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LESS IS MORE? – EXPLORING DESIGN PRINCIPLES OF MODERN ARCHITECTURE IN THE CONTEXT OF SPACE HABITATION

David Wong
United Kingdom, david.wong@starlightarchitecture.com

Regina Peldszus
Germany, regina@spaceflightdesign.org

This paper begins by asking a hypothetical question: "If Mies van der Rohe was to design a space station or a building on the Moon, what would it be like?"

German-American architect Ludwig Mies van der Rohe (1886-1969) is widely acknowledged as one of the masters of modern architecture that has defined generations of urban cityscapes around the world. For his minimalist approach towards design, he is often linked to the aphorism "less is more". Also his contemporaries among them Austrian American Richard Neutra (1892-1970) explored ways of reconciling compact, paired down designs with the needs of a new generation of dwellers for flexible living and a conscious integration into landscape context. The legacy of their work continues to be influential to the development of architecture today.

Considering space architecture that has been realised to date is, in many aspects, as removed as it can be from the sleek and discreet aesthetics often associated with modernism.

This paper discusses aspects of space architecture by exploring how the thinking from some of the 20th century's greatest architects could be applied to planetary surface and interplanetary settings, whether their architectural principles are technically and conceptually relevant for the design of architecture in space today, and how they could influence design approaches to space architecture in the future.

The discourse begins by highlighting some of the architectural values which help define many modernist masterpieces, and put them in the context of space architecture: From the emphasis of a clarified structural order, to the ideology which determines the use of materials and the associated construction process, to the preference of free open space, the consideration of the exterior setting of a building and its users' needs, to the ultimate goal of becoming an expression of the ethos of a society.

INTRODUCTION

Space Architecture today is a very specialized field, with applications within a very specific context in connection to the human element inhabiting or operating a spacecraft. Even though the theoretical basis for Space Architecture is far reaching and in certain aspects it can be regarded as the generalization of terrestrial architecture [1], in practice the space-based discipline operates within a very limited scope and shares few professional interactions or exchanges with its earth-based counterpart.

Modern Architecture is often used as an all-encompassing term that is loosely applied to the myriads of architectural movements that began at the turn of the 20th century, of which many were instigated as a response to the major social and technological transformations were taking place at the time. Its exact definition has remained contentious to historians and practitioners alike. [2]

However, there is much to gain from a discourse linking the two fields. More specifically, by comparing and cross-referencing some of the design principles from the Modern Architecture movement to that of Space Architecture in this theoretical exercise, new insights can be derived from exploring the reciprocal relationship between the two disciplines. Here, the emphasis of the study is placed on the philosophical approach rather than on specific buildings or projects. As such it is not the intention of this paper to create a definite 'reference design' which takes into account the findings from the discourse, or attempt an exhaustive or comprehensive analysis of the movement. Rather, this paper aims to carve out a set of principles values of Modern Architecture – with a focus on the principles adopted by Mies van der Rohe and Richard Neutra*, that could be applied to the setting of Space Architecture.

MIES VAN DER ROHE

German-American architect Ludwig Mies van der Rohe (1886-1969), or Mies as he is commonly referred to, began his architectural career as a draftsman. He set up his own architecture office in Berlin in 1912, working primarily on independent residential commissions. In the following decades Mies established himself as one of the leading figure in the avant-garde

* *Sections authored by D. Wong for Mies, and R. Peldszus for Neutra, respectively.*

movement, seeking and experimenting with new architectural style that could better represent the modern times. He served as the last director of the German avant-garde design school Bauhaus in the early 1930s until it was forced to close down due to political pressure from the Nazi regime. Later in the same decade, Mies moved and eventually settled in Chicago, United States, where he was appointed as the director of the architecture department at the newly established Illinois Institute of Technology. It is through his works in the United States that Mies further developed and realized his vision of 'skin and bones' architecture – concepts of which are evident in many of his famous works such as the Crown Hall of the Illinois Institute of Technology in Chicago or the Seagram Building in New York. His contribution to architecture was recognized by the award of the Gold Medals by both the Royal Institute of British Architects (RIBA) and the American Association of Architects (AIA). Mies was also the recipient of the *Pour le Mérite* of Germany and the Presidential Medal of Freedom of the United States.

Design Principles

It would be futile to try summarising the design approach by a master architect such as Mies within a few paragraphs and expecting any level of adequacy. Therefore the focus of the discourse is based on selective aspects of the design philosophy adopted by the architect, of which the author believes to be relevant to Space Architecture.

Structural Clarity

As explained by Mies van der Rohe himself in his own words, 'by structure we have a philosophical idea. The structure is the whole from top to bottom, to the last detail, with the same ideas.' [3]

It was of great importance to Mies that the structures of his built works were explicitly derived from respective functional requirements. [3] Mies believed that the structure of a building should be expressed in a clear and reasonable manner and should not carry any unnecessary weight. However, it is worth noting that the architect did not aspire to the ideal of pure rationalism, which is predominantly about coming up with a logical and objective design solution, but pays little regards towards aesthetics, or how the design might be perceived or experienced in subjective terms.

Instead, Mies approached his design subject by going beyond the direct or 'pure' response to the functional requirements, and created a subtly articulated design solution that is distilled from the pragmatic reality, which is often overtly complex and difficult to comprehend. It is the quality of this extra layer of refinement that makes the architect's works such an inspiration to those that followed.

Materials & Technologies

Mies van der Rohe expressed a preference to use materials that could be industrially produced and could represent the technological achievement at the time. [3] (e.g. rolled steel beams, large pane glasses, etc.). Their applications were always carefully detailed, and acknowledged the specific characteristics of respective materials.

Contexts

In his built works, Mies van der Rohe acknowledged the surrounding contexts with subtle and rational design decisions. For instance, the selection process of building materials took into account the effects of local climate, the expected wear and tear, and the available budget. The complexity of the architectural details was determined by economics. The choice of building colours was based on the buildings' relationship in relation to the urban or rural landscape.

In general, Mies allowed his architectural design to react to the contexts, but not to be driven by them. The functional demands of the building programme determined the overall design strategy for his buildings.

Regarding nature, Mies adopted a markedly different approach when compared to that of Neutra.

In his built works, Mies made no attempt of blending his architectural design with nature. A conscious decision had been made by the architect to create a distinctive contrast between his architecture and the nature surrounding it, to recognize them as two distinct entities.

Mies stated, 'Nature, too, shall live its own life. We must beware not to disrupt it with the color of our houses and interior fittings. Yet we should attempt to bring nature, houses, and human beings together into a higher unity.' [4]

As illustrated in one of his architecture master piece, the Farnsworth House, the sublime architecture of the dwelling acts as a framework to engage with the natural surroundings, drawing the nature into the building as it is, with minimal interference caused by man-made elements. The interaction between architecture and nature as two separated entities allows one to appreciate both of the elements in its respective true forms, while creating some truly inspirational spatial interactions between them, making it one of the most iconic dwelling designs in the last century.

Will of the Epoch

Mies van der Rohe once stated that 'architecture is the will of the epoch translated into space.' [5] He believed architecture should be an expression of the

spirit of the age, reflecting the nature of its contemporary social settings. Its design should be shaped by science, technologies, industrialization and economy – the driving forces in a technological society.

Implications to Space Architecture

At first glance, the *modus operandi* of Space Architecture design seems to share many common attributes with the architectural design principles adopted by Mies van der Rohe as mentioned above.

Due to the extremely high cost of launching materials into the Earth's orbit and beyond, space architecture have been driven by economics to come up with structures that are extremely efficient in terms of spatial design, and are highly optimized for fulfilling its many functional requirements. Use of materials that have high strength to weight ratios, such as aluminium, carbon fibre and glass composites, etc. are preferred in order to reduce the structural weight to the absolute minimum. The drive to eliminate all unnecessary weight resonates with Mies' pursuit for a clarified structural order within his built works. The technological use of materials and construction techniques within the space industry represents a good compliment to Mies' preference of using materials as a mean to reflect the technological achievements at the time

There are some subtle differences however in terms of how Space Architecture is related to its contexts when compared to that of Mies van der Rohe. While both acknowledged the environmental contexts with rational design decisions, Space Architecture has to deal with an environment that is mostly hostile to life. Driven by pragmatic necessities, its relationship with the environment tends to be more about providing protection or achieving separation, and less about making contrast or setting up connections.

Furthermore, Space architecture that had been realized to date was predominately based on a purely rational design methodology. This approach takes on design from a hypothetical zero stand point, and subsequently adding elements or systems that are deemed critical to fulfil its various functional and mission requirements. Aesthetic values and architectural principles were generally not of significant concerns. As a result, architectural expressions were mostly a by-product of engineering manifestations, rather than a conscious display of architectural intentions. While the resulting composition of its structure and architectural elements reflect a certain 'physical truth' with their presences, they had no underlined purposes other than the sole aim of fulfilling the respective functional requirements.

This stands in marked contrast to Mies' design approach; he was interested in articulating his architectural concept through a process of refinement towards the essence of design. It is also at odds with the architect's desire to reflect upon the spirit of the epoch through architectural expression. Mies believed that the design of architecture should acknowledge, but not be prescribed by, pragmatic reality; it should go beyond simply addressing the demands of the functional requirements, and create a coherent design concept through aesthetic refinement that is encompassed within every element of the design.

RICHARD NEUTRA

As one of the most prolific American architects, Richard J. Neutra was on the cutting edge of modernist architecture [6] [7]. Born in Vienna in April 1982 into a science- and art-loving family, Neutra studied architecture at the Technical University of Vienna under Adolf Loos, whom he became to admire for his non-ornamental approach [7]. Having briefly worked in Berlin in the 1920s, Neutra emigrated to the United States to expose himself to the work of luminaries such as Frank Lloyd Wright, and settled in Los Angeles [7]. Working until the very end of a career spanning more than five decades (he died of a heart attack at a client's house in Wuppertal, Germany, in April 1970), Neutra was lauded not only for his innovative style, but his approach to afford both protective shelter and scene for 'confronting and enjoying life' through his architecture [7] (p. 7). The key theme of his planning activities connected human and nature, which he understood as an integral continuum rather than opposites, and the notions of technology by which this relationship could be achieved. [6]

Neutra was in constant dialogue both with his peers and professionals in the fields of science and technology. Upon invite of Mies van der Rohe, Neutra became professor at the Bauhaus in Dessau, Germany, in 1930 [6]. In the following decades, he extensively wrote for professional and public audiences, both opinionated and informed by his wide correspondence and interests in the sciences. One of his best-selling book 'Survival Through Design' [8] illustrated his core dictum: good design served as tool to sustain and enrich human life even in challenging or radical environments. This design philosophy was epitomised in his work for public spaces, homes, or institutions such as universities, but also service facilities, infrastructure and urban planning across very different climatic and cultural zones. Personally, he lived and worked in an 'ultra-modern, experimental residence' among an aggregation of features that afforded comfort, utility and 'a strange sense of detachment from the usual world' [6].

Design Principles

The following thoughts on Neutra's work in relation to habitable space structure draw not so much on his buildings and drawings, but equally his ideas and publications. These served as a repository of the fundamental principles of his work, three of which are outlined in the following: his approach to the architectural site, the focus on the human element, and his relationship to technology.

Integration of the Site

Neutra's unique approach to take into account the idiosyncrasies of the architectural site in his work for public spaces and private residences contain insightful approaches for tourism-related architecture in space or professional platforms in lower earth orbit (LEO). There, engaging with the immediate outdoors in orbit would serve the intrinsic purpose of being in situ for leisure, or add an invaluable off-duty and operational safety feature in work settings. Neutra achieved this by creating ambiguous spaces linking the internal and external environment through thresholds like terraces separated from living rooms by floor-to-ceiling sliding doors, or large windows [6]. These features come to the fore in naturally sparse landscapes or more hostile climes, where the outdoors can thus be experienced in shirtsleeve. This resonates particularly in the radical settings of a planetary surface to even orbital and therefore largely 'void' settings – void of landscape context or void of sensory cues.

Neutra subscribed to an ecological approach of seeing humans and the environment. Especially on restricted sites or difficult terrain, he managed to create lofty and spacious habitable volume, addressing the challenges of the site by integrating or circumventing them elegantly, rather than imposing a structure. He branched out into very different biotopes, including more extreme tropical or alpine settings, to whose dynamic climate and daylight cycles he responded by placing windows prominently, but also installing outdoor pools that would reflect changing lighting patterns indoors and, he argued, would have a restorative impact on the inhabitant [8]. These type of 'intangible' provisions can be superimposed onto existing habitability systems in the interior of a spacecraft – in fact, similar approaches have been proposed as early as the 1960s by Fraser particularly for spacecraft [9].

Human-Centred, Participatory & Evidence-Based Design

More crucially perhaps, beyond orbital tourism or LEO-based science, crewed space platforms may in the future include planetary surface structures, itinerant deep space habitats or extraction and energy related facilities. Neutra's relevance to this type of space architecture is particularly evident in his designs for more complex industrial and military infrastructure in the aerospace and maritime sector, such as mills, loading docks, or temporary housing commissioned by organisations such as the US Navy, Air Force, Pentagon or by port authorities [10].

Throughout his career, Neutra placed the focus on the human, both in his or her capacity as commissioning client or eventual end-user, engaging in what would in contemporary design terminology be called co-creation, collaborative or participatory design [10]. Accompanying his thorough examination of the architectural site, Neutra conducted extensive background research on individual user requirements. He then adapted his ideas to the requirements of the client with a 'neutrality that tolerated and encouraged the client's own vision and creativity' [7] (p. 6). Supporting this was his ingenuity to equip a new generation of dwellers with the means for living, through flexible interiors that enable users to adapt the interior volume according to different activities, open spaces to afford transition between activity centres, but also internal fixtures, fittings and furniture (e.g., see his patent for an adjustable table [11].

Beyond the 'subjective' practical or personal needs of the client, which Neutra valued, he was an equally avid proponent of what today may be termed evidence-based design, particularly related to psychological and physiological needs [10]. He is arguably one of the most knowledgeable architects of the 20th century when it comes to the biological and behavioural sciences and their impact on architecture (and vice versa) [7]. Pointing out that much of the modus operandi of contemporary society was subjected to fast-paced change and featured the cumulative negative effects of 'non-optimally planned technology environment' [10] (p. 390), and that design often resulted in 'trial-and-error' or apparently lacked an 'ultimate method', Neutra advocated that 'of unavoidable necessity are more precise and pertinent data, preventive and constructive programs, blueprints. … To plan for (man) we must know his characteristics' [8] (p. 20).

To him, technology was not meant to be used for its own sake, but for the good of the user by utilizing innovative combinations of materials such as concrete, glass and wood, and novel construction paradigms, including industrial production and prefabrication [6].

Systems Approach

Neutra's focus on evidence and the user resonates with systems engineering, which was consolidated in the US aerospace sector in the 1960s [12]. Fed by his keen interest in science, particularly Neutra's infrastructural work appeared to be informed by his fascination with laboratories and experimental spaces [10]. However, he acknowledged the constraints of technical infrastructure and civil engineering, particularly in the hydro and energy sector, where 'engineers … have no budget for aesthetic tasks at their discretion' [10] (p. 369). However, he argued that these constraints should not prevent planners to push their considerations of potential functions of infrastructure further, and recognise, for instance, that in its simplicity, a road-side water reservoir featured a simplicity and beauty that could edify passers-by, and enhance the quality of the local environment beyond pure utility.

Neutra became what can be called a 'systems thinker'. By focusing on the triad of technology with its potentials and constraints, the human from a biomedical perspective with sensory aspects, human behaviour and latent psychological needs, and the natural environment, he achieved true integration in his designs that would somewhat foreshadow thought processes later formalised in human systems integration in space. His comprehensive approach was matched by his advocacy for standardisation and 'a functional concept of what a thing *is* or rather how it ought to perform are unavoidable in an industrialised world', which would eventually benefit both the user and the producer or manufacturer of a design [8] (p. 54 & 63, his italics).

As a later admirer of the futurist Richard Buckminster Fuller [6], who one year before Neutra's death would publish his seminal *Operating Manual for Spaceship Earth* [13], Neutra did, indeed, comment about actually dwelling in space, and the associated human condition in the early 1960s. Although he did not live to see the dawn of long duration habitats in earth orbit during the 1970s with the first crewed space stations Salyut and Skylab, he appeared to have followed the developments of both the Apollo and Soviet space programmes, and pondered on how technology could meet the astronauts' physical and psychological needs. In turn, he advocated spin-off of using the findings of space research for the benefit of the ground-based population (e.g. [10] [14])

DISCUSSION

The flexibility of activity centres hailed by both architects is already one of the key features of Space Architecture by necessity of volume constraints. And in the following discussion, the caveat applies that many Space Architecture practitioners will have internalised and would, indeed, readily embrace the principles that are re-iterated comparatively in this section – were they not forced by the constraints of circumstances in which cost and development time drive design.

Structural Clarity

Both Mies and Neutra's approaches contain many means beyond engineering to rein in the chaotic complexity generated by elements of many engineering systems that are required to support a habitable environment in space. Their strength lies in rearranging and ordering the 'components' of a habitable system, guided by a strategy of structural clarity and coherence that applies to the whole spacecraft, with an aim of reducing the visual clutter, and to create a clear and reasonable expression of the underlined primary structure.

Mies' design process was a derivative of rationality and based on functional criteria and pragmatic necessities, while Neutra traded off the practical needs of the inhabitant against difficult sites and economy in materials. These approaches are not so dissimilar to the common practice for designing space architecture.

Natural context and vernacular

Both architects were interested in emerging construction techniques and advanced materials. In contemporary Space Architecture, innovations such as parametric design, 3D printing and composites such as carbon or glass fibre or synthetic polymers are taken up both for conceptual design studies and applied experimentation with great verve. Especially applications in in-situ-resource-utilisation (ISRU) would resonate with Mies' and Neutra's interest in exploring new architectural idioms, but also in the vernacular, whether for dwellings inhabited by humans or by resourceful animal populations such as termites. Interestingly, both had a different approach to landscape and natural context, Mies by respectfully keeping it a separate realm, Neutra by inviting it inside – a pertinent issue when dealing with radically hostile or unusual external and internal vehicle environments such as reduced gravity, daylight cycles, pressures or temperatures.

Whether or not we can regard the current paradigm of space architecture 'native' or 'vernacular', in that it relies on modules in dimensions constrained by our launch systems, or whether it is precisely the paradigm of ISRU that will make for real vernacular dwellings, is worth a separate discussion.

Space Architecture as Extension of Modernist Architecture?

Also whether space architecture per se can be considered an extension of modern architecture is worthy of examination. Historically, Space Architecture began to emerge as the movement of Modern Architecture was drawing to a close; but both share many similar characteristics. Or, rather, modernist principles may represent prerequisites that resonate with what Space Architecture could ideally represent by embracing the cutting edge of technology, placing the user in the fore, and implementing fundamental principles of coherency and legibility. Unlike Modern Architecture, Space Architecture has concerned itself less with philosophical concerns and more with addressing pragmatic realities and technological challenges presented by the space setting, even while ultimately supporting the implementation of more high-level societal goals of international cooperation by the often multilateral organizations overseeing most space construction projects.

If, indeed, there is a continuum of both fields, it could be argued that Space Architecture has inherited a legacy of architectural principles and values, which could be more practically recognized, and, vice versa, that its connections to the development of contemporary architecture merits further engagement.

CONCLUSION & RECOMMENDED WORK

In an effort to contribute to the nascent debate on theory in Space Architecture, this paper represents a thought experiment in revisiting the design principles of two prominent architects – who, themselves, never worked in a space context, and did not live to see the first temporarily inhabited space structures beyond the Apollo and Soyuz programmes.

We outlined the respective approaches of Ludwig Mies van der Rohe and Richard Neutra, who developed powerful design principles of simplicity, functional and stylistic coherence and user-centred design, pairing utility with a conscious, unique aesthetic. These, we argued, could serve Space Architecture well in its bid to achieve better human system integration, both in crewed space platforms, but also in the ground segment with its launch facilities, operations centres, space ports or public buildings.

Yet, there are a number of issues that were simply not on the explicit agenda at the time, but today represent primary concerns for architecture. One of these is sustainability, which deserves a designated discussion in the context of Space Architecture and its possible relation to Modernism; as contemporary architecture with a modernist legacy has demonstrated, the two are compatible with each other.

Equally, if it is our interest to derive relevant principles from ground-based settings, it is imperative to point out that there is merit in many other movements of architecture. Further discussion is needed both on the historical relationship of the fields juxtaposed in this paper, but, more practically, also in the lessons that can be learned from other schools of designing and building.

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