Common Sense Human Environments

Dion Moult

February 14, 2015

Abstract

This article explores how human comfort is prioritised and satisfied in standalone artificial environments.

1 A miracle of architecture

In 1998, NASA (USA), RKA (Russia), JAXA (Japan), ESA (Europe), and the CSA (Canada) joined forces to construct the world's most expensive cross-cultural project to date. An investment upward of 150 billion USD developed an inhabitable structure the size of a rugby field (110m in length) moving fast enough to experience 15 sunrises and sunsets each day in low earth orbit. It would fend off a hostile natural environment and house a complex programmatic mix of residential, recreation, gym, clinic, factory, science lab, transport hub, education and diplomacy. This structure is the *International Space Station*.

Hailed as a miracle of engineering, the ISS allows life in an environment where nature murders rather than nurtures. However, the ISS is not merely a feat of engineering. Once mid to long term human habitation became an issue, engineers were deemed unable to form satisfactory solutions for the *quality* of life. Architects were called upon for their trained abilities to juggle thousands of physical parts, mutually conflicting stakeholder requirements, commune with diverse specialties, and "create order out of chaos" all with a focus on human needs[2].

In 2002, the Millennium Charter defined the role of a space architect to design an artificial environment within a surrounding that would otherwise compromise the *firmness*, *commodity* and *delight* of a building. Although similar to an architects role on earth, there is one difference: there is little positive externality in the surrounding environment. Whereas Earth architecture can use natural scenery and social constructs to excuse a substandard internal environment, in space, *there is nothing but the architecture*. With limited resources, no vernacular to build upon, and an ethical responsibility to design well, space architects are forced to start from scratch.

Space architects can no longer take the environment for granted and instead have to seriously question and answer what basic elements we actually need. They have to reinvent natural habitats, redefine context sensitivity, and rebuild social infrastructure. These are simple questions with not so simple answers: what we need to survive, what makes us feel comfortable, what makes us feel loved, what inspires us, and what we hold dearest. These questions span from the most basic human needs to pushing the boundaries of how humanity percieves itself. The ISS—a design which has tackled these questions—isn't merely a miracle of engineering: it is a *miracle of architecture*, and is worth learning from.

2 Don't die

In 1971, the RKA launched Salyut 1: the world's first space station. Three cosmonauts would stay in a ø4x20m cylinder for a month, during which a variety of biological indicators would be measured as they performed daily scientific tasks[3].

After a successful dock, it took 23 days for the cramped setup to settle into a routine. Soon after, a retrospectively harmless electrical fire broke out. Even after eliminating the threat and being made aware of its harmless nature, the event had raised enough alarm to shatter the crew's pioneering spirit. Despite a mere seven remaining days, they abandoned the mission for an emergency ride back home. Our last records are of them overjoyed and joking with each other on the return flight, and so it was a shock for the successfully landed capsule to reveal them dead in their seats.

Their deaths were due to a pressure related technical fault. Similar to how building codes are formed, this disaster is the reason why astronauts now have to wear pressure suits in transport. However, achieving survival is a straightforward engineering exercise. For architects, this event set the first clear human priority for all astronauts: *don't die.*

3 What is comfort?

3.1 Non-architectural comfort comes first

The next opportunity for redesign occurred in the Skylab space station. As there was little guiding precedent, architects consulted astronauts on their needs. With the emphasis on survival, the feedback given was simple: "decor is frivolours ... the purpose of flying is to achieve the mission objectives—anything else is a distraction"[4]. NASA disagreed with this perspective, stating that human factors and human experiences in space were as important as the mission itself. With the dominant engineering culture, the ideas were difficult to propagate. However, Skylab designers still incorporated basic living standards[5]. Skylab featured better hygiene systems, personal storage space, and a dedicated wardroom for relaxation. Despite the upgrades, astronauts were dubious about the efficacy of the architectural changes, and even rejected an inbuilt media entertainment facility. Instead, they requested non-architectural improvements, such as more edible food, music players, and books.

The concept of architectural comfort was only better defined later, when astronauts staying in Skylab for prolonged periods of time complained about the lack of acoustic and light isolation, and limited ventilation control. But these complaints were petty compared to a famous journal entry by cosmonaut Valery Ryumin, who stayed in the Salyut 6 space station: “All the conditions necessary for murder are met if you shut two men in a cabin measuring 18 feet by 20 and leave them together for two months.”[6] Design priorities were evolving into a multi-dimensionsal consideration, and space architects realised that you couldn’t rely on humans to adapt to a foreign environment, even given its novelty context. This was the beginning of an important design realisation: *the environment has to adapt to us, not the other way around.*

3.2 Types of comfort

About this time, Russia had built Mir, the 8th space station. Although Mir had little architectural change apart from increased internal volumes, it did accumulate articles of every day life: photos, children’s drawings, books, and instruments. A cosmonaut named Valeri Polyakov—the world’s longest space resident—has lived a total of 437 days on-board. He is both a pioneer in proving long-term habitability and a test subject for studying long-term discomfort. Specifically, he identifies four types of discomfort:

1. Space discomfort: micro-gravity and its physiological changes (mainly metabolism and proprioceptive processes)
2. Architectural discomfort: confinement, isolation, unnatural ventilation, elevated noise levels
3. Task discomfort: elevated physical and mental workloads
4. Social discomfort: lack of privacy, isolation from family and friends

The negative impacts of these discomforts are measurably paramount during the first 3 weeks on-board (similar to the time taken for a routine to form on Salyut 1) and during the first 2 weeks back on Earth. However aside from these 5 weeks—4.8% of total space-time—measurements indicate an “impressive stability of mood and performance” and “no long-lasting performance deficits at follow-up assessment”[7]. In short, overall mental and physical needs can be maintained—even if the environment isn’t designed for comfort—as long as there is a minimum volume per person. This minimum volume is identified at $\sim 100m^3$ per person, and is used for all stations after the Salyut 6[8]. Mir had proved the strength of human attitude in overriding architectural failure[9].

Meanwhile, NASA pitched the idea of human comfort as an engineering exercise. Architects would identify the more abstract human needs and reduce them down into tangible and quantifiable factors for the engineers to help understand and optimise. For example, whilst basic survival needs were unchanged, other concepts were introduced, such as: “spatial perception and mobility, anthropic ergonomic utilisation, exterior observation, and equipment rationalisation”, and "recreation spaces and communal organisation". Together, this formed a framework of nine concepts that were used to rigorously test and document the quality of future space station designs.

Over time, this iterative process formed a documented set of quantitative requirements and qualitative recommendations known as the NASA Space Flight Human-System Standard[10]. Split into two volumes, the second (Human Factors, Habitability, and Environmental Health) uses politically correct terminology to describe how to "maintain basic physiological and psychological performance"[11]. Although it reads similar in structure to everyday building regulations, it delves into a level of detail on what makes a desirable environment that makes architects realise how much we take for granted.

For example, the volume contains expected clauses about egress and fire, and covers environmental properties such as optimum thermal, humid, acoustic and illumination qualities. The not so obvious include the aesthetics of potable water, the need for a fridge to drink cold drinks, for food to be presented in an appetising manner, for people to wear clothes they want to wear, and to privately inspect one's body. Personal space is given a volume, isolation has a duration, and a circadian rhythm is enforced. Details go down to rounded edges/corners, the strength and capabilities of our fingers, and the legibility of material schemes in understanding where we are and what we are facing. Each clause is accompanied by a rationale to explain why it is important. This allows architects to appreciate design subtleties such as the glare of a vital status indicator in a small space when trying to sleep, the annoyance of a direct airflow from a ventilator, or even the sharp ripping noises of Velcro in the middle of the night. The document states the blindingly obvious: that people like varied food, that people don't like to sleep at their office, and that people don't like sharp things. What might sound like axiomatic generalisations are actually vital to the success of these design spaces.

The ISS has already incorporated many of these basic needs, and the results are immediately obvious. The crew is able to spend more time living and less time adapting. There is little fear of death, and people have made themselves at home. A mere year after the ISS was operational, the time was right to admit the first space tourist: *the environment had adapted to the people.*

3.3 Comfort case studies

Despite the incredible progress in under 50 years, we have merely scratched the surface of designing comfortable environments. Requests from tourists and expedition crews show that there is still a need for an improved living environment, especially for longer-duration missions. In particular, they cite crew isolation, the ability to personalise the space, and individual self-expression.

To solve these issues, we can use isolation simulators, such as submarines, Arctic stations, and artificial ecosystems. Examples include the ISEMSI-90 (Isolation Study for the European manned Space Infrastructure), its successor: EXEMSI-92, HUBES-94 (Human Behaviour in Extended Spaceflights), Biosphere-2, BIOS-3, and FMARS (Flashline Mars Artic Research Station).

These give insight on the psychological reactions to long-duration isolation and potentially stressful fieldwork in artificial environments[12].

These tests reveal that non-architectural changes such as varied food and exercise are usually best at tackling these more abstract human needs. Food and exercise here is not just to keep healthy, it acts as a catalyst for social activity and reliever of isolation-induced stress. Architecturally, the crew only seem to—at a minimum—require physically and acoustically separated private quarters which have facilities for interacting with select friends and family.

Architectural changes that go past the minimum can be seen in existing artificial environment stations, such as the Halley VI Artic Research Station[13]. In the station, bedrooms are 2.5x3.6m, designed to be "homey", comfortable spaces that promote emotional well-being without being so comfortable that residents hide away from the community. Each has windows for natural light and daylight-simulation lamps. Space personalisation is done through pin-boards and storage alcoves behind the beds for personal possessions. A warm colour palette is selected by a colour psychologist to minimise seasonal affective disorder. Fully structural perimeter walls allow structure-free interiors for reconfigurable layouts, and discourage needless partitioning to boost social interaction. Even during brutal outdoor activity, hardened windows are available in all rooms to still provide knowledge of the ongoings outside and a psychological connection to the exterior. Circulation spaces are designed to be generous both in width (1800mm) and height, allowing for accidental meetings, and reducing the "rat-in-a-maze" perception. Strong colours are used to increase programmatic legibility and improve orientation. Each module also has a "feature view", an opening up to a spectacular snowy landscape which punctuates the journey between modules. Despite the repeated standard module design, a special larger central module is designed with clear materiality differences to be recognised as a hub and primary destination. This materiality change consists of a warm pallete of timber heavy interior design and carpeted, lounge-like furniture. It also includes heavy "graffiti-like" photo pinups of all the past visitors, which makes for excellent story-telling.

Despite the scientific orientation of the habitat, the central module is designed as a rest and recreation area, including spaces for saunas, gyms, music rooms and group dining. The central module is also separated into quiet and noisy zones, with areas for retreat that offer spectacular natural views. At the very heart, the central module features a hydroponics installation, to "provide the refreshing sight of greenery at the heart of the station—an unexpected moment of spatial drama". Physically centered in the station's configuration, the central hub physically separates the sleeping and working areas which encourages daily circulation through public space.

Each of these design characteristics have developed organically out of the needs of a community living in an extreme environment. While it make take time for technological and economic factors to allow these human upgrades to occur, and it is hard to pinpoint individual elements that contribute the most to communal living, the path ahead seems pretty clear.

4 Surpassing comfort

The Earth in all its complexity has far surpassed our basic social, environmental, and physical needs. It has brought upon us inspiration, motivation, and abstract feelings of wonder and delights that would be fruitless to quantify. These concepts are tricky, individual, highly subjective, and very difficult to pinpoint in architecture. However, one thing is clear: the ISS has, and is continuing to make big changes to the way humanity perceives itself. The ISS is easily explained in practical terms, but it offers something that goes beyond any commercial or scientific utility.

Canadian astronaut Chris Hadfield says "Station[sic] is so much more than some remote laboratory where some small number of people and robots are doing something that no one knows about. Station is so much more than that. It is our first great human outpost in space. It is our way of seeing our world that's unprecedented in the history of the human species. It's an amazing platform for human self-discovery."[14]

For architecture to make a contribution, this platform needs to grow, and it is: stations will soon be available to much more than the select billionaire tourists that have visited the ISS. The commercial industry is just beginning, with Genesis I and II paving the way for the Bigelow Commercial Space Station, which will again highlight the focus on human experience. This new space station features an inflatable endoskeletal structure that allows large open spaces and more complex internal layouts similar to open-plan buildings. Volume-wise, it is an incredible leap forward in station design potential[15]. In addition, the Genesis stations are launched with various life-science projects, investigating the possibilities of nurturing non-human life on-board the station.

This initiative is just one sign of what the Federal Aviation Administration predicts to be billion-dollar market by 2030. A mere 4 years since the prediction, government agencies and Virgin Galactic have collected in excess of 300 million dollars, plus other unmeasured private agencies. With surveys suggesting that the primary barrier to occupation and tourism is cost, we can expect an explosion of people to join the industry as the commercial startups push price ranges down the income brackets.

These initiatives grow a space industry and infrastructure that allows for larger and more complex volumes, the supply and demand of communities, and the introduction of ecosystems. This infrastructure will remove many of the constraints that have forced space architects to start from scratch. Perhaps at that point, architects can return to "design not from rigorous analysis...but from a process which is creative and individual rather than rational"—but to get to that stage, it is not without understanding the fundamentals of what humans truly enjoy.

Space architecture is not about space. It's about humans.

References

[1] Abraham Maslow, "A Theory of Human Motivation", Psychological Review 50 (1943), 370-396

[2] Brent Sherwood, "What is Space Architecture" in *Out of this World: The New Field of Space Architecture*, (USA: American Institute of Aeronautics and Astronautics, Inc., 2009), 3

[3] David M. Harland, John Catchpole, "The world's first space station" in *Creating the International Space Station*, (UK: MPG Books Limited, 2002), 13

[4] David M. Harland, John Catchpole, "Skylab" in *Creating the International Space Station*, (UK: MPG Books Limited, 2002), 26

[5] Douglas Aircraft Company Inc, Life Support and Environmental System in *Manned Space Laboratory Requirements and Conceptual Designs for Mid-60s Deployment*, 1962, 109

[6] Jack Stuster, "Group Interaction" in *Bold Endeavors: Lessons from Polar and Space Exploration*, (USA: Naval Institute Press, 2011), 165

[7] Manzey, D., Lorenz, B., & Poljakov, V. Mental performance in extreme environments: Results from a performance monitoring study during a 438-day spaceflight, Ergonomics, 41 (1998), 537-559.

[8] Kriss J. Kennedy, "Vernacular of Space Architecture" in *Out of this World: The New Field of Space Architecture*, (USA: American Institute of Aeronautics and Astronautics, Inc., 2009), 10

[9] Reinhold Ewald, "The Right Staff: The Human Component for Long-term Spaceflight" in *Beyond the International Space Station: The Future of Human Spaceflight*, (Netherlands: Kluwer Academic Publishers, 2002), 30

[10] NASA, NASA-STD-3001 NASA Space Flight Human-System Standard, Volume 2: Human Factors, Habitability, and Environmental Health, 2011

[11] NASA, Human Factors Engineering Standards at NASA, accessed November 2014, https://archive.org/stream/nasa_techdoc_20080010655/20080010655#page/n0/mode/2up

[12] Susmita Mohanty, Susan Fairburn, Barbara Imhof, Stephen Ransom, Asdreas Vogler, "Human-Space-Mission Simulators" in *Out of this World: The New Field of Space Architecture*, (USA: American Institute of Aeronautics and Astronautics, Inc., 2009), 333

[13] Hugh Broughton, "Halley VI Antarctic Research Station" in *Out of this World: The New Field of Space Architecture,* (USA: American Institute of Aeronautics and Astronautics, Inc., 2009), 363

[14] Joel Achenbach, "The Skies. The Limits", The Washington Post, September 14, 2013

[15] Erik Seedhouse, *Bigelow Aerospace: Colonizing Space One Module at a Time*, (Switzerland: Springer International Publishing, 2015)