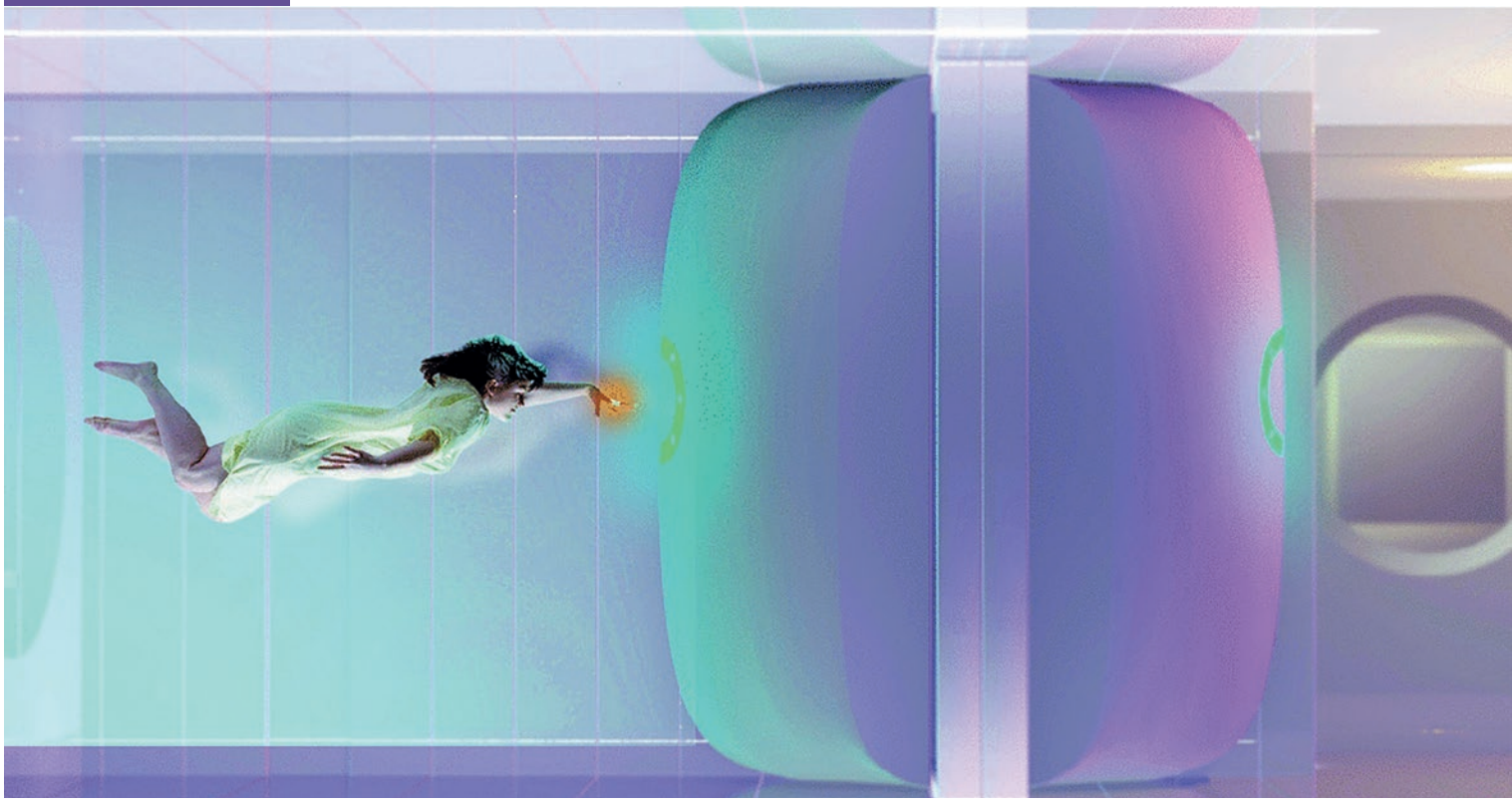


▲ A new sensitive environment for space in which interactions between the astronauts, equipment, machines and spaces are intuitive.

Designing for life in outer space

Many new disciplines are emerging as part of humanity's drive for increased long-term space missions with the ultimate goal of permanent large-scale human habitations in space. One of these newly emerging disciplines, Space Design, focuses on innovation, technology, new materials and wearables to facilitate manned space missions and improve comfort for crews in confined environments and microgravity conditions. Pioneer in the field, Annalisa Dominoni, writes here about her design concepts for habitation modules, devices and equipment to increase well-being and facilitate missions in space.

Annalisa Dominoni
Politecnico di Milano, Italy

Design is characterised by a strong propensity for 'vision'. It is a discipline that can act as a 'bridge' between Earth and space. Crossing different areas of knowledge and fields of applications, there are behaviours and technologies from space that can be translated to Earth (spin-offs) and vice versa - terrestrial technologies and behaviours can inspire new projects for astronauts (spin-ins). Design projects, research and experience are revealing the strategic role of design in space, indicating in which fields it can intervene and in which contexts its competences and skills are most required.

The International Space Station (ISS) is an inspiration, not least because it exemplifies two best practices that we would all do well to aspire to; it is an extraordinary example of sustainability because it functions as a sensitive organism and now recycles up to 100 percent of its waste, and it is the only outpost where crews of different nationalities and ethnicities work together in harmony for a common and shared world project; a case study of a multicultural, co-design and interdisciplinary approach.

▲ T-shirt for Eneide mission's GOAL experiment. The aim of the GOAL experiment was to increase astronaut comfort and efficiency by improving psychological and physiological well-being by means of garment wearability, aesthetics, colours, thermal stability and bodily hygiene on board the ISS.

Two design-based experiments were carried out on board the ISS in the early 2000s. VEST, Integrated Clothing Support System for Intra-Vehicular Activities (IVA) was performed during the Italian Marco Polo Mission in April 2002, and GOAL, Garments for Orbital Activities in weightlessness, was carried out during the Eneide Mission, in April 2005.

VEST and GOAL were the tangible results of a vision for an innovative integrated system of garments to be used during human space flight missions with dedicated characteristics, for microgravity conditions and confined environments to increase comfort, efficiency and wearability.

The aim of the on-orbit VEST and GOAL experiments was to demonstrate that the provision of specific garments to the crew would increase their well-being, not only through the use of specific fabrics for confined environments, able to improve thermoregulation and body hygiene, but also through tailored models designed for the Neutral Body Posture (NBP) assumed by humans in microgravity. The latter integrated re-positionable pockets and restraints to move better through the interior of the ISS, as well as to fix the body when stationary activities are required.

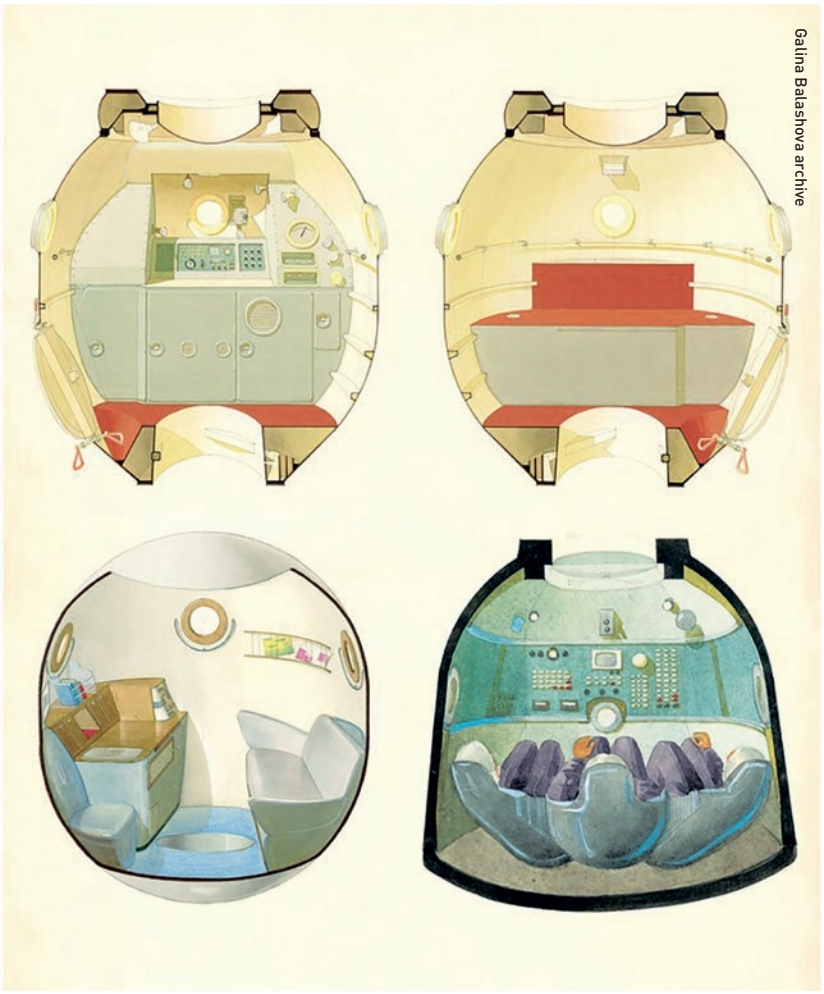
Space is still a pioneering sector, with very high costs, and comfort will only be recognised as an issue after 'primary' health and safety needs have been met

The comfort aspect of the designs, allowing for the NBP, is an example of spin-in whereby cuts and seams used in snowboarding clothing were translated to new space garments because the posture used in performing this sport is very similar to the compact NBP assumed by the body in microgravity with knees towards the shoulders.

The design domain fields for space appear to be huge and variegated, embracing the world of artifacts and human beings. Space is a very stimulating world to explore for a designer who wants to deal with the new and 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 suitable, useful and also beautiful, for a new generation of people who will inhabit other planets.

But this vision is not widely shared by today's space scientific community. Having first and foremost to deal with survival and difficult technical issues, the space industry is dominated by scientists, coming mainly from medicine, and engineers, who seem not to understand the importance of design in increasing the well-being of the crew and, as consequence, the whole mission success. We must consider that space is still a pioneering sector, with very high costs, and

▼ An image of the transposition of the concept design, Integrated Clothing System VEST, created into a collection of clothing worn by the astronaut Roberto Vittori during an experiment on board the Space Station.



▲ Architect Galina Balashova's designs became the defining aesthetic of the Soviet era space programme.

▲ Galina Balashova (left) presenting her designs in Moscow, Russia, in 2017.

By increasing the well-being of the crew, the functionality of the activities and the usability of interfaces and tools for astronauts, we can achieve better goals that directly affect the success of a space mission

comfort will only be recognised as an issue after 'primary' health and safety needs have been met regarding survival in a hostile environment.

When I started in space design over 20 years ago, I was practically alone and I wondered if an architect, a designer, could play a strategic role in designing for space. I started from scratch, finding the right people, agencies and industries in the field of space, and writing papers and participating in conferences in order to build my scientific networks. I also wanted to create a new language to connect human science, technology and beauty, understanding the engineers' perspectives but at the same time looking at the needs of the astronauts. When the results of my first projects that the Italian Space Agency selected, in response to the first call for the Technological Utilisation of the Space Station, convinced the ASI's scientific community to include in their protocols, alongside safety requirements, the concept of comfort and well-being, I considered it a great success.

The acknowledgment of Space Design is largely due to the evolution of strategic programmes for interplanetary exploration in which humans will spend increasingly longer periods of time in reduced gravity and extreme conditions and will need a higher level of comfort. It is certain today, with the experience collected over more than twenty years on board the ISS, that by increasing the well-being of the crew, the functionality of the activities and the usability of interfaces and tools for astronauts, we can achieve better goals that directly affect the success of a space mission.

We have to consider also that now, and in the future, not only super-skilled astronauts with a strong training behind them, but also researchers, scientists and, not least, tourists, will have the chance to experience space travel. This means that the space environment must be totally rethought and redesigned according to the physiological and psychological needs of space travellers, as well as objects, facilities

and tools for daily life activities which should make life in space easier, trying to reduce the difference between living in space and living on Earth. For these reasons, the role of Design in Space is important.

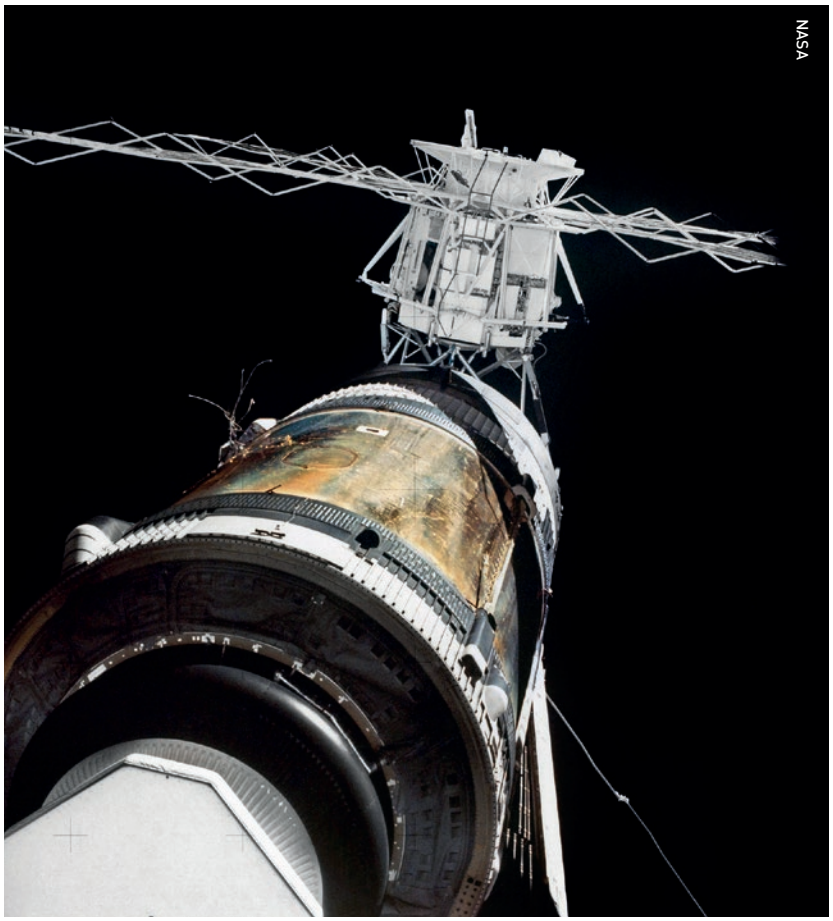
Pioneering architects and designers have introduced, with difficulty, innovations related to comfort, beauty, perspective and the use and interpretation of colours. Russian architect, Galina Balashova's watercolour designs defined modules and furniture for the interiors of Soyuz, as well as the Mir and Salyut space stations. French-borm American industrial designer, Raymond Loewy's designs for Skylab emphasised efficiency and psychological comfort and, perhaps most importantly, he designed a window which, despite initial resistance, was installed in Skylab.

Despite the first timid steps of NASA towards industrial design there is now the promise of greater involvement of architecture and design in the next human space exploration programmes. The launch of SpaceX's Crew Dragon spaceship on 30 May 2020 showed that space architecture and design already drive the private space industry. SpaceX wanted a voyage in Crew Dragon to be an enjoyable experience for its passengers. The black-and-white ultramodern design of the capsule is visually stunning and looks like it came straight out of a science fiction movie.

Design is therefore a discipline and profession with a great capacity to answer to the needs of the human being and the environment, as well as those of the industry, and it has the power to influence and change the behaviours of the society. The products which have more success are those able to arouse emotions and become a source of inspiration for people. The environments which attract 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 shapes and light that imitate or evoke nature.

In space, environmental conditions affect life and consequently, the design of objects and tools. Space design offers a project territory outside the rules that we are used to applying on Earth, and the designer's experience is freed from conventional references to enrich itself with new points of view. The task of the designer for space is complex and involves being able to predict and imagine how astronauts live and move in confined environments and in microgravity, conditions that are not part of our common experience. The environments also force astronauts to live in isolation without natural environmental stimuli such as natural air and light, without privacy, or the possibility of using water for washing, while the body undergoes strong physiological, postural, and even perceptive alterations.

If we experience confinement on Earth – and lately, thanks to COVID-19, most of us will have done to some extent – we will confront some of the problems that astronauts face, such as the stress generated by the impossibility of 'getting out' or, in extreme cases, the alteration of circadian rhythms due to the lack of natural light. Space designers must use their experience and imagination to envisage what the project they are designing will be like, how the astronauts will be employed and especially how they will react to their responsibilities and environments. This has led to a system of use and gestures encoded in a specific methodology called Use & Gesture Design (UGD), in which the usage scheme of an object must be specified simultaneously with the design of that object.



▲ Raymond Loewy's design firm was commissioned to make Skylab habitable. His insistence that windows were added was initially resisted but the space station was eventually equipped with one, a feature the astronauts rated "spectacular". He also advocated the use of bright colours as a way to prevent visual boredom.

Space architecture and design already drive the private space industry

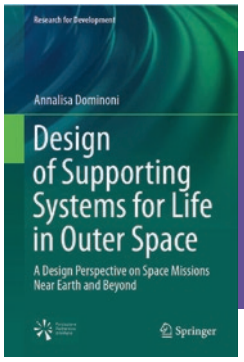
Design enriches technology with an aesthetic value by becoming a mediator between science and beauty

Italian design style

The challenge is to transform extreme environmental conditions from a limiting factor to an opportunity and, for example, to try to design environments and objects that take advantage of microgravity, rather than just being subject to it. It might also be advisable to think of environments for the amusement and entertainment of the crew. For example, designer Benedetto Quaquaro and I recently led and developed a project commissioned by Thales Alenia Space for a new spaceship. It looked at a recreational space, with more room for astronauts' entertainment, aimed at emphasising the Italian style by Design and also introducing proposals for fashion and product design elements in the interior's habitat.

'Re-configurability' was the key to gaining internal space and flexibility. The aim was to increase the well-being of the crew optimising use of the interior habitat and the expansion of the living room to add a new recreational area. The identification of crew systems/outfitting items (e.g., flexible partitions) are considered very important to enhance space re-configuration for crew privacy and socialisation aims. The racks on the ISS are replaced by easily removable cylindrical structures that can slide and transform themselves into 'tailored chaises longue' for a free room optimisation. The cylinders run on tracks serving as soft surfaces of support, as well as shelves, or removable containers. The internal space of the cylinders is foreseen for stowage of equipment and tools.

▼ Preliminary Design Solutions for the Support to New Orbital Infrastructure Recreational/Habitable Configuration designed by Annalisa Dominoni and Benedetto Quaquaro for Thales Alenia Space.



This article is based on extracts from Design of Supporting Systems for Life in Outer Space by Annalisa Dominoni (Springer International Publishing 2021, ISBN: 978-3-030-60941-2).

Colours and lighting modulation is a positive physiological feature to foster relaxation during recreational activities and a large window area also enhances the crew's visual experience of the surrounding space. This characterisation of the recreational section by light and colour shows how design expertise can change the environment, even if extreme, into comfortable, beautiful and more efficient solutions.

Architects and designers have been making important and fundamental contributions since the very beginning of human space exploration to increase the conditions of crew comfort – which directly reflect on greater operational efficiency and therefore on the success of a mission – and, above all, to create environments and objects that are not only functional, but also beautiful to look at and to live in/with. Design enriches technology with an aesthetic value by becoming a mediator between science and beauty and keeping man and his needs at the centre of the design process (User Centered Design, UCD), for a new interpretation of beauty, which also says "take care". In space, this challenge takes on greater dimensions and stimulates the designer to transform extreme environmental conditions from limits into opportunities, and demonstrate how the discipline of design is able to generate innovation thanks to a strong capacity for 'vision'. ■

About the author

Annalisa Dominoni is an architect, designer and professor at Politecnico di Milano, Italy, where she earned a PhD in Industrial Design in 2001. It opened up a new realm of research and experimentation into Design for Space & Extreme Environments. She has developed new design concepts for habitation modules and equipment to increase astronaut well-being and facilitate missions in space, collaborating with ASI, ESA, and NASA and a variety of companies in the private sector. She was the Principal Investigator of the VEST GOAL experiments on the International Space Station. In 2016, she and Benedetto Quaquaro created the Master's Degree in Product Design for Innovation (Space4Inspiration), the first course of its type in the world recognised and supported by ESA. She has chaired international symposia and workshops on design for outer space and has written books and published numerous papers in scientific journals. She has been the recipient of several prestigious awards, including ADI Design Index and Premio Compasso d'Oro.