Chapter 1
The Strategic Role of Design for Space

1.1 The Fascination for Space

On 20 July 1969, the whole world was facing the Moon. It seemed impossible that the Apollo 11 could bring human beings to our satellite and bring them back safely. The landing happened in the evening, I remember it because I was at the sea in Liguria, the sky was clear, and I was very curious to see the astronauts touch the lunar ground. To the *naked eye*. That’s right. I was 4 years old, and I was sure that going out in the garden and sitting comfortably in my small chair I would see them, Armstrong and Aldrin, walking and running on the surface of white iridescent dust. And there they were, I only saw shadows, but I was sure I saw them. I was very excited and very happy. Of a deep happiness that I still remember. This episode was the beginning of my attraction to the cosmos and the stars.

A long time later I realized that Space that summer had not only fascinated me, along with other children, but had contributed to the planetary explosion of the *Space Age*, a period of contemporary history born between the 1950s and 1960s parallel to the human space exploration that influenced the common imagination and directed the technological development of humanity. All the creative currents, from literature to music, from architecture to cinema and from fashion to art and design, have undergone in those years the charm of Space producing powerful icons: just think of the film *2001 A Space Odyssey*, by Stanley Kubrick (Fig. 1.1), the comic book *Barbarella* by Jean-Claude Foret, the fashion of the *Sputnik Girls* by Pierre Cardin or the design of the television *Brionvega Doney 14* by Marco Zanuso (Fig. 1.2), which looks like a helmet for astronauts. Objects with lunar shapes that interact with environments and architectures inspired by Space’s iconography, and in which characters dressed in white and silver seem to move raised from the ground, were the tangible expression and widespread optimism for the conquest of Space that brought with it great expectations of growth and development.
The Space Age also coincides with the economic boom, with the birth of the Pop Art, which celebrated irrepressible consumerism made of products dressed in attractive and redundant communication, and with the triumph of plastic over other materials, for practicality, low cost and the ease with which it allows to generate smooth, curved and aseptic surfaces like those of a spaceship: round shapes, soft and organic, replaced rigid and squared volumes of the traditional style, thanks to technological innovation (Dominoni and Quaquaro 2017a; b). From this brief excursus, it is evident that initially the Space inspiration, as far as Design is concerned, had its most powerful expression in the definition of a style innovation, through a language that used mainly shapes and colours that reflected the imaginary of the Space Age. Then, it is a technological innovation, the plastic, which determines the possibility of creating new soft and organic shapes. The style intersects with the technology and breaks the pre-constituted order: it is not necessarily the form that is decisive in the design process, even technology can suggest new forms that were not even possible to imagine in advance. Thanks to the research of designers who, in close contact with the industry, first of all in Italy the Kartell, begin to experiment with material and molds going to the limit and beyond the feasibility, the Design explores new expressive languages and gives form to new artifacts that determine a real revolution: new types of objects are added to existing ones, and many objects built with other materials are now made of plastic to the advantage of a significant reduction in costs and a greater lightness and flexibility of use. This innovation determined a wide spread of objects and democratization of Design: they increased the performance and aesthetic qualities of objects and we saw a change in lifestyles. But the most important point related to the plastic is that

**Fig. 1.1** The Fascination for Space is expressed in many creative fields as movies that have predicted some aspects of space travels: here an interior view of 2001: A Space Odyssey. Credits by Warner Bros
it was a *revolutionary innovation* pushed from a vision, and Design is a central element in every typology of innovation, but overall in this one (Dominoni 2009) that make the difference. Because Design approach is able to add a meaning value to innovations translating them in products and services which are bearers of dreams, images, expectations of more well-being. The results of the revolutionary innovation are breakthrough and *disruptive ideas* which create a scenario completely new, also modifying the existent consumers’ behaviour on Earth, and why not, in Space.

1.2 Space Design for Disruptive Ideas

This book allows me the opportunity to present the newly emerging discipline of Space Design, aimed both to enhance the research of wellness in Outer Space, increasing the comfort of the space travellers, and to generate innovation through the contamination of living in Space and living on Earth, crossing different knowledge and fields of applications, as behaviours and technologies that can be taken as inspiration by Space and translated to Earth, and vice versa, becoming spin-offs and spin-ins.

In this first chapter, I explain through experiences, projects and researches *The Strategic Role of Design in Space* introducing aspects, methodologies, principles and tools, specific of the discipline, that will be treated with more comprehensively in the following chapters. My aim is to give an idea more precise of what Design is,
what it does on Earth and what it can do for Space, and in what domain fields it can intervene, in which contexts its competences and skills are required.

Design is a discipline and a profession with a great capacity to answer to the needs of the human being, as well as those of the industry, and with the power to influence and change the behaviours of the society. As architect and designer, I believe we should design more conscious objects and environments. The objects which have more success are those able to arouse emotions and make people think, when they become a source of inspiration for people. The environments which obtain more attention are those where people are at ease and where visual and sensorial stimuli produce a sense of well-being and happiness that is imprinted in the memory through the shapes and light that express the architecture of the space.

The Design domain fields for Space appears to be very huge and variegated embracing the world of artifacts and the human beings. Space is a very stimulating world to explore for a designer who wants to deal with the new, the unknown, and who is able to imagine disruptive environments and objects, which do not belong to our daily life experience on Earth, but which could be very suitable and useful, and also beautiful, for a new generation of people who will inhabit and perform them.

Having to first deal with survival and extremely technical issues, the space industry is dominated by scientists, coming mainly from medicine and engineering, who seem do not understand the importance of the Design in increasing the well-being of the crew and, as consequence, the whole mission success.

In Industrial Design for Space (Dominoni 2002), I introduced the assumptions to create a dialogue between Industrial Design and Space Industry to demonstrate that Design could have a fundamental and strategic role for Space in designing new environments and tools that can facilitate human movements and activities, foreseeing new ways of using instruments and new gestures in relation to the extraordinary conditions, and choosing scientific and industrial partners with the specific know-how required for each project. Approaching and developing the first researches, I realized that there were necessary new tools to face a context so different and challenging as Space is, and I started creating and experimenting a new methodology specific for Space Design that I called Use and Gesture Design (UGD). This method is based on the interactions between the human being and the objects that design a new way to decode gestures, movements and postures in microgravity and in confined environments.

My intention was to convey the importance of observing people and reality, alone and in the environment in which they live, move and interact with each other and things, to design conscious objects and environments that can correspond to the character, desires and needs of each of us, on Earth and in Space. The designer is an acute interpreter who registers the world as it is, but equally capable of developing a new thought. Thanks to its ability to observe the reality that surrounds us and know-how to interpret the many signs that every day we receive from the environment, watching how people behave, move and interact with each other and interpret in absolutely unique way life experience.

Through the lens of Design, we can translate latent needs, not yet expressed by people in general, and astronauts, in particular, through their behaviours,
spontaneous gestures, and also, improper use of objects, into projects to make people feel good, in ethical products that really could help astronauts to live and work better, and which have more than one kind of utility, which it is emotional in nature, as well as functional. We must not underestimate the decisive role which has emotions in the choices that we do every day and that lead us to surround ourselves of objects charged with sense able to arouse in us pleasant memories of past experiences or reactivating atavistic memories that make us act on impulse, with the belly and not with the brain. Therefore, the skills of a designer have to include a mix of intuition and psychology, to investigate the unconscious and the most hidden parts of the human being learning how to use thinner languages that make visible those parts that are expressed through gestures. This practice brings out an increasing attention to those factors related prevalently to the emotion and psycho-perceptive sphere combined with an artistic approach based on aesthetic research that places the human being at the centre and makes use of expressive languages aimed to enhancing the poetics of the objects and the environments.

Disruptive ideas arise from the capacity of Space Design to develop an attitude to the project looking beyond the functional aspects of the products, or the innovation technologies, focusing on how products and environments can reflect lifestyles, values and aspirations.

Following the evolution of the designer figure, both researcher and professional, appears evident a constant that concerns the multidisciplinary approach to the projects, in which the formal and functional qualities of the products interact transversally with coming knowledge by engineering, human sciences, technology or economy innovation, bearing in mind the specificity that has always distinguished Design, that means the attention to people, the interest in the human factors as well as irrational and sensorial perceptions, the mental mechanisms of childhood that with time hide in the unconscious, the influence of experience on our view of the world. Considering the complexity of managing projects for Space, in another part of the same book (Dominoni 2002), I suggested the strategic importance to create cross-disciplinary teams of specialists with different competencies, together with industries with different know-how, of both Space and private sectors, able to face with different typologies of products and tools and find innovative solutions.

For the designer, accustomed to dealing with productive “terrestrial” realities, the Design Research in Space is possible only with the constant presence and participation of industries, institutions and R&D centres able to provide all the necessary information and know-how to face from time to time the design assignments. As a consequence, the group is a natural amplifier and accelerator of the creative process which serves as a collective brain, with much higher potential of the single individual brain. Therefore, the advantage resides in the characteristics of speed and richness of response to the demand for innovation (Dominoni 2009).

Cross-collaboration and interdisciplinarity are becoming more and more prominent in the last years in both academic and industrial conversations. As within western societies knowledge has been subject to fragmentation, cross-disciplinarity is considered as an attempt to overcome fragmented thinking and develop holistic modes of enquiry, decision-making and practice (Kline 1995). Indeed, it was
broadly discussed the need to cross-disciplinary boundaries in order to tackle contemporary complex problems, such as climate change (UNESCO 2015).

Having analysed in depth the group dynamics in the past, I can affirm that the context of cross-disciplinary innovation teams is particularly interesting as a slightly more open door for designers to step in the space industry. In recent years, there has been a growing evolution in the Space field, triggered by future planned human space missions, which once again propose the desire for exploration as the main engine, now driven principally by the private sector which looks at space tourism as a propellant to increase interest and budget. With a permanent settlement on the Moon and a manned landing on Mars as goals to support pioneer ambitions and efforts, a great boost is given to the research, in order to fill the gaps that still make these perspectives impracticable. Following a trend already widespread in several industrial sectors, space agencies are turning to the adoption of cross-disciplinary teams as a tool to stimulate innovation.

Design is, indeed, synonymous of innovation focused on the human needs, and by time it developed including knowledge from engineering, innovation economics and technology, in order to better interface with science as the basis for novel applications (Dominoni 2009).

Design for Space means redefining the task of industrial design in this particular context, find interlocutors and possible areas of convergence, methodological and operational tools in order to offer its expertise to space agencies and industries and contribute to solving the problems of living and working in confined environment and in microgravity conditions with innovative projects.

The design activity, even if indispensable, is not sufficient for the success of the project if it is not integrated with the participation of these other actors. Once this happens, small agile and cross-disciplinary teams are nowadays recognized as the main drivers of innovation.

From the beginning, I was convinced that the role of the designer was to build a bridge between different disciplines and knowledge to develop new products and tools to allow astronauts to live and work in better conditions in Space, and specifically on board the International Space Station (ISS). The task of Design, in this particular context, is to increase the comfort and well-being of the crew designing environments, equipment and tools in order to facilitate human movements and improve the performance of the various activities, in favour of greater productivity and quality of life on board. There was to build a whole new world.

1.2.1 The Design Domain Fields for Space

Design can intervene in the design process for Space at various levels and scales: designing beautiful and functional environments to make astronauts feel better when living and working on board the ISS, maybe changing the internal configuration in order to increase the habitability performances, or introducing innovative lighting system to change the perception of space and balance the circadian rhythms
that in Space are altered for the lack of natural stimuli; proposing equipment to facilitate the various activities, for example, fitness in microgravity, in order to maintain bone and muscle mass, but also try to make physical exercises more attractive introducing entertainment; creating specific tools for the preparation, consumption and conservation of food, or objects to facilitate self-care and guarantee a good level of personal hygiene; increasing the performance of the working instruments to support astronauts during the various tasks; and improving the leisure time favouring both the needs of privacy and conviviality or imagining new way to make easy the communication with family and friends. These are only a few examples of the activities, needs and fields of applications the Space Design face with that in the absence of gravity are much more complex and require the designer greater attention to the human body—from the physiological, perceptive and psychological point of views—which responds in a different way to the various particular extreme conditions, and to the interaction with objects and environment.

There is no substantial difference between the project of a designer who creates new objects and structures for Space compared to those who are dedicated to making a better place the Earth. In my opinion it worth, in both the cases, the historic slogan of Ernesto Nathan Rogers from the spoon to the city in which the Milanese architect and theoretician of architecture intended to express the breadth of the territory project of our profession, which allows to act simultaneously on different scales of complexity in relation to the human being. Of course, in Space the movements and gestures that each of us acquires living and having direct experience through the environment surrounding are altered, as well as the shape, the posture and physiology of the body, which in microgravity undergo obvious transformations. Then our spoon will have surprises for us, in case we want to try to use it to consume a breakfast of milk and cornflakes, because we would see small white spheres together with flakes of cereals start to float and go around the International Space Station (ISS), most likely clogging the air filters. Maybe a straw is better. Or maybe, even better would be that the designer would think how to solve this need through a new thought that does not refer to the experience of all the days on Earth, but based on extraordinary conditions in Space, and situations sometimes much closer to dreams than to reality.

When we dream, we can do somersaults in the air just like the first astronauts experimented during the first Skylab human space mission, or we can have fun breaking an egg and watching the egg white that remains around the yolk as if it were the most natural thing in the world (Dominoni 2015). Design can improve the function and the interface usability of the electrical appliances and the control and navigation systems as well as the quality of the lighting systems. For example, how we could wash garments in Space? When I led a feasibility study for a space washing machine to be used on board the ISS, I asked myself if it was possible to think of washing clothes without water and using the vacuum outside the spaceship. I have chosen as industrial partner of the project Electrolux Zanussi, a big international company in electrical appliances, to give me the possibility to face new technologies and imagine new ways to clean garments in orbit. I built a cross-disciplinary team to have the terrestrial know-how related to the washing
technologies together with chemists, to imagine new enzymes and molecules to face the vacuum alternatives, and space engineers, to guarantee the spatialization of the new washing machine for Space.

The study of lighting, as it happens already for the design of both small rooms and big office spaces that not always can rely on the outside light, must take into account to balance the circadian rhythms. Natural light is fundamental to regulate sleep and waking, and its lack in confined environment causes strong alterations of the physiology of the human being generating insomnia and general impatience. A good design has to develop illuminating bodies with variants, in terms of temperature of light and luminous intensity, similar to natural ones (Fig. 1.3). Light can also create space partitions defining private rooms or can change the perception of the environments, overall if in isolation conditions. Using lighting effects, we can recreate the Sun that filters through the windows reflecting multiple and vibrant shadows. Also in the science fiction imagination, there are solutions that seek to recreate environmental stimuli natural, as you can see in the movie Solaris by the Russian director Andrei Tarkovsky, in which the sound of the wind was reproduced through strips of paper placed under the aeration fans of the space station. Coming back to the reality, in Space the crew members often in the absence of adequate solutions try to create a better environment through the most unthinkable devices that they have available as the cosmonaut Anatoly Berezovoj who in 1982 spent part of his 7 months on board of Salyut 7 listening to a cassette player in which they had been recorded the sounds of woods, birds, wind and of the storming of the leaves, in short, the terrestrial sounds (Clark 1988).

The well-being of the astronauts depends also on natural stimuli that in confined environments should be recreated as using lighting effects to balance circadian rhythms. Credits by Space4InspirAction (S4I) Course, 2nd edition 2018, Politecnico di Milano

Fig. 1.3 The well-being of the astronauts depends also on natural stimuli that in confined environments should be recreated as using lighting effects to balance circadian rhythms. Credits by Space4InspirAction (S4I) Course, 2nd edition 2018, Politecnico di Milano
scents, flavours and sounds—that normally we live and feel on Earth and that are able to stimulate the vital functions, and that unfortunately in Space the artificial environment of the habitation modules is not still able to reproduce, and over time provokes monotony, a loss of widespread interest and also depression. The human being, under normal conditions, reacts to these stresses tuning its balance with nature and the surrounding environment. For these reasons, the lack of a single natural stimulus can therefore compromise biological and mental health.

Increasing the scale of the project, the Design is fundamental to design means of transport to Space, as the fleets of the launchers Apollo, Shuttle and the new generation Falcon and Crew Dragon, but also new space stations (Fig. 1.4), Moon and Mars bases, and rovers to explore the extreme territories. In these contexts, the designer contributions can regard the shape of the external structure, the interior habitat for the crew and the furniture defining all the details, such as the coatings, the colours, the materials, the structures of the seats that will welcome the astronauts on the space vehicles, or the restraint systems to anchor inside the ISS, and even clothing for living and working in confined environment and in microgravity conditions (Souza et al. 1991–1998). At this scale, the most important aspect that affects the design choices is precisely the confinement and the lack of gravity (Stuster 1986). The designer deals with very small spaces that need to be used intelligently to allow crew to live and work in a comfortable and efficient way, both individually and in a team, without bothering each other too much and with the possibility to have some private space to relax and find their own balance.

Living the confinement in small environments in which all the activities are concentrated in little space and in which one must live for a very long time (without the possibility of going out to take a breath of air, as it happens on board the ISS)
causes an increase in the need for privacy, and cascading, emotional stress, aggression, nostalgia and depression. There are numerous tensions experimented on board between the crew, and between astronauts and ground controls, such as the mutiny of Carr, Gibson and Pogue against the mission leaders in Huston, ended with radio silence from the three men of the Skylab (Di Bernardo 1997).

Perhaps the closest experience to us that can be comparable to the life on board the ISS is the forced isolation, living in our homes, imposed by the Covid-19 pandemic emergency (Fig. 1.5). I had the occasion to live this experience with the students starting in the second semester this year, at the end of March 2020, the Space Design Course Space4InspirAction (S4I) at the School of Design, Politecnico di Milano, that it is presented as case study in this book in chapter 4 Space Design Between Research, Project and Education. There are some specificities of Space Design that makes this discipline an interesting testing ground for

![Fig. 1.5](image)

Fig. 1.5  Living in forced isolation during the Covid-19 pandemic and teaching in distance helped us to be more close to the astronauts’ feelings and understand better their needs. A screenshot taken during the final presentation of Space4InspirAction (S4I) Course, 4th edition 2020, Politecnico di Milano. Credits by the author.

1The Space4InspirAction (S4I) Course, this year at its 4th edition—created and led by Annalisa Dominoni and Benedetto Quaquaro from 2017 inside the Master of Science in Integrated Product Design, School of Design, Politecnico di Milano—is the first and unique academic Course of Space Design in the world recognized and supported by the European Space Agency (ESA) through experts and scientists who suggest and then deepen the project themes, in line with the objectives of the all space agencies’ strategic programs, with the aim to generate disruptive ideas and visions to increase the well-being of living in Space through Design approaches, methodologies and thinking.
the development of distance learning methods during a pandemic: astronauts live in a confined environment that brings lack of privacy, deprivation of natural stimuli and sometimes depression or nervousness for the impossibility of getting out that were close to the situation of us and our students living in isolation, maybe without a personal space in which to work or relax, and with the desire to move and practice sport in the open air. In this situation, students could be closer to their users and their needs to design new products which could better satisfy the functional, physiological and psychological requirements when living on board the ISS.

The designer can act to reduce the negative effects of confinement, designing an artificial environment rich of sensorial stimuli that are able to reproduce in the best possible way those already present in a natural environment.

The Design skills are also required to design the layout of the human space settlements, the architecture of the space stations, such as Mir and ISS, and the lunar and martian bases, the last two for now only projects on paper, and sometimes some habitat demonstrator units in 1:1 scale to test dimensions, habitation requirements and activities inside the base and outside the territory. These activities, as Desert Research and Technology Studies (Desert RATS or D-RATS) led by NASA, are designed to exercise prototype planetary surface hardware and representative mission scenario operations in relatively harsh climatic conditions where long-distance, multi-day traversing activities are achievable (Fig. 1.6). At this scale, from the lens of Design, the project develops focusing on the objectives of logistics, the functional distribution of indoor and outdoor spaces, as well as the transition of

Fig. 1.6 Desert RATS are led in the high-desert terrain and isolation of the Northern Arizona and are designed to exercise prototype planetary surface hardware and representative mission scenario operations focussed on equipment and spacesuit tests, vehicular excursions and exploration. Credits by NASA
the crew passing from inside the habitat to outside the territory; on the applications of innovative technologies and on the most appropriate structural configurations to integrate the living areas to the surrounding territory, maintaining a systemic and organic vision of the project. The logistical nature prevails and requires of considering different alternatives to transport to Mars, for example, all the material needed to build the various modules of the settlements. The aspects linked to the dynamics of living, in which Design plays a fundamental role, are still far away. Today, the task of architects and designers is aimed at the development of structural concepts and feasibility studies of housing scenarios, in which the morphological and distributive aspects of the spaces are assumed. The most popular idea is to use the Moon as a test bed to gain experience in anticipation of the next missions to Mars, but also for other destinations, thanks to temporary habitats that integrate autochthonous materials and allow astronauts to live and work at the lunar base sheltered from the hostile environment.

Another case study described in this book in chapter 4 Space Design Between Research, Project and Education concerns the concept of a Moon base called Moony built inside lava tubes using inflatable technologies for the habitat modular system, and 3D printing technology to create a safe rigid structure with regolith. Creating a permanent habitat on the Moon, precisely under its surface, in the lava tubes, is a challenging project at this moment. In our project, it is supposed the habitats will be pressurized and heated, with a useful area of about 125 m² and a height of about 3 m. They will require only three/four astronauts for assembly operations, which are not expected to last more than a few hours and can be disassembled and repositioned many times. It is important to keep in mind that the crew will work outside wearing the bulky suits for Extra-Vehicular Activities (EVA), which make everything slower and tiring, so the simplicity and speed of the habitation modules installation of modules are among the priority requirements. During the simulation period, a system of sensors will allow to monitor structural and housing performance to study how to optimize energy consumption, how to reduce packaging during transport, how to facilitate assembly and disassembly operations, and how to increase comfort for the life and work of the crew. The projects of interplanetary colonization, in which we work on the architecture, in the broadest sense of systemic organization, the human performances in relation to the environment and the tools that will be used on site, at the moment, increasing value. Even if at present, greater importance is focused on robotic assistance, especially in the early exploratory phases of the territory, human space missions are recognized essential to test the habitability conditions looking at the great opportunity to expand life on other planets.

Moony—a whole modular base located under the lunar surface, in the natural tunnels of volcanic origin called lava tubes—was designed by Irene Zaccara and Emilia Rosselli Del Turco under the supervision of the professors Annalisa Dominoni and Benedetto Quaquaro, experts in Architecture and Design for Space, at the Design School of the Politecnico di Milano. The project is part of Igluna Esa_Lab@ program supported by the European Space Agency (ESA) and coordinated by the Swiss Space Center.
Another Design field of research and project concerns the clothing system specific for extreme environment, with micro and reduced gravity, that consider the transition between inside the pressurized modules and outside the Space environment. The results of the project of the clothing system for Intra-Vehicular Activities (IVA) that I developed in two phases—VEST, Development of an Integrated Clothing System, and GOAL, Garments of Orbital Activities in weightlessness—and that I was able to test with astronauts through two experiments on board the International Space Station (ISS) during the missions Marco Polo, in 2002, and Eneide, in 2005, confirmed to me, but especially to the scientific community, that the designer really has the opportunity to increase comfort, psycho-physiological conditions, and the quality of life and work in Space: it is a pioneering field still little explored and, for this reason, with great potential for the contributions that the Design can give. The projects and the experiments VEST and GOAL are treated as case study in chapter 4 of this book Space Design Between Research, Project and Education. The implementation of these projects of garments designed specifically for Space—in which comfort, smart textile to increase body hygiene and thermoregulation, and wearability were for me the priorities to achieve—also provides researches and experimentations for new performance of fibres and fabrics that should have responded in an increasingly precise way to the environmental requirements in terms of safety and toxicity: encouraging, for example, the possibility to collect and contain, through the tissues in contact with the skin, the skin peeling, an important and amplified phenomenon in confined environments where hygiene and air quality are inevitably compromised; providing for the insertion of sensors in garments to monitor the biomedical parameters of the crew, without interfering with the subject or with his activity and without requiring direct and conscious participation; integrating to the clothes systems prosthetic wearable to support the movement and the stability of the astronauts; and considering different degrees of reduced gravity, so as to facilitate the maintenance of the posture during the various activities (Dominoni 2005).

I am leading in this moment researches on this topic, considering that the activity in Space is directing its attention towards planetary colonization programmes that include different environments and levels of gravity, in which astronauts will carry out activities in orbit and on lunar and martian territories—passing with a certain regularity from places internal and external—and must therefore have a clothing system adapted to the different environmental conditions. One of the most important aspects to ensure the protection and safety of human beings concerns clothing, a system of multi-layer garments able to ensure adaptability to various environments with reduced gravity—International Space Station (ISS), lunar orbital platform Gateway, Moon and Mars bases and external surfaces—and flexibility in movements for carrying out various Intra-Vehicular Activities (IVA) as work, fitness, rest, self-care, food preparation and consumption, etc., and Extra-Vehicular Activities (EVA) as rovers guide and robotic instrumentation, walks, surface missions for excavation work, extraction, construction, component assembly, etc. These researches are part of a wider, medium-term project to develop a new clothing and accessories system for both IVA and EVA consisting of multi-layer
garments made of intelligent materials that integrate innovative technologies focused on health care and wellness, protection, and support for low-gravity human movement.

The Design domain fields for Space are very huge and we can say that embrace the entire artificial world created by the human beings and can therefore be of great help to suggest a more adherent approach to the needs of the human beings also in Space. Through the application of methodologies and techniques aimed at identifying factors as security, functionality, usability requirements and pleasantness, to the advantage of an increase in quality of life, not only psycho-physiological, but above all emotional, condition that will become more and more also important for space travellers. This is the reason why the designer has such a function important in Space Design, as extension of our world.

1.2.2 The Role of Space Design

Before going in depth into Space Design discipline, it is indispensable for me to focus on the meaning of Design and its role, which is something more and beyond the only shapes and surfaces of the objects. You know that today in Italy to define a beautiful object and that it has a style we use to say: it is “di design”. I do not mean it is little, since the made in Italy is recognized as excellence worldwide.

Actually, Design can play a much wider and more strategic role. I like to define Design approach as a problem-creating discipline, which generates innovation and increases people’s well-being, and this is true both in Space and on Earth. The Design places the human beings at the centre, with a User-Centred Design (UCD) methodology, trying to interpret their needs in the most sustainable way: if an astronaut lives and works in a comfortable environment, with equipment and facilities designed properly to be used in Space, its performances increase as well as the quality of the activities, individual and collective, and can be determinants for the success of a mission. So, the most significant characteristic that distinguishes the designer’s approach is the pre-eminent attention to the users of the products.

When I started designing and researching for Space more than 20 years ago, I wanted to go further to a UCD approach that belongs to Design discipline and find new tools specific for Space. In my first book Industrial Design for Space, as I already mentioned at the beginning of this chapter, my aims were to demonstrate through the results of the projects I developed during the first years the fundamental and strategic role of Space Design to increase the comfort and the well-being of the crew and, as a consequence, the good results of the whole human space mission.

---

3Even if it is inappropriate, a literal translation of “di design” in English should be “of design” that means an object made in Italy, which belongs to the Italian design style, an object beautiful and well done.
The structure of the book is composed of three principal parts: the first it is an overview of Living in Space, focusing on the principal characteristics that make Space an extreme environment, like microgravity, the biggest difference with Earth which causes strong alteration in the human being both physiological and postural (Fig. 1.7), the confinement, in which people have to live in small rooms in isolation for long time as already experimented in other extreme environments like Antarctic bases, and cosmic radiations, the most dangerous for the human being and whose effects are still little known; the second part, the core of the book, presents the potentialities of Design to have a central role in Space and describes a new approach Designing for Space bringing as case studies my first projects that shown the development of my researches and the results achieved; in the last part, I focus on the strategic objectives and on the new methodologies, as the Use and Gesture Design (UGD) that I found to increase the design process, according to the Space requirements and methods of working in Space, and the vision I wanted to exploit, in which the human being is at the centre of the human space flights, considering physiologic and psychological factors, together with functional and emotional needs.

I aimed to underline the peculiar condition in Space, among which microgravity and confinement are the major challenges to face with, and in which Design competences could offer valuable solutions to reduce difficulties of living and working in Space; for example, the attitude to consider the effects of microgravity not only on the physiology of the human body, but on objects and postures assumed by the human body, looking at the alteration of objects and movements with the environment, as well as the attention for the isolation issues related to spend long time in a confined environment, without privacy and the possibility to go out to take a breath (Fig. 1.8). My objectives were to report the theoretical reflections and the practical experiences acquired during 3 years of research activities, led for my Ph. D. in Industrial Design at Politecnico di Milano, focusing on the topics which arise from dealing with, and designing for an environment so unfamiliar as Space is.

I wanted to create a new discipline, nobody before has written a book on Space Design, but I did not want to limit myself to the description of what I might have done in this field, I wanted to bring real examples, case studies able to support my thoughts and demonstrate that Design could lead to disruptive ideas for Space.

I chose Space because it is the most complex and innovative field on the international scene, but overall, the most challenging, full of potential and still unexplored project opportunities, making it extremely interesting to the scientific community involved in industrial design. Therefore, I started my Ph.D. in 1998, the same year in which the construction of the International Space Station (ISS) began, and I considered this coincidence a very exciting and promising point of start. The conviction that animated me put Design as a bridge between Space and human being needs, able to dialogue with different communities of engineering, science and technology and give shape to new products and environments for the next generation of space travellers. Space today is an increasingly important and strategic field: the human beings are pioneers and are moved to the primal essential need to understand where we come from, and what surrounds us. It means
exploring new worlds, investigating the presence of life on other planets, and at the same time, caring for the Earth, protecting it from external, but also internal threats. For the same reason, we went beyond the oceans and the poles, towards unknown horizons, we are attracted by the Moon, to know it and discover, for example, how one can survive in its orbit for days. Only in this way we will be able to move towards Mars, overcoming all the critical issues of such a journey: the impossibility of being supported by Earth, the exploitation of in situ resources. None of this would be possible without accumulating experience and professionalism in the industry. We are called to understand what problems could be faced in the future as we are invited to anticipate them to solve them before they present themselves, and Design can play an important role in the whole process, thanks to its methodological approaches and strategic tools. The designer must interpret, by means of the formal and symbolic qualities of its projects, people’s needs, expectations and desires, and at the same time elevating the degree of their general well-being. One of the visible signs that testify to the evolution of civilization is precisely the level of comfort—from the satisfaction of essential needs to their progressive sophistication—which is reflected directly by an improvement in the quality of life (Maldonado 1987). This explains why until now Space field has not included Design expertise in the strategic programmes of the human space missions: Space is an environment that has been subjected to very limited exploration, and in many ways, it is still an environment of pioneering, although great progress has been made since the 1950s. The boundaries of intervention areas for Design seem to
converge into a new figure specialized in the *new human factors* halfway between Design and human sciences (Jordan 2000) characterized by increasing attention towards the user and the value relative to the use and the emotions aroused by the product, on one hand, and by strong involvement in the processes of technical–scientific innovation on the other hand.

From the Design point of view, a good knowledge of the Space environment and, above all, of its effects on the human being is fundamental to identify the needs and the requirements, developing a path for the projects to follow, to offer the crew beneficial effects in terms of comfort and efficiency during their on board activities. But to gather information regarding life in Space, it is not an easy task: Space is an environment of pioneering with very limited access, manned missions are still few, and the experience collected by the Russian and American missions over the 60 years of activity has produced insufficient data to be transferred and translated into scientific knowledge that can now be shared. Also, being the de-briefing of each cosmonaut or astronaut subjective, the information about the experience of a human being in Space is sometimes vague and at times contradictory. To this lack of reliable information, I add the fact, proven by my direct experience while de-briefing with astronauts, that it is very difficult to obtain indications by them that could improve the efficiency or the quality of the existing products they use on the International Space Station (ISS).

Astronauts are trained to follow commands and procedures and maybe, for this reason, it is not easy for them to ask: *what if?* What if this tool had a different grip?
Could I improve the performance of a restraint? In which way? What would I anchor myself better? What would I need to move better?

*Design is also asking the right questions and making the right choices according to the feedbacks collected in order to increase the well-being of the crew.*

During this time, the expansion of manned missions in Space exploration and, above all, the gradual increase in the length of the uninterrupted periods spent by cosmonauts and astronauts, before on board the Mir and then the International Space Station (ISS), have encouraged researches and studies carried out on the habitability and focussed to confined environments in microgravity conditions.

*The main objective is to guarantee now and in the near future—looking towards Moon and Mars as next interplanetary human settlements—a way of living and working which may be more comfortable, more functional and consequently more efficient: an expected first acknowledgment of the Design discipline for Space.*

The growing attention given to human needs is also evident from the evolution of the strategic programmes for Space exploration led in the recent years by the National Aeronautics and Space Administration (NASA) in which the development and the importance of the *human factors* are strictly connected with the *security* of the human space flights. The consequently increased awareness of the crew’s physiological and psychological needs that have always been neglected and considered secondary compared to other priorities, as typical of pioneering fields, has allowed that engineers, physicists, chemists, biologists and doctors to have with increasing frequently the collaboration of psychologists, sociologists, architects and designers, very useful for the definition of the context and the first requirements of a human space mission. It appears evident, therefore, how the importance of the *quality of life* is gradually spreading throughout most of the activities that involve the presence of humans in orbit, imposing itself strategically through projects aimed specifically at providing efficient *countermeasures* to the disadvantages induced by the extraordinary situation concerning the life in Space. To this purpose, the study of the physiological behavioural and interpersonal dynamics, together with the interactions between the human being and the environment, can furnish instruments for the kind of investigation that is of primary importance during the design process and can lead to solutions really capable of improving the crew’s level of well-being. Despite the obvious importance of Design to facilitate activities and life in Space, the scientific community is still dominated by an engineering matrix that fatigues, for the cultural education and background, to understand the contribution of Design for the success of a human space mission: I will never tire of repeating that if an astronaut feels better, thanks to a Design-oriented approach aimed at meeting the needs of the crew, also its performance and the quality of the results increase. But for now, as will be seen in chapter 3 of this book *Research and Design for Space Life*—in which I describe the main involvements of designers in projects and

---

4 The Space scientific community uses the term *countermeasures* to describe all the devices, facilities, physical exercises, medications, drugs, procedures and other strategies that support and help astronauts healthy and productive during human space flights, with the aim to counteract the negative effects due principally to the microgravity.
researches for Space from the beginning of the Space Race until now—the complete acknowledgment of Space Design is still far away. But something fortunately is changing. The SpaceX’s Crew Dragon Spaceship (Fig. 1.9) in partnership with NASA’s Commercial Crew Program allowed through Design to add an emotional value to the human space flights, making the experience of the crew more comfortable and beautiful as well as efficiency and safety (Fig. 1.10).

One of the objectives that I would like to achieve with this my book is to give visibility to Space Design. In the scenario which I would describe, the Space field appears ready to accept and include, in the planning of the projects and definition of requirements, those factors that specifically pertain to Space Design, because of its highly multidisciplinary nature, can coordinate all the anthropologic, social, sensorial and perceptive aspects that regard the relations of the interface between operators, their second skin, the garments and tools with the surrounding environment.

The contribution of Design in Space, in this particular environment characterized by extreme conditions—three of which, microgravity, close confinement and cosmic radiations, have a determining effect on the human being and, as a consequence, on decisions regarding habitation projects—is to increase the comfort and the well-being of the crew designing instruments that can facilitate human movements and improve the execution of the various activities, to the advantage of greater productivity and a higher level of the quality of life in on board. I have to make it clear—after my more than 20-year experience in researching and designing habitation modules and tools that have been experimented and used by astronauts on board the International Space Station (ISS) and looking at the international experiences collected in few tens of years by space agencies and Industries—that increasing the well-being of the crew, the functionality of the activities and the usability of interface’s instruments and tools for astronauts, we can achieve better goals that directly affect the success of a human space mission.

In this third millennium, the human beings are definitely the protagonists of a New Space Era and have at last conquered a primary role within the scale of values that characterizes a human space flight: they are no longer only professional and super-skilled astronauts, with years of demanding training in preparation for the mission, but can be also scientists, researchers, and not least, tourists ready to experiment space travels, but not trained therefore to live in an extreme environment, in conditions of permanent emergency, with limited resources and services, to the detriment of their physical and mental well-being.

The New Human Being is a person who wants to live in a comfortable way and, why not, has fun. This means that the whole environments must be totally re-thought and re-designed according to the physiological and psychological needs of the space travellers, as well as objects, facilities and tools for the daily life activities (living, working, sleeping, eating, taking care of ourselves, resting, etc.) which should make easier the life in Space trying to reduce the difference between living in Space and living on Earth. For these reasons, the role of Space Design is fundamental.
1.3 Use and Gesture Design

The lack of possibility to reference to a consolidated experience built over a very limited number of human space missions and the impossibility of assessing the true validity of the designer’s hypotheses until it is already in orbit jeopardize the success of the project development in the Space field. For this reason, the visualization and analysis of all the gestures and movements possible in relationship to extra-terrestrial environments should be introduced as a determining factor during the design of the objects to deepen the dynamics of human body when in microgravity. A designer must have the capacity of imagine how could be the life in Space, also if it is not part of the normal experience of a human being, how his body could move in microgravity, how their postures and gestures would change in relation to objects and which could be the new objects to design properly for Space. Designing for Space means starting anew, applying a different logic for a different environment, conceiving new instruments for uses and activities difficulty in envisaging for us who are living on Earth, but which presuppose a different relationship between our bodies, the objects and the surrounding environment.

I found that the most important and most interesting difference between Design for Earth and Design for Space can be identified in the design process, which regards the capacity to forecast the design of use and gesture visualizing possible human gestures and movements in Space, in confined environments and in microgravity conditions, which cannot be compared to the human experience on Earth. This means imagine, for instance, which could be the alteration sustained by...
the astronauts assuming the Neutral Body Posture (NBP) and predict what the needs might be supported according to the ergonomic, physiological, perceptive, psychological, emotional, motor factors facing conditions completely new and unknown to the human being (Fig. 1.11). In order to manage better the transition between the two environment and practices, Design for Earth and Design for Space, I created a specific methodology which I called Use and Gesture Design (UGD) that means projecting the features of the future object on the scene of its possible uses, and visualize it in action: in your hands, put on you, in the environment to zero gravity where the object will be used, and foresee how it will be used, in which ways, in which environments and with which interfaces.

The design activity to create a new object, or an environment, for Space, should be contemporary to the forecast of the use of the new object, or environment. In this design process, the designer becomes a filmmaker, able to create a potential script of a new tool, which implies the relation with the environment, the movements and the gestures of the astronaut. It is as if the formal idea and performance of a project developed contemporary to a potential screenplay of movements and gestures of the operator (Rabardel 1997). In the design process, the artifact is of equal importance compared to the usage’s scheme and creation of an idea, a concept design for the space, derives from the simultaneous design of action, movements and gestures that are simulated in function of how and could be used the designed object, how and with which procedures, how long and by how many operators, etc.

If Designing for Space means projecting the whole features of the new object on the scene of its possible uses and visualize it in action—in the hands of the user, or in the case of garments and accessories worn, and in the environment of

Fig. 1.10 SpaceX Crew Dragon Spaceship interiors are designed to make the experience more comfortable and beautiful, maintaining as well as efficiency and security requirements. Credits by SpaceX
microgravity where it will be used—it follows that also the user is the artificer of the object, because its performance makes it complete and fully completed the project. Each use and gesture action has in fact to be understood as an *interpretative action*.

The transversal reference to the background of the choreographic ideology—which is to say the structuralist intention on the basis of which every action can be separated into a series of single movements and reconstructed as a sequence of movements—may be useful when illustrating the methodology that the designer should apply when designing for use and gesture. Like a director who must conjugate the engineering of screenplay narrative and the figurative nature of the storyboard—tracing the thread through the identification of the nodal points essential to film editing, and include and determine the geometry of actor and extra movements, as well as camera movements, connecting all with soundtrack rhythms—so the designer of structures and equipment for living and working in Space expresses, through a programme of use or a programme of gestures, a predefined sequence of actions that enable operators, in this case astronauts, to reconstruct designed movements for use of new products and therefore to reproduce them.

Going back to the choreographic ideology, the designer must not only foresee the series of actions involved in the use of the object, but must enhance, at the planning stage, both the gestures and the movements that accompany the object, and the object itself, like in a dance, must take on the role of the artificer of a series of gestures, a programme of ritualistic movements.

**Fig. 1.11** Examples of Neutral Body Posture (NBP) in Space and similar underwater postures with average geometry and measurements. Credits by NASA-STD-3000
The first project on which I defined and applied the Use and Gesture Design (UGD) methodology in reality, realizing prototypes that have been tested underwater to check comfort and usability, was during the development of a system of portable tool holders that I designed for Thales Alenia Space (TAS) called Portable Caddy System in 1998. This device system was be carried or worn by the crew members for use as an aid in the ordinary maintenance on board the Columbus European Laboratory of the International Space Station (ISS).

Compared to the existing containers at that time on the ISS that are rigid toolboxes sized made to be integrated into the racks room dedicated to storage, I studied a system of soft containers, fabric, that was portable, and also wearable easily by astronauts. The project follows the principle of considering microgravity as an advantage, not a limit, trying to exploit the new potential that can have weightless objects floating in space. The idea was to imagine the containers close to the astronauts, as useful assistants, but independent, of the kind of console that could become rigid—if you had to lean and fix the tools that were not needed at that time, avoiding that they begin to float in the air, or that they were attached in a scattered way to the body of the astronauts with the Velcro®—and return soft, to be rolled, once used the tools and stored in the Portable Caddy System, to occupy the minimum of space possible. This project is described in detail in chapter 3 Research and Design for Space Life at the paragraph The Birth of a New Discipline. The Design is based on the possibility of simulating on Earth the operator’s movements by means of advance verification of the body’s possible uses and gestures in

**Fig. 1.12** A sequence of gestures and movements performed by the astronaut Roberto Vittori during GOAL experiment led by the author on board the ISS. Credits by the author
relation to the objects and the Space environment. Design in compliance with use and gestures—that is, the analysis of the movements most suitable for using the containers and the tools and recomposed them into precise sequences of gestures—was carried out inter-linking it with the parallel development of the morphologic and functional characteristics of the tool holder system. To plan the gesture of how to use the containers and the tools—that is, how to recognize the tool required for a particular operation, how to take it out of the container, how to anchor it to the body and to the structure of the Space habitation module in a situation of microgravity, how to put it back into the container, etc.—and to design the shape of the objects themselves—relative to the physiological, perceptive, ergonomic, psychological and motor aspects of the operator, but also to the structural, material, mechanical and functional aspects of the instruments on board—are actions that interpret a unique design process where theory and practice overlap, and in which the value relative to the use of an object is strictly connected to the intrinsic value of the object itself. To have recourse to consolidate practice is desirable both for the designer, who can operate in a familiar field, according to predetermined and consequently easier to manage conventions, and for users, who have the advantage of greater confidence in and control of actions, which are the same as, or similar to, familiar gestures.

Forecasting capacity is one of the requirements most important that a designer must possess for design gestures for objects and propose innovative solutions that are not polluted by experience acquired of daily life, but which can instead respond to latent and not yet expressed needs in a conscious way by the people: functional needs and emotional in which the poetics of the object has a fundamental role.

This skill of having a strong capacity to foresee the new designed objects and environments together with the use and gestures that will be performed by the astronauts (Fig. 1.12) is strongly connected to another one that embraces cognitive psychology and the mental processes behaviour to design products and create environments well organized (Norman 1988) and adapted to the needs of people, in order to find solutions really capable of improving the crew’s level of comfort and efficiency and the whole well-being on board.

Recently, I developed a design research exploring architecture of motion as scenarios of movement and stasis, very perceptible in Space, to evolve the Use and Gesture Design (UGD) methodology integrating experiences of kinaesthetic awareness and generate new ideas and scenarios to facilitate creativity and innovation (Dominoni and Fairburn 2015). We believe that the level of consciousness coming from the awareness of body, object and environment, of each gesture and movement necessary to perform a task, can help the designer and the performer to analyse in depth the need and the most hidden behaviours of people. Looking at Space as inspiration we wanted to offer scenarios that may be of use to enrich design processes for non-extreme environments. Working and observing astronauts who live in microgravity conditions we have been forced to slow down the rhythms to which we are accustomed on Earth during the design process. Could slowness become a new and important approach in the design process to innovate? In this context, the Design becomes a slow mediator able to read usages, gestures and
behaviours of the people and translate them into new useful products to increase the well-being and answer to the need of the humans by observing the experience of living and working in Space or on Earth, and also, by transferring the results from one field to another and vice versa. Could a constructed design scenario, for example, an immersive experience in an unfamiliar environment, induce a state that shifts our perspectives and in turn generates new conditions for Design approach?

1.4 Designing the Space Experience

These themes refer directly to the User Experience Design (UXD), the process aimed at increasing users’ satisfaction by improving usability, ease of use and overall the pleasure provided in the interaction between the user and the products. The design of the user experience includes the traditional human–machine interaction design and extends it to all aspects of the product or service as perceived by users. Pushing us further, we take into account that today not only trained astronauts, but also researchers and tourists look to Space as an opportunity ever closer and possible. And so, why not also think about designing the experience of those who want to make a spacewalk in all safety and freedom (Fig. 1.13), with a drone following them, which is always close to them, and then “embraces” them to bring them back into the International Space Station (ISS)? Of course, the same drone, in addition to serve and entertain space travellers, can serve astronauts during Extra-Vehicular Activity (EVA) and, therefore, could assist them during difficult and dangerous operations outside the ISS, where time spent in Space is inversely proportional to the security of the mission. This project, an example of User Experience Design (UXD) applied to Space, was developed inside the Course of Space Design named Space4InspirAction (S4I) that I created and direct, together with Benedetto Quaquaro, at the School of Design, Politecnico di Milano, inside the Master of Science in Integrated Product Design. S4I, treated in this book as a case study in chapter 4 Space Design Between Research, Project and Education, is the first and unique Space Design Course in the world recognized and supported by the European Space Agency (ESA) with experts and scientists who suggest and then deepen the project themes, chosen every year together with us, in line with the main objectives of the space agencies and industries’ strategic interplanetary programmes. The collaboration between our S4I Course and ESA is not a spot project, but the beginning of an ongoing agreement about teaching—research—design to ensure the development of innovative projects in which the contribution of Design discipline is fundamental and strategic to generate disruptive ideas and visions for habitability in Space, with particular attention to human factors and interactions between operator, tools and environment.

5While I’m writing this book, we’re leading the 4th edition 2020 of our Course of Space Design Space4InspirAction in distance learning for the Covid-19.
Aim of our Course S4I is to create new professional figures able to connect both technology and beauty languages, increase creativity and visioning, find design solutions crossing know-how and research, imagine new cultural and business models to increase well-being according to sustainability.

The Course Space4InspirAction is for the students an opportunity to develop a strong capacity of visioning looking at Space as an inspiration, to innovate and design new projects of space habitats, objects and tools, but also new scenarios that could help people to live better in a sustainable way (Dominoni et al. 2018). The Space field allows them to develop creativity with intense visioning activities by confronting with confined and microgravity environment that is not part of our common experience. Thanks to ESA support, we are able to compare our design vision with real conditions and requirements and find innovative solutions designed for Space, but that can be also transferred to daily life on Earth becoming spin-offs, and vice versa, becoming spin-ins.

In the case study of the spacewalk (Fig. 1.13), I showed you an example of how Space Design can design new exciting experiences for both astronauts and tourists, creating equipment and objects the support their exploration of Space, but we could go further. The project of the drone is useful for me to introduce another potential strategic role of Space Design which concerns the ability to find new applications of Space technologies and behaviours to generate spin-offs and spin-ins, from Space to Earth and vice versa. The drone for the spacewalk may be a suggestion for another

Fig. 1.13 A spacewalk in totally freedom and security, thanks to a drone-mate designed to increase the value of the experience for astronauts and space travellers. Credits by Space4InspirAction (S4I) Course, 1st edition 2017, Politecnico di Milano
This project can be considered a spin-off from Space to Earth, and an example of our methodology of designing through the crossover of Space and Earth, along with different disciplines and areas of applications, to bring two seemingly incompatible environments closer because they are both inhabited by human beings. And the role of Design is to look at the human being increasing the comfort and the well-being of the people for a more sustainable society. I believe Space innovations will have a strong influence on how people behave and perform in the near future, as well as Design that gives shape to our world and tries to humanize technology to meet the needs of a sustainable society. I also believe Space Design discipline can really inspire students—it is enough to think the strong attraction that Space has always generated on society, thanks to its narrative power—and help them to understand better how they can be more conscious of the transformation technology brings.
1.5 Design for the New Space Economy

The Space designer could be seen as a contemporary influencer of our society and the Design discipline a booster for the new Space Economy.

Designing for Space, and specifically with microgravity conditions, extends the area of design research outside of the common rules and consolidate methodologies that we use to consider and apply in a design process. Looking through the transformative lens of Space, we are freed from the conventional references and potentially advantaged by different points of view and new scenarios (Dominoni and Fairburn 2015) and at the same time, we have the advantage to apply the lessons learned from one extreme scenario to another one. Using the experience of Design for Space to inform methodologies for Design on Earth may generate a paradox, as clearly microgravity isn’t a condition on Earth, but therein lies the opportunity to find analogous ways to create this state, and other states, to generate new conditions, in turn leading to design innovation.

The fascination for Space started in the 1960s during the Space Age while there was an optimistic mood for the conquest of Space, brought with it a great expectation of growth and trust in the future. Design looked at Space as inspiration to create many products became icons of style that deeply influenced the aesthetics of our world. Today, in the era of the Space Economy, in which finance and private companies have become the boosters of the new Space Race, Design become a producer of ideas and suggestions, a connector between futuristic visions and technological development. So nowadays also the role of Design has changed and no longer deals only with giving a space mood to the objects: Design is a method of actions, a problem-creating approach that drives innovation through research and develops business success exploring and understanding the users and their needs in a sustainable way.

1.5.1 Design Research for Innovation

Research for innovation represents today the industry’s indispensable tool to hinder the international concurrence throughout new Design solutions aimed to optimize the know-how and the skills of each single firm. The enormous change and the exponential speed of transformation driving the evolution of contemporary society aims the designer to understand how to manage complexity and find solutions to the problems arising from it.

Likewise, industry is forced to undertake design research for the only fundamental resource that allows it to create a competitive advantage to weather market turbulence: knowledge. If we think about the most significant innovation factors of company systems which are spreading in the market, and the strategies suggested by the management, it seems evident that many methodologies applied inside the companies belong to the theory and practice of the Design discipline.
A design research, to be considered such, must produce some form of knowledge that should be useful, but also lend itself to being shared with the scientific community and the industry within which it is generated and to being extended to the outside world as well. That is to say, we could sum up the notion of design research with the formula: Design + Knowledge. The design research is a programme of research and action characterized by quality which defines itself gradually studying and negotiating constantly oneself reasons with the aim to focus the attention on the context and the situation without punctual analysis or précised collected data (Laurel 2003). This means to measure oneself throughout our own personal wisdom in front of a reality unforeseeable and in continuous movement interpreting the results of data in a subjective way. Let us deepen into Design and innovation relationships.

Design is to formulate hypotheses, identify ideal solutions, outline future scenarios and choose. It also means receiving stimuli and processing them, confronting oneself with models of thought and value systems. Which happens, above all, when referring to a line of antecedents, that is turning to the past logical context of the problem one wishes to solve. This leads us to the conceptual relationship of planning with creating, inventing and discovering and, last but not least, deciding. According to Tomás Maldonado, the creative moment is to a large extent identified with the all but irrational one of problem-solving (Maldonado 1999). And it is here that one discovers what inventing and discovering have in common with Design, because Design always means confronting and creating problems. And nowadays, the size of the problems to be confronted and created is such that it is bringing about a change of project activity and, indirectly, of the role and tasks of the designer. The approach of professional people who work in the Design field has more and more in common with that of researchers who, when confronted with complex problems, are willing to collect information, organize it so it is ready for use, formulate hypotheses and come up with innovative solutions. Observing reality and people behaviour, generating ideas through brainstorming process, mocking up working models in order to visualize possible solutions, refining concepts and creating product or service with technological and scientific implementation are the techniques more utilized by the best design bureaux, as IDEO, to make good design (Nussbaum 2004). The interest of the whole system of the business companies for the design research brings to the absorption of the Design strategies in the managerial sphere producing a hybridization between design and management culture and the emerging of the design thinking as core of the new decisional process. And the design thinking is based on some specific capabilities of the design strategies which are connoted by visual and perceptive aptitudes. The design research is an articulated whole consisting of the expertise, capacity, sensitivity and tools used by the designer-researcher to deal with complexity and the pace at which said problems change so as to then translate such design experience into new knowledge that can be transferred and acknowledged by the scientific community in which the research itself was generated. This sort of figure, somehow embodying the relationship between research and practice in industrial design, can operate in universities as well as with firms having state-of-the-art research and development
centres. To work on design research, one needs a real principal submitting a problem and the conditions characterizing it, in short providing a context: the principal would thus come to engage in constructive dialogue with the designer to generate innovation.

Innovation today is no longer only a single enterprise initiative, but an innovative result born from a network of relationships and cooperation that comes from the outside and even through the organization of multidisciplinary working groups, capable of contributing with other points of view, to the growth of a new manufacturing reality (Dominoni 2009). Innovation is a system of activities and behaviours aimed at an objective to produce growth: human resources, know-how, financial skills, technological tools, but overall, research and development thought connections and networks with different subjects and realities.

Design and innovation tend to overlap when we find that Design is synonymous of innovation centred on the human needs. And the collaboration among Design, industry and science is the base for successful projects, products and services. Nearby the expressive, formal and functional qualities of industrial products, the Design has been enriched of knowledge which belong to engineering, technology and innovation economy. Also, the research activities are articulated and extended beyond the boundaries traced out at the beginning from the discipline, through unexplored territories of investigation and experimentation, increasing new Design questions and new tools to answer them. Design is distinguished from the other disciplines for a strong attitude in regarding beyond the functional aspects of the products with the aim to generate new visions, concentrating on “how” innovation can find “potential applications” in different fields, allowing spin-offs of technologies, materials, processes and working methods which can evolve in new products and services systems. To innovate is necessary to consider some actors that emerge strongly from the world global change which impose companies’ new Design tools to confront the market dynamics and their effects on human beings, society and the environment.

The base of this approach suggests to give a great attention to balance, during the design development, four important actors, with the aim to consider and frame innovation opportunities in a way that leads to success in the market: the companies’ needs, to explore new productive and business potentialities in relation to the market transition maintaining the pre-existing know-how, with the aim to increase the brand value; the users, to understand which products could reflect human lifestyles, values and aspirations in order to absorb people outside our existing market; the technology, to find the best technologic tools and processes compared with the other three actors; the environment, to preserve our natural resources for a more sustainable future (Brown 2009). These actors have to be considered inside a strategic macro-area in which the design capabilities are integrated with the management structure of the industrial system to produce innovation in terms of new processes, products and materials crossing different expertise and areas of application to generate spin-offs and spin-ins: towards a new design culture that goes beyond Earth into Space.
1.5.2 Space Inspires Innovation Through Design

A new Space Era is slowly coming into focus. It is a future where space agencies won’t be the only actors and will increasingly expand their partnerships with the private sector (Hufenbach 2017). The International Space Station (ISS) is the fastest moving incubation centre, and it has proven itself as a business accelerator: scientists and private companies are invited to take advantage of this opportunity. I was invited by the European Space Agency (ESA)—which organized a new kind of event in London during the autumn 2016—together with Benedetto Quaquaro to discuss cultural aspects of Space introducing some of our works, as Fashion in Orbit that used Space as inspiration. The Space for Inspiration—ISS and Beyond event (Fig. 1.15) was an open invitation to a broader community to join the Space club, and it was also a unique opportunity to build cross-sector relationships and learn about promising research taking place in orbit. ESA invited Space and non-Space industry representatives to sit together for the first time and exchange ideas on what the future of Space exploration holds for them both on Earth and in Space.

The newly emerging discipline of Space Design is in between Space and Earth that combines technological research, space inspiration and aesthetics to enhance the research of behaviour for life in Outer Space and on Earth. The role of Space Design is strategic because it is able to speak both the different languages of science and beauty putting at the same time the human being in the centre. If astronauts live better in a comfortable environment (considering functional, physiological, psychological and emotional factors), their performances and the success of the whole mission increase. This is the reason why Space Design can increase the comfort of the astronauts and find new applications for space technology in daily life on Earth. In this context, the Design approach can be a powerful engine for the Space Economy able to translate Space inspiration into new products involving both Space and non-Space industries.

Space exploration offers fantastic scenarios of experimentation that can be transformed and reinterpreted by the language of Design, an area that is far removed from the scientific world and yet has an important role to play by finding new products or applications for Space technologies that can enhance the performance of people and the quality of life (Dominoni and Quaquaro 2017a; b).

Furthermore, the new Space Economy is looking for attractive ways of communicating Space. In an age crowded with digital innovation mainly involving the movements of our fingers, the Space community must find a new tool to entice the public and help explain why Space research and its impact are so important: for this

---

6Fashion in Orbit is the first Higher Education Course in Space Fashion and Technology created and directed by Annalisa Dominoni and Benedetto Quaquaro at POLI.design (the Consortium of Politecnico di Milano) as consequence of the success of Couture in Orbit project and supported by the European Space Agency (ESA). Couture in Orbit and Fashion in Orbit are presented as case studies in chapter 4 of this book Space Design Between Research, Project and Education.
reason, the Design approach can really be the new *space tool*, and I explain here why through two projects I developed recently.

The first project, *Couture in Orbit*, is an example of spin-off: we have been inspired by space technology to find new application in terrestrial products to be used on Earth increasing the garments’ performances.

The second project, a *Space Acoustic Object*, is an example of spin-in: we transferred innovation technologies used in new products on Earth to Space environment with the aim to reduce noise on board the ISS.

### 1.5.3 Space Technology Spin-Offs Through Fashion

The project *Couture in Orbit* was launched by the European Space Agency (ESA) in 2016 to communicate to a huge public the role of ESA in developing innovation and *inspiring people through design and fashion language* that celebrates space exploration and research exploitation, and their impact in many fields of our life. I was invited by ESA to represent the Italian side of the project to create a *capsule collection* of garments inspired by space scenarios, using ESA technologies, and designed to be worn every day on Earth. The results were presented with a catwalk\(^7\) of the whole collection at the London Science Museum. This project is treated as a case study in this book in chapter 4 *Space Design Between

---

\(^7\)The video of the final catwalk of *Couture in Orbit: from Spacewalk to Catwalk* at the London Science Museum, European Space Agency (ESA), 28 September 2016 [https://www.youtube.com/watch?v=B99ncZ5eSM0&list=ULtD4c8evE4YA&index=42&app=desktop].
Research, Project and Education. For the moment, it is useful to me to introduce Couture in Orbit here, and the following spin-off Fashion in Orbit (Fig. 1.16).

My principal aim was to find relations between life in Space and life on Earth connecting the two environments and considering not only technological spin-offs or spin-ins but also emotional language and usability.

Together with a group of students—that have been chosen specifically for this project from the Master of Science in Design for the Fashion System which I led at the School of Design, Politecnico di Milano—we transformed inspirations into shapes and textures, by looking at astronaut postures and movements in micro-gravity and considering their activities in Space, in relation to the objects they use, to generate new gestures and ideas for our projects. I wanted to imagine new uses of space technologies that they do not yet have applications other than the original, but they could in a short time become very interesting.

Translating high fashion concepts into the language of technology was an essential skill for an endeavour like the project Couture in Orbit. I have been the go-between, with the students on one side and the industries involved by ESA on another, among which Rina Consulting, the Italian partner of ESA for Technology Transfer Solutions, and Extreme Materials, a small company specialized in textile-related technologies, which has in the past included such innovations smart materials embedded in textiles and composites. The students have sought a clear explanation of how these technologies are used in practice, and in other cases, consulted with the companies involved in the project, to find original solutions and developments to the problems they have posed.
1.5.4 Adding an Aesthetic Value to Technology

We pushed creativity and encouraged the students to come up with apparently crazy applications—to stay as crazy as possible—while we were the ones with our feet on the ground, to take into consideration the feasibility of implementation of ideas in concrete, workable way. For instance, could a wearable cooling system be modified to gradually deliver fragrances instead? And could an innovative ESA patent for a 3D antenna can be printed directly on textiles with conductive ink? The drawing similar to a rose made of concentric little circles that you can see at the knee height (Fig. 1.17) is the configuration of a real antenna created by ESA which currently consists of three-dimensional cones, and that we imagined printed on fabric with conductive ink.

You can foresee the potential applications of this idea on clothing and accessories to amplify the signal of the mobile phone in reception and transmission. But you can also imagine how design can add an aesthetic value to technology. Paradoxically, the idea of the dress is disruptive even without the technology working. In addition to the configuration of the ESA antenna, which is objectively a beautiful pattern, we were inspired by Space Age of 1960s choosing colours like silver and white in all the lunar nuances, looking at materials such as aluminium and reflective surfaces, selecting curved shapes and imagining textiles printed with wonderful pictures taken by astronauts with their camera, looking out of the

---

8https://www.esa.int/Science_Exploration/Human_and_Robotic_Exploration/Couture_in_orbit/The_go-between.
International Space Station (ISS) towards Earth, as well as by satellites, with marvellous colours, patterns and phenomena of light.

In the era of the Space Economy, the designer becomes a producer of ideas and suggestions, a connector between futuristic scenarios and technological development. Though design is possible to create a dialogue between distant productive knowledge to generate innovation, find new applications for space technologies which can be integrated into new terrestrial products to improve the quality of our everyday life and vice versa, to involve companies of the private sector which do not belong to the Space field, but that for their know-how could make a great contribution to the development of human space flights.

1.5.5 Space Technology Spin-Ins Through Design

The second project, a Space Acoustic Object (Fig. 1.18), can be considered an icon of our way of designing between Space and Earth, a project that combines technological research, Space inspiration and aesthetics crossing different fields of applications: this product increases astronauts’ well-being, because it is made of specific material able to absorb the noise when living on board the ISS and creates a dialogue between distant productive knowledge, because of the contamination through distant knowledge, to generate disruptive innovation.
This *Space Acoustic Object*, which I designed together with Benedetto Quaquaro⁹ for Caimi Brevetti, was born by combining the sound-absorbing technology of *Snowsound Fibre¹⁰* fabrics with the textile processing of luxury fashion, giving rise to a rather surprising shape, suggested by the structure of the pleating, which, in addition to being beautiful, increases the acoustic performances due to the compression of the fibres. It consists of a frame in painted tubular steel, a core in fibrous sound-absorbing polyester material and a cover in plissé *Snowsound Fibre* sound-absorbing fabric, as well as in polyester. Physically large, it can be fixed to a wall or ceiling where it creates a dialogue between different production techniques: the sound-absorbing technology of *Snowsound Fibre* fabrics blends with the textile processing of the fashion industry.

Meanwhile, with Thales Alenia Space, we are testing new acoustic products to use them on the International Space Station (ISS). *Pinna¹¹* is a concrete example of how Design can speak different languages and act as bridge between human sciences, technology and beauty.

### 1.5.6 A Bridge Between Human Sciences, Technology and Beauty

In the first chapter, I presented the strategic role of Design for Space underlining its capacity to create disruptive ideas and to be a bridge between human sciences, technology and beauty to generate innovation and increase the people’s wellness, in Space and on Earth, for a more sustainable society.

Design can speak different languages, combines science and beauty, becomes a mediator between space technology and needs through projects that generate new scenarios and new paradigms with which to confront. We have seen in the previous paragraph some examples of what Design can do for Space and that the role of Design for the space industry derives from the need to carry out research in confined spaces and microgravity conditions, performed by human beings, in order to test out new scientific equipment and investigate environmental and behavioural

---

⁹Co-owner of the design studio (a + b) Dominoni, Quaquaro, founded in 2011 in Milan by Annalisa Dominoni and Benedetto Quaquaro with the aim of contaminating research and technological innovation with poetry. Among their latest projects, in addition to a feasibility study of *Preliminary Design Solutions for the Support to New Orbital Infrastructure Recreational/Habitable Configuration* of a new space station for Thales Alenia Space, there are the *Leonardo* trains of the Milan Metro for ATM, produced by Hitachi Rail, and the *Space Acoustic Object* for Caimi Brevetti, both selected by ADI Design Index.

¹⁰The patented Snowsound Fibre technology by the design company Caimi Brevetti is based on soft interwoven polyester acoustic fibres that are inherently fire-resistant. The interaction between the special acoustic fibres and the design of the object and the support system helps reduce annoying acoustic reverberation in rooms, while improving quality of both life and work.

¹¹We named *Pinna* this *Space Acoustic Object* because of its shape: a large three-dimensional fan that resembles the fin of a fish.
dynamics in relation to the crews. We know that we need to increase know-how and experience to design inhabitable systems for long interplanetary voyages and missions, to colonize other planets, starting from Moon and Mars. Design can play a crucial role in making everyday activities much easier in any setting or context, helping us perform more efficiently and also enhancing our mental and physical well-being. The Design discipline studies surrounding reality and interprets all those signals we receive from the environment by focussing on how people live, behave, move, show their emotions and interact with each other. A designer is capable of leaping out-of-the-box and developing a new and different line of thinking translating latent demands, not yet expressed by the people, into projects designed to help astronauts, serving emotional as well as practical purposes.

The task of Design in Space is to be a bridge between science and culture of beauty, finding a common language that can help the hi-tech research and industrial worlds communicate and collaborate. When I tried to define the boundaries of the Design discipline in this first chapter, I affirmed that designers are no longer problem-solvers, asked to come up with solutions, but they are rather problem creators capable of calling into question the world in which we live, exciting and amazing the general public just like artists can do, thanks to their ability to explore the complex and delicate process of interaction between people, objects and environments (Dominoni 2015). If on one side Space Design can increase the comfort and the efficiency when living and working in reduced gravity, exploring and understanding the astronauts and their needs to find innovative solutions to make easier human performances on board, on the other side, it finds new applications for space technology, adding also an aesthetic value to the final project, and drives the development of business models. I would like to conclude this first chapter with a comparison between a picture of the interior of the International Space Station (ISS) as it is today and an image of how it could be the next interior of a new spaceship, looking at example to possible solution for the cis-lunar orbital station Gateway that we have developed inside the 2nd edition 2018 of the Space4InspirAction (S4I) Course of Space Design at the School of Design, Politecnico di Milano, supported by ESA and Thales Alenia Space.

On board the ISS space is reduced to a minimum, each task provides procedures to conduct experiments, but not to adapt optimally to the confined environment, astronauts must adapt along with direct experience in the field. The visual perception of the whole space is quite chaotic, with cables and devices put everywhere, that makes tasks of the crew arduous and more difficult to achieve (Fig. 1.19).

The interfaces of the equipment are for the greater part obsolete if we consider the advances of the technology and above all the development of solutions intuitive and more friendly in order to facilitate the use of many today household appliances of wide consumption on Earth. The experiments, prepared by scientists and engineers who do not bother to make the interface human-friendly, are quite rudimentary “boxes” that must work. Since it is no longer possible to do without machines, we should learn to live with them and communicate with them, imagine a technology with a soul (Norman 2007). Space is a pioneering sector and should be at the forefront in investigating and experiencing the most innovative interaction
dynamics. Instead, the crew lives and works in an environment that is the opposite of what it should be: comfortable, orderly and efficient way. In my opinion, the Space Design’s contribute on the environment would be able to improve the living and working conditions of the astronauts, focusing on the well-being and on the psychological and emotional aspects that, together with biomedical ones, are essential for the success of a mission. The internal volumes of the Space habitation modules should be completely re-designed, maybe alternating large areas with foldable structures that could be transformed according to the various needs of space; mobile and light tools could be fixed at any point of the Space Station to work or rest; interactive screens could cover the instrumentation, while allowing astronauts to interact with them, to achieve an overall visual order and a more clear perception of the whole environment.

What about a new sensitive environment for Space (Fig. 1.20) in which interactions between the astronauts, equipment, machines and spaces are intuitive and requires simple tasks? This idea, described in chapter 4 of this book Space Design Between Research, Project and Education, inside the case study of Space4InspirAction Course, is about a specific design concept for new astronauts’ private spaces. By using soft robots and flexible OLED technology, we could be able to create a comfortable personal space where astronauts can relax, enjoy their free time and sleep. The soft robots are now able to expand themselves six times the starting length giving the possibility to assure astronauts a reactive product that is also able to provide pressure on their body and making him feel more comfortable with microgravity consequences. This is just an example that looks forward the future technology, then slowly but inevitably biological technology will arrive,
perhaps accompanied by devices for perception, memory and even for the increase of muscle strength. We are living now the expansion of an augmented and immersive VR to allow a wider and varied perception of space. Designers are the first to raise the problem because they are the ones to translate ideas into reality and to produce impacts on society.

References

Brown T (2009) Change by design. How design thinking transforms organizations and inspires innovation. Harper Collins Publishers, New York
Clark P (1988) The Soviet manned space program. An illustrated history of the men, the missions, and the spacecraft. Orion Books, London
Di Bernardo G (1997) Vedo la terra azzurra. Editalia, Rome
Dominoni A (2002) Industrial design for space. Silvana Editoriale, Milan
Dominoni A (2005) VEST. Clothing support system on-orbit validation. In: SAE technical paper series, ISSN 0184-7191, Proceedings of ICES 35th international conference on environmental systems, Rome, 11–14 July 2005. SAE Society of Automotive Engineers, Warrendale, Pennsylvania, USA
Dominoni A (2009) Creative network system for innovation. In: Proceedings of INTED 2009. International technology, education and development conference, Valencia, 09–11 Mar 2009. Association of Technology, Education and Development (IATED), pp 002572–002580
Dominoni A (2015) For designers with their head beyond the clouds. Politecnica. Architettura, Ingegneria, Scienze, Maggioli Editore, Milan
Dominoni A, Fairburn S (2015) Designing from the unfamiliar: how designing for space and extreme environments can generate spin-offs and innovative product. In: The value of design
research. Proceedings of EAD 11th European academy of design conference, Paris Descartes University, 22–24 Apr 2015
Dominoni A, Quaquaro B (2017a) Dressing up for space. ROOM. Space J 13, Fall 2017:106–109. The Aerospace International Research Center (AIRC). Publishers Press, Vienna
Dominoni A, Quaquaro B (2017b) Future fashion. Space research inspires innovation in fashion. ROOM. Space J 10, Winter 2017:102–107. The Aerospace International Research Center (AIRC). Publishers Press, Vienna
Dominoni A, Quaquaro B, Pappalardo R (2018) Space design learning. An innovative approach of space education through design. In: Proceedings of IAC 69th international astronautical congress, Bremen, 01–05 Oct 2018
Hufenbach B (2017) Space is open for business. Room. Space J 10, Winter 2017:102–107. The Aerospace International Research Center (AIRC). Publishers Press, Vienna
Jordan P (2000) Designing pleasurable products. An introduction to the new human factors. Taylor & Francis, London
Kline P (1995) Models and personality traits in occupational psychological testing. Int J Sel Assess 3:186–190. https://doi.org/10.1111/j.1468-2389.1995.tb00026.x
Laurel B (2003) Design research: methods and perspectives. MIT Press
Maldonado T (1999) Tecnica e società. I nuovi scenari. In: Riccini R (ed) Il Contributo del disegno industriale, All’insegna del Pesce d’Oro, Milan
Maldonado T (1987) Il futuro della modernità. Feltrinelli, Milan
Norman D (1988) The psychology of everyday things. Basic Books Publisher, New York
Norman D (2007) The design of future things. Basic Book Publisher, New York
Nussbaum B (2004) The power of design. Business Week, May
Rabardel P (1997) Gli strumenti dell’uomo. Dal progetto all’uso. In: Ergonomia, n. 7
Souza K, Etheridge G, Callahan PX (1991–1998) Life into space. Space life sciences experiments. Ames Research Center, Kennedy Space Center 1991–1998
Stuster J (1986) Space station habitability. Recommendations based on a systematic comparative analysis of analogous conditions. NASA Contractor Report 3943. Scientific and Technical Information Branch
UNESCO (2015) UNESCO science report: Towards 2030. UNESCO Publishing, Paris