PLANNING FOR UNEARTHLY PLACES: UTILIZING METABOLISM DESIGN PRINCIPLES FOR FUTURISTIC CITIES

by

OLIVIA BIGNER

(Under the Direction of Jack Crowley)

ABSTRACT

Mankind fantasized about space travel and living on other worlds long before technology allowed it to get there. Now that the concept of a permanent presence in space is a more viable option, it has become critical to plan not just the way to get there, but also how to grow and sustain successful and thriving life upon arrival. The organic ideals of Metabolism may offer that solution. The Metabolism movement was created when a group of young urbanists proposed a transformative paradigm shift from conventional modernist ideals toward a biological Utopianism. This study examines and considers the key design principles of Metabolism and analyzes how those principles can be applicable when planning for space colonization, and illustrates how an idea, once considered extreme, can act as a substantial foundation on which to build mankind's future.

INDEX WORDS: Metabolism, utopian urbanism, Kenzo Tange, space colonization, megastructure, resilient cities, Japan

PLANNING FOR UNEARTHLY PLACES: UTILIZING METABOLISM DESIGN PRINCIPLES FOR FUTURISTIC CITIES

by

OLIVIA BIGNER

Bachelor of Landscape Architecture. University of Georgia, 2008

A Thesis Submitted to the Graduate Faculty of The University of Georgia in Partial Fulfillment of the Requirements of the Degree

MASTER OF ENVIRONMENTAL PLANNING AND DESIGN

ATHENS, GA

2016

PLANNING FOR UNEARTHLY PLACES: UTILIZING METABOLISM DESIGN PRINCIPLES FOR FUTURISTIC CITIES

by

OLIVIA BIGNER

Major Professor:	Jack Crowley
Committee:	Umit Yilmaz Mark Reinberger Pratt Cassity

Electronic Version Approved:

Suzanne Barbour
Dean of the Graduate School
The University of Georgia
August 2016

DEDICATION

This thesis is dedicated to my mother who has paved the road for me through selflessness and countless sacrifices in pursuit of my dreams and happiness. She is the one upon whose shoulders I stand. She is a constant and unflinching source of unconditional love and support. Thank you for everything. You are my best friend.

I love you.

I'll meet you in Monroe.

ACKNOWLEDGEMENTS

I am thankful for my professors for being a source of inspiration and invaluable contributions to this study.

First and foremost, I'd like to thank my major professor, Dr. Jack Crowley, whose door was always open to listen to my thoughts and ideas, some better than others. Without his guidance and insight, I would not be the planner that I am today. I would also like to thank the members of my thesis committee: Pratt Cassity, Dr. Mark Reinberger, and Dr. Umit Yilmaz for their encouragement, participation, and astute comments.

Finally, I am thankful for the countless individuals who continuously strive for greatness and test the limits of human intellect. Without them, I would not have the opportunity to explore and celebrate mankind's potential.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER ONE

INTRODUCTION

The idea of space travel and humans living in space and other worlds is a fantasy that has consumed mankind's mind for centuries. In recent years, the prospect of these fantasies becoming a reality has grown exponentially with the advancement of technology and the drive of organizations to achieve it.

1. Problematic

In the last 50 years, man's presence in space has grown immeasurably and includes countless unmanned satellites orbiting Earth to astronauts living on the International Space Station. These are only the beginning of man's permanent presence in space. In recent years, the overwhelming excitement of space travel has been reignited due to factors like cinema and pop culture making people take seriously the thought of living in space and on other planets.

What happens when humans make it to other worlds or between worlds? It's not enough to simply discuss getting humans to another planet, but attention must be paid to how people will settle the new territory claimed upon landing. A long-term vision for settlement establishment is necessary to build upon the knowledge acquired in nearly the last 50 years. (Nair 2008, pg. 1338) A significant challenge that accompanies space colonization is transitioning humans into realms beyond our planet within self-contained environmental systems that do not act as "a void but as a culture medium" while supplying those humans with the basic necessities needed to survive; air, water, gravity, energy. (O'Neill 1974)

2. Purpose

The primary objectives of this study are: (1) to evaluate the driving forces behind the Metabolist movement in Japan of the 1960's, (2) illustrating how space colonization, from a spatial planning standpoint, is not beyond the range of present-day knowledge; and (3) showing how historic design principles of Metabolist projects, often considered to be extreme models, can be utilized to effectively address the needs of the new colonies. Through case studies of prominent Metabolist proposals and examination of environmental factors that can help reduce stresses within a space colony, the overall research question can be answered.

3. Significance

Metabolist and other Utopian city plans have not been critically studied for their ability to satisfy the spatial needs of space colonies. These methodologies are often overlooked as being excessively radical despite many plans taking place in extreme environments such as outer space. The results of this study could encourage organizations to learn from these past architectural and planning movements when adopting colony planning strategies as humans begin to make the transition from Earth into space. In addition, space programs may also understand the benefit of considering these historic movements as powerful tools for future urban and habitat planning.

4. Definitions

Metabolism is a word that describes the natural processes of living organisms. A group of young urbanists and architects used the term to describe the proposed paradigm shift to incorporate Japanese cultural beliefs of impermanence while planning for the reconstruction of Japan following World War II. This group believed it appropriate to think of cities as ever-evolving and changing entities and that urban plans should encourage growth and development. Thus, they used the biological term 'metabolism' to describe their principles in order to illustrate the movement's unqiue influences.

The *key figures* mentioned in this study of the Metabolist movement and the creators of the Metabolist Manifesto were several young architects, Kiyonori Kikutake, Kishō Kurokawa, Fumihiko Maki, and their mentor, Kenzō Tange.

> **Arata Isozaki** was a member of the Metabolism movement most notable for his critiques of the city as process. He believed that cities should be viewed as cyclical, including a stage of ruins from which the city could be reborn.
>
> **Kiyonori Kikutake** was a student of Kenzō Tange whose proposal for Ocean City, after being presented at the World Design Conference in Tokyo, spearheaded the formation of the Metabolism movement. Kikutake was considered one of the group's intellectual leader and facilitated design views encompassing aesthetics, politics and economics, land use planning, technology, and human psychology.
>
> **Kishō Kurokawa** was also a student under the tutelage of Kenzō Tange. He proposed a number of radical models like Space City and Helix City. Using his "Philosophy of Symbiosis" he created the famous Nakagin Capsule Tower, the National Art Center in Japan, and the Toyota Stadium.
>
> **Fumihiko Maki** was a member of the Metabolism movement who often

critiqued and analyzed the group's manifesto while exploring new methods of adapting to their changing beliefs. Among his notable designs are 4 World Trade Center at Ground Zero and the new United Nations building.

Kenzō Tange was influenced by Le Corbusier, was one of the first modern architects in Japan, and played an important design role in the postwar rebuilding of Japanese cities. Though never an official member of the Metabolism movement, his role within the group was significant. He acted as a teacher and mentor to many Metabolism architects, and his presentation of his students' work at the World Design Conference in 1960 brought international attention to the movement. Some of Tange's most widely known buildings are the two national gymnasiums constructed in Tokyo for the 1964 Olympic Games, and he is probably best remembered for the Peace Memorial Park in Hiroshima. His transformation of Hiroshima converted a site of tragedy and ruins into a tranquil place of contemplation.

5. Limitations

This study was greatly limited by the overall content in the field in terms of space colonization. At this point in mankind's history, scientists have made little headway with regard to exploring the possibilities of humans living anywhere other than Earth. Timing is a hefty limitation for this study because, at this point in time there is little evidence-based research or experience with humans living in space, let alone building cities in space or on other planets. An additional limitation is significantly dated information. Much of the limited quantitative information regarding the formation of environments and cities in space comes from studies conducted in the 1970's and stemming from the celebrity, entertainment value, and the successful ushering in of the Space Age with the moon landing in 1969. (Miller 2007, pg. 512) Finally, there existed a limitation of the language barrier in terms of firsthand Metabolism works.

6. Delimitations

While the Metabolism Movement became a global vision and influence on architecture and design, this study will focus solely on aspects of Japanese Metabolism. It is also recognized that there are several countries with substantial space programs whose habitation criteria may be different from those of the United States. For the purposes of this thesis, all standards and spatial requirements for colonization shall be accepted from the information set forth by the National Aeronautics and Space Administration (NASA) in the United States. Finally, political and economic issues associated with colonization of other planets will not be taken into meaningful consideration at this time.

7. Methodology

The primary objective of this study is to evaluate the driving forces behind the Metabolist movement in Japan in the 1960's and how these principles and ideas can be utilized as useful design solutions for space colonies. This thesis will be guided by the following central questions:

1. How did the Metabolists cope with the unique societal and environmental stresses of postwar Japan through architecture and urban planning?
2. What are the spatial and environmental needs of humans in space?
3. Can the design principles presented by the Metabolists be utilized as successful spatial solutions in space settlements?

In order to investigate these answers, examples of Metabolist city plans for Tokyo are reviewed and their design ideas are evaluated as options for space colonies. The Utopian design elements are identified through a comprehensive literature review and case studies of Ocean City (1960), Space City (1960), Helix City (1961), and the Tokyo Bay Plan (1960). Case studies are then compared to the spatial requirements set forth by NASA to evaluate the alleged appropriateness of the spatial design patterns.

8. Chapter Summaries

Chapter Two acts as a literature review of the Metabolism movement in Japan giving a brief history of what influenced its creation and what its key design principles are. It goes on to describe its nuances and the ideas of "city as process," planning as resilience, and megastructure versus group form.

Chapter Three introduces the idea of space flight, space colonization, and their significance. The chapter defines the three most prominent options of space colonization and briefly discusses the unique design aspects involved. Finally, the criteria for the development of an appropriateenvironment in space is introduced giving a glimpse what human needs are in terms of habitation in space itself.

Chapter Four introduces four case studies of prominent utopian city plans, examines the driving forces behind their creation and discusses spatial organization as appropriate solutions for the programming needs.

Chapter Five analyzes the four case studies in terms of the environmental design requirements for space colonies and discusses key characteristics of the design proposals and overall appropriateness within the realms of space.

Chapter Six presents final thoughts on space colonization and the Metabolism movement. It discusses how each case study is unique to certain types of colonies and environmental criteria. The chapter also discusses major arguments against utopian city plan and the overall appropriateness of using such principles for contemporary and futuristic design.

CHAPTER TWO

METABOLISM LITERATURE REVIEW

1. History of Metabolism

Visionary urban planning practices often stem from societies that are experiencing major transitional periods be those changes political, economic, aesthetic, or a combination of all. (Lin 2010, pg. 3) As a response to its unique set of circumstances, the development of the Metabolist movement and various utopian city plans created by Japanese society were no exception.

The imperialist propaganda concept of the mid-1930's, known as the "Greater East Asia Co-Prosperity Sphere," set forth the notion to free Asia from the colonial powers of Western societies, but quickly transitioned into a way for Japan to maintain resources and remain a modern superpower. Formally announced on August 1, 1940, by Japanese Foreign Minister, Yosuke Matsuoka, the movement aimed to unify East Asia and to facilitate close political linkages between the countries involved. (See Fig. 2.1)

Figure 2.1: Map illustrating active Co-Prosperity Sphere countries. 1942. Digital Image, 2011. (Accessed June 2016)

Supported by many Japanese nationals, the concept was highly regarded and praised as a constructive effort for peace. The Japanese Army often compared it to the Monroe Doctrine, while Japan's self-interest within the movement was viewed as synonymous with the Third Reich. (Rhodes 1993, pg. 252)

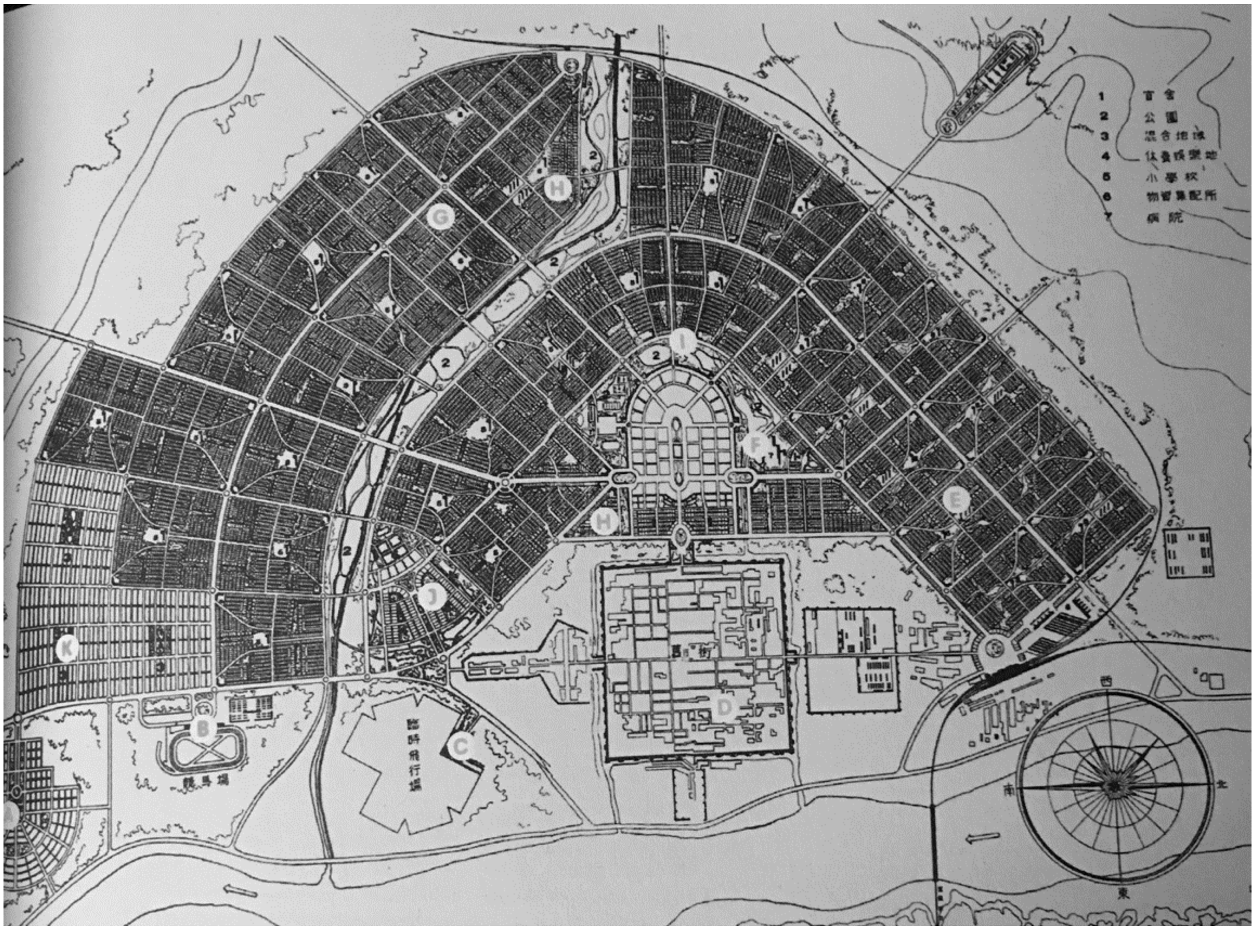

Figure 2.2: Master plan for Datong demonstrating the works of Japanese planners in Japanese occupied Mengjiang during the era of the Greater East Asia Co-Prosperity Sphere. 1938**.** Koolhaas, Rem, Hans Ulrich. Obrist, Kayoko Ota, and James Westcott. Project Japan: Metabolism Talks. Köln: TASCHEN GmbH, 2011. Page 67.

The idea of expansion for Japanese architects and planners was a breath of fresh air, and professionals at the time took advantage of the opportunity to start anew by designing stunning modern utopias throughout the "sphere," one Metabolism architect noting his fondness for the Datong master plan. (Koolhaas 2009, pg. 12) (See Fig. 2.2) Interestingly, the Japanese surrendering to the Allies in August of 1941 led to the collapse of the “Greater East Asia Co-Prosperity Sphere” and forced those same planners to turn their focus back to Japan itself. The aftermath of two atomic bombings left them with a country of depleted national morale and cities in ruin. Postwar Japan presented planners the unique opportunity for the creation and implementation of something different and new.

Kenzō Tange was one of these designers who rose in the profession through his work in Japan-occupied China. Tange won several design competitions, but his designs were unfortunately unrealized. Upon returning to Japan at the end of World War II, Tange became a professor at the University of Tokyo where he began mentoring students and preparing his commissioned designs in what would come to be called the Tange Laboratory. Though he would again propose several similarly unrealized plans for the reconstruction of war torn Hiroshima and Maebashi, the foundations of the Metabolism movement would nonetheless be molded under his mentorship in the Tange Lab. (See Fig. 2.3) Though he was never a formal member of the movement, his teachings and ideas played a vital role in its formation. (Lin 2010, pg. 2)

Figure 2.3: Kenzo Tange shown standing with his plan for Tokyo Bay, a plan that influenced Metabolism. 1960**.** Koolhaas, Rem, Hans Ulrich. Obrist, Kayoko Ota, and James Westcott. Project Japan: Metabolism Talks. Köln: TASCHEN GmbH, 2011.

Tange was later invited to participate in the Congres International d'Architecture Moderne (CIAM) in the 1950's to help define and promote the Modernist Movement throughout the architectural world via the Athens Charter. The Charter's key premise was that the character of a space would develop naturally over time. Upon seeing the impact of the destruction of the war on Japan and the impermanence of infrastructure, both the Athens Charter and CIAM were placed under scrutiny by Tange. (Stewart 2002) Student Arata Isozaki recalled the events and influence of Hiroshima:

> The experience of Hiroshima had to be accepted as the indelible origin of the reconstruction process. I belonged to the generation that had experienced once and for all the bankruptcy of Japan as an export commodity, the destruction of its cities. The transformation of the social structure, and above all, the end of history at Hiroshima. Stained upon my eyes was the scene of destruction and extinction that came first, before the beginning of everything else. Yet the reality of construction and growth preceeded space. Though the architect and urbanist are dedicated to progress, it is nonetheless impossible to escape all together a recurring premonition of total collapse. (Lin 2010, pg. 126)

The resulting urban design strategies created by Tange's students, while logical and cutting edge, would not gain momentum until 1960. It was at this time that Tange presented the radical city plan of "Marine City," developed by Kiyonori Kikutake, as a demonstration of what his students believed to be a "functional city" for the World Design Conference in Tokyo. The plan was quickly adopted as part of the Metabolism Manifesto.

2. Principles of Metabolism

In the beginning, the movement had no real defined theory, guidelines, or even a name. The architects and planners involved were merely intrigued and driven by the faint echoes of the city in the principles of life and life's processes. (Lin 2010, pg. 23) These similarities deserved investigation. Upon further development, the introduction of the manifesto in 1960, *Metabolism: The Proposals for New Urbanism*, opened with the following passage describing the group's perspective and definition of the movement:

> "Metabolism" is the name of the group in which each member proposes future designs of our coming world through his concrete designs and illustrations. We regard human society as a vital process – a continuous development from atom to nebula. The reason why we use such a biological word, metabolism, is that we believe design and technology should be a denotation of human society. We are not going to accept metabolism as a natural historical process, but try to encourage active metabolic development of our society through our proposals. (Koolhass, 2011)

This statement helped give structure to the ambitious new movement and helped convey that they believed the city to be an "organic function of material and energy exchange between living organisms and the exterior world." (Lin 2010, pg. 22) Ultimately, the Metabolism movement adopted the following set of principles that would guide future designs:

1. *Cities as process.* The city should be treated as a super organism with no beginning and no end. The planning of the city should ignore the accepted convention of presenting the design as a final product and as an end point but rather give it a rigid central structure and let it expand and evolve from that.
2. *Planning as resilience*. One unique aspect of the movement was the incorporation of traditional Japanese cultural philosophy of 'impermanence' into its design

proposals. Tange recognized that cities should be a system of spatial components that could be adapted for different scales and durations. With permanent structures such as infrastructure and transient structures such as housing, it was necessary to allow periodic self-renewal as required by the city as a whole. This would allow the city to act as a dynamic process of ceaseless transformation and adaptability.

3. *Collective society.* The design proposals presented by Metabolism were merely meant to set the stage for the people and communities living at the sites to change and grow in the ways that allowed them to claim the city and make it their own.

Japan presented its own unique challenges both in the postwar era and geographically that helped sculpt and push Metabolist designers to propose truly ambitious plans to meet its needs:

1. The Japanese archipelago has run out of space between its mountainous terrain and the country's centuries-old parcels of land ownership.
2. Being prone to natural disasters such as tsunamis and earthquakes makes construction dangerous and urban areas highly vulnerable.
3. Technology and design make the potential of systematic construction valid solutions. (Koolhaas 2009, pg. 13)

Through the assessment of past failures and a principled design approach, the young urbanists set out to make a difference. (Pinder 2002, pg. 230) Based on the immediate need to house large populations, both architects and urban planners embarked on a revolutionary style that would evolve with the populous. Form and function were at the epicenter of a movement that would maximize efficiency and allow enough flexibility to accommodate needs for the good of the group. Springing from the belief that cities and buildings are not static entities, designers rejected traditional architecture in favor of structures with limited lifespans. Living spaces are designed and built to be replaced by building them around an infrastructure using prefabricated, replaceable cell-like parts that evolve with the needs of the people. Metabolists aimed to link cultural tradition with universally applicable and structuralist spatial conceptions. (Schalk 2014, pg. 281)

3. City as process

Metabolist planners believed in the notion of "city as process" and compared the parts of the city to the parts of the cell and energy cycle – forever intertwined and reacting with one another. The city was to act like a super organism in the notion that a single building should not be designed to be completely functioning as an object but rather it should be built directly into the fabric of the city itself making the building a part of the whole. This idea of cities as process allowed the Metabolists to reject the traditional idea of master planning that envisioned a city in a final stage of development and drove them to envision cities that grow and renew themselves. (Lin, pg. 873) The complexity and changing aspects of natural organisms and their processes became the model for their proposals and the dynamic nature of said processes became an inseparable design element. They sought to encourage balance between the different processes of the city; change and preservation, flexible and permanent. (Schalk 2014, pg. 281)

4. Planning as resilience

In addition to being prone to natural disasters, Japan was at a unique time in its history when the Metabolist designers began thinking critically about the country's city plans.

Tange remarked on the emotion and hope he felt when approaching Japanese reconstruction:

> …when we saw our national land turned into scorched earth with sporadic burnt concrete structures, we had a dream and hope of drawing a new city as if over a blank white sheet…facilitating a 'historically rare confluence of avante-garde and government'

The disastrous effects of World War II on both Japan's landscapes and cultural identity, in addition to the sudden economic boom of the 1950's, meant that architects and planners had the opportunity to plan for systemic change. They were presented with a blank slate that enabled them to freely design proposals for resilience so that communities and spaces within the city could easily and readily adapt to the changing environment in which they lived.

Planners at the time likely envisioned a utopia of resilience. This regarded the actualization of 'regeneration' or 'replacement of the old with the new' as being "one of the most essential features of living things," (Koolhaas, 2010, pg. 235) This concept of impermanence and ephemerality was prominent in the Japanese culture and way of life. (Lemes de Oliveira 2011, pg. 80) Kishō Kurokawa went on record defending this point in 1960 about the necessity of thinking about cities in a different way:

> The future city must change and renew itself uniquely to adapt continuously to the life of tomorrow with a certain common basis. Therefore, every segment needs to be transformed constantly so as to keep a common system. Thus, the city will

> grow, constantly renewing itself, rebuilding its individuality and yet maintaining the universal unit of life. (Koolhaas 2009, pg. 194)

As mentioned, being heavily influenced by the Japanese philosophy of 'impermenance,' caused designers to approach planning as regenerative, meaning that within the city as a whole the central infrastructure should house constantly adapting buildings, homes, and public spaces. The comparison of the movement's design strategies to metabolism within a cell served to "evoke the notion of a recreatable genetic architecture in vernacular forms. They strove to gravitate between an urbanism of large, technical and institutional infrastructures and individual freedom with an architecture of customized cells and adaptable temporary configuration of dwellings, which could expand and shrink according to need." (Schalk 2014, pg. 280) Given the movement's founding principles, architects and planners focused efforts into designing a city that could morph and transform as quickly and easily as society and nature required.

5. Megastructure and group form

The Metabolists generally agreed on the driving forces behind the movement regarding spatial organizational patterns and their relationship to society as a connection to organic forms and processes, resilience to change, and accommodation to growth. As the architects and urbanists began to explore this manifesto, a dichotomy soon arose between the different approaches to urban planning. In 1964, Fumihiko Maki published one of the more prominent critiques of the movement, *Investigations in Collective Form*, identifying and investigating three styles of urban patterns and how the forms agreed with the principles of Metabolism: "compositional form," "megastructure," and "group form."

(Maki 1964) Maki describes the differing opinions of the designers and attempts to create a unified “voice” as such:

> …it would have been quite difficult to summarize. If I had to describe our attitudes, I’d have to say the Kikutake and Kurokawa (megastructure), for instance, were more interested in techno-utopia. I wasn’t interested in technology per se, but in urbanism, which isn’t necessarily associated with techno-utopia. Yet the Metabolism group resected each position. Despite our differences, we always tried to be friends, and I still have strong affiliations with them. No one tried to come up with a unifying blanket statement. That is very important. (Koolhaas 2009, pg. 301)

These competing belief systems stemmed from the differences in prioritization between the part and the whole within the design of an urban environment.

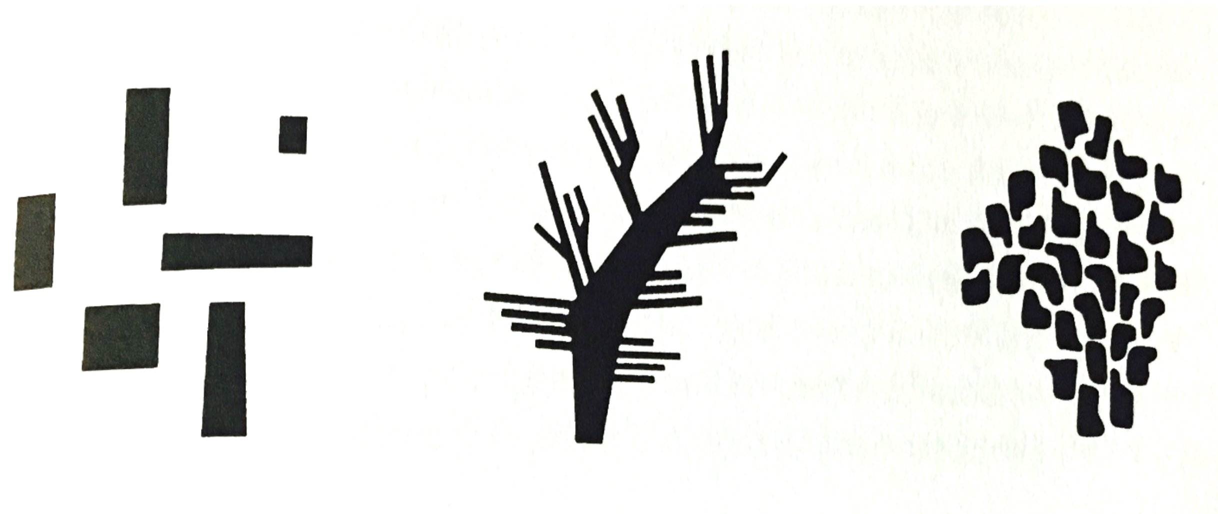

Figure 2.4: Diagram from Maki's publication illustrating his three collective forms; compositional, megastructure, and group form. Lin, Zhongjie. *Kenzō Tange and the Metabolist Movement: Urban Utopias of Modern Japan*. New York: Routledge, 2010. Page 113.

Compositional form was derived from conventional modernist approaches to planning, meaning that the elements of the collective are predetermined separately and attempts to juxtapose them together occur as a final thought. (Maki 1964) (See Fig 2.4) The principles of megastructure tended to place the idea of the whole before the individual parts. The city plans often consisted of large buildings with predetermined programming and organization set to a "super scale" (Lin 2010, pg. 112) around which all community growth, functions, and development thrived. The notion of a "master system" was valued over a "master plan." Maki commented on megastructure's approach to the master system as being in "ever new stages of formal and structural equilibrium, while preserving the visual integrity." (Schalk 2014, pg. 291)

Kiyonori Kikutake, Kishō Kurokawa, Kenzō Tange, and Arata Isozaki are notable practitioners of the megastructure form. Some of the more renowned megastructure Metabolism projects associated with this collective form category include Marine City, Helix City, Agricultural City, and Tokyo Bay Plan. (Lin 2010, pg. 112) It has been argued that the megastructure design form is reflective of modernist built forms whose designs appear organic and the megastructures themselves, situated in the center of the master system, are to be equated with and behave as, in Maki's words, "the great hill on which Italian towns were built" in an attempt to create a linkage between the modern and vernacular.

The proposals seek to "resolve conflicts between design and spontaneity, the large and the small, the permanent and the transient" (Schalk 2014, pg. 292) allowing for individual purposes to be fulfilled but within a hierarchy of a larger predetermined design.

Maki disapproved of the static and rigid nature of the megastructure form. He supported the concept of group form which allows the individual to dictate the form of a city as a whole by grouping smaller elements together; "a system of generative elements in space." (Lin 2010, pg. 114) A colleague and megastructure supporter, Isozaki has described his qualms with the idea of group form as "I guess everyone was on board with the idea that the city is formless and accidental. However, one does need form to make a project. Here's the contradiction." (Koolhaas 2009, pg. 37) Despite the skepticism of his colleagues, Maki continued to define and defend group form as a collective design pattern:

> The ideal is not a system, in which the physical structure of the city is at the mercy of unpredictable change. The ideal is a kind of master form which can move into ever new states of equilibrium and yet maintain visual consistency and a sense of containing order in the long run. (Maki 1964, pg. 11)

Maki's primary issue with megastructure is that the designer assumes which functions of the city will succeed, fail, or change. Oftentimes, the very foundations of a society can be shaken and changed very unexpectedly, like the issues that arose with the atomic bombings which called for cities and communities to be rebuilt from the ground up. "It is difficult to predict which part of a pond a stone will be thrown and which way the ripples will spread." (Maki 1964, pg. 11) The concept of group form is one of true evolution; "it is not necessary to limit composition to inorganic, geometrical, structural, or mechanical patterns. Rather group form is an intuitive, visual expression of the energy and sweat of millions of people in our cities, of the breath of life and the poetry of living" (Schalk 2014, pg. 291) He states that:

> There is a need to distinguish 'form' and 'design.' Form implies what a building, be it a church, school, or house, would like to be, whereas the design is the circumstantial act evolving from this basic form, depending on site condition, budget limitation or client's idea…as soon as form is invented, it becomes the property of society…a design, on the other hand, belongs to the designer.

A design is an individual creation, a form is a collective act. (Lin 2010, pg. 114) Maki's belief in group form is an attempt to unify and form linkages between both the social and physical needs in terms of organization and seeks to "surrender to change rather than imposing mastery, and that asserts interdependence among disparate, even unfinished elements, rather than hierarchy and isolation." (Koolhaas 2009, pg. 302) This focus on Maki's critiques of the movement shine a light onto another one of many facets of Metabolism and any one of these differing belief systems can provide additional valuable planning strategies for future cities.

CHAPTER THREE

SPACE COLONIZATION LITERATURE REVIEW

1. From Utopia to space?

It is widely accepted that human migration to a permanent space colony is inevitable. Once the transportation dilemma is resolved, people will begin the irreversible journey to a new home. How will the long-term comfort and happiness of the colonists be ensured? What are their needs and how will they adapt to a new, and likely harsh, environment? Metabolism may provide key methodologies that will support the success of a variety of space colonies, whether orbiting, mining or surface-based, and defining what is necessary for man's survival in space is the next crucial step.

2. History of spaceflight

Mankind has experienced a deep connection with the idea of space and space travel long before science was able to catch up to man's imagination. Few people took these ideas seriously and these dreams remained the works of fiction and fantasy until two important events occurred. First, the realization that other places in the universe exist, a result of Galileo discovering Venus, Mars, and Jupiter in the early seventeenth century, introducing the notion of the existence of other worlds beyond our own. The second event was that the technology to get to those places had rapidly evolved and space travel was soon to be a reality. Even Leonardo daVinci famously predicted space travel and designed his own craft in the fifteenth century. However, the invention of the hot air balloon by Etienne and Joseph Montgolfier in the late eighteenth century allowed humans to transcend their limitations both mentally and physically and led to a flurry of art, ideas, and literature about the potential of new worlds. (Miller 2007, pg. 502)

After centuries of technological advancement, Sputnik I, the first successful unmanned orbital launch, was successfully completed by the Soviets on October 4, 1957. This launch offered scientists a unique opportunity to gather data about the Earth's outer atmosphere including temperature and pressure. One month later, the Soviets launched Sputnik II into orbit carrying the dog, Laika, who became the first animal in orbit. These successful missions helped to usher in the golden age of space flight, a source of entertainment, celebrity, and patriotic frenzy among many citizens. (Miller 2007, pg. 511) The United States then began funding its own space program sending their own unmanned satellites into orbit. When on April 12, 1961, the Soviets sent Yuri Gagarin into orbit on Vostok I becoming the first man in space the United States officially declared itself in a "Space Race" with the Soviets as a response.

With the start of the Luna program, the Soviet space program turned their sights on getting to the moon. In 1966, Luna 10 became the first unmanned satellite on the moon. On July 20, 1969, Apollo 11 quickly followed and became the first manned spacecraft to land on another celestial body. (Rumerman 2007, pg. 21) For many, space travel has become an irreplaceable example of what it means to be an American. It is a deeply-rooted cultural idea of manifest destiny, progress, and exploring that final frontier that has stuck throughout the history of American spaceflight. (Billings 2007, pg. 483) Developments in the realm of space travel are often viewed as a modern-day settling of the wild west in that it's new, dangerous, and untamed.

The space race's legacy has left a lasting impression on us as a society in our relationship to space. There are countless numbers of communication and weather satellites orbiting Earth and the push for space technology established the groundwork for manned missions to Salut 1-7, MIR, and the International Space Station. (Nair 2008, pg. 1138) All of these played a critical role in solidifying man's permanent presence in outer space, whether scientific expeditions or privatized excursions. Nearly 50 years have passed and space missions have grown larger, faster, more comfortable and more capable. (Rumerman 2007, pg. 9) This kind of progress is what is needed for man to stay in space and live on other worlds rather than simply visiting.

3. Types of colonization

The prospect of people actually living in space or on another planet is a concept that remains quite daunting to truly grasp mentally. Despite this, the growing innovations in technology and the continuous discovery of a number of potentially habitable planets make colonization a more increasingly viable option. People in today's world tend to have more questions than scientists have answers at this point, though studies indicate that:

1. if work is begun soon, nearly all our industrial activity could be moved away from Earth's fragile biosphere in less than a century from now,
2. the technical imperatives of this kind of migration of people and industry into space are likely to encourage self-sufficiency, small-scale governmental units, cultural diversity and a high degree of independence, and
3. the ultimate size limit for the human race on the newly available frontier is at least 20,000 times its present value. (O'Neill 1974)

These findings illustrate the necessity for planning and preparedness for extending mankind's reach in the universe. At this time, scientists and private corporations have barely begun to experiment with moving people into space. It is believed that Antarctica represents the most appropriate comparison of life in space and allows for the experimentation of sustainability strategies here on Earth. (Andrews 2011, pg. 4) In addition to Antarctica, astronauts are allowed to inhabit the International Space Station, but to truly progress, there exist three primary models for space colonization: free space settlements, surface-based colonies, and space mining.

Free space settlements

Free space settlements are typically considered to be the most viable form of space colonization. These communities would be large cylindrical, torus, or spherical shaped space craft that are not bound to a surface but rather permanently in orbit around a celestial body such as Earth, another planet, space mine, etc. The circular or wheel shape of these structures allows for the controllable production of artificial gravity through centrifugal force. (Globus 2009)

In addition to the simulation of gravity, the complete creation of artificial land and natural areas are a unique feature of free space settlements. (See Fig. 3.1) This grants environmental designers the freedom to incorporate elements of nature into the environment, such as forests, rivers, meadows, etc, and to plan entire ecosystems and communities inside of a completely self-contained unit.

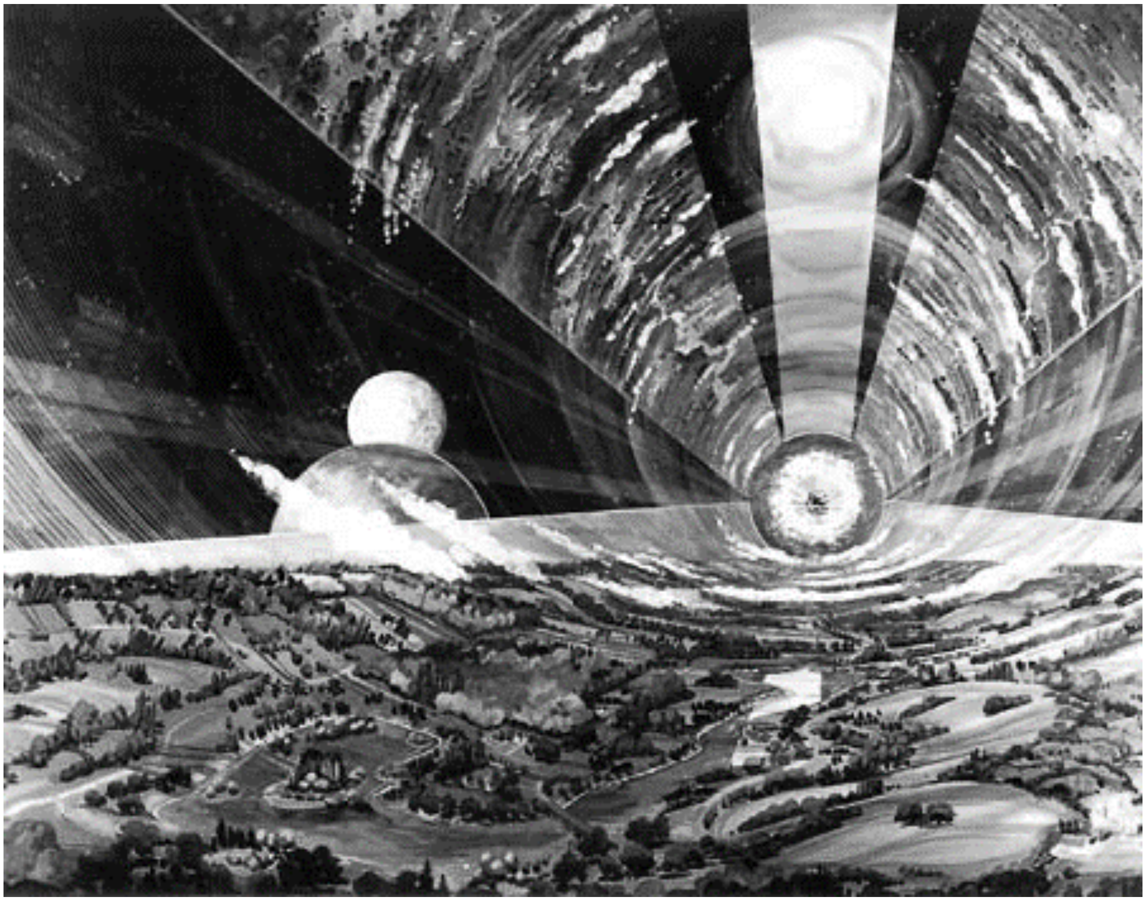

Figure 3.1: Conceptual image of free space settlement. Globus, Al. "Space Settlement and the Environment." *Ad Astra* (December 2009).

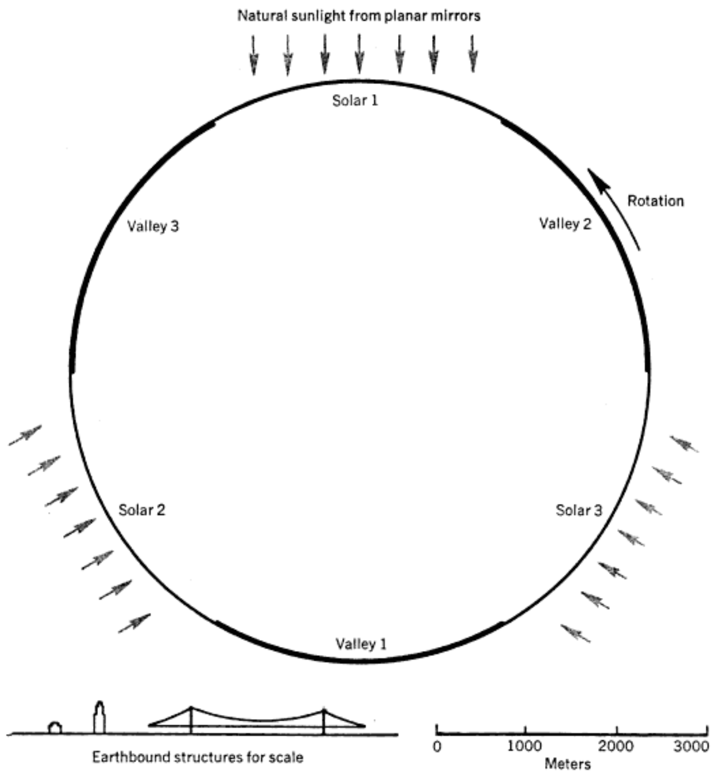

Figure 3.2: Section view of free space settlement. O'Neill, Gerard. September, 1974. Colonization of Space - Physics Today. American Institute of Physics, College Park, MD. Accessed June 2016. http://www.nss.org/settlement/physicstoday.htm

According to physicists, these shapes are most effective in terms of cost efficiency, proximity to Earth for supplies, and providing the colonists the physical necessities for survival. The rotation of the cylinders would simulate gravity and offer a controllable day and night cycle in order to allow colonists the semblance of a biological clock as well as provide optimal growing seasons for food production. (See Fig. 3.2) Varying between 16 and 20 miles in length and 4 miles in diameter, free space settlements could not only provide vast natural expanses but also refuge to millions of colonists while simultaneously provides unrestricted viewsheds of space. (O'Neill 1974)

Surface-based colonization

Surface-based colonization is settling on or below the surface of a planet or moon. It provides a permanent base that remains in the same location. (See Fig. 3.3)

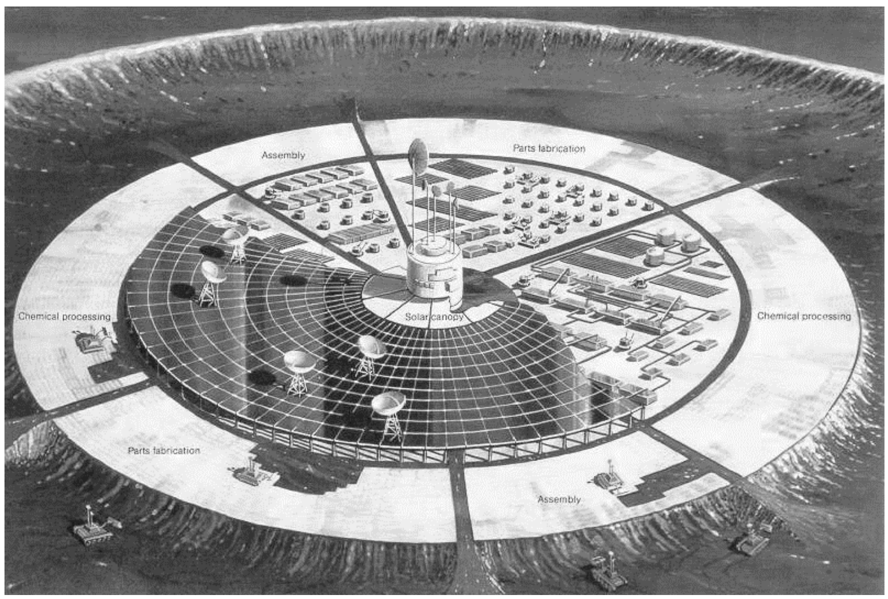

Figure 3.3: Early concept for a self-expanding lunar settlement. National Aeronautics and Space Administration. *NASA Conference Publication 2255*. (2010)

The Moon and Mars are typically considered the most reasonable options at this time for surface based colonization due to their proximity to Earth and abundance of building materials. While surface-based settlements are generally more similar to cities here on Earth in terms of planning and design, most scientists agree that free space settlements will come first because of their ability to control the environment itself while in space. Establishing a colony on the Moon or Mars would subject the colonist to the existing harsh environmental conditions. (See Table 3.1 and 3.2)

Table 3.1 Specific features of surface and environment of the Moon

No.	Parameter	Description
1	General terrain condition	Significant terrain asymmetry of the visible and hidden sides
2	Composition of rock	Lunar rocks contain large amounts of refractory materials
3	Magnetic field	Magnetic field strength of the Moon is considerably weak
4	Gas cover	The gas cover around the Moon comprise of hydrogen, helium, neon, and argon
5	Gravitational field	16% of Earth's gravity
6	Propagation of seismic waves	Weak attenuation to seismic energy
7	Strength of seismic activity	Lunar-quakes are very weak compared to earthquakes
8	Composition of atmosphere	No atmosphere

(Nair 2008, pg. 1340)

Table 3.2 Specific features of surface and environment of Mars

No.	Parameter	Description
1	Composition of atmosphere	95% carbon dioxide, 2.5% nitrogen, 1.5% argon, 0.1% oxygen
2	Atmospheric pressure	Considerably lower compared to Earth
3	Daily temperatures	-22F to -112 F
4	Dust storms	Planet-wide dust storms with up to 186 mph winds
5	Terrain features	Wide diversity of geographic features
6	Volcanic activity	Non-active volcanoes
7	Presence of water	Sub-surface ice and ice in polar regions
8	Life on Mars	Still speculated
9	Gravity	38% of Earth's gravity

(Nair 2008, pg. 1340)

Constructing a refuge of this kind would require extensive knowledge on how to sustain life off of Earth. For this reason, it is generally viewed as a very futuristic idea and one that is beyond the scope of immediate colonization. (O'Neill 1974) Later settlements can begin expansion across the solar system and universe, utilizing the water on Jupiter's moons and exploiting the resources in the asteroid belt. (Globus 2016)

Space mining

The third generally hypothesized model for space colonization is mining, asteroid, and solar, for both colonization and economic gain. Asteroid mining presents a unique opportunity to not only gather raw materials for the construction of space colonies but also the import of these raw materials to Earth itself. The asteroid belt is rich in resources such as water, nickel, iron, silicate rock, and more valuable materials like platinum. (Sonter 2006) In addition to asteroid mining, there are discussions of harvesting solar power from space colonies to send to earth and allowing shipping via orbit and the space colonies as an alternative to water freights. Scientists maintain that initially any resource mining off of the planet will be done remotely from Earth but eventually there will be a need for humans to maintain and interact with the machinery, requiring preparation for habitation near the mine, whether it be a settlement orbiting the mine or surface-based on the mine itself. (Andrews 2011, pg 3) This may even evolve into a permanent human presence with mining allowing for quicker expansion and a decrease in travel time sending a person into space each maintenence cycle. The universe is rich in matter and energy and is ours to harness. (O'Neill 1974)

There are real benefits of utilizing the previously mentioned free space settlement that outweigh the colonization of a different planet regarding available land, resources, and ability to expand. The Moon and Mars are sites most frequently considered for surface-based colonization, and critics of this model argue that “their combined surface area is only about one-third that of Earth. In contrast, the materials in the single largest asteroid (Ceres) could be converted into space settlements with a combined living area of between 100 and 1,000 times the surface area of Earth. Each of those millions of settlements would be a space craft housing tens of thousands of people in a separate, closed ecosystem. Their relatively small size would make environmental accountability quick: if the occupants of a settlement failed to follow sound environmental practices, their home would rapidly degrade and become unlivable, but this would not affect other settlements, giving life redundancy and resiliency.” (Globus 2009)

4. Spatial needs for colonization

Despite our lack of long-term experience, the concept of humans living in space or colonizing other worlds is becoming a more realistic and achievable goal. When planning for a transition as monumental as leaving Earth forever there are certain needs that must be met for humans to survive. Factors such as gravity, food and water, atmosphere, energy, transportation, communication, and shelter from the vacuum and radiation of space must be considered. (NASA 1975, pg. 25-27) For the purposes of this study, the environmental needs of humans in relation to the design of the built environment will be examined.

It is the task of the architectural and environmental designer to reduce stressors by shaping and interrelating structures and surroundings to meet the psychological, social, cultural, and aesthetic needs of the colony’s inhabitants, while also satisfying their vital physiological needs. (Glaeser 1975) The importance of active human involvement with their surroundings is taught and emphasized in both educational and professional settings. (Sommer 1969) It is suggested that when creating a self-sustaining space habitat, that the following are taken into consideration so as to reduce the effects of environmental stress and isolation:

1. *The colony must be both planned and ambiguous*. This criterion lends itself to helping offset the feel of artificiality and sterility in the colony as a built environment.
2. *Freedom of choice should be given to the colonists.* Choice within the colony as a whole gives the colonists an escape from, potentially, very rigid and prescribed personal spaces. It stimulates the intellect and gives individuals goals to pursue when seeking alternative routes whilst exploring or proceeding with day-to-day function.
3. *Units must be easily produced.* Sources of building materials and units themselves must lend themselves to demonstrating maximum efficiency, minimum mass and be "fairly flexible, light weight, easily mass produced, capable of fast efficient erection, and yet allow a variety of spaces to evolve."
4. *Colonies must be both spatially and physically aesthetically pleasing.* Not only in the public spaces but freedom of choice must also be given to colonists in terms of alteration of private spaces, growing plants, caring for pets, children's playgrounds, etc., in order to create a more aesthetically pleasing and stimulating environment in which the colonists will live.
5. *The built environment must aid in reducing the feeling of artificiality and isolation*. Artificiality and isolation are two of the more significant

psychological concerns with regard to space colonization. Aside from allowing colonists to personalize private spaces, public spaces can be utilized to lessen the effects of artificiality by providing individuals access to large open spaces, panoramic vistas, views of the Moon and Earth, and manicured landscapes. This programming would assist in adding dimension to the colony by affording humans the opportunity to “take full advantage of life in space” and increase “awareness of reality beyond the human scale.”

6. *The colony must have adequate space and land use planning*. Determining the spatial needs of the colonists allows for planners to establish appropriate population and urban density to help limit the sense of crowding reducing the effects of environmental stress. Comparing population densities to that of existing cities on Earth is a starting point. (See Fig. 3.4)

Table 3.4: Chart illustrating the available land per capita in selected cities and towns.

Location	Per capita area, m^2 /person
Boston, Mass	185.8
Chicago,Ill	171.2
El Paso,Tex.	950.5
Jersey City, N.J.	150.1
New York, N.Y.	98.3
Manhattan Borough, N.Y.	38.2
San Francisco, Calif.	164.3
St.Paul, France	27
Vence, France	46.2
Rome, Italy	40.0
Columbia, Md.	503
Soleri's Babel IIB	15.1
Space Colony	>= 40

National Aeronautics and Space Administration. *Space Settlements: a Design Study*. Washington D.C.: United States Government Printing, 1977. Page 28.

In addition to adequate space and not unlike current cities, a variety of land uses is required to build a livable community including residential, commercial, public and semi-public enclosed space, public open space, light service industry, wholesale and storage, allocated areas for mechanical subsystems, transportation, and agriculture (NASA 1975, pg. 28)
(See Table 3.4)

Table 3.4: Chart explaining necessary community space and area allocations.

Space use	Surface area required, m^2/person	No. of levels	Projected area, m^2	Estimated height, m	Volume, m^3
Residential	49	4	12	3	147
Business: Shops Offices	2.3 1	2 3	1.0 .33	4 4	9.2 4.0
Public and semipublic; Schools Hospital	1 .3	3 1	.3 .3	3.8 5	3.8 1.5
Assembly (churches, community halls	1.5	1	1.5	10	15
Recreation and entertainment	1	1	1	3	3
Public open space	10	1	10	50	500
Service industry	4	2	2	6	24
Storage	5	4	1	3.2	16
Transportation	12	1	12	6	72
Mech. subsystem Communication distr. switching equipment for 2800 families	0.5	1	0.5	4	.2
Waste and water treatment and recycling	4	1	4	4	16
Electrical supply and distribution	.1	1	.1	4	.4
Miscellaneous	2.9	3	1	3.8	11.2
Subtotals	94.2	-	46.6	-	823.3
Agricultural space requirements (a) Plant growing areas	44	3	14.7	15	660
Animal areas	5	3	1.7	15	75
Food processing collection, storage, etc.	4	3	1.3	15	60
Agricultural drying area	8	3	2.7	15	120
Totals	155.2	-	67.0	-	1738.3

National Aeronautics and Space Administration. *Space Settlements: a Design Study*. Washington D.C.: United States Government Printing, 1977. Page 29.

CHAPTER FOUR

CASE STUDIES

With the environmental planning needs of potential space colonies being defined, this study will now examine four case studies for proposals presented by Metabolist urbanists. The individual problematics driving each proposal will be examined and the suggested design solutions will be analyzed for spatial organization, growth patterns, and humanizing elements that would be compatible with the design criteria presented by NASA.

The case studies selected include Ocean City, Space City, Helix City, and the Tokyo Bay Plan. The proposals were chosen for their unique perspective of being "disconnected" from nature and their surroundings. Metabolists were known for utopian experiments of building on artificial land, sea, and sky which required a certain amount of self-sustainability. These features allow the Metabolism movement to be echoed in the notion of planned cities quickly emerging from almost nothing, a critical concept to consider within the realm of space colonization.

1. Ocean City

Ocean City was comprised of two separate but intertwined utopian plans: "Tower City" and "Marine City." Developed by Kiyonori Kikutake in 1958 and presented in 1960 at the World Design Conference in Tokyo, Ocean City (see Fig. 4.1) was developed from

1958-1963 and helped drive what would become the Metabolist movement into decades of research and design proposals. (Schalk 2014, pg. 287)

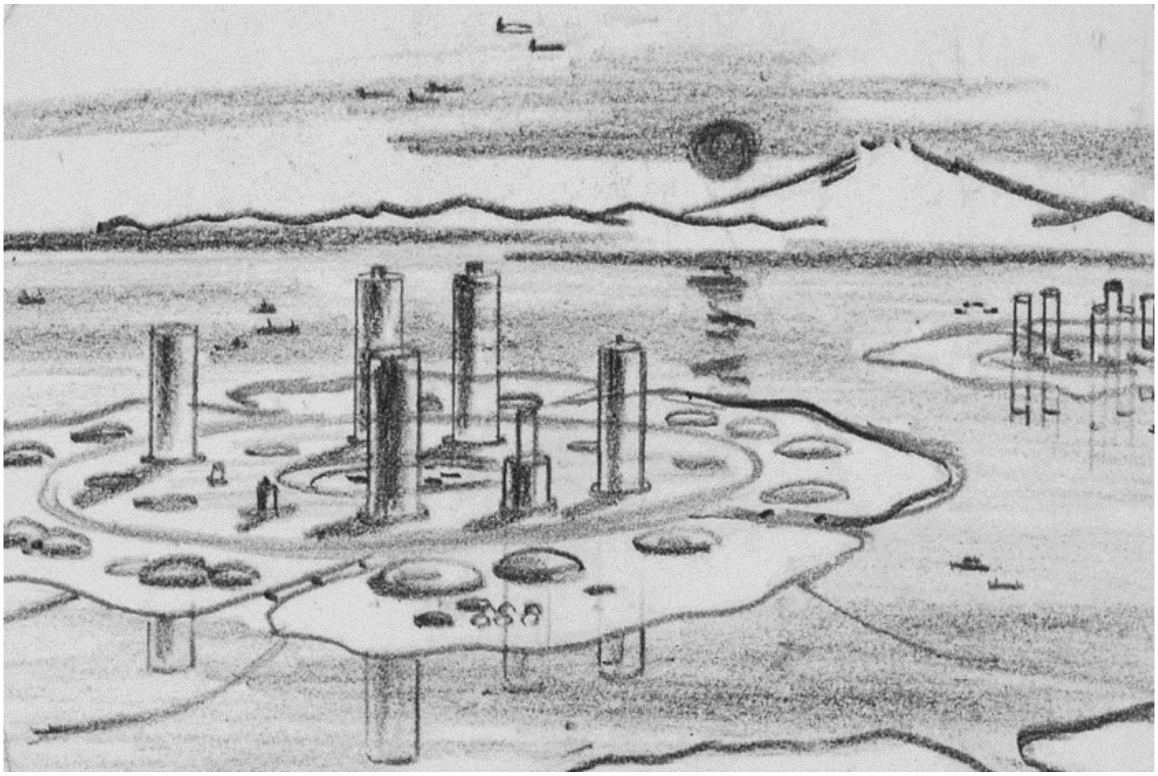

Figure 4.1: Sketch of Ocean City by Kikutake presented at the Tokyo World Design Conference in 1960. Kikutake, Kiyonori. 1958. Digital Image, 2012. Source: http://www.uncubemagazine.com/blog/7518525/ (Accessed June 2016)

Marine City

Marine City was the first in his series to explore the concept of creating a floating city on the sea in response to identifying a critical need for land reclamation that could provide additional land area for industrial usage. He became inspired by the industrialization and urbanization happening during the post-war reconstruction of Japan and his forms attempted to respond to that need. The first iteration proposed that the city itself be constructed upon artificial land and be allowed to move and float freely through the water; the forms changing and evolving as needed. (See Fig. 4.2) However, when technology advanced beyond the city and it became uninhabitable, Marine City would ultimately sink itself and become a part of marine life in the bay. (Lin 2009, pg. 27)

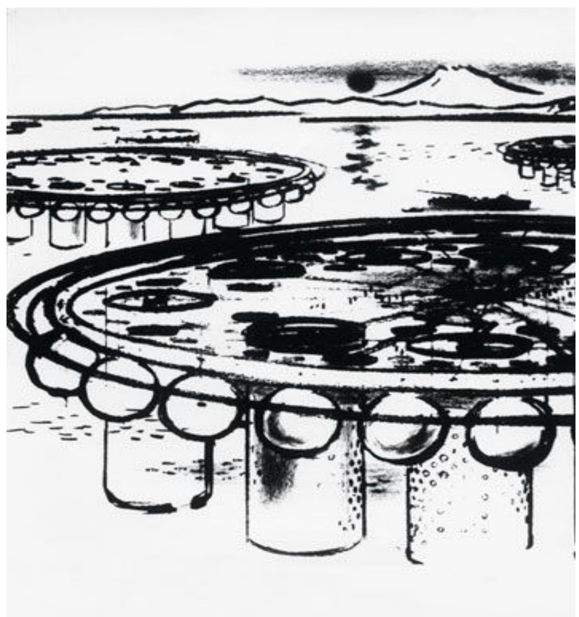

Figure 4.2: Original sketch of the floating Marine City by Kikutake presented at the Tokyo World Design Conference in 1960. Kikutake, Kiyonori. 1959. Digital Image, 2011. Source: http://www.wallpaper.com/gallery/architecture/book-project-japan-metabolism-talks/ (Accessed June 2016)

Tower City

Kikutake's original plan for Tower City introduced a new concept and organization of urban dwellings. The plan featured a series of self-contained concrete cylinders standing 950 feet tall that could accommodate the housing and infrastructure of the entire city: utilities, residences, transportation, and a plant to make new housing units as needed. Each tower could house 1,250 dwelling units and up to 5,000 residents. Individual housing units were recommended to be prefabricated and could be built on-site and attached to existing towers. Horizontal passageways between the towers allowed for connections between residences of the expanding and evolving city. (Lin 2010, pg. 26) This created "vertical land" and eliminated the need for traditional land; the towers acted as "a vertical submarine, its nose poking above the water but its main operations taking place beneath the surface. (Koolhaas 2001, pg. 357) (See Fig. 4.3) Kikutake compared it to a silkworm making silk and described it as "the combination of individual and society, architecture and city, as well as a new modern monument". (Lin 2010, pg. 26)

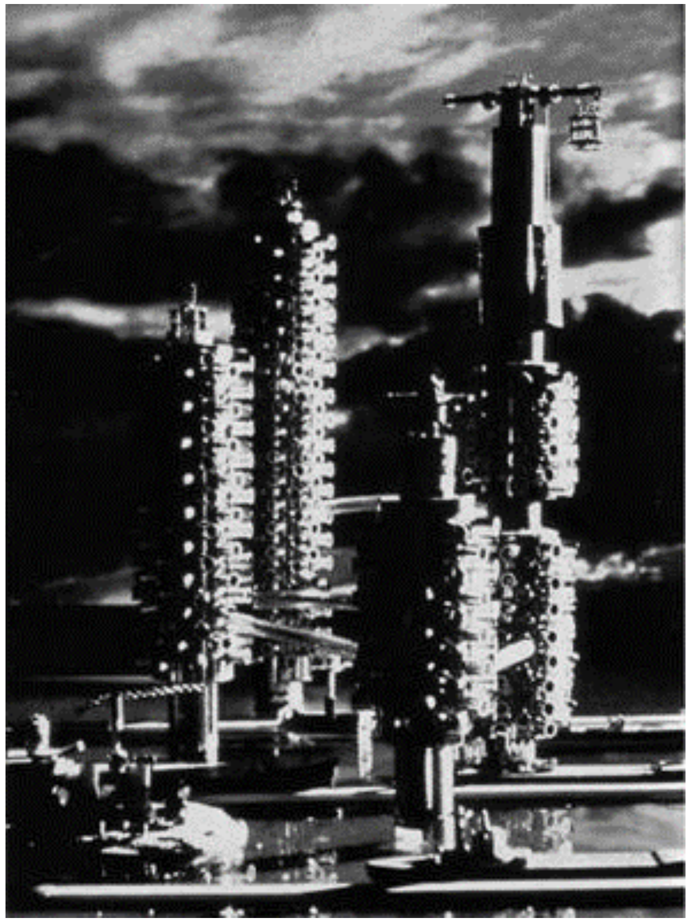

Fig. 4.3: Model illustrating the concepts of Tower City. Kikutake, Kiyonori. 1959. Digital Image, 2006. Source: http://jill-hazel.blogspot.com/2006/08/development-of-ocean-city.html (Accessed June 2016)

Soon Kikutake began to develop his plans for this floating city further by combining ideas from both Marine City and the first Ocean City through the creation of artificial land and vertical cities. These new ideas took place on a larger scale, and the city as a whole could accommodate up to 500,000 people rather than the original estimate of 5,000 per tower in the plan for Tower City. Spatially more organized, the city plan consisted of two primary rings of development: the inner ring dedicated to housing and administration; and an outer ring used for agriculture and industry. The water bodies within the cities possessed delineated uses as well with the innermost body of water used for recreation and the water located between the inner and outer rings used for fishing and industry. (Lin 2010, pg. 27) (See Fig. 4.4)

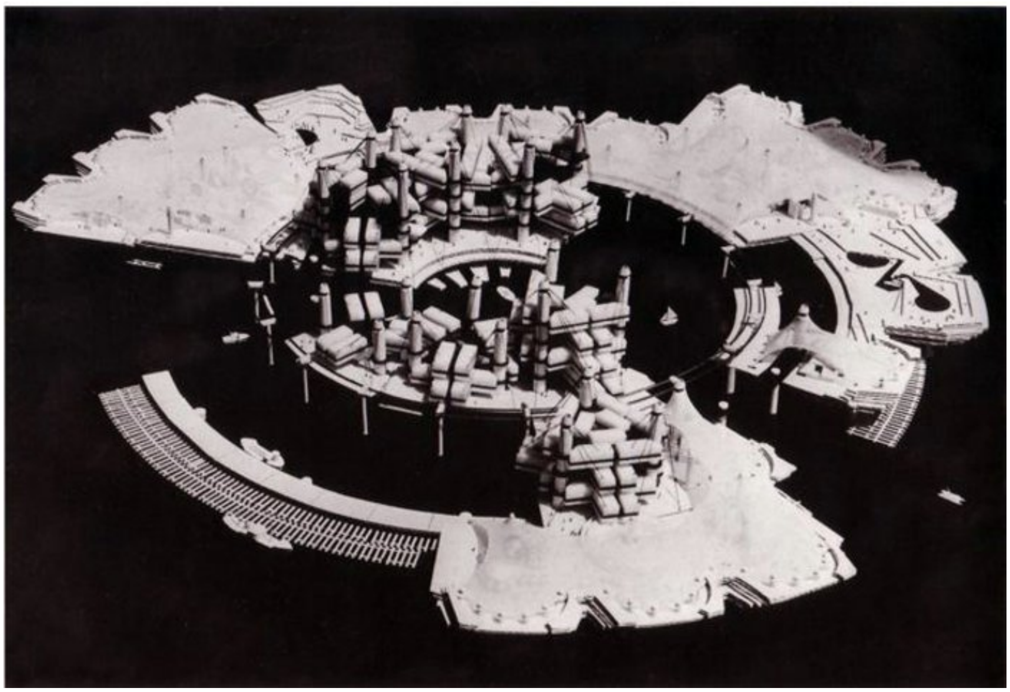

Figure 4.4: Model of the floating Ocean City Unabara. Kikutake, Kiyonori. 1959. Digital Image, 2011. Source: https://ekgroup.wordpress.com/2011/12/05/metabolism/ (Accessed June 2016)

Kikutake also began imagining an ever-expanding city and explored potential ways in which the city could grow and be shaped as the demands for housing rose in Japan. He envisioned the vertical forms and high rises resembling trees of modular housing; the urban "forest" form is, in fact, a concept that Kikutake would continue to explore throughout his career. Modular and prefabricated housing options allowed the city to easily grow. As the city's towers met their limit, they would be able to split, like a cell, forming a new city and creating "linkages" between each one. (Lin 2010, pg. 28) (See Fig. 4.5)

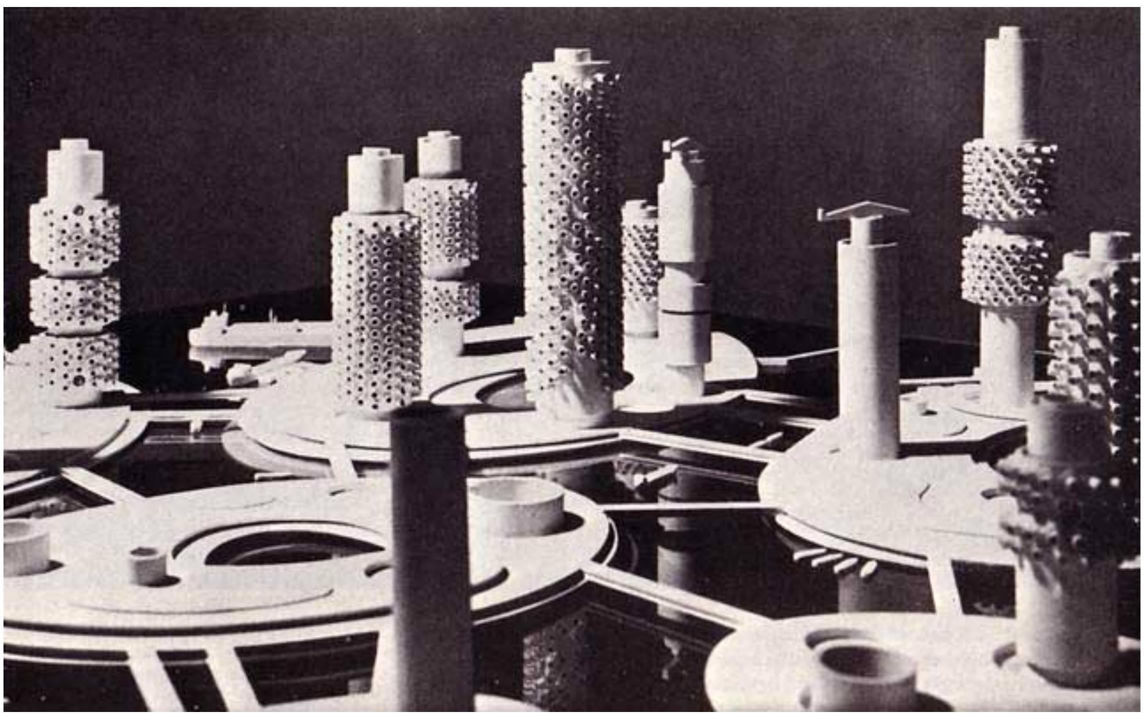

Figure 4.5: Expanded and developed model for the Ocean City. Kikutake, Kiyonori. 1968. Digital Image, 2006. Source: http://jill-hazel.blogspot.com/2006/08/development-of-ocean-city.html (Accessed June 2016)

With enough growth and evolution, the city would evolve into a much larger intertwined network of communities. (See Fig. 4.6) The same spatial concept of Ocean

City Unabara, with its central ring dedicated to residential and outer ring used for agriculture and industry, in its expansion Ocean City becomes “a floating archipelago conceived for the middle of the ocean, made up of ‘mother cities’ and ‘small cities’ connected by bridges.” (Koolhaas 2001, pg. 356)

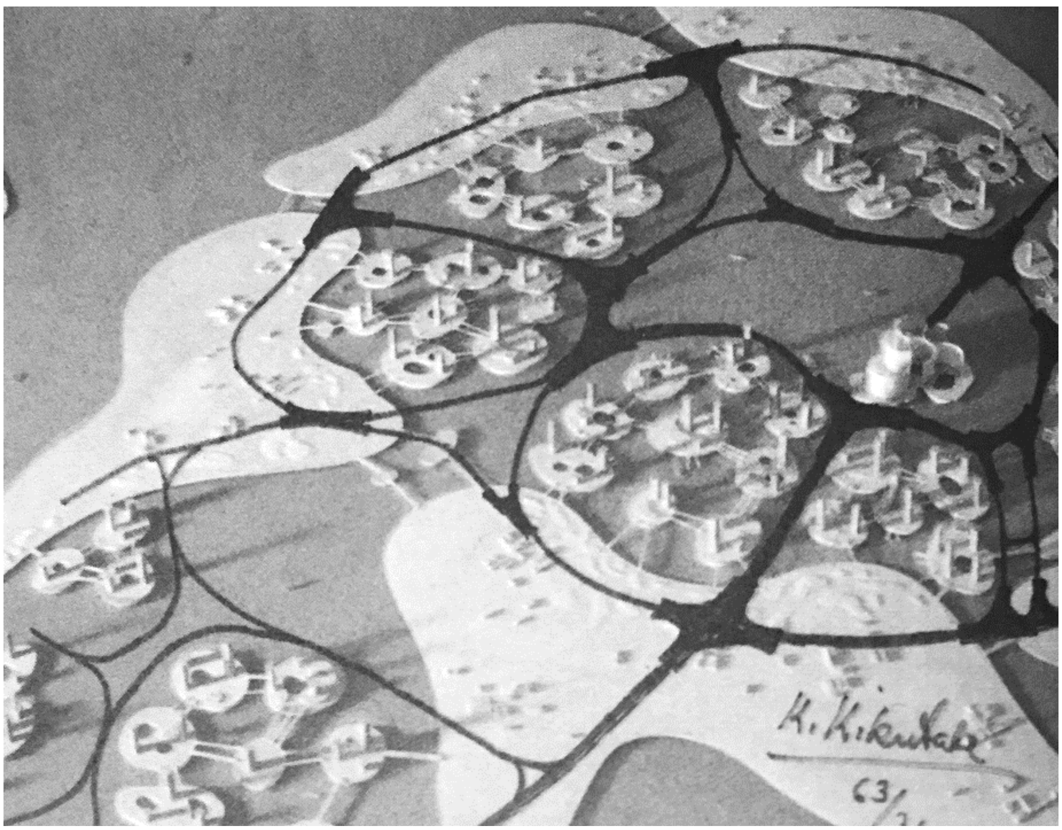

Figure 4.6: Model showing network of Ocean Cities. 1963**.** Koolhaas, Rem, Hans Ulrich. Obrist, Kayoko Ota, and James Westcott. Project Japan: Metabolism Talks--. Köln: TASCHEN GmbH, 2011. Page 356.

Kikutake claims that his megastructure acts in response to recurring crises and is "ordained when man occupied, then clung to and expected too much from the land." (Koolhaas 2011, pg. 354) The design was meant to transcend and free man from the bonds of being forced to live on land.

2. Space City

The essay "Space City," written by Kishō Kurokawa in 1960, contained plans for four different projects: "Wall City," "Neo-Tokyo Plan," "Agriculture City," and "Mushroom House." This study will only examine his plans for Agriculture City and Mushroom House due to their interconnections and their applications to potential future cities.

Agriculture City

The design for Agriculture City originated in response to the destruction caused by the Ise Bay typhoon in 1959 which destroyed many rural villages. Kurokawa wrote, "I witnessed an almost evenly distributed grid of thatched roofs above the vast sea of mud water covering paddy fields. It was an odd scene." (Koolhaas 2001, pg. 341) Kurokawa stated in his essay "Space City" that, "The city is eternally moving as a container of future life. There exists a changing cycle which differs according to each section of the city. There exists a difference in the durability and scale in the basic urban structure, urban connectors, living units, and architectural equipment. One must, therefore, devise an urban design which will enable a flexible expansion between these difference elements." (Kurokawa, 1960) Through designing in response to the crisis, Kurokawa took the opportunity to experiment with flexible expansion through the integration of agriculture and city life while simultaneously planning for disaster mitigation.

His solution proposed another form of artificial land in an elevated city grid. (See Fig. 4.7) The grid would be made of concrete and raised about 13 feet off of the ground. The community created would be able to accommodate 2,000 residents in 25 blocks. Spatially, the central block would be utilized for public facilities. such as schools and religious institutions while the surrounding blocks would feature residential units. (Lin 2010, pg. 30) The linear patterns allowed for strips of the grid to grow and expand as dictated by the people.

The elevated aspect of these designs frees the entirety of the land, "allowing agriculture and communal life to coexist safely and unimpeded," (Koolhaas 2011, pg. 341) and to be devoted to agriculture while also raising the city's residents out of the flood zones.

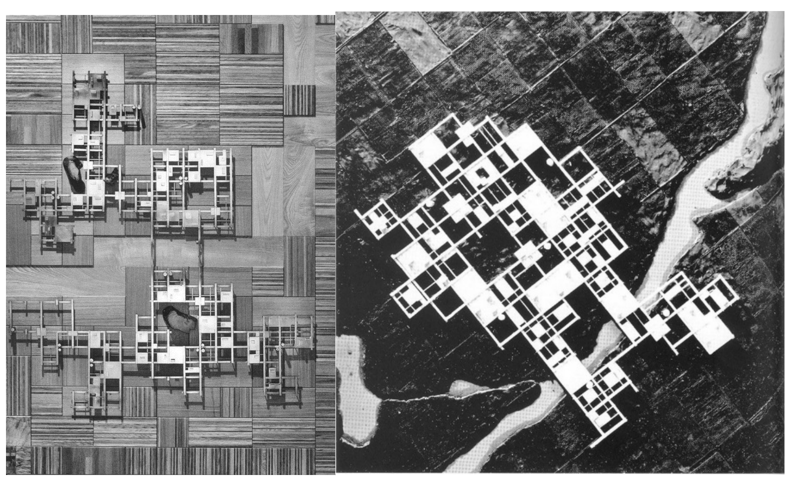

Figure 4.7: Agriculture City master planning options. Kurokawa, Kishō. 1960. Digital Image, 2015. Source: http://socks-studio.com/2015/02/24/agricultural-city-by-kisho-kurokawa-1960/ (Accessed June 2016.)

Mushroom Houses

It is proposed that residents live in Kurokawa's Mushroom Houses that were designed to spring out from the grid pattern like mushrooms in nature. (See Fig. 4.8) Colleague Kawazoe describes the city's mushroom form as "standing on a rice paddy field, anyone is drawn to a deep sense of solitude. Kurokawa wrapped a house with something neither roof nor wall, so that the landscape is shuttered off and the sight line is guided to the ground. The tea room attached to the core underneath the living space, on the contrary, expands the view." (Koolhaas 2011, pg. 341)

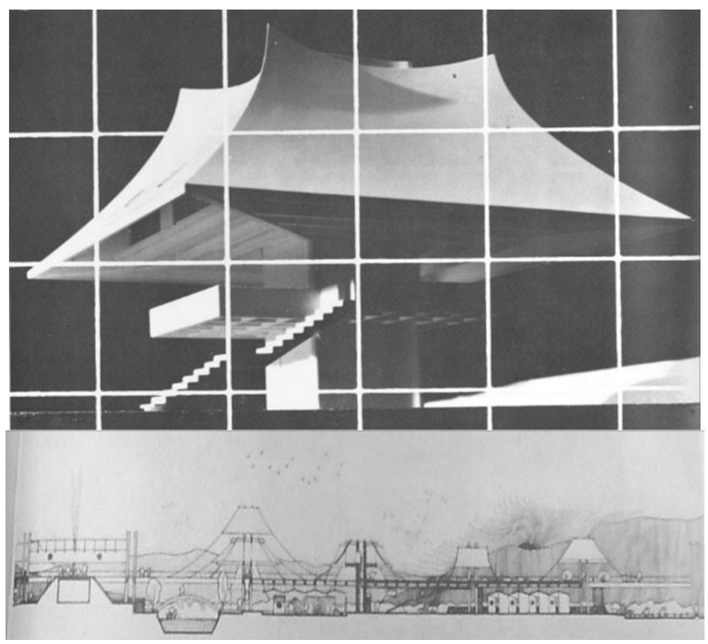

Figure 4.8: (top) Mushroom house model, (bottom) Incorporation of mushroom houses within the Agriculture City. Kurokawa, Kishō. 1960. Digital Image, 2015. Source: http://socks-studio.com/2015/02/24/agricultural-city-by-kisho-kurokawa-1960/ (Accessed June 2016.)

The mushroom houses serve as two or three story residences that are further elevated off of the grid. Concrete walls offer limited views and a sense of privacy and solitude while inside with only natural light entering from the roof, but should the residents desire to be sociable then they can join the community by sitting in the outdoor tea room. (Lin 2010, pg. 31)

Kurokawa discusses the concept of his households in his essay: "…autonomous, linking these units together creates a village. The living units multiply spontaneously without any hierarchy, gradually bringing the village into being the traditional rural settlement has developed throughout Japanese history." (Kurokawa 1960)

3. Helix City

With the discovery of the DNA double helix in 1953, Kurokawa began experimenting with these forms in his designs for the Helix City in 1961, while exploring options for the dramatic shortage in housing in Tokyo. (See Fig. 4.9)

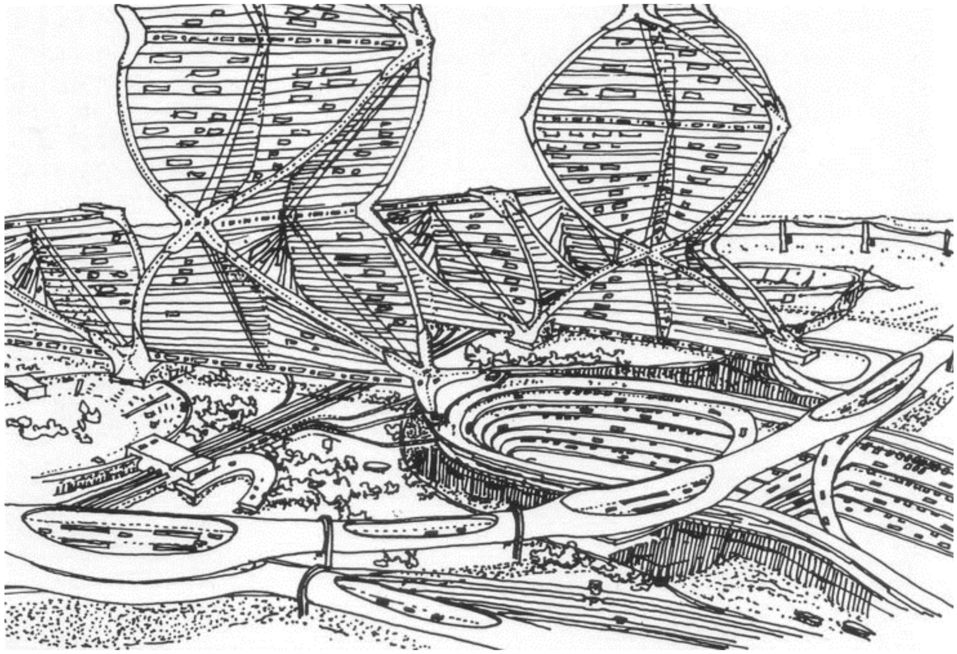

Figure 4.9: Sketch depicting proposed Helix City. Kurokawa, Kishō. 1961. Digital Image, 2012. Source: http://acidadebranca.tumblr.com/post/24225343510/black-white-sketches-013-kisho-kurokawa (Accessed June 2016.)

Capable of housing 10,000 people per tower, the proposal consisted of massive spiral towers with a permanent core and the option for growth and customization with module units. These residential units could stack neatly within the structure and in any order needed and, to allow for growth in population, once the tower was full another one could be constructed nearby. Each tower was connected to another with a bridge allowing for linkages and community networking. As proposals were created for the area surrounding the site of the new international airport near Lake Kasumigaura to address the housing crisis, Kurokawa used his Helix City as inspiration for his very own Floating

City as a way to integrate nature with modern living. (Koolhaas 2011, pg. 355) (See Fig. 4.10)

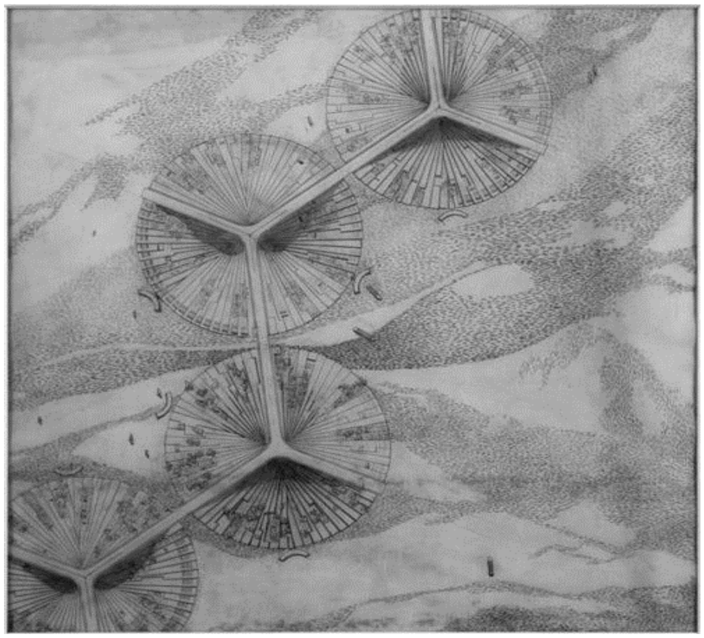

Figure 4.10: Floating City structural detail sketch. Kurokawa, Kishō. 1961. Digital Image, 1999. Source: http://www.photo.rmn.fr/C.aspx?VP3=SearchResult&IID=2C6NU0E6NI4F (Accessed June 2016.)

Similar in structure to Helix City, his Floating City featured a permanent centralized infrastructure in which modular residences are placed neatly while vehicular and pedestrian traffic would utilize the roofs of the structures allowing for connections between the respective towers. It was Kurokawa's belief that regulation and standardization made "production more efficient, and as people were freed from the constraints of the land, they would enjoy more leisure time.” (Lin 2010, pg. 92) For this reason, he drew sketches and concepts to illustrate a life of relaxation for Floating City’s residents. (See Fig. 4.11)

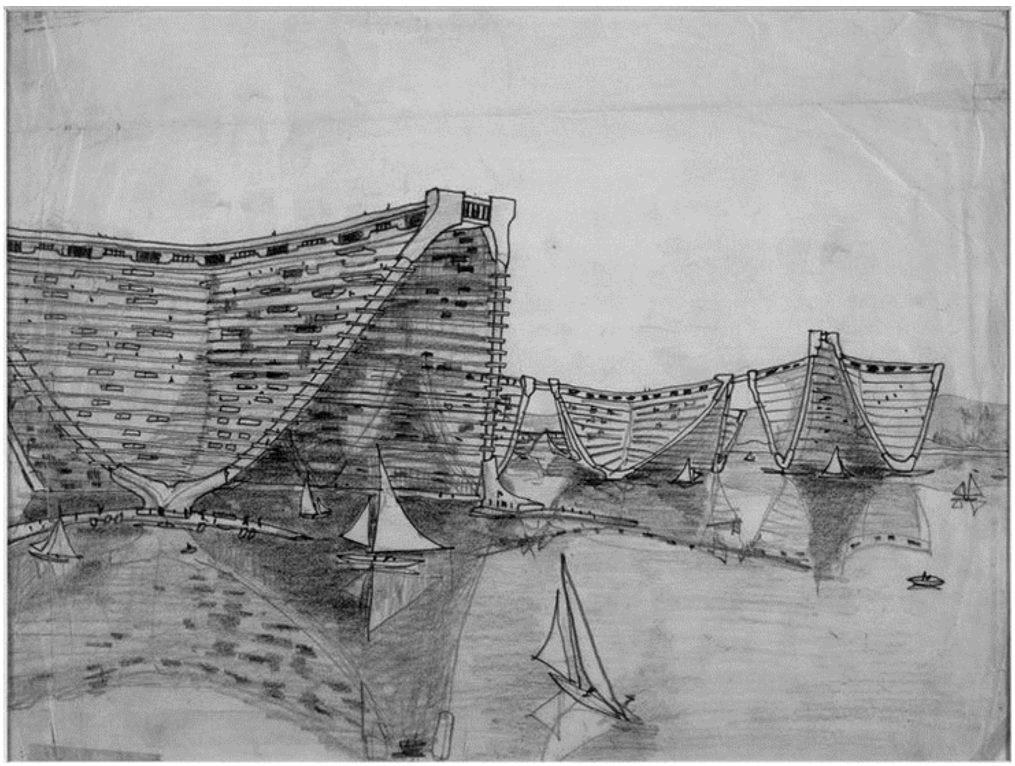

Figure 4.11: Floating City sketch. Kurokawa, Kishō. 1961. Digital Image, 1999. Source: http://www.photo.rmn.fr/C.aspx?VP3=SearchResult&IID=2C6NU0E6NI4F (Accessed June 2016.)

One characteristic of Metabolism is the designers’ portrayal of city plans as journey or process. This often includes depictions of what growth and expansion could become after some time. Kawazoe remarked on the nature of city growth, “The dwelling of the future will be reduced to ‘parts’ and attached on to the ‘city structural unit,’ but these factory-produced parts will be capable of endless combinations and change by means of standardized systems and joints. People will be able to select suitable shapes, colors, and qualities according to their liking and put them together in entirely free sizes on the necessary scales.” (Lin 2010, pg. 92) What was unique about Floating City was its opportunity for both vertical and horizontal expansion. (See Fig. 4.12)

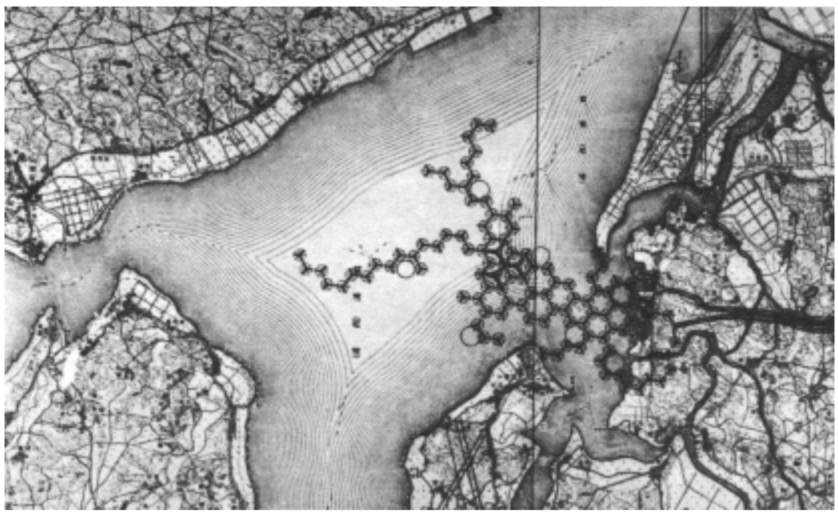

Figure 4.12: Floating City Kasumigaura master plan. Kurokawa, Kishō. 1961. Digital Image, 2012. Source: http://db.flexibilni-architektura.cz/o/48 (Accessed June 2016.)

4. Tokyo Bay Plan

Kenzō Tange presented his plan for Tokyo Bay in 1960 in response to the city’s unique expansion crisis. In addition to fulfilling Japan’s urgent need for reconstruction after World War II, there also occurred an economic boom in 1950 as a result of the Korean War. This led to an exponential rise in population and industrialization. At that time, Tokyo was still utilizing its medieval city plan of tightly packed streets and featured very little urban planning and structure. (Koolhaas 2011, pg. 284) In describing Tokyo's struggling urban plan, Tange states, "Because this pattern is not discarded, every time a fine new building is erected in the metropolitan centre, the city moves one step closer to a comatose state….the permanent structure of the modern metropolis is incompatible with the movement that is necessary to the life of the metropolis. The old body can no longer contain new life." (Tange 1961) To offset the dysfunction of the existing urban infrastructure, a radical plan was introduced that would change how Tokyo Bay was perceived and would illuminate the extent of the urbanization crisis within the city.

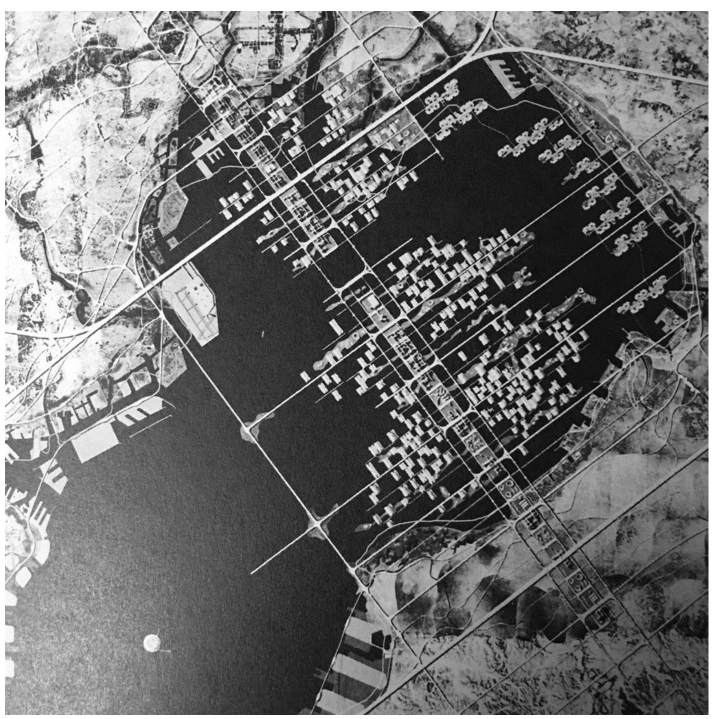

Figure 4.13: Master plan for Tange's Tokyo Bay Plan. 1960**.** Koolhaas, Rem, Hans Ulrich. Obrist, Kayoko Ota, and James Westcott. Project Japan: Metabolism Talks. Köln: TASCHEN GmbH, 2011. Page 285.

First, the construction of a "spine" crossing Tokyo Bay acted as a city center, connecting parts of the city. (See Fig. 4.13) Next, highways stemming from this spine offered a connection to the major existing roadways within the city, in addition to the spine itself, creating an integrated and cyclical transportation network. This network would assist the flow of traffic for millions of people. (Schalk 2014, pg. 288) Tange intended this feature to reinforce the objective of an open system which would blur the lines between Tokyo Bay and the city itself. For transportation, creating an open system across the bay would allow for ease of permeability for both cars and pedestrians allowing for increased mobility throughout the city as a whole. Further, each vertebra of the spine acted as a self-contained city in itself built on different levels of artificial land. (See Fig. 4.14) Non-modular, yet self-contained, housing megastructures, sheltering 5 million people, offered dwellers the flexibility of creating houses based on individual preferences, while not interfering with the city as a system. (Koolhaas, pg. 284)

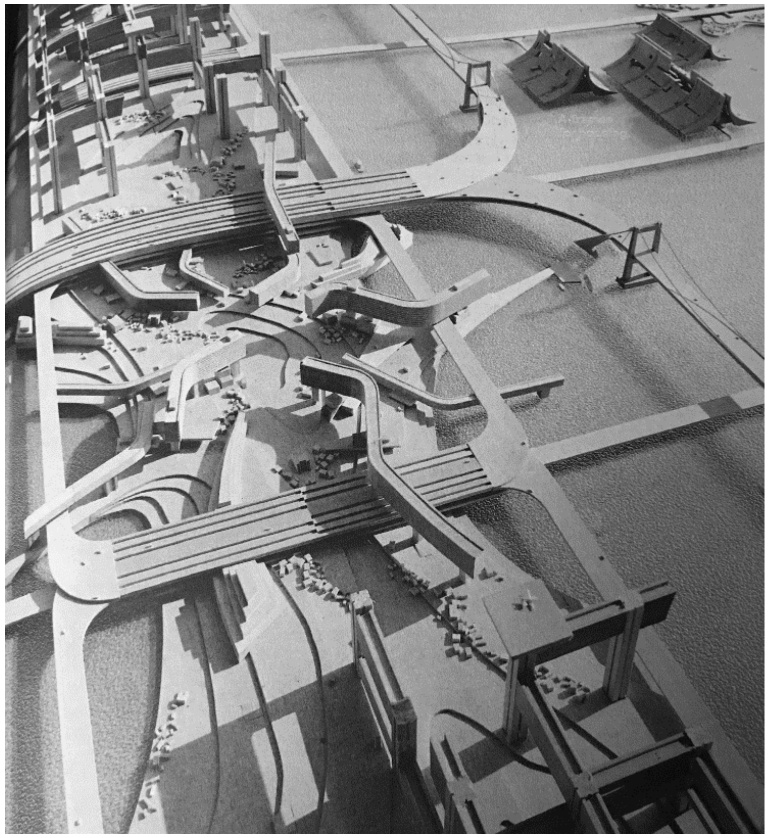

Figure 4.14: Model illustrating the 'vertebrae' detail within Tange's Tokyo Bay Plan. 1960**.** Koolhaas, Rem, Hans Ulrich. Obrist, Kayoko Ota, and James Westcott. Project Japan: Metabolism Talks. Köln: TASCHEN GmbH, 2011. Page 287.

Growth and regeneration occurred in a linear fashion extending outward from the spine or city center. He spoke about his plan for addressing land use and growth, "In this system, it would be possible while taking into account the space, for the surroundings, to form well-planned continuous urban space that are not closed in nature. In effect, zonal planning methods used in urban planning today would be replaced by organized spatial planning." (Tange 1961) This approach to zoning permitted society to grow and change as dictated, while merely falling into place within the actual infrastructure of the city and not submitting to predetermined land use requirements.

Tange's plan focused on three main objectives: creating an open structure through the utilization of linear development, encouraging growth and regeneration that organically blends into the existing fabric of Tokyo, and the planning for viable spontaneous mobility within the plan. (Tange 1961) The primary goal being the implementation of an open structure which would be used to facilitate the other two objectives. (Lin 2010, pg. 153)

CHAPTER FIVE

CASE STUDY ANALYSIS

1. Analysis of case studies

In order to achieve the objectives and answer the research questions, this study's methodology investigated four case studies of Metabolist city plans, identified the key principles that acted as the driving forces behind the designs, and examined what spatial organization and programming arose from these principles. Once these principles and spatial programming were determined, they were analyzed for their compliance with the guidelines set forth by NASA that have been determined to be necessary for successful space colonization. As repeated in Chapter 2, it is suggested that when creating an artificial habitat, the following are taken into consideration so as to reduce the effects of environmental stress and isolation:

1. *The colony must be both planned and ambiguous*. This criterion helps offset the feel of artificiality and sterility in the colony as a built environment.
2. *Freedom of choice should be given to the colonists.* Choice within the colony as a whole gives the colonists an escape from, potentially, very rigid and prescribed personal spaces. It stimulates the intellect and gives individuals goals to pursue when seeking alternative routes whilst exploring or proceeding with day-to-day function.

3. *Units must be easily produced.* Sources of building materials and units themselves must lend themselves to demonstrating maximum efficiency, minimum mass, and be "fairly flexible, light weight, easily mass produced, capable of fast efficient erection, and yet allow a variety of spaces to evolve."
4. *Colonies must be both spatially and physically aesthetically pleasing.* Not only in the public spaces but freedom of choice must also be given to colonists in terms of alteration of private spaces, growing plants, caring for pets, children's playgrounds, etc., in order to create a more aesthetically pleasing and stimulating environment in which the colonists will live.
5. *The built environment must aid in reducing the feeling of artificiality and isolation*. Artificiality and isolation are two of the more significant psychological concerns with regard to space colonization. Aside from allowing colonists to personalize private spaces, public spaces can be utilized to lessen the effects of artificiality by providing individuals access to large open spaces, panoramic vistas, views of the Moon and Earth, and manicured landscapes. This programming would assist in adding dimension to the colony by affording humans the opportunity to "take full advantage of life in space" and increase "awareness of reality beyond the human scale."
6. *The colony must have adequate space and land use planning*. Determining the spatial needs of the colonists allows for planners to establish appropriate population and urban density to help limit the sense of crowding, thus reducing the effects of environmental stress. (NASA 1975, pg. 28)

After the comparison, it was determined and discussed which city plans and in what ways they complied with the spatial necessities for future colonies. (See Table 5.1)

Table 5.1 Comparability of Metabolist city plans with space colonization needs. Table created by author.

Spatial Needs for Colonization	**Ocean City**		**Space City**		**Helix City**		**Tokyo Bay Plan**
	Marine City	Tower City	Agriculture City	Mushroom Houses	Helix City	Floating City	
Planned and ambiguous	•	•	•			•	•
Freedom of choice	•	•		•			•
Easy production		•			•	•	
Aesthetically pleasing		•		•	•	•	•
Reduction in artificiality			•	•		•	•
Space and land usage	•	•	•	•	•		

2. Ocean City

Kikutake's designs for Ocean City shaped the developing group's manifesto and introduced solutions that would act as a driving force within Metabolism and can be applied to the planning of space colonies. The idea of creating free moving artificial land on the vast expanses of the underutilized Tokyo Bay was a key premise of Marine City, as was its innovative feature of creating linkages to nearby "mother cities." Tower City explored the depths of possibilities for moveable components. Kikutake sought to create a flexible and mobile city and to encourage the idea of replicability, movability, and adaptability in his Ocean City proposals. This flexibility and mobility of land use and expansion would be useful when planning space colonies.

Kikutake's proposals for both Marine City and Tower City, and later Ocean City Unabara, demonstrate the necessity of planned complexity and general ambiguity to stave off a sense of banality. This is demonstrated by the prescribed yet complex organization of both the city as a whole and the tower megastructures within it. Residents feel at ease in the familiarity of the spatial *planning, yet the design is ambiguous* enough for individuals to freely explore and make discoveries. This planning ambiguity encourages *freedom of choice* amongst the dwellers, particularly within the towers themselves. The prefabricated units of Tower City and the plans give residents freedom to alter the interiors as desired to help offset the perceived rigidity of modular living. While in Marine City, this choice is given when responding to Ocean City as a system rather than the individual mother cities themselves. The mother cities are fairly prescribed, with their two-ringed form. On the other hand, the network and interconnectedness of Ocean City in total provides mental stimulation through exploration of alternate routes. This is a concept that will be critical to the success and sustainability of a space community. (See Fig. 5.1)

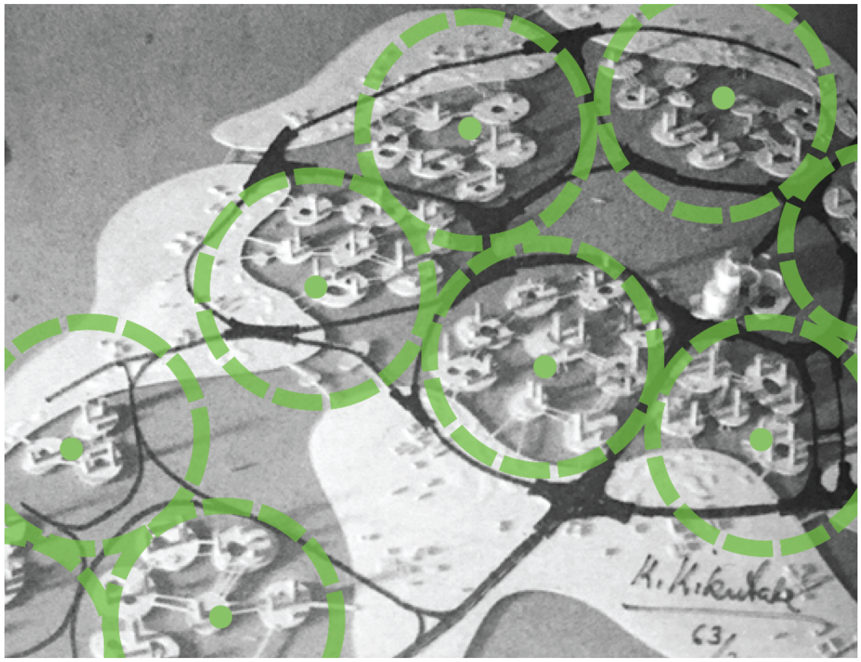

Figure 5.1: Overlay illustrating city clusters forming an ambiguous network in Ocean Cities. 1963**.** Koolhaas, Rem, Hans Ulrich. Obrist, Kayoko Ota, and James Westcott. Project Japan: Metabolism Talks--. Köln: TASCHEN GmbH, 2011. Page 356. Overlay by author.

In terms of feasibility and *ease of production,* Kikutake's artificial land in Ocean City must be called into question due to its lack of technology regarding production and the lack of technical drawings illustrating how the land would be constructed. It is imagined that once the process of building and establishing the artificial land and the initial infrastructure required to support dwelling units is fashioned, then the overall ease of production will increase. The modular units themselves are designed to be completely self-contained and prefabricated, promoting fast and efficient production to allow the city's form to change and adapt as quickly as required. This particular component of

Ocean City, if implemented as is, would quickly be rendered inefficient and time-consuming, contrary to Metabolist ideals. Detailed production plans and technical items must be clearly delineated prior to departure as requisite earthly resources, even gravity, are nonexistent in space.

While in Kikutake's plan for the Ocean City seems to bestow dwellers ample freedom of choice within the tower's private residential units in terms of encouraging a strong sense of *aesthetic pleasure*, the same cannot be determined with regard to the planning of a variety of public outdoor spaces to help reduce the *sense of artificiality and isolation*. First, the initial Tower City plan does not call for physical land at all; the structures act as self-contained networks of primarily submerged indoor spaces, completely limiting dwellers' access to open space and natural panoramic vistas. Next, the very nature of Marine City's design consists of constructed islands freely floating through the sea. All-in-all, Ocean City offers limited planned outdoor space and little opportunity for residents' to meander throughout, thus greatly increasing the sense of artificiality and isolation.

Ocean City utilizes appropriate *spatial and land use planning* as necessary for space colonization. Kikutake offers predetermined planning solutions with Ocean City's double ringed form with prescribed land uses and Tower City's population control. (See Fig. 5.2) As a result, the design informs the city itself when and how it should expand in order to accommodate an increasing population and reducing environmental stress by preventing a sense of overcrowding.

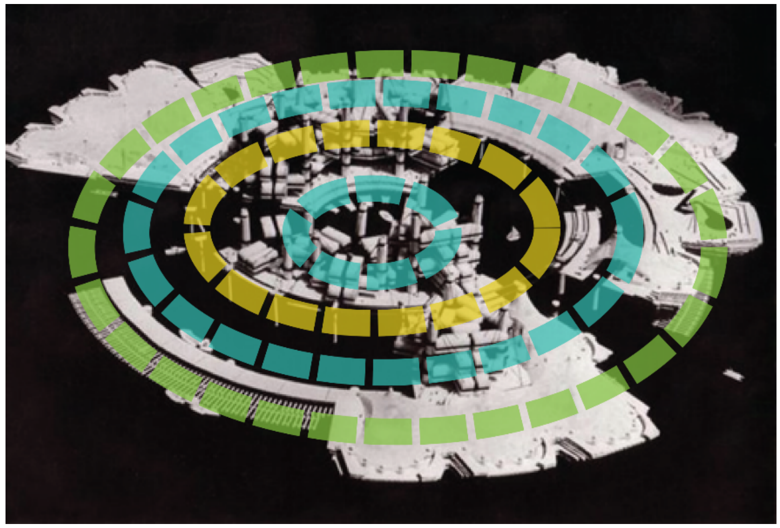

Figure 5.2: Image illustrating land use zones prescribed by Kikutake. Kikutake, Kiyonori. 1959. Digital Image, 2011. Source: https://ekgroup.wordpress.com/2011/12/05/metabolism/ (Accessed June 2016) Overlay by author.

Kikutake's plan enforced the idea of creating a network of cities with predetermined expansion limits in order to provide structure to the cities themselves while facilitating expansion as needed. These values would be a viable option for surface-based colonization based on the assumption that a colony of this type would want to begin with its own self-sustaining fully functioning city. The careful land use planning would allow for needed preparation and efficient establishment. Once the primary colony reached its inhabitant limit then expansion becomes the simple task of constructing an adjacent new colony and beginning a network.

3. Space City

Kurokawa designed the plan for Space City, specifically Agriculture City and Mushroom Houses, in response to the vast decimation of rural villages caused by the Ise Bay Typhoon. The Agriculture City design proposed an elevated grid system of 25 blocks, with Mushroom Houses interspersed, to allow for full utilization of the land below and surrounding the city for farming, while also offering flood protection to the village itself. His overall goal was to experiment with the cohabitation of agricultural and urban areas with ease of expansion while incorporating disaster preventative measures.

It would be appropriate to call Agriculture City *planned and ambiguous*. Initially, the gridiron form of the city itself appears to be very formal and linear, but as the city grows and expands the edges of the city become blurred causing a typically rigid pattern to feel more organic. A single Mushroom House on its own would not be convincing in terms of ambiguity, but in the context of a village of Mushroom House scattered randomly throughout, the grid pattern undeniably assists in making the city feel less utilitarian. The emergence and perceived randomness of the placement of the Mushroom House informs the city as a whole and influences the residents' *freedom of choice*. Intermittent Mushroom Houses formed by establishing clusters and open spaces not only breaks up the monotonous grid but reinforces the development of community categorization. This, in turn, allows individuals the freedom to explore and discover alternate routes through the city, a key premise of Metabolism.

Kurokawa's Space City was not necessarily designed for *ease of production*, and it does not act as the ideal case study for it, but rather as an example of preventative construction in Metabolism. The grid and Mushroom Houses are not meant to be interchangeable and movable but rather sturdy and able to be built upon. The houses do, however, feature a variety of movable interior walls for the dweller to alter the individual's private living space as desired, creating an *aesthetically pleasing* environment in which to live.

Man's connection to nature is undeniable and it is necessary to *reduce the environmental stresses of artificiality and isolation*. Space City's linkage between city and country life presents a unique opportunity for its residents to interact directly with nature. Through the interior design of the Mushroom Houses, dwellers are also allowed to choose their own level of solitude based on whether they stay indoors or move the family to the outdoor tea rooms, creating a sense of interconnectivity within the community.

Agricultural City aims to make the most of its *space and land usages* through its integration of agriculture into the city itself. With a more lenient approach to land use, Kurokawa recommends that only the center of the main block within Agriculture City be zoned for public services, allowing residents the freedom to choose where and with whom they live, in the areas surrounding the central block, thus further strengthening the sense of community.

Space City is approached from the perspective of the combination of agriculture and urban forms. Free space settlements could benefit from this powerful design solution due to its inherent nature to provide the colonists with natural elements from Earth such as forests, lakes, meadows, and farmland. Seeking to give residents a stronger connection to nature while being highly efficient with the agricultural land is crucial given the importance of food production for self-sustainability in space.

4. Helix City

Stemming from the necessity for additional housing to accommodate the developing area around the future international airport, the second Kurokawa design in this study consist of Helix City and Floating City. His original design for Helix City was inspired by the discovery of DNA structure in 1953. He imagined massive spiraling towers of self-contained modular units that allowed for continuous expansion. Utilizing Helix City to inspire his Floating City design, Kurokawa then explored the ideas of expansion in two dimensions and artificial land.

Similar to Space City, Floating City has a very complex *planned yet ambiguousness* to the design. Individually, the spiral towers are rigidly planned, while the ambiguity of the design lies within the network of towers as a whole, creating unique relationships with one another. This ambiguity helps remedy any staleness that might result from a tower on its own. (See Fig. 5.3)

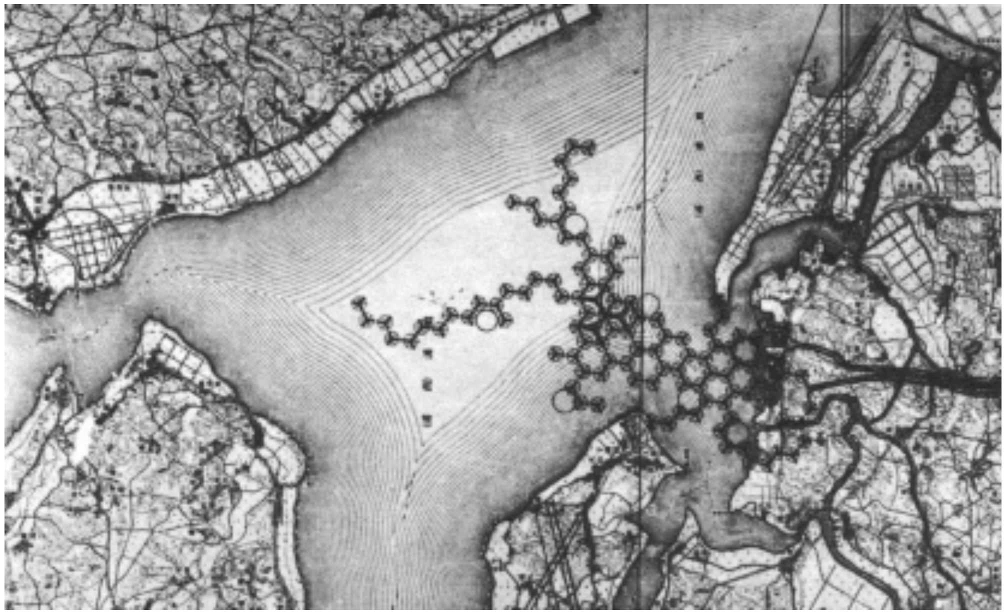

Figure 5.3: Floating City Kasumigaura's network. Kurokawa, Kishō. 1961. Digital Image, 2012. Source: http://db.flexibilni-architektura.cz/o/48 (Accessed June 2016.)

A shortcoming of this particular project's ambiguity is the severe form which permits only one linkage between towers. This single channel of communication and transport between massive towers does not give individuals the *freedom of choice* or the opportunity for exploration. (See Fig. 5.4)

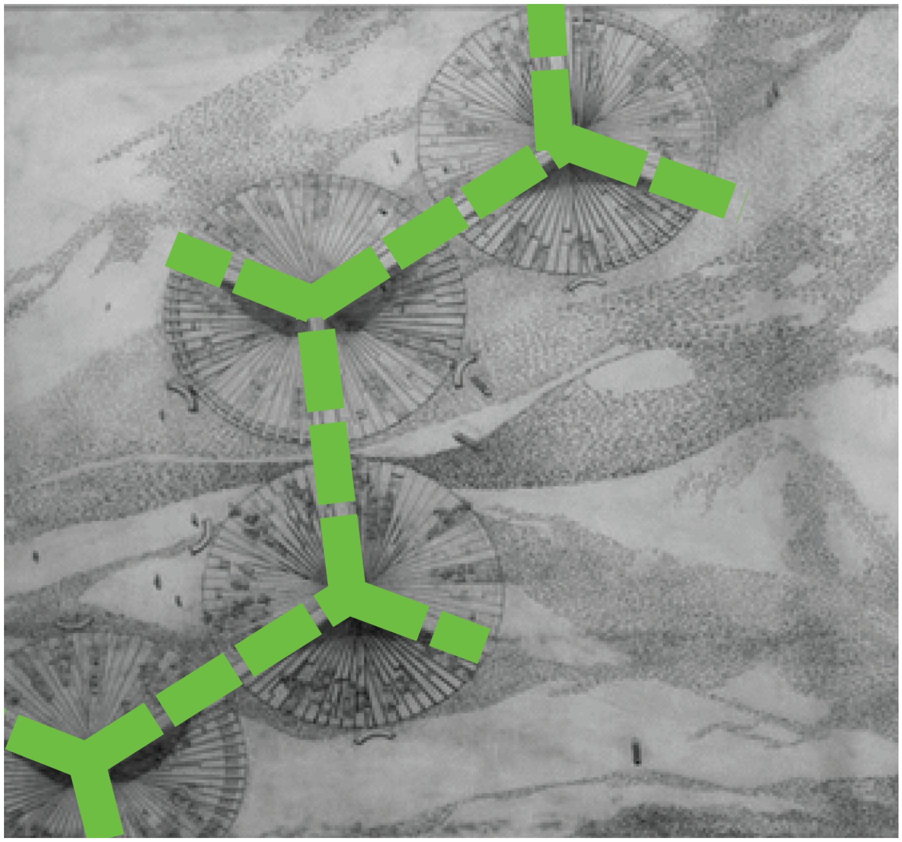

Figure 5.4: Overlay showing Helix City's singular direction in its network. Kurokawa, Kishō. 1961. Digital Image, 1999. Source: http://www.photo.rmn.fr/C.aspx?VP3=SearchResult&IID=2C6NU0E6NI4F (Accessed June 2016.) Overlay by author.

Helix City and Floating City were designed with expansion and *ease of production* in mind. Excluding the infrastructure "spine" of each tower, the megastructures are made up almost entirely of prefabricated modular units. Each of these self-contained units can be arranged and personalized to suit the needs of the individual dweller, affording the opportunity to plan for *positive aesthetic qualities*. Views and outdoor spaces were also taken into consideration in terms of aesthetics. Each tower is designed with its own harbor where active and passive water recreation is encouraged. These readily available outdoor activities encourage socialization and community-building, ideally reducing the effects of the *artificiality and isolation* of the city.

Helix City offers unique perspectives for the potential of space colonization, particularly with its strong self-containment and growth strategies. These types of principles of self-containment and self-sustainability would be optimal for space mining colonies allowing the miners to spend limited amounts of time exposed to the harshness of a mining environment. The opportunity for both vertical and horizontal growth would allow for appropriate expansion as needed and as space becomes available within the mine itself in addition to the least physical land preparation needed for establishment.

5. Tokyo Bay Plan

The Tokyo Bay Plan of Kenzō Tange is perhaps the most notable and influential urban design in Japan for its time and is a comprehensive manifestation of his approach to the urban design issues that Tokyo was encountering. An "open infrastructure" was proposed which featured long axes that spanned the bay itself providing much-needed connectivity and transportation networking for the existing residents as well as future residents. In addition to the linear system, a central hub of development, consisting of a self-contained city, would be built along the main axis encouraging organic expansion outward.

In terms of space colonization needs, Tokyo Bay Plan's principles and forms could prove to be useful. The plan agrees with the criteria of being *planned yet ambiguous*. Tange's belief in a non-zoning oriented city center meant that growth could be unhindered by zoning laws allowing residents to expand as society saw fit within the city's infrastructure. This notion encourages the idea of community-building, enabling the growth of unplanned ambiguity throughout, a direct contradiction to the very rigid forms proposed. The formation of these social and business clusters would fulfill the dwellers' desire to explore the communities and determine alternate routes to the individuals' destinations providing a substantial feeling of *freedom of choice*.

Tange's plan would not necessarily agree with NASA's desire for *ease of production* when building dwelling units. The Tokyo Bay plan proposes massive megastructures that afford each family its own level where it can build a desired home. The lack of modularity and prefabrication would prove to be a shortcoming. However, the amount of customization afforded in this style of housing, in addition to the lack of zoning regulation, would greatly improve the colony's *aesthetic quality*.

The individuality of the housing options, strong forms, and the experience of connectivity that is essential to the Tokyo Bay plan causes a *decrease in the feeling of isolation and artificiality* that is somewhat inherent in the other floating cities lending to a unique sensitivity to the dwellers.

One of the more distinctive factors in the design of the Tokyo Bay Plan is the open structure of the proposal. (See Fig. 5.5) Its spine-like city center with the freedom of society-driven expansion within the rigid boundaries of the city give it a truly organic character. This strategy of open structure could be applied to any of the types of colonization: free space settlements, surface-based colonies, or space mining. It would allow humans to organize the central systems and prescribed boundaries while permitted the colonists the freedom to situate expansion in the most appropriate spots within the colony itself based on the given space environment.

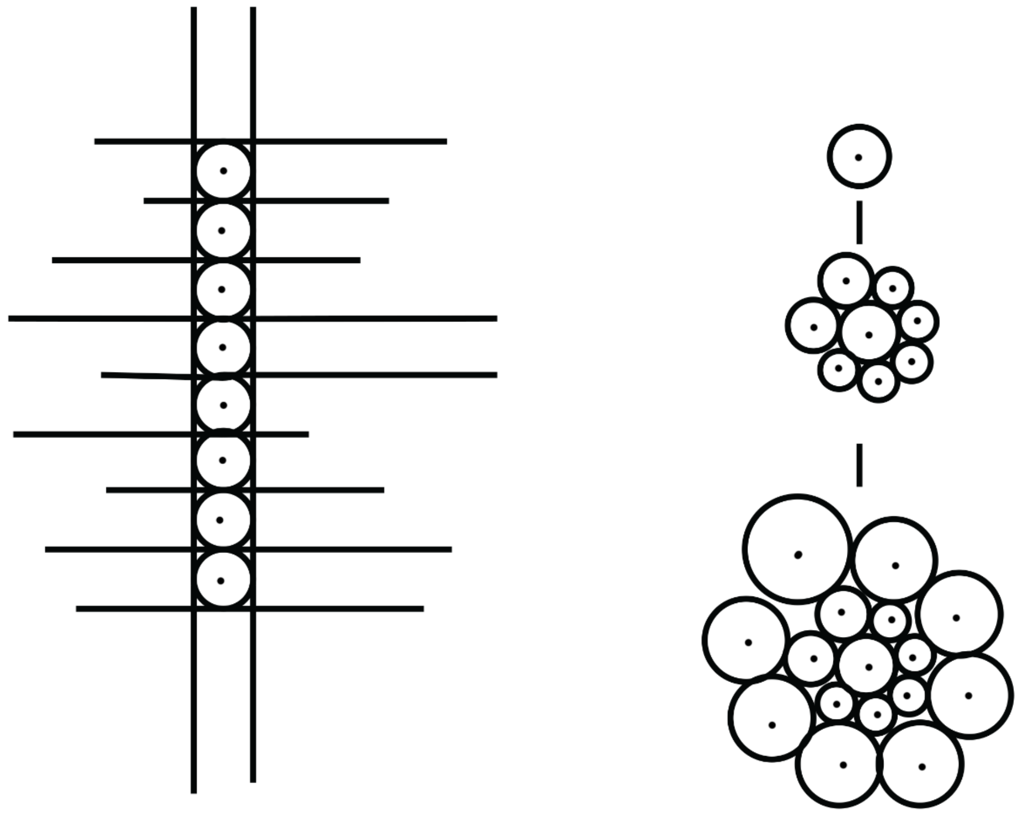

Figure 5.5: Illustration of the Tokyo Bay plan open structure in comparison to closed structure based on Tange's sketch. Tange, Kenzō. 1961. Drawing by author.

CHAPTER SIX

CONCLUSION

1. Discussion

As mentioned in Chapter One, the primary objectives of this study are: (1) to evaluate the driving forces behind the Metabolist movement in Japan of the 1960's, (2) illustrating how space colonization, from a spatial planning standpoint, is not beyond the range of present-day knowledge; and (3) showing how historic design principles of Metabolist projects, often considered to be extreme models, can be utilized to effectively address the needs of the new colonies. Through case studies of prominent Metabolist proposals and examination of environmental factors that can help reduce stresses within a space colony, the overall research question can be answered.

2. Methodology of utilizing Metabolism for space colonization

The Metabolist movement emerged in response to postwar reconstruction when Japan was fraught with physical destruction, depleted morale, over-population, and a boom of industrialization. These young urbanists proposed visionary plans that attempted to bolster the linkages between Japanese culture, technology, and architecture that would alleviate the problems of the then fragile society. Inspired by the cultural significance of impermanence, they sought to create an ever-transforming environment that struck a balance between the uncertainty of society and nature with the order and rigidity of infrastructure and architecture. Taking cues from nature, the cities were planned as a renewable and productive systems that gave way to adaption and evolution as necessary; super-organisms that experienced growth and life cycles. It is believed that the particular principles and design solutions presented by these case studies can be used when designing and planning for space colonization. While most Metabolist design principles discussed would prove to be applicable to all types of space colonization, there are certain programming elements that may be more appropriate than others.

Kikutake's Ocean City proposals put Metabolism on the radar of architects and planners across the globe with their artificial land and modular residential towers. As they relate to space settlement, however, only the design strategies for land planning and self-containment primarily for surface-based colonization will apply, rather than incorporating a tower element. The proposals feature small cities with rigid land use plans but allow for expansion and facilitate the creation of a network of settlements. This ideal would prove useful for surface-based colonization because it allows the colonists to live and thrive in completely self-contained and self-sustaining cities but it permits the creation of additional self-contained cities as required. The set land use would also encourage limited exposure to the harsh environment due to the inherent preparedness of the plan.

Kurokawa's Space City proposed a series of raised grid structures that would protect rural villages from flooding and yield building footprints on the land to the local agriculture. Space City's relationship with nature and agriculture are what makes this plan a valuable asset to free space settlements. All types of colonization will require food and agriculture of some kind, but the Space City plan lends itself to free space settlements through its incorporation of important natural elements, such as forests and lakes, into the colonies in addition to agriculture. In that type of settlement, land area will be of the essence, therefore discovering ways to juxtapose nature and agriculture with the residential areas themselves will not only prove efficient but also fulfill the dwellers' necessity for a connection to nature.

Kurokawa's Helix City lends itself to extreme self-containment, self-sustainability, and modularity in its units in addition to the ability to expand in two dimensions, vertically and horizontally. It also requires minimal land preparation for initial construction. These principles would be beneficial to consider when planning for a space mining settlement. The rigid self-containment and modularity of the proposal allows for limited exposure when colonists are not mining, as well as for hasty establishment and ease of expansion as space becomes available.

Tange's Tokyo Bay plan arose in response to the boom in the city's economy and how its lack of urban infrastructure impeding the growth needed. One of the more distinctive factors in the design of the Tokyo Bay Plan is the open structure of the proposal. Its spine-like city center with the freedom of society-driven expansion within the rigid boundaries of the city give it a truly organic character. This strategy of an open structure could be applied to any of the types of colonization: free space settlements, surface-based colonies, or space mining. It would allow humans to organize the central systems and prescribed growth boundaries while permitted the colonists the freedom to situate expansion in the most appropriate spots within the colony itself based on the given space environment.

While these arguments are interesting, the Metabolist movement and utopian urbanism are not without weaknesses given the modern understanding of city planning patterns and environmental psychology. Compact and satellite cities typically lack long-term regional planning strategies that often end up with the main city growing and expanding beyond its sustainable limit. This rapid expansion leads to the consumption of the smaller cities creating a nucleated metropolis for which a larger scale regional plan is typically needed to prevent sprawl and transportation issues. (Middleton 2009, pg. 40) The idea of like-mindedness and solidarity are also prevalent within Metabolism and other utopian movements in terms of housing and community structure. These projects often utilize highly ordered spatial form which gives illusion to a harmonious and peaceful society. This is often viewed as illusory in nature and associated with dystopian ideals. (Pinder 2002, pg. 231-233) Japan was no different when Metabolist design proposals began to come to light in response to the destruction of the war and depleted national morale. By today's standards, the sense of impermanence derived from modular and prefabricated housing in addition to the oblivious lifestyle encouraged by some city plans would be considered a shortcoming in modern day city planning.

Despite these shortcomings, this study asserts that Metabolism could be utilized as a meaningful option when planning space colonies. The very nature of a space colony requires a certain level of compactness to the extent that sprawl would not be a foreseeable issue. Additionally, the preparation and cost required to get humans into space would inevitably embed careful and meticulous planning into the potential settlement. Simultaneously, NASA calls for the shelter for these colonies to be prefabricated and easy to produce, making modular housing one of the most viable options despite its impermanence and artificiality, and offering designers a unique opportunity to explore options to mitigate these deficiencies. All-in-all, Metabolist city planning still holds value and opportunity for leaving Earth, while it may not necessarily be the most appropriate option on this planet.

3. Concluding message

Providing a foundation on which to flourish is the very essence of Metabolism. The movement grew out of Japan's necessity for reconstruction and gained momentum as a result of its visionary ideas that would prevent a repeat of the devastation of losing everything by treating cities as a process and encouraging change and growth. It proposed a rigid infrastructure that could be altered and evolved. When one part was no longer needed, it died and fell away, like leaves from a tree. In fact, losing leaves does not cause a tree to die but rather makes room for more branches with more leaves. It thrives. Metabolism has the opportunity to be mankind's tree as it makes its transition into space. It can give humans the foundation needed to not only become established in space, but also grants mankind the refuge to catch its breath after leaving Earth before expanding toward newer and grander urban design proposals as technology advances and populations grow. Metabolism is organic and is meant to die, but it can make a superb transitional buffer as humans move from Earth to the stars.

4. Future research

The intent of this study is to introduce a conceptual solution to the problem of designing space colonies through the examination of design principles within the Metabolist movement. It is acknowledged that the breadth of Metabolism and its influences extend far beyond the scope of this project, the country of Japan, and the case studies selected. Thus, deeper analysis of the movement is required to fully develop a holistic synthesis of all appropriate design solutions. Therefore, future research should include the analysis of other Metabolist proposals considering that the movement evolved and changed as it transitioned into the 1970's, especially into other countries. Future study should also examine the differences between proposed master plans and fully realized designs. Further investigation is also needed in the realm of self-contained environments. It is acknowledged that there have been several experiments testing these types of environments here on Earth in addition to space. Examining the design strategies of those experiments will expand the pool of knowledge in order to bring colonization into greater feasibility. In the pursuit of utilizing principles and programming as a future solution for the environmental planning of space colonies, it will be critical to research and develop an experimental growth model, land use plan, and master plan options for the proposed colony.

REFERENCES

Andrews, Dana. “Space Colonization: A Study of Supply and Demand” *Habitation Throughout the Solar System*, 2011.

Banham, Reynor. *“Megastructure: Urban Futures of the Recent Past”* London: Thames and Hudson, 1976.

Billings, Linda. "Overview: Ideology, Advocacy, and Spaceflight – Evolution of a Cultural Narrative." In *Societal Impact of Spaceflight* 2007, edited by Steven J. Dick and Roger D. Launius, 483-500. Washington D.C.: NASA History Division, 2007.

Caldwell, Damon. “Godzilla vs. Mechagodzilla: Radical Urban Structures Past and Future.” *Subtropical Cities: Design Interventions for Changing Climates* (October 2013).

Dark, Taylor E. "Reclaiming the Future: Space Advocacy and the Idea of Progress." In *Societal Impact of Spaceflight* 2007, edited by Steven J. Dick and Roger D. Launius, 555-571. Washington D.C.: NASA History Division, 2007.

Friedmann, John. “The Good City: In Defense of Utopian Thinking.” *International Journal of Urban and Regional Research* 24, no. 2 (June 2000).

Ganjavie, Amir. “Role of Utopia for Design of Future Cities: Utopia in Urban Planning Literature.” Studies in Literature and Language 5, no. 3 (2012): 10-19.

Glaeser, Ludwig. "Architectural Studies for a Space Habitat." Princeton University Conference Meeting no. 127, on Space Manufacturing Facilities, Princeton University, May 1975.

Globus, Al. "The Design and Visualization of a Space Biosphere." *Space Manufacturing 8, Energy and Materials from Space*, Space Studies Institute, Princeton, NJ, May 1991, pages 303-313.

Globus, Al. "Space Settlement and the Environment." *Ad Astra* (December 2009).

Koolhaas, Rem, Hans Ulrich. Obrist, Kayoko Ota, and James Westcott. *Project Japan: Metabolism Talks--*. Köln: TASCHEN GmbH, 2011.

Lemes de Oliveira, Fabiano. "Of Metabolism: Future Cities for our Contemporary World." *Correspondentes* 14. No. 2 (2011): 77-81.

Lin, Zhongjie. "Metabolism: Restructuring the Modern City." *Fresh Air*: 871-878.

Lin, Zhongjie. *Kenzō Tange and the Metabolist Movement: Urban Utopias of Modern Japan*. New York: Routledge, 2010.

Madhavan Nair, G, K.R. Sridhara Murthi, and M.Y.S. Prasad. "Strategic, Technological and Ethical Aspects of Establishing Colonies on Moon and Mars." *Acta Astronautica* 63 (2008): 1337-1342.

Maki, Fumihiko. *Investigations in Collective Form*. St. Louis: Washington University, June 1964.

Metabolism: The Proposals for a New Urbanism. Bitjutu Syuppan Sha, 1960.

Middleton, Deborah. “Growth and Expansion in Post-War Urban Design Strategies: C.A. Doxiadis and the First Strategic Plan for Riyadh Saudi Arabia.” Ph.D. diss., Georgia Institute of Technology, Atlanta, 2009.

Miller, Ron. "Spaceflight and Popular Culture." In *Societal Impact of Spaceflight* 2007, edited by Steven J. Dick and Roger D. Launius, 555-571. Washington D.C.: NASA History Division, 2007.

National Aeronautics and Space Administration. *Space Settlements: a Design Study*. Washington D.C.: United States Government Printing, 1977.

O’Neill, Gerard. “The Colonization of Space.” *Physics Today* 27, no. 9 (September 1974).

Pinder, David. “In Defense of Utopian Urbanism: Imagining Cities After the ‘End of Utopia’.” *Geografiska Annaler* 84 B (2002): 299-241.

Rhodes, Anthony. “*Propaganda: The Art of Persuasion World War II.”* New York: 1993.

Rumerman, Judith. “U.S. Human Spaceflight: a Record of Achievement.” *Aerospace History*, no. 41 (December 2007).

Schalk, Meike. “The Architecture of Metabolism. Inventing a Culture of Resilience.” *Arts*, 3 (June 2014): 279-297).

Sommer, Robert. *“Personal Space: The Behavioral Basis of Design”*. Prentice-Hall: 1969.

Sonter, Mark. “Asteroid Mining: Key to the Space Economy.” *Ad Astra* (2006)

Stewart, Dennis B. "*The Making of a Modern Japanese Architecture: From the Founders to Shinohara and Isozaki"*. New York, United States: (2002).

Tange, Kenzo. "A Plan for Tokyo, 1960." *Shinkenchiku* (1961).

Williams, Lynda. "Irrational Dreams of Space Colonization" *Peace Review: a Journal of Social Justice* 22: 4-8.