application of the scale enables analysis of architectural impact on the three pillars of sustainable development-environmental, economic, and social-in a gradual and context-based manner. As SSRL levels increase, architecture transitions from limiting negative impacts, through partial regeneration and environmental stabilisation, to functioning as an element of a local ecosystem; simultaneously, its capacity to reduce costs, limit operational risks, and support users’ psychosocial well-being increases. The SSRL scale, therefore, constitutes an analytical tool complementing classical approaches to sustainable development, enabling structured transfer of solutions developed in space architecture to terrestrial architecture, with particular emphasis on system resilience, adaptability, and long-term quality of the living environment.

5. Discussion

The developed Self-Sufficiency Readiness Level (SSRL) scale was defined as a tool referring to the level of a single architectural facility, enabling precise analysis of relationships between architecture, resources, and users. At the same time, this constitutes one of the main limitations of the scale, as architecture functions as part of broader spatial, infrastructural, and social systems. Applying the SSRL scale to levels higher than a building would require significant modification and the inclusion of factors characteristic of the urban scale, such as infrastructure networks, resource logistics, and collective management mechanisms.

The application of the scale in this dissertation had a pilot character and was based on qualitative analysis of a limited set of case studies, which excludes statistical validation.

The scale was used as an interpretative framework appropriate to the exploratory nature of research on architecture in extreme environments. Its further development could include testing across a wider range of typologies and at different stages of a facility's life cycle; however, this exceeds the scope of the present dissertation.

One of the key conclusions resulting from the application of the SSRL scale is that not every building must or should aim for high levels of self-sufficiency. In many contexts, especially urban ones, intermediate levels may be optimal, increasing facility resilience and efficiency while simultaneously utilising existing infrastructural systems. The SSRL scale enables conscious adjustment of the level of self-sufficiency to the function, context, and expected duration of facility use.

The analysis also demonstrated that as the level of autonomy increases, the complexity of technical and organisational systems, as well as investment costs and operational requirements, also increases. For this reason, the highest levels of the SSRL scale are primarily realistic in extreme environments, or critical infrastructure, where autonomy constitutes a condition of safety and operational continuity.

The SSRL scale was defined at the building level, however its internal logic reveals a gradual transition from perceiving architecture as an object to understanding it as part of a system and subsequently as a living environment. In this sense, the scale may constitute a starting point for further research on self-sufficiency in larger spatial structures, both in the context of terrestrial architecture and future space environments.

6. Conclusions and Summary

The conclusions formulated in the dissertation directly address the research problem and objectives, as well as the relationships identified through the analysis of space architecture, ICE (Isolated, Confined, Extreme) environments, and selected case studies. In addition to findings related to architectural self-sufficiency and the possibility of its evaluation using ARF factors and the SSRL scale, the research enabled broader reflections on the role of architecture, the relationship between buildings and infrastructure, and the evolving role of the architect in the face of future challenges.

Architectural self-sufficiency as a strategy for resilience and safety

Contemporary architecture primarily operates within a model dependent on external infrastructural systems. However, current forecasts indicate that resource security is not a permanent condition. According to reports by the Intergovernmental Panel on Climate Change, intensifying extreme phenomena, disruptions in access to water and energy, and increasing migration pressures will significantly influence the functioning of the built environment. Architectural self-sufficiency, therefore, constitutes a strategy for preparing buildings to operate under crisis conditions, such as natural disasters or infrastructural disruptions. Its significance is particularly evident in facilities requiring operational continuity, including civil shelters, civil protection infrastructure, and critical infrastructure, where the ability of buildings to operate autonomously, even temporarily, directly determines user safety. The conducted analysis allows for the identification of the concept of *safety architecture*, in which self-sufficiency becomes a fundamental condition for protection and operational continuity.

Scaling needs as a condition for rational self-sufficiency.

The study demonstrates that architectural self-sufficiency should be understood as a gradual and scenario-based response - different operational contexts, from stable urban environments to crisis-prone and extreme environments, require different levels of systemic autonomy. The SSRL scale enables the conscious adjustment of self-sufficiency levels to specific threats and functional requirements, preventing both excessive technological overdevelopment and insufficient preparedness for future challenges.

Architecture as an adaptive system

The findings derived from the ARF and SSRL analyses demonstrate that architectural self-sufficiency cannot be reduced to a set of technical solutions. In extreme environments, architecture functions as an adaptive system regulating relationships between humans and their environment through spatial organisation, resource management, and stabilisation of psychosocial conditions. Factors such as spatial legibility, privacy control, lighting, and sensory stimuli are shown to be critical for long-term system stability and user well-being.

Contribution to architectural theory

A significant contribution of the dissertation is the development of the SSRL scale as a conceptual framework that organises the notion of self-sufficiency through qualitative thresholds rather than quantitative simplification. The scale enables comparative analysis of buildings of different functions and scales and provides a foundation for further research into self-sufficiency beyond the building scale. The work contributes to the development of qualitative research methodologies in architecture and urban studies.

Contribution to design practice

The research confirms that solutions developed within space architecture can be selectively implemented in terrestrial architecture as elements enhancing resilience and efficiency without requiring full autonomy. These include additive manufacturing technologies, closed-loop water and energy systems, local food production, resource monitoring systems, and spatial strategies supporting user well-being. The SSRL scale proves particularly valuable in the design of critical infrastructure and architecture prepared for crisis scenarios.

The evolving role of the architect

The analysis of extreme environments highlights the need to redefine the architect's role as a designer of integrated living environments rather than solely spatial forms. Designing under resource constraints requires systems thinking, integration of environmental, technological, and psychosocial processes, and conscious risk management. Lessons from space architecture demonstrate that architecture increasingly functions as a life-supporting environment, and designing self-sufficient structures requires designing relationships between form, function, and system metabolism.

Summary and original contribution

The dissertation demonstrates that the level of architectural self-sufficiency in extreme environments is determined by a complex configuration of environmental, technological, and social factors rather than individual design solutions. Key determinants include the degree of external and internal environmental extremity, resource availability and potential for local acquisition and recovery, the autonomy and

serviceability of technical systems, and human factors such as user numbers, duration and purpose of occupancy, and habitability understood as the ability of the environment to sustain long-term human functioning in isolation.

The analysis of space architecture, ICE environments, and case studies confirms that experience gained from space missions and analog habitats constitutes an important source of knowledge transferable to terrestrial architecture. This transfer includes design strategies, technologies, and spatial organisation methods that enhance resilience and the operational capacity of the built environment under conditions of limited resources and increased risk. The principal original contribution of the dissertation is the identification of Architectural Resilience Factors (ARF) and the development of the Self-Sufficiency Readiness Level (SSRL) scale, enabling a multidimensional qualitative assessment of architectural self-sufficiency in environmental, technological, and psychosocial dimensions. Within the scale framework, an original, comprehensive definition of architectural self-sufficiency was also developed, integrating technological, spatial, and social solutions.

The research demonstrates that architectural self-sufficiency should be understood as a gradual and scenario-based characteristic adapted to risk scale, operational duration, and contextual conditions rather than as an absolute objective. The dissertation contributes to the discipline of Architecture and Urban Planning by introducing an analytical tool supporting research on resilient architecture and by identifying pathways for transferring knowledge from space architecture to the sustainable development of terrestrial built environments.

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