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Space Habitats and Habitability

Designing for Isolated and Confined Environments on Earth and in Space

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Foreword

When I was a young boy, and my mother wanted to get the truth from me, she would capture my attention and say; "Tell me what *really* happened."

This book is like that: It captures your attention, and lets you look long and honestly at what's happening as we gain experience for projected long-term living in space. It surveys the many earth-bound "analogue" studies done, and summarizes the on-orbit experience to date, including the former Soviet Salyut and Mir, the US Skylab, and current International Space Stations. Across all of these, the lessons are clear: We can keep space crews alive and working productively in the confines of space craft, but we have not yet learned how to give them a *home away from home.* Living in space has been until now a high-tech camping trip at best. As we extend stays on the Moon and possibly Mars, it is going to have to become something different, and more. Habitats will have to become supportive and nurturing homes for their inhabitants.

The authors are well suited to make this case: One is a Social Psychologist with decades of experience in the Extreme Environments field. The other is a Space Architect with the keen sense of how Design plays a crucial role in how crews of Isolated and Confined Environments experience and perform throughout their stays. Together, they show through the interviews they've collected that while we've got the engineering right for the most part, we are just beginning to appreciate the social psychology involved, and we as yet have to acknowledge effects of the *habitat design*.

Hopefully, their book will help change all that. It is really something that every spacecraft engineer and planner should read: This is what is actually happening to the people we are sending aloft. It is a testament to their bravery and fortitude that they have performed as well and consistently as they have. But it has not been because of the design of what they lived in, but mostly in spite of it. And the communications protocols, the command structures, the crew selection procedures have not helped all that much either, and have occasionally proved almost disastrous. But crews find workarounds, and endure, and occasionally rebel. But they do not *thrive*. And that is what they will have to do if we envision years or more far away from Earth.

It is tempting to think that all of this is a question of improved technology: Give them more video games, higher fidelity communications, a space “smartphone,” perhaps. But it’s not. It’s about how they live and interact every day, and how the environmental design of the habitat supports all of that. And what this book brings clearly home is that we haven’t begun to think about how good that could be. We’ve taken the “bargain basement” approach instead, thinking that if we get the physics and the basic physiology supported, all will be well. But it won’t be, and this book shows why.

Reading it is in some ways like sitting down in a quiet “Bier Stube” with all of those former crewmembers of all the analogue bases and previous space stations and asking them: “Tell me what really happened.” Then listening very closely, because through the pages of this book, they will tell you.

Richland, WA, USA James A. Wise

Preface

Objective of the Book

Human factors and habitability are important topics for working and living spaces. For space exploration, they are vital for mission success. Human factors and certain habitability issues have been integrated into the design process of human operated spacecraft; however, there is a crucial need to move from mere survivability to factors that support thriving. 'Habitability' and human factors will become even more important determinants for the design of future non-commercial and commercial spacecraft and extraterrestrial habitats as larger and more diverse groups occupy off-earth habitats for longer periods of time. The '*risk of an incompatible vehicle or habitat design*' (NASA [HSIA], 2020)[1] has been identified by NASA as a recognized key risk to human health and performance in space.

This book provides an overview of the historic advancements of human operated spacecraft, as well as highlighting various current and future concepts of *habitability* and their translation into design. The main goal of this book is to promote a dialogue between the diverse concepts of *habitability* and their socio-spatial and psychological dimensions. Selected dimensions are reviewed from multiple backgrounds, and possible design and architectural related applications are illustrated and discussed. The authors explore various concepts of the term *habitability* from the perspectives of the inhabitants as well as the planners and social sciences and highlight common features and differences. A major focus of this book is to explore and hopefully stimulate creative solutions to the unique challenges inherent in crafting livable spaces in extraterrestrial environments, fostering a constructive dialogue between the researchers and planners of future inhabited spacecraft and extraterrestrial habitats.

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[1]NASA [HSIA], 2020. Risk of Adverse Outcome Due to Inadequate Human Systems Integration Architecture, published 07/30/20. https://humanresearchroadmap.nasa.gov/risks

The book will benefit individuals and organizations responsible for human operated space missions. It also provides insights of interest to researchers of social sciences, psychology, engineering, architecture, and design.

The focus of this book is on the issue of designing living spaces for extreme environments and, particularly, extraterrestrial environments. Its findings address the basic socio-spatial relationships as they are applicable to other extreme environments and even for compact urban living on Earth. In addition, it unveils the authors' experiences of the relationship between habitable space and the environment and thus relates back to Earth and our very normal daily life.

How This Book Came into the World

> Psychologists and architects are natural allies, joined by their search to support people in their varied endeavors[2] (Harrison 2009, p. 890).

The authors share a common passion on the relationship between space and humans, and have approached their research from different angles. While Sheryl has always been hunting for the answer to the question of '*what constitutes the "best" fit person to live happily in extraterrestrial environments*', Sandra has been chasing after '*what constitutes the space to live happily in (extraterrestrial) environments*'. This book is a real synergetic achievement towards designing living spaces for space environments, and this chapter tells you how it started.

Sandra Häuplik-Meusburger and Sheryl Bishop have known each other for many years through their work. They first met in person at a conference in Glasgow in 2008. A bit later they started to collaborate on research projects and publications. And during a lunch in Vienna in 2017, collaboration for a book project was set into motion. Before the authors talk about their collaborative work on this project, read the individual stories of Sandra and Sheryl.

Sheryl's Story

I can remember the sense of relief I felt when I discovered Bertalanffy's *General System Theory* (1968)[3] in college which defined a system as a complex of interacting elements, open to, and interacting with, their environment, acquiring qualitatively new properties through emergence and continually evolving. Bertalanffy considered general system theory a 'general science of wholeness'. In an era where

[2]Harrison, A. A. (2010). Humanizing outer space: architecture, habitability, and behavioural health. *Acta Astronautica 66*(5–6), 890–896.

[3]Bertalanffy, L. (1968). General System Theory: Foundations, Development, Applications. New York: George Braziller.

reductionism and specialization was king, I thought '*Finally, something that fits me*'. In his advocacy of interdisciplinary inclusiveness, I found permission to pursue a career as a 'generalist' instead of following the trend of professional specialization. As a social psychologist, I was free to pursue all aspects of human development across the entire lifespan and range across the vast spectrum of 'normal' (aka non-pathological) human behavior as my interests took me. It served me well as I pursued the fairly esoteric answer to 'what constitutes the 'best' fit person to live happily in extraterrestrial environments'? Answering THAT question would lead me to pursue hundreds of factors that influence wellbeing and afforded me opportunities to work with all kinds of engineers, architects, biologists, neurologists, geologists, physicians, astronomers, astrophysicists, chemists, pharmacists, and not a few of my own colleagues from the fields of psychology and psychiatry over the last 30 years.

In the mid-1980s, I had the good fortune to stumble across the work of a fellow psychologist/mathematician/environmental scientist, Jim Wise, who was proposing that including patterns in interior designs that mimicked the same kinds of patterns found in nature improved human performance and wellbeing. His work and subsequent others (e.g. Wise and Rosenberg 1986; Wise and Taylor, 2002)[4] suggested that we could craft human habitats that were automatically functionally beneficial and supportive in addition to providing shelter and ensuring survival. Coupled with the myriad evidence for the beneficial effects of including 'natural' elements (aka plants, trees, water features) in the 'built environment' from other sources, there was an explosion of interest and research on incorporating nature, eventually called biophilic design, into every aspect of human habitation. And, thus, my research into how to ensure optimal adaptation and functioning for small groups situated in extreme environments such as those our future space explorers would face intersected with the world of architecture and interior design. Because *where* we live affects *how* we live.

The early attempts to explore how incorporating natural elements affected individual and group dynamics were met with large indifference from the primarily engineering-oriented research community associated with space. Humans were viewed as those irritatingly inconsistent and unpredictable 'users' that repeatedly went 'off-nominal' with virtually everything involved in a spacecraft. They demanded windows to look out of when there was no functional need for windows, cues for 'up' and 'down' in a microgravity environment that could take advantage of 360° of surface and unconsciously circumvented surfaces used for eating instead of taking the more efficient path of floating over them. There were irreconcilable cultural differences over the types of hygiene facilities desired (showers versus saunas) and water treatment (iodine versus biocidal silver) that resulted in duplicated

[4]Wise, J. A. & Rosenberg, E. 1986. *The effects of interior treatments on performance stress in three types of mental tasks*. Technical Report, Space Human Factors Office, NASA-ARC, Sunnyvale CA.; Wise, J. A., Taylor, R. P. (2002). Fractal design strategies for enhancement of knowledge work environments. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting, 46*(9), 854-858.

systems (water treatment) and initially minimal bathing facilities (washcloths) for the International Space Station. Proposals to add such unessential aesthetics such as color, textiles, or textures much less actually introduce living plants were enough to put architects and environmental/social psychologists on the 'do-not-invite' list for space project planners. But we simply would not go away. As my circle of architect colleagues expanded and I was blessed with opportunities to work with individuals like my co-author, the need to move to 'thriving not just surviving' became undeniable and eventually was incorporated into NASA's Human Research Roadmap. As with all paradigm shifts, rhetoric eventually leads to action. All I can say is that it was about time!

Sandra's Story

I love the combination of science and fiction, in that it includes a vision of where we want to go and a possible path to reach it. I have always wanted to know how things work and how they are connected. When I started to study architecture, I became even more intrigued by the interrelations between space and humans. I had always felt that built space influences human behavior and now I was about to look behind the mechanics of this 'human-space system'.

I enjoyed lessons on how material properties can change user behavior and that the actual physical surroundings are related to certain human behavior. Humans read space; they connect physical appearance to function, to social behavior. Without having to think about it we (in the Western hemisphere) 'know' how to behave in a church, in a dwelling area, or at a playground. No signs are necessary. This close relationship between *built space* and *lived space* slowly became unveiled and I started to translate those experiences into real architecture. My first designed and built space was a fashion shop in Vienna for one of my best friends. It was a tiny space, and had to function as a tailor's workshop, a showroom, as well as an event location. I designed every single piece of interior, from the lamp to the stowage space, and we choose the materials very carefully. The interior concept followed the idea of a catwalk and became a multipurpose yet minimalistic space. Today in 2020, my friend is one of the top Austrian designers and the shop interior still fits the changing garments and activities. Retrospectively, I also realized that in order to create a real sustainable space, it is of huge importance to identify (which is a most complex and sensitive task) and integrate the client's requirements and identity into the design process from the very beginning.

Later, for my dissertation I chose to research the relationship between humans and 'space' (the social and physical space they live in) in an extreme environment. The idea was that in an *extreme environment* (see Chap. 1), where inhabitants cannot exist without a built environment, where they heavily rely on 'what is there', and where they 'cannot go outside to take a breath of fresh air', I would discover something new.

I was blessed to have Richard Horden, former professor in Architecture and Product Design at the Technical University of Munich[5] and the creator of the term 'micro architecture',[6] as my dissertation mentor. He was a wonderful person to talk with and I still have great appreciation for his way of looking at the world. He had a minimalistic approach to architecture, in that the 'space in-between' was more important for him than the structure. He wanted to only 'touch the Earth lightly' with his projects. In addition, he introduced me to the world of product and industrial design.

My PhD resulted in a comparison and analysis of all inhabited human spacecraft and space stations in relation to human activities that later turned into the book *Architecture for Astronauts*.[7] I evaluated those extraterrestrial habitats from a human activity point of view: The Apollo Spacecraft and Lunar Module, the Space Shuttle Orbiter, and the Space Stations Salyut, Skylab, Mir, as well as the International Space Station. To facilitate orientation and to ease comparison with architectural drawings and diagrams, each category was assigned a specific color. Design directions for each category concluded each chapter. Next to an overview of the architecture and configuration concerning the interior layout and a comparison of the spatial and time allocation of human activities, the main part of the book concentrated on the investigation of the relationship between the environment and its users. At that time, it was the first compendium that included comparable information of all inhabited spacecraft from an architectural and user point of view. For that, I have to thank the many astronauts and cosmonauts that I personally spoke to. Their unique input became very valuable, even trailblazing, and often contradicted some official views and revealed something new.

The search for '*what constitutes the space to live happily in (extraterrestrial) environments*' is continuing, and I am grateful to integrate my research with my work as an architect, on Earth as off Earth.

Towards a Habitability for Humanity

This book is a real synergetic achievement towards designing living spaces for extraterrestrial environments, and this chapter tells you how it started. It started with the idea of writing a compendium on space habitability from the human point of

[5]Fusing high-tech engineering with industrial-design methods, he and his research students in Munich have created an innovative range of revolutionary buildings in a broad variety of settings. From the Ski Haus (delivered to the Alps by helicopter and used by mountaineering and rescue teams) and Antarctic living modules to the Micro Compact home, a fully self-contained pre-fab home that fits into a 2.65 m^2 cube, these structures are designed for their adaptability to our changing planet, lifestyles, and basic human needs.

[6]See the book: Micro Architecture: Lightweight, Mobile and Ecological Buildings for the Future by Richard Horden, 2008, Thames & Hudson.

[7]Häuplik-Meusburger, S. (2011). *Architecture for Astronauts – An Activity based Approach.* Springer Praxis Books, Vienna.

view, and became elaborated, queried, and adapted with many discussions in both personal and online meetings.

In the middle of the book process we decided to do a habitability survey and integrate it into a new chapter. The work process was intensive as we really worked in an interdisciplinary way. The questionnaire was developed together, discussing all the questions. The list of possible participants was gleaned from both of our extensive networks of acquaintances, friends, colleagues, collaborators, and all their contacts. Distributed by word of mouth and through emails and social media, we received responses from around the world from those that had spent time in isolated, confined environments both here on Earth and aloft. The scope of the response was an amazing testament to how interconnected we all are: dozens of professions, ages that ranged from 29 to 72, and participants from 15 different countries. Each gave us the benefit of their experience. It took our interdisciplinary collaboration to new heights. Instead of just two of us, we became many with their willingness to share. That set the tone of the entire book. We strove to elaborate on almost everything with personal quotes from others. Instead of confining ourselves to a preplanned outline, we followed the flow of emergent issues. We did not cover everything there is to cover . . . the book would have been five times longer. We may not have even covered all the really important things. As you will see, what is important frequently differs. But we hope that we have covered *enough* to excite discussion and further exploration among the worldwide community.

Vienna, Austria — Sandra Häuplik-Meusburger
Santa Fe, TX — Sheryl Bishop

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[8]The list is not complete as some of the interviewees preferred to answer anonymously.

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Special acknowledgement goes to James Wise and Georgi Petrov for their thorough review of the final manuscript.

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Contents

About the Authors

Sandra Häuplik-Meusburger PhD, is an architect and researcher specializing in compact habitability design solutions for extreme environments. She teaches at the Institute for Architecture and Design at the Vienna University of Technology and is appointed academic director of the course Space at the Science Academy in Lower Austria. Sandra uses cross-program comparison and analysis of inhabited isolated, confined, and extreme environments (ICEs) on Earth and space from a human perspective as a basis for the systematic assessment of existing and future living and working environments. She is corresponding member of the International Academy of Astronautics (IAA) and Vice-chair of the Space Architecture Technical Committee (SATC) of the American Institute of Aeronautics and Astronautics. Sandra has published several scientific papers and is author of the books *Architecture for Astronauts* (Springer, 2011) and *Space Architecture Education for Engineers and Architects* (Springer, 2016).

Sheryl Bishop PhD, is a social psychologist and behavioral scientist who has applied her skills widely over her career. A Professor Emeritus at the University of Texas Medical Branch, she has taught in all four schools, Medicine, Nursing, Health Sciences, and the Graduate School of Biomedical Sciences as well as served as faculty for the International Space University, Strasbourg, France. As an internationally recognized behavioral researcher in extreme environments, for the last 35 years Dr. Bishop has investigated human performance and group dynamics in teams in extreme, unusual environments, involving deep cavers, mountain climbers, desert survival groups, polar expeditioners, Antarctic winter-over groups, and various simulations of isolated, confined environments for space, including a number of missions at remote habitats. She has routinely presented her research at numerous scientific conferences, has over 60 publications (including contribution to NASA's Historical Series on Psychology in Space), and over 50 scholarly presentations in both the medical and psychological fields. She is frequently sought out as a content expert by various media and has participated in several television documentaries on space and extreme environments by Discovery Channel, BBC, and 60 Minutes.

Chapter 1
Introduction

This chapter outlines why an extraterrestrial environment can be considered an Extreme Environment (EE) and how extreme environments entail demands that cannot be ignored or underestimated. Habitability considerations for such conditions are vastly impacted. A discussion of how the general envelope of human factors and habitability are affected by the unique characteristics of Isolated and Confined Extreme Environments (ICEs) is presented with an emphasis on the costs of not including habitability as a critical design component. Basic assumptions, the selection of examples used throughout the book and sources of information are identified.

1.1 The Unforgiving Environment

When we talk about the environment of 'outer space' or **extraterrestrial environments**, we refer to a natural environment that is beyond Earth or not from Earth. According to our current knowledge there is no extraterrestrial environment that is naturally livable for human beings as they lack critical resources (e.g., breathable air, water) or involve hostile environmental challenges (e.g., microgravity, high radiation). As such extraterrestrial environments are categorized as **extreme environments (EE)**.

Any environment can be described through their environmental or physical variables, such as temperature, lighting and specific characteristics, and also through their psychological and social variables. Psychologist Peter Suedfeld describes *extreme (or unusual) environments* in contrast to 'normal environments' along two dimensions: (1) degree of extremeness and (2) unusualness (Kring 2008, p. 212; Suedfeld and Mocellin 1987). As such, an extraterrestrial environment would be considered one of the most extreme environments with a high degree of extremeness (physical dangers and discomfort) and a high degree of unusualness as contrasted to a normal environment. Psychologists Manzey and Lorenz (1997) defined EEs as

S. Häuplik-Meusburger, S. Bishop, *Space Habitats and Habitability*, Space and Society, https://doi.org/10.1007/978-3-030-69740-2_1

"*settings for which humans are not naturally suited and which demand complex processes of psychological and physiological adaptation*".

EEs are commonly referred to as *settings that possess* ***extraordinary (extreme and unusual) physical, psychological, social (or interpersonal), and technological demands*** *that require significant human adaptation for survival and performance* (Suedfeld and Mocellin 1987; Manzey and Lorenz 1998; Kring 2008) (see Box 1.1).

Box 1.1 Extreme Environments: Definition

Jason Kring (Kring 2008, p. 212) has summarized the findings on EEs as follows:

First, extreme environments possess extraordinary and unique features in three key areas:

– Physical characteristics of the environment,
– Interpersonal and social dynamic of individuals and groups living and working together in the environment,
– Psychological variables that influence how an individual responds to the environment.

Second, EEs require significant human adaptation in order for people to live and work in a manner that supports physical and psychological health, promotes successful task performance, and protects individuals from injury (Kring 2008, p. 212).

The social, psychological and also spatial significance of living in an extraterrestrial environment has become more explicitly characterized by a further refinement of the term to incorporate the extraordinary isolation and confinement found in all extreme environments. Such environments are those in which "*physical parameters [. . .] are [. . .] outside the optimal range for human survival [. . .] and which conditions [. . .] deviate seriously from the accustomed milieu of most [and further] involve physical remoteness [. . .] and a circumscribed spatial range*" (Suedfeld and Steel 2000, p. 228).

Human challenges of ICEs include: prolonged isolation and confinement, a hostile natural environment with limited mobility outside the habitat, high autonomy of the crew and habitat, life in a 'microsociety'[1] (and often in a multi-cultural setting), and a high probability of under-stimulation and boredom on long-duration missions, etc. Such conditions place demands not only on the type of persons who would be 'best fit' to inhabit such environments but also on the living spaces that must be crafted to support human habitation in such environments. Next to extraterrestrial habitats, polar and underwater habitats are examples of this building typology.

[1]A small, self-contained community or milieu governed by its own conventions, rules, etc.

Table 1.1 Physical and social factors that have been reported to cause stress (Evans et al. 1988, p. 4; Connors et al. 1985; Cohen and Häuplik-Meusburger 2015)

Physical stressors associated with ICEs	Social and Psychological stressors associated with ICEs
Changes in pressure Extreme temperatures Unusual environmental hazards (meteorites, radiation, etc.) Physical threat to life in exterior environment Loss or alteration of time markers/ Zeitgeber Irregular or unnatural light cycles Noise and vibrations Limited available space Short focal distance stressed near-sightedness Poor ventilation Sterile and monotonous surroundings Restricted diet	Isolation and confinement The feeling of being crowded The feeling of loneliness and separation from one's normal social group Reduction of privacy The necessity of forced interaction with a small group of people Dependence on a limited community Disconnection from the natural world No separation of work and social life No family life Repetitive and often meaningless tasks Limited habitability (limited hygiene, sleep facilities, isolation from support systems)

One of the critical characteristics for living and working in those environments—and thus mission success—is the dependency on the habitat, its technological capability as well as the sociospatial framing. Inhabitants, who are exposed to remote and hostile environments, not only must overcome the challenges posed by the dangers and limitations imposed by the particular environment itself, but also experience significant distress from being confined indoors and isolated from civilization and social contact. Table 1.1 lists a selection of physical and social factors that can become stressors for the inhabitants.

All of these factors and their associated stress responses must be taken into consideration when designing livable space or habitats for ICE environments. Yet, historically, such habitats have lacked all but the merest attention to such details with a focus primarily on surviving rather than thriving. This is changing and the built environment is slowly becoming an important factor to ensure both physical and psychological wellbeing.

1.2 Defining Habitability

"*Early spacecraft had been designed to be operated, not lived in*" (Compton and Benson 1983, p. 130). Mercury[2] astronauts did not climb into the spacecraft, they put it on. At that time, spacecraft design was primarily functional. After the first space

[2]Project Mercury was the first human spaceflight program of the United States and ran from 1958 to 1963.

missions, when NASA and the Soviets were advancing their goals for long duration missions to prove that humans could live and work in space for extended periods, the habitable design of the interior became increasingly important.

In 1963 Reed and White started their paper with the question "*What does habitability mean?*" (Reed and White 1963). Interestingly, their examination of the meaning directly led to the discussion of the interplaying factors "*related to the man, **his** machine, **his** environment and the mission*". Kubis (1967, p. 399) stated a few years later that habitability "*depends upon the purpose of man's presence within that environment, the time he plans to remain, and the type of performance he expects to achieve*". Psychologist Dr. James Wise defined **spatial habitability** as: "*Spatial habitability refers to the ways in which the volume and geometry of livable space affects human performance, wellbeing and behaviour*" (Wise 1988, p. 6).

Today, the term, **habitability,** is understood to be an umbrella term that describes the suitability and value of a built habitat for its inhabitants in a specific environment (cf. Häuplik-Meusburger 2011). It is a complex system related to the individual as well as society in relation to the (built) environment. Figure 1.1 highlights the interrelating factors between the inhabitant(s) and the lived-in environment.

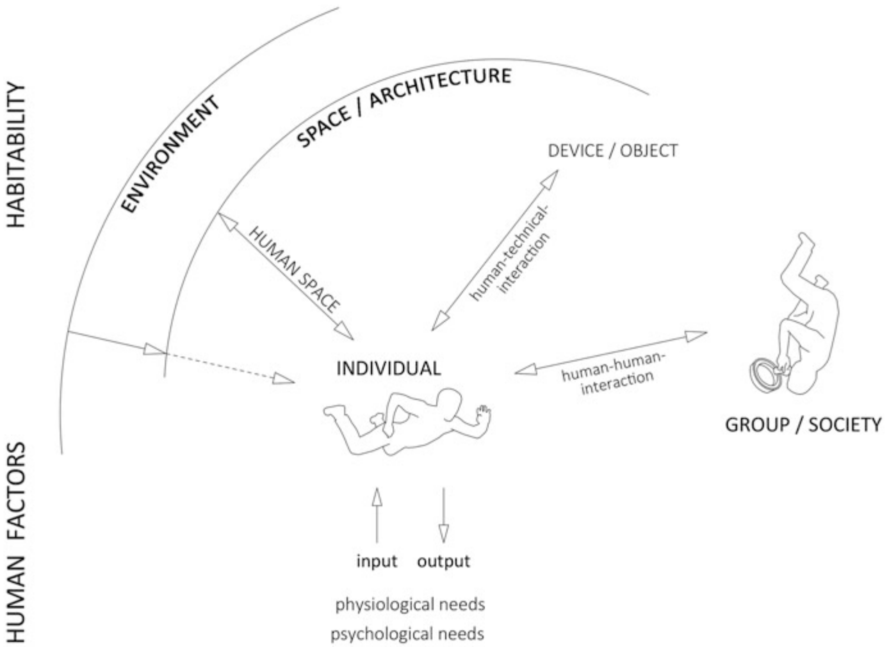

Fig. 1.1 The Habitability system—Diagram showing the interrelating factors between the inhabitant as an individual or group with its built and natural environment. (credit: Häuplik-Meusburger)

1.2.1 Elements of Habitability

Components of the system (Fig. 1.1) include:

The **Setting**: The physical environment in which human operated missions take place is life-threating and physically, psychologically and socially demanding. The longer the mission lasts the more strenuous it is psychologically for the individual crewmember, as well as for the whole crew. In addition, longer missions place more sophisticated technological demands on the habitat and associated technology and systems. Subcomponents include conditions of the actual environment, mission length, tasks, type of habitat, and others.

The **Individual**: So far individuals for space missions come from a small spectrum of our society. They have been carefully selected based upon specific characteristics, based on either select-out (physical and/or psychological disabilities) or select-in criteria (knowledge, experience, personality, etc.). Subcomponents include physical and psychological condition, behavioral health, experience, and others.

The **Group or (Micro)society**: In extraterrestrial habitats a small group of people are living together in a relatively small space. This is often referred to as a micro-society. Isolated from the normal social matrix on Earth, social relationships often become more intense and, thus, can produce interpersonal challenges for the whole group. Subcomponents include: crew composition, selection, gender, culture, and others.

The **Time**: The length of the mission affects every component—the individual, the whole group—as well as the habitat and technical facilities. Subcomponents include: mission length, changes during the mission, and scheduling.

1.3 The Cost of (Not Including) Habitability

How much does it cost to include habitability into the design process? And how much will it cost NOT to include habitability into the design process?

In the 1963 Manned Space Laboratory Conference, Celentano, Morelli and Freeman emphasized the importance of habitability with an excerpt on 'Habitability problems aboard Navy vessels' from 1891. "*The physical condition of the men, when it comes to action or to conditions of war, is of greater moment than the ... extra knots ... for which we are asked to sacrifice so much*". Later in the same paper the author reminded us that "***each generation of designers**, in their zeal for getting the most with the least, and packing the greatest into the smallest (or lightest), **frequently forgets the essential factors of habitability and needs to be reminded***" (Celentano et al. 1963).

Support and evidence for the need of integrating habitability can be found in every decade. Thomas M. Fraser suggested "*that habitability can be considered as that equilibrium state, resulting from **man-machine-environment-mission***

interactions *which permits man to maintain physiological homeostasis, adequate performance, and psycho-social integrity*" (Fraser 1968, p. V). Later Harrison (2010, p. 891) pointed out the relation between the benefits and costs. He stated that environmental stressors "*magnify risk, undermine performance, and raise the human cost of occupancy*". For him, it is clear that "*by minimizing environmental stressors*" habitability "*serves the interests of behavioral health*". Embedded into the discussion on human factors, habitability is a major factor in the design of any inhabited environment, including its facilities. However, in extraterrestrial and isolated and confined environments, habitability is critical for the physical and psychological wellbeing of the inhabitants as well as mission success. In extraterrestrial environments and most of the environments characterized as ICEs, the basic requirements of human existence can only be secured by an additional technical envelope, such as the habitat or a space suit. Isolated from the Earth, astronauts must live for long durations within a small and confined environment, completely dependent on mechanical and chemical life support systems. This building type must be subject to careful design, planning and construction that incorporate both elements for surviving as well as those for thriving.

Habitability design integration is an important aspect when planning long-duration missions. To date, given historical missions missions of short duration, it was seen as 'nice to have' but it becomes vital when mission length increases. As stated by Frances Mount (Mount 2002, p. 87): "*The impact of a poorly designed switch or lack of stowage area is different for a mission of six months compared to a mission of one week.*"

The research into effective habitat design for human health and wellbeing in isolated, confined and extreme environments is still nascent and distributed across multiple disciplines. The recent intersection of several critical lines of research are beginning to frame multiple intriguing new approaches to implementing environmental design in ways that integrate 'place and use demands' as deliberative elements fostering restoration, wholeness and maximizes adaptation and response through evolutionarily honed cognitive processes. Paired with the power of new technological tools for delivering levels of realism that are increasingly difficult to distinguish from 'reality', habitation has expanded beyond the mere physical space we occupy into the perceived space around us. We hope this book will take that discussion and exploration beyond what has been addressed before into those brave new worlds of possibilities ahead of us.

1.4 Basic Assumptions

There are a number of basic assumptions related to future extraterrestrial missions that underlie the areas dealt with in this book. These assumptions will be discussed in detail in the different chapters of the book, but it is worthwhile to mention them now as an orientation to the rest of the book.

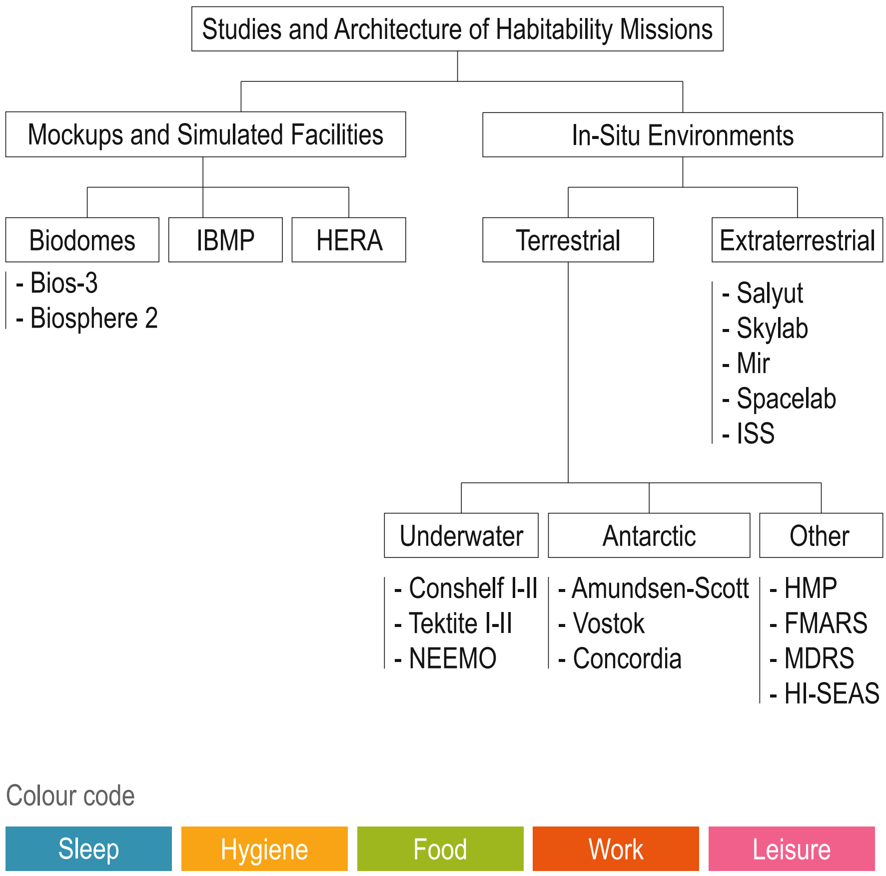

Fig. 1.2 Overview of habitability studies and relevant habitats that are introduced in Chaps. 4 and 5. A color code is used to make comparison of the plans and sections easier and comparable

Selection of examples. This book is a co-project combining the psychology of a person living in extreme environment with the socio-spatial dynamics of a group living in extreme environments. Examples are largely drawn from missions that involve living over a period of time in a habitat that serves as protection from the extreme environment (see Fig. 1.2). Expeditions, i.e., missions that involve constantly moving from one point to another with transient 'camps' along the way, are only mentioned when it is relevant to understand the context.

Sources of Information. Reports and personal experiences from inhabitants have been one of the most important sources for both authors. They are used for describing the research topic and for the definition of preliminary relevant topics. Sources include written as well as oral material from interviews by and with inhabitants of extreme environment facilities. Furthermore, a number of relevant studies from the fields of space psychology, sociology, extreme environmental medicine, as well as personal reports from analogue simulations are referenced.