

KALIL STUDIO: PROPORTION AND MEANING AS KEY COMPONENTS OF SPACE STATION DESIGN

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ABSTRACT

From earliest recorded history humankind has expressed a desire to affirm its place in the cosmic order. This yearning is, at heart, a search for meaning in, and unity of, existence. Centuries old sacred geometric traditions are a clear manifestation of this longing to connect to a greater context than one's own individual life and thereby give meaning to life. These traditions underlie many of humankind's most cherished architectural constructions and variations can be found throughout the numerous cultural traditions of our world. This paper will explore the relevance of these traditions to a new place of habitation for humankind, that of extraterrestrial space.

Relevant to this discussion is the concept of 'quantum architecture' developed by the Kalil Studio. The term 'quantum architecture' implies an understanding of the relationship of humankind to place, and the proportional structure that underlies it, that is referential to concepts of discreteness and continuity in quantum physics.

This paper will further develop and define the concept of 'quantum architecture.' It will also review the 'Smart Communication Room' design for Armstrong World Industries, 1983-1984, and the work generated by Kalil Studio during the NASA contract cycles as applications of these concepts.

INTRODUCTION

During the years 1984 to 1986, the Kalil Studio engaged in two NASA sponsored contract cycles under the monitoring of Marc Cohen. The purpose of these contract cycles was to develop design proposals for the interior of a habitation module then being proposed as part of a space station to be constructed by NASA. The work accomplished by the Kalil Studio elucidated the studio's perceived meaning of the inhabitation of space and described proportional systems to be used in evolving designs suitable to space habitation. Additionally, the studio developed two preliminary design concepts specific to NASA's proposed habitation module to demonstrate its ideas.

The results were remarkable in many ways and the work has had a life span beyond the conclusion of the contract and the untimely death of Michael Kalil in 1991. In November and

December of 2001, the work was exhibited at the Department of Architecture, Parsons School of Design, The New School University, in New York City. The Museum of Modern Art of New York has also expressed strong interest in making the model and related drawings a part of their permanent design collection.

At the heart of the Kalil Studio's design approach is a concept of the relationship between Individual and Place that is governed by proportion or ratio. David Bohm, in his book Wholeness and the Implicate Order, provides a compelling description of this concept in the following passage:

It is clear that measure is to be expressed in more detail through proportion or ratio; and 'ratio' is the Latin word from which our modern 'reason' is derived. In the ancient view, reason is seen as insight into a totality of ratio or proportion, regarded as relevant inwardly to the very nature of things (and not only outwardly as a form of comparison with a standard or unit). Of course, this ratio is not necessarily merely a numerical proportion (though it does, of course, include such proportion). Rather, it is in general a qualitative sort of universal proportion or relationship. (Bohm pp. 20-21)

The Kalil Studio was rightly concerned with all aspects of the relationship between Individual and place. Although the work presents a geometrically derived proportional ordering approach to the configuration of space, it is not just geometry and ratio in the strictly mathematical sense that is important. Rather there is an attempt to describe and interpret the total relationship between Individual and Place, not just the physical relationship.

Michael Kalil and Jean Gardner wrote:

It is our premise that the fundamental issue in the creation of architecture is how the

relationship between Individual and Place is understood. This premise applies in our construction of architecture from the mud hut to the Space Station. (Kalil & Gardner p. 1)

The studio actively researched sacred geometry and employed concepts and approaches learned in that study to the unfolding of designs for the habitation module. But as the quote from David Bohm suggests, there was a serious attempt to understand the "very nature" of humankind's relationship to place in general, and extraterrestrial space in particular. In the process of doing so, the concept of Quantum Architecture was developed. This concept was elaborated in the writings of Michael Kalil and Jean Gardner and took the form of a myth of the seven stages in the evolution of individual's relationship to place. The myth was grounded, however, in a very real attempt to relate current understandings of universal structure and evolution as expressed by quantum mechanics theories, to the understandings of sacred geometric traditions.

LITERATURE REVIEW: THE CONTEXT IN WHICH THE STUDIO WORKED

An enormous volume and variety of work on, or related to, space station design was accomplished during the mid 1980's by individuals and groups employed by NASA or under contract to NASA. Michael Kalil and Martin Spiegel represented the Kalil Studio, at the Seminar on Space Station Human Productivity on March 1, 1984 and at the Space Station Human Factors Research Review on December 4, 1985.

According to personal communication from Mark Cohen, the Kalil Studio contract was part of a significant effort on the part of NASA to "humanize" the space station. Examples of issues tackled are "functional décor" (Coss et al.), "body orientation cues" (Coss, et al.), interior designs (Kalil & Gardner and Taylor et al.),

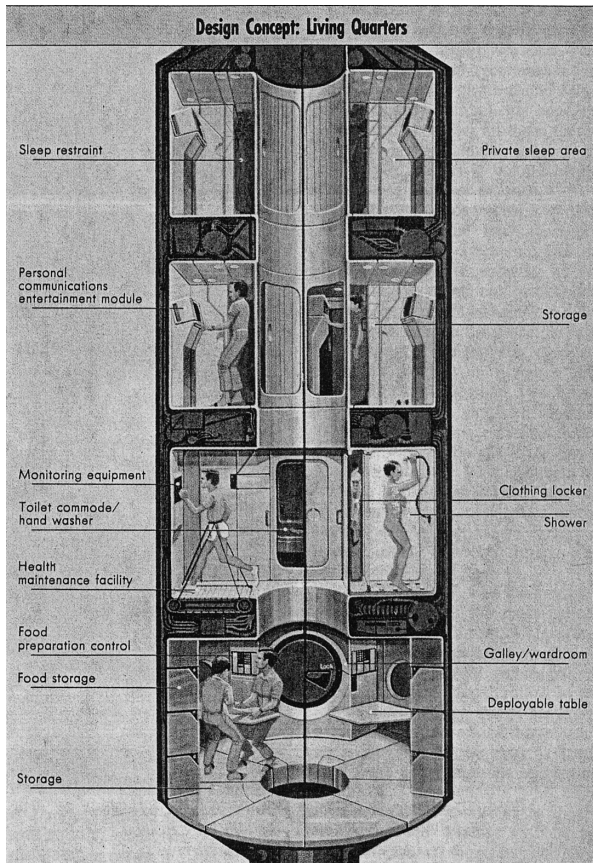


Figure 1

A design concept for the living quarters of the space station.

“privacy needs” (Harrison et al.) and “space station windows” (Haines). In particular, the work of the Taylor group is noted, as the Kalil Studio was in ‘competition’ with this group, having been given the same problem to address, the design of a living environment within the confines of the habitation module.

The Taylor group and Kalil Studio approaches to the problem were very different. The professionals involved with the Taylor group had considerable “severe and hostile environment” experience (Taylor et al., 1987, pp. 3-10). Their approach to the problem was analytical and informed by personal experience of the practical

realities of equipment and life support needs when living in remote jungle and arctic environments.

A different understanding of the problem to be addressed in designing a space station habitation module, as well as time constraints, meant that the Kalil Studio barely considered the realities of equipment and life support. Instead, the Studio was very concerned with establishing the philosophical groundwork and a system of basic proportional relationships which could be used to guide the unfolding of an arrangement of space and supporting mechanization. The Kalil Studio work began by establishing a universal concept of Individual and Place, from which it proceeds to pure geometric study, using sacred geometric traditions as a basis.

In comparing and contrasting the two approaches, a statement made by Mr. Kalil during the 1985 conference is informative:

I think the interesting thing that has come out of these three days is the turn-about in what I've been looking at for the past two years. Humanity in this whole space station system seems to be a servant to the machine. But what these past two to three days has been doing has been turning it around for me. It seems that machinery is finally starting to serve basic human needs. This is a big change from everything I've been seeing. I think that a major important thing to look at, because it's a very different point of view – that you are the master to the machine and that the machine is not the master to you. That you don't start becoming a sort of test object or a gopher in a cage. This is a very important place, and this is a very important time, and that's made a big impression on me. (Cohen et al. 1985)

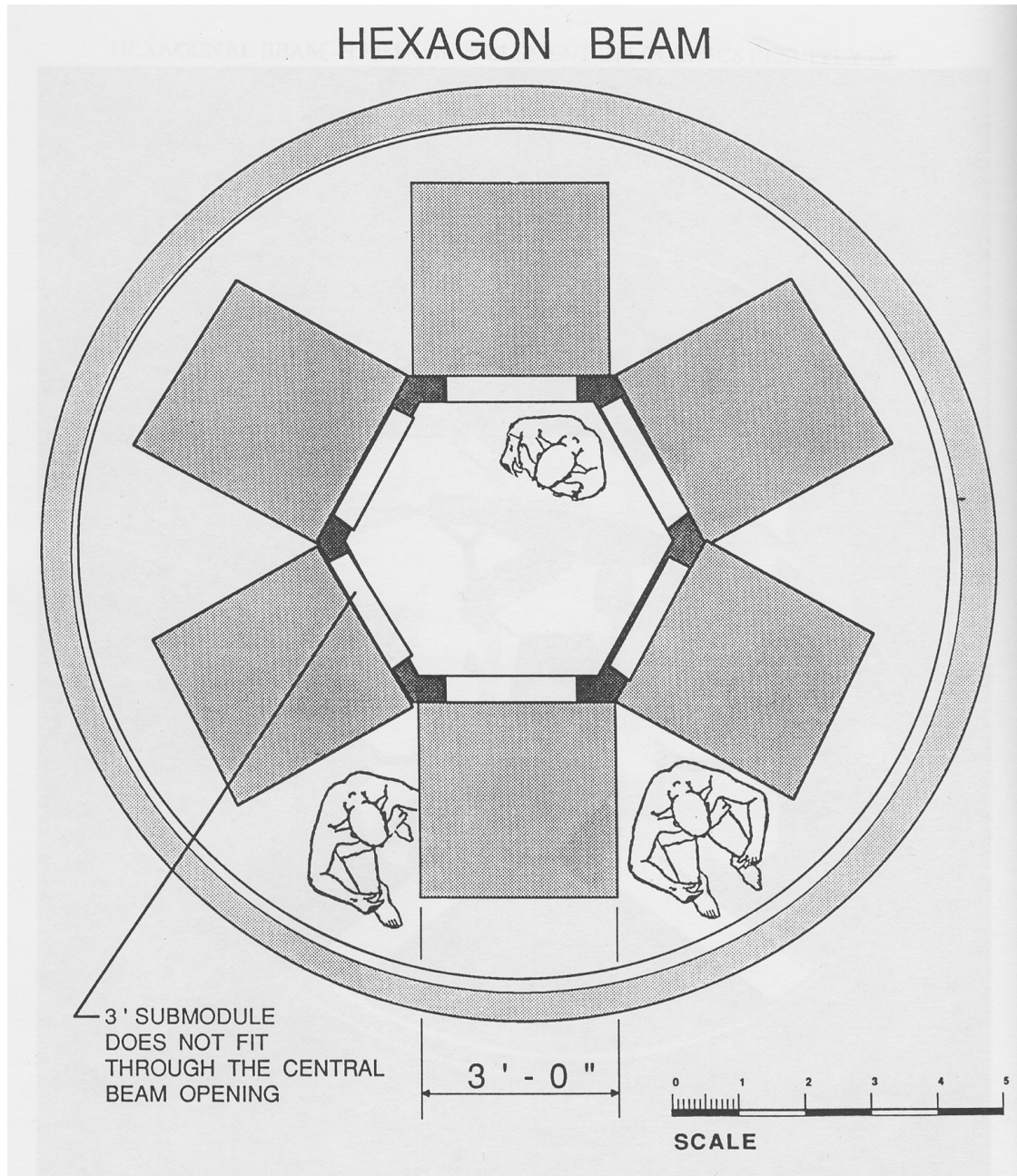


Figure 2
(Taylor et al., p. 94)

Compare also figures 1 with 12 and 2 with 11. 1 and 12 both depict an organization of space within the habitation module confines, but are radically different in approach. Figures 2 and 11

depict concepts of space arrangement based on the hexagon, but could not be more different in their results either. The Taylor concept is focused on equipment and 'service packing' of the cylinder, while the Kalil Studio concept is

focused on space making for human beings. It is interesting to note the difference in how a human figure fits into each of the schemes.*

Clearly, the Kalil Studio wished to start with the fundamental relationship between human being and place of habitation. From there, spatial arrangement was generated with strict adherence to proportional guides. Once the fundamental space making requirements were understood, and spatial arrangement began to take shape, the practicalities of equipment and life support were to have been integrated.

PROPORTION OR RATIO, THE SACRED, SPIRIT AND MEANING

As has been stated, the Kalil Studio began by developing its concept of the relationship between Individual and Place. This concept was based on the idea that the universe is a continuum and that the continuum has a 'preference' for, and is accessible through, certain proportions or ratios. Proportion or ratio was further understood as being more than mathematical, as in David Bohm's explanation of the ancient understanding of 'ratio' quoted earlier. For the Kalil Studio proportion or ratio was an intimate part of a philosophical framework, just as it was for Pythagoras and Plato, for whom mathematics was inherent in philosophy. Proportion or ratio was, then, at the center of meaning and connection to a universal continuum for the Studio.

From earliest recorded history humankind has expressed a desire to affirm its place in a cosmic order. This yearning is, at heart, a search for meaning in, and unity of, existence. Centuries old sacred geometric traditions, upon which the Kalil Studio approach was in part built, are a clear manifestation of this longing to connect to a greater context than one's own individual life,

and thereby give meaning to life. These traditions underlie many of humankind's most cherished architectural constructions and variations can be found throughout the numerous cultural traditions of our world.

The desire to experience connection to a cosmic or universal continuum may have a partially satisfactory explanation as a characteristic that is favorable to survival, but such an explanation inevitably falls short of the full scope of the emotion or feeling. Qualitative aspects of human experience, such as desire, belief, reverence, love and hate, carry depths that defy description in any quantitative sense. They constitute the qualitative side of experience and are prime animators and motivators in the unfolding of human life. These aspects of human experience are among the inscrutable characteristics that comprise what can be described as the 'animating spirit' of human nature.

This qualitative or 'spiritual' side of human nature can have a profound effect on outcomes, even at relatively mundane levels. Belief is a case in point. The placebo effect in healing is a well-known phenomenon. It has been shown not only to activate healing upon administration of a medication protocol that has no demonstrable reason to be effective, but also to be a necessary component in activating treatment protocols that do have demonstrable reasons for effectiveness. Similarly, when taking mathematics exams, men and women of comparable ability will perform equally well when told that the exam is gender neutral.[†] (All in the mind, 01.21.2002)

In short, belief matters. But the act of belief itself, and the depths to which it can reach, are as yet, inscrutable. Understanding that we are connected to a cosmic continuum and allowing that understanding to support a qualitative sense of connection is essential to well being.

* It should be noted that figure 12 is based on one of the original drawings submitted in progress reports by the Kalil Studio. The original drawing did not include human figures. The figures shown are children in a ring apparently dancing.

[†] Interestingly enough, the balance is achieved through a rise in the scores of women, and a fall in the scores of men (relative to a control group).

A concept of the sacred becomes manifest, not just explicitly in reference to geometric traditions, but also implicitly as the result of an attitude of deep and profound respect for the ratio of things. This attitude of respect creates the realm of the sacred as it seeks to connect and then act through understanding without violation. This view of the sacred makes it a principle that belongs to all of humanity and gives it a place in space station design.

Respecting the ratio or relationship of things means seeking to understand in the fullest way possible, and acting with the highest regard for, the place of each thing in the universe of relationships that constitutes our world. It also means that no thing can be truly understood apart from that universe of relationships in which it participates. In this regard, a sense of the sacred can and should permeate all of life. Human relationships of all kinds are profoundly enhanced through an attitude of respect, and therefore, a measure of the sacred.

In some ways, the western scientific and industrial revolution unfolding over the last 500 years can be viewed as a huge success because the mastery of certain concepts of physics and mechanics has led to amazing capabilities, such as the space exploration programs that offer the opportunity for this paper. Unfortunately, this scientific and industrial revolution appears to create problems as fast as it solves them. Isolation and fragmentation are serious problems of our world. Also significant is the extent to which the quantitative is emphasized over the qualitative. Progress gives and takes in equal amounts at best.

The compartmentalization (and consequent fragmentation) of things and ways of understanding is fundamental to the western mindset. Gregory Bateson, in essays entitled "Form, Substance, and Difference," and "Epistemology and Ecology," both from his collection of essays entitled The Ecology of Mind, describes the problem as a separation of

substance from pattern, which he says goes back to the Greeks who asked whether you consider what something is made of or it's pattern. He talks about the effect on the science of ecology:

Ecology has currently two faces to it: the face which is called bioenergetics – the economics of energy and materials within a coral reef, a redwood forest, or a city – and second, an economics of information, of entropy, negentropy, etc. These two do not fit together very well precisely because the units are differently bounded in the two sets of ecology.

He goes on to say that:

...there are bridges between the one sort of thought and the other, and it seems to me that the artists and poets are specifically concerned with these bridges... art is concerned with the relation between the levels of mental process. ... Artistic skill is the combining of many levels of mind ... to make a statement of their combination. ... It is when we recognize the operations of ... (patterns, proportion) ... in the external world that we are aware of 'beauty' or 'ugliness.' (Bateson)

What the Kalil Studio recognized is that current 'progress' simultaneously solves and creates problems because ways of thinking are developed and things are acted on or created without a full understanding of their place in the continuum. Indeed, much of the time there is no true realization that there is a continuum. Therefore, mastery of proportion and relationship at one level is achieved in ignorance, sometimes deliberate and sometimes not, of other important relationships at other levels. Key to the recovery of a sense of the whole is a willingness to allow the spiritual or qualitative or artistic a seat at the table as a uniting animator and motivator that makes possible a full experience of the continuum.

At this point it should be acknowledged that there is a danger in allowing the qualitative a role alongside the quantitative, or the spiritual a role alongside the material. Humanity in general can become unreasonably and destructively attached to particular beliefs. Throughout history, and particularly throughout recent history, ways of looking at the world have been continuously revised as the boundary of perception has been steadily extended in both the subtle and gross directions. Theories are regularly challenged and replaced by new ones that more accurately predict the conditions revealed through this extended view. It is essential that as the qualitative assumes a roll alongside the quantitative, openness to the challenges offered by new or extended perceptions be maintained. To tenaciously and even violently hold on to old beliefs in light of new facts is a tendency of humanity that needs steadfast resistance.

QUANTUM ARCHITECTURE

The Relevance of Quantum Mechanics to Space Station Architecture

In considering the relevance of quantum mechanics to the problem of a proportioned and meaningful design for human habitation in extraterrestrial space, it is important to understand that order and the means of comprehending and describing it changes depending on the grossness or subtleness of a particular manifestation relative to the scale of unaided human perception. Clearly, the scale of atomic and subatomic particles, the realm of quantum mechanics, is extremely subtle relative to the scale of our bodies. What, then, is the relevance of the perception level of sub-atomic behavior to the perception level of human habitation in space?

Discreteness of Quantity

A basic principle of quantum behavior is discreteness of quantity. A quantum is the

smallest unit of radiant energy for a given frequency. It further refers to the idea that there are discrete, that is, preferred levels of energy for a particle or system of particles.

Discreteness was believed by the Kalil Studio to hold throughout the subtle and gross levels of perception, and consequently, it becomes an important organizing principle for human habitation. The Studio re-affirmed the basic tenet of sacred geometry, that there are specific, preferred, even mandated relationships among things at all levels. By paying attention to these preferred relationships, there is a more fulfilling engagement with the world, either because there is less 'friction' due to a non-proportional relationship of parts, or, even better, the things created out of this relationship are more useful, even a pleasure to use or be part of, because relationship and proportion have been rightly understood. In the language of 'human factors,' when the conversation is about the development of relational arrangements that make things easier to use or, in contemporary terminology, more 'user friendly,' often the subject is really proportion.

The Continuum

The perception of the Kalil Studio was that the universe is a continuum. Quantum theory at the time, as well as more recent discoveries and theoretical developments of particle physics, tend to support that point of view. The idea of a continuum is an extremely important re-discovery of ancient truths. It is significant both practically and spiritually. By understanding that everything is interconnected and related, it is possible to support and maintain an attitude of respect for the right relationship or ratio of things. To isolate any particular piece of the whole, as western society tends to do, and work on it or from it, breaks the chain of relationships and the result is likely to both give and take away, even if some kind of proportional or relational understanding is applied within the isolation. The Kalil Studio insisted on growing designs out from

fundamental understandings and always attempted to maintain connections at all levels of perception.

This has practical benefit in the development of physical relationships that are more successful and spiritual benefit in maintaining a sense of connection to the whole, or the one. By acknowledging a universal continuum in which all things participate, and by seeking to 'tune' our selves and our designs to the proportions and ratios of that continuum, meaning and the realm of the sacred are established.

It should be acknowledged, however, that care should be taken in attempting to apply the specific relationships operating at one level of perception to another. Relativity and quantum mechanics suggest entirely new and strange geometries when traveling near the speed of light or perceiving at the scale of subatomic structure. The Kalil Studio chose Euclidian geometry as the appropriate geometry to pursue for arbitration of the relationship between Individual and Place.* Tools and perceptions must be used within the limits of their accuracy and usefulness for description and prediction. Very subtle tools should not be used to describe gross phenomenon or levels of perception and gross tools are not valuable at very subtle levels.

The Concept of Quantum Architecture as Expressed by Kalil Studio

Michael Kalil and Jean Gardner wrote:

The basic premise of Quantum Architecture is the fundamental unity of the universe. Post-Einstein science, whether it be Quantum Physics, Astrophysics, Jungian Psychology, Neuroscience, Ecology, or Biology, is moving toward a unified conception of the universe. For the

* Today, fractal geometry or catastrophe theory might have been considered for incorporation into the thinking of the Studio.

purposes of this study, we refer to the fundamental sub-atomic level of this undividedness as the Neutral Vibratory Field, which Quantum Architecture unfolds and mirrors.

Theoretical Physicist David Bohm has analyzed this vibratory domain as having an order. He describes the order as an enfolded or implicate one. The physical or explicate world unfolds from the unified field in such a way that each seemingly independent part remains interconnected.[†]

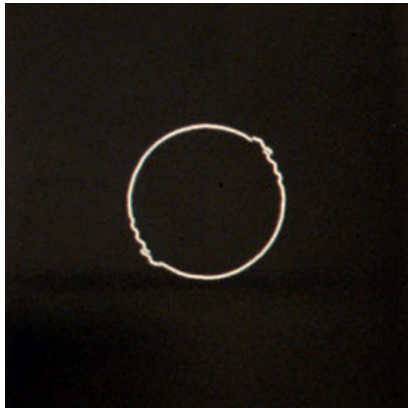
The research of Karl Pribram, Stanford Professor of Neuroscience, confirms that our physical world is constructed of vibrations from the unified field. Our physical bodies receive these vibrations and order them into our everyday reality by using proportions reflective of this field.[‡]

Metaphorically, the relationship between our physical world and the Neutral Vibratory Field is similar to that of the part of a hologram to the entire hologram. The part can reconstruct the entire image. Each part unfolds from the unified field so it still contains the underlying order of the whole because it is proportionally related to it. A consequence of this is that the whole determines the behavior and properties of relatively independently behaving parts such as Individual and Place.

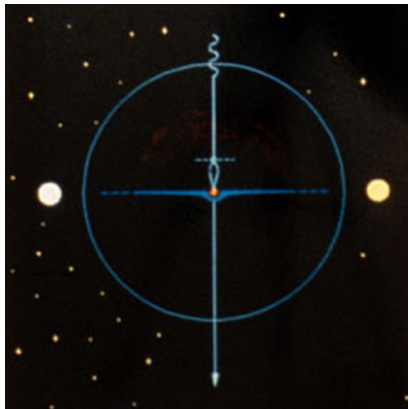
The behavior and properties of Individual and Place become the basis of Quantum Architecture, which is their visual echo. Defined in this way, Architecture mirrors the order of the whole, creating space

[†] The original work from which this quote is taken did not reference the source other than by author. It is likely that the information came from David Bohm's book, Wholeness and the Implicate Order.

[‡] The original work from which this quote is taken did not reference the source other than by author.



A



B



C

Figure 3

Diagrams from the seven stages of the unfolding of Individual and place developed by Michael Kalil and Jean Gardner.

*within which man can dwell with dignity.
(Kalil & Gardner p.)*

Figures 3A (desire moves the vibratory field), 3b

(individual materializes) and 3C (individual is freed from planetary constraints) illustrate the first, fourth and seventh stages of the unfolding of desire in the universe.

PROPORTION AND RATIO

Proportional Relationships in Nature

Mathematical proportion and ratio figure prominently in the work of the Kalil Studio. Therefore, it is appropriate to review some history regarding proportion and ratio.

The original source for humankind's understanding of geometry and proportion is the earth and its flora and fauna. The original meaning of the word 'geometry' is 'to measure the earth.' Geometry and proportional relationships abound in nature and knowledge of this is ancient.

To quote the Kalil Studio study:

In reviewing the history of proportional relationships, one must consider the role of natural phenomenon in the overall sense of harmony. Natural evolutionary growth processes first established dimensional ratios. Early mathematicians then analyzed these natural phenomena, mathematically surfacing various proportional values such as the Golden Section, $\sqrt{2}$, $\sqrt{3}$. These ratios can be found in crustaceans, plants, insects, shells, pinecones, the human face and in a myriad of other forms. Some are resolved within spiral configurations and others are found in the relationships of linear dimensions and each is related to the growth pattern of the organism*

*Dimensional ratios are inherent in the fabric of the universe. The use of these ratios is favored by natural selection to the extent that it can shorten instructional code (DNA) and confer advantages to the organism, such as densest packing of seeds. See Stewart for a fuller explanation of this point of view.

As humans, our proclivity to use, and preference for, particular ratios goes deeper than the fact that consciously, a given shape or form is pleasant to the eye. Our continued exposure to these proportional ratios in nature for eons has provided us with innate preferences for this range. For centuries, shaman, artisans and architects of many civilizations have exhibited a preference for these. As examples of this order we can look at specific expressions such as Stonehenge, the Parthenon, Chartres, the Garden of Ryoan Ji, where man has used proportional systems stemming from nature in ordering his creations. It is clear that those human creations, which we define as enduring, express a truth, a relationship to the basic pattern-forming process of nature. (Kalil & Gardner, pp. 4-5)

Ian Stewart argues the fundamental importance of patterning and proportion eloquently in his book, Life's other secret : The new mathematics of the living world. According to Stewart, genes make strategic use of patterning and proportional systems inherent in the universe. Through the deployment of pattern and proportion, the genetic coding required to build an organism is significantly shortened and simplified. Stewart makes the claim that patterning and proportion are every bit as important to reproduction, growth and development as DNA. In making this argument he writes:

As a consequence (of focusing exclusively on DNA and genes), we are in danger of losing sight of an important fact: There is more to life than genes. That is, life operates within the rich texture of the physical universe and its deep laws, patterns, forms, structures, processes, and systems. Genes do their work within the context of physical laws, and if unaided physics or chemistry can accomplish a task, then the genes can safely leave them to it. Genes nudge the physical universe in



Figure 4a
A six-petal flower.

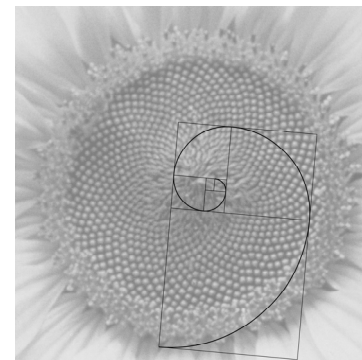


Figure 4b
The head of a sunflower.



Figure 4c
A five-petal flower.

specific directions, to choose this chemical, this pattern, this process, rather than that one, but the mathematical laws of physics and chemistry control the growing organism's response to its genetic instructions. (Stewart pp. x-xi)(parenthesis added)

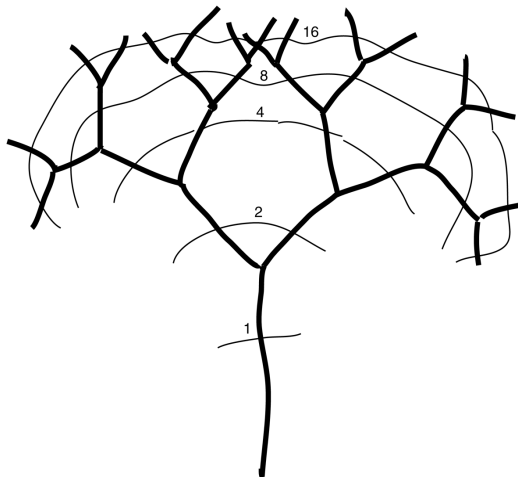


Figure 5a
2($\sqrt{2}$) Branching

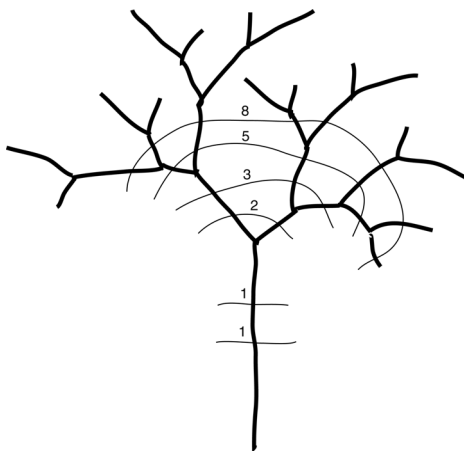


Figure 5b
Fibonacci Series Branching

Figures 4a through 4c are three of the myriad of varieties of flowers that exhibit the $\sqrt{3}$ and $\sqrt{5}$ (golden mean) proportions. Figure 4a shows a blossom exhibiting a hexagonal arrangement, which is the $\sqrt{3}$ ratio. Figure 4b shows a variety of sunflower which exhibits a golden mean spiral where the ratio of increment is $\phi = 1.6180339$. Figure 4c shows a blossom with a pentagonal structure that is the $\sqrt{5}$ ratio, which also leads to

the golden mean or ratio.

The golden mean spiral is a logarithmic spiral with a ratio of enlargement related to ϕ . This progression is based on the Fibonacci number series, an additive number series where the sum of the last two numbers becomes the next number in the series:

$$1 : 1 : 2 : 3 : 5 : 8 : 13 : 21 : 34 : \dots$$

The relationship of any two successive terms approximates $1:\phi$, and that of any three successive terms approximates $1:\phi:\phi^2$.

Ratios and forms resultant from the Fibonacci and related similar number series are found to underlie growth patterns throughout nature. Robert Lawlor* describes two main branching patterns in the growth of plants, one governed by the geometric progression of $2(\sqrt{2})$ (figure 5a) and the other by the Fibonacci Series (ϕ) (figure 5b). He also describes a pattern of distribution of leaves around a central stem that is governed by the Fibonacci series. (Lawlor p. 58) Most of us are familiar with the Chambered Nautilus, which also exhibits a golden mean growth pattern.†

The analysis of proportion in nature has been extensive both in ancient and modern times. Numerous sources of confirmation exist in printed form and on the Internet.

Sacred Number and Geometry

That humanity would discover mathematically definable pattern relationships in nature should

* Michael Kalil and Jean Gardner met with Robert Lawlor and studied his book on Sacred Geometry.

† It seems there may be more to nautilus symmetry than just a golden spiral. Apparently the nautilus occupies a new chamber each lunar month. According to information found on the William J. Patterson University web site <http://www.wpunj.edu/cos/envsci-geo/nautilus_shell.htm>, the lunar month relationship is so accurate and long standing that fossilized nautiloids can be dated in this way because the length of the lunar month has been steadily changing over time!

be of no surprise. Humans are a pattern loving species, as are most forms of life on the planet. To love pattern is to have enhanced predictive capability, and consequently, a favored chance of locating or producing food. To want to describe such pattern in terms that can be relayed from one individual to another and from one generation to the next is also understandable in terms of survival or competitive advantage. Nor is it surprising that these descriptions of order and pattern in the world should become more than just a tool to enhance food capture or production. But it must have been an astonishing thing to discover such order in the natural world. Astonishment frequently accompanies the discovery of the patterning side of things. These discoveries are given a qualitative dimension by regarding them as special or sacred knowledge. Developing a deep abiding respect for the relationship of things, a strongly held sense of connection between ourselves and those things, is, to say it again, an intrinsic part of well being.

Earliest evidence of the development of sacred geometry and mathematics appears to indicate that it had a practical predictive value in addition to being perceived as revealing divine or sacred structure in the universe. Early cultures of Egypt and Mesoamerica used numerical relationships to apportion land after spring flooding and develop calendars predicting the movement of the Sun, Moon and visible planets.*

These agrarian societies had real need to be intimately connected to the rhythm of the seasons and for them, number and calculation were very different in nature than they are for us. Numbers rule humanity today, but it is largely in a quantitative sense. These ancient civilizations used numbers in a qualitative, sacred sense, as

* The Egyptians were capable of calculating relationships for which we now use algebra and trigonometry to calculate. The Mayan civilization developed a highly sophisticated calendrical system incorporating all of the planetary cycles. Both did it without a concept of Zero and the Mayans did not know fractions either.

being descriptive of the right order of things and in need of respect. Robert Lawlor makes a distinction between societies that take a sacred approach to proportion and ratio and those that take a mundane approach through a discussion of 1 and 0 as the center of their respective number systems. The sacred approach begins with:

...meditation on a metaphysical Unity, followed by an attempt to symbolize visually and to contemplate the pure, formal order which springs forth from this incomprehensible Oneness. The mundane approach begins with a "network of intellectual definitions or abstractions." (brought about by the use of zero as a place holder and the subsequent development of irrational numbers). (Lawlor p. 17) (parenthesis added)

Compare this to the following from Kalil and Gardner:

Establishing Unity as the seed from which proportional systems have evolved, these systems establish order and a basis for dimensional parameters. We are exploring the various universal harmonic proportional methods unfolding from Unity defined (in this case) as the given diameter of the cylindrical Space Station Module shell. These systems demonstrate their ability to generate a foundation for the appropriate selection of the interior architectural arrangements. (Kalil & Gardner p. 1) (parenthesis added)

Lawlor traces the origin of the concept of zero to India, where it paralleled the development of a particularly ascetic pursuit in both Buddhism and Hinduism. That pursuit sought the achievement of a completely inactive consciousness.[†] (Lawlor

[†] Philosophically, it is interesting to contemplate that modern technological society relies increasingly on machines whose language is built entirely on two characters, one and zero,

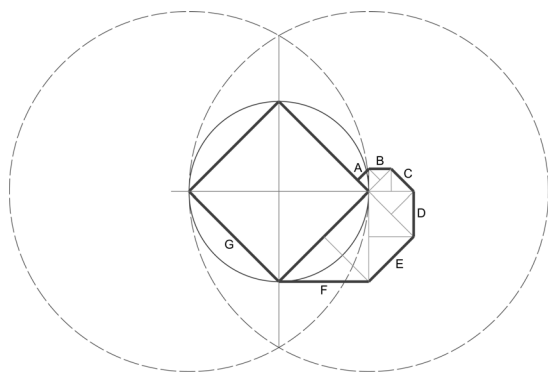


Figure 6

$\sqrt{2}$, Method of Cellular Growth
A = 1, B = $\sqrt{2}$, C = 2, D = $\sqrt{8}$, E = 4, F = $\sqrt{32}$, G = 8

p. 17) It is tempting to relate the introduction of the placeholder of zero to the draining of meaning or the qualitative side of perception and reaction, as the mathematics it makes possible has been central to the scientific and industrial revolution. Robert Lawlor provides an extensive discussion on this matter in his book and the reader is referred to his treatment of the subject.

At a certain point, sacred geometric practice became separated from its roots in agriculture and persisted primarily as a means of understanding and describing a universal order and translating it into built form. There it served to mediate the relationship between humanity and the immutable. It also continued to supply qualitatively better spatial experience than when not employed.

Traditional (Sacred) Proportional Relationships

In considering traditional or sacred geometries, three proportional relationships stand out. They are $\sqrt{2}$, $\sqrt{3}$ (Vesica), and $\sqrt{5}$. The Kalil Studio reports prepared for NASA discuss in detail the first two, and mentions the third in passing. Only

used in strings to develop expressions for everything else. One and zero, wholeness and nothingness. Out of that arises the capacity for infinite description.

the $\sqrt{2}$ and $\sqrt{3}$ (Vesica) systems are used in the unfolding of designs for the Habitation Module.

$\sqrt{2}$ (Kalil Studio Method of Cellular Growth)

This method is one of the most basic to traditional sacred geometry and is to be described as the squaring of the circle. In this method it is the relationship of the side of the square to the diagonal of the square that yields the proportion of $\sqrt{2}$. This method can be used to construct a geometric progression as demonstrated by figure 6.

In proportional progressions a key concept of sacred geometric understanding is revealed:

The relationship between the fixed and the volatile (between proportion and progression) is a key to Sacred Geometry: everything which is manifest, be it in the physical world or in the world of mental images and conceptions, belongs to the ever-flowing progressions of constant change; it is only the non-manifest realm of Principles which is immutable. (Lawlor p. 29)

Designation of this progression as the method of “cellular growth” by the Kalil Studio is from sacred geometric tradition. The halving of the square by its diagonal is also the doubling of the square, since the diagonal constructs a larger square exactly twice the area of the first. Thus, this unfolding symbolizes cellular growth.

$\sqrt{3}$ (Traditional and Kalil Studio Method of Vesica)

The Kalil Studio study describes the method of Vesica as “ratios generated by intersecting circles whose centers are specifically located relative to each other” (Kalil, Gardner, p. 9). In Robert Lawlor’s book it is known as *Vesica Piscis* and is described as the primary sacred geometric configuration with a fundamental ratio of $\sqrt{3}$, of

which there are traditionally understood to be two (the secondary is derived from the diagonal of a cube). (Lawlor p. 31) It is initiated by drawing two circles, each with its center situated on the circumference of the other. From this point many different geometric constructions can be unfolded. Figure 7a illustrates the construction of the $\sqrt{3}$ rectangle and proof that line $CD = \sqrt{3}$.^{*} Figure 7b illustrates the construction of the hexagon from the Vesica Piscis.[†] Lawlor writes that there are few figures that carry so much meaning historically. Both Lawlor and Keith Critchlow (in *Time Stands Still*) discuss this history. The Kalil Studio also attributes superior aspect ratios (most pleasing proportions), to this method.

The Flowering, or $\sqrt{3}$ method described by the Kalil Studio is really the Method of Vesica again, at least as it relates to sacred geometric concepts. It is based on the hexagon unfolding illustrated in figure 7b.

$\sqrt{5}$ – The Golden Ratio

This method is not described by the Kalil Studio reports, but it needs inclusion when considering traditional proportional relationships for use in design. “The $\sqrt{5}$ is the proportion which opens the way for the family of relationships called the Golden Proportion” (Lawlor p. 37). This proportion is generated when two squares are placed together to form a rectangle of 1 to 2 in proportion as in Figure 8a. If $AB = 1$, then the diagonal BC of this rectangle is the $\sqrt{5}$. As this method leads into the golden ratio, it is also, therefore, related to the Fibonacci series mentioned earlier. The construction of the pentagon from a circle and the $\sqrt{5}$ rectangle is shown in figure 8b and also leads to the golden ratio and the Fibonacci series.

^{*} By constructing the equilateral triangle CML and assigning a value of 1 to radius length AB , it can be demonstrated that $CD = \sqrt{(CM^2 - DM^2)} = \sqrt{3}$.

[†] The proof that $CD = \sqrt{3}$ is the same as for the vesica rectangle construction.

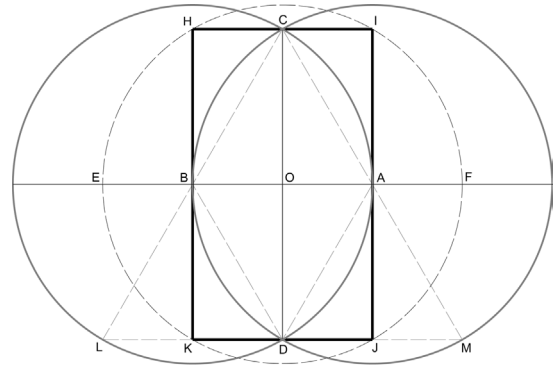


Figure 7a
Method of Vesica
 $HI = OI = \text{radius } AB = 1$
 $HK = CD = \sqrt{3}$

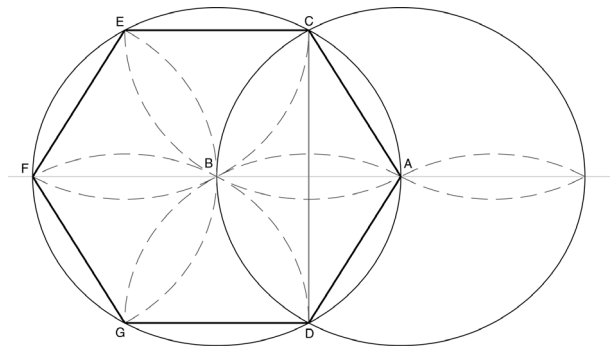


Figure 7b
Method of Vesica
 $CD = \sqrt{3}$

This ratio is unique among ratios in traditional or sacred geometric practices in that it is a two-term relationship. It is considered to be the most fundamental, in the sense that it possesses the smallest number of terms in its algebraic description of relationships that can unfold a universe from 1, or wholeness.

A:B as C:D is known as a four-term relationship.

A:B as B:C is known as a three-term relationship.

A:B as B:A+B is known as a two-term relationship. This relationship can also be expressed as A:B as B:1, and thus it is traditionally described as the perfect division of 1,

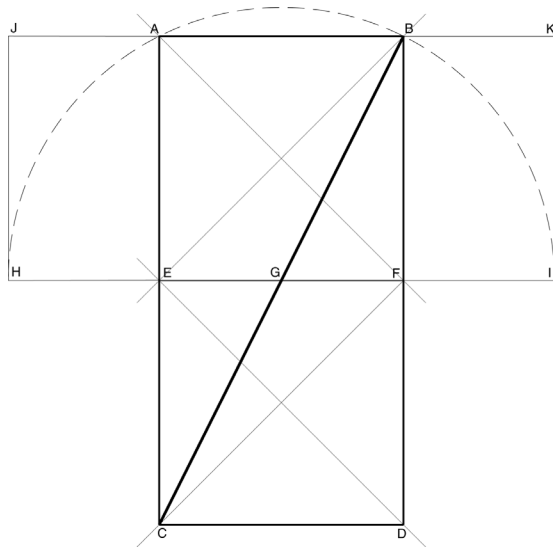


Figure 8a

$$AB = 1$$

$$BC = \sqrt{5}$$

$$EI = \phi = 1.6180339$$

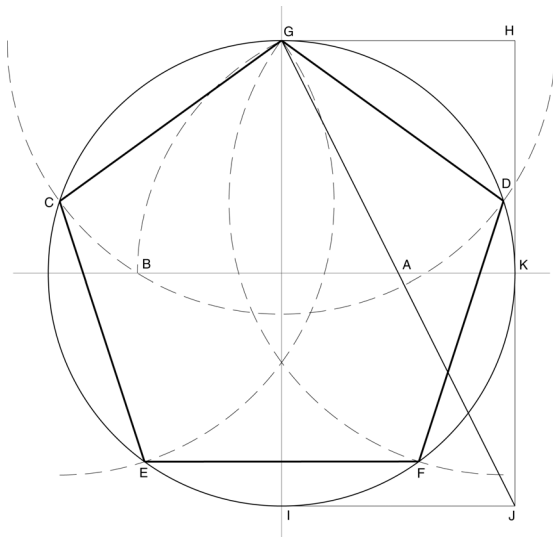


Figure 8b

$$GH = 1$$

$$HJ = 2$$

$$GJ = \sqrt{5}$$

$$GA = GD = GC = CE = EF = DF = \sqrt{5}/2$$

$$BK = \phi = 1.6180339$$

as it is the most basic relationship that will divide one without symmetry. (Lawlor, pp. 46-47)

ARMSTRONG WORLD INDUSTRIES “SMART COMMUNICATION ROOM” DESIGN

The Armstrong World Industries ‘Smart Communication Room’ was the first fully developed design of Kalil Studio to suggest that the floor is not only what we stand on, but in addition, the source of everything needed to inhabit a space (see figures 9 a, b and c). The idea is that the floor is mechanized and computerized, and able to unfold out of itself all the requirements for doing work, exercising or relaxing. In a sense, the floor becomes the ‘vibratory field’ of human interaction with space, adjusting to each need or desire. The entire room is developed into a responsive ‘organism’ capable of perceiving and responding to the needs and desires of individual.

Regina Cornwell described the sequence of entering, arranging and working or relaxing within the room as follows:

Hand: A hand is placed on the entrance. The handprint, on file in the memory of the computer, is read by a scanning system and unlocks and opens the door.

Mind: On entering, the space is clear. A keyboard surfaces from the floor to a height of five feet, establishing a “human mind to computer mind” relationship. The keyboard acts as a mind-to-mind intermediary through which the user makes arrangements for the furniture needed and communications required for that particular day’s tasks.

Foot (figure 9a): Very nearby is a recessed steppingstone, inviting the user forward. Stepping on the stone causes the furniture just selected –in this case a chair- to surface from within the floor into an open position, responding to the individual’s presence.

Sound: Once seated in the chair, the user is positioned behind a horizontal bar. This is a sound resonator control system, designed to pick up voice and other sounds; through them it is programmed to activate images on the four glass screens, including holograms of participants at conferences, personal computer data, slide presentations, etc.

Temperature: Heat sensors rise on vertical columns on either side of the individual. When the sensors are touched, it is the user's body temperature, which sends signals to the computer, which in turn affects color change in the room through manipulation of light.

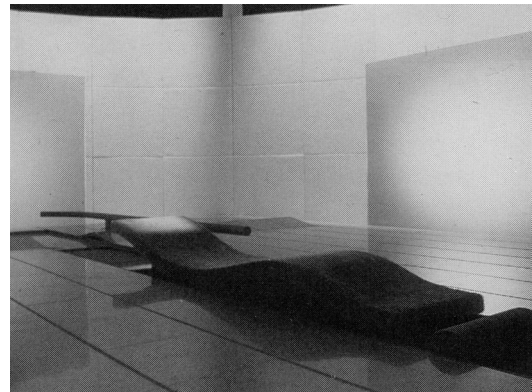
Once finished at the workstation, the user is ready to move to the center of the pavilion. The voice resonator system picks up the user's sound signal and follows through with the needed changes in the room and communications process. The chair returns to a closed position. The horizontal bar lowers, turns, acting as a gate, inviting passage into the balanced center of the room.

Body (9b and 9c): Reaching the center, the user encounters a flat surface lifting from the floor. The surface has a scanning program with it, able to read any person's body shape, to conform to that shape and to support it. Here, at its center, the pavilion establishes conditions exploring extrasensory perception. (Cornwell)

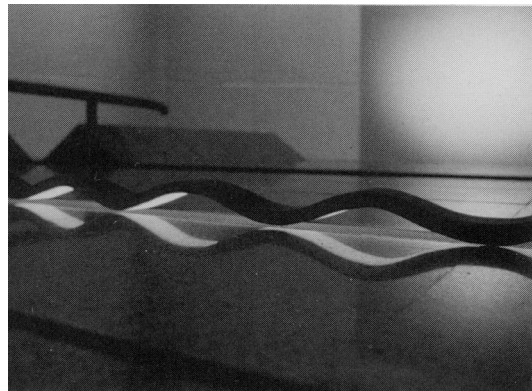
Although the computerized mechanization concepts suggested by this project were never realized in the designs for the habitation module, they are implied in the initial unfolding of the design and are important to comprehend as an eventual goal of those designs. It can be assumed that had the habitation module designs progressed, the Kalil Studio would have conducted a deep exploration into 'surface



A



B

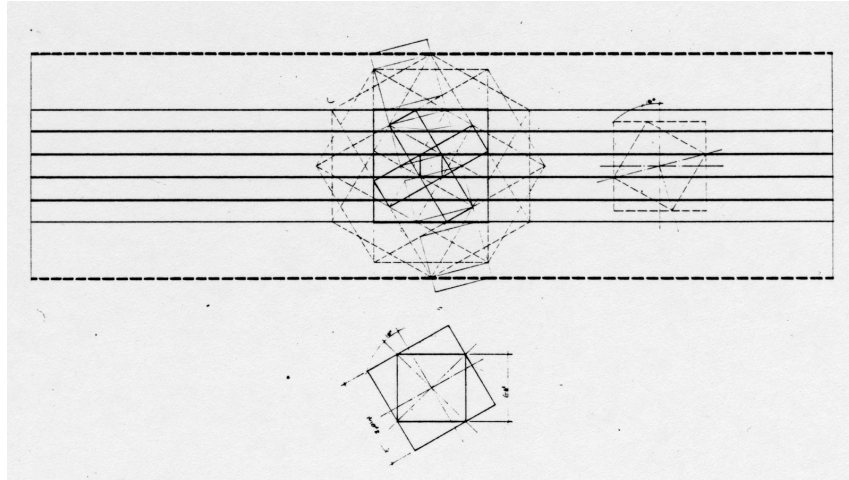


C

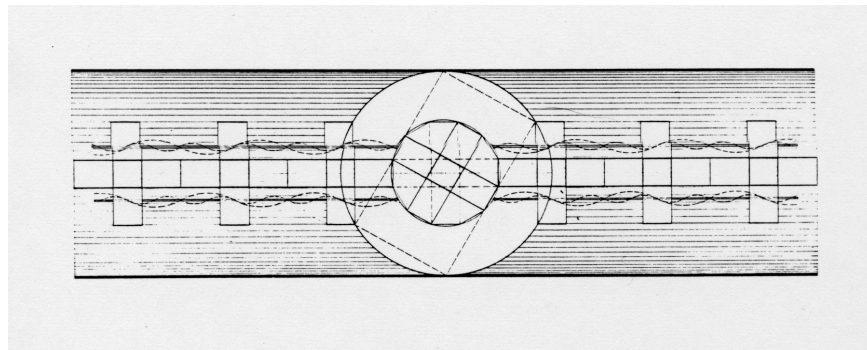
Figure 9
Armstrong Smart Communications Room

mechanization' and animating possibilities such as biofeedback.

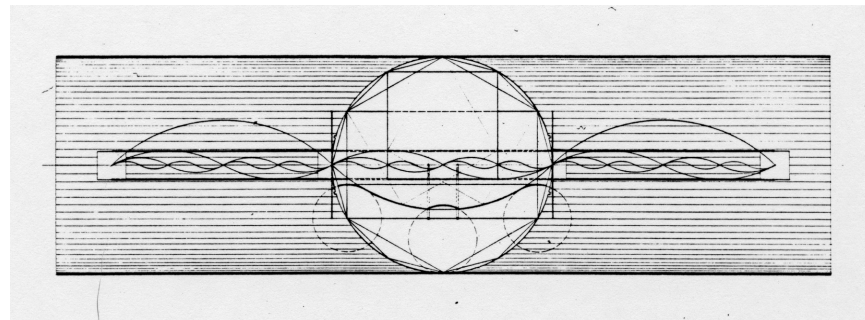
Another attribute that the Armstrong room and the space station have in common is the use of



A



B



C

Figure 10
Geometric Studies for the OM Design

geometry as an ordering principle. The proportions of the $\sqrt{2}$ order. The Armstrong room took the form of a circle with a square raised floor plane, and inverted pyramidal ceiling. The room was largely based on the

THE NASA SPACE HABITATION MODULE PROJECT

General Use of Proportion and Geometry

As has been indicated, certain proportional relationships discovered in nature and abstracted to geometric configurations, then analyzed into algebraic and numerical relationships and codified in practices of traditional and sacred geometry, are to serve as the basis for the proportioning of space and the surfacing of form opportunities in the Habitation Module. The Kalil/Gardner report identifies two 'powers' fundamental to the generation of timeless architecture. They are Individual and Place. Because the form of the Habitation Module is a given, the report identifies it as a third power (Kalil & Gardner p. 8). It is the diameter of the cross section of the Habitation Module that serves as the unity from which proportion and geometry were unfolded and then 'tuned' to the needs and desires of Individual.

Geometry becomes the selection tool for right

proportional relationships according to the Kalil/Gardner report:

The vehicle for narrowing the choices of the ratios selected is geometric form. Chosen geometric forms have preferred proportions that have been established as basic elements of design. Geometric forms aid in the construction of known ratios in ranges that give choice. Also, they provide basis for evaluating in-between ratios for the refinement of a harmonic proportional order. Ratios other than those created from geometric construction might be selected to best suit the root system that is most applicable, however, the geometric method is being used to find the most appropriate range for selection. (Kalil & Gardner p. 9)

Geometric Studies for the Osmotic Membrane Design

The geometric studies conceived by Kalil Studio in exploring the design of the habitation module

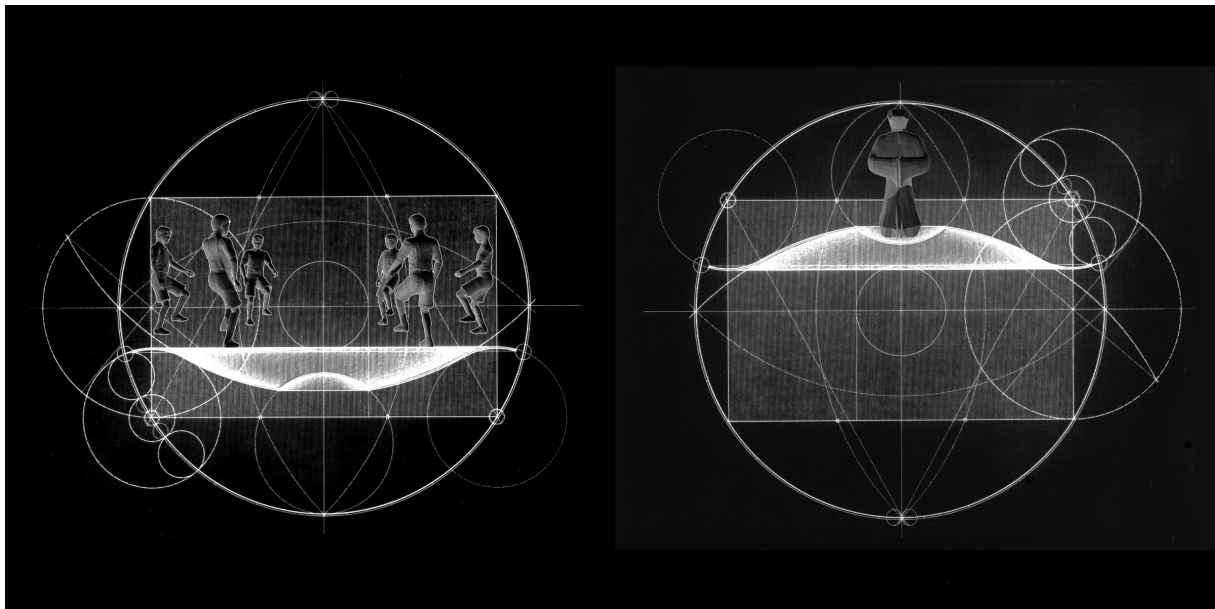


Figure 11
The Community Dish

are based on the $\sqrt{2}$ and the $\sqrt{3}$ relationships described above. A series of geometric studies constitute a harmonic analysis of the cylinder. "The harmonic analysis sets up the resonating field from which unfolds the harmonic themes for investigation in Phase III." (Kalil & Gardner p. 13)

In figure 10A we see the floor system of the Armstrong Smart Room design referenced by 5 linear strips, as well as continuing exploration of the cross, the square and the rectangle as possible surface or container opportunities. This particular drawing suggests an abstracted atom structured on platonic solids. Note also the skewing of geometric opportunities (the rotated cross and the rotated square within the square). This skewing or rotation creates asymmetry. As the ancients required an asymmetry to create the

opportunity for unfolding, and physicists require an asymmetry to explain the existence of matter, so the Kalil Studio approach frequently focuses on asymmetries to yield motion within the design.

In addition to harmonic analysis, form is being explored as well. In figure 10B there are indications of functional form that make appearances in sketch models photographed for the project. In this case the 'community dish' of the Osmotic Membrane (OM) design can be seen referenced, as well as an initial idea of a pair of rails running the length of the cylinder. The wave pattern appearing to wrap around the rails is suggestive of the vibratory field referred to elsewhere, as well as the possibility of carrying 'conduits' for electricity, water and air. The cross is another form opportunity that is explored as

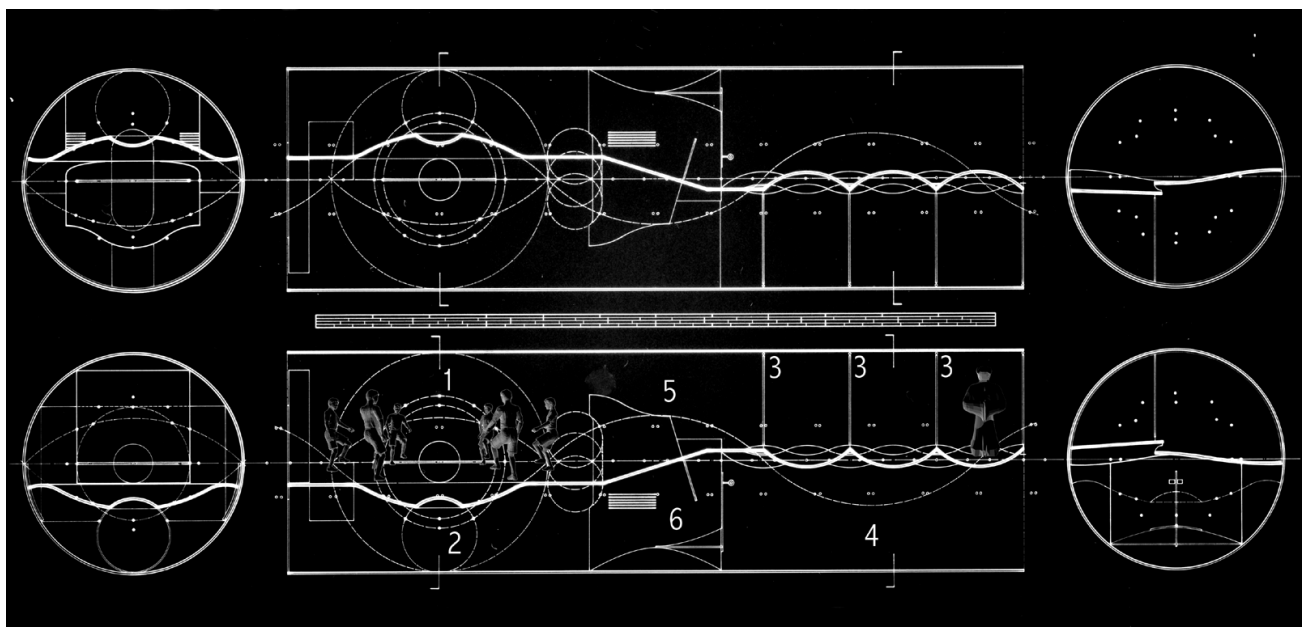


Figure 12
Sectional Drawings of OM Design

1. Community "Dish"
2. Place for Single Individual
3. Individual Crew Quarters
4. Exercise/Recreation Area
5. Command Area
6. Privacy Cylinder (Toilet)

surface or container.

In figure 10C the beginnings of what will become the base concept of the OM design can be seen. This drawing maintains the 'animating' rails, which both hold and transmit, but the wave pattern is enlarged and begins to create the shape of the 'community dish'. This drawing is both longitudinal section and cross section.

The Osmotic Membrane Design

In figures 11 and 12 the idea of the membrane is fully developed and described. The drawing presents a mirror image to emphasize that where there is no gravity, the regulating instrument of up and down is the horizontal line of the eyes and our sense of orientation around them. Orientation is a problem in zero gravity environments. The Osmotic Membrane is the regulator to assist the eyes in establishing orientation.

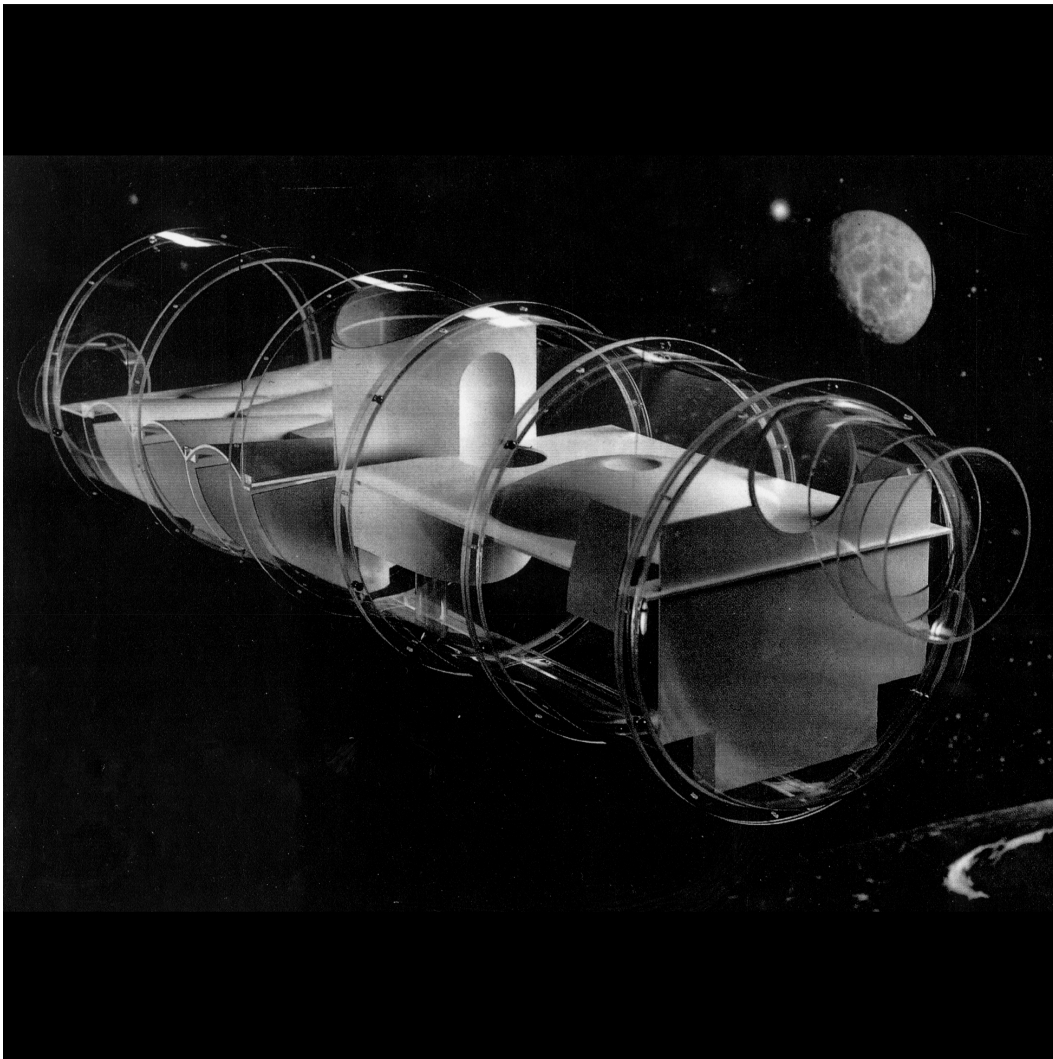


Figure 13
Model of OM Scheme

It seems best to quote the description offered by Kalil and Gardner of this design approach:

A consideration demanding high priority in the design of the Space Habitation Module is ease of body motion or mobility while being aware of the requirement of the economy to space – volume. The OM order is one spatial organizer of the Habitation Module that is composed of an undulating plane generally oriented along the axis of the enclosure and roughly dividing the cylindrical space into two sections. A pattern of waves is built into this surface membrane having a pitch that observes the appropriate proportionality and conforms to the dimensions of the human body. The membrane as such is derived from a projection of an equivalent room as experienced in space. No longer is there an up or down so the floor and ceiling merge to form a dynamic plane. In

the absence of gravity, the ceiling and floor become one and the same, with freedom of motion on both sides of the membrane. By partitioning elements attached at the crest of the waves and extending to the shell, individual habitation sections are formed. To enter these sections, one travels along the waves to an opening through which 'room' entry is made.

The basic theme guiding the design of the undulating membrane of OM is earth, perceived as the outer skin of our planet and having the texture of hills and valleys. (Kalil & Gardner p. 18)

This design relies on proportioning that grows out of the vesica method, where $\sqrt{3}$ is the prime proportional relationship. This can be seen in the hexagonal base geometry of the drawings in figure 11 wherein the geometries and proportions of the 'community dish' are explored. The pair of

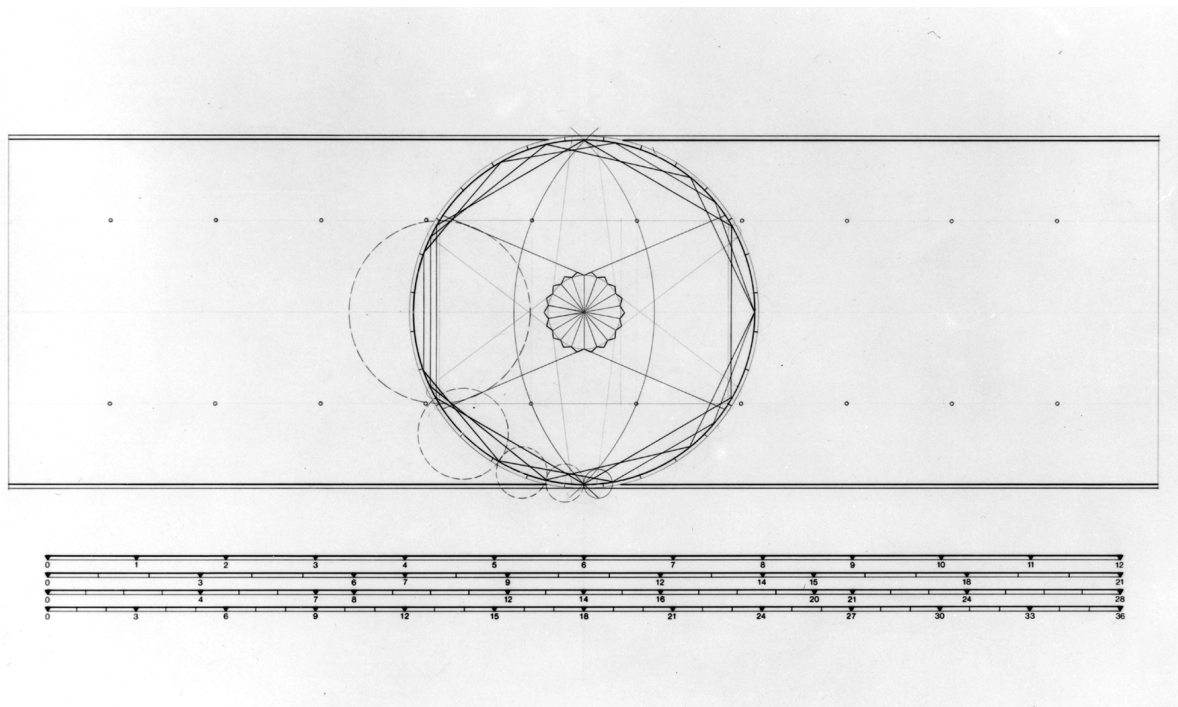


Figure 14
Geometric Study of DNA Design

drawings demonstrates the membrane as an organizing principle that is 'floor' from both directions at the same time. We see that the shape of the dish is not only useable from both sides, but implies a community habitation on one side, and individual habitation on the other. This concept is also implied through the mirror imaging of the longitudinal section drawing in figure 12. The ability for forms to be used in both their positive and negative aspects is a powerful quality unique to zero gravity environments and deserves further exploration.

THE "DNA" DESIGN

Kalil and Gardner wrote the following about this scheme:

The following DNA studies are unique as an ordering system to the shape of space. Stepping out from our tradition it investigates the creation of a new language of communication in the making of architecture. This system is made up of a helix not unlike the ladder rungs in the DNA molecule. The DNA ordering system unfolds pairs of partial conic sections

attached at the small end and oriented on the same axis. Each pair of cones is attached to an adjacent pair and the axis of each pair is displaced 60 degrees. This ordering principle produces two qualities of spaces, a double circulating system (Diverse) and the personal sleeping quarters (Neutral Atria) of the Habitation Module. The path to each opening is along the interspaces of the cone pairs and produces a rhythm of motion that the individual responds to in a 0 gravity environment. (Kalil & Gardner p. 23)

Figure 14 demonstrates the proportional and geometric relationships that were explored in the DNA concept. The hexagon, septagon and nonagon all appear in the central geometric figure, but it is largely the hexagonal proportionality that is dealt with by the rotating conical system that is developed from it.

Figure 15 is a study drawing of the rotating cone system. It demonstrates the helical rotation of the double cones. The bottom section drawing is rotated 90 degrees to the top section drawing.

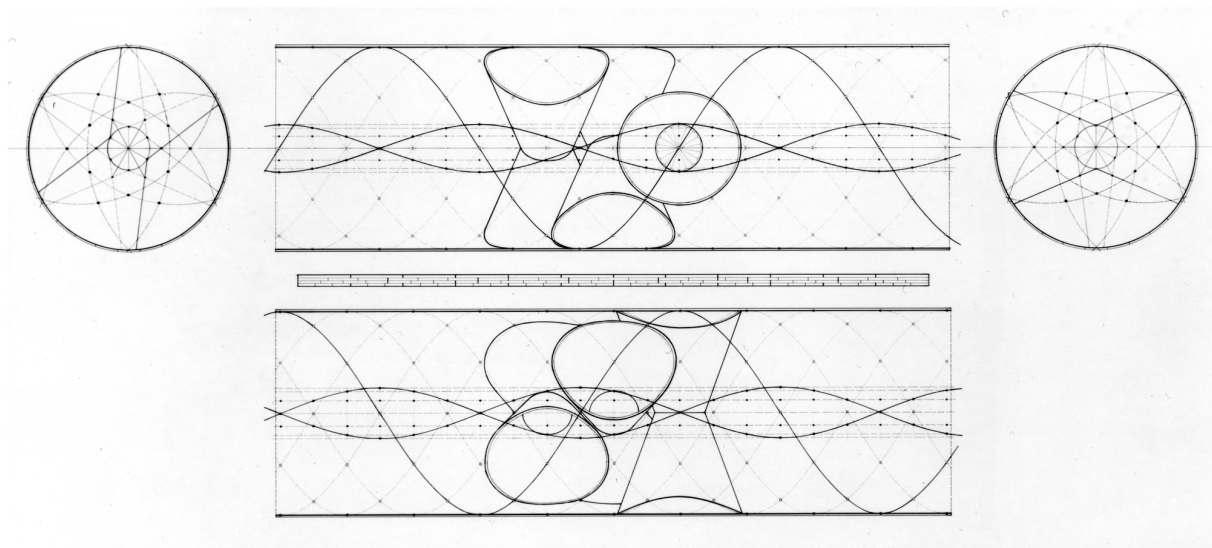


Figure 15
Geometric Study of DNA Design

Figure 16 is a geometric study of the DNA design. Shading is used to give an impression of the undulating surface that would result by 'fusing' the cones together to develop a continuous membrane. Something like the osmotic membrane of the OM scheme is

achieved, but it is more dynamic and has more possibilities.

The cone shaped individual quarters offer a unique environment for the individual and one seemingly well suited to providing private

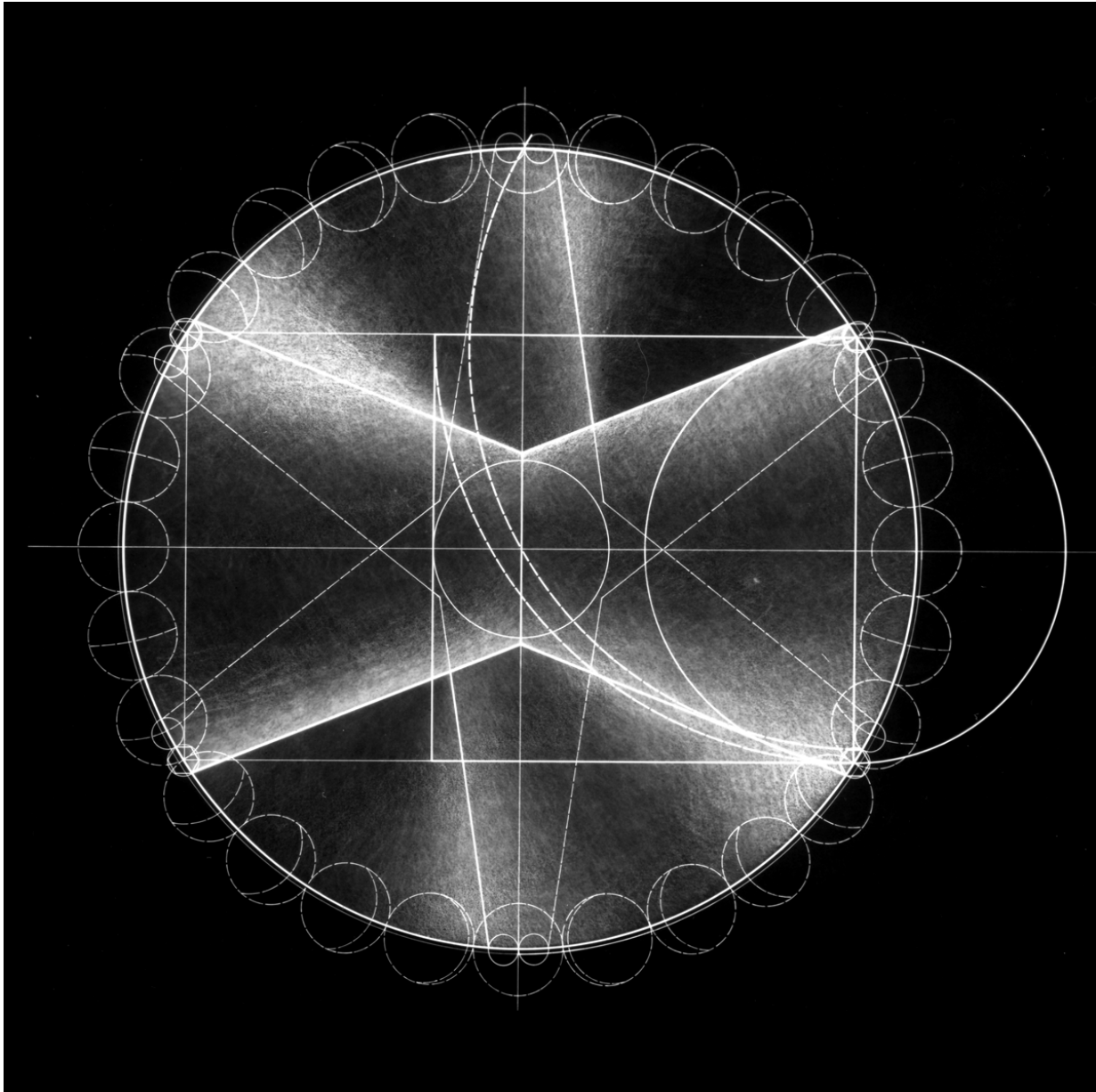


Figure 16
DNA Geometric Analysis Drawing

quarters in the least amount of space possible. With the individual positioned feet towards the narrow end of the cone, the broadest section of the cone accommodates the head, shoulders and arms. By rotating the pairs of cones they can be more densely packed together. Depending on the degree of rotation, which here is based on the sixty degree rotations of the hexagonal geometry, more or less space can be created outside the quarters. It should be noted as well, that when applying a continuous membrane over the surface of the cones, significant space remains between cones and membrane for the carrying of services.

Structurally, this rotating cellular configuration would offer significant potential for great strength from a minimal use of materials as a result of the curving geometries. This strength is conferred in all directions, thus making it suitable to the resistance of the multidirectional forces that it would be subject to during its life cycle.

Another aspect of this design that is of great interest is the significant increase in surface area throughout the module and the way in which it is 'orientation complex,' while consistently offering local orientation reference. It appears that this particular configuration makes fuller use of the unique characteristics of zero gravity and warrants substantial investigation.

The DNA emerged subsequent to the OM design and is not as fully developed. The Kalil Studio felt at the time that this approach was potentially the most exciting of the two developed. Even now it seems worthy of follow up.

CONCLUSIONS

The designs developed by the Kalil Studio and presented in this paper are still compelling almost two decades later. **Discreteness** and **the idea of the continuum** are the major lessons of the work.

The methodology of beginning with a

fundamental idea of individual and place as interacting principles engaged in an ever-unfolding dialogue is significant (**continuum**). The dialogue is one of desire, perception, action and remembrance. Through this dialogue, contemporary fragmentation is overcome, meaning and the realm of the sacred are developed, and machines are made to serve the individual, and not the other way around.

The coupling of this methodology with the use of proportional systems (**discreteness**), confirmed in nature and by thousands of years of human development (**continuum**), ensures that the dialogue is raised to its most beneficial level. Wherever life exists, there is confirmation that proportional structuring and patterning are essential ingredients to its manifestation. These lessons are not unique to zero gravity. They are applicable everywhere humankind seeks to dwell.

There are also lessons unique to the environment of zero gravity. The work achieved the realization that a surface is useable from both sides in a very real sense. A shape means one thing, is useable one way, from one side, and means another, is useable another way, from the other side. What is ceiling is floor and vice versa. On the one hand, there is a problem of orientation for the individual, calling for a regulating line to keep the horizon established. On the other hand, there is an opportunity to be exploited. Through dialogue, opportunities are continually surfaced.

The Kalil Studio work covered in this paper points the way to an exceptional future, grounded firmly in traditions and understandings of the past. In spite of its incompleteness, there is a great deal that is revealed. In returning to the work, there is also the realization that numerous trails were glimpsed, but never followed to their end. It is hoped that this paper can serve to light the way back to some of those trails, so that the work can be carried forward again.

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Figure 1, from Clearwater, Yvonne (July 1985), A Human Place in Outer Space, Psychology Today, p. 35. Courtesy NASA.

Figure 2, from Taylor et al. p. 94. Courtesy NASA.

Figure 3a, Unknown

Figure 3b, Unknown

Figure 3c, Unknown

Figure 4a, Michael Kriegh

Figure 4b, Michael Kriegh

Figure 4c, Michael Kriegh

Figure 5a, Michael Kriegh, after Lawlor, (1982) p. 58.

Figure 5b, Michael Kriegh after Lawlor, (1982) p. 58.

Figure 6, Michael Kriegh

Figure 7a, Michael Kriegh

Figure 7b, Michael Kriegh

Figure 8a, Michael Kriegh

Figure 8b, Michael Kriegh

Figure 9a, Langdon Clay

Figure 9b, Langdon Clay

Figure 9c, Langdon Clay

Figure 10a, Michael Kriegh

Figure 10b, Michael Kriegh

Figure 10c, Michael Kriegh

Figure 11, Michael Kriegh

Figure 12, Michael Kriegh
Figure 13, Michael Datoli
Figure 14, Michael Kriegh
Figure 15, Michael Kriegh
Figure 16, Michael Kriegh

ADDITIONAL CREDITS

In addition to the authors of this paper who collaborated on the Kalil Studio work in various ways, there were numerous individuals involved with the Studio at the time and many contributed to the work presented here. Because the Studio did not always give credit to those participating, and because various individuals participated without knowing or interacting much with others, it is not possible to know the full extent of any one individual's contributions to the work. Nonetheless, we want to endeavor to recognize those who we know were working with the Studio at the time.

Jun Okushi, Thomas Garvey, and Martin Spiegel most certainly made direct contributions to the work at issue in this paper. Peter Barna made major contributions to lighting design and other aspects of the Smart Communications Room. Additionally, Dale Goncher, and Frieda Serrano (who helped keep the studio financially straight) were also working with the Kalil Studio at the time and whether or not they made direct contributions to the NASA contract, they were certainly part of the spirit of the Studio and therefore contributed in immeasurable ways.

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