WHAT IF? WHAT NEXT?

SPECULATIONS ON HISTORY'S FUTURES

SESSION 1C

MODES OF ARCHITECTURAL HISTORY

Architectural History in the Digital, Virtual and Gaming Age/Space

TO CITE THIS PAPER | Craig McCormack. **"The Depiction of the Body in Microgravity: Projecting a Physiognomy of Space."** In *Proceedings of the Society of Architectural Historians Australia and New Zealand: 37, What If? What Next? Speculations on History's Futures*, edited by Kate Hislop and Hannah Lewi, 136-148. Perth: SAHANZ, 2021. Accepted for publication December 11, 2020.

PROCEEDINGS OF THE SOCIETY OF ARCHITECTURAL HISTORIANS AUSTRALIA AND NEW ZEALAND (SAHANZ) VOLUME 37

Convened by The University of Western Australia School of Design, Perth, 18-25 November, 2020

Edited by Kate Hislop and Hannah Lewi

Published in Perth, Western Australia, by SAHANZ, 2021

ISBN: 978-0-646-83725-3

THE DEPICTION OF THE BODY IN MICROGRAVITY: PROJECTING A PHYSIOGNOMY OF SPACE

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Theorists have long conjectured upon architecture's meaning through drawing out its correspondences with the human body. Vitruvius believed that the development of architecture should refer to the proportions of the ideal human body's proportions as a model of natural perfection. Overlooked in the critical examination of such representations is the reading of space and its physiognomies that is as fundamental to the coherence of corporeal existence as is the body as self and as the other. It is only recently that the question of how a body inhabits terrestrial space has translated to the condition of microgravity has been raised, with the venturing of humankind away from the Earth and thus from a horizon-based perspective.

Outer space was originally conceived as a utopian destination, one that would allow for the emancipation of a humankind that had been disadvantaged, in a sense imprisoned, by its existence on Earth. The Russian 'father of rocketry,' Konstantin Tsiolkovsky believed that, once exposed to the condition of outer space, humankind would eventually and inevitably evolve, so that the body would no longer require spacesuits and life support systems for survival. Speculative projects produced in the 1970s incorporated ambitious hypotheses for artificial gravity systems that suggested access to the liberation from terrestrial bonds might be imminent. The designers of the first US space station, Skylab, envisaged a hyper- functional interior condition where astronauts could work independently on the various internal surfaces, each with their own localized 'verticality', unimpeded by Earth's gravity. Despite such aspirations, there would be little in the way of liberation, but instead much in the way of confusion and decentring of the body, both physiologically and spatially, with the astronauts aboard Skylab finding it disorienting to abandon a common vertical orientation. In venturing into space, the astronaut's had brought their ontological system with them, hardwired into their neuro-receptors. Chronicling the historical representation of the human body in outer space, projecting a future of the physiognomy of space and its implication for the limits of architecture this paper will propose the impact of cultural and biological factors upon the experience of outer space and microgravity.

The Restrained Body: Introduction

Vitruvius' *De architectura* has served as the locus for bodily comparisons to architecture where ideas of order, symmetry, and form are concerned. Overlooked in the Vitruvian progenies has been the role of gravity in the architectural reading of inherent qualities but also as a governing value. Newton published his law of universal gravitation in 1687, so it is understandable that this gravitational reading was absent from early texts that referred to the body.[1] Darwin's 1859 theory of evolution could have provided information for a contemporary reading of architecturally referenced and evolved bodies, in order to implicate the effect of gravity on architecture and the physiognomy of space. Gravity has had considerable impact on the evolution of the organic world and the human body. It determines, "...the form and the size of organisms, the development of skeletal supporting organs, and energetics".[2] As it is, gravity has largely been absent from the conflation of the human body and architecture though it has influenced the living trees and human bodies, historic references for architecture's origin. This paper proposes the inclusion of the gravity-effected body in architectural history that sees a reframing of the body by way of a brief survey. Beginning briefly in the Renaissance and Mannerist periods, depictions of the gravity-effected body are then found in the twentieth century, where technological developments promised an emancipation through the entering of space, with some time spent discussing the illustrated body and its transition to the condition of microgravity.

The depictions of the Passion by the likes of Dürer and Michelangelo are not unlike Leonardo's *Vitruvian Man* in terms of their secular importance. The use of the cross in Jesus' crucifixion expressed a feature of a mortal, or a terrestrial existence; an existence restrained to the Earth by gravity. As well as displaying the body in an arranged or quantified stance for the purposes of public examination, the artists reveal much about the characteristics of the environment and its effect on the body. Whilst the Renaissance was a period of great discovery, the scientific understanding of gravity would come later.[3] Artists during the late Renaissance and the subsequent Mannerist period would begin to reveal the effects of gravity through their description of the "irreducible variety of phenomena" associated with life on Earth.[4]

Figure 1. Albrecht Dürer, *Crucifixion* from the *Small Passion*, 1511.
https://en.m.wikipedia.org/wiki/File:D%C3%BCrer_-_Small_Passion_24.jpg

Rather than a complete rejection of the classical model, Mannerism integrates an additional expressionistic mode of representation. Richard Viladesau explains that, "[t]he characteristics of Mannerist painting included...convoluted and artificial poses; exaggerated musculature; the elongation of figures...".[5] Dürer and Michelangelo were examples of artists who transitioned from sacred art towards increasingly secular depictions of the body of Christ as subject. Though both are considered examples of High Renaissance humanists, they also expressed Mannerist tendencies that "were not entirely consistent with the religious purposes of sacred art".[6] Christ's body was depicted in such an expressive manner that the effect of gravity on the body is unmistakable, though unintentionally articulated. Dürer's 1511 *Crucifixion from the Small Passion* (Fig. 1) describes a Christ with arms that appear to be stretched beyond their normal length. Michelangelo has skilfully rendered the force of gravity on Jesus' body in both the *Crucifixion with Mary and John* and the *Marsyas Crucifixion*. Gravity has been weaponised against not only the body of Christ, but also all of humanity.

The Emancipated Body

If Copernicus had revealed that humanity and its cradle were not the centre of the universe, then Newton provided the tools to begin to understand humanity's place in the universe. Once Newton had revealed gravity as drawing humankind towards the Earth, people were motivated to conquer it. The post-Newtonian aspiration saw Cosmists, amongst others, look to outer space as a means through which to dictate the evolution and thus the emancipation of the human body. Cosmists, a group that included Konstantin Tsiolkovsky, believed the *space* of outer space to be a medium of evolutionary transformation. Much like the images that depicted the heavenly bodies, outer space was the post-Newtonian equivalent to the medieval conception of objective spatial order. Up, or now outwards, was where gods ruled, and mortals could define their own divinity.

The early 20th century saw rocketeers realise the rocket's potential to transport a human payload into outer space.[7] The Russian rocketeer and cosmist Tsiolkovsky did not view the body entering space as restricted to a military or colonial expansionist strategy. Tsiolkovsky, being a Russian cosmist, believed that the potential contained in visiting outer space was the capacity to provide liberation for the human body, so far restrained by the Earth and its gravity.[8] Tsiolkovsky thought of outer space as a medium for the purposeful evolution of the body, which through entering it would gain a means of liberation. He and other cosmists believed that entering outer space would equate to the determination of humanity's own destiny and would elevate humanity to a god-like status.[9]

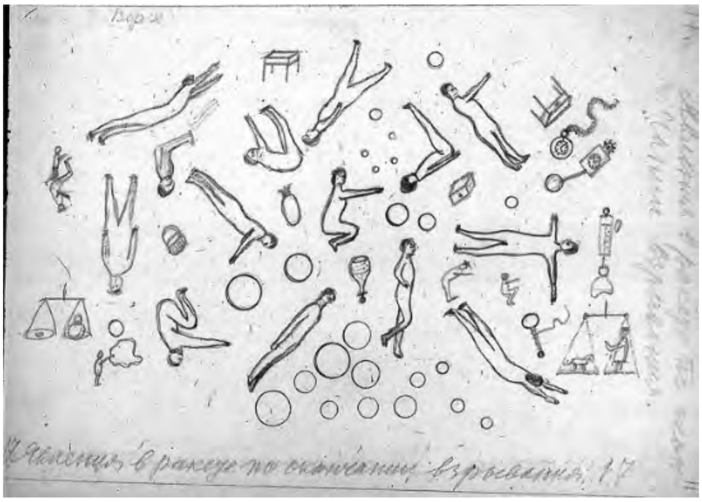
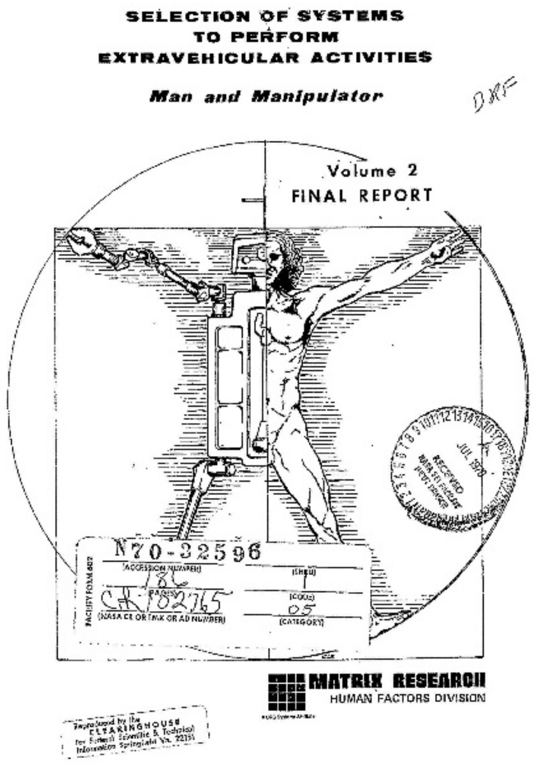


Figure 2. Drawing of people and objects in a microgravity environment, Konstantin Tsiolkovsky, Album of Space Travel, page 11, 1933, https://commons.wikimedia.org/wiki/File:Tsiolkovsky_Album_11.jpg

In a 1920 text, Tsiolkovsky conjectured that, "maybe even Man himself will change so much that he will need neither space-suits nor dwelling-houses in space".[10] Drawings from Tsiolkovsky's 1933 paper, "Album of Space Travel" illustrate confident bodies in complete control of their station, as though they could somehow manoeuvre in the microgravity environment. (Fig. 2) This, in part, could be rationally explained by Tsiolkovsky's imagined selection process for those entering space. These specimens were refined until, "[t]hose who passed were practically ideal men and women, angels in human form". Outer space was for Tsiolkovsky to be a spatial medium of determined evolutionary transformation, and the built environment created to shelter humankind would conduct potent social modification. The body was to have access to the liberation from our terrestrial bonds that space would provide.



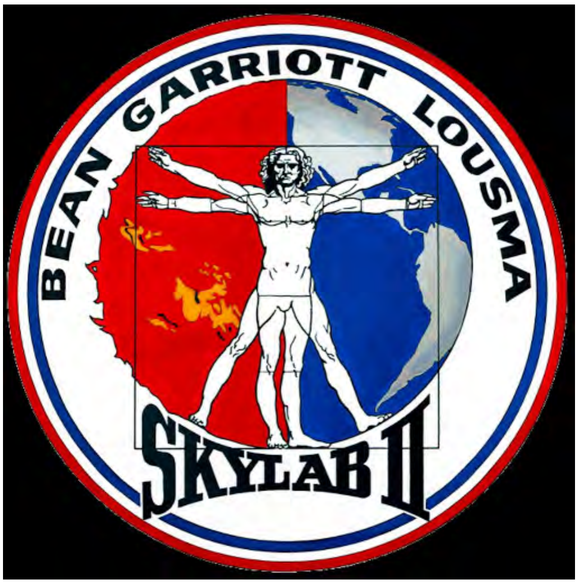


Figure 3. (L) Cover sheet to the Selection of Systems to Perform Extravehicular Activities; Man and Manipulator Volume 2 Final Report, Human Factors Division, NASA, 1970.

Figure 4. (R) Skylab III mission, second crewed mission patch (the first Skylab was crewless), launched May 25, 1973. The graphic represents the body in mediation between the Sun and Earth, with increased cosmic freedom. https://upload.wikimedia.org/wikipedia/commons/5/55/Skylab2-Patch.png. Accessed on August 23, 2020.

The Body Adrift

When the body finally found itself in the microgravity of outer space, it found itself in a precarious position, unable to live out the lofty destiny that had been designed for it. Illustrations such as Figure 3 adorning the covers of technical NASA documents would suggest that this was not unexpected. Despite such aspirations, there would be little in the way of liberation, but much in the way of confusion and decentring of the body, both physiologically and spatially, within a microgravity environment. The posited hyper-functional repurposing of defined space, like that of the space station Skylab, was to allow a wholly new conception of space and its inhabitation.[11] Astronauts aboard the space station found that, in addition to a host of physiological symptoms, they felt disorientated when not conforming to a commonly shared vertical.[12] The body was revealed to be bound by its terrestrial relationship to space and that the slow progression of evolution and the associated physiognomy of space could not be undone nor redesigned within a mission duration. A corporeal emancipation was not to be, as the spatial tabula rasa could not be overcome. The body was unable to establish itself as it was projected in the mission patch graphics (Fig. 4) and found itself decentred and adrift.

Architectural phenomenologist, Dalibor Vesely, describes space as a unification of “topology, orientation, and physiognomy of space”, explaining, “that the integrity of space is reflected in the coherence of human experience”.[13] This phenomenological conception of space would be tested through practical experience in outer space. In contrast to Vesely’s observation, the designers of the space station, Skylab, envisaged a hyper-functional interior condition where astronauts could work independently on the various internal surfaces within, each with their own local vertical, unimpeded by gravity: picture the interior of a cube, with six individuals operating on each of the six interior faces. Referring to the astronauts aboard the space station Skylab, Vesely noted however that “most of the members of the team turned out to be so reluctant to give up the idea of a single vertical, such as they had enjoyed on earth, that the designers despaired of their more ambitious plans”.[14] The astronauts found it difficult, and even disorientating, unless they all shared the same orientation.[15] As Vesely explains, “the Earth functions not as an object or as a centre of gravity but as the primary reference of our spatial existence and of our world”.[16] Without the continuum of reference to the Earth, the body loses its coherent experience. This terrestrial reference was made difficult to maintain for the bodies aboard Skylab as, although there was a viewing window for the astronauts, it was not pointed consistently to the Earth. In addition to the disorientation of the body within a microgravity environment, it was discovered that there would be an extensive physiological impact.

Figure 5. The relaxed posture of a body in microgravity. Anthropometric source book. Vol. 1: Anthropometry for designers, NASA-RP-1024, 1978. https://ntrs.nasa.gov/citations/19790003563. Accessed on August 5, 2020.

The depiction of the body in microgravity is markedly different than it is within a regular Earth-gravity environment. Unrestrained from its terrestrial condition the body loses its physical orientation and relationship to the ground below it and it appears to undergo regression to a semi-foetal position or, in the Source Book’s terminology, to an ‘unrestrained posture.’[17] The closest terrestrial approximation would be that of a body floating underwater.[18] Without the constant of gravity acting upon the body, the microgravity condition of space appears not to act as an evolutionary, but as a de-evolutionary medium. Figure 5 describes such a posture, suspended within the interior of the Skylab space station. As if to unintentionally illustrate a removal and decentring from the circumscribed geometries of the bodies of Vitruvius, Leonardo, and Dürer, the geometric structure is detached from the suspended body. The built environment would find its precedent for order to be weakened. The posture of the weightless body is the posture that the environment enforces as, “To force other postures on the body, either by the subject himself or through external constraint, frequently leads to discomfort, fatigue, and inefficiency”.[19]

As the weightless body in microgravity lacks a gravity-induced vertical without a planetary body with which it can draw it towards, the body required a more thorough understanding to assist in better describing its orientation within such a radically different space. (Fig. 6) It was suddenly possible for the body to find itself in countless positions relative to its environment and not to be consistently perpendicular. (Fig. 7) In the *NASA Anthropometry* guidebook, illustrations expressed the appropriate nomenclature of the relevant anatomical planes and orientations necessary to understand the body in a naturally orientation-less space. (Fig. 8) The central axis of the body was determined to the centre of the pelvis, reinforcing the datum of the body from the navel as had been described by Leonardo and Dürer. The body had returned as the source of focus as it was during the classical revival of the Renaissance period but serving in a quest to find an order now lost and no longer inherent.

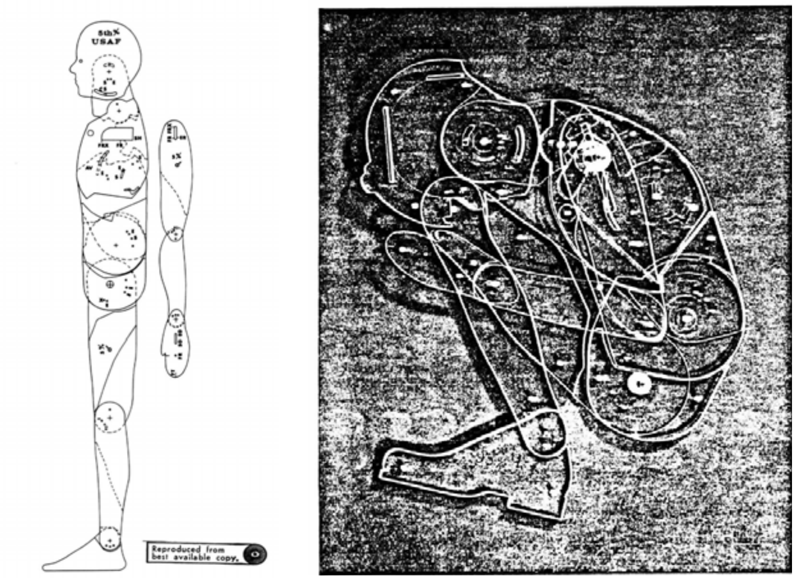


Figure 6. Anthropomorphic studies of the human body similar to Dürer's mid-16th century proportional studies, Anthropometric source book. Vol. 1: Anthropometry for designers, NASA-RP-1024, 1978. https://ntrs.nasa.gov/citations/19790003563

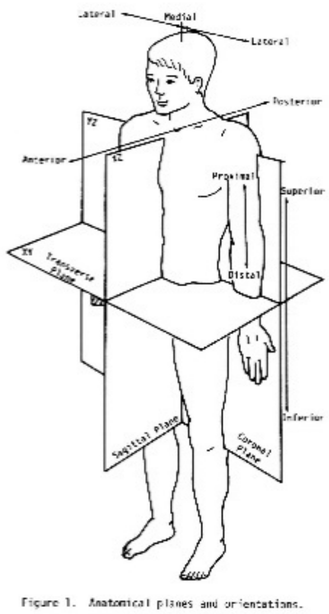


Figure 7. (L) Various positions of a body in an environment designed for microgravity. Anthropometric source book. Vol. 1: Anthropometry for designers, NASA-RP-1024, 1978. https://ntrs.nasa.gov/citations/19790003563

Figure 8. (R) *Anatomical planes and orientation*, Anthropometric source book. Vol. 1: Anthropometry for designers, NASA-RP-1024, 1978. https://ntrs.nasa.gov/citations/19790003563

The Post-Vitruvian Body

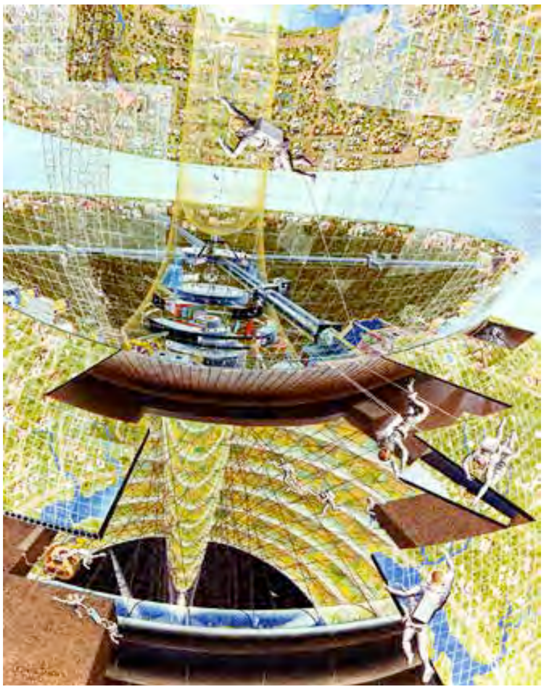
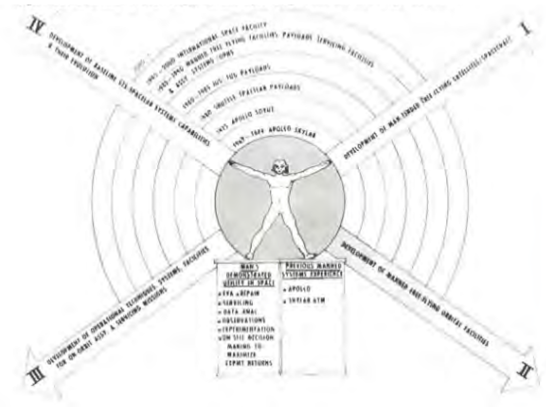


Figure 9. Construction crew at work on O'Neill's Island One colony. Don Davis, NASA Ames Research Center, 1976, NASA ID number AC76-1288, Public Domain.

Figure 10. (L) Detail of Island One space colony interior. Rick Guidice, NASA Ames Research Center, 1976, NASA ID number AC76- 0628, Public Domain

Figure 11. (R) View of reduced gravity activities within Island One space colony. Rick Guidice, NASA Ames Research Center, 1976, NASA ID number AC76- 0628, Public Domain.

Whereas Tsiolkovsky was referring to entering space via rocket, and remaining within it and its restricted interiority or nearby it (at least to begin with) and subsequently influencing all rocket-based outer space missions, American physicist Gerard K. O'Neill speculated upon space colonies of immense size and capable of sustaining thousands of people (Fig. 9).[20] O'Neill's speculative space settlements would integrate artificial gravity in a way that presented a spectrum of gravity (Figs 10 and 11), from that of Earth's through to weightlessness, and would incorporate novel features, such as low-gravity swimming pools.[21] There was a realisation that post-Skylab and the experience of the associated astronauts, gravity would be necessary for sustained human life. Highly aspirational, O'Neill's settlements illustrated the provision of an environment within which the human body has proliferated thus far, although the spatial freedom that microgravity afforded the body would still be accessible.[22]



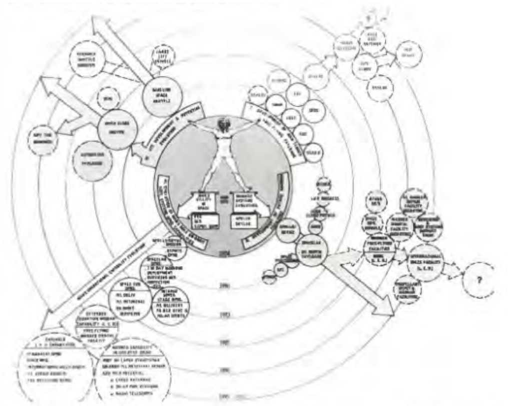


Figure 12. (L) "Evolution of Four Major Manned Space Flights and Candidate Program Elements," from Jesco von Puttkamer, "Developing Space Occupancy: Perspectives on NASA Future Space Program Planning" in Space Manufacturing Facilities (Space Colonies), 1977.

Figure 13. (R) "Evolution of Earth Orbit Space Community," from Jesco von Puttkamer, "Developing Space Occupancy: Perspectives on NASA Future Space Program Planning" in Space Manufacturing Facilities (Space Colonies), 1977.

The Vitruvian Man returns within two illustrated diagrams communicating humanity's outward expanse into space, in support of O'Neill's project. German-American aerospace engineer Jesco von Puttkamer included the well-known Vitruvian figure twice in the conference paper "Developing Space Occupancy: Perspectives of NASA Future Space Program Planning".[23] The diagrams, entitled *Evolution of Four Major Manned Space Flights and Candidate Program Elements* (Fig. 12) and the *Evolution of the Earth Space Community* (Fig. 13), are the only description of human figure. The purpose of von Puttkamer's paper was to "discuss selected NASA planning aspects of potential future manned space flight missions, and their evolutionary relationship to both presently formulated near-term developments and such far-future undertakings as space colonization, space industrialization, and manned planetary exploration".[24] The use of the Vitruvian Man in relation to the Earth behind it suggests an awareness that the body could not be separated from it.

In the wake of the realisation that O'Neill's *lesser worlds* were too immense in scale to be seriously pursued, regardless of their theoretical potential, the planning and development for a new NASA space station in a low Earth orbit began. Continued study of the body with respect to the developing space station saw it further systematised and reduced to normative data sets and made compatible with the technological systems that supported it.

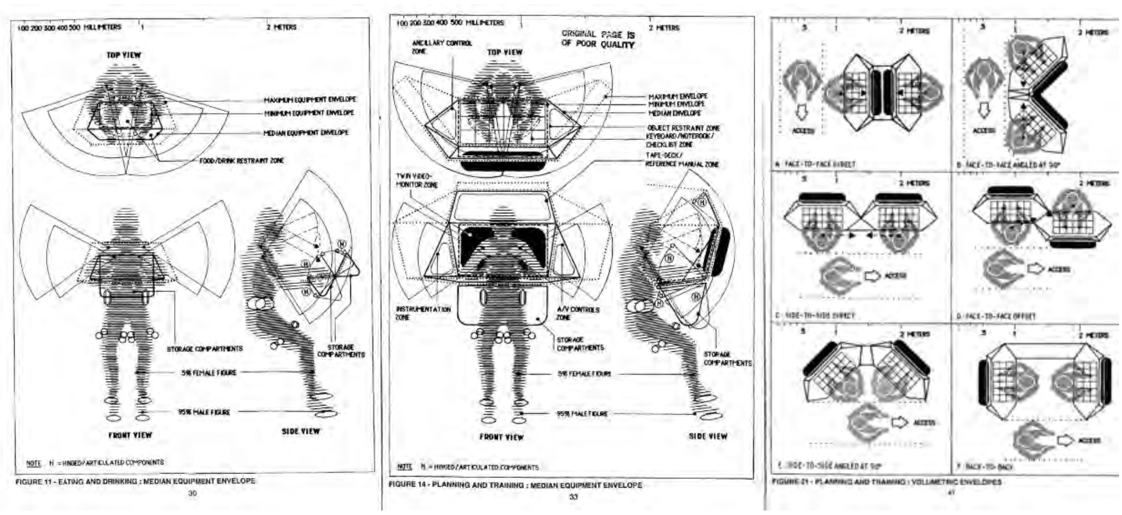


Figure 14. Space station crew workstation studies, NASA Contractor Report 4010, David Nixon, 1986. https://ntrs.nasa.gov/citations/19870012152.

Diagrams included in the 1986 "Space Station Group Activities Habitability Module Study" report by David Nixon of the Institute for Future Studies (SCI-ARC) depict the body losing its integrity through the quantisation of mean statistical data.[25] (Fig. 14) This data-based, amorphous form illustrates a body under threat of assimilation by the very environment that was created to support it. This reduction of the individual to that of a series of inputs and outputs manifested "a new integrated structure where man – the physiology of his ingestion and excretion – becomes part of the system he inhabits, as a combustion device".[26] This integration of the human within an artificial environment resulted in what Lydia Kallipoliti terms a "cybernetic model", illustrating, "an operational fusion between man and his milieu".[27]

The Purgatorial Body: Conclusion

Translated to the condition of microgravity is the way in which the body inhabits terrestrial space, resisting the opportunity for the abandonment of its original spatial orientation. The International Space Station (ISS), which as it continues to orbit, maintains a consistent alignment to the Earth.[28] This is to allow for the continued scientific observation of the planet 'below.' This also allows astronauts aboard to understand their body in relation to its terrestrial origin. One of the most popular activities on board the ISS is gazing downwards toward the Earth from the station's cupola, or viewing window, turning the space station into a planetary panopticon. Our home planet becomes a mecca for an architecture in space, in search of a datum, or an orientation for its inhabitants and their bodies.

Designs that preceded the ISS had perpetuated the notion of bodies inhabiting a microgravity environment with conflicting local verticals. (Fig. 15)

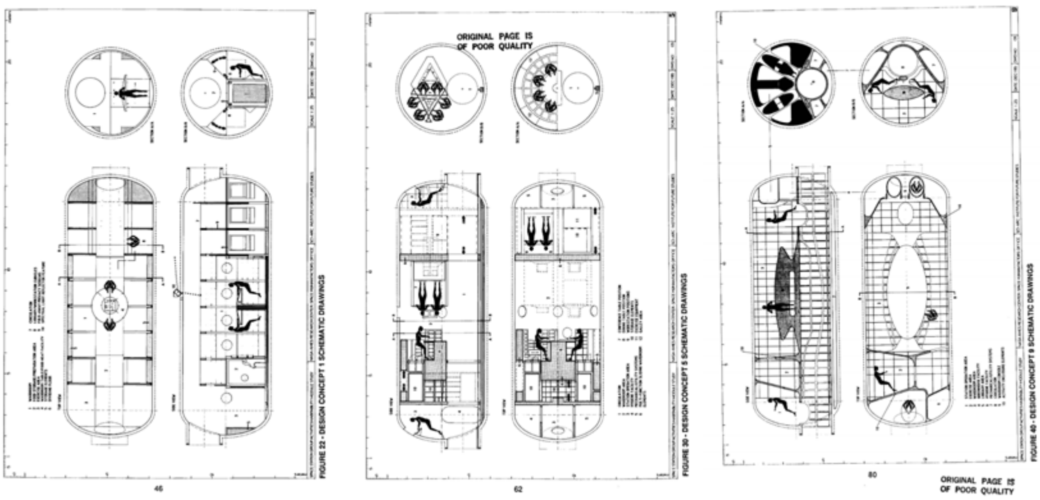


Figure 15. Space station group activities habitability module study, NASA Contractor Report 4010, David Nixon, 1986.

Within the section 8.0 Architecture of the 1995 NASA Manned System Integration Standards, under the subsection 8.4.3 Orientation Design Requirements, a consistent orientation for crew stations (Fig. 16) was outlined, in which several bodies were depicted sharing a local vertical (Fig. 17).[29] The following subsection provides an explanation of the difficulty astronauts experienced within Skylab stating that,

> One of the modules of Skylab, the Orbital Work Station (OWS), had a consistent local vertical and another module, the Multiple Docking Adapter (MDA), did not. It was found that people adapted more quickly to the orientation of the OWS than they did to the MDA. It also took crewmembers longer to locate a particular storage container in the MDA than the OWS.[30]

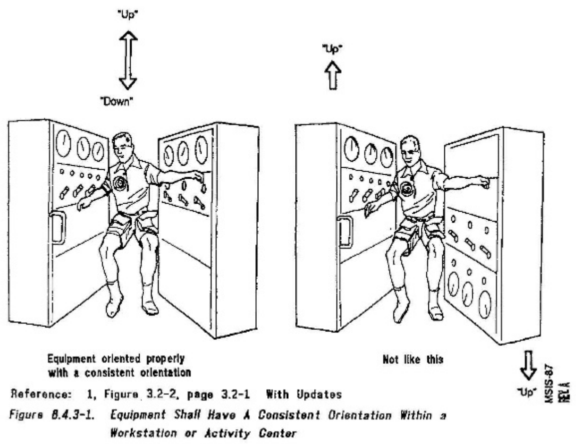


Figure 16. Equipment orientation diagram. NASA Technical Standard NASA-STD-3000, “NASA Space Flight Human Systems,” Volume 1 “Man-Systems Integration Standards,” Rev. B, July 1995.

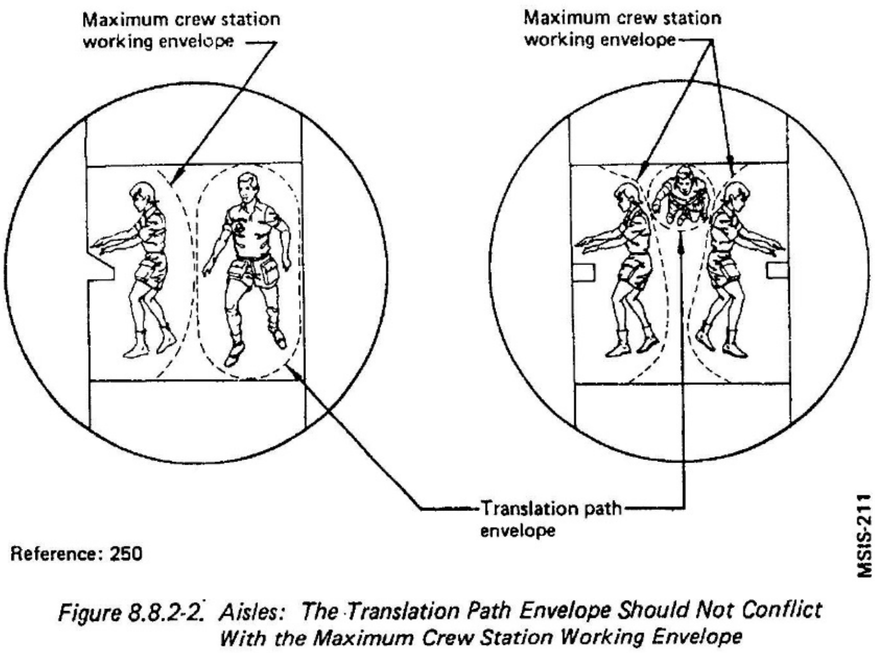


Figure 17. Translation path diagram. NASA Technical Standard NASA-STD-3001, “NASA Space Flight Human Systems,” Volume 2 “Man-Systems Integration Standards,” Rev. B, July 1995.

The result of an enforced local vertical for bodies aboard the ISS, itself consistently oriented towards the Earth, (Fig. 18) allows for the comprehension of what Jeff Malpas describes as subjective, allocentric, and objective space.[31] “Subjective space is centred on the body…” and allocentric space involves the relationship between objects and the locations of these objects in respect to one another.[32] An environmentally-defined vertical, as stipulated in the NASA Standards, resolves these structural elements of space. Malpas explains that, “…maps are taken to be representations of objective space”.[33] The knowledge of where one’s body *is* in respect to a larger objective framework is also necessary to be successfully spatially oriented, lest a rat in maze know nothing beyond the maze.[34] For astronauts aboard Skylab, knowing that there is an objective space but not understanding their orientation within it, contributed to the disorientation of the body in microgravity, as without a gravity-defined vertical, visibility of the structural elements of space is necessary. Vesely echoes this, writing that it, “is not just the visible appearance or surface of things but the visible manifestation of the whole topography of the actual space in which it is possible to recognize the physiognomy of things as well as their place and purpose”.[35]

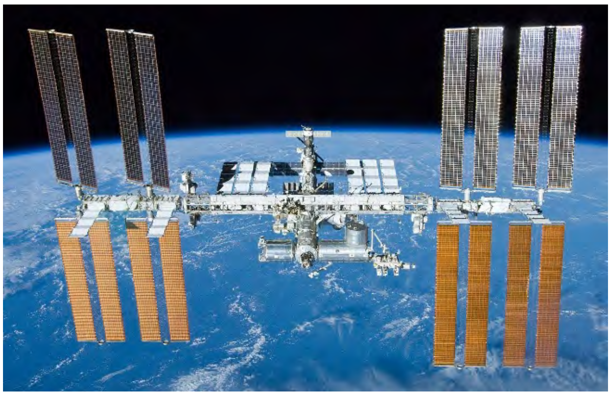


Figure 18. International Space Station oriented to the Earth, 2010, http://spaceflight.nasa.gov/gallery/images/shuttle/sts-132/hires/s132e012208.jpg

Figure 19. NASA Extravehicular Activity Patch designed by NASA engineer Fred Keune for suit manufacturer Hamilton Sundstrand. The description by the National Air and Space Museum reads, 'Flown, embroidered patch with Vitruvian Man depicted in EVA space.' https://commons.wikimedia.org/wiki/File:Space_suit_patch.jpg.

As if to recognise the limit that the befalls a body's integrity as it moves into outer space, the 'Vitruvian Astronaut' mission patch (Fig. 19) is appended to the spacesuits of the bodies that partake in extra-vehicular activities, or spacewalks. Though the Vitruvian figure is certainly inside the space suit, the human body is no longer shown as it has been in the previous depictions. This graphic is one of the latest in a lineage of depictions, and the final image of the body in this paper's brief transect, that signify that the body and its associated architecture and built environment are limited to and bound by a resilient relationship to the Earth's gravity.

Endnotes

[1] Proposition 75, Theorem 35: p.956 - I. Bernard Cohen and Anne Whitman, translators: Isaac Newton, *The Principia*: Mathematical Principles of Natural Philosophy. Preceded by *A Guide to Newton's Principia*, by I. Bernard Cohen. University of California Press, 1999.

[2] N. P. Dubinin, E. N. Vaulina, The evolutionary role of gravity. *Life Sciences and Space Research*. 1976; 14: 47-55.

[3] The Scientific Revolution that came about in part due to the publication of both Nicolaus Copernicus' *On the Revolutions of the Celestial Spheres* and Andreas Vesalius' *On the Workings of the Human Body* (both published in 1543) challenged the established anthropocentric and humanist belief systems.

[4] Richard Viladesau, *The Triumph of the Cross: The Passion of Christ in Theology and the Arts from the Renaissance to the Counter-Reformation* (New York: Oxford University Press, 2008), 241.

[5] Ibid, p241.

[6] Ibid, p231.

[7] Michael G. Smith, *Rockets and Revolution: A Cultural History of Early Spaceflight* (Lincoln: UNP - Nebraska, 2014).

[8] Cosmism is a combination of technological utopianism and spiritual mysticism that was prevalent in Russia during the transition to the 20th century. Boris Groïs, ed., *Russian Cosmism*, (Cambridge: EFlux-MIT Press, 2018).

[9] Vladimir Verdansky, a cosmist and geochemist, upheld the notion of outer space as an evolutionary medium, referring to it as the noosphere. The noosphere describes a third successive phase of development of the Earth. The first phase is the geosphere, the second phase is the biosphere, and the third phase is the noosphere; the biosphere transformed by human cognition. Verdansky believed that humankind's mastery of nuclear processes would result in the generation of the noosphere. The French philosopher Pierre Teilhard de Chardin developed the noosphere concept simultaneously though a theological approach to the concept was promoted, differing from Verdansky's geological methodology. Teilhard theorised a sphere of thought that encircled the Earth as a product of humankind's evolution and the associated development of our global consciousness. The Biosphere and Noosphere Reader: Global Environment, Society and Change, edited by Paul R. Samson and David Pitt: London/New York: Routledge. 1999.

[10] Konstantin Tsiolkovsky, *Beyond the Planet Earth; Translated from Russian by Kenneth Syers* (Oxford: Pergamon Press, 1960) 94. Originally published in 1920, this work was founded on Tsiolkovky's 1903 *The Probing of Space.*

[11] Skylab consisted of two modules with competing local verticals or a defined up and down.

[12] Upon entering outer space within a vessel the body would suffer from many effects that include but are not limited to; muscle atrophy; skeletal deterioration; intracranial pressure; excess flatulence; poor sleep; decreased red blood cell production; imbalance; eyesight disorders; weakened immune system; reduced body mass; loss of taste; significant fluid redistribution; and motion sickness. Within the medium of outer space, architecture's primary role is therefore as that of a life support system.

[13] Dalibor Vesely, *Architecture in the Age of Divided Representation: The Question of Creativity in the Shadow of Production*, (Cambridge: MIT Press, 2006), 71.

[14] Ibid, 71.

[15] Cooper, *A House in Space*, 111.

[16] Vesely, *Architecture in the Age of Divided Representation*, 68.

[17] *Anthropomorphic Source Book Volume I*, I-19.

[18] Buzz Aldrin, after experiencing, the weightlessness of space firsthand during early Gemini and Apollo missions, drew comparisons to underwater diving of which he had experience. This resulted in the development of the Neutral Buoyancy Laboratory (NBL) underwater training facility for training astronauts.

[19] *Anthropomorphic Source Book Volume I*, I-19.

[20] Gerard K. O'Neill, *The High Frontier; Human Colonies in Space*, (New York: William Morrow and Company, Inc., 1977).

[21] T. A. Heppenheimer, *Colonies in Space* (Harrisburg: Stackpole Books, 1977), 150.

[22] Craig William McCormack and Nigel Westbrook "After the Gold Rush, or another Spaceship Earth." In *Proceedings of the Society of Architectural Historians, Australia and New Zealand: 33, Gold*, edited by AnnMarie Brennan and Philip Goad, 452-462. Melbourne: SAHANZ, 2016.

[23] Jesco von Puttkamer, "Developing Space Occupancy: Perspectives on NASA Future Space Program Planning," in Space Manufacturing Facilities (Space Colonies): Proceedings of the Princeton/AIAA/NASA Conference, May 7–9, 1975, ed. Jerry Grey (New York: American Institute of Aeronautics and Astronautics, Inc., 1977), 209-220.

[24] Ibid, 209.

[25] David Nixon, Space station group activities habitability module study, NASA Contractor Report 4010, 1986. https://ntrs.nasa.gov/citations/19870012152. Accessed July 3, 2020.

[26] Ibid, 68.

[27] Kallipoliti, Lydia. "Closed Worlds: The Rise and Fall of Dirty Physiology." Architectural Theory Review, 20:1, (2010) 67-90: 80.

[28] Skylab's solar panels were fixed, and required the station to modify its alignment to the sun whereas the ISS's solar array aligns itself irrespective of the space station to allow for alignment. This, combined with its two-

module configuration that did not share a common vertical may have induced a heightened feeling of disorientation aboard Skylab.

[29] NASA Technical Standard NASA-STD-3000, "NASA Space Flight Human Systems," Volume 1 "Man-Systems Integration Standards," Rev. B, July 1995.

[30] Ibid, 8-9.

[31] Jeff Malpas, *Place and Experience: A Philosophical Topography*, (Taylor & Francis Group, 2018), 58.

[32] Ibid, 58

[33] Ibid, 59.

[34] Ibid, 51.

[35] Dalibor Vesely, *Architecture in the Age of Divided Representation: The Question of Creativity in the Shadow of Production*, (Cambridge: MIT Press, 2006), 71.