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Performance Pods- a shell spatial housing system

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Abstract

The world population is expanding exponentially, UN [13]; it is currently estimated that over 3 billion people now live in urban contexts; and this number is expected to swell to almost 5 billion by the year 2030. Many of these new urbanites are poor and live in slum environments. Warfare, loss of tribal lands, and the search for a better life, often driven by technology, is shifting human-kind from low-density indigenous rural settings to high-density urban centers where new urbanites are often economically deprived and lack the basic essentials of life; food, water, sanitation and habitation, Kusa [9]. Modern society, in an era of dwindling fossil-fuel energy, is experiencing unprecedented pressure to adapt cities for accommodation of the impoverished with affordable sustainable habitation, Reuters[11]. Our recent research is focused on improved habitation for urban slum dwellers; we realize the complexity of the necessary political, legal, financial and infrastructure improvements that will be necessary pre-requisites to the realization of major urban design habitat projects. Encouragingly, world-wide, many non-profit organizations are making efforts to assist with this monumental problem of human habitation, often through financial donations or volunteer materials and labor for housing. Our research hypothesis is that technology, the "thing" often attributed as the culprit that has caused of much of the poverty and human deprivation in the modern world, can be part of the answer to global housing. We feel technology should, and will, be a major contributor to future resolutions to human inequality and affordable sustainable habitation in the 21st century.

Keywords: Performance Habitation, Performance Pods, Free-Form Design, Organic Architecture, Biomorphic, Repetition, Modular Housing

1. Introduction

He who wonders discovers that this in itself is wonder.
M. C. Escher

The world population is expanding exponentially; it is currently estimated that over 3 billion people now live in urban contexts; and this number is expected to swell to almost 5 billion by the year 2030. Many of these new urbanites are poor and live in slum environments. Can we deliver "better" architecture to the masses? Our work is searching for answers in per-formative free-form digital design exploration as well as performance based "*repetitive"* architecture for mass production and customization of human habitation. In Section 2 we will review the context of the global housing crisis; in Section 3 we will look at 20th century architects' modular house concepts and efforts. In Section 4 we will discuss vernacular architecture and see examples of indigenous habitation; and in Section 5 we will review the connection of art, nature and design principles. Section 6 will provide an overview of our concept for organic cellular fabricated habitat modules (i.e. Performance Pods- © ® ™); and in Section 7 we provide a summation of findings and make conclusions.

We realize the complexity of the necessary political, legal, financial and infrastructure improvements that will be necessary pre-requisites to the realization of major urban design and habitat projects. Our research hypothesis is that technology, the thing often attributed as the culprit that has caused much of the poverty and human deprivation in the modern world, can be part of the answer for the improvement of 21st century human habitation.

2. The world housing crisis in context

The world population is expanding exponentially; it is currently estimated that over 3 billion people now live in urban contexts; and this number is expected to swell to almost 5 billion by the year 2030 (see Figure 1). In 2008, for the first time in history, more than half the world's human population of approximately 6 billion people are living in urban areas. Many of these new urbanites are poor and live in slum environments; for many low income city workers, the slums or squatter settlements at the edge of town are their only option for habitat (see Figure 2).

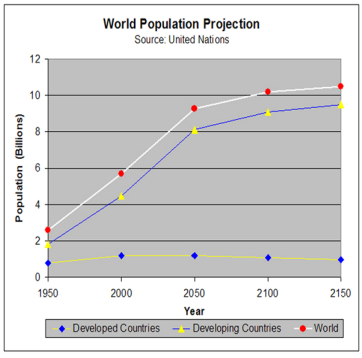

Figure 1: World population increase projections (Source – United Nations)

Figure 2: Slums are the only option for many low income city dwellers

Most of the 21st century urban growth will take place in Africa and Asia. Warfare, loss of tribal lands, and the search for a better life, often driven by technology, is shifting human-kind from low-density indigenous rural settings to high-density urban centers where new urbanites are often economically deprived and lack the basic essentials of life; food, water, sanitation and habitation Kusa [9] (see Figure 2: photo - Olutosin Kusa – Nigeria – 2007).

The United Nations Millennium World Summit met in New York in 2000 and adopted the United Nations Millennium Development Goals. These goals consist of an eight point action plan that hopes to eradicate extreme poverty, hunger and assist with habitat and environmental sustainability for future generations. The most serious problems confronting cities include inadequate financial resources, spreading homelessness and expansion of squatter settlements, inadequate and deteriorating building stock, improper land use, insecure land tenure, rising traffic congestion and increasing pollution.

The following is a quote from Olutosin Kusa, a concerned young Nigerian architecture student studying in the US:

With the projected increase in urban population and converse proportionate increase in slum population, we can anticipate a situation where most of the urban population will live in housing that lacks the basic conditions of decent housing, adequate sanitation and healthy environment. Therefore, effective strategies need to be adopted to provide suitable housing for the projected increased urban population.

Modern society, in an era of dwindling fossil-fuel energy, is experiencing unprecedented pressure to adapt cities for accommodation of the impoverished with affordable sustainable habitation. In the next section we review 20th century architects' ideas and concepts for modular housing. Encouragingly, world-wide, often through financial donations or volunteer materials and labor for housing, many non-profit organizations are making efforts to assist in finding a solution to this monumental problem of human habitation.

3. Architecture and 20th century fabricated housing

Early modern architects and theoreticians felt the basic human need for shelter was the perfect commodity through which mass-production principals could be put to test in

architecture. The following is a quote from Walter Gropius regarding his view of the responsibility of the professional architect:
Architects have a responsibility towards society to help solve its acute housing problem; therefore, their involvement in this process is inevitable to assume the role of integrators of "the scientific, social, technical, and economic factors, inherent in the new architecture of the industrial age", (Sullivan [12]).

Gropius predicted, if architects dismissed their responsibility, industry would eventually assume that role on its own. Gropius made two attempts in the MH arena (Herbert[8]); both the Copper House and the Packaged House were confronted with political and financial problems, (Barrow, Kumar, and Alarayedh [6]). The following images depict some of the seminal examples of efforts by great 20th century architects to address modular housing (see Figures 3).

Figure 3: From left to right; Gropius Copper House, LeCourbusier's Le Pessac, Fuller's Dymaxion House, and The Living Pod by the Archigram Group.

The current US manufactured housing industry remains archaic and problematic (Barrow and Alarayedh [5]). As a general summation, our research shows that architects, for various reasons, have had significant difficulties in making a sustainable contribution in the area of manufactured mass housing.

4. Vernacular architecture

The wealth of housing knowledge found in indigenous cultures is not surprising. For centuries, and in the absence of architects, the indigenous have addressed their housing needs. Often they have developed know-how and skills through trial and error or as a result of their extreme sensitivity to their own environmental surroundings, cultural context, needs, restrictions, and lifestyle, (Oliver [10]). Pure aesthetical considerations, rarely if at all emerge as a factor when *struggling* to provide for their necessities (see Figure 4).

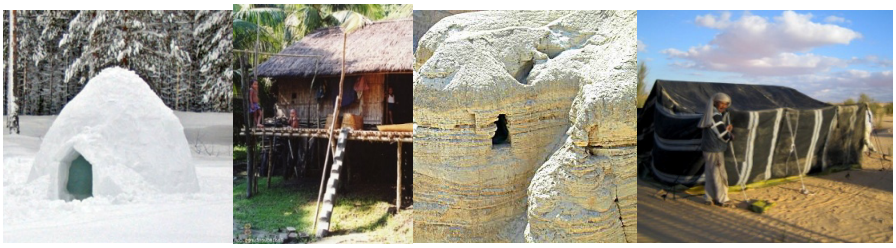

Figure 4: Different forms of vernacular housing

The issue of cultural sensitivity, iconography and mass-customization is an important and critical issue that is beyond the scope of this paper; we recognize this is a critical consideration for mass housing adoption and implementation. We will leave this section with this simple finding and key-point; vernacular architecture is not a style, rather it is habitation that "works" for mass-culture at a given place and time in history based on the evolution of their society and needs for sustainable healthy habitation.

5. Nature, art and repetitive design

For centuries, nature has served as a source of inspiration and module for ultimate beauty that artists, architects, and engineers strive to emulate. Leonardo Da Vinci, influenced by his studies of nature's forms and patterns, expressed that:

Although human genius through various inventions makes instruments corresponding to the same ends, it will never discover an invention more beautiful, nor more ready nor more economical than does nature, because in her inventions nothing is lacking, and nothing is superfluous Cheng [7].

Da Vinci's analysis of the occurrence of the Fibonacci sequence in plants was reflected in the proportions of his "Vitruvius man" (1492) and his renowned Mona Lisa (1507), linking the beauty of the human body to what he referred to as the "divine proportion". The following images depict examples of form in nature (see Figure 5).

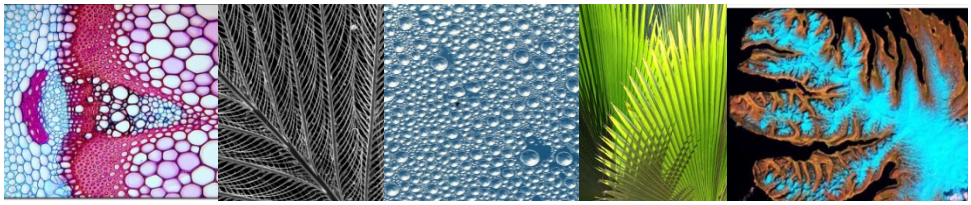

Figure 5: Natural forms

A seminal case of design inspired by nature is the Crystal Palace; as gardener and engineer, Joseph Paxton, was working to cultivate a water lily, he was inspired by the strength illustrated by the vein structure of the flower's leaves. The structural system of the lily leaf was the basis for the winning proposal of the Crystal Palace competition, a structure described as "the first miracle of prefabrication" (Sullivan [12]) (see Figure 6). Buckminster Fuller was likewise inspired by the efficiency of nature (see Figure 7).

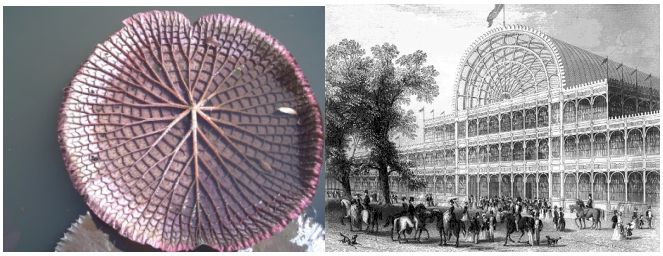

Figure 6: This Water Lily leaf inspired the design of the Crystal Palace

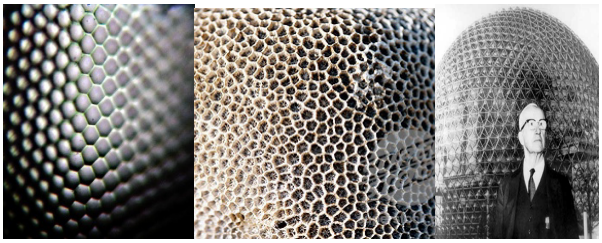

Figure 7: This Fuller's Geodesic dome inspired by hexagons in natural structures

Nature has offered inspiration for artists and designers throughout history; typically in the area of geometry and structure (Barrow and Alarayedh[4]). However, we feel a critical understanding of nature as a highly efficient metabolic system is now critical as a means of understanding biological systems and energy conservation as inspiration for holistic thinking for sustainability. The topic of energy and sustainability, while critical, is beyond the scope of this paper.

6. Performance Pods- concepts for habitation

Our goal is to develop a durable, modular, mass produced pre-fabricated housing system that utilizes new technology via innovative materials and manufacturing methods. The following is our design criterion:

- The house should be capable of sleeping a minimum of four persons and provide flexibility for extended family accommodations.
- The housing system should be seismic resistant.
- The solution should explore the possibilities of innovative assemblage technology to expedite on site assembly.
- The system must be modular and interlinking (scalable) capable of being mass produced
- The system should be flexible, lightweight, and relatively easy to assemble and dismantle on-site with minimal tools and technology.
- The housing system must be durable- capable of withstanding repeated dismantling and assembly.
- Solution must be universal and adaptable to both tropical and temperate climatic conditions.
- Finishes and exterior skin should allow local surface treatment & customization.
- System must consider sustainable domestic waste water and sewage treatment strategies.
- The materials used should be sustainable; recyclable & biodegradable materials.
- Provide space saving design to facilitate logistics, shipping and handling.

The primary driving force behind the conceptual form is *fluid dynamics,* multi-units/stories and seismic load resistant. Buildings (i.e. houses) are not static objects in space; rather, they are subject to the same relative fluid forces as cars, planes, and ships (i.e. Industrial Design artifacts). Therefore, we have coined the term "Performance Pod (PP) (Copyrighted, Trademarked and Patents Pending).

The Performance Pod is a durable multi-story housing system that is energy efficient and *performs* under extreme weather and acts of nature events. Our inspiration is the efficiency and beauty found in nature and organic forms; we are particularly inspired by M.C. Escher and his mimicking of nature in his work. His work pursued uncertainty and exploration and searched for reinterpretation of elements of nature in terms of repetitive patterns. Most important to our pursuit of form is his inherent sensitivity to the forces and efficiency of nature in his work; he consistently not only expressed the repetitive geometries found in nature, but he inherently expressed a deeper understanding of the fluid dynamics as he often used themes of elements of nature suspended in air or water (see Figures 8-10).

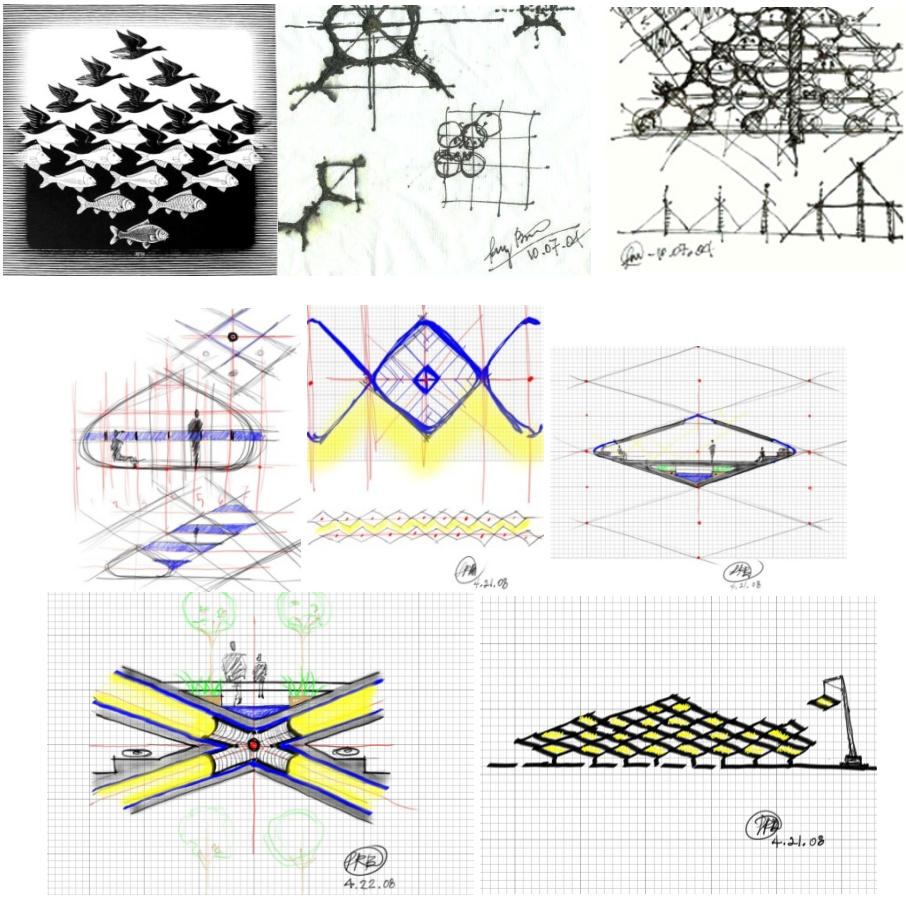

Figure 8: Performance Pods; ideas and conceptual development

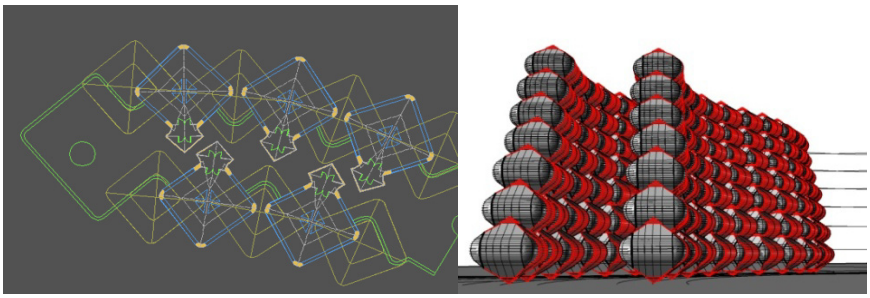

Figure 9: Digital Studies and Modeling

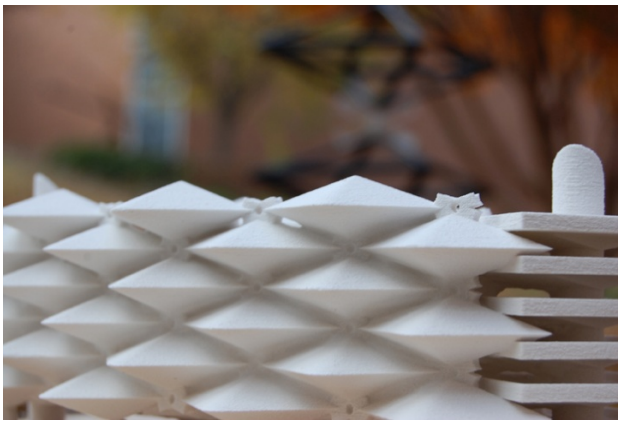

Figure 10: Performance Pods - 3D model

The basic form and structural efficiency of Performance Pods is based on cellular autonoma "shells" that are interlinked both vertically and horizontally to form a "shell" spatial housing system. Based on our literature review and patent searches, this approach to factory-built housing modules is a unique original strategy and is Intellectual Property (IP). The term "Performance Pod" (PP) is (Copyrighted, Trademarked and Patents are Pending).

7. Conclusion

Emerging technology enables new forms to be conceived, visualized, analyzed, fabricated and assembled. Some designers promote temporality and transformability, others pursue durability and performance; we believe, as have many of our past and contemporary architects, that technology can be better understood and applied to CADCAM factory-built housing componentized systems, for better quality mass-housing. We believe emerging CADCAM in architecture, with the adoption of Industrial Design principals and learning from Nature, can assist with both societal and architectural *beauty*.

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