Designing in Microgravity: Digital Living Lab as an Enabler of Knowledge and Innovation through Extreme Design.

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Abstract
The paper explores how designers can operate within a highly complex sector such as Space by adopting extreme design strategies. In this context, designers take on an advanced role, open to collaborative innovation models, and can accelerate their learning processes through the integration of methodological and digital tools. The aim is to put creativity at the service of a field characterised by strong regulatory constraints, especially in the design phase, while promoting the cross-fertilisation of highly specialised technical knowledge and design-driven practices to explore new design solutions.
The result of this research, developed as part of the "Beyond the Space Life" and conducted by the Department of Architecture of the University of Bologna in collaboration with Thales Alenia Space Italia, is the Space Digital Living Lab: a physical-digital space designed to facilitate both the entry of future designers into the Space sector and to enhance synergies between experts in the field and other entities/professionals outside this field, increasing innovative capability and sustainability. Here we take a closer look at one of the four tools that make up the model: the Design Innovation Research-Action Lab, its most tangible dimension, where interdisciplinary teams iterate possible concepts for future product systems for space habitats in rapid cycles of exploration, prototyping and reflection.

Keywords
Extreme Design
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FRAMING THE EXTREME: MEANINGS AND CHALLENGES

Every design process involves engaging with constraints, users, and environmental contexts, anticipating reactions, testing solutions, and progressively adapting the project on the basis of observational data. Various iterative approaches based on field research, analysis of user practices, and contextual studies have consolidated methodologies, models, and processes aimed at generating design solutions attentive to user needs and environmental conditions. However, not all design scenarios allow these principles to be applied directly.

Increasingly, designers are confronted with situations that can be defined as *extreme*.

According to the NASA Astrobiology Institute, the term "extreme" is relative [1]. As described by Wingfield, Kelley, and Angelier (2011), there is no universally shared definition of what constitutes extreme conditions. Indeed, "extreme" does not refer exclusively to geographical or environmental contexts - such as space missions, polar stations, deserts, ocean depths, or humanitarian emergencies and natural disasters - but rather identifies a design condition characterized by exceptional constraints, where physical, social, technological, and temporal variables appear radically altered compared to ordinary operations. As Bannova (2016) notes, its definition should therefore be expanded to encompass all aspects of human life, including social, cultural, economic, and political events that, for example, do not guarantee life support, communications, or sustenance.

The extreme, therefore, is not merely a *where* but also a *how*: it implies working with scarce resources, minimal margins for error, compressed timelines, and often high pressure. It also introduces a crucial psychological dimension: those who design (and those who inhabit) these contexts are subject to prolonged stress, continuous uncertainty, isolation, or cognitive overload (Manzey & Lorenz, 1998), factors that affect decision-making processes and the effectiveness of design solutions.

Designing for the extreme thus means confronting limiting conditions that test not only the technical functionality of a project but also its capacity to support, orient, and accompany the human experience in destabilizing contexts. In this sense, the extreme serves as an advanced testing ground for contemporary design, prompting a rethinking not only of *what* is designed, but *how*, *for whom*, and *under what conditions*.

These conditions are defined by Suedfeld and Mocellin (1987) as extreme and unusual (EUE), also entail significant methodological implications: in extreme environments, many established design practices, from in-situ observation to iterative prototyping, become difficult to implement or require substantial adaptation.

In such contexts, designers must replace direct observation with alternative strategies for data collection and the construction of plausible scenarios. Throughout the design process, from field analysis to the development of user-informed solutions and prototype testing, the methodologies employed are complex to apply. This generates the need to define an approach that supports design in extreme conditions and facilitates the transfer of interdisciplinary knowledge.

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[1] https://astrobiology.nasa.gov/nai/media/medialibrary/2015/01/AB-Poster-ScienceBackgroundText.pdf

Designing for extreme environments and conditions thus entails addressing resource limitations, isolation, hostile physical or climatic conditions, and the impossibility of immediate external intervention. Yet it can also take on a strategic role, becoming not only an adaptive response but an anticipatory device and a laboratory for radical innovation (Bannova, 2021).
Within this field of investigation, a rapidly expanding sector in which the European Community is also poised to invest (European Commission, 2025) is life beyond Earth, a new and significant arena of innovation and competitiveness for the economic as well as cultural prosperity of nations. Living, working, and interacting within Space stations and habitats confronts designers with one of the most constrained and extreme contexts imaginable, where the prolonged presence of humans demands environmental configurations capable of ensuring safety, efficiency, and psychophysical sustainability under both normal and emergency conditions. The absence of gravity, confinement, limited resources, and the impossibility of external intervention call for a rethinking of environments, products, and interfaces, particularly with a view toward future users and crews who will inhabit and share these environments ((Le Roy et al., 2023; Häuplik-Meusburger & Bishop, 2021). As highlighted not only in the literature but also in current international policies, an increasing number of private companies and diverse organizations will be able to access this sector, reimagining the purposes of exploration as not only public but also commercial in nature, and proposing new models of cooperation among various actors toward a *New Space Economy* (Dominoni, 2021; Van de Wiele, Giglio & Lecomte, 2025).
In this emerging context, the concept of extreme gains is relevant not only in relation to humans but also to the environment itself. On one hand, as future crews are likely to be less trained to endure such hostile conditions, the environments they inhabit will need to be more attentive to psychological needs and promote inclusive and responsible practices to mitigate environmental stress, foster relational balance, and support the experiential dimension of living in extreme conditions. On the other hand, the relationship between the environment and the user must encourage sustainable design strategies.
Moreover, this and other extreme contexts necessitate replacing empirical verification with the construction of plausible scenarios, deductions based on operational analogies, and the integration of heterogeneous knowledge and digital simulation tools. The variability and instability of these environments require design responses capable of adapting not only to objective constraints but also to relational and behavioral dynamics that are only partially predictable.
Against this backdrop emerges the project *Beyond the Space Life. Digital Living Lab for Human Life in Space*, developed in collaboration between the University of Bologna (UNIBO), as lead partner, and Thales Alenia Space Italia. The research is part of Spoke 1 of the PNRR PE11 – MICS (Made in Italy Circolare and Sostenibile) program and aims to develop innovative tools and approaches for analyzing, simulating, and supporting human life in space environments, fostering the design of sustainable, human-centered solutions that view the extreme as a Space for innovation both beyond and on Earth.
How can design support more adaptive and customized design processes, capable of responding not only to basic needs but also to human wellbeing requirements in extraordinary contexts and conditions?
This project focuses on a specific research area within this project and its initial outcomes. In particular, it seeks to demonstrate how designers, within

highly complex and hostile design processes (Vaccino et al., 2025), can take on an advanced role: no longer merely mediators between needs and solutions (Celaschi, 2008), but facilitators of complex decision-making processes, capable of integrating specialized knowledge and managing the production of design scenarios in the absence of direct experimental validation (Succini et al., 2024). This requires tools able to simulate use conditions, collect data, and preliminarily verify hypotheses through alternative detection and validation systems (Mohanty et al., 2006), as well as to propose open innovation processes during the ideation phase in a sector that is inherently rigid due to stringent regulations dictated by the high risks faced by individuals in these environments (Succini, 2025).
The Space Digital Living Lab represents the outcome of this approach: a physical-digital space designed to facilitate the entry of future designers into this domain and accelerate synergy and cross-fertilisation between the Space sector and other fields, promoting creativity and competitiveness in a sustainable perspective. This contribution explores one of the four tools that make up the model: the Design Innovation Research-Action Lab, the most tangible dimension of the Space Digital Living Lab. It examines how open innovation models guided by extreme design strategies, collaborative processes, and cross-disciplinary exchanges can contribute to building new skills for designers, enabling them to tackle the increasingly uncertain challenges of the future.

THE EXTREME AS A DESIGN CONDITION: APPROACHES, PARADIGMS AND PRACTICES FOR INNOVATION IN UNCERTAIN FUTURES

In recent decades, design has increasingly confronted contexts that are more complex, uncertain, and unpredictable, which - as previously defined - are extreme due to the limiting conditions they impose on physical, social, environmental, and technological levels. While extreme contexts restrict the application of conventional methods, they simultaneously foster original and adaptable solutions. The need to respond to exceptional conditions generates configurations of high flexibility and potential transferability, capable of anticipating future needs and positively influencing less critical domains. Crisis and the extreme thus become generative elements of innovation (Balch et al., 2020).
Faced with such challenges, design operates beyond the everyday, renegotiating objectives, tools, and purposes. This evolution marks a transition from a discipline aimed at solving ordinary problems - characterized by stability, predictability, and resource availability - to a design practice that acts under conditions of uncertainty, resource scarcity, environmental stress, and accelerated change (Boehnert et al., 2022). In these scenarios, design is called upon to prefigure and imagine forms of adaptation, to build transformative capacities, and to mediate between technologies, bodies, and environments in constant transition (Raviselvam, 2021). In this sense, design in extreme scenarios takes on a role closer to strategy and anticipation, rather than emergency response (Ferronato, 2017).
To better understand how design tackles the extreme, several methodological approaches can be grouped according to their temporal orientation and primary design goal, enabling a clearer comparison of their scope and limits. Among these, *ex post* approaches respond to emergencies or catastrophic events. *Design for survival* (Papanek, 1971) operates after catastrophic events

(Massoni, 2020), developing essential, often low-tech solutions that guarantee human survival in precarious contexts, such as mobile shelters, water purification systems, or first aid kits. In parallel, *design for emergency* (De Angelis, 2024, Rawsthorn & Antonelli, 2022) intervenes predominantly during crises, implementing rapid, flexible, and deployable strategies to manage sudden events, focusing on logistics, communication, and resource coordination.

Preventive and long-term approaches such as *design for resilience* (Disconzi & Saurin, 2022; Hukerikar & Engelmann, 2017) work Before critical events, enhancing the adaptive capacity of systems and communities. These approaches aim to reduce vulnerabilities and improve responses to future shocks, acting on infrastructures, organizations, and collective learning. *Speculative design* (Dunne & Raby, 2013) and *design fiction* (Sterling, 2013) construct plausible futures to test social, ethical, and cultural implications of emerging technologies. Conversely, *critical design* (Bardzell & Bardzell, 2013) questions existing systems and highlights contradictions, acting across all temporal phases but with primarily discursive and reflective goal.

In parallel, in the architectural and engineering fields, *design for/in extreme environments* has emerged. The main challenge of this methodology lies, on one hand, in addressing architecture for isolated, confined, and extreme (ICE) environments that meet both the physical and psychological needs of inhabitants as well as the technical and performance requirements of structures in contexts such as deserts, Arctic regions, or orbital Space (Dominoni, 2023; Meusburger & Bishop, 2021; Bassingthwaighte, 2017, Van Ellen et al., 2023); and, on the other hand, in architecture capable of addressing other extreme conditions that are beginning to characterize various locations on Earth, such as climate change, which brings with it new territorial configurations and constraints (Saprykina, 2019).

These approaches contribute valuable perspectives; however, each focuses predominantly on one dimension (survival, immediate crisis response, long-term adaptation, or discursive provocation) providing a partial ability to act within highly regulated and uncertain technological domains such as Space. Alongside these approaches, more recent theoretical and operational reflections are emerging that attempt to synthesize or transcend more traditional categories. Among these is *translational design* (Drolet & Lorenzi, 2011; Hornbuckle & Page, 2024), which proposes a design model capable of translating knowledge across different domains (scientific, social, technical, experiential) and between seemingly distant contexts. Another is *Responsible Advanced Design (RAD)* (Succini et al., 2024), which, thanks to the intersection of the features of Advanced Design - including anticipation, open innovation, collective intelligence, and interdisciplinarity - and those of Responsible Innovation - including inclusion, ethics, and transparency - seeks to anticipate change by responding to challenges through continuous innovation activated by collaborative processes and projected toward possible, probable, and potential futures.

Specifically, the innovation direction of the design process in Advanced Design (Celi, 2015; Celaschi et al., 2019), guided by the space-time factor is defined as *extreme design* (Celaschi, 2016), where the concept of the extreme is adopted as a project condition from which to extract original constraints and highly performative solutions, exploring new technologies, methods of efficiency, and attention to human and environmental well-being, transferring stimuli and design solutions between very different sectors.

The notion of *Extreme Design*, as understood within *Responsible Advanced Design*, is an ambivalent concept that does not merely involve designing in extreme contexts but also transferring innovation from one sector to another, in a continuous evolutionary process shaped by constraints and boundary conditions, activating innovative design processes in radically unstable scenarios and pushing design beyond its traditional boundaries.
Roaf et al. (2019, p. 808) also discuss "Extreme Design," arguing that it is difficult to approach this design mode without intertwining design visions aligned with these hostile conditions with adaptation strategies.
When comparing these approaches in relation to the challenges/constraints/needs of design in space habitats, it emerges that Responsible Advanced Design is the approach most transferable to this field of research.
From this perspective, *Extreme Design,* represents a way of approaching the design process capable of accelerating responsible and advanced innovation in design.
It is demonstrated not only theoretically but also in practice that the concept of *Extreme Design* applied within the project takes shape as a design strategy that enables designers to act responsibly and interdisciplinarity in conditions of uncertainty, scarcity, complexity, and accelerated change. It is not the extreme condition itself that defines extreme design, but the quality of the design response: the way in which a challenge is interpreted, processes are organized, resources are activated, and unconventional solutions are envisioned. It is an approach expressed in the ability to transform extraordinary constraints into design levers.
This strategy, applied to this extreme context, requires the creation of new synergies between disciplines and industrial, social and cultural sectors, but also new relationships between observation, design, development and project verification practices. The Space digital living lab becomes the application model.

EXTREME DESIGN AS AN ENABLER OF THE SPACE DIGITAL LIVING LAB

The Space Digital Living Lab, one of the main objectives of the project 'Beyond the Space Life. Digital Living Lab for Human Life in Space', is a conceptual and applicative model designed to offer, through the integration of digital and physical actions, a set of knowledge and tools complementary to those already available in the sector. Its added value lies above all in their level of integration and adaptability: the resources are in fact accessible within a platform and can be used by different types of designers (novices, experts, etc.), and are useful in the early stages of a project, when it is possible to propose product and experience innovations.
The objectives of the Space Digital Living Lab are therefore:

- to operate as an open, interdisciplinary design laboratory to collect data and validate solutions for microgravity environments, integrating expertise from other sectors.
- to act as an advanced anticipation device, capable of constructing plausible and future-oriented scenarios to design innovative and flexible solutions through the cross-pollination of heterogeneous scientific knowledge;

- to learn to design the first concepts of space habitats by integrating socio-cultural and wellbeing factors for future crews into standard guidelines;
- to observe the environment using advanced technologies to help designers better understand what it means to design for microgravity and to improve the flexibility of spaces based on human factors.

The Space Digital Living Lab is articulated into four interconnected operational areas that, together, feed an iterative design ecosystem oriented toward experimentation. Each area plays a specific yet complementary role, contributing to knowledge building, solution validation, and the activation of cross-cutting competencies essential for designing in the extreme.

1. **Extreme Observatory** is a curatorial and analytical platform that collects and systematizes a selection of case studies from past space missions, aiming to highlight the most advanced solutions adopted to date in technological, ergonomic, and psychological domains. Alongside these references, the observatory includes design examples (products-services-experiences) drawn from other terrestrial extreme contexts that provide useful and transferable analogies for Space design. Through comparative and interdisciplinary analysis of these projects, the Extreme Observatory provides a solid and stimulating knowledge base, helping designers bridge the gap between everyday experience and the extreme scenarios of space habitation, offering concrete inspiration and strategic guidance for subsequent phases of the design process.
2. **Adaptive Configurator** is a design space dedicated to generating spatial layouts capable of responding to the physical, psychological and relational needs of crews who will live and work in extreme environments. The configurator allows modular configurations to be built in which elements are organised according to the affinities between activities and functions, taking into account both the specificities of the mission and the composition of the teams, as well as parameters related to the social and emotional sphere, in addition to the regulatory and normative inputs that characterise the Space sector.
3. **Virtual Experience**, made possible using a headset, takes place within Thales Alenia Space's Space Home virtual environment, where designers can explore and evaluate interactions between bodies, objects and spaces by simulating microgravity conditions. This phase aims to provide an understanding of the perceptual impacts and intrinsic values of the proof of concepts and modules developed through the various experimentation activities. It also allows users to view the metadata of these products, arrange them in space, and take notes. The metadata linked to the modules created by the Configurator can also be viewed.
4. **Design Innovation Action-Research Lab** represents the tangible experimentation of the Space Digital Living Lab, where interdisciplinary teams iterate solutions through rapid cycles of exploration, prototyping, and reflection. In the future, the area may integrate data from the observatory and possible layouts generated by the configurator, and results from immersive simulations, providing a fertile environment for collective knowledge building. Here, many of the design competencies related to Extreme Design are directly developed and activated, such as

anticipatory, reflective, and inclusive thinking; creative adaptation; management of uncertainty; operational flexibility; immersive empathy; interdisciplinary collaboration; and systemic vision.

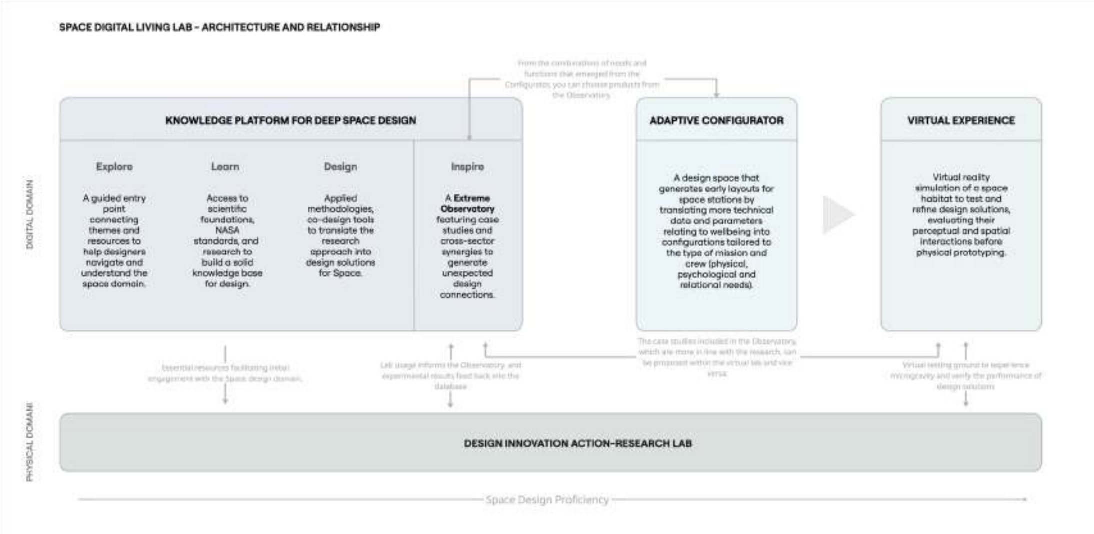

Fig. 1
Summary diagram of the Space Digital Living Lab

The dynamic interaction among these four areas **Fig. 1** makes the Space Digital Living Lab an advanced design device, capable of generating solutions for orbital Space but also of transforming design itself into an adaptive, reflective, and interconnected process potentially applicable to other contexts and extreme conditions in the future. In this system, the project evolves from a linear sequence to a continuous learning environment, where the extreme becomes an opportunity to test the most advanced competencies of contemporary design.

EXTREME DESIGN IN ACTION: FROM THEORETICAL FRAMEWORKS TO PROTOTYPING HUMAN LIFE IN SPACE

The **Design Innovation Action-Research Lab** is a cross-cutting tool that, since the beginning of the project, has made it possible to address critical issues in the context and apply theoretical concepts related to Extreme Design, which forms the basis of the Space Digital Living Lab, to practical actions. Similarly, it is here that the other digital tools (described above) have been tested and validated and combined with the various practices and actions used within the Research-Action Lab.
The experience that best embodies this data is *Extreme Design: Designing the Circular and Sustainable Relationship between Humans and Extreme Spaces*. The aim of the initiative was to explore, together with a diverse group, contexts capable of challenging human performance, imagining strategies to reduce environmental impacts on humans (and vice versa), generating new relationships between environment and people, and how to respond to unexpected bodily changes and unexpected sensory changes.
Thanks to the creative and innovative capacity of 60 young designers, the contribution of 5 expert researchers from techno-humanistic fields, and the know-how of 4 companies (one operating within the relevant sector and three active in contexts far removed from extreme environments), it was possible to activate a particularly fertile process of research, dialogue, and design

development. The encounter of heterogeneous knowledge and cross-sector contamination fostered unexpected stimuli, accelerated idea development, and surfaced innovative design solutions, even for problems distant from the original focus of the research.
As anticipated in previous sections, designing systems and environments for extreme contexts such as space requires a multidisciplinary, human-factor-oriented approach capable of integrating technology, comfort, and psychophysical well-being. To meet these needs, industrial actors with complementary expertise were involved:

- Thales Alenia Space Italia, a leader in the aerospace sector and a partner in the research line, provided technological expertise and specific knowledge in designing solutions for Space exploration, defining the constraints and opportunities of the context.
- 3F-Filippi, with its experience in Human-Centric Lighting, enabled exploration of lighting strategies that support biological rhythms and psychological well-being in environments lacking natural light.
- Galletti, specialized in environmental comfort, offered adaptive and customizable climate-control solutions crucial for maintaining optimal living and working conditions.
- Phononic Vibes, a young start-up focused on metamaterials research, contributed technologies for noise and vibration control.

Over the four months of joint work, strategies typical of Extreme Design were adopted, fostering the development of advanced and responsible competencies throughout the design process. From the initial definition of challenges and contexts to be explored, the process unfolded through modes of observation and needs analysis, examination of relationships among different users, and the design of tools and processes (ensuring active stakeholder involvement), culminating in conceptual solution development and prototyping.
In the first phase of context analysis and knowledge building, anticipatory, reflective, and inclusive thinking was cultivated through the use of typical design tools capable of fostering dialogue among diverse knowledge domains

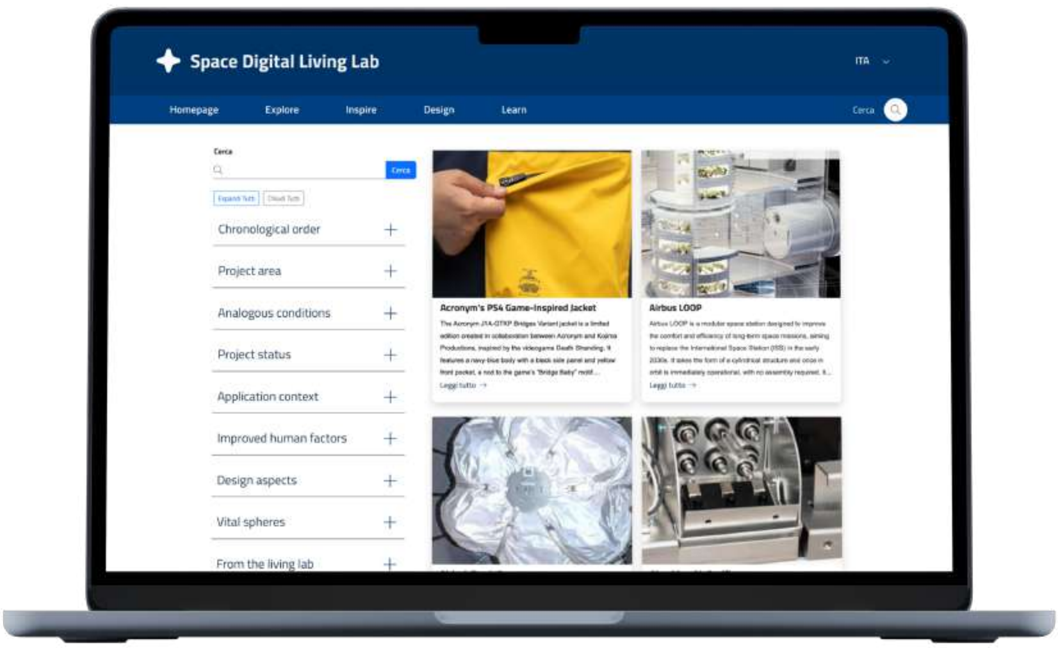

Fig. 2
View of the case studies within the Extreme Observatory

and stimulating a systemic approach. Peer-to-peer co-design activities were conducted, in which the creativity and ideation skills of young designers intersected with the technical and research expertise of companies and the research team. In parallel, simulative observation practices were tested in digital environments (game-based experiences) aimed at developing spatial awareness under simulated microgravity conditions.
A central role was played by the custom-designed tool already mentioned the Extreme Observatory **Fig. 2**. Accessible and continuously updatable, the Observatory fostered a shared and open mindset, facilitating collaborative problem construction and deconstruction for future challenges. It also served as an effective activator of multisectoral knowledge, contributing to the development of a systemic vision of the challenges to be addressed and transcending disciplinary and sectoral boundaries.
Subsequently, participants were organized into 12 work teams and assigned extreme contexts (related to microgravity, but also extreme cold, deep darkness, extreme heat, and minimal spaces) has enabled us to broaden our vision.
This design opening helped teams understand how cross-cutting competencies, such as design resilience and the ability to face unpredictability, are key to creatively traversing and recombining disciplinary, cultural, and material boundaries, transforming design constraints into generative levers for innovation.
On this basis, projects such as Elis Gilia, and Nott were developed, each interpreting the challenges of microgravity in different ways, anticipating future needs and emphasizing the human dimension in the relationship with space and technology:

- Elis **Fig. 3** is an advanced first-aid system for cardiac emergencies in microgravity, designed to ensure patient stabilization and facilitate care through continuous vital-sign monitoring and an adaptive inflatable structure capable of molding to the body. It also improves routine monitoring moments, enabling future users to experience this activity in a relaxed and comfortable way. The project addresses the need to anticipate emergencies while prioritizing the psychophysical well-being of both patient and operator, not only in critical moments but also during routine checkups. This ensures flexibility and adaptability of the designed product systems.
- Gilia **Fig. 4** offers a reflection on food-sharing and ritual in space habitats. Starting from the idea of recreating a technological hearth, it envisions a concept in which a tabletop integrates lighting, sound, and air purification systems. The project transposes Earth's relational and ritual dynamics into hostile environments, reinforcing crew belonging and cohesion.
- Nott **Fig. 5** proposes a design dedicated to regeneration, intimacy, and sensory comfort during rest. It is a new crew-quarter system conceived to both improve astronauts' sleep quality and foster more personal relationships among crew members. The module features layered sound-absorbing materials to enhance acoustic insulation, an expanded internal volume allowing for stretching movements, and storage space for personal items accessible from both inside and outside. Moreover, the arrangement of the four sleeping pods is designed to facilitate social interaction and group cohesion, even during transitions between sleep and wakefulness.

Fig. 3
Elis. Designer: Samuele Patti, Nicholas Petrucci, Samuele Priano, Federico Redaelli with Advanced Design Unit, Department of Architecture, University of Bologna. Companies: Thales Alenia Space Italia with Lucia Grizzaffi and Elia Sindoni, 3F-

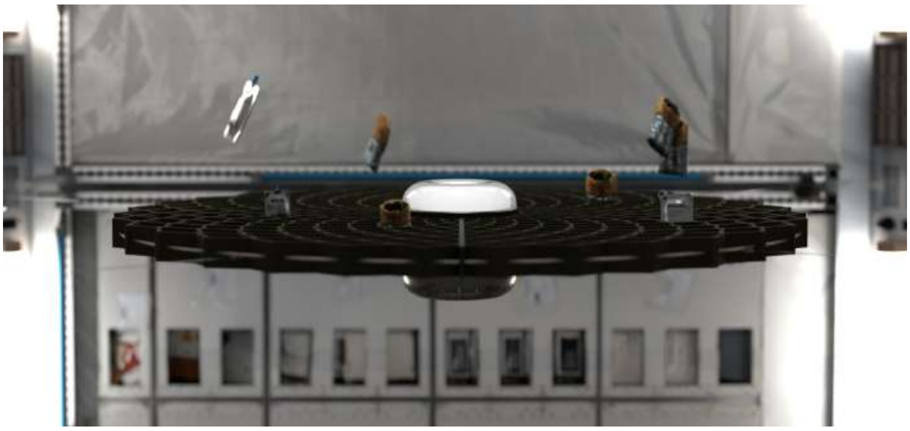

Fig. 4
Gilia. Designer: Giulia Bastoni, Raffaele Montemurro, Veronica Pasini, Luca Barbieri, Edoardo Govoni, Filippo Murotti, Irene Maria Caterina Ponteduro, Giorgia Valentini in collaboration with Advanced Design Unit. Companies: 3F-Filippi S.p.A., Galletti S.p.A.,

Fig. 5
Nott. Designer: Raffaele Montemurro, Veronica Pasini, Sara Mattei, Niccolò Maggiorani, Samuele Frassineti in collaboration with Advanced Design Unit. Company: Thales Alenia Space Italia with Lucia Grizzaffi and Elia Sindoni

The product systems have been integrated into the Space Home virtual environment, where their relationship with space, flexibility of use, and modes of interaction with the designer have been analysed. These systems will also be included in the Observatory in the section dedicated to projects focused on crew wellbeing. The aim is to understand how the Space Digital Living Lab model, thanks to the integration of its tools, can facilitate the initial stages of design and accelerate innovation.

DISCUSSION

The experiment conducted within the Design Innovation Action-Research Lab demonstrated the effectiveness of the Space Digital Living Lab model and how important it is, in such a complex design process to integrate various practices and tools in the initial stages of learning and ideation.
The advanced design approach and extreme design strategies applied to the Action-Research Lab highlighted how integrating unpredictable factors into the design process, cultivating systemic vision, fostering cooperative attitudes, and developing sensitivity toward the human dimension are key competencies for approaching extreme contexts with responsibility and creativity.
A crucial element for designers was the use of a curated databases of case studies (Observatory) which has activated a deeper and more situated understanding of design constraints and fostered critical thinking. For both the research team (ADU and Thales Alenia Space Italia) and the young designers, it was important to employ virtual simulation systems to visualize these same product–systems within a space habitat, to understand the relationships they establish with the environment and other elements present, and be able to view data relating to the human factors associated with them. This experience, as a whole, strengthened, across the entire design community, the ability to think and design starting from the body not only in its physical dimension but also its emotional aspects.
Moreover, close collaboration with companies allowed dialogue between experimental innovation and concrete application, enriching both the professional paths of the designers and researchers involved and the capacity of enterprises to explore new design horizons through an advanced design approach.
In this sense, the projects developed can become an exploratory tools, implementing strategies and practices capable of generating cultural and methodological change in this field.
This first experimentation of **Action-Research Lab** also revealed several challenges, mainly due to the complexity of contexts, the diversity of actors involved, and the need to go beyond the known to understand how constraints can become levers for innovation. The main challenges identified are:

- Temporal and cultural misalignment between companies and young designers. A period of mutual knowledge is necessary to build a relationship of trust that promotes synergy and the generation of innovative ideas.
- Immediate difficulty in transferring concepts to business logics. The proofs of concept developed were conceived from a standpoint of radical exploration. Many of the conceptualized solutions are difficult to implement in the short term, as they envision problems and scenarios that are future-oriented and distant.

- Tension between speculative vision and project concreteness. The anticipatory and immersive approach – VR, observatory, future scenarios – proved extremely useful for generating new ideas but still requires further experimentation within design dynamics involving actors with heterogeneous knowledge and skills.
- Difficulty in simulating cultural, emotional, and sensory variables related to extreme scenarios. This can limit the depth of design empathy and lead to misjudgment of certain parameters.

CONCLUSION

The research project currently under development, thanks to the experiments carried out and the observation of criticalities that emerged both within the activity just described and in other actions undertaken, is implementing its initiatives across the various dimensions that characterize the Space Digital Living Lab.
The experience described and the evolution of certain projects – such as Gilia and Nott, which have entered further prototyping stages – demonstrate how the application of strategies for Extreme Design in highly complex contexts or conditions activates a form of generative knowledge. From these experiences emerges a collaborative and transversal expertise capable of transforming stringent constraints into original design opportunities for non-terrestrial contexts. Within this framework, design functions as a *cognitive agent* capable of anticipating, exploring, and enabling radical futures.
Both these two prototypes and the other concepts developed will become a catalogue of advanced design-centric product concepts, capable of providing the market in this sector with new opportunities for partnerships and design approaches, while also serving as a virtuous example and starting point for future designers.
The Space Digital Living Lab can become a place of transition between Earth and Space, between real and possible, where the design practice of Extreme Design, experimented in extraterrestrial contexts, also enables new forms of innovation for terrestrial applications.
Today, the research is coming to an end, in a moment of transition from experimentation to feasibility, or rather in a stage of interaction between these phases, which will continue to iterate between each other both in this final part of the research project and beyond.
The model also has a number of limitations related to maintaining this hybrid space over time and its accessibility. Together with the research team, we are evaluating how some more complex tools, such as the Configurator, can be made available to a wider audience, and how to bring the immersive experience to life even for those who do not have the appropriate tools.

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