Space 2006
19 - 21 September 2006, San Jose, California

AIAA 2006-7331

# Habitation in Space: The Relationship between Aesthetics & Dwelling

Elizabeth Song Lockard[1]
*University of Hawaii, Honolulu, Hawaii, 96813*

**[Abstract] As goals in Space exploration expand from short-term scientific missions to the eventual colonization of the Moon and Mars, new 'human factors' criteria need to be developed to address a different set of physical and psychological requirements. The designing of living conditions for long-duration stays should take into account quality-of-life considerations, as well as those of survival and functionality. To that end, this paper discusses the necessity of an aesthetic perspective in this process.**

## Nomenclature

*space* = as used in an architectural sense
*Space* = as used in an astronautical or cosmological sense; also referred to as 'outer space'

## I. Introduction: Why is Aesthetics important, and what role does/should it play in Space?

Aesthetics is a field that communicates to us through the senses, but entails much more than what is merely pleasing to them. Aesthetic considerations are not simply a matter of superficial prettification, like wrapping a stylistic 'skin' over the structural and technical 'bones' of a building. The role of aesthetics, in communicating through our senses, is to help us assimilate our empirical world by giving meaning and order to it. This function, as I will elaborate on later in this paper, will be critical to our longevity in Space. And this is why for any endeavor involving humans, aesthetic considerations should be an essential part of the overall design process. If aesthetic criteria are then thought of as substantive rather than stylistic, the design process should in turn be integrative rather than applied. Therefore, though life safety concerns take precedence over quality-of-life issues, both must be considered simultaneously, rather than sequentially.

Aesthetics, along with structure and utility, are the three components that comprise the field of architecture.[2] [fig.1] Whereas the requirements of structure are absolute and independent of the perception of the user, the other two are anthropocentric: utility addresses the physical needs of its users, aesthetics responds to the psychical needs. It is a commonly accepted notion that form should be subservient to, and primarily determined by, function. But this principle ignores the importance of human perception and the meaning that forms convey to us. While the structural character provides safety and shelter, and the utilitarian character allows us to function, the aesthetic character of a space is what moves us; it establishes a psychical connection with our external world, and gives us a sense of well-being.

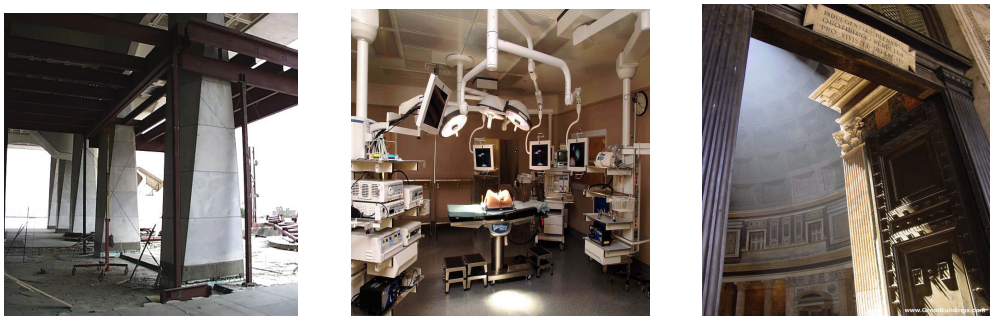

**Figure 1. The components of architecture: structure, utility, aesthetics**

[1] Ph.D. Candidate, Department of Political Science, Saunders Hall, AIAA Student Member
[2] Based on the Vitruvian triumvirate of firmness, commodity, and delight

In order to design habitats in Space to better meet our psychical needs, especially given the extreme differences between the physical conditions of Earth and those of Space, we must first understand on the most fundamental level how humans perceive and experience their surroundings. How do the issues that are unique to living in Space – various gravity conditions, times cycles, lack of natural light, cosmic radiation, soundlessness, immense distances, temperature differences, various atmospheric conditions – come to bear on the psychical condition of humans over a prolonged period of time, and how can we respond to them through aesthetic means, so that they are not simply obstacles to our survival, but rather aspects of a new way of dwelling? Rather than simply adjust or extend existing Earth paradigms, entirely new paradigms must be developed (or perhaps old ones revisited). If we first understand the basis for how we assimilate our surroundings, we can better anticipate solutions for unknown or unexpected conditions. As we embark on an era of longer-duration space travel and eventually habitation, aesthetic criteria will play a more significant role in understanding and developing the human-environment interface.

## II. Perception: Empathy and Abstraction

There is the world we inhabit physically, but the world that each of us creates for ourselves perceptually is a synthesis of empathy and the alienation, reflecting the degree of psychical connection or detachment we feel towards our empirical world.[3] Empathy is the capacity to which we can connect to something or someone outside of ourselves. We have empathy for things that are familiar to us, and thus resonate psychically within us. It is a condition of perceptual interiority or inclusion. Conversely we tend towards alienation when faced with things over which we feel we have no knowledge or control, which are foreign and thus perhaps threatening to us. The act of abstraction is therefore our response to impose order on or to make sense of alien (or alienating) external phenomena through aesthetic manipulation; hence abstraction is a condition of perceptual exteriority or exclusion. Empathy is the act of remembering; abstraction is the act of imagination: this dichotomy between the familiar and the alien will become even more polarized when we leave the confines of Earth for unknown territory.

When we are lacking the conditions that facilitate those empathetic connections, we become nostalgic and melancholy for the past and things that are familiar to us. On the other hand, when we are lacking the conditions that demand the use of our imagination to satisfy our abstractive urges, then we become disengaged from the world around us, and our realm of perception becomes increasingly insular and solipsistic. In short, we need both a balance of passive comfort, and active challenge in our living environments. Because Space lies wholly outside the realm of collective human experience, it relates far more to our abstractive capacity than to our empathetic one; hence, re-establishing these empathetic connections will need to be given careful attention in the design of our living habitats in Space. This is not to advocate that we should attempt to re-create terrestrial living conditions in Space; this would be an oversimplification of the problem. If we examine our psychical needs from a humanistic perspective, then we can explore solutions that transcend issues of race, gender, age, as well as the actual environment itself.

An example of the dialectic between our empathetic and abstractive tendencies can be clearly seen in art [fig.2] and architecture: the use of organic materials and forms, along with a strong connection to the earth upon which it sits, appeals to our empathetic sense [fig.3], whereas manufactured materials and geometric forms, with little acknowledgement of their context, tap into our abstractive sense. While the former feels "home-grown", the latter seems to subjugate its landscape. [fig.4] One is warm, tactile and inviting; the other is cold, exacting and detached. (These are however, value-neutral adjectives; from an aesthetic point of view, it could be argued that both examples provide the appropriate iconography.) Rather than developing altogether new technologies, the use of primitive/terrestrial models in Space may prove practical in addressing this issue as well as others.

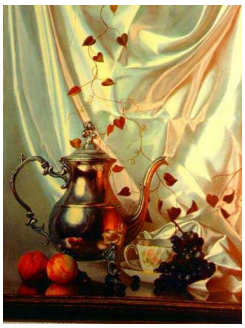


**Figure 2. Still life with fruit**

**Figure 3. Organic architecture**

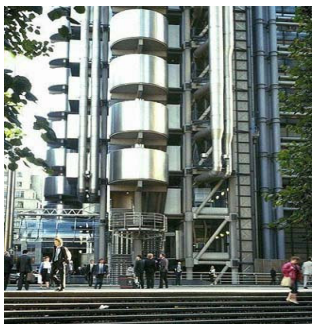

**Figure 4. Synthetic architecture**

[3] From Wilhelm Worringer's doctoral dissertation, later published as *Abstraction and Empathy.*

## III. Perceptions of Space: Cultural Perspectives

How the concept of 'Space' is translated in different languages, and the metaphors associated with them, say much about the degree to which different cultures empathize with, or feel alienated by it. Our various attitudes towards Space profoundly influence how will be able to adapt to life beyond Earth.

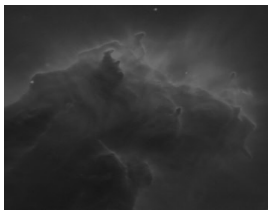

**Figure 5. The Void**

*Space as no world:* One of the words for 'Space' in Chinese for example, is 'tiān kōng', which literally translates as 'empty sky', signifying that Space is devoid of any presence within it. In Vietnamese, the word 'không gian' makes the even stronger assertion of Space as nothingness. [fig.5]

**Figure 6. The Wild West**

*Space as the new world:* The Americans, whose history and cultural spirit is founded on pioneerism, conceive of Space as something to be explored and conquered. [fig.6] The use of the term 'outer space' in the English language clearly indicates that Space is viewed as an entity distinct and remote from ourselves and our cognitive sphere.

**Figure 7. Japanese tea room**

*Space as the same world:* The Japanese on the other hand, see themselves as a part of the universe, not as distinct from it. Space ("uchuu") is viewed as if from the inside rather than from the outside, as a member rather than as an observer. The Japanese teahouse [fig.7] serves as a figurative microcosm of the universe, in which the architecture and tea ceremony symbolize respectively the realm of nature and human interaction contained within it.

**Figure 8. Escher's 'Liberation'**

*Space as the free world:* The Russians' attitude towards Space is reflected in the title of Tsiolkovsky's treatise, "Free Space", in which Space is benevolent, and weightlessness is viewed as a liberating condition. [fig.8] For Tsiolkovsky, Space was not a hostile or threatening place; on the contrary, it was where humanity would not only evolve to insure its own survival, but ascend to greater happiness.

*Space as other-world:* Metaphysical meanings have also been ascribed to Space. In religious and spiritual contexts, Space and the universe represent a transcendental state, possessing an other-worldly or ethereal quality. [fig.9] The notions of Heaven and Hell directly relate to perceptions of Space and gravity: 'the starry heavens above' (in the sky, free of gravity) and 'firey hell below' (at the core, the source or center of gravity).

**Figure 9. Heaven**

## IV. Geography of Space

*"Place is security, space is freedom; we are attached to one and long for the other."* --Yi-Fu Tuan, geographer

Once humans have discovered space—whether that be open space or outer Space—we immediately attempt to humanize it, or in other words to create a sense of 'place'. The irony of this however, is that in so doing we annihilate the very thing we long for. Outer Space – the ultimate "great outdoors" – is a metaphor for both chaos and

freedom, because it represents the realm of the undiscovered and unknown. As such, Space is alien and thus appeals to our abstractive tendencies.

Place, on the other hand, is space to which meaning has been ascribed, therefore appealing to our empathetic tendencies. If Space is an abstract concept, then place is what we know through experience. Space has neither location or context, nor scale or reference; whereas place does. Until we can conceive of 'where' something is, it is not yet a 'place'. Moreover, the extent of our perception of place is defined by the limits of our senses. I can see the Moon, so I have a sense of where it is although I can't describe its location. Though millions of miles away, I know where certain stars are in the night sky because I can apprehend them in reference to other stars or constellations. In fact, I have a more direct experience of those entities, despite their distances, than I do of Antarctica, which is in fact, much closer, but not visible to me. I can imagine, as I stand on the shores of Waikiki Beach, that if I face due south, Antarctica is directly in front of me, but because I don't immediately perceive it, it remains more abstract to me than the Moon. For the same reasons, the Moon feels rounder to me than the Earth does, because I don't experience the latter in a scale that would convey its 'sphere-ness' to me. In addition, the transformation of space into place is contingent upon the human presence, even ephemerally. The televised scene of Neil Armstrong's first steps on the Moon and the planting of the American flag holds immense historical meaning to us, and only this symbolic gesture was sufficient to transform the Moon into a place. [fig.10]

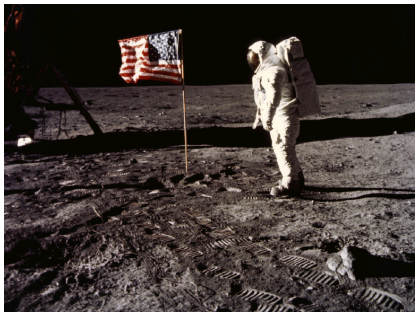

**Figure 10. The Moon becomes 'place'**

As we eventually establish settlements and venture out even further into the solar system, our definition of outer Space will change accordingly. Lagrange points, the Moon and Mars – in becoming gradually more familiar to us through direct experience – will no longer be considered "outer" Space, but rather as places within our perceptual proximity, which in turn will push the perceptual boundaries of outer Space further beyond. The 'new' outer Space will then be referenced in relation to inhabited loci in the inner realm of Space, much in the same way we reference the Moon and Mars in terms of their distance and size to Earth.

The process of measuring distance and time are ways in which we give order to our lives. Space is quantified by applying both scale and reference. Humans developed various methods of mapping – i.e. landmarks, topography, axes, grids, etc. – to establish relationships between their immediate habitat and their remote surroundings. Likewise, migrating animals create their own cognitive maps of their habitat by inspecting the surrounding territory; in this way they establish the boundaries of their domain. This process of developing relationships within and between our surroundings is what gives it meaning to us as well.

One of the challenges of living in Space is that the scale of distances is too vast for humans to comprehend on a visceral level. As a result, this relationship of place to its greater surroundings becomes perceptually inaccessible. This is why views of the Earth from Space stations have had such an enormous psychological impact, not just because it is simply pleasant to look at, but because it sensorily re-establishes a connection to a place that is not only familiar to us but also gives us a sense of our own relative location (context). In orbit how do we mark the path we have traveled, or convey physical location? There are neither landmarks nor changes in the topography nor any conditions where one can identify a place or context. In order for humans to understand our place in our perceptually expanding universe, new methods of mapping are required. The forces of gravity on Earth restrict us to occupying space in a planar, or two-dimensional fashion. In the absence of gravity, space can be occupied volumetrically; thus the mapping of outer Space will necessarily become three-dimensional.

## V. Concept of Home and Dwelling

If Space represents chaos, freedom, and mystery, then home represents order, security, comfort, and familiarity.

The house is a physical structure with a fixed location, but the home is a place defined by individual perception. Because the notion of place is a human construct, it is the *act* of dwelling that transforms space into place. Our house is the physical mediator between us and the space beyond it; but our home is the psychical one. A shelter that ensures survival by providing physical protection from the outside is still a house; a dwelling that makes us feel safe and gives us a sense of well-being is a home. The home is the origin of our empathetic connection to the world beyond. In contrast, Space is the origin of our alienation. As 'emigrants' from Earth, there is little yet that we can connect to empathetically in the realm of Space; thus re-establishing these fundamental psychical connections--creating a sense of place in Space--will be a critical goal of the habitat architecture.

On the most seminal level, architecture responds to our empathetic and abstractive needs through establishing interiority and exteriority in our living environment. Each passage through a door is a transformative one that requires a cognitive shift to adapt to different spatial conditions. Each gaze through a window is an act of assimilation in the world, a cognitive portal that recalls our relationships to people, objects, and places outside of ourselves. These are some of the elements that can provide those essential psychical connections to the outside world. [fig.11] Living in confined environments however, severs our relationship to the external world. In Space, humans have no way to physically experience/inhabit "the outdoors". Without this relationship, a confined environment will never be fully experienced as a habitat but rather as a place of incarceration. In order to develop an empathetic connection to Space, we need to experience it directly. Our understanding of home is reinforced by our experience of being away from it.

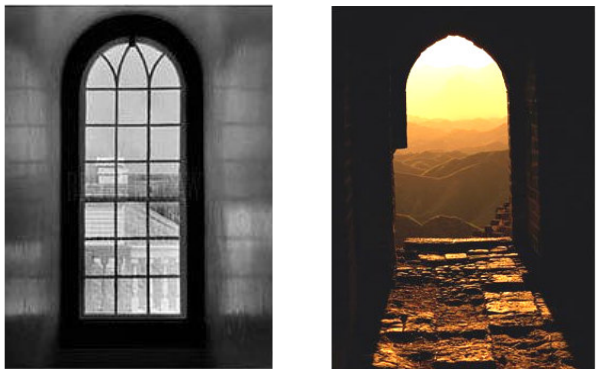

**Figure 11. Portals: transformative elements of architecture**

Another important aspect of home is the human activity that occurs within it. Events and rituals are moments in time that give both order as well as meaning in our lives. Some events in Space will be the same as on Earth (such as birthdays), or occur on a different time interval (such as the lunar new year on Mars) but many will also be new (such as intersections between Earth's day and Mars' sol). The habitat architecture should take this into account, and – besides designing for work, rest, and play – support these activities as well. Rituals, like events, are fixed within regular measured intervals of time and occur in various timeframes. There are daily rituals such as mealtime, and less frequent ones such as worship. Some rituals cannot be practiced in Space. Sitting down at the dinner table or kneeling in prayer, for example – rituals which have social significance on Earth – are no long practical or even feasible in zero gravity conditions. These rituals will be missed, and rather than abandoning them in our daily life in Space, the architecture should attempt to accommodate new ones while trying to preserve those of Earth as well through new ergonomic systems.

## VI. Natural v. Constructed Environments in Space

Since habitats in Space will be constructed in remote and extreme environments, how can the architecture address the subsequent problems of isolation and confinement? Ideally the architecture should establish a dialogue between place and space, as well as between indoors and outdoors. Although the technical requirements to sustain human life in Space make it virtually prohibitive to directly experience the outside, the habitat should not reinforce the perception of isolation from the outside world either. The architecture should instead serve to exalt its surroundings, rather than attempt to repress them.

There are various architectural approaches to mitigate isolation and confinement. A conservative strategy is to create contrasting interior spaces within the overall enclosure so that inhabitants can enjoy varied experiences in qualitatively different zones. [fig.12] The purpose is not to simply eliminate confining spaces but to allow the

occupant to experience a variety of spaces which in turn will contribute to greater stimulation. Creating a single large, unmediated, open space does not in fact, lessen the sense of confinement--it just makes for a larger prison; whereas creating a mix of both intimate, closed, contained spaces with relatively larger, public, open spaces is more effective, though still not a substitute for the experience of exterior space. Elements that rotate, pivot, slide, fold, collapse or are removable allow the user to manipulate his/her space accordingly. Private space could then be used either as a workstation, or for quiet contemplation, entertainment, exercise, etc. as well as simply communal or intimate space-making. Not only is this approach practical in terms of economy of space in accommodating different functions and activities, but the experience of variety--expressed through scale and reference in this case--is experientially more important than unbounded space, which is equally disconcerting in its lack of any scale or reference.

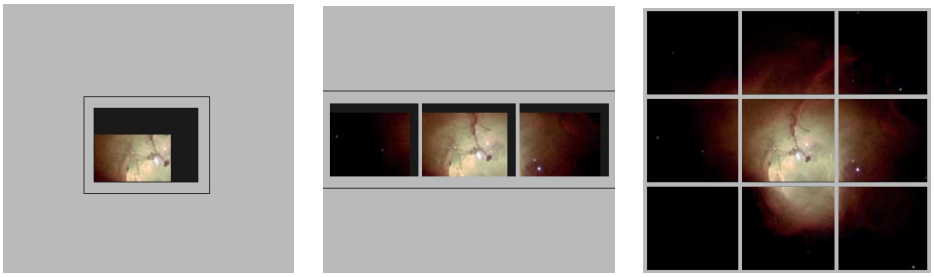

**Figure 12. 'Dematerialization' of enclosure**

A transitional strategy to help relieve the sense of confinement is to re-establish a direct relationship to the exterior by redefining what is perceived as external space. Here we can refer to terrestrial analogs: porches and balconies for example, are transitional spaces that mediate between the house and outdoors. [fig.13] They allow distant and panoramic views of the landscape, sounds and smells of nature, fresh air, and natural light. They are experienced much like exterior space, yet while still enjoying the protections and security of being within the home. Though porches and balconies may in fact be enclosed spaces, our experience of them is qualitatively very different from the internal one; on the balcony we are much more engaged with what exists externally.

Habitats in Space should similarly have some kind of ancillary enclosures that serve the same purpose as porches and balconies do on Earth. Artificial phenomena or events can be created on the exterior of the habitat as well, so that perception is periodically focused outward. By raising awareness of external phenomena, the habitat architecture can encourage extroversion, ward off egocentric tendencies, counteract sensory deprivation, and mitigate the sense of confinement. EVA's are one way to experience the "outdoors", albeit mediated by cumbersome equipment. But this is an act of *leaving* home, which is not the same as bringing the experience of the outdoors into the home.

**Figure 13. The porch**

Why is it so important to maintain a relationship to the outside? Because the outside world sets the context for the interior condition we call home. The notion of personal domain is synthesized in reference to what lies beyond it. Thus because home is subjective and personal, the external world – which lies outside our ability to manipulate and control – will always constitute the overriding reality. Consequently, the weaker our perceptions are of the outside world, the more disconnected we feel from an objective reality.

An even more challenging way to address the condition of confinement would be to provide dynamic and interactive elements, such as flexible exterior boundaries. A fixed structure unequivocally defines the boundaries of inside and outside. If it were possible however, to make these enclosures flexible, the perception of these boundaries would then become more ambiguous. For example, if the exterior building envelope were a tensile membrane that could be stretched or extended well beyond its normal perimeter, then what was once exterior space has been

annexed to the interior. Moreover, because the enclosure itself can be manipulated, it gives the occupant a greater ability to control over his/her environment. If we could take this even further and create membranes that were so flexible that one could venture far beyond the initial enclosure, the perception of interior space would change radically. Each venture outward would be a uniquely individual one. It would be experientially similar to that of a spacesuit tethered to the mothership, where one could explore space that has not been pre-defined by structure.

These various approaches not only maximize utility by creating efficient, multi-functional spaces, but on a psychical level they also offer variety, stimulation, control, and choice to the user. The user is therefore no longer a passive, reactive and adaptive participant in his/her space, but an active one who has the ability to reconfigure his/her dwelling spaces to accommodate different activities as well as a range of social settings from the communal to the private.

The habitat architecture can also provide elements other than those of physical enclosure. For example, to compensate for conditions of nature that we take for granted on Earth but are absent in Space, the architecture can offer artificial devices which create a temporal infrastructure, such as lighting systems that shift angle and change intensity to simulate the cycles of the sun throughout the day. This would give a sense of temporal orientation, especially in distinguishing between daytime and nighttime, which would then allow the body to develop more regular patterns of sleep and to function more efficiently. Special clocks and calendars could be designed and integrated into the interior habitat that reflect both real time on Earth and--on another planet--the new planetary time.

User control over his/her interior environment is essential to a sense of well-being and personalization. Whereas the state of *having control* is a static condition, the process of *controlling* is a dynamic one; the difference between 'state' and 'process' are vast in terms of how we interact with our surroundings. For example, the experience of the sea from a cruise ship, where navigation is automated, is very different than that of a sailboat, where the sailor must use the conditions of the wind and the water in order to navigate it. The habitat architecture can address the issue of control by providing spaces that promote appropriate degrees of spontaneity, discovery and playfulness. This can be accomplished through use of color and light, texture and materiality (which is seldom considered), contrasting and dynamic forms, flexible functions--or even elements that can alter themselves, grow or mutate. An example of the latter would be a plant-responsive climate control system, where the needs of the plants dictate the interior micro-climates, rather than by a random program or one that is human-controlled. This again would also help humans maintain awareness of the presence and needs of other forms of life outside of their own.

Humans respond empathetically to other organic entities. We have a need for some connection to the outdoors and to nature, which is why we often bring plants and animals into our habitats. In environments where there is a deficit of living things, humans will yearn for this attachment. Because mechanistic environments are non-organic in their nature, they constitute another form of alienation.

Inflatable structures on the other hand – in contrast to the coldness and sterility of mechanistic structures – are very appealing. [figs.14,15] Besides the practical advantages inflatable structures offer as viable habitats in Space, they may also prove to be the most aesthetically satisfying living environments as well. Inflatable structures have a natural similarity in their forms to other organisms, something which is not present in the mechanistic structures. Their surfaces are soft and pliable. They "come to life" when they are inflated and invite tactile engagement. There is even something playful about them. We respond to them in such a visceral way because they recall an empathetic connection to our primordial home, namely that of the womb--our first encounter with an "inflatable structure". The use of water shields to protect against cosmic radiation would also reinforce this sense of womb.

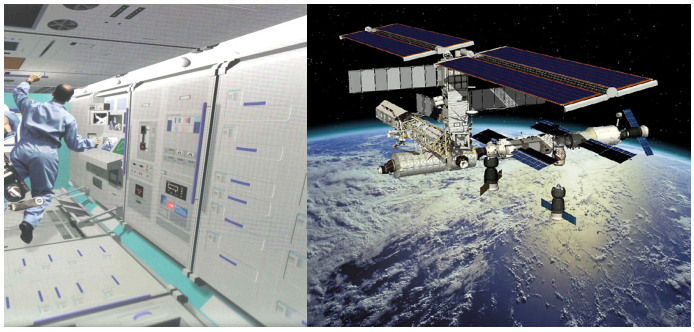

**Figure 14. synthetic forms, mechanistic interiors**

**Figure 15. organic form and materials**

However, when we speak of organic architecture, we are referring to its organic qualities metaphorically or representationally. They serve a purely aesthetic purpose in that they *resemble* an organism. But what if new technologies could lead to an architecture that was truly organic? What would be the benefits of developing such a technology? Currrent developments in architecture are embracing the concept of biomimetic structures – architectural design that is derived from, and mimics biological organisms or systems, such as ant hills or beehives – where the architecture actually *functions* like an organism. [fig.16] The principle behind the field of biomimetics is to design structures by referring to precedents in nature which have already solved the same problems, then employing the same techniques.

Some advantages of biomimetic architecture are:

- Sustainable technology in the truest sense (a new or primitive paradigm?)
- Creates the experience of nature, brings a sense of the outdoors inside
- Developed to uniquely suit its particular environment
- Establishes a new aesthetic and therefore an empathy/connection with our Space environment
- Reveals and informs us about the nature of other life and our interdependence

This may someday lead to the development of biosynthetic architecture, which does not simply mimic biological organisms, but actually *becomes* a living organism itself. It would be truly organic in every sense – not just mimicking it – in that it would be made of living material that could grow, self-heal, mutate or adapt to changing conditions. [fig.17]

Such technology would also give rise to a new architectural nomenclature:
- Building envelope = membrane
- Structure = skeleton
- Interior spaces = cavities
- Construction = harvest, growth

The even greater advantages of biosynthetic architecture would be:

- Not just a sustainable, but a productive technology that promotes the environment rather than simply maintains the status quo
- Could evolve itself to suit its particular environment
- Fosters respect for other life forms, actively engages occupant through care and maintenance of living habitat; the 'will' of the organism establishes something outside human control; presents challenge and adaptivity
- A development in technology that reinforces our relationship with the natural world, ultimately blurring the distinction between the natural and constructed environments

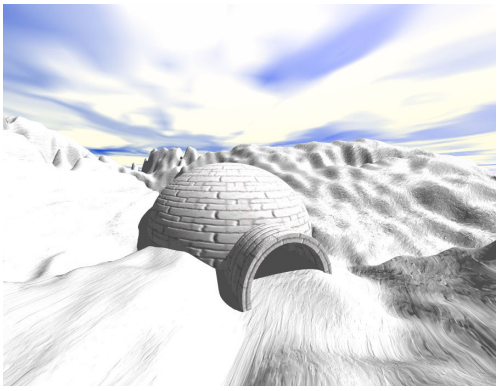

**Figure 16. biomimetic structure**

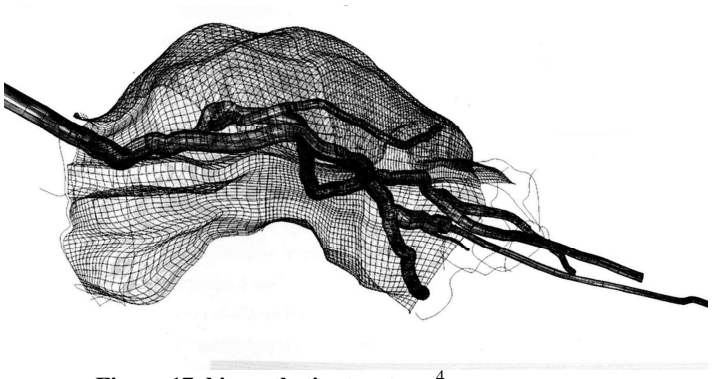

**Figure 17. biosynthetic structure** [4]

[4] Student project by Constanza Albero and Valeria Alvarez for the Genetic Architectures Master Program, Escola Tecnica Superior d'Arquitectura, Universitat Internacional de Catalunya, Barcelona, 2001.

## VII. Conclusion

In designing our habitats, there is a natural inclination to strive for the highest level of comfort and ease. We increasingly have the technology to virtually eliminate physical labor, and also to some degree intellectual effort. Technology is commonly believed to have provided a better quality of life in freeing us from tedious work and allowing us more time for other loftier or leisurely pursuits. The down side of this however, is that our reliance on technology mediates our experience of the natural world, causing us to become increasingly disengaged from it. As a result, we have gradually become passive inhabitants in a world that ends up controlling us through technologies upon which we have become dependent. We no longer know how to interact with our environment.

Despite advanced technologies, our initial habitats in Space will be a far cry from five-star luxury accommodation. The purpose of an aesthetic perspective however, is not about trying to achieve a certain level of comfort, but finding new or appropriate ways to dwell in Space. Living spaces and furnishings should of course, be comfortable, but also challenging and adaptive. The more interactive they are, the more they engage the user. They should also be flexible enough that their full potential can be discovered through the imagination of the user. (Flexible or multi-functional spaces should not be equated with generic spaces however; the former serves many specific purposes whereas the latter serves none.)

In the end, design cannot and should not provide for every function; besides being infeasible, users would eventually become complacent in their environments. Good design satisfies the required program, but great design lends itself to the invention of new and different uses. Moreover, the body needs a certain degree of resistance to overcome--all of athletics for example, is based on our overcoming the forces of gravity in some fashion. While weightlessness might seem to be a liberation from those constraints, it also deprives us of the challenge to physically overcome this resistance, to test and push the limits of our bodies.

An astronaut once spoke of his experience living in a confined vessel, and his longing for the joy of unbounded movement. But what we really long for is the joy of conquering obstacles and transcending our limitations. Our habitats, in serving our needs, should not deprive us of that process but instead provide us with that opportunity. The continued exploration of Space should not focus solely on developing new technologies, but developing new ways of (co-) habitating in our physical environment as well. This is where an aesthetic perspective can contribute.

*"Human experience should not be in service to science...[ on the contrary,] science is meant to serve the human experience."* --Chris McKay, Planetary Scientist, NASA Ames Research Center

## References


Agrest, Diana I., "On the Notion of Place", *Architecture from Without*, MIT Press, Cambridge, Massachusetts, 1991.

Bachelard, Gaston, "House and Universe", *The Poetics of Space*, Beacon Press, Boston, 1994.

Bluth, B.J., "Sociology and Space Development", *Space Social Science*, edited by T.S. Chesterton, 1983.

Dollens, Dennis, *Genetic Architectures*, Lumen Books/SITES Books, Santa Fe, New Mexico, 2003.

Dollens, Dennis, "Design Biomimetics: An Inquiry and Proposal for Architecture and Industrial Design", report to the Genetic Architectures Program and Department of Ecology and Architecture, Escola Tecnica Superior d'Arquitectura, Universitat Internacional de Catalunya, Barcelona, Spain, September 2005.

Finney, Ben, "Anthropology and the Humanization of Space", *36th Congress of the International Astronautical Federation*, Stockholm, Sweden, October 7-12, 1985.

Gangale, Thomas, "Practical Problems in Astrosociology", *AIAA Space 2006 Conference*, San Jose, California, September 2006.

Krueger, Ted, "The Architecture of Extreme Environments", *Space Architecture*, Rachel Armstrong (Editor), Wiley-Academy, March 2000.

Lockard, Elizabeth, "Design Considerations for Long-Term Habitation in Space: the Role of Aesthetics and Human Cognition", *presented at the Space Exploration Conference*, International Space University, November 2005 (unpublished).

Maruyama, Magoroh, "Aesthetics and the Environment in Outer Space, Subterranean and Underwater Communities", *Futures*, Butterworth & Co. Ltd., April 1984.

Tuan, Yi-Fu, *Space and Place*, University of Minnesota Press, Minneapolis, Minnesota, 1977.

Vogler, Andreas; Jorgensen, Jesper; "Windows to the World, Doors to Space: a Reflection on the Psychology and Anthropology of Space Architecture", *Space: Science, Technology and the Arts* (Workshop), ESA/ESTEC, Noordwijk, The Netherlands, May 2004.

Vogler, Andreas, "Change of Paradigms: Designing Habitat vs. Designing Machines", NASA RFI04212004, May 2004.

Worringer, Wilhelm, *Abstraction and Empathy*, Ivan R. Dee Publisher, Chicago, 1997.