UNIVERSIDAD POLITÉCNICA DE MADRID

ESCUELA TÉCNICA SUPERIOR DE ARQUITECTURA DE MADRID
DEPARTAMENTO DE PROYECTOS ARQUITECTÓNICOS

CONTINGENCY IN POSTSITUATIONIST ARCHITECTURE

PhD thesis

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January 2016

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DOCTORAL PROGRAM:
Teoría y Práctica del Proyecto RD778/1998

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TITLE: Contingency in Postsituationist Architecture

DIRECTOR: Emilio Tuñón Álvarez, PhD architect

PROGRAM: Theory and Practice of Architecture Design

(Teoría y Práctica del Proyecto (RD778/1998))

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Resumen

La presente tesis tiene su origen en un ejercicio sencillo. Tomando el título del programa de doctorado en el que se enmarca la investigación, 'Teoría y Práctica del Proyecto', el doctorando toma la teoría de mayor repercusión del siglo XX, la teoría de la relatividad, y traza las relaciones entre las mutaciones producidas en la práctica del proyecto arquitectónico contemporáneo y en las estrategias creativas de éste vinculadas a las transformaciones de nuestro modo de entender el mundo introducidas por dicha teoría.

El espacio-tiempo ha sustituido el concepto incompleto de espacio, y a su vez éste es usado ahora por el arquitecto como materia a modelar. Como tal debemos conocer las propiedades de éste, propiedades de su geometría no euclidiana y de su métrica, fijando así la óptica bajo la cual el espacio-tiempo es manipulado, modificando su topología mediante la acción artificial de delimitación de los campos de acción derivados de la construcción urbana.

La presente tesis rastrea los vínculos que existen entre la práctica arquitectónica contemporánea y la asimilación de los conocimientos científicos adquiridos a lo largo del siglo XX que más hondamente han transformado nuestra manera de entender el mundo. Si bien la teoría de la relatividad sirve de base organizativa de la presente tesis doctoral, la multiplicidad de referencias e influencias que afectan a los modos de creación arquitectónica es diverso y multidireccional. Se asume que la arquitectura, como disciplina de creación cultural, digiere el conocimiento y las interpretaciones creadas desde otras ramas de creación cultural o de organización cosmopolita con diversos grados de intensidad.

Abstract

This thesis stems from a simple exercise. Taking the title of the PhD program in which the research is framed, 'Theory and Practice of Architectural Design', the doctoral candidate takes the theory with greater impact of the twentieth century, the theory of relativity, and traces the relationship between the mutations produced in the practice of contemporary architectural design and its creative strategies with the transformations of our understanding of the world introduced by the theory.

Space-time has replaced the incomplete concept of space, and in turn it is now used by the architect as modeling matter. As such we must know its properties, properties of its non-Euclidean geometry and its metric, securing the optical under which space-time is manipulated by modifying its topology through the artificial action of delimitation of the action fields that arise from urban construction.

This thesis traces the links between contemporary architectural practice and the assimilation of scientific knowledge acquired over the twentieth century that have most deeply transformed our understanding of the world. While the theory of relativity serves as organizational foundation of this thesis, the multiplicity of references and influences affecting the modes of architectural creation is diverse and multidirectional. It is assumed that architecture, as a discipline involving cultural creation, digests the knowledge and the interpretations created from other areas of cultural creation or cosmopolitan organization with varying degrees of intensity.

La investigación desarrollada trata de identificar la manera en la que la arquitectura se enfrenta a la realidad post-relativista y la manera en la cual el discurso arquitectónico ha variado su dirección de un discurso basado en consideraciones estilísticas deterministas vinculadas a normas de empleo de la geometría euclidiana como herramienta de control de la disposición relativa de los diversos elementos constructivos, hacia un discurso no lineal que asume el acontecimiento como la unidad básica de realidad existencial. La arquitectura pasa de ser una disciplina de creación de objetos físicos (edificios) en donde las relaciones geométricas entre partes definen un objeto concreto inmutable, a un proceso de creación de estrategias complementarias de establecimiento de relaciones entre acontecimientos y de disposición de la materia en el espacio tiempo que permanece en constante evolución, adaptación y transformación. Según este punto de vista la arquitectura podría definirse como el arte de físicamente delimitar e interrelacionar acontecimientos.

La tesis se organiza en tres núcleos de investigación complementarios e interrelacionados que nacen del conocimiento adquirido de los postulados de la teoría de la relatividad:

El primer núcleo de estudio centra su interés en la multiplicidad de los eventos acontecidos en el espacio-tiempo y cómo éstos han sido asumidos por la arquitectura como sistemas dinámicos dispersos en el paisaje centrándose en la contingencia en arquitectura y el empleo del símil científico de los sistemas dinámicos en interacción en el espacio-tiempo. Si bien el origen de este cambio se encuentra en el cambio de métrica relativista, la tesis estudia el modo en el que el funcionalismo determinista ha mutado hacia el entendimiento de la naturaleza caótica de las actividades humanas en relación a principios científicos vinculados a los sistemas dinámicos como son el principio de incertidumbre, la teoría del caos y la ecología de sistemas.

El segundo núcleo de investigación estudia las propiedades topológicas de la arquitectura y de los límites establecidos a los eventos por la materia dispuesta en el espacio-tiempo. La materia interrumpe el espacio

The undertaken research tries to identify ways in which architecture is facing post-relativistic reality and the way in which the architectural discourse has changed its direction from a discourse based on deterministic stylistic considerations related to rules of employment of Euclidean geometry as a tool of control relative of the arrangement of the various construction elements, to a non-linear discourse that assumes the event as the basic unit of existential reality. Architecture goes from being a discipline of creation of physical objects (buildings) in which the geometric relationships between particular portions define an immutable object, towards an active creative process of complementary strategies of relationship between events and matter arrangement in space-time while remaining in constant evolution, adaptation and transformation. According to this view architecture could be defined as the art of physically delimiting and interrelating events.

The thesis is organized in three complementary and interrelated research cores that arise from the knowledge acquired from the postulates of the theory of relativity:

The first research core focuses its interest in the multiplicity of event happening in space-time and how these have been assumed by architecture as dynamic systems scattered in landscape. As a consequence, architecture drifts its attention towards contingency and the use of the scientific simile of dynamic systems interacting in space-time. While the origin of this shift is the relativistic metric change, the thesis studies the way in which the deterministic functionalism has mutated towards the understanding of the chaotic nature of human activities in relation to scientific principles linked to dynamic systems such as the principle of uncertainty, chaos theory and systems ecology.

The second research core studies the topological properties of architecture and events' limits set by matter arranged in space-time. Matter interrupts space-time, and consequently determines its contingency. This section of the thesis focuses on the topological properties of architectural matter and how topology

tiempo, y como consecuencia condiciona la contingencia de éste. Este apartado de la tesis se centra en las propiedades topológicas de la materia arquitectónica y cómo la topología se ha constituido como la principal disciplina matemática aplicada al proyecto arquitectónico post relativista más allá de la geometría euclidi-ana.

El tercer núcleo de estudio se centra en el hecho de que cualquier acontecimiento implica una transformación energética. Energía, materia y contingencia son tres caras de una misma realidad. Si la relación entre materia y contingencia del espacio-tiempo es el territorio del proyecto arquitectónico, el arquitecto debe tomar conciencia de que al disponer la materia y al definir las propiedades topológicas de la arquitectura y de su entorno en el espacio-tiempo está también definiendo el campo de contingencia de procesos de intercambio energético.

En la presente investigación se asume que la arquitectura es una forma de conocimiento cultural que forma parte de un ecosistema creativo sofisticado cuyas fuentes de interacción son múltiples y variadas. Dentro de este ecosistema la arquitectura está directamente vinculada e influida por las interpretaciones que la práctica creativa no funcional hace de los mismos conocimientos científicos que transforman nuestra disciplina. Por ello, cada una de las tres ramas de investigación vinculadas a la realidad post-relativista es complementada por la interpretación que los artistas hacen de estos fundamentos científicos. Este acercamiento de investigación asume que el conocimiento científico transforma nuestra manera de ver el mundo, pero que la interpretación y los modos de operar dentro de este nuevo contexto son múltiples y abiertos. La arquitectura post-relativista es, como respuesta directa a su asimilación de esta nueva realidad, una disciplina compleja no aislada en constante evolución, que interacciona con multitud de agentes y acontecimientos de manera procesual.

has been established as the main mathematical discipline applied to post relativistic architectural project beyond Euclidean geometry.

The third area of study focuses on the fact that any event implies an energy transformation. Energy, matter and contingency are three faces of the same reality. If the relationship between matter and the contingency of space-time is the territory of architectural design, the architect must be aware that by arranging matter and by defining the topological properties of architecture and its environment in space-time is also defining the contingency field of energy exchange processes.

In the current research it is assumed that architecture is a form of cultural knowledge that is part of a sophisticated creative ecosystem whose interaction sources are multiple and varied. Within this ecosystem architecture is directly linked and influenced by the interpretations that non-functional creative practices make from the same scientific knowledge that transforms our discipline. Therefore, each of the three branches of research related to post-relativistic reality is complemented by the interpretation that artists make of these scientific principles. This research approach assumes that scientific knowledge changes our way of inferring the world, but that the interpretation and ways of operating within this new context are multiple and open. Post-relativistic architecture, as a direct response to the assimilation of this new reality, is a non isolated complex discipline in constant evolution, which interacts with a multitude agents and events in a procedural way.

Stanford Anderson (Top Right) with other members of the Institute of Architecture and Urban Studies.
Casabella359-360 (1971)

Methodology of the Thesis

The thesis has been developed using the scientific methodology of research projects defined by Imre Lakatos in 'Proofs and Refutations' applied to architectural theory linked to architecture design. This same methodology was applied by Stanford Anderson throughout his career as a critic and architectural theorist when analyzing the architecture of Le Corbusier, Aalto, Behrens and Eladio Dieste, among others. The thesis consists of three interrelated research projects (one for each of the sections defined previously) that interact with each other interdependently to define a larger research project, post-relativistic architectural design. Each research project has a hypothesis that defines the core of the project that is ultimately supported and reinforced by a set of complementary hypothesis.

The set of complementary hypotheses are supported and defined through an analytical deductive method of comparative study of the history and philosophy of modern science (twentieth century), the artistic practice and recent architectural practice (last 50 years). The context of study emphasizes on the practice and theory of architecture from 1960 (although it refers to some modern architectural theory and practice (1920-1950)) and how it is directly influenced by the transformation in the way we comprehend the world through Einstein's theory of relativity and subsequent scientific theories linked directly or indirectly to the research nuclei such as Heisenberg's uncertainty principle or chaos theory among others.

Therefore, this PhD thesis is an interdisciplinary study between the theory and practice of architectural design and the history and philosophy of modern science. The research is based on the literature review of

Ignacio Peydro lecturing at MIT on topology and architecture
April 2013

¹Although this thesis is developed as part of a doctoral program at the Universidad Politécnica de Madrid it has been supported by a two-year stay in Cambridge, Massachusetts, where several research papers were written with the support and advice of professors from the Massachusetts Institute of Technology and Harvard University. Stanford Anderson taught me the methodology that has been described. He also supported and advised me during the development of a paper of the first research core (contingency). Throughout the time of development of the thesis I had the chance to listen and discuss the matter under research with extraordinary people that lit the way towards the fulfillment of this research.

the two disciplines that has been assisted by the support of teachers¹ of both branches, the analysis of selected architecture projects, and analytical studies of the influence exerted on architectural design by other creative practices directly linked to the way of interpreting the existential reality through the prism defined in each of the three research projects that conform this thesis. This has allowed the doctoral candidate to obtain an overview and detailed knowledge about the addressed issue that enables the production of a projective post-analytical thesis that may eventually be synthesized in a design methodology that digest the obtained conclusions; a methodology that stems from the interaction of the logical results of each of the research cores.

Acknowledgements

This thesis is dedicated to all of you that have contributed in some way or another to help me overcome this process. The list is long. If you are not here it does not mean that I forgot you. I am grateful to all of you that spent one minute of your time listening to me, reading my papers or giving me support to keep going.

Although this thesis is developed as part of a doctoral program at the Universidad Politécnica de Madrid a two-year stay in Cambridge, Massachusetts, where several research papers were written with the advice of professors from the Massachusetts Institute of Technology and Harvard University, provided me with different points of view and methodologies. Without the help and funding of the Fulbright program for foreign students and the Fulbright Foundation in Spain it would have been impossible for me to have this experience. Thank you for providing me with this wonderful concatenation of events. During those years I had the chance to meet wonderful people. Stanford Anderson taught me the methodology that has been described. He also supported and advised me during the development of a paper of the first research core (contingency). Kiel Moe and Sanford Kwinter opened my eyes to the energetic face of the world. Nader Teherani was a great support in the development of the second research core (topology) and here in Madrid Emilio Tuñón encouraged me to get to the end of my research.

During these two years my son was born in a hospital at Harvard University. Just for that I shall always remember this period of time. To him I specially dedicate this effort. To him and to his mother, Isabel, as always, with you by my side there is nothing impossible.

4D One Ocean World Town Plan - R. Buckminster Fuller 1927

Introduction

Architecture is about life. Everything else is circumstantial. I came up to the clarity of this statement through a research on the influence of certain scientific models of the New Sciences made on architectural design. The intuition of that simple fact can be validated by certain conclusions of various scientific models that explain reality as it is, or at least, as we believe today it is – as we know time can change everything. It is not the task of the architect to prove right or wrong our scientific understanding of reality. Nevertheless, knowing (even in a tangent way) the content of their laws and theories can let the architect step out of the closed boundary of architectural tradition, thus permitting him to have a wider view of what architecture is about in the wide sea of knowledge and creation. However, the creative processes, such as architecture, do not absorb knowledge from a single source. While it is true that scientific knowledge of the world allows the architect to act with some certainty over constantly changing matter, metaphysical or poetic practices, from philosophy to art, sometimes contain intuitive approaches to certain realities that are equally useful for activating imagination in the creative process of architecture.

Architecture is imbedded in the continuum process of becoming of space-time. The architect's ideas are transformed and communicated through drawings that latter become matter through the action of construction, and then a latter transformation happens when the action of life that follows the appropriation of the building by its inhabitants is carried on. Architecture design is a complex multilayered reality that evolves through the action of mutation derived from the overlapping of multiple layers of information; la-

²According to Delleuze with Kant time becomes parameter not reducible to a lower category. Time ceases to be a measurement, and stands as a new limit of thought; it becomes an inherent limit interior to thought, equivalent to space.

tent information of architectural sites, architectural programs (or probable events that may occur within it), together with the multiplicity of references and sources of inspiration that transform the way each architect sees or thinks about the world. Every design decision generates later mutations of the perception of life in dialog with the disposition of matter that surround us on urban environments. However, these decisions are directly related to architectural tectonics and material properties that are only displayed when they are put into action through construction. Thus design, events, mutation and construction are coexistent and simultaneous in the constant becoming of architecture in life continuum.

Space-time has replaced the incomplete concept of space, and in return space-time is now used by the architect as the new matter to be modeled. As such we must know its properties, properties of its non-Euclidean geometry and its metric, thus fixing the point of view under which space-time is manipulated by changing its topology through the artificial action of delimitation of action fields linked to urban construction.

To do this we must begin to apprehend how the theory of relativity transformed our understanding of physical reality. This thesis begins by introducing the change of conception of space and time through a brief summary of the evolution of the philosophical notion that occurs, according to Gilles Deleuze, with the logic work of Kant², to then continue with a brief description of the principles of the two theories of relativity - the special theory of relativity and the general theory - both complementary and separated by a short interval of time.

Surfer 1960's - Photo: Dr. Don James Illustration I.I. Architectures of Time, Sanford Kwinter. p. 2

Special relativity introduces three main contributions that affect the way we understand space and the environment in which events occur. Three-dimensional space is replaced by four-dimensional space- or space-time. Minkowski, who was a professor of Einstein in Zurich, was the first to describe this medium but for him it is a flat four-dimensional medium. The increase in the dimensions of space is relevant from the perspective of the architect because not only the means of existence is transformed but also its smallest unit. The minimum existential reality is now the event. The point (x, y, z) of Euclidean geometry is replaced the event (x, y, z, t) . Any reduction below this level is a simplification or derivative lacking some level of complexity.

In addition, the upsurge in one dimension of space implies that time is inextricably linked to space-time; any change in one implies changes in the other. As a derivation of this indissolubility the special theory of relativity introduces new concepts such as proper time and time dilation. Speed shrinks distances and time expands or contracts for each inertial observer according to its unique speed. While these are concepts that are noticeable only on a large scale, they define a different way of understanding existence in relation to classical physics that were governed by universal principles equivalent to all observers.

Besides the two above considerations, special relativity establishes the equivalence between referential systems, abolishing the predominance of any of them. This change, which radically breaks with the rules of classical Euclidean geometry and expands the possibilities of manipulation and conception of space-time, allows the equivalent conception among multiple fields of action. As we shall see, the connection between the event as the new minimum unit of existence and the equivalence between referential systems opens up

White U - Toyo Ito - Interior view of actions in space-time

urban and architectural design to probabilistic contingency and is the conceptual basis of the first research core of the thesis, which is supported as well in the scientific knowledge provided by the branch of modern physics that studies dynamical systems.

In the case of the general theory of relativity Einstein expands the principles of special relativity to non-inertial referential systems. The first contribution of this theory was the principle of equivalence, which states that you cannot know if the reference system of an observer who is moving with an accelerated motion relative to an inertial observer or if instead is affected by a local gravity field. This principle implies that space-time is not only deformable by the speed of the observer as described in special relativity's time dilation, but it is also deformed by the local action of gravity, thus changing the medium in which events occur.

This phenomenon was captured on a beautiful photograph taken by Sir Arthur Eddington to a solar eclipse in 1919 where it is clearly seen that light rays have curved paths in areas close to the sun. This empirical photographic image that showed the deformation of spacetime was further developed by the German physicist Karl Schwarzschild, who gave its mathematical description. Spacetime suffers continuous topological transformations when affected by gravitational fields. Even in black holes or wormholes spacetime 'breaks' by unfolding upon itself, maintaining the continuity of the medium. This implies that space-time is a topological space. This property of space-time is the basis of the second research core of this thesis in which the thesis delves into the use of topology as a mathematical tool to endow the use of geometry to a higher level of complexity updated within spacetime reality.

Sketch of the Parthenon. Le Corbusier exploring the parallax effect

³The Minkowski space is a precondition for the General Theory of Relativity. It is a flat space which has not been altered by the gravitational effects of the bodies that are in its environment and does not take into account its topological properties of deformation and alteration.

The third research core has its origin in the famous formula of equivalence between mass and energy $E = mc^2$ which is presented as part of the principle of non-linearity of the general theory of relativity. While it is known that the scale of equivalence between matter and energy is not directly applicable to architecture itself, indeed is the synchronism between the equivalence of matter and energy and the awareness of the first law of thermodynamics, which states that any event involves an energy transformation. Architects must therefore understand the world as seen through energy and its transformations.

While there have been previous approaches from architecture towards the scientific paradigm shift that is born at the beginning of the twentieth century from the theories of relativity, this research work focuses not on adapting the stylistic architectural discourse to the theory of relativity. On the contrary, it traces the connections between the changes in the physical notions and the modes of thinking and executing architectural design. Sigfried Giedion is the first that makes an attempt to adapt architectural practice to relativistic reality in his book 'Space, Time, Architecture' first published in 1941. Although Giedion mentions the Minkowski space³, he mainly focuses on the ways of perceiving architecture in accordance with the movement of the observer, making a supposedly relativistic reading of Le Corbusier's *promenades architecturales*. This is a recurring error on how to address the relationship between relativity and architecture. However, addressing time as a measurement of movement is a pre-relativistic conception and does not assume its quality as a parameter intrinsic to existential reality. The variability of perception in motion actually has its origin in the discourse of eighteenth century architects during the Enlightenment in France around the phenomenon of parallax. This phenomenon, which was discussed among members of the Academy of France long before Albert Einstein was born, is actually a complex application of the principle of relativity

What is the Earth - Illustration from Sunspots. Steve Baer. p. x

Galileo enunciated in 1632.

This thesis attempts to establish a research project that serves as conceptual framework to address architectural design from the understanding of post-relativistic reality. To this end, it focuses its attention on the change in the metrics of space, the properties of the new space and the implications that the equivalence between matter and energy denote towards this complexer reality. As discussed below, contingency, topology and energy are interdependent realities consubstantial to our environment and our existence. Therefore, if we are able to understand and grasp them, we will be able to address our creative work as architects with less friction with the reality that we transform, ultimately sublimating our life in a changed medium in which the work of the architect is diluted in actions of filtering, synthesising and interpreting of information within a complex system of simultaneous events in spacetime.

Contingency, which is defined as the possibility for something to happen, defines our medium because it provides the possibilities of action. In any media events happen regardless of planning. The sun rises in the morning, its rays heat the surface of the area under consideration – a gentle slope somewhere on Earth –, the moisture from that surface hydrates the air, an insect alights on a grass that waves in the morning breeze, while a worm erodes the soil which contains its roots. Near the described sequence of actions an embankment marks a different environment. Sound waves from the actions that occur over the embankment reach the ears of the insect, which has now moved to the pistil of a flower and is sucking its pollen, uncaring that the increase in sound energy that it has just perceived indicates that a car has collided with a truck. If we now observe what happens over that embankment, we observe a hard black surface extending

‘In the ‘Picturesque Atlas. Vol. 1: the observatory’ (2005) Iñaki Abalos pleads for a hybrid practice of architecture design that employs techniques from disciplines that use larger scales of observation than the used by architectural tradition. Ábalos in his book urges us to adopt a vision that has long been brewing and has been institutionalized in landscape architecture programs in various US universities. Junya Ishigami in turn, in his book ‘Another Scale of Architecture’ advocates the use of a territorial or landscape scale in Architecture. Reiser and Umemoto used landscape references to define architectural tectonics in his ‘Atlas of Novel Tectonics’. All of these are a few examples that display that the interest in increasing the scale of observation and in stripping architectural thinking from the stylistic, formal and compositional biases through landscape architecture and its tools is a global phenomenon.

longitudinally in the landscape. The truck overturned when maneuvering and in now crossed on the road. Little by little vehicles circulating in the same direction are accumulating. There is no room to move, a traffic jam has risen. From the opposite direction a fire truck, police cars and a couple of ambulances arrive from a nearby urban center. They have received the notice through the mobile phone of the copilot of a car that was about to collide, but it could stop a few inches from the truck.

I could go on describing the set of events, media and times in which they occur, from inside of the ambulance to the cable carrying the electrons produced in the turbine of a nearby wind generator, from there to the processing center, and thence to the alarm at the fire department from which the truck that now helps remove the vehicles from the road came out. However, what interests me in this description is the identification with the way we operate as creators of urbanity, as transformers of media. Every design decision involves variations in the contingency of spacetime. Events are enabled, delimited and constrained when media specializes. This view of architecture as enabler and bounder of events is directly linked to the growing interest in understanding architecture design as a landscape practice⁴.

While landscape is the academic practice which we can use to order architectural thinking to understand how to deal with spacetime media to enable recurring actions, military tactics is the form of probabilistic thinking that more accurately has worked on ways in which events happen on a certain medium at a determined time. It is no coincidence that the military forces at the command disposal are named contingent. These are what allow a diverse degree of actions, what measures the contingency of an operation or set of operations. Spacetime is a field of actions, the medium in which multiple dynamic systems overlap. It is

New Babylon Nord - Constant - Photo of model

⁵See KWINTER, SANFORD: "Volar con la Bala" Epilogue in 'Rem Koolhaas. Conversaciones con estudiantes'. Ed. Gustavo Gili. p.75

perhaps for this reason that Sanford Kwinter, describing the mode of practice of Rem Koolhaas, and to extol his ability as a contemporary architect embedded in the time-space reality, in his paper 'Flying with the bullet', he compared Koolhaas, not with another architect, but with Chuck Yeager, a military jet pilot with such dexterity in air combat that he operated 'stretching the boundaries of space-time'⁵.

Situationism is perhaps the avant-garde movement of the twentieth century that more naturally has assumed space-time reality. Situationists are the first to show the city as a continuum without predetermined preeminent references. This produces a liberation from all referential systems in the city. Situationists incorporate the reality of the disappearance of hierarchies in referential systems. In the Situationist urban conception referential privileges disappear. Their *Dérive* is based on the equality and equivalence of the translations produced in the city. Their *Dérive* has no predetermined direction, time or speed. In opposition to the classical and baroque urban conception that order the city through referential axes, Situationists understand the city as a non-hierarchical space-time fluid. The *Dérive* is defined as "the technique of rapid transit through different environments" and it is the practice of situationist's psychogeography in which they "look to recognize the psychic effects of the urban context". It is an eminently contingent practice, that assumes in when it is created and described by Situationists the inability to prefix the happening of actions in space-time.

Situationist practices serve as the basis of understanding and conception of urban reality to subsequent tactics of urban contingent media creation. Thus, the way in which Constant describes the ideal Situationist city in his project New Babylon, serves as a reference when deciding actions in architectural operations to

Solar eclipse- Photo by Sir Arthur Eddington

different groups of postsituationist architects, generating a stream of urban thought rooted in the post-relativistic understanding of event fields and dynamical systems. The British Cedric Price and Archigram, the project for Beaubourg – that will then become the Centre Pompidou – or the design strategies of Enric Miralles, are all linked in their ways of operating in architectural design with this understanding of the urban reality through contingency. A way that prefers to navigate the sea of events and dynamic systems rather than imposing the compositional rules of a creative system absorbed in its own hermetic history.

Space-time, the medium in which every event happens, is a topological space, as demonstrated by the equations that define its geometry; a medium that undergoes continuous transformations due to the gravity of bodies. It is therefore necessary to understand its geometry and its topological properties to operate accurately in space-time. To say that Architecture uses geometry as a means of design is as obvious as to say that medicine uses biological knowledge as part of its discipline. The classical orders of Architecture have imbedded within themselves a system of geometrical proportions and relations that have been linked with the perception of beauty and proportionality of classical architecture. Vitruvius, in his Ten Books on Architecture, makes direct reference to the use of geometry in the disposition of architectural elements as an expression of human culture (Frith, 2010). All along the history of architecture, geometrical expressions and relations in two and three dimensions have helped architects to achieve beauty and harmony in their designs and geometrical relations between building parts enabled the classification of architecture in style categories (i.e. Romanesque, Gothic, Doric, Ionic, Corinthian, etc.). The Modern Movement tried to break with historical styles, but Euclidean geometry still ruled the decisions taken by architects in their designs. Indeed, Le Corbusier was obsessed with the golden mean and extensively developed a geometrical system, the

Map of the Iberian Peninsula. circa 1200

Real geography and represented map are topologically equivalent. Representation is deformed by a temporal variable of experience.

Modulor, which established different geometrical proportions in relation to the human body linked to this classical geometrical proportion. In more recent days, Euclidean geometry and systems of repetition and relations within it have been used by many architects as basic tools to decide and establish the disposition of architectural elements in space.

However, this use of geometry in architecture is incomplete in relation to the knowledge we have today of four-dimensional space. Even though certain attempts to unfold and understand the transformations that architecture has suffered since this metric change was made, those have been incomplete or imprecise. As previously it anticipated, in his book “Space, Time, Architecture” Siegfried Gideon tried to approach the variation that architectural design experienced when the metric of space was expanded to four dimensions due to relativistic understanding of space-time. Nevertheless, Gideon centered his thesis in the dynamic perception of architectural promenades used in modernist architecture. This approach, which understands time as the unit to measure movement and not as a linked dimension of space, is more related to Galileo’s relativity principle than to the properties of four-dimensional space described by Einstein in his theory of relativity. Indeed, the relative dynamic perception of architectural elements had been a theme of discussion during the first discussions between Claude Perrault and François Blondel at the French Académie Royale d’Architecture, and was then defined as the effect of parallax (Blunt & Beresford, 1999). This approach understands time as a unit to measure movement and not as an interdependent dimension to space.

Nevertheless, ever since the general theory of relativity was described, and later proved by Sir Arthur Eddington’s photograph of a solar eclipse (Schwinger, 1986), we have become aware that space-time, the

Two Libraries at Jussieu University, Paris
OMA, Rem Koolhaas
Continuity diagram - Unfolding of project

new fourth-dimensional space, is a topological space that experiences continuous transformations due to the action of gravity. If architecture deals with space-time, it must deal with its properties and complexities and evolve its way of generating knowledge and matter to fit the new understanding of reality. As a consequence, architecture should be aware that geometry not only defines the relative position of architectural matter in space, but also defines the topology of spaces and determines the way we experience those spaces and move around and within them. It defines contingency gradients and enables or limits actions. If space is topological, architecture should use topology. From a topological point of view architecture's use of geometry to enclose spaces will set the topological properties of continuity, porosity and permeability of spaces. The boundaries that enclose spaces have also their own topological properties that will be defined by the architect in order to set the possibilities for events that may occur within architecture and to establish relations between multiple events.

Two Libraries at Jussieu University, Paris
OMA, Rem Koolhaas
Continuity axonometric diagram

The aim of the research project linked to topology is to show how the topological properties of structures and spaces have become the main concern of certain architects beyond the traced geometry contained in the plans that define their projects. In order to do so, I study two modes of operation in different geographical locations that share relationships and common processes. On the one hand, the topological tactics of OMA - Rem Koolhaas - and the derivations and influences in some Western linked practices. On the other, I analyze the design strategies that underlie in the architectural design approach of three generations of Japanese architects depicted, but not limited to, by Toyo Ito, Kazuyo Sejima / SANAA and Junya Ishigami. The research shows that the approach towards built form that these offices bear is radically opposite to that in which design remains on the realm of style characterized by the geometrical relations of volumetric forms and construction elements.

This research core makes a comparative analysis of the use that architects make of geometry in order to establish the interrelation between geometry, matter and topology: on one hand the traditional approach of Euclidean geometry as a way of defining the position of building parts in space and on the other the use of geometry as a way of defining topological properties of space and of the boundaries that define it. I describe and define the different topological properties and then trace the relations between these properties and architectural design, specifically in relation to the work of the three above-mentioned Japanese architects/firms. From the Sendai Mediateque by Toyo Ito to the 2010 Venice Biennale Installation of the Japanese Pavilion by Junya Ishigami, multiple applied architectural design examples are analyzed and evaluated in terms of their topological properties and the continuous topological transformations that generated their form. As a consequence of these analyses, the conclusions of the analytical research will ultimately lead

A Home is not a House
 Anatomy of a Dwelling
 Reyner Banham, Francois Dallegret. Art in America, 1965, vol. 2, NY: 70-79

to determine the common methodology that can be applied to match architectural design to the complex properties of space-time, even though this methodology might be incomplete and only takes one level of information within the sophisticated open system of active architecture.

As anticipated above, the third research core focuses on the fact that every event involves an energy transformation. Energy, matter and contingency are three faces of the same reality. If the relationship between matter and space-time contingency is the territory of architectural design, architects must be aware that by arranging matter and when defining the topological properties of architecture and its environment in space-time they are also defining the contingency field of energy exchange processes.

Ever since human beings began searching for shelter from the elements, and later created artificial constructions to house our everyday lives, energy has been linked to architecture. In his famous essay 'A Home is not a House', Reiner Banham, like many others, saw the origin of our control over the environment as having two main roots: first a passive strategy related to the physical blocking of weather conditions (caves > roofs > tents > buildings), and second, an active variation of the thermal conditions through the use of controlled fire to generate a warmer thermal atmosphere around it. Indeed, in Latin languages the etymology of the word 'home' is linked with the word 'hearth' ([focus (fire) > focar (home, hearth)]), so home is where the fire is. In his paper Banham centered the problem of this relationship in the possibilities that mechan-

Energy diagram. Howard T. Odum
Sanford Kwinter speaking in front of slide projection
What is energy and how else might we think about it?
Graduate School of Design. Harvard University

ical systems have to alter the environment by generating heat (or cold) that would lead him to propose a reactive architecture that is only linked to the way energy is managed in order to generate livable spaces. This radical architecture diminished the tectonic presence of the house, reducing the outer skin to a simple bubble, and made its thermal machinery its defining element (as can be seen in François Dalegret's elegant drawing that illustrates the text).

The problem with this point of view, which is linked to the modernist optimism that flourishes from the Industrial Revolution, is that it forgets about the thermal (energetic) properties of the exterior shell (walls and roof) that protects us from the natural environment, relying completely in the active transformation of weather conditions through mechanized systems and energy consumption. This approach towards architecture as a combination of two complementary ways of transforming the environmental conditions inside architecture is linked with the previous research conducted by Gottfried Semper in 'Die Vier Elemente de Baukunst' (1851) where basic architectural elements were divided in two complementary systems, the first is constituted by the tectonic envelope formed by roof, walls and floor, and the second is the hearth, the place for the fire that transforms the internal environmental conditions of a basic dwelling unit, a hut.

The latter research core of the thesis traces the connections and interdependencies between design decisions and energy transformations associated with the set of simultaneous events of the inhabitable

Photograph showing the active experience of accessing Blur. Diller and Scofidio. Whitney Museum New York. P. 86

environment. Starting from the interpretation of the laws of thermodynamics and the various principles and definitions related to energy, ways of operating in architectural design are analyzed, described and synthesized. This modes of operation allow the practice of architecture to evolve into a sophisticated system that assumes the multifaceted complexity of a reality with multiple layers of information. From the research and design methodologies contained in the various handbooks of architecture and climate of the brothers Victor and Aladar Olgyay or Edward Mazria, to the atmospheric interventions of Diller and Scofidio and Olafur Eliasson, creative and architectural practices are organized related to systems ecology and links with the two previous research cores are crossed. As a consequence, a principle of equivalence in the practice of architectural design is established; an equivalence in which the employed decisions and strategies can be complementary to both the possibilitation of events action and to the probabilistic control, optimization and synchronization of energy exchanges that events produce.

The thesis concludes by establishing the interrelationship and interdependence between the three research cores, defining an open systemic architectural practice that allows us to operate superimposing different levels of complexity linked to contemporary reality.

Inmanuel Kant

⁶The interpretation of the conception of time according to the philosophy of Kant presented here is taken from the book Gilles Deleuze 'Kant and Time' (Sp. Ed. Cactus, Buenos Aires, 2008)

⁷ Michelson Morley experiment of 1887 where it was verified the absence of ether as the matter of propagation of light, allowing the understanding that the speed of light is constant. In the same year Charles Edouard Jeanneret (Le Corbusier) was born.

Background

1. Time and Space before relativity

According to Gilles Deleuze⁶ the first great schism in relation to the concept of time in human thought happened in Kant's philosophical writings. With Kant time became a parameter and ceased to be just a number or a measurement. Before Kant, in antiquity, there were two directions of thought around the concept of time, both have in common that they affirm the merely modal role of time, converging on the ancient theory of the world soul. The first direction corresponds to the concept of time as the number of movement, subordinated to the physical cosmos. The other direction, which was originated with Plotinus is the one that links time with the soul.

In classical philosophy space is the limitation of being. Space is the limit, the obstacle of thought. With Kant time became a parameter that is not reducible to a lower category, by disappearing as a measurement, time positioned itself as another limit of thought, an internal inherent limit of thought as determining as space.

It seems that Kant brings into the surface of human thought an intuition about the equality of space and time as a frame or a canvas of existence of phenomena. However, a hundred years had to pass since the first publication of the *Critique of Pure Reason*, until the experiment⁷ that gave a scientific shift in relation to the verification of Kantian intuition and the subsequent formulation and precise scientific explanation was made.

world line (weltlinie)

2. Geometry in Architecture Design

To say that Architecture uses geometry as a means of design is as obvious as to say that medicine uses biological knowledge as part of its discipline. The classical orders of Architecture have embedded within themselves a system of geometrical proportions and relations that have been linked with the perception of beauty and proportionality of classical architecture. Vitruvius, in his Ten Books on Architecture, makes direct reference to the use of geometry in the disposition of architectural elements as an expression of human culture (Firth, 2010). All along the history of architecture, geometrical expressions and relations in two and three dimensions have helped architects to achieve beauty and harmony in their designs and geometrical relations between building parts enabled the classification of architecture in style categories (i.e. Romanesque, Gothic, Doric, Ionic, Corinthian). Modernists tried to break with historical styles, but Euclidean geometry still ruled the decisions taken by architects in their designs. Le Corbusier was obsessed with the golden mean and extensively developed a geometrical system, the Modulor, which established different geometrical proportions in relation to the human body linked to this classical geometrical proportion. Even in more recent days, Euclidean geometry, and systems of repetition and relations within it (i.e. fractals), have been used by many architects as basic tools to decide and establish the disposition of architectural elements in space. However, this use of geometry in architecture is incomplete in relation to the knowledge we have today of four-dimensional space.

3. The Theory of Relativity as the new framework of understanding of reality

3.1. Special Theory of Relativity:

Due to the fact that this thesis is framed within an architecture postgraduate program I will reduce this section as much as possible, just enough to pick crucial transformations in our understanding of the world that alter the way we work with space and time as designers of cities, buildings and environments. If you want to deepen into the physics of relativity I recommend Julian Schwinger's 'Einstein's Legacy' that is probably the easiest and simplest reading on the matter. This ease of understanding is surely linked to the fact that the book follows a set of documentaries prepared for the BBC called 'Understanding Space and Time'.

In 1905 Albert Einstein published three papers that radically transformed physics. The last of them, entitled "On the electrodynamics of Moving Bodies", contained what is today known as the Special Theory of Relativity, which states that the perception of space and time depends on the state of motion of the observer, although the content of the laws of physics remain the same for both observers (Schwinger, J. (1986)).

Hermann Minkowski

The geometry of the theory is due to Hermann Minkowski, Einstein former professor at the Polytechnic in Zurich, Minkowski coined the term “spacetime” (Raumzeit) and gave the appropriate mathematical form. Minkowski’s space-time is a four-dimension variety of space in which the three dimensions of space and time are intertwined in an insoluble manner. In the Minkowski space-time, the motion of a particle is signified by its “world line” (Weltlinie), a curve whose points are determined by four different variables: the three spatial dimensions and time. Through the integration of a higher complexity level through the introduction of a new variable Minkowski forced a reinterpretation of the concepts of the existing metric. The three-dimensional concept of point was replaced by the event and the magnitude of distance is replaced by the magnitude of interval. Thus events are the minimal units of existence.

referential system equivalence

Contributions of the Special Theory of Relativity:

Before the theory of relativity, particle physics, which explored and explained matter, was a complementary but segregated discipline to electromagnetic physics. The laws and theories of Isaac Newton constituted the main corpus for the first while James Clerk Maxwell was at the time Einstein wrote his first papers the main contributor to electromagnetic physics. (Schwinger, 1986). The theory of relativity was able to unite physics into a single science that was able to validate physical principles of both matter and energy.

- a. **New medium of existence:** the reality of any particle is defined by its Universe line, this being a curved line formed by a continuum of events defined by four interrelated variables (x, y, z, t) . Space-time continuum is a reality in constant flux that cannot be experienced twice (as was space in the Euclidean conception). Memory is the faculty that allows us to recognize this reality through the record of previous perception (e.g. experience of a room at two different times).

Temporary map of Europe by Klaus Spiekermann (1999)

- b. Liberation of Referential system:** The special theory of relativity established in its first postulate new equations that allow passing from one inertial reference system to another. The laws of physics are the same in all inertial systems. In other words, there is no privileged inertial system of reference, which can be considered as absolute.
- c. Relativistic time and time dilatation:** the interactions between the four variables imply that the variation of any of them will define changes in the other three.
- I. Proper time:** is the time measured for an observer who is traveling through space-time at a certain speed. The concept of proper time is necessary in Einstein's theories of relativity to describe effects such as time dilatation.
 - II. Time dilation** is the relative perception of time in which one observer notes another observer's time pass more slowly than his own time. There are two types of time dilation, the one produced by speed and the one produced by the action of gravity (defined in the general theory of relativity). Time dilation leads to a contraction of space due to the interaction between the parameters of space and time, as we see in the temporary map of Europe by Klaus Spiekermann (1999) that shows the contraction of geography due to the speed of transportation between various geographical points of Europe.

Continuous transformation or distortion of space-time due to the action of gravity (bottom)
Geometry of a Schwarzschild black hole - when gravity is too strong space-time unfolds within itself transforming its topology - (Top)

3.2. General Theory of Relativity:

The success of the Special Theory of Relativity led to the acceptance of the theory by most physicists. Prior to the formulation of general relativity, there were two incompatible physical theories: on one hand, the special theory of relativity that properly integrated electromagnetism, and on the other, Newton's theory of gravitation that explained gravity. Even when the special theory of relativity integrated matter and energy, it was incomplete in relation to gravity.

The need to find a theory that integrated the two previous theories required Einstein's search for a theory of gravity that was compatible with the new principles introduced by his Special Theory of Relativity. In addition to the formulation of a relativity theory of gravitation, Einstein was searching to generalize the theory, which was initially conceived as applicable only to inertial referential systems, to accelerated systems providing an appropriate physical description for a completely general referential system.

The first element to be incorporated into the general theory of relativity is the principle of equivalence, which states that it is impossible to determine whether a system of reference of an observer is moving with accelerated motion in relation to an inertial observer or if it is being affected by a local gravitational field. Einstein postulated, therefore, that *the laws of physics must be of such nature that can be applied to all referential systems, regardless of its movement in relation to the distribution of mass of the universe*, or in other words, that the effects produced by a gravitational field are the same as those produced by an accelerated motion.

Photograph of a solar eclipse made by Sir Arthur Eddington in 1919

One of the consequences which can be summarized schematically from the general theory of relativity postulated by Einstein is that space-time can be distorted, not only by the effect of time dilation explained before as a consequence of speed, but also due to the gravitational effect of bodies. A photograph of a solar eclipse made by Sir Arthur Eddington in 1919 in which the curvature of light rays close to the surface of the sun due to the gravitational effect of the star can be observed verified this deformation of space-time. As we can see in this image, space-time suffers a continuous transformation due to the effect of the gravity of the sun. Space-time is curved or bended due to the action of gravity.

The event as the new existential unit

The Special Theory of Relativity, as explained previously, introduces the substitution of the three-dimensional concept of point by the four-dimensional one of event. This will have major consequences later in the design of both the territory and architectural matter. The event as a minimum unit of measurement of space-time reality makes the architect approach reality in different ways making it seem poor to keep Architecture just as a set of lights and shadows that act on static volumes. The approach proposed in certain projects of Archigram (Monte Carlo, or Instant City), Bernard Tschumi's Event Cities and Toyo Ito's *architecture as a container of fluid space in which the acts of humanity develop*, and the later derivatives in the architecture of his disciples SANAA and Junya Ishigami, are signs that the architect's role must change and that change has already begun.

Sigfried Giedion. Space, Time, Architecture.

Once we recognize that the way architecture has used geometry to organize matter is incomplete in relation to the knowledge we have today of four-dimensional space it comes the time to look for the way architecture must deal with this new understanding. Even though, certain attempts to unfold and understand the transformations that architecture has suffered since this metric change was made, those have been incomplete or imprecise. The first attempt to establish a change in the conception of Architecture derived from this new scientific knowledge is made by Sigfried Giedion's book 'Space, Time, Architecture' first published in 1941.

According to Giedion space has three hierarchical levels: first, the tectonic order which is the result of the assembly process defined by the addition of the constructive elements; second the stereotomic level, which comes out from the interior of matter obtained by its own subtraction; and finally the level of Interrelation, which is also called transitional space, and establishes the link between interior and exterior space. In this later level, the perception of space varies according to our position on it. In architecture, it introduces a new factor: us. The position we occupy in front of the architecture, or the interior of it, is definitely for the perception of the fact that we will have of Architecture. This is a unique relative vision of space-time. According to Giedion, if we look at a point without moving we will have a two-dimensional or three-dimensional perception, as if we were in front of a painting or a sculpture. But if we move around the building, if we walk inside, we get a new experience: the fourth dimension.

Giedion also states that the evolution of architecture corresponds with the discovery and enhancement of each of these hierarchical levels. In a simplified view, the conception of space in Sigfried Giedion, has three stages: first, the architecture as volumes of radial spaces as found in the ancient architecture of Egypt, Mesopotamia and Greece, dominated by external volumes without the consideration of interior space. The second stage corresponds with the architecture as an interior space found in Roman, Medieval, Renaissance and Baroque architecture. In this stage, religious and social changes are behind the changes in the architectural forms and the discovery and development of new techniques and technologies. Finally, the third stage according to Giedion is the one where architecture acts as a sophisticated combination of both volume and interior space that was developed by the decisive influence that came from the revolutionary construction methods developed by the industry of the nineteenth century.

Even though Sigfried Giedion's has a valuable historical vision of the evolution of architecture in time, his view of the relationship between modernist architecture and space-time is reduced to the inner perception of Architecture in an observer that moves around a building. Even though he introduces the concept of unique world line, the one of the self, of the observer, his conception of time is pre-relativistic as it considers time as the unit of measurement of movement and not as a parameter related to space. The effect of perception of the fourth dimension of which Giedion writes, is the optical effect of parallax, and its variation with position changes, which had already been taken into account by classical architecture; (neoclassical) and had been widely discussed in neo-classical academic environments particularly it had been a theme of discussion between Claude Perrault and François Blondel, and other Académie members, at the French Académie Royale d'Architecture (Blunt & Beresford, 1999).

Saint Genoveve church in Paris. Detail of reinforcement of columns.
Jacques Germain Soufflot. This detail sought the stylization of columns to enhance parallax effect

On the other hand, Giedion referred to Minkowski space-time prior to the General Theory of Relativity, which is a flat space that has not been altered by the gravitational effects of bodies that are in the environment of the considered fragment of space-time nor takes into account its topological properties of deformation and alteration.

Therefore, the effort to link the actions of the architects of the modern movement with the science knowledge acquired in the Theory of Relativity is merely a literary tool used by Giedion to bond his historical classification of architecture. In fact, there is no clear intention in architecture that takes into account the relativistic modifications until after nearly fifty years since the general theory of relativity was enunciated in 1915. Le Corbusier used repeatedly what he called the *promenade architecturale* referring to the perception of architecture in motion, the change of viewpoint displacement. Nevertheless, like Giedion in his critical writing 'Space, Time, Architecture', Le Corbusier uses time as a measure of movement, a resource used long before by Soufflot in Saint Genoveve after studying Notre Dame and of widespread interest in eighteenth century architecture as expressed by Peter Collins (1998) in page 21 and 22 of his book *Changing ideals in modern architecture, 1750-1950* "The changes in the mid-eighteenth century refer to new ideas for parallax effects. These consist of the "apparent displacement of objects caused by a change of view"". In fact, the parallax effect exploited in architecture is simply an application of Galileo's principle of relativity enunciated in 1632.

CONTINGENCY

Event constellation

The event as the new existential unit.

The Special Theory of Relativity, as explained previously, introduces the substitution of the three-dimensional concept of point by the four-dimensional event. This will have major consequences later in the design of both the territory and the matter that architecture should work with. The event as a minimum unit of measurement of space-time reality leads the architect to approach reality in different ways, it now seems poor to keep Architecture just as a set of lights and shadows on static volumes. The approach proposed in certain projects of Archigram (Monte Carlo, or Instant City Living City), Bernard Tschumi's Event Cities and Toyo Ito's *architecture as a container of fluid space in which the acts of humanity develop* are signs that the architect's role must change and that change has already begun.

Flow of Events as Architecture

As I explained before, I believe that deterministic functionalism has mutated towards an understanding of the chaotic nature of human activities that happen within architecture. This change, that has its origin as we have seen, in the metric change introduced by the theory of relativity is also influenced by other knowledge of the new sciences such as the uncertainty principle or the chaos theory.

Simultaneity of events in space and time. The Garden of Earthly Delights. Bosque

Contingency of Space

Architecture is about life. Everything else is circumstantial. These were the two sentences that I used to introduce this paper. What I am trying to synthesize with these two sentences is the relationship between architectural matter and individual freedom of actions. This idea assumes that environmental design disciplines (architecture, urbanism and landscape architecture) define the material framework in which human activities are developed. From that point of view it is useful to understand events as dynamic systems that interact with the boundaries that define their flow and delimit them on one hand, and with the contingency attractors that generate events and flows towards these. When I write about the contingency of space I mean the capacity that a certain space has to accommodate events within a specific space-time. Contingency of space is a measurable gradient that depends on various factors such as size or topological properties of space. For example, the contingency of a hypostyle hall is different from a diaphanous one with the same dimensions. This gradient is not fixed but variable and dynamic. Enric Miralles understands this dynamic and changing nature of the contingency of space related to the way matter is arranged in space, and he plays with it. He knows that grouping columns, expanding ceilings, releasing spaces from structure, are all operations that affect the way in which spaces can be used. He used all this type of operations to place matter in space-time with the same freedom as a composer (as John Cage) places notes on a staff (or any other form of diagram in the case of Cage).

Secuencias 58. Juan Genovés.

Contingent Gravity

Contingent gravity is defined as the capacity that certain material bodies have to attract subjects and generate events in a particular space-time. This gravity generates a subjective deformation in space-time. A kiosk that sells drinks and ice cream in a beach is an attractor in that action field; it has the capacity to generate social events through a catalyzer (the drink or refreshment). When drinking and resting a conversation starts and social interaction occurs. We can think of architecture and the city as the choreography between attractors with various degrees of contingent gravity. This approach is linked to the continuous flow of space-time where events happen once – even when they are planned as periodical or recurrent – and is quite a renovated view of Vitruvian *utilitas*.

Action Fields

The idea that space-time is the place where events unfold corresponds with the one of action fields, places of potential action where events are dormant. This concept of space, which resembles the abstract understanding of game boards or battlefields, invites us to think in space with the conceptual tools of probability. There is no certainty of latent events. While these can be preconceived, the certainty of concrete action can only be addressed in probabilistic terms. Positivist functionalism has no place in this conception of space-time as a place that is always open to countless sets of possibilities for action. The impossibility of

trjectory of particle at CERN
extracted from BBC series Understanding Space and Time by Julian Schwinger

accurately knowing the trajectory of a particle is explained by Heisenberg in 1927 in his uncertainty principle; once again science corroborates the intuitive thought of the artists. For Miralles this reality of uncertainty of actions is perhaps what mostly attracts him of architecture. Miralles enjoys imagining how his buildings are inhabited. This is how he draws them, with people touring the wake of his pencil.

From the sciences, the uncertainty principle helps us understand that even if the trajectories of particles follow on similar traces, these paths are not precisely determinable but we must satisfy ourselves just with the knowledge of the range of possibilities in which they move. According to the uncertainty principle the more precision we seek in determining the position of a particle, less accurate is our information about the state of motion of it. If we accept the analogy of the fluid of events in space-time as a particle system in motion, then many are the scientific references that open up to influence our discipline, from fluid dynamics to chaos theory.

A dynamical system is said to be chaotic if it has particles that tend towards attractors and particles that escape from it at the same time. The most frequent situation is that there are multiple simultaneous events happening at the same time in the dynamical system of the action fields of architecture. Therefore, the flow of events that occur in architecture tends to be chaotic.

tower of the winds of Andronicus
elevation

Systems and Models. Synthesis and Simulation

Abstraction today is no longer that of the map, the double, the mirror or the concept. Simulation is no longer that of a territory, referential being or a substance. It is the generation by models of a real without origin or reality: a hyperreal. The territory no longer precedes the map, nor survives it. Henceforth, it is the map that precedes the territory.

In a previous section, where the concept of contingent gravity was made, an allusion to the update of the Vitruvian concept of utility was made. Architecture has always been linked to human activities. It is a discipline that provides the material limits of the places where life happens. The distance between walls or the place where a door is placed determines the way in which a space is inhabited. The utility of space is essential to architecture.

In May 2009, Bernard Cache writes an article on the Tower of the Winds of Andronicus of Kyrros for Architectural Theory Review magazine. In that article, the building is used as a tool to establish the foundation and contemporary understanding of architecture as a synthetic informational tool of events. For Cache, the Tower of the Winds is a machine for transmitting astronomical information and to measure the passing of time. Not a machine for living as Le Corbusier would have defined it, but a device that allows human beings to understand the variations occurred in time cycles.

tower of the winds of Andronicus
plan

As Cache explains, the Tower of the Winds was built about one hundred years before Vitruvius wrote his work *De Architectura* (27 BCE). The same building was quoted by Terrentius Varro in a volume devoted to architecture in its ten-volume encyclopedic work *Disciplinae*. The Tower of the Winds is the first building cited by Vitruvius in *De Architectura*.

Bernard Cache makes a contemporary reading of the Greek building, comparing it to the project by the Japanese architect Toyo Ito, also called Tower of the Winds. The ancient construction is an octagonal building inscribed in a circle, a Roman type known as *aedes*, characterized by the lack of a predominant direction, and therefore lack of orientation. From the point of view of this thesis, the article by Bernard Cache is particularly interesting in its classification of the fundamental structure of the Tower of the Winds in the quadripartite division of *corpus*, *locus*, *tempus* and *actio*. A division based on the separation between space and time and the arrangement of the elements in space and time. Action is the body in space and time. Four realities linked and classified into static pairs (*locus*, *corpus*) and dynamic ones (*tempus*, *actio*).

Under the friezes on the inside of each of the eight sides of the octagon there was a sundial. According to Cache, the American archaeologists who studied in depth the building of the Tower of the Winds in Athens also assure that there was even a ninth sun dial on the convex side of the cylindrical body. However, Vitruvius does not mention these elements, nor in the book first or the ninth book, entirely dedicated to the science of *gnomotics*, which studies the way in which objects are oriented relative to the Sun or the moon and foundation for the construction of sundials. The Tower of the Winds had also a large weather vane that allowed to know the direction from which the wind blew.

tower of the winds in Yokoham - Toyo Ito
photo: Tomio Ohashi

For Bernard Cache, the Tower of the Winds is a sophisticated device for measuring time and atmospheric events. It is a machine that processes information events around us and decodes to make them communicable. Architecture mediates between nature and man to segregate levels of information in understandable layers. In opposition with harsh nature in which noise and overlapping of information makes unreadable the laws of life processes, architecture allows filtering of astronomical events for further interpretation in an early stage in the history of human knowledge. That is the parallelism between the project quoted by Vitruvius and the one made in the late 1980s in Yokohama by Japanese architect Toyo Ito. The Tower of the Winds in Yokohama had wind sensors that translated atmospheric information into light signals, real-time decoding of terrestrial and atmospheric events transformed into transmitting light signals that allowed their interpretation. Architecture acts here as an information filter of reality.

Today we have tools of interpretation of reality that allow us to carry out simulations on non-existing realities. The model is prior to reality, yet contains all the above realities probabilistic information provided to us. Today we work on hyperreality of the future reality. If both towers were artifacts winds reacting to actual events, architecture today can work on virtual models that anticipate their behavior by simulation or simulacra.

While this simulation capability is an extremely powerful tool from the pragmatic point of view to anticipate the reactions to actual physical conditions, it is extremely naive to think we can anticipate the reality before it happens. However the ability to massively analyse data related to specific geographic locations that techniques such as GIS provide, allow city design fields to stem solutions out of probabilistic action. The

CERN axonometric view of entrance
(cms-docdb.cern.ch)

definition of a model in which the variables are set allows the study of possibilities or variations of conditions when altering the parts. Where the architect was merely a sighted guru, now becomes a massive data analyst, an interpreter of simulations.

Dynamical Systems

We have seen how the theory of relativity represents a change of metric that increases the complexities of referential systems even if they are equivalent. What in Euclidean geometry was a position, a point, a location; in four-dimensional space-time the minimum reality is the event. With that change, what happens and how it happens begins to establish itself as the center of attention of architects. While the study of four-dimensional relativity space allows architects to understand the environment in which life takes place, is just as a medium, as a place, the way we understand relativistic spacetime.

However if from this perspective we try to approach architecture, or the project of urbanity, to create places of social interaction, we find the understanding of space-time as a medium of relatively little use. The theory of relativity isolates events for study, as we see in the experiments conducted at the CERN in Switzerland. On the contrary, both general systems theory and dynamic systems allow us to address urban reality in its complexity once we have assumed that the event is the minimum existential reality. In the city events may or may not be isolated, thus being an open set of interconnected open and closed systems.

Norbert Wiener at MIT

General systems theory has its origin in biology, in the early 1950s Ludwig von Bertalanffy is the biologist who states and gives concrete form to the theory. However various applications were developed earlier. As Peter Galison describes in his 1994 text *The ontology of the enemy*, Norbert Wiener, as an eminent member of the MIT that contributed to the advancement of quantum theory, ballistics, theory of integration and communications technology, worked at the end of the World War II in the development of an automated anti-aircraft shield that was able to predict the movements of pilots through the study and computation of their previous actions. While such anti-aircraft shield could not be completed before the end of the war, the knowledge gained from its development was the basis of cybernetics. It is in direct confrontation of science and technology with raw reality when scientists realize the limitations of isolating physical and mathematical problems in finite closed systems. A large number of theoretical physicists and eminent scientists were active members of the board that developed the scientific project of the anti-aircraft shield, among whom were Lee DuBridge, M.G. White and even Julian Schwinger (author of the main literature on relativity used in this research and subsequent science communicator on the BBC with his serie of documentaries *Understanding Space and Time*).

Norbert Wiener was aware of the limitation of their first anti-aircraft shield. This system reduced the behavior of the pilots only to a servomechanic problem and had ignored the psychological impulses of pilots, who when found in distress acted unpredictably. Therefore, together with Arturo Rosenblueth, a cardiologist and visiting professor at Harvard Medical School, they developed a theory of behavior in order to introduce psychological factors into the sophisticated technological apparatus. In their text “*Behavior, Purpose and Teleology*” differences between human and machine are traced. It is the birth of cybernetics.

The anti-aircraft predictor
Illustrated at The Ontology of the Enemy - Peter Galison
Critical Inquiry vol. 21 No. 1. (Autumn 1994) p. 239

In this paper it is suggested that all brain functions can be duplicated by electrical systems. In doing so Wiener is introducing a new level of complexity to the previous system, which is only made possible by having defined and thought the problem from a systemic point of view from its inception.

General systems theory is a mode of systematic and scientific approach to reality. Limits, behaviors and actions are defined, and relationships between them are established. It is a holistic and integrated practice that allows its evolution over time, adapting to multiple variations on each of the parts. In opposition to a reductionist analytical approach, general systems theory allows the study of an organic whole in which the relationships between the parts and their actions set the overall behavior of the system.

Dynamic systems are systems that evolve over time. They are not stationary or static but are subject to the evolution and transformation of both its members as well as the exogenous variables that affect the system from the outside of the parts.

If we understand that architectural practice is linked to urbanity whilst setting the mode of living of human beings in the world, we should understand relevant the use of dynamic systems as a tool for architectural thinking. From this point of view architecture as stylistic and compositional practice is extremely reductionist since it focuses just on the shape, texture and materiality of the object and not in the manner in which enables the actions of humanity and establishes relationships, connections and interactions between them, thereby affecting the whole of urbanity. A systemic architectural thought will embed prior architectural knowledge, but will not block or reduce the discipline to its further expansion towards higher levels of complexities through the introduction of new layers of knowledge that affect the urbanity.

Where is Waldo - Martin Handford

State of Aggregation of Events

Having reached this point we have assumed to be valid that the event, or set of them, has become the center of attention of the architect. To address architecture from contingency, architects makes use not only of the understanding of four dimensional spacetime, but assume architectural practice as an open system in which multiple layers of information and complexity overlap.

Taking a particular subsystem at a particular space-time, the architect can make a simulation model of the planned events. For this, an estimation of the types of uses to be allocated within the space-time will be done. This operation does not differ much from classical and modern functionalist practice in which particular necessities are assigned functions and areas within the premises of the project. However in architecture of contingency decisions are not based on freezed specific time when activity is at its functional summum, but life is addressed in the city as a space-time flow in constant evolution.

Time and activity management become fundamental in defining concrete actions of architecture. Only then projects such as Instant City by Archigram, which will be discussed later, may be conceived.

While the previous section showed the utility of using the tools of dynamical systems to facilitate architectural thought, now the analogy with the states of aggregation of matter will help understand or simplify the way in which the flow of urban events modifies its density.

Spacetime is not colonized with the same intensity at all times, people come and go, the rooms are filled unevenly according to the event that happens in them. Spaces can be designed in compliance to the maximum use, which can result in the abandonment or under-utilization of space for not responding dynamically to urban realities. They can also be dimensioned according to the minimum use or the maximum average recurrence. Any of these strategies that freeze design decisions in a particular state of the contingency model has its limitations.

In his book “The Hidden Dimension”, Edward T. Hall refers to the importance of distance between people in each of our cultures. While the book focuses on the psychological perception of the distance of people in interaction, it shows the differences between the near and distant actions. We are constantly changing the distance between the people around us and this distance can be a variable to classify events. As well as matter has solid, liquid and gaseous states of aggregation, and the same material element can move from one to another depending on the absorbed energy, spacetime fluid density changes according to the state of aggregation of individuals.

By this simile it is easy to think in material response through architecture as transitions in changes of state. Take the example of the underground trains at rush hour. The state of aggregation of events inside the car is solid because of the density of occupation of the same. The platform works as an intermediate state in which the particles (users of the underground network) are ordered to proceed to the change of state aligned on the edge of the platform at the gates of each of the cars.

The Naked City
Dérive Situationist Diagram

This view which may seem overly scientific, where the inhabitants are reduced to mere particles is taken, metaphorically or directly, by various postsituationist architects. From Bernard Tshumi in his *Manhattan Transcripts* to Enric Miralles, transit and the fluid movement of people in architecture and the city serves to address architectural design. Matter arranged in spacetime defines not only an artistic and architectural style, but rather serves as limit, as membrane, as environment to human activities.

Contingency and relativity in the Situationist International (SI)

The Situationist International might be the avant-garde movement of the twentieth century that has more naturally assumed space-time reality.

Regarding the release of referential systems the Situationists incorporate the reality of the liberation of hierarchies in reference systems through action. In Situationist urban conception privileged references disappear. The drift (*dérive*) is based on equality or equivalence of the translations produced in the city. In opposition to the Classical and Baroque urban conception where clear referential axes define the city, the Situationists understand the city as a non-hierarchical space-time fluid. The *Dérive* is defined as “the technique of rapid transit through different environments” and is practice of the situationist psychogeography discipline, which “looks towards the recognition of the psychological impact of the urban context.” (Perniola). From the concept of *Dérive* it is of special interest to this research that it is a fusion between the objective reality of space-time through the assumption that the medium in which events occur in life has

New Babylon Paris. 1963. Constant. Haags Gemeentemuseum

⁸ Extracts from PERNIOLA, MARIO: "Los Situacionist. Critical History of the last avant-garde movement of the XX century".
Spanish Ed. Acuarela

⁹ Internationale Situationniste Magazine n° V, p. 43

no predetermined hierarchy together with the personal subjectivity that generates psychical and emotional effects on us.

The media of existence as it is presented since the theory of relativity, in which we are immersed in a medium that is a continuum of space-time and our life is defined by a continuity of events, is assumed by the Situationist International through the *Dérive* and the Situation, activity that names the movement itself, which is defined as “a moment of life concretely and deliberately constructed by the collective creation of a unitary environment and a set of events”. The situation allows, unlike the *Dérive* – to which is complementary –, the handling of events that occur in space-time with the intention of satisfying a particular desire.

⁸*Dérive* and Situation are two complementary activities, which are together the base of situationist discipline of psychogeography. Psychogeography is also the premise of a much larger cognitive project of urban renewal, the ‘unitary urbanism’, which the SI defined as the “theory of the involvement of all the arts and techniques in pursuit of building an environment dynamically linked to the experiences of behaviour”⁹. Situationist Unitary urbanism is determined, first of all, in the polemic against functionalism. According to the situationists functionalism is merely concerned with the suitability of the means with respect to the end of production and plays a conservative role and is supporter of bourgeois society and its miserable idea of happiness hinged on two key themes: the movement of vehicles and the comfort of home. In this way, according to Mario Perniola functionalist architects finally end building ‘concrete cemeteries where large masses of people are condemned to bore until death’ or huge housing units isolated, separated by green extensions that prevent the direct and the free development of sociability. Unitary urbanism was not ment to be an

Model. New Babylon. Constant

urban doctrine, but rather a critique of urbanism as a separated and specialized discipline, a criticism that was born from a vision of society as a whole and tended to a 'global creation of existence'. It was therefore not a new poetic architecture but had the intention to become an effective improvement of art. Perniola states that traditional art activity cannot even be considered as true self-created and should be abandoned by the unitary urbanism. Through it the artist architect should cease to look for ways in which to become a builder of environments and comprehensive ways of life. In fact, the Situationist international proposed transformation of the discipline of urbanism affects not only to the urban structure but also and more importantly to the behavior of its inhabitants. They state that it is inseparable from the pursuit of revolutionary forms of existence, such as game, nomadism or adventure. Following this change of conception, as we shall see, many of the works after the Situationist International of certain actors (architects) of contemporary architectural activity assume the relativistic space-time evolution of the Situationist International as a point of no return and try to avoid a reappearance to the conception of architecture and the city as a simple composition and articulation of volumes that contain uses. Actions, their boundaries and their interrelationships will be positioned as key issues in certain architectural acts since the presentation of New Babylon and the birth of the Situationist discipline of unitary urbanism.

Map of New Babilon Nord. Constant.

¹⁰ New Babylonians: Contemporary Visions of a Situationist City. Academy Press. ISBN-10: 0471499099; ISBN-13: 978-0471499091

¹¹ PERNIOLA, MARIO: "The Situationist. Critical History of the last avant-garde movement of the XX century" (Los Situacionistas. Historia crítica de la última vanguardia del siglo XX). Ed. Acquarela, p.27-29.

Architecture of Contingency:

From New Babylon to Beabourg: the city as a stacking of action fields

New Babylon: Constant's proposal to the Situationist City

New Babylon is shown for the first time in Amsterdam¹⁰ in December 1960 in the Stedelijk Museum in Amsterdam and presented internationally at the Venice Biennale in 1966. For Constant¹¹, a member of the Situationist International since 1960, unitary urbanism leads towards a covered city project, which he named New Babylon. This would be a collective suspended dwelling space, extended to the whole amplitude of population and separated from traffic, which passes below and above it. It would be rich in environments for social life and all kinds of stimuli, which would be periodically renewed and transformed by the hand of a squad of specialized creators (professional situationists). Constant illustrates this new city with a series of drawings and models which were exposed at the Venice Biennale in 1966. Most of the Situationist claim that Constant's thesis seems to overestimate the technical question over the social concerns on vital expressions. Among these expressions, game is subject of special attention. The Situationist concept of game arises as qualitatively different from that which has been stated in the past two centuries in relation with the capitalist exaltation of productive labour.

From the standpoint of this work, what is most interesting of New Babylon, beyond the social aspect related to Marxism, is the concept of territory as a constructed unit, but with complete freedom to create and re-create all kinds of leisure subspaces tailored to the specific needs of each time. From the relativistic point of view, New Babylon, is a place that has no privileged referential axis, it is a network whose references are dynamic and mutable. Homo Ludens inhabitants occupy part of their own time in the transformation

New Babylon. Model of one Sector. Constant

¹²BANHAM, REYNER: "Megastuctures. Urban Future of the recent past". Spanish Ed. Gustavo Gili. ISBN: 84-252-1851-9. P.83

and mutation of the city itself. Secondly, the city of New Babylon takes the event as the minimum unit of existence, and recognizes the city as an accumulation of events conducted in an artificial environment that has been adapted to the actions that will happen in the city. Actions and events are essentially the pulses that keep the city alive. Although Constant formalized New Babylon in an architectural way, freezing it at a specific technological and space-time moment, the city is actually defined by the actions carried out in it, which are all defined by freedom and playfulness – separated from capitalist production – by the constant migration of its inhabitants within the city and with an endless non-hierarchical growth.

Constant's colleagues in the Situationist International blame him for the deterministic freezing in time of a complex idea or system. Due to this, he is even forced to abandon the group. In the point of view of his opositors, Constant reduced the postulates of Situationist International's unitary urbanism to a mediocre product in relation to the original intent of the new urban discipline. As Reyner Banham **states**¹²: *Despite all its nobility, this ludique vision is reduced in the end to bricks and mortar, and it is very possible that it was the conclusive note of bourgeois practicality which irritated his Situationists colleagues, who mocked Constant until he left the movement.* (Banham, Megastructures)

Fun Palace controlled environment volumes. Cedric Price.

¹³BANHAM, REYNER: "Megastructures. Urban Future of the Recent Past". Sp Ed. Gustavo Gili. ISBN: 84-252-1851-9. P.83

After New Babylon:

Fun Palace:

According to the Situationists themselves New Babylon was a limitation of the potential of the principles of the Situationist International, a reductionist objectification of the concepts of Homo Ludens, psychogeography and unitary urbanism. At a topological level, the flexibility of the boundaries was reduced to a stacking of planes. Since New Babylon was organized in layers – even when each layer meant to be free – the whole city was fixed to a stratified structure.

As Reyner Banham¹³ has said the Fun Palace was a real project whose “purpose was to enable almost detail by detail, the kind of flexibility required for New Babylon”. The Fun Palace was promoted by Joan Littlewood in 1964 and commissioned to the English architect Cedric Price, the engineer Frank Newby and the system consultant Gordon Pask. It was described by those who designed it and conceived it as a media device, as a service, as a mobile space or a giant toy. They did not think of it as a building. It is interesting that this project is no longer described in terms of architecture as the discipline of finite elements placement in order to create a building, but as a place that is variable in time to incorporate improvisation and multiplicity of events as an essential aspect of its conception. It is therefore events what unifies architecture, and temporality and dissolution of boundaries what define the spaces and characterize the building.

This relativistic view, in relation with the importance of the event and the space-time continuum, is emphasized in the words of Cedric Price: “The sense of confinement on the space is reduced by the deliberate extension of its visible boundaries. The activities planned for the site must be experienced, and the place

Cedric Price. Fun Palace, view of the model.

¹⁴ PRICE, CEDRIC. *New Scientist*. London, May 14, 1964. P. 433.

itself dispensable and variable. On the one hand, the organization of space and the objects that occupy it should challenge the mental and physical ability of the participants, and on the other, it should allow spatial and temporal fluidity that facilitates an active and passive pleasure”¹⁴.

Even if the proposed mechanical systems depended on the existence of qualified personnel responsible for maintenance and management, an issue that would have irritated the Situationist because of the dependence of citizens to a system of control, Fun Palace variability was much greater than the one in New Baylon. The pragmatism in the project, which came to meet strict and outdated English fire codes of the time, would have allowed its implementation. It was due to funding problems that the project was finally paralyzed.

The Fun Palace, a project that was developed between 1962 and 1967, was a model of free use of structures and, by extension, of cities. It influenced and served as a reference for a later generation, especially in Britain and in particular to students from London schools and the proposals grouped under the collective / magazine Archigram.

Walking City. Sketch, Ron Herron. October 1964

Archigram:

Archigram, the magazine founded in London in 1961 by Peter Cook, who later became an architects collective (Peter Cook with David Greene, Ron Herron, Warren Chalk, Dennis Crompton and Mike Webb), under whose name various projects and proposals were raised supported upon non architectural technology (industrial, aeronautics, space, etc.) and inspired by the values of the aerospace technological future derived from the 'Space Race' carried out on both sides of the °Iron Curtain cities. Archigram show us cities that walk or that are moved from one place to another when they are needed or used.

Walking City - originally known as Cities: Walking - is a project that is known for its utopian vision, a city contained in a superstructure that carries and moves around the world. It is interesting in these cities that from a relativistic point of view they establish two simultaneous reference systems, what happens within the city, and what happens outside, that in addition is forgotten because of the translational motion of the city itself. However, from a relativistic point of view, the series of projects included under the title 'Instant City' are far more interesting as they assume time as a variable that shapes the project, time is no unit of measurement of movement, translation (in Walking City), but is a variable that defines space-time position and action of the city itself. Instant city is there, transforming the pre-existing old city, in a given interval of time to allow the happening of scheduled events. Instant city happens.

Instant City includes several projects under one same point of view that emphasize one same intention: the intensity of use of the city is variable, and therefore architectural artifacts that allow the intensification of events that occur in a city at one particular time should not be permanent in time nor in space. Archigram

Instant City. Airship mode: airship in Lancashire; Instant Country Cartoon; Sequence of effect on a typical English town.
1970-71.

proposes the use of fabric sheets suspended from balloons in the form of decks, and mobile audiovisual devices that help events to happen. All of the elements are movable and have a temporary use. There is no permanence. Everything appears, displays and disappears.

Out of all the different versions of instant cities, the Airship Mode is perhaps the one that, more clearly, synthesizes spatial-temporal Archigram's vision of the city. Unlike Walking Cities, the propagation medium is different from the utilization medium; the city eventually moves through the air, condensed into an airship and lands on earth where it displays its full potential. The airship is not a city in itself, but complements the city that sits on at a given time. There is a symbiosis between the old city and the device that gives the old city a set of equipment, which is not available in the city structure, in order to enable the happening of certain type of events.

Once the event for which the aircraft was moved, technological devices and physical support are then collected and the airship parts to another place that needs of its potential. Instead of filling cities with dead structures that are misused, Archigram propose the activation of multiple cities with a travelling structure that is constantly active.

Aerial photo of Paris before the Centre Pompidou completion. The plot is used as parking linked to the market in Les Halles (under closure during the competition). 'Du Plateau Beaubourg au Centre Georges Pompidou' ISBN-10: 285850377X.

Materialized Utopia: Plateau Beabourg

In 1971 Georges Pompidou, the same who was prime minister during the Paris student riots of May 1968 allegedly started by the influence of the Situationists, announces an architectural competition to fill a gap in the city of Paris, Beabourg Plateau. That empty space of the city appeared due to the demolition of part of the urban fabric by an outbreak of tuberculosis in 1930. It was used at the time of the competition as a parking lot and the intention of the competition was to place there a multipurpose cultural center. The competition, received a total of six hundred and eighty-one proposals, and was won by one proposal that almost did not arrive. A proposal that represented the evolution of urban thought derived from Situationist thought delivered by Richard Rogers, Renzo Piano and Peter Rice (Ove Arup).

The team, after carefully reading the competition brief, decided to focus their project on the versatility and variability of the building. To reach this they apply ideas that had been inherited from the Fun Palace or Archigram's Plug-in Cities projects. Everything in the cultural center will be modifiable and reconfigurable. The building will be an attractor of urban activity and will be connected at all levels. These assumptions will guide the subsequent project decisions but flexibility will be the real essence of the proposal. Flexibility understood as a response to the unpredictability and unclassifiability of events that happen in the city. Thus, the project, which is complemented by an outdoor plaza where citizens act freely, is established as a stacking of plazas – seven in the competition and five in the finished building. Each of the stacked plazas is open; it does not have any structure that interrupts its continuity. The five levels are unconditioned spaces that can be colonized by furniture or partitions in multiple ways depending on the moment and the events that are being housed.

Photo of the jury meeting. Phillip Johnson convincing the rest of the jury. 'Du Plateau Beabourg au Centre Georges Pompidou' ISBN-10: 285850377X.

Versatility is carried to such an extent that, as Renzo Piano said after the completion of the building, *“It is now a cultural center... but maybe tomorrow it could be an open university... and then, I do not know, a cattle market?”* These words express in a very natural way the conception of what happens in the city is changing and unpredictable. In Madrid for example the opposite example to Renzo Piano’s words is happening, a slaughterhouse (a cattle market) is being transformed into a cultural center because the city has changed and evolved, and the energy required for this change is greater than that needed if it had nine buildings in Legazpi equivalent to the Centre Pompidou (as far as versatility is concerned).

Beabourg cultural center connectivity diagrams extracted from the panels and the memory of the competition. 'Du Plateau Beabourg au Centre Georges Pompidou' ISBN-10: 285850377X.

As can be seen in the connectivity diagrams submitted to the competition, from a topological point of view, the project focuses part of its speech in the cultural center connectivity at different levels. On one side, it is very important the connection of the access level with the city through the maximum permeability. The level of access, in a first moment, would have been completely open to the city, so there were no barriers that would stop free-flowing access from the street level into the building. On the other hand, it is extremely powerful the intended idea to connect the center with other centers in the country and the world through a wave communication system in order to share information between different cultural centers. It is important to note that this idea is long before the use of the Internet by civil society. This remote connectivity, which we are extremely familiar nowadays thanks to the inherent presence of the internet and wireless communications, it was of great innovation at that time and establishes a clear attitude of the project team in seek of an open, permeable and accessible, compared with interior insulation, the opacity and inaccessibility of most previous orthodox models of existence. Therefore, the decision to open (connect) the building to citizens responds to the same interest of the design team to connect complementary cultural centers at a level of information communication.

Photo of the model presented in the competition. Note the antennas that connect the building with the rest of the world as there are free gaps in the configurable superstructure and activity of people in the entrance plaza. 'Du Plateau Beabourg au Centre Georges Pompidou' ISBN-10: 285850377X.

The Pompidou Center project makes direct use of time, used as a design tool, making the building completely configurable to the events that occur in it. From this point of view, the building assumes the reality of post-relativistic space very naturally. The building must adapt to events that will occur inside and not vice versa (events must adapt to the dimensional and topological conditions of the existing architectural spaces set in the building). In Beabourg everything must be adaptable. The competition team knew that this required a complex development and implied the rise of the cost of the building. However, as compensation to that effort they were aware they would achieve a versatile device, a variable framework of experiences. The structure allowed the building to be used freely throughout the occupation, the mechanical facilities are not to disrupt the perimeter (nor cause any discontinuities in space) and all the vertical communications, the floors could be retired and moved vertically (only in the competition scheme), escalators could turn around and get positioned as needed to connect to the city. All in all, every building component and technology was used to support a simple goal, to free up use of any material discontinuity and conditioning to allow maximum flexibility of use. This can happen in any event at each of the levels stacked in the building, the same that happens in the square that serves as entrance to the building. To sum up, the project tries to find a set of 'fields' that can be activated with the highest degree of freedom within the technological restrictions of its time.

Enric Miralles reflected in his crystal ball

Enric Miralles between Time and Action

Flow of Life as a Material for Architecture

Architecture is about life. Everything else is circumstantial. I came up to the clarity of this statement through a research on the influence of certain scientific models of the New Sciences made on architectural design. The intuition of that simple fact can be validated by certain conclusions of various scientific models that explain reality as it is, or at least, as we believe today it is – as we know time can change everything. It is not the task of the architect to prove right or wrong our scientific understanding of reality. Nevertheless, knowing (even in a tangent way) the content of their laws and theories can let the architect step out of the closed cell of architectural tradition, thus permitting him to have a wider view of what architecture is about in the wide sea of knowledge and creation. However, the creative processes, such as architecture, do not absorb knowledge from a single source. While it is true that scientific knowledge of the world allows the architect to act with some certainty over constantly changing matter, metaphysical or poetic practices, from philosophy to art, sometimes contain intuitive approaches to certain realities that are equally useful for activating imagination in the creative process of architecture.

In the case of Enric Miralles, architecture is imbedded in the continuum process of becoming of space-time. One project leads to the other, transforming itself through the action of construction, and then through the action of life that follows the appropriation of the building by its inhabitants. For Miralles design is a complex multilayered reality that evolves through the action of conversation – actual conversation with the actors of construction and development and silent conversation of the designer with the latent information

Diagonal Park. Site Plan. Enric Miralles

¹⁵ See ZAERA, Alejandro. A Conversation with Enric Miralles. *El Croquis* magazine number 72(II). Enric Miralles 1995. *El Croquis*, Madrid. 1995. pp. 17

¹⁶ See TUÑÓN, Emilio and MORENO MANSILLA, Luis. Notes on an Informal Conversation. *El Croquis* magazine number 100/101. Enric Miralles / Benedetta Tagliabue 1996/2000. *Maps for a Cartography*. *El Croquis*, El Escorial, Madrid. 2000. pp. 12

¹⁷ See MONEO, Rafael. Things seen left and right (without glasses). Enric Miralles Moya PhD Thesis (Text in Spanish). *DC PAPERS Magazine* 17-18. Polytechnic University of Catalonia, Barcelona. 2009. pp. 118

of architectural sites and programs on one hand, and with the multiplicity of references and sources of inspiration that transform the way he sees or thinks about the world on the other.

Enric Miralles is one of those rare specimens that very infrequently inhabit the space-time of architectural discipline. He dexterously surfed and sailed in the wide sea of knowledge and creation. He had the fluency of a young Mozart and the slyness of a mature Picasso when setting in his drawings the actions that would place matter in space and time to define architectural experience. That is something infrequent. The same as Mozart he died young. But he enjoyed life and enjoyed transforming its framework. He understood that every design decision generates later mutations of the perception of life in dialog with the disposition of matter that surround us on urban environments. However, these decisions are directly related to architectural tectonics and material properties that are only displayed when they are put into action through construction. Thus design, events, conversation and construction are coexistent and simultaneous in the constant becoming of life continuum. During design he used to imagine the flow of future people experiencing the building, and this thought made matter converge towards the paths that this flow traced, as if matter danced around the movement and the experience of people within the building “... *the flow of the inhabitants sometimes accounts for a third of the building's weight*”¹⁵ – he said in 1996 and restates in 2000 “... *people are the working material*”¹⁶ .

Before studying to become an architect Enric Miralles was a great basketball player and he had to decide between professional basketball and architecture¹⁷ . Therefore, he knew that game and training are two sides of one same coin; to enjoy playing it is necessary to train yourself to get the most out of you during

Studies for water surfaces in Diagonal Park. Inkblots by Enric Miralles

¹⁸To see a complete view of the thought tangle see conceptual ecosystem diagram at the beginning of this text

the game. For Miralles design has to be joyful and entertaining. It is not through suffering how design has to emerge. It should be something that generates itself in an unconscious way, a way that has its origin in the replication of actions repeated on the basis of the multiplicity of complex layers of information of the project. Study is part of this repetition, of this superposition of information. Once this superposition of information has been pushed to its limit, then an unconscious movement that contains the remembrance of all those complex layers of information arises.

This text seeks to disentangle the set of influences that stimulate Miralles' thought (which are partially shared by other contemporary architects to him – always in a relative and unique way). This complex tangle of references and influences is populated by both precise knowledge inherited from the new sciences, and intuitive winks and diffuse methodologies from multiple artistic, philosophical and literary groups that share the knowledge and belief that creativity, like existence, is unique¹⁸.

Studies for walkways and flows in Diagonal Park. Color sketch by Enric Miralles

The New Sciences Influence Architecture Creativity

I will begin this act of disentanglement of the conceptual influences with the impact that scientific knowledge acquired from the new sciences has on architecture design. The first thing to consider is that space-time has replaced the incomplete concept of space, and in turn this new concept is now used by the architect as matter to be modeled. As such, we must know its properties, properties of non-Euclidean geometry, and its metric, thus fixing the optics under which space-time is manipulated by modifying its topological properties by the artificial action of delimitation of action fields that arises from urban construction. In this section of the paper I will seek the link between contemporary architectural practice (particularly in the work of Enric Miralles) and the acquired assimilation of the scientific knowledge that has more deeply transformed how we understand the world throughout the twentieth century. I will try to identify ways in which Miralles' architecture is facing post-relativistic reality and the way in which his architectural discourse has shifted from a previous discourse based on stylistic considerations related to employment of standards of Euclidean geometry (as a tool to control the disposition of building elements), toward a nonlinear practice that assumes the event as the basic unit of existential reality. This approach will lead to the study of contingency in architecture and of the use of the scientific metaphor of dynamic systems interacting in space-time. In this sense, I believe that deterministic functionalism has mutated towards an understanding of the chaotic nature of human activities in relation to the uncertainty principle and the chaos theory among others.

This architectural sketch depicts a complex building layout with several interconnected volumes. The drawing includes various geometric shapes, such as rectangles, triangles, and irregular polygons, some of which are shaded to indicate depth or material. Annotations include the number '437' in the upper right, '438' in the lower right, and '439' in the lower left. A small, detailed inset sketch on the right shows a cross-section or a specific architectural detail. The overall style is that of a conceptual architectural drawing, using light and dark lines to define the forms and their relationships.

Architectural creation in Enric Miralles (His personal description)

Doubt and the Continuous Transformations (deviations)

In a synthetic way we can say that the operating mode of Miralles was structured by doubt as a method of advancement, the way Ortega y Gasset described it in 'Ideas and Beliefs', that "sea of doubts that is the place of ideas". Doubt allows Miralles' imagination to activate, leading to the advancement of his continuous vital research. For Enric Miralles each project was a continuation of the previous one, all were linked, and through doubt and deviations he arrived to a different projects. Doubt, as referred by Enric Miralles, is a tool in the process of creation that completely rejects imposing character and plays with the voluntary suspension of reasoning, about a specific issue of the project, at any given time. This use of doubt enabled the triggering of cognition, reflection and dialogue, and even distraction, before taking a step forward towards the embolde-ment and advancement of his projects and his learning.

Doubt does not vanish from Miralles' projects until construction is completed. It is at this time when only the most important reveals, the essential, the refined yet complex scheme of the project. This arises when the doubt disappears to move to another project and repeat the same creative process based on doubt and deviations.

Before exercising this imaginative process linked to doubt, Enric Miralles, observes and analyzes the in-herent complexity variables of reality. Through observation and assimilation of the interpretation of the information provided by these variables, and from the doubts raised about them, the project could begin to

Dresden flower exhibition. Competition photomontage. 1998

¹⁹Greffage or graft was the term proposed by the French critic Edouard Jaguer to refer to a collage

be formalized, always within the framework of existing knowledge, using geometry and lexical expression orders of construction and structure (links impassable connection with reality), in conjunction with Miralles' own subjectivity.

Enric Miralles observing the ruins found on Santa Caterina Market project site. March 2000. Absorbing information prior to reinterpretation. Unfortunately the continuous process of reinterpretation of information ended three months later when death imposed its rules over Miralles.

By superimposing variables taken into account at the time of start of the project, and always continuing on the wake of previous research, the first drawing of each project appeared, which had its origin in the traces that arose from the interpretation of the these superposition of layers of information, or as a deviation from a previous concern (a part of a previous project or issue from a prior process of creation). From that first drawing a succession of deviations that tend towards infinity happened. The deviations, as explained previously, arose from the doubts of the project itself in finding its internal consistency. This consistency was acquired through construction and structural principles that force the transformation of the geometrical definition of the drawings that define project when put in action. The work of Miralles was only interrupted at the time the work is completed, disappearing with this culmination, the doubts that were present during the construction process, although these deviations in architecture continue over time through the use that inhabitants make of the building. Within this framework of deviations that derived Miralles' design three kinds may be described: those arising from the author's subjectivity by reinterpretation of a previous situation, the one that are adaptations to construction needs, and those that appear by chance. The first two

Enric Miralles observing the ruins found on Santa Caterina Market project site. March 2000. Absorbing information prior to reinterpretation. Unfortunately the continuous process of reinterpretation of information ended three months later when death imposed its rules over Miralles.

¹⁹Greffage or graft was the term proposed by the French critic Edouard Jaguer to refer to a collage

came under the supervision of the architect, while the third had an uncontrollable nature, was accepted and incorporated in the design process by Enric Miralles at the same level as the other two.

Given that Enric Miralles would never present the way he worked as a method, the way he proceed when faced with a project is basically by superposition, aggregation and juxtaposition of multiple layers of information. This way to work is linked in a way to inclusive architecture defined by Robert Venturi in the early 60s in his book 'Complexity and Contradiction in Architecture'. Miralles assumes the complexity of reality in the way he approaches architecture. He denies simplification and reductionism. Miralles acts as an assembler, having much of the grafts (greffage)¹⁹ of Edouard Jaeger, placing emphasis not so much on the technical issue of Jaeger practice but on the organic character it.

Some New Artistic Practices as a source of Inspiration. Creative practices of individuality

The Bride and the Hanged Female are a projection comparable to the projection of a four-dimensional "imaginary entity" in our three-dimensional world (and even a re-projection of these three dimensions on a two dimensional surface in the case of the flat glass).

Marcel Duchamp. Letter to André Breton, 1955.

Raymond Queneau. Cien mil milliard de poemes

Enrique Granell ends his 2012 article 'A suitcase full of architecture' with this quote from the letter that Marcel Duchamp wrote to André Breton in 1955. After navigating through the sea of influences and references of Enric Miralles, Granell (who was a classmate of Miralles and shared with him incursions into the libraries of Barcelona) we discover that what Enric Miralles is looking for in the Situationists, in the Dada or Pataphysics is not a critical rupture with society, but he is rather searching to immerse himself into the complexity of four dimensions; he wants to step out of the straitjacket of three-dimensional Euclidean geometry that has anchored architecture throughout history. The quote is extracted from the 'Green Box' a book that was originally edited by Octavio Paz in Mexico, and that they both bought in Laie bookshop in Barcelona when the Marcel Duchamp exhibition showed at the Fundació Miró was opened in February 1984.

According to Enrique Granell, Enric Miralles is not a Situationist because he is not interested in the Marxist destruction of society. Nevertheless he does believe in Situationist actions and life strategies as a way of interacting with the world. Miralles identifies himself as a *homo ludens* who enjoys life as a medium towards production and refers indirectly in multiple occasions to various methods of design and construction that are linked to Situationist practices. Miralles finds inspiration in the ideas of the IS, but also in those of their predecessors such as Breton and the surrealists and the CoBrA group, especially by the pictograms of Christian Doremont. He uses all of his influences in a playful way, without the rigidity of academic methodology, but as an excuse to test and play within a set of rules or ways of behavior. In this sense, Miralles is not apocalyptic, as Granell defines the IS, but playful and unworried. He enjoys the game of making matter dance around the simultaneous events that occur and the uncertainty of what is happening. In the way that Pataphysique reacts towards uncertainty, especially in the OuLiPo group, Miralles finds an inspiration

'The Situationists' at the Museum of Contemporary Art of Barcelona (MACBA). Plan of the exhibition. Enric Miralles

of design behavior, a way to make design react to the multiplicity and uncertainty of events in space-time. His infinite project that transforms itself from one case study to the other by means of superposition of complexity of information can be read as an adaptation of Raymond Quenau's *Cent mille milliards de poèmes* to the complexity of four-dimensional architectural realm.

As I said before Granell anticipates in his article that Miralles is not a Situationist, as he was not interested in the destruction of capitalist society. Even though this lack of interest in the abolition of the capitalist system (Miralles did not have time to waste on the social debates of the Situationist International) is true, we should not forget that the Situationists themselves were segregated into two large families, on one hand that one leading to a social breakdown, headed by Guy Debord, and on the other one that was focused on bettering society through scientific and technical improvements, led by Constant and Pinot-Gallizio (Periniola, 2008).

Enric Miralles was not a Situationist activist, he was not interested in the reinterpretation of the Marxist revolution proposed by Guy Debord, but nevertheless was immersed in the Situationist ideas in relation to unitary urbanism, his lexicon betrays him. Although Miralles avoids making direct use of the Situationist glossary, he refers in multiple occasions to Situationist practices as derive or ludic life – his buildings may well be understood as places to practice ludic derives. In November 1996, along with Elias Torres, Miralles organized the exhibition 'The Situationists' at the Museum of Contemporary Art of Barcelona (MACBA). This exhibition mainly focused its attention on New Babylon project, the nomad and multilayered city proposed by Constant, and in some other urban projects done for Paris, Amsterdam, Copenhagen and Turin. Accord-

New Babylon. Drawing by Constant exhibited in the MACBA from November 13, 1996 to January 6, 1997. MACBA files.

ing to the museum's own chronicle the emphasis laid on the architectural and urban proposals, leaving a secondary role to the revolutionary ideas linked to social forms developed by the Debord sector of the SI. As curator for the MACBA exhibition, Miralles is showing his interests on the work of the International Situationist. The act of selection is an act of delimitation of interests; it is a condensation of Miralles knowledge on the urban strategies of the group, urban strategies that are directly related to the metric change produced by relativity, in which events become the minimum manifestation of reality. Individuality and multiplicity of events, together with the uncertainty to trace the precise actions that may happen in space-time will thrive conceptual actions in Situationist urban proposals.

For Miralles his work has to be experienced as a flow, it is an action, his architecture responds to dynamic transformations, but it is not the visual change of perception what interests him. The continuous flow, the active interaction with the building is not related to a change in the view point, as was the interest in the 'promenades architecturales' of Le Corbusier or in the parallax effect discussed in the French Académie during the Enlightenment; what calls Miralles attention and is used as a design strategy is that each moment is different, that space-time is continuously modifying itself, it is not only the viewpoint that changes; everything is different and irreplaceable. This point of view is radically different to the one that centers its attention in the visual world. It is a point of view that understands the nature of four-dimensional space-time, whereas the previous one is related to the Relativity principle of Galileo that keeps time as a unit for measuring movement within the constraints of three dimensions, understanding that space-time is constantly and irremediably flowing shows that his thought is evidently post-relativistic.

Even though it might be possible to say that one of the first direct understanding of reality after Einstein's Relativity in urban disciplines is done by the Situationists (Fredrik Kiesler makes the first rigorous attempt), Miralles is aware that there is a tradition of thought linked to the thought of the SI that is prior to them and that was applied in other realms of reality, from visual arts to literature. Miralles is a great reader; he read anything, from philosophy to music theory, from novels to architecture criticism. That joy for literature made him get into contact of ideas that activated his imagination. Miralles was a reader but, the same as Schopenhauer, Miralles only read when he was not inventing, not creating, as a way of filling out the own gaps in his mind.

Architecture and Landscape

It has been some years since there is a growing interest in addressing the project of the city, the metropolitan project, from the discipline of landscape. Since its inception in 1900, the landscape architecture program at the Graduate School of Design at Harvard University the school has militated for the understanding of the metropolis as landscape, while it is not the only American school that focuses on the merger of the two disciplines, Architecture and Landscape. The University of Virginia headed by the Spanish landscape architect Teresa Galí-Izard and Columbia University have been working on the merger of the two disciplines (see picturesque atlas Volume One: the observatory Iñaki Abalos page 55.).

Bernard Tschumi. The Manhattan Transcripts

As explained above, in the moment that we understand post relativistic space-time reality, we understand also that space-time is a field of action, a place where events happen, whether they may be. Landscape architecture, maybe due to the scale on which has historically worked, is a discipline that factly works on contingency gradients present in a territory. In this discipline there are large areas in which it is assumed that the degree of contingency is minimal, while complementing it with places where the contingency and activities are concentrated; places that act as attractors in those fields of action. The arrangements of places of activity in the territory represent social attractors toward which population or residents flow. This mode of operation is particularly clear and visible in the English and American landscape garden, although it is present also in the French neoclassical garden and in the Italian Renaissance garden, where caves and green rooms allow social activities beyond walking (or activities agricultural). However it is especially more visible in contemporary landscape architecture where vast areas of territory with diverse nodes of activity are the object of analysis and work.

Bernard Tschumi developed the Manhattan transcripts from 1976 to 1981. Tschumi had a growing interest in post situationist relativist reality (he later wrote three books titled Event Cities where urban reality is approached from the perspective of the event). In the series of the Manhattan Transcripts the representation of urban events is addressed in a series of etchings in which sequences of actions through photographs in black and white, dihedral drawings and motion diagrams are represented. It is no coincidence that the first series is dedicated to the park. In this first serie Manhattan's Central Park is taken as an object, the great natural gap within the artificial metropolis of New York, which gives great freedom of action to the inhabitants of the city.

Parc de la Villette. Bernard Tschumi. Competition proposal. Axonometric view

In Tachumi's engravings the incomplete reality of architectural representation is evident. Architecture and urbanism representation is not able to contain the inherent complexity of urban reality. This is a graphical criticism of the limitation of our discipline.

Architectural drawing is essentially schematic and contains only picked layers of reality. While many layers generally refer to the ordering of matter to become building systems, on other occasions it delimits property boundaries or the structures of flow of movement within the metropolis. However, at that time architectural representation is rarely used to describe actions, movements, fluxes or social realities. However, every material decision imposed on the city means changes, limitations and conditions to the previous realities.

In 1982 to reinvigorate the abandoned area of the meat market and slaughterhouse of la Villette in Paris an international competition is convened. The brief sought the transformation of almost 55 ha of land into a park. The competition received over 470 proposals and Bernard Tschumi's project is awarded the first prize. This project does not address the proposed park from a landscape disciplinary point of view, but performs a superposition of several complementary layers. It has 35 elements that add called follies placed on the park within a matrix. These elements are designed as attractors of variable contingency. They are places where various actions can happen and to which people will flow with varying intensity at different times. The proposal clearly and aggressively addresses the conception of the city as a variable contingency field of action.

Parc de la Villette. Bernard Tschumi. Competition proposal. Perspective view

The 35 Folies do not respond to a predetermined program requirement on the bidding documents, rather on the other hand the architect designs them as infrastructures that can be activated in different ways in space-time. In fact some of them only recently are being managed as tourist information centers, restaurants or cafes.

Bernard Tschumi's project is a proposal in which the action, its management and the variable density of occupation of the city by the inhabitants marks the strategy of definition of the elements of the park. What matters is not the materiality of each of the 35 pieces, their tectonic, composition or style; what is essential is that they activate the landscape on the proposed new park. They are all resolved with red metal structure as a means of homogeneity within diversity. All of them are different to create different actions. The most important aspect of the project (perhaps what has been more deficient due to its lack of definition) was the activation of the landscape with multiple unspecified activities. To do so, in the manner of the situationist city of New Babylon, the most important thing was the management of activity and the creation of events and actions; the creation of situations.

Another project, perhaps the most transgressor from the 470 that were submitted with the one by Tschumi, was the one developed by the Dutch architect Rem Koolhaas. While the treatment of the territory is closer to the landscape tradition, organizing an allotment in horizontal bands that divide the landscape into smaller elements with a more manageable scale, this project also incorporates greater emphasis on land and activity management. Time and action are essential in both proposals. Activities and temporality are what articulate the decisions of the design and landscape architecture. In both projects the use of geo-

metric tools to organize the elements arranged in landscape is collateral to the actions occurring in the territory. Contingency of space-time stands over architectural composition. What is important is not material, functionality and durability; what matters is how live and the events that make up a particular metropolitan area develop.

The Cartesian matrix used in la Villette by Tschumi to place the elements is used as a method to minimize the impact of geometry. It is a way to downplay geometry. Perhaps inspired by the Lightning Field of Walter de Maria, the grid used to arrange the elements uniformly over the existing territory is the easiest way to provide eminence to the event enabled by the provision of a given material object. The action potential is what is really important for the work. In the case of de Maria's piece, the steel posts on an almost flat territory shall attract lightning during a storm. Our expectation of such an event, our hopes, and the fleeting moment of the shock is the subject of the artwork. All this would be equivalent if the arrangement of the poles is altered. The Cartesian array does not give any value to the work that would not be present in the case of having the same poles randomly placed on the same territory. As in other works of Land Art form is unimportant; it is the action itself and its footprint on the territory, the way it transforms it, what is really important.

In the case of the Parc de la Villette, what matters is not the color of the follies or their form. The important thing is to establish a transformation of the territory that allows the appropriation of the territory by the inhabitants of the city of Paris, establishing a tension between the follies, and thus activating the interstitial territory between them. For that reason it may be why the final work can be attributed to excessive

Parc de la Villette. OMA. Competition proposal. Plan layers

ornamentation in the definition of each of the follies that seem to want to become micro monuments arranged on the park in the mode of ornamental garden sculptures. That was perhaps the criticism that made bring more value in the recent years to the proposal by OMA, which suggested a more vague definition of the territory and a lower definition of architectural detail. However, this value may be due to the fact that OMA's project remains within the realm of non-materialized ideas.

TOPOLOGY

Tashima Art Museum. Interior View. Ryue Nishizawa

Architecture as the Art of Demarcation: Topological Architecture

Most modern architecture does not draw its form from the world out of the topological fluid materiality, but from the rigid meta-world of the ideal, the excessive machinism (naive) and of the dead geometry. This captive world, blind from temporal dimensions, produces an equally blind architecture, an architecture that from the meta-world is projected onto the real world as a leaden fishing tackle in the refreshing river of time. There is simply no hooks or streams that can keep it afloat.

Sanford Kwinter

"Flying the Bullet: or When did the Future Begin." Epilogue for "Rem Koolhaas. Conversations with students" (1996)

If the Special Theory of Relativity written by Einstein in 1905 introduced the change in metrics derived from the relationship between space and time in one indissoluble reality, that places the event as a new existential unity; the General Theory of Relativity, through the principle of equivalence that equates the effects of gravity to those of acceleration, shows that space-time (the environment in which every event happens) is deformable by the action of gravity and curves itself as it approaches bodies. This transformation is a continuous transformation, the bending of space-time does not change the continuity of it, and therefore we can say that space-time is a topological space, as topology is defined as the branch of mathematics that studies the properties of geometrical bodies that remain unchanged by continuous transformations.

So far Architecture has been the art of arranging columns, walls, floor and ceiling geometrically relating these elements to each other. However, from a relativist understanding, Architecture must deal with the wrapping of events. Architecture delimits (traces boundaries) and links various events with each other, events that happen in space-time. This leads us to assume that architectural space should be space-time, or subspaces of it, and therefore, architectural space is a topological space.

From this point of view architecture should be the art of delimitation, of demarcation. Therefore, the boundary between events or between subspaces should now be the subject the architect is dealing with, and in order to understand architecture acts carried out in these terms it is necessary to understand the topological properties of these boundaries.

**SPACE WITH
DISCONTINUOUS
BOUNDARY**

each of the four corners
is an avoidable
discontinuity

**SPACE WITH
CONTINUOUS
BOUNDARY**

there are small
variations of direction
of the boundary at each
point

**SPACE WITH
CONTINUOUS BOUNDARY**

there are small variations
of direction of the
boundary at every point
but the curvature is
smaller and therefore the
local variation is faster

²⁰ It is important to understand that time is a fundamental variable to all topological properties. The same boundary can behave in one way in t_1 and in a different one in t_2

Topological Properties

In order to center the study in the field of architecture this text focuses on five topological properties that are applicable to architectural delimitation of space-time²⁰:

- 1. Enclosure:** it refers to continuity of the boundary in all of its extension and to the cyclic nature of its definition.
- 2. Continuity:** it refers to disruptions that may arise along the boundary.
- 3. Connectivity:** it refers to the connection or disjunction between different spaces.
- 4. Porosity:** it refers to the number of holes on the boundary.
- 5. Permeability:** it refers to the relative size of the holes (in relation with the rest of the boundary)

ENTIRETY CONTINUOUS FUNCTION

at each point there are small variations in the values of the function in the vicinity of point A

1. Enclosure

A space can be opened or closed. An open space is unbounded and propagates itself infinitely, whereas a closed space is surrounded by a boundary that defines its limits. In architecture, urban design and landscape design, the only space that is considered to be open is exterior and public space, even though it is an enclosed finite space defined by the spherical constrain of the geometry of the Earth and its gravitational force. A closed space is defined by a boundary that separates it from another space that is exterior to it. If this boundary is completely contained inside the exterior space, then the closed space is said to be a hole inside the exterior space.

2. Continuity:

Continuity is the topological property of space that influences more directly our experience of architectural space, and thus it is crucial for designers to know what continuity is and how it is defined. In mathematics, a continuous function is defined to be the one that suffers small variations throughout its extension; this means that there are no abrupt changes along its path or surface. Commonly it is said that continuous functions are those that can be drawn without lifting (or stopping) the pencil from the paper. If a function is not continuous is discontinuous. In topology, the branch of mathematics that studies continuous transformations, the easiest way to define continuity is through the definition of the discontinuities that may appear in a space.

Essential discontinuities are those that occur in a point where the function splits in two or more independent functions whose boundaries do not intersect. Holes are one type of essential discontinuities. On earth, a hole appears in the continuum of outer space every time matter is placed in contact with the surface we step on, whether this is the ground or an artificial surface, in such a way that a new boundary appears. From this point of view, a house built in a valley is a hole in the exterior space of the valley, and its walls act as boundaries that define both the interior space of the house and a limit to exterior open space. If we walk along the valley the house is inaccessible and we will need to surround it to keep walking. We will only be able to enter this hole if we have the key to open the door of the house, and when we open it, we will be opening a temporary hole in the boundary that defines the internal space of the house. Lets imagine we keep walking along this valley and that we meet a forest; in this case, all of the trunks of the trees that form the forest are holes in the continuous exterior space that we are experiencing. As a result, we will need to modify our trajectory each time we meet a tree because their trunks do not belong to the space we are traversing. Whenever we build a wall or a column to raise a building we are then interrupting the continuity of external space.

**DISCONTINUOUS FUNCTION IN A.
JUMP DISCONTINUITY**

in the vicinity of point A a jump of
the function is produced (the limit
breaks in two at point A)

A different kind of discontinuities are jump discontinuities, which are those types of discontinuities where the path or surface of a function changes values in a single point or line or curve (in the case of surfaces). The best example to illustrate jump discontinuities is a cliff, where the landscape suddenly falls from one height to another. In our daily life we also coexist with architectural and landscape jump discontinuities such as stairs. A stair is nothing else than the floor that bends itself to gain a small height with each of our steps, as Julio Cortazar beautifully expressed in his poem 'Instructions on how to climb a staircase'.

**DISCONTINUOUS FUNCTION IN A.
AVOIDABLE DISCONTINUITY**

in the vicinity of point A abrupt variations of
the values of the function exist (change of
direction)

'No one will have failed to observe that the floor frequently folds up in such a manner that one part rises at a right angle to the ground and later the next part is placed parallel to it, then giving rise to a new perpendicular – a behavior which is repeated in a spiral or in broken line up to exceedingly variable heights. Bending down and putting the left hand on one of these vertical parts and the right hand on the corresponding horizontal, you shall be momentarily in possession of a "step." Each one of these steps, formed by those two elements, is situated as equally higher and forward as the preceding one, a principle which makes sense out of the stairs since any other combination would produce forms which perhaps would be more beautiful or picturesque albeit incapable of connecting the first floor to the second.

Staircases are climbed from the front since backward or sideways would be particularly uncomfortable. The natural posture consists of remaining in a standing position, arms comfortably at the side, head upright yet not lifted so high that the eyes cannot see the following step, breathing slowly and regularly. You begin climbing the staircase by lifting that part of the body situated to the bottom right, which is almost always wrapped in leather or suede, and that with few exceptions fits exactly on top of the stair. With that aforementioned part placed on the first step (which for convenience's sake we shall call a "foot"), take its equivalent part on the left side of the body (also called a "foot," but do not confuse it with the previously mentioned foot), and carrying it highly, continue forward until it is placed upon the second step so that it rests there, while the other foot rests upon the first step. (The first steps are always the most difficult until you can acquire the proper coordination. The coincidence of the names foot and foot makes the explanation cumbersome. Take special care not to raise the foot and the foot at the same time).

Having arrived at the second step in this form, it is enough to repeat alternatively those movements until you find yourself at the end of the staircase. You can easily leave the stairs with a slight tap of the heel that fixes it in its place, from which it shall not move until the moment of descent.

END

[Cortazar, 1962]

B inside A

B is a hole
(discontinuity) of A

A wrapping B

A is continuous (does
not have holes)

A next to B

A and B are adjacent

A conected with B

punctctual conection.
the conection is a
border (limit) of C if
it is permanent in time
(fixed)

A separated from B by C

A and B are holes of C
(they conect each other through C)

The last type of discontinuity is avoidable discontinuities, which are expressed as a sudden change of the expression of the function in a point or a line. While it is commonly said that in topology a square is equivalent to a circle, this is not completely true in terms of the topological properties of the boundaries that define the circle or the square, as in each of the corners of a square, due to a sudden change of direction, there is an avoidable discontinuity. This might explain the current trend towards the abolition of the corners and the curved edges in the work of certain contemporary architects.

However, this trend to curve the defining boundaries of architectural space is just one symptom of the increasing interest in the topological properties of space in contemporary architecture. It is not only continuity of space what is driving certain practices of contemporary architectural design, but also the way the gradient between continuity and discontinuity can be altered and designed through the definition of the porosity and the permeability of the boundaries of subspaces.

3. Connectivity:

Out of the five topological properties covered by this study, connectivity is the first one that relates to the relationship between subspaces, the relationship between their boundaries, and the properties of spaces and subspaces themselves taken individually. Connectivity is directly related to porosity, as two subspaces will only be connected when at least one hole (discontinuity) exists in their boundaries.

Connectivity, except in punctual connections, is intertwined with the topological concept of adjacency (two regions are said to be adjacent if they have a border segment in common, not just a point) or the

A0 BOUNDARY

CONTINUOUS: YES
 CONECTIVITY: NO
 POROSITY: 0 HOLES
 PERMEABILITY: 0 %

A1 BOUNDARY

CONTINUOUS: YES/NO
 CONECTIVITY: RESTRICTED
 POROSITY: 1 HOLE
 (VARIABLE)
 PERMEABILITY: 4 %

A2 BOUNDARY

CONTINUOUS: NO
 CONECTIVITY: MULTIPLE
 POROSITY: 23 HOLES
 PERMEABILITY: 33 %

A3 BOUNDARY

CONTINUOUS: NO
 CONECTIVITY: MULTIPLE
 POROSITY: 170 AGUJEROS
 PERMEABILITY: 96 %

concept of contiguity (immediacy of something with something else). To measure the degree to which two adjacent spaces are intermingled it is necessary to take into account the topological properties of porosity and permeability of the common border.

4. Porosity:

Porosity is the topological property related to the number of gaps or holes. It is directly linked with continuity, with the property of permeability and with the property of connectivity.

5. Permeability:

Permeability, as indicated above, refers to the relative size of the holes relative to the rest of the boundary. It depends on the degree and freedom of connection between subspaces: the more permeable the boundary of a space is, the more connected the space will be with its adjacent space.

Taking the above described properties of a boundary of a topological space we can assert that:

- Any enclosed space has at least one other adjacent space.
- If a space has a single adjacent space, the first will be a hole in the second.
- If one space is connected to another one, their boundaries should be discontinuous.
- The connectivity of a space with another one is directly proportional to the porosity of the boundary that separates them.

Eyebeam Museum. Diller & Scofidio. Section
bending slabs - connecting levels - stretching space

3.2. Continuous Transformations in Architecture Design

Once the different topological properties have been defined, the actions that can be applied to transform matter in a continuous way can also be described as tools for design. The main continuous transformations actions for design are:

Bending: to bend is to change the curvature of a function (space or boundary).

Stretching / Shrinking: to stretch or shrink a function implies a change of the original length but keeping the topology inaltered.

Connecting: connecting implies a change in the previous topological properties. For example, if we connect two ends of a cord the topology changes by generating a loop and a central hole that encloses an interior space. New connectivity can be achieved by bending or stretching spaces or by cutting and stretching boundaries.

Photo of the construction of the Berlin Wall. Agosto 1961

²¹KIPNIS, JEFFREY "Perfect Acts of Architecture". ISBN: 0-87070-039-1. Museum Of Modern Art, New York. P.14.

OMA: From Urban Disruption to Fluid Continuity

Rem Koolhaas visits the Berlin Wall while studying at the Architectural Association in London and is struck by the reality there contemplated. Then he claims “Neither those in the west or the east side are free, only those trapped in the wall are truly free”. There is no doubt that the deliberation about the properties of the walls, property of division, obsesses the approach to architectural design of Rem Koolhaas, which are dramatically expressed in the project submitted together with Elia Zenghelis, Madelon Vriesendorp and Zoe Zenghelis to the competition for new visions of the city organized by the Italian magazine Casabella in 1972 and that later served Koolhaas as final thesis project: “Exodus, or the voluntary prisoners of architecture”²¹.

Koolhaas’s words around the Berlin Wall condense social reality related to the topological property of separation of walls: on each side of a wall there are different standards of behavior. Surely the words of Rem Koolhaas refer to citizens of East Berlin in search of an act of liberation from the norms of behavior and thought that they venture to cross it and are killed by the guard at the time of maximum freedom in an own act of seeking change, without submission to a particular mode of behavior and without the lethargy due to the material accommodation (of bourgeois west side).

The Stip' in KIPNIS, JEFFREY "Perfect Acts of Architecture". Museum Of Modern Art, New York. P. 17.

²² Prologue to the project 'Exodus, or the voluntary prisoners of architecture' by Rem Koolhaas, Elia Zenghelis, Madelon Vriesendorp and Zoe Zenghelis. In KIPNIS, JEFFREY "Perfect Acts of Architecture". ISBN: 0-87070-039-1. Museum Of Modern Art, New York. PP.16-17.

The project “Exodus, or the voluntary prisoners of architecture” emerges as a derivation from the idea that those who are free are those who surrender freely to the wall:

“Once, a city was divided in two parts.

One part became the Good Half, the other part the Bad Half. The inhabitants of the Bad Half began to flock to the good part of the divided city, rapidly swelling into an urban exodus.

If this situation had been allowed to continue forever, the population of the Good Half would have doubled, while the Bad Half would have turned into a ghost town.

After all attempts to interrupt this undesirable migration had failed, the authorities of the bad part made desperate and savage use of architecture: they built a wall around the good part of the city, making it completely inaccessible to their subjects.

The wall was a masterpiece.

Originally no more than some pathetic strings of barbed wire abruptly dropped on the imaginary line of the border, its psychological and symbolic effects were indefinitely more powerful than its physical appearance.

The Good Half, now glimpsed only over the forbidding obstacle from an agonizing distance, became even more irresistible.

Those trapped, left behind in the gloomy Bad Half, became obsessed with vain plans for escape. Hopelessness reigned supreme on the wrong side of the wall.

As so often before in this history of mankind, architecture was the guilty instrument of despair.²²”

The reception area. Photomontage. In KIPNIS, JEFFREY "Perfect Acts of Architecture". ISBN: 0-87070-039-1.
Museum Of Modern Art, New York. P

²³KWINTER, SANFORD: "Flying the bullet: or when did the future begin" Epilogue for "Rem Koolhaas. Conversations with students". Spanish Ed. Gustavo Gili. ISBN: 84-252-1890-X. P. 66-67. Translation: Ignacio Peydro.

The project “Exodus, or the voluntary prisoners of architecture” is an inhabited wall, a wall within which the patterns and rules of behavior are freely accepted by its inhabitants. Koolhaas intends to establish an architecture that is the antithesis of the Berlin Wall. Inside the wall that divides the city of London opposite principles of those that result of division, isolation, unequanimity, aggression, destruction will be promulgated... all the negative aspects of the Wall (Berlin, shame...) will serve to establish a new paradigm of architectural war in search of a totally desirable alternative life.

According to Koolhaas only those that are strong enough to love what the wall gives to them will be able to volunteer to become prisoners of it. From a stylistic point of view Koolhaas focuses on the symbolism of the project and claims that it is a liberating and self-generative architecture that avoids the creative suffering and masochism of architects. But from a topological point of view, it is actually a project of oppositions, you form part of the wall or you're out. It greatly enhances the quality of separation of the wall and takes advantage of the only two access points, one north and one south, to incorporate two neoclassical porticoes that symbolically mark the only two holes (discontinuities) that give access to Koolhaas's ideal city.

The project consists of various sectors which are related to the type of activity that takes place in them, linked in some way – or winking to – Constant's New Babylon city project. Although it is not interesting from the point of view of this thesis to look at the architectural details of the various sectors of the project, it is interesting that each type of event or use corresponds to a given topological type of container (each sector is a square).

'Strip'. Photomontage. In KIPNIS, JEFFREY "Perfect Acts of Architecture". ISBN: 0-87070-039-1. Museum Of Modern Art, New York. P. 19. Notice how the wall divides the city of London in two parts (as in the case of the Berlin Wall). There is also a certain historical symbolism and sarcasm to select London as the recipient of the anti-wall (as opposed to the Berlin Wall).

²³KWINTER, SANFORD: "Flying the bullet: or when did the future begin" Epilogue for "Rem Koolhaas. Conversations with students". Spanish Ed. Gustavo Gili. ISBN: 84-252-1890-X. P. 66-67. Translation: Ignacio Peydro.

What actually interests Koolhaas is what happens inside the wall and how what happens in each of the sectors is related to what happens in the other. In other words, what matters to Koolhaas are the events in space-time or to “([Koolhaas] takes the actual flow of historical conditions as its privileged matter of architecture (not the usual domain of architecture, masonry, stone and glass)” – as Sanford Kwinter says – “and he works on it, he adapts it, through transformations and deformations to generate and forge its (architectural) form.”²³

Sanford Kwinter refers to ‘transformations and deformations’ of the topological properties of the architecture of Rem Koolhaas. He begins with an interest in the separation properties of the wall, and according to this he experiments making a project that emphasizes the property of separation, impermeability, insulation, and yet contains within it a set of actions that highlight the opposite of what has historically the wall represented. It is a poem: the antiwall.

But soon Rem Koolhaas begins to be interested in manipulating the topological properties of architectural elements, and instead of emphasizing the division and the difference – even when actions of extreme freedom are placed inside the boundaries of restricted space – he begins to look for continuity, fluidity and permeability in urban life. In this way, we discover that in the project for the ZKM the whole stacking of uses is wrapped with a continuous spiral that winds and connects the street around the building.

As it happened in Beabourg, the ZKM building is a stack of containers, more or less neutral that allow hosting a variety of changeable uses, that connects with the street level only at the points of access and landing of stairs or ramps. Rem Koolhaas is aware of this restriction imposed by architecture, where the

Photo of the model for the competition project for two libraries in Jussieu University in Paris, El Croquis N° 53+79, P. 120

architect sets a connection in a boundary or wall the recurrent action of stepping from one room to another occurs. In a connection point (a door) fluency does not exist, it is a constraint of space-time.

Therefore, in the 1992 Rem Koolhaas in his research on the topological properties of the boundary makes a subsequent experiment that involves a radical change in the conception of public space (space-time with unrestricted access) in the project for the two libraries in the Jussieu University in Paris.

Architectural orthodoxy seems to mark that, except for strict use requirements (auditoriums or theaters), floors, placed one above the other, must be horizontal, with the exception of ramps or stairs (formerly also roofs) which are elements that allow the connection between floors. Rem Koolhaas, interested in extending the public space inside buildings, as many others had been since the birth of the Situationists discipline of unitary urbanism, the project for the two libraries at Jussieu University in Paris, performs a topological transformation of this architectural principle of orthodoxy. He cuts, folds and connects all the floors of the building... suddenly everything becomes one same thing, ramps are not only ramps nor floors are just floors, everything is ramp and floor at the same time. As in the city where streets are not always horizontal and adapt themselves to topography in order to ensure continuity, in this building the floors warp and fold themselves to ensure continuity of space-time inside the building. You can enter the building and walk through it up to its coronation in the same way you would do in the city, as if the city had twisted upon itself. You can practice the drift (Situationist *Dérive*) in this building. 'Happenings' (Situations) could also happen, events that occur inside of it would simply change with the relocation of furniture, but, unlike what happened in Beaubourg (where each floor was independent from each other), the continuity of this building

Photo sequence of the process of folding and connecting the floor slabs upon each other in the project for the two libraries at the University of Jussieu in Paris, *El Croquis* N° 53+79, P. 118-119. Note the lack of vertical scale and the non-correspondence with the final geometry. With this critical documentation of the architectural competition OMA is trying to strengthen are the topological properties of the building: its continuity and internal connectivity.

allows events to get linked dynamically upon each other without any constraint (only the total floor space of the building will condition the actual versatility).

Although space-time continuity is achieved (partially) inside the building as can move around it with freedom of movement, free from the punctual constraints of prior buildings, there are many avoidable discontinuities (in the terms stated in the section dedicated to the topological properties of boundaries – BTP – in this paper). There is an avoidable discontinuity at each edge, at each intersection between the floor slabs, and Rem Koolhaas is aware of this. This avoidable discontinuities are assumed as a lesser evil of this project, he knows that much has been achieved. However, later on OMA applies the principles of topological continuity not only to the space-time continuum of the building, but to the membrane that contains it as well. In the Educatorium in Utrecht, although it is not intended to achieve the degree of continuity in the vital experience of the building as the one of the project for the two libraries in the University of Jussieu in Paris, Rem Koolhaas merges floor, wall and ceiling (elements that classically define a room) in a continuous material boundary that encloses space-time. He simply understands floor and ceiling planes as a single thing, as he had done in Paris through folding, but in this case he curves the single material boundary upon itself, just as space-time curves by the action of gravity, thus making the avoidable discontinuities disappear.

Sharing the interval of time with the discoveries about the topological continuity of the boundaries of a building and its implications for space-time continuum that it surrounds achieved in Koolhaas's office through experimental architectural projects, several collaborators of the Office for Metropolitan Architecture (OMA) become independent and established their own offices. There they will work on the basis of the

VPRO Villa photo (Hisao Suzuki), El Croquis N° 86, MVRDV P. 92-93

knowledge gained in OMA and transformation and manipulation tools of the architectural boundaries inherited from Rem Koolhaas will be applied, sometimes as a stylistic tool and other as a possibility to deepen in the understanding of the topological properties of the space-time wrapped by architecture.

Thus a common line of research arises, a ramification of the discipline of architecture associated with Koolhaas's vision of post-situationist urban reality. In VPRO villa, MVRDV uses the tool of folding and curving horizontal boundaries in a less coherent and less radical way than Koolhaas, mixing different families of relationship between uses such as stacking, continuous boundary and diagonal relationship through double heights.

On the other hand, Alejandro Zaera and Farshid Mousavi will continue a radical and theoretical research of the possibilities of relations, growth and separation of the curved and folded architectonical boundaries. The Möbius strip, which is the paragon of cyclical continuity, will serve as a research basis to their design team. In the project for Cineplex multiplex cinemas in Tehran FOA (Foreign Office Architects - name of the office of Zaera and Mousavi), they performed a study of the possibilities of material relations between different uses through multiply curved surfaces. The roof of the Yokohama International Port Terminal is used to research on the possibilities of continuous translation on space-time between different levels. But it is maybe in the Virtual House, a thematic project, where they more radically delve into the possibilities of systematic continuous growth of the architectonical boundaries according to the scalar needs project.

Seandai Mediateque sketch. Toyo Ito: 'Blurring Architecture' Catalogue for the exhibition at the Suermond Ludwig Museum in Aachen from October 1999 to January 2000. P.102.

²⁴ It should be taken into account that more than 20 years have passed since that definition, and therefore the thinking of Toyo Ito may have evolved. However, it serves for its clarity and duality, as a reference to support, such as a compass, heading on the path of the analysis of his approach to architecture.w

Toyo Ito: Between Fluid Urbanity and Architectural Tradition

As a starting point let's take the description of architecture given by Toyo Ito (1991)²⁴ :

"I think that in architecture there are always two contradictory actions and that they face each other. On the one hand, it has a function that is oriented toward a fluid space that corresponds to the actions of people who are changing constantly, the other one is the function that is oriented toward the still monument, setting architecture forever. The first claims that architecture remains a metamorphosis in which meanings are formed later, while the second, by contrast, aims to fully immerse themselves within the system of meanings that already exist, constantly trying to incorporate them into the stable order."

Seandai Mediateque sketch. Toyo Ito. 'Blurring Architecture' Catalogue for the exhibition at the Suermond Ludwig Museum in Aachen from October 1999 until January of 2000. P.103.

Systems and models. paths and artifacts.

Toyo Ito is one of those architects, who in the manner of Walt Whitman, are vast and contain multitudes, and that are not concerned with the fact that someone may blame those contradictions. Toyo Ito is looking for answers to his questions, he does no longer believe in the stable architecture that settles under the light. Even though he acknowledges the inclusion of our discipline into the tradition of tectonics, which conditions it and sometimes gives meaning to his architecture, he is eager to find new interests that transcend this tradition. In order to find answers to the doubts posed by his intuition, he is aware that experimentation is necessary. He simultaneously traces with his thought and practice multiple complementary research paths, which can cross or intertwine, but separate paths of interest in the end. Ito traces those paths through the generation of architectural systems of growth that allow for universal expansion beyond a unique crystallization of a single building. In this sense, every building belonging to a particular family of thought (embedded in a path) is taken as a prototype first and as a model afterwards. We could say that each building is the artifact that Toyo Ito uses to move along each path or trajectory; each building constitutes the possibility to evolve within certain thought or interest.

White U. Preliminary sketch

²⁵ Translation from Spanish by the autor.

Boundaries and space-time: topology as a tool

“So we can build an architecture that allows a fluid program, would not be necessary to reconsider from the beginning the concept of boundary”

[...] “What we need now is that thought itself builds softer and diffuse contours. Does the concept of boundary resemble to an osmotic film that does not separate the inside from the outside? We, who have lived before in the spaces only divided by shoji and fusuma, are able to imagine a limit that transparents itself and allows air to pass among the external and internal spaces. When we get to think of architecture that has loose boundaries, without such evident contrast between both sides, front and back, inside and outside, and me and another person, an architecture with a wide universal view appears.”²⁵

Toyo Ito (1996)

Toyo Ito repeatedly refers to the concept of boundary (limit) and expresses his concern with the confrontation between tectonics and the flow of events that happen within architecture. This concern drives him to try to avoid the packing of the actions of people inside the walls of buildings, a packing that causes those actions become isolated from each other. One of the key objectives of his research trajectories corresponds with his desire to reach the diffusion or dilution of the boundaries of buildings. For Toyo Ito to get an architecture where the boundaries are not precisely defined means to achieve a transcendental goal, a vision of universal scale.

Exterior view of White U. Tokyo. 1974. Toyo Ito. 'Blurring Architecture' Catalogue for the exhibition at the Suermondt Ludwig Museum in Aachen from October 1999 to January of 2000. P.62.

We must remember that topology has its origin in the study of limits and that boundaries and its properties are the main aim of the discipline. If we examine Toyo Ito's writings we will find a glossary of terms that are used repeatedly; terms such as boundary, connectivity, open system, diffuse border, fluid architecture or fluid of actions (or events), which show that Toyo Ito has the knowledge of two complementary scientific theories or fields of study, on the one hand the theory of relativity (fluid actions/events) and on the other, the knowledge of the discipline of topology, holding a deep understanding of both its definitions and the way it performs. This proves that for Toyo Ito three-dimensional spatial reality has been replaced by space-time reality and space-time, a space with topologic qualities, a space that is malleable and that experiences changes due to the state of motion and the action of gravitational fields, is the material to be shaped by his architecture in the path that drives the search for the dilution of the boundaries of architecture.

The first project in which Toyo Ito performs a topological transformation of Cartesian space is White U, the house that he designs in Tokyo for his sister in 1976. This is a house where the living room serves as articulation between the private area of the bedrooms and the service area and kitchen. To avoid the need to go through the hall to access the kitchen and give continuity to the housing, Toyo Ito doubles the initial scheme until the ends are connected, leaving a central courtyard (outdoor space wrapped by the house) and enhances the dynamic character of the main space of the house through its curvilinear definition. White U is the product of bending a linear house scheme to connect both ends to enhance connectivity and change the way the dweller may experience the inside of the building.

column structure

each column is a
discontinuity (hole) of
A

**space/column
topological
relation**

the interior of each
column is a subspace
(filled with matter)
contained in A

sendai mediateque

in Sendai mediateque the
interior of each column
is stretched until it
reaches the right size
for each contingency
that will be placed
inside

Returning to the first description of architecture given by Toyo Ito, the Sendai Mediatheque illustrates the duality between the stability of existing architectural language and the containment of the fluid of events. This is present in the first sketch of the building where we can clearly be aware of the duality of intentions, on one hand the flow of people and their activities, on the other the use of pre-existing architectural language, of tectonic tradition, which gives permanence to buildings (materialized in these drawings through the clear horizontal lines representing the floor slabs).

The Sendai Mediatheque is an intermediate case between the initial projects of Toyo Ito, more linked to the architectural traditions of orthodox modern movement, and the system of space-time appropriation of the project for the Music Center in Ghent (that I would discuss later).

The remarkable topological performance of the Sendai Mediatheque is the topological transformation of Le Corbusier's Dom-ino structural system: the pillar is inhabited and acts as an attractor of new events; it becomes a new condenser of uses. Unlike in other architectural projects where space is freed for events, taking structure, vertical communications and facilities to the perimeter of the building, such as in the Pompidou Center in Paris (Beaubourg), Sendai Mediatheque assumes the discontinuity that results from the orthodox (modernism) structural grid in order to distort the size of the discontinuities and introduce into them both vertical communications and facilities. This generates, as sensed in Toyo Ito's initial sketches of the project, forces of attraction or gravitation on how to use each of the levels of the building.

Emerging grid: the schwarzschild void grid

Toyo Ito in a descriptive book of the design systems used as a medium of tracing trajectories of architectural research, he begins the book with a system called 'Emerging Grid'. 'Emerging Grid' is a space colonization system that consists of a single two-sided surface that configures two continuous and polycentric spatial subsets. This type of space has the quality to match the structure with the spatial structure, thus the classic architectural triad of walls, floors and ceilings disappears merging into a single tectonic surface. As a consequence, the original intentions of the Sendai Mediatheque, where the flow of events was introduced into the structure activating it as an attractor of events, is enhanced to the point where the structure and the fluid of events are blending into a single material reality.

In order to fulfill Toyo Ito's intention to dilute the boundaries of architecture and the fluid of events, the geometrical formalization of each unit of the 'Emerging Grid' matches the geometrical representation of a black hole in the Schwarzschild metric. Karl Schwarzschild was a German physicist who geometrically formalized Einstein's general theory of relativity. The Schwarzschild void (or Schwarzschild black hole)²⁶ is defined by the Schwarzschild radius corresponding to the radius of the horizon of events (in a non-rotating black hole). Toyo Ito uses the Schwarzschild void due to its topological properties of continuity in three dimensions, as it is one of the only geometrical functions that can expand uniformly simultaneously in three directions. Once the grid of multiple Schwarzschild voids is set, the next step is to transform the size of each unit through continuous transformations (stretching and shrinking) in order to meet the programmatic requirements of the building.

Toyo Ito. Taichung Metropolitan Opera House. Photo of the model. A+U Architecture and Urbanism number 472 P.23.

The repetition in matrix of the geometric form of the Schwarzschild voids and its subsequent adaptations to the unique topology of each version and each project, shows that Toyo Ito is aware of this scientific knowledge, which is used by Ito as a tool for linking architectural advancement and evolution to the progresses in the knowledge of reality through other disciplines different from architecture. With this attitude, the balance that defines architecture in Toyo Ito's point of view (fluid of actions and architectural tradition), turns towards the side of the definition of a new way of providing a place for the acts of humanity, not related to the articulation modes of finite architectural elements, but linked to contemporary understanding of the fluid boundaries of events happening in space-time. Matter now dances continuously in space-time enfolding our lives and our activities.

In the case of the Berkeley Art Museum instead of using a grid of black hole like continuous surfaces as in Ghent and Taichung, Toyo Ito transforms of a traditional grid that has its origin in the repetition and intersection of parallel and perpendicular walls. Multiple repetitions of parallel walls in two perpendicular directions is a timeless exercise of space subdivision that generates independent rooms that are classically used as both living and transitional spaces. The connectivity of rooms in this kind of space subdivision depends on the number and position of doors that connect the spaces. In a building that is generated by this classical system, from Versailles Palace to Almere Kunstlinie by SANAA, in order to generate a flow in one direction doors have to be placed in the two walls that are perpendicular to the flow. In the Berkeley Art Museum Toyo Ito alters this necessity to open doors by bending and stretching the edges of the rooms, by transforming the topology of the boundary that defines the rooms.

Berkeley Art Museum by Toyo Ito.
Geometry of walls: Curvature radius on corners establish the different connectivity gradients

Berkeley Art Museum by Toyo Ito.
Axonometric view of walls and rooms + diagram showing the topological transformation of the wall grid

Even though the Berkeley Art Museum and the SANAA project in Almere are both defined by a grid of walls, the connectivity between rooms is completely opposite. While in Almere the architects assume the disaggregation of spaces in gridded systems, in the case of Toyo Ito's project the connectivity of the whole is deeply altered. Although the grid is maintained in the Berkeley project, the need to open holes in the walls in order to provide connectivity disappears. This is a consequence of the connectivity between spaces produced in the corners, which is attained through the bending of the walls that define the boundaries of the rooms.

Serpentine Gallery Pavilion. Sketch. SANAA

Kazuyo Sejima and Ryue Nishizawa (SANAA):

The material becoming of architectural diagrams

Kazuyo Sejima graduated from Tokyo Women's University in 1981 when she starts working in Toyo Ito's office until she opened her own office in 1987. Although certain direct formal influence can be located in the first houses (Platform I and II houses) that she made right after establishing her own office, there is a reinterpretation of Ito's interests in her later work that it is purified towards a more refined and personal focus of certain aspects of architecture. In 1996 she opened SANAA (Sejima And Nishizawa Associated Architects), a new office in partnership with Ryue Nishizawa that has been developing the bigger and more complex projects that have been commissioned to the architects. Some of the smaller projects have been developed independently by each partner, letting each of them explore their own interests. The dialogue between the two architects generated a richer evolution of the previous interests of Kazuyo Sejima that ultimately lead to the sophistication of their latter work. The quality of greater sophistication in the work of Sejima and Nishizawa is the refinement towards the essential. Their architecture tends to a conceptual schematic, but this schematic requires a great technological and tectonic effort when performing the transposition into the realm of the material, when the variables of the real exert their action on ideas. This eagerness for purity is carried out in the various paths of their architectural research, from those in which the arrangement delve into program variables within the architectural tradition, as in the cases in which the manipulation of the topology of matter is the cornerstone of the project. In this latter case, their architectural design research digs into the exploration towards the understanding of continuity of space and the way architectural matter

Villa in the forest. Plan. Kazuyo Sejima

interrupts this continuity. In some projects (as we have seen in the Almere project example), Kazuo Sejima assumes the disruptive quality of matter placed over ground; we can interpret that she assumes that spaces are subdivided by architecture and she works in the relation between the multiplicities of independent spaces within architectural tradition. Projects such as the Almere Kunstlinie, the Kanagawa Art Museum, the New Museum in New York and the House in a plumb grove among others belong to that research path. Nevertheless, there is another research trajectory that deals directly with the subject that this research focuses on: architectural topology. The exploration starts with the Villa in the Forest and follows with the Toledo Art Museum Glass Pavilion, in which (together with the Arne Jacobsen installation) the exploration on continuous transformations is expanded to the surface of a transparent material membrane, and reaches culmination in the Rolex learning center in Lausanne. This project will finally open a new methodology for architecture design that is directly linked with the topological design tools of stretching, bending, shrinking, opening holes and connecting. This methodology has been extensively used in the projects that have come after the Rolex Learning Center and still drives many of the ongoing projects.

Villa in the Forest

The Villa in the Forest is located in the Nagano prefecture, two hours away from Tokyo to the northwest by car. The house is organized around two circular structural concrete walls whose centers are displaced to break the centrality of the interstitial space between the two walls. The inner circle, whose centrality is inevitable due to the geometric properties inherent to its geometry, contains the tearoom, a place for rest and contemplation that is closely linked to the Japanese tradition. The tearoom acts as a hole in the space surrounded by the outer wall, which is transformed into a space whose nature is essentially dynamic due to

Villa in the forest. Plan. Kazuyo Sejima

the displacement of the centers of the circumferences that define the two walls. In this space the non-static transitional uses are housed and the perception of the space is accelerated towards those places where the dimensions of the space enclosed by the two walls is reduced. Around this area, the various static uses are connected independently, creating an open concatenation of ways to use the house. Each room intersects perpendicularly to the wall, opening holes in it, disrupting its dynamism and allowing a direct connection to the circulation ring of the house. While the topology of the house is similar to the one of White U by Toyo Ito, a project in which uses are arranged around a central space producing a centripetal dynamic circuit, in Sejima's Villa in the forest the dynamism and continuity of the space is enhanced by purifying the centripetal space and by placing all of the specific uses of the dwelling in independent units that connect directly to this annular space.

Glass Pavilion for the Toledo Art Museum. Plan. SANAA (Kazuyo Sejima + Ryue Nishizawa)

Glass Pavilion for the Toledo Art Museum. View from the inside of the interstitial space that connects the different rooms. SANAA (Kazuyo Sejima + Ryue Nishizawa)

Glass Pavilion for the Toledo Art Museum

In the Glass Pavilion project for the Toledo Art Museum (Ohio) Sejima and Nishizawa make a topological reinterpretation of the grid architecture, where the various functions are located in separate spaces arranged in a rectangular grid. While in Toyo Ito's Berkley Art Museum the reinterpretation of the rectangular grid was made by topologically manipulating the opaque walls that enclose each of the uses, in the case of the Toledo pavilion, two complementary levels of perception are superimposed: the visual and the tactile. From the point of view of visual perception, the Toledo project seeks continuity between all the inner and outer spaces, interrupted only by the reflection of the glass, which constantly changes according to the lighting conditions. However, on the tactile or translational level each use is contained in a separate space. To connect these spaces Sejima and Nishizawa draw on a skillful reinterpretation of massive walls structures. In the same way that in Toyo Ito's Sendai Mediatheque the pillars of the Domino system are inhabited, in the glass pavilion at the Toledo Art Museum the spaces that in stereotomic architecture are occupied by stone walls are now inhabited. The duplicate lines in the drawing no longer represent the thickness of a stone wall that disrupts the space but represent almost visually imperceptible glass membranes, which delimit the spaces that connect the different rooms.

Rolex Learning Center in Lausanne. Plan. SANAA
(Kazuyo Sejima + Ryue Nishizawa)

Rolex Learning Center in Lausanne. Exterior View. Detail
of bended structure connecting the exterior campus with
the interior courtyards. SANAA (Kazuyo Sejima + Ryue
Nishizawa)

Rolex Learning Center

The culmination in the manipulation of topological properties of matter in architecture in the work of Sejima and Nishizawa occurs in the project for the Rolex Learning Center at the University of Lausanne. The project is fully understood by Sejima and Nishizawa as a continuous topological space that is altered by a set of external forces to the program itself. Thus, the space of the learning center undergoes various topological transformations in order to react variables such as the connectivity with the surrounding urban environment and light and ventilation requirements. The space bends and stretches to allow the flow of people accessing the interior courtyards, which are opened and manipulated in the original space as a response to the dimensional and lighting requirements of the program inside. The project is fully designed as if the architects were dealing with a rubber object that could be freely stretched, bent and manipulated.

In the Lausanne project Sejima and Nishizawa become aware of the poetic potential that has to understand architecture as the topological manipulation of space-time continuum, that fluid space of life events that Toyo Ito referred to in his writings. From this time onwards, Sejima and Nishizawa have been addressing most of their projects from this point of view in some extent, showing that they have indeed assumed the relativistic properties of space. From the pavilion for the Serpentine Gallery in London to the Grace Farms project or the Tashima Art Museum, they are all projects that use the same design tools that had been employed in Lausanne. Since then, they have approached the definition of matter in their architectural projects as elastic bodies that are bent and stretched with the freedom of a child playing with a ball of clay.

Architecture as air (12th Venice Biennale installation). View of the collapsed structure. Junya Ishigami

²⁷ Fragment of the interview between Magali Elali and Junya Ishigami in February 2013

²⁸ Toyo Ito worked in Kiyonori Kikutake's office before opening URBOT (first name of Ito's office) in 1971.

Junya Ishigami: Disappearing Architecture

-Junya Ishigami: *Architecture is not about creating buildings. It's a philosophy [...]*

-Magali Elali: *What do you enjoy the most? Making architecture or making furniture?*

-Junya Ishigami: *Making the world*²⁷

Junya Ishigami was born in 1974 and graduated from Tokyo University of Fine Arts and Music in 2000. He works for four years in SANAA before establishing his own practice. Even though I have done no reference until now, the three generations of architects that are being studied in this research, are heir to a fourth previous generation²⁸: the generation of Metabolism. Metabolism has always been classified as an architectural practice linked to technological utopia. From Reyner Banham in his 1976 book “Megastuctures. Urban Futures of the Recent Past” to Rem Koolhaas in his recent book “Project Japan: Metabolist Talks”, all the critics who have written about Metabolism agree that they should be considered as a group of architects that rely on technology applied to architecture to improve the world. Junya Ishigami belongs to that lineage of architects. Ishigami believes in architecture as a tool for transforming the world; architecture should not be restricted to the art of tectonics, to the art of building. While it is necessary to master this discipline to transcend into the real what initially is born in the diffuse nebula of imagination, architecture is philosophy in the sense that it deepens in and transforms the way in which human beings live; the way we inhabit the world. That way of living and inhabitation is constantly evolving and should avoid stagnating itself in the pre-conceptions that have been acquired through our cultural heritage. For Ishigami, as for many other archi-

fects – especially those who are loosely termed ‘utopian’ – architecture is a superior metaphysical discipline that has the power, not only to understand the world as is given to us, but it is able to transform it towards its evolution and improvement.

From the point of view of this research, Ishigami is aware of the topological qualities of matter, especially the capacity of matter to interrupt the continuity of space-time when it is arranged in it. For this reason, much of his work focuses on the obsessive exploration towards the disappearance of architecture; disappearance in the visual sense, and disappearance in the physical sense: if we perceive less matter, if we dilute the physical presence of architecture, the events that happen inside it can flow with a greater amount of freedom, in a more akin way to their natural state in the space-time continuum of the cosmos to which we belong.

In his first project, the KAIT workspace for the Kanagawa Institute of Technology, Ishigami explores the phenomenological dimension linked to the physical presence of the structure. If in the Sendai Mediatheque Toyo Ito topologically transformed the pillars to make them inhabitable and Sejima and Nishizawa dematerialized the grid of walls in the glass pavilion for the Toledo Art Museum, in this case Ishigami blurs the boundaries between structure and livable space. In Kanagawa everything is space and everything is structure at the same time; they become simultaneous events; there is neither duality nor separation between the two levels. The space completely inhabits the structure (not only in the auxiliary uses) and the structure reacts to the contingency of space, to the set of possibilities of action that space contains within it.

KAIT workspace for the Kanagawa Institute of Technology. Furnishing sketch. Junya Ishigami

To do this the structure is atomized and subdivided into infinitesimal units, pillars are no longer stretched from the inside and transformed in a continuous way maintaining their hierarchical presence in space as it was done in Sendai, but they are exploded into pieces, spreading their presence to the whole space. Once this dispersal strategy has been assumed, Ishigami manipulates the presence of the pillars as if he was dealing with a constellation or a forest, a place where the trajectories of events vary when they flow within their presence. In fact, in his book 'Junya Ishigami - Another Scale of Architecture' published in 2011, Ishigami reveals how, due to the similarity of the structure of the pavilion with the trees that form a forest, the tools of defining their position in space are more related to landscape than to the hierarchical orders of architecture. For Ishigami the pavilion for the Kanagawa Institute of Technology is an environment, a landscape strewn with light steel bars that will be avoided when inhabitation occurs and that define the possibilities of the flow of events that happen inside.

Following this line of research, Ishigami makes two projects for two consecutive Venice Biennales, the eleventh and twelfth, held in 2008 and 2010. In this paper I will focus on the one made in 2010, called 'Architecture as Air' where Ishigami performs an installation that extremes the material conditions of compression structures to their limits. If the fragmented structure of Kanagawa merges spatiotemporally the livable space with the structure, the installation in Venice performs an uninhabitable space that is bounded by a network of imperceptible tensors that delimit and contain it. The installation is performed as material poetry in order to reveal the ability of matter to interrupt the continuity of space-time.

Architecture as Air. Installation for the 12th Venice Biennale. General view. Junya Ishigami

Mile of String. New York. 1942. Marcel Duchamp

During Sleep. Kunstraum Maximilianstrasse, Stadtforum München. 2000. Chiharu Shiota

Ishigami's installation for the 12th Venice Biennale can be understood as a reinterpretation of 'Mile of String', the installation made in New York in 1942 by Marcel Duchamp for the retrospective exhibition of Surrealist painters curated by André Breton. In this exhibition Duchamp colonized the exhibition space with a web made of a mile of string. By doing this the exhibition space ceased to be inhabitable, and therefore could not be visited by the public anymore, who should observe the exhibited works from the outside; only a few children were able to go between the strings into the room. The exhibition ceased to be a place that showed art works made in other time to become a unique event in space and time. This work, which delves into the same principles of disruption of space-time by matter that Ishigami is concerned, has been reinterpreted as well by other contemporary artists. In 2000 Chiharu Shiota performed an installation in Stadtforum in Munich that consisted in a room full of beds (in one of which the artist was lying) that was colonized by a web of black thread, thus limiting the movement within the space. Thereafter there are multiple reinterpretations of such action, both by her and by other artists. Of particular interest to this research, is the research conducted by the Chilean artist Tomás Saraceno around spider webs and their laws of growth in space.

The core research in Tomás Saraceno's works (who has been trained as an architect) focuses on the properties of space-time, and his vision on creative references focuses simultaneously in multiple areas, from the ideas of Buckminster Fuller to multiple natural events. Saraceno, which makes a previous scientific investigation based on the laws of growth of spider webs, is interested – as expressed on his visit to MIT last November of 2012 – in the topological properties of the spider web and the correspondence of that topology with the geometry of the universe. For that reason, his installations interrupt space, not only from the translational point of view but also visually, to allow their inhabitation in order to enable phenomenological

Galaxy Forming along Filaments, like Droplets along the Strands of a Spider's Web, 2008.
 Venice Art Biennale. 2009. Tomás Saraceno.
 Photo by Halvor Bodin.

Architecture as Air. Installation for the 12th Venice Biennale. Structural detail. Junya
 Ishigami

experience by the visitors, who can then may start to comprehend the topology of the performed web structures.

Junya Ishigami (who should know the work of Saraceno displayed a year before at the Venice Art Biennale) however focuses on the dual separation between tactile perception and visual perception. If in the glass pavilion for the Toledo Art Museum (Ohio) Sejima and Nishizawa physically manifested the topological duality between what the eye sees and what the body senses through the use of glass, in the 2010 Venice installation, Ishigami uses the resistant properties of carbon fiber to blur the visual boundaries of the space. In Ishigami's work there are no reflections that betray the demarcation of space, but instead it is necessary to cordon off the perimeter of the installation to prevent visitors from stumbling unexpectedly with the carbon tensors (that would not only might made the structure the collapse, but also produce cuts on the bodies of the visitors).

In another project (perhaps less architectural due to the lack of program or use beyond display) made for the exhibition 'Space for your Future' organized at the Tokyo Museum of Contemporary Art, Junya Ishigami takes to the limit his intention of disappearing of architecture in the space-time continuum. "Balloon" is a non-orthogonal aluminum prism that floats in the exhibition hall. The structure that weights a ton contains the exact volume of helium to counteract the effect of gravity on the mass of aluminum. This project is a clear reinterpretation of "Cloud 9" project in which Buckminster Fuller proposed spherical structures (also manufactured in aluminum) that had a volume of air large enough to enable their levitation in the air due to the pressure difference between the inner air and the outer air. The pressure difference is produced by the

Balloon. Detail section (cropped). Junya Ishigami

Cloud 9. Photomontage. R. Buckminster Fuller

heating of the inner air, that is a consequence of the impact of solar radiation on the surface of the spheres.

Once again Ishigami's work matches the references of Chilean artist Tomás Saraceno, who has also recently made a reinterpretation of Cloud 9 in his project for the 'Museo Aerosolar'. In this case, Saraceno understands the physical principles of Fuller's proposal and performs a clever variation of the construction material. Instead of using an aluminum structure, identical to the one used by Fuller in his geodesic domes subdued to the action of gravity, he uses a cheap material resistant to stress (the force that pneumatic structures must support): supermarket plastic bags. By joining the bags together, Saraceno (together with groups of local artists) creates a gigantic plastic bag whose inner air is heated by the sun, making it levitate in the air and interact with the wind that will eventually transport it to other locations.

In the case of the Ishigami installation at the Tokyo Museum of Contemporary Art the intention is not to provide a solution to a nomadic city such as in Fuller's project, but the non-inhabitable volume reflects the purpose of showing the possibility of levitation of architectural matter over our heads. Ishigami creates an unusual phenomenological perception, the structure is not anchored to the ground anymore because the need to support its own weight has disappeared, as the role for support has been relegated to the volume of helium that naturally exerts vertical pressure on the structure. Therefore, the structure no longer interrupts inhabitable space, even when the properties of space are constrained and transformed under the aluminum volume. This opens up a new dimension to architecture: the possibility of covering spaces without interrupting its continuity, the possibility of transforming the environmental conditions of the spaces in which the events occur without having to deal with gravity to perform this operation.

Museo Aerosolar. Tomás Saraceno et al

Balloon. View of the installation with Junya Ishigami looking up

"La Nube". ETFE floating structure to cover the Plaza de Maria Pita in La Coruña, Spain. DOSIS (Ignacio Peydro + Isabel Collado)

This new anti-gravitational dimension of architecture, which is linked to 1969 Archigram's utopian proposal for 'Instant Cities', is inadvertently developed in an almost contemporary time by two Spanish architecture offices. On the one hand Dosis, of which the present writer is a member, proposes to La Coruna City Hall to cover the Plaza de Maria Pita, the central square of the city, with "La Nube (The Cloud)", a gigantic pneumatic structure made of transparent ETFE and inflated with helium, allowing the one hectare space to be used for events, as is usual in the city, regardless of the weather conditions of each moment. "La Nube" is responsive to the needs of the moment, being able to alter its relative distance to the square to change the environmental conditions of the covered space. In addition, the transparent quality of the cloud surface enables it, not only to protect the square from rain, but also to alter the thermal conditions if necessary, by costlessly heating the air of the square due to the greenhouse effect produced by solar radiation. On the other hand, two years after the office AMID / Cero 9 presents his proposal "Golden Dome" as part of the exhibition "Architectural Environments for Tomorrow" also held at the Tokyo Museum of Contemporary Art. "Golden Dome" is a pneumatic dome to cover events that are held outdoors. What in Ishigami's installation is approached as a poetical alteration of the gravitational conditions of architectural matter (as a reinterpretation of the ideas of Buckminster Fuller), it is brought to full complexity of urban life and architecture by the two Spanish offices. The actual incorporation of the complexity of architecture shows that weightlessness is a technologically achievable property of architecture that will empower greater continuity in space-time, which will ultimately maximize the freedom of flow of events as announced by Archigram. The time to release urban events from the burden imposed by weight has arrived... today is possible.

樹木の集まり方によって森林の環境構造ができあがると、柱と梁の配置と集合のしかたによって、この建物のなかに多様な環境の原型が形成され、この建物の空間構造がたちあがられる。

Just as the structure of a forest environment is formed by how the trees are grouped, prototypes for various environments are formed according to how the pillars and beams are positioned and grouped, shaping the spatial structure of the building.

070 | Forest

新築環境林の森林構造。a) 5m 高さ—風が通らず日光も入らない。b) 10m 高さ—風が通るが日光も入らない。c) 20m 高さ—風が通るが日光も入らない。
Structures of forests in various land protection woods. a) High-density forest. Blocking out both wind and sunlight. b) Thinned forest—A small amount of light enters through trees in various stages of growth. c) Open type—Abundant sunlight and free passage of air.

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Conclusions on topology

The text in this section has provided evidence, not only that there is a correspondence between architecture design and the physical properties of space-time and matter, but also that the understanding of this correspondence is leading to a topological practice of architecture and art. In the particular case of OMA and the three Japanese architecture firms analyzed in this paper, this topological practice is leading to a new architectural tectonic tradition that deals with matter in a different way. Matter is not placed in space as a set of independent architectural elements that relate to each other as a way of defining a style that may define the author or the moment of time in which the building is being conceived, but on the contrary they interact between each other in order to arrange a framework for life activity. The perception of this framework, of this background where our lives happen, changes in relation to the topology of the boundary that defines the limits of spaces. As we have seen, the perception of topology can vary between the senses; two spaces can be visually connected (having a visual perception that continuity exists) while they are actually separated in the realm of touch and translational movement. This duality is being explored (especially in the work of the SANAA and Ishigami) and is driving the design of extremely poetical projects. Nevertheless, almost all of the projects that we have discussed remain fixed within time – without any temporal variation beyond the events that happen inside and the aging of their materials. Only some auxiliary elements such as doors and windows adapt themselves to the changing nature of space-time (as it has been for ages). Even when design is being conceived as a dynamic process of space manipulation (bending, stretching, shrinking and connecting), the architectural product remains static once it achieves materiality. From all of the projects done by this three generations of Japanese architects, the only project that has a dynamic

Virtual House - FOA - Alejandro Zaera + Farshid Mousavi

behavior within space-time flow is 'Balloon'; it is the only one in which the topological properties of the space change in time. What usually defines the properties of architecture (structure, envelope and space) becomes variable in time when the physical interactions that define it are blurred. As Fuller had already envisioned, the overthrow of gravity from architecture will ultimately open new ways of thinking about our cities and the possibilities to use them. Nevertheless, we should not think that this is the only possible way of incorporating architecture into the fluid realm of space-time; it is one way of making architecture become architecture an event in itself, and not only be the boundary for the happening of events within it. In order to widen the possibilities of this transformation it is necessary to expand the notion of event towards the whole essential parts of architecture. It is necessary to unlock the time variable of all three levels of complexity of architecture, structure, envelope and space. Instead of arranging structure at random fixed distances to locate a multiplicity of events maybe the structure of architecture should explore the temporal dimension in order to respond with more accuracy to the complexity of four-dimensional reality. The same should be performed with the envelope or boundaries that, together with structure, define the properties of space held within them. Even if this exploration has already begun, it is necessary to keep exploring and researching on this path of material manipulation to make architecture embrace space-time qualities into the essential aspects that define it.

ENERGY

Tropical Hut. Gottfried Semper

Energetic space. Contingency, matter and energy

Until this point we have remained within the realm of mechanic, dynamics, and slightly introduced ourselves into certain concepts of dynamical systems in relation to the uncertainty of predicting events that occur within architecture. Now we are about to enter into the uncertain world of energy in architecture.

Ever since human beings began searching for shelter from the elements, and later created artificial constructions to house our everyday lives, energy has been linked to architecture. In his famous essay '*A Home is not a House*', Reiner Banham, like many others, saw the origin of our control over the environment as having two main roots: first a passive strategy related to the physical blocking of weather conditions (caves > roofs > tents > buildings), and second, an active variation of the thermal conditions through the use of controlled fire to generate a warmer thermal atmosphere around it. Indeed, in Latin languages the etymology of the word 'home' is linked with the word 'hearth' (*focus* (fire) > *focare* (home, hearth)), so home is where the fire is. In his paper Banham centered the problem of this relationship in the possibilities that mechanical systems have to alter the environment by generating heat (or cold) that would lead him to propose a reactive architecture that is only linked to the way energy is managed in order to generate livable spaces. This radical architecture diminished the tectonic presence of the house, reducing the outer skin to a simple bubble, and made its thermal machinery its defining element (as can be seen in François Dalegret's drawing).

The problem with this point of view, which is linked to the modernist optimism that flourishes from the Industrial Revolution, is that it forgets about the thermal (energetic) properties of the exterior shell (walls

and roof) that protects us from the natural environment, relying completely in the active transformation of weather conditions through mechanized systems and energy consumption. This approach towards architecture as a combination of two complementary ways of transforming the environmental conditions inside architecture is linked with the previous research conducted by Gottfried Semper in '*Die Vier Elemente de Baukunst*' (1851) where basic architectural elements were divided in two complementary systems, the first is constituted by the tectonic envelope formed by roof, walls and floor, and the second is the hearth, the place for the fire that transforms the internal environmental conditions of a basic dwelling unit.

As we know today – after the multiple conversations in class that had their origin in a compound set of complementary readings – the interaction between architecture and energetic interchanges is more sophisticated and complex than this simplified dual separation between protective envelope and heated space. Nevertheless, this simplified duality may also tend to correspond to the simplified duality contained in the Carnot cycle and even with two complementary transformations of our understanding of reality introduced by Einstein: events that occur in space-time and the equivalence between energy and mass.

The duality between the enclosure of the inhabited space as a buffer against inclement weather on one side, and the heating action of the air by fire on the other, present in both Gottfried Semper's primitive idea of architecture as in Banham's more refined idea of energy bubble, can be interpreted also from the relativistic approach towards reality. The boundary is nothing else but arranged matter in space-time to alter the continuity of space. As we saw earlier by wrapping space with matter we alter its continuity by creating a hole in the previous space. This hole is a separate subspace that has independent properties. However, in

**energetic interchange of
boundary with environment
depends on topology of
matter**

holes (B) permit energy flow
mass (A) passive / inertial flow

**higher degree of
permeability enables
major interchange**

permeability of boundaries
increases energy flow between
interior and exterior

**higher degree of porosity
enables major adaptability**

active porosity (variable number
of holes) of boundaries increases
capability to adapt to
environmental conditions

addition to establishing the way in which topological transformations take place in pre-existing space-time, architects also provide the way in which both subspaces exchange energy with each other. Architect defines the material (and therewith its conductivity properties as energy and inertia) and the thickness that the material must have in order to form the building tectonics. As seen above, the porosity of the envelope varies the relationship between the subspaces. While the previous section referred to the relationship between events or uses that occur in each subspace, this relationship also applies to energy exchanges between the two sides of the enclosure.

Opening holes and increasing the permeability of the boundary increases the connectivity between the inner and outer subspaces allowing energy interaction between both systems. A hole, like the windows in Semper's hut, enables energetic interchange and interaction with the energetic events that take place within the exterior space (heating by sun radiation, cooling by changes in air pressure and air humidity, etc.). Is not casual that in traditional architecture the only elements that took into account the time factor were directly related to the permeability of the boundaries of spaces (doors, windows, curtains and blinds), since the variation in time allows adaptation to the specific needs of each moment. While doors relate to adaptability in the connectivity between spaces, the other elements associated with the holes of the boundaries of the spaces are devices that permit variations in the conditions of energy exchange between the interior and the exterior.

Architecture as a thermodynamic discipline. Thermodynamic design principles

Active and Pasive Energy Processes. Interpretation of the Carnot Cycle

The Carnot cycle, which seeks the impossible ideal of the reversibility of energy exchange processes, establishes two types of complementary processes: the isothermal processes (1-2 and 3-4) and the adiabatic (2-3 y 4-1) processes. The former refers to processes in which the isolated system receives no heat source and hence the temperature remains constant, whereas in adiabatic processes energy exchange occurs by bringing a heat source resulting in a temperature differential in the system. While it is true that the Carnot cycle is an idealization of thermodynamic processes, it is also true that its simplicity can be applied to understand the two types of actions that occur in architecture from an energetic point of view.

The insulation of the interior space through the arrangement of a material enclosure is a process that ideally resembles to isothermal processes where the closed system is isolated from its surroundings, while the thermal processing by applying heat is adiabatic processes similar to those of the Carnot cycle. If in the Carnot cycle isothermal processes can be considered passive processes while adiabatic processes are active processes, the two complementary actions of protecting the interior with a boundary and heating the space applied in architecture to alter the environmental conditions of its interior can be classified similarly. What is most interesting from this point of view of traditional architecture is that adiabatic processes are not limited solely to the production of a heat source alien to the enclosure, but rather the topology of the enclosure is altered, its porosity and permeability is altered, to enable an energy flow with the exterior system.

Two simultaneous events happen in the Pantheon: thermal equilibrium between the inside and the outside is provided by the absorption of heat by the mass of the walls and sunlight heats partial parts of the building and lights the space to enable interior use. Architecture here does not need any source of heat to happen

This time-varying use of the topological properties of the boundaries of spaces as a manner of allowing the temporary activation of the energy flow with the outside through its connectivity, that is made in traditional architecture in temperate climates, is an application of the zeroth law of thermodynamics, which states that when two systems are each in thermal equilibrium with a third system, they are also in thermal equilibrium with each other. This same law is the principle that governs the thermal equilibrium of a cave or building of stone mass in which the indoor environment is insulated through a thermal equilibrium that occurs between the interior and the exterior through a third system: the thickness of stone surrounding the interior space. A beautiful example of insulation through thermal inertia in conjunction with the disruption of the boundary to allow energy to flow inside is found in the Pantheon. There the temperature difference between inside and outside is acquired through the thermal equilibrium between the outer face of the wall and its inner surface while the central oculus promptly heats parts of the interior space while illuminating the space to allow for the development of activities inside.

Energy diagram. Howard T. Odum + The Limits to Growth Forrester World Dynamics diagram

Sanford Kwinter in front of slide projection

What is energy and how else might we think about it?

Graduate School of Design. Harvard University. 2013

Odum, Systems Ecology Model, 1974-79

Forrester, World Dynamics Model, 1963-1971

Accountability of Energy and Irreversibility of Processes. Exergy, Energy and Transformity

“Systems of nature and humanity on all scales are part of a universal energy hierarchy, which is the network of energy transformation processes which joins small scales to larger scales, and these to even larger scales.”

Howard T. Odum. Energy Accounting

While I have previously outlined a simplification of the energy exchanges that occur in architecture, we must have in mind that this is a view that reduces the complexity and sophistication of today's architecture energy needs. As explained previously, architecture accommodates within itself the flow of events of life. Every event involves energy transformations, from the transformation of chemical energy into kinetic energy when we move through space, to the transformation of electromagnetic energy from sunlight into chemical energy produced by photosynthesis on the leaf of a tree. To understand energy transformations and its relationship to different activities Howard T. Odum (1996) coined and used several concepts that can address more precisely energy transformations. The first term that Howard T. Odum defines to understand and simplify energy transformations accountability is Exergy. Exergy is defined as “the availability of energy of one kind that is used up in transformations directly or indirectly to make a product or service.” According to Odum the amount of energy to be transformed increases with the sophistication of the process for which energy is used. In order to understand the whole complexity of reality we must not conceive the

multiple processes as isolated ones, but as a set of interrelated events that interact within each other in energy systems networks. The concept of emergy tries to give a measurable quality to the common idea that something that takes more effort to be produced is more valuable. One of Odum's most valuable concepts to understand this relative measurement of the need of certain energy sources by each process is transformity. Transformity measures the relative amount of emergy in relation to the energy that is consumed in the process and its units are emjoules/joule. The higher the transformity, the least energy the product has and the higher amount of energy was needed to make it. While it is common to use a measurement relative to the production of energy of the sun (solar emjoules/joule) the concept of transformity permits to make relative measurements with any source of energy. The uses of the energy of the sun as a common reference is due to the fact that every other source of energy, from wood to petrol, from carbon to glucose, have their imbedded energy as a result of an accumulation and transformation of solar energy.

If emergy refers to the energy that is available for a particular product or action, the concept of exergy refers to the quality of energy and it is directly linked to the second law of thermodynamics, which states that available energy is constantly degraded. Exergy measures the maximum work that can be produced during a process. The concept of exergy is directly linked to that of irreversibility of thermodynamic processes. Once a material is processed with heat exchange the quality of the transformed energy is reduced. We must remember that the set of relations to account for energy transformations were partly originated from the correspondence between mass and energy; let us not forget that nearly forty million tons a second of solar mass are consumed in its combustion process.

Michelle Addington explaining Exergy matching
What is energy and how else might we think about it?
Graduate School of Design, Harvard University. 2013

The set of energy accounting concepts introduced by Odum along with the understanding that every event involves energy transformations, and that once it is produced, the quality of energy of the system is lowered leads to two complementary concepts. The first corresponds to the fact that the entropy of a system may be the power source of another adjacent system. This is the case of solar energy on earth; all the energy of our energy system is the entropy of the combustion process of the sun. The following concept, introduced by Michelle Addington is emergy matching. She presented this concept in April 10, 2013, at a lecture she gave for a small group at Harvard University, the class instructed by Sanford Kwinter and Kiel Moe 'What is nergy and how else might we think about it? In which I participated. The idea of matching the type of energy with each activity that occurs in our system involves the reduction in energy conversion processes to prevent loss of exergy. This matching process is scalable and can be understood from the global scale to the scale of the processes required in a building.

To implement this concept of correspondence it is necessary not only to know precisely the energy properties of matter and processes, but it will also be necessary to know what are the events that will presumably occur in the system under consideration and the type of energy that each of these processes demand. This is a conceptual process similar to the one dietitians or endocrines make when corresponding the food products with physical activities through their knowledge of the body's metabolic processes. Similarly, even though humans intuitively regulate their diet, the precise correspondence between the energy and the vitamins and supplements produced by food products during the metabolic processes allows a better adaptation to the performed physical activity (i.e. in the case of athletes); in the case of building and urban environments, although architecture contains embedded in its tradition rudimentary correspondences between

Ecological levels of organization hierarchy; seven transcending processes or functions are depicted as vertical components of eleven integrative levels of organization (after Barrett et al. 1997)

uses happening inside and energy exchanges necessary for them to be developed (the central position of the hearth in Semper's hut is not casual) energy exchanges can be atomized into smaller units that allow a more accurate correspondence between them and uses that they activate.

Ecosystems: networks of energy systems

This way of conceiving the relationship between the events that occur in architectural or urban space-time makes architecture become a network of energy systems related to systems ecology. As we are becoming aware of, there is an inherent irreversibility to architecture, both from the point of view of energy as from the one of the continuum linked to the flow of events in space-time. Once again the simultaneity of events and of their levels of complexity define reality. It seems that architecture fits into the description that Prigogine makes of dissipative structures, since both events happening within architecture and energy transformations related to those events, are processes in which the temporal dimension is asymmetric, as time flows only in one direction. As Norbert Wiener stated, it is necessary to establish effective communication within both worlds. Once we identify the irreversibility of the processes that constitute architecture, it is time to make the architectural creative process react to this reality.

Therefore, it seems clear that architecture should be opened more decisively to its temporal aspect. As Valeri said *"time is construction"* (as Prigogine reminds us at the conclusion of his book *Order Out of Chaos*). Therefore, architecture should stop being passive, should stop hosting events through a simple wrapping

Fig. 1-4

Figure 1-4. Compared with the strong set-point controls at the organism level and below, organization and function at the population level and above are much less tightly regulated, with more pulsing and chaotic behavior, but they are controlled nevertheless by alternating positive and negative feedback—in other words, they exhibit *homeorhesis* as opposed to *homeostasis*. Failure to recognize this difference in cybernetics has resulted in much confusion about the balance of nature.

of inert matter, to become a sophisticated network of events in interaction with its users, embracing and channeling events with active matter (in the same terms as Prigogine). This activation of matter implies the constant sophistication of systems in evolution responding to the ever-increasing levels of complexity that define them.

This change towards the becoming of architecture as an active interaction between the structures that support them, the definition of the boundaries of the events that occur within its space-time, and the energy transformations that are linked to all of these processes, has already begun, but is still at a very primary stage of its phylogenetic evolution. Only time can provide the platform towards this becoming.

While the term ecology has more than 100 years, the biologist Ernst Haeckel coined it in 1869, the scientific discipline of ecology is relatively recent as described by Eugene Odum in his book '*Fundamentals of Ecology*'. Etymologically ecology means the study of life at home, and as science it deals with all biological and environmental processes in our planet. However, the concern for ecological processes is integral to the economic advancement of humanity. Without a thorough understanding of the interactions with the environment the economic development of what we now call the primary sector would have been impossible. However, it was not until 1968 and early 70's that the scientific discipline of ecology experienced its greatest development and expansion. This development is closely linked with the fact of being able to observe the whole earth from space. When become aware of the relative size of our planet and its fragility within the universe the collective consciousness is activated. It is from this time on that the science of ecology begins to receive both financial resources and legislative tools to consolidate its research and conclusions. This

WHOLE EARTH CATALOG

access to tools

Fall 1968

\$5

momentum will allow the whole humanistic and economic disciplines to become holistically sheltered by ecology. (E. Odum, 2004).

In 1968 Stewart Brand launches for the first time the Whole Earth Catalog, a publication released with the intention of passing in a simple manner concepts of systems ecology and environmental proposals for the use of land, construction, industry, telecommunications, the transmission of knowledge and the establishment of social communities. Through ideas and concepts inherited from Buckminster Fuller, the magazine makes practical proposals for the use of natural resources, alternative energy sources and channeling of energy flows between interdependent systems. It is not a scientific journal promoted by any research or educational institution, but rather a free collection of contributions of a group of people who share their intuitive concern for the degradation of the planet earth.

In the same year 1968 the Club of Rome is established. It is a think tank composed of members of multiple nationalities that was legally formalized in Switzerland in 1970. To address the deterioration of the environment of the planet due to increasing industrialization without environmental control occurred at that time, the Club of Rome entrusts the famous document '*The Limits to Growth*' to the Massachusetts Institute of Technology. The study was undertaken by seventeen scientific researchers who were led by environmentalist Donella Meadows (Chernyakova, 2013). By using methodologies developed by Edward T Odum in systems ecology, they analyzed the earth as a set of interconnected energy systems.

This text had great media coverage and served as the basis of scientific support for multiple popular environmental movements. Both the conclusions as the necessary actions to alleviate the population

growth, and with it the exploitation of natural resources and the industrial development for the production of consumer goods, shall be the basis of both the content of the programs of action of multiple environmental organizations, as of various political treaties to stop the destruction of the natural environment.

From the point of view of this research, it is important to establish the scale of the ecological systems to contemplate. The above two texts address the problem of the ecosphere in full planetary scale. While this scale may seem too distant to be considered from the point of view of architecture, the planetary scale is composed of a finite aggregation of smaller interacting subsystems. As Odum explains in his text on energy accounting, a system is in equilibrium if its subsystems are in equilibrium. Therefore, if we seek the balance of the ecological system of the planet, it is necessary that the component subsystems are balanced with each other or are themselves in balance.

Using the same inverted cone in the book of Eugene Odum '*Fundamentals of Ecology*', we can establish that the scope of action of the architect extends from the organism to landscape, being out of reach the cell, tissue, organ, organ system as well as the biome and the ecosphere. The balance of the smaller scales to the organism is due to the biology of the own organism, to its nature. Therefore, the balance of the subsystems within our action field is crucial to achieving the overall balance of planet Earth.

David Scott on the Moon

Non-tectonic Architectures of the technological utopia

In a previous section it has briefly explained how Howard T Odum establishes equivalence ways to carry out a real and balanced energy accounting that takes into consideration both the kilowatts produced as the time of generation of said energy capacity. Introduces a temporal aspect related to energy, as well as a way of measuring power quality. Based on these concepts it has been also subpoenaed Michelle Addington and her idea of linking processes and qualities of energy.

In the late 1960s and early 70s there was a large group of people, including many architects, seeking a life in harmony with nature. While in many cases these are linked to political pacifist movements groups (especially those who strongly requested the end of the Vietnam War), there is a great disparity in their political positions. However, awareness is consolidated around the use of energy sources and the environmental implications of mercantilist consumption. This awareness generates a stream of practical thinking that tends to minimize the use of resources. The final form in which this awareness is embodied is very diverse. From the pneumatic structures of Ant Farm to water purification strategies by using different plant species developed by John Todd, there are many groups that pragmatically deal with the problem on how to improve the efficiency of our way of inhabiting the world.

According to the principles of energy accounting all sources of energy and energy demand must be accounted and entered into the system. When thinking about architecture, buildings or cities, architects must take into consideration and introduce into the accounting system all of the processes that affect the energy

Drop City Joy Festival poster

system, from solar radiation and winds to vegetation photosynthesis and transformation of chemical energy in metabolic processes. Everything counts.

In architecture, Buckminster Fuller had long established the conceptual and methodological foundation for a holistic architectural practice and design that systemically took into account the relationships between each designed element with its surroundings, both at a neighborhood scale as at planetary one. Long before the year 1968 Fuller had written and lectured at numerous symposia and universities throughout the United States about the importance of every design decision, as each designed element is in relation to the whole. His personal research was extensively developed around processes and not in relation to the internal laws of design objects themselves as other theorists contemporary to him had done. This is the reason why the teachings of Fuller underlie in many of the aforementioned groups that operate within the context of counterculture during the late 1960's and early 70's.

Drop City was built entirely with wood frame geodesic domes with different types of recycled cladding or paneling. Wood is not only a material that is easy to use and assemble, but it is also the one that needs less energetic processes to be manufactured. The use of wood in construction is a way of using solar energy in the production of the material to be used. From an emergy accounting view, wood is a material storage of solar energy, somehow like a battery that holds embedded solar energy.

Photo of the geodesic dome at MIT lab in 1950 with students (Carl Zane Yost is third on the left) and R. Buckminster Fuller on the far right (Document U986. 083. 033)

²⁹ November 7 - November 18 1949; January 9 - January 20, 1950; February 27 - March 10 1950; May 1 - May 5 1950.

³⁰ MIT Museum archival coding: the first four digits indicate the year of donation and introduction into the archive, the second four digits indicate the donation number in that year (the dome was the 83rd donation of 1986) and the last four digits indicate the element number upon the set

Origin and proliferation of wooden geodesic domes:

The 8th of November of 1949 William R. Wurster presented R. Buckminster Fuller to the MIT Architecture community as Visiting Lecturer for that academic year. Fuller was appointed to spend seven weeks at MIT during the academic year 1949-1950²⁹ working with the Graduate students and assisted by Professors Carl Koch and Ralph Rapson that would direct the studio when Fuller was not in residence with the assistance of Burnham Kelly, Director at that time of the Bemis Foundation of the Prefabrication Industry in the USA at MIT, which funded Fuller's wage as a Lecturer.

In 1986 the MIT Museum received the donation of the remains of a geodesic dome built at MIT during the fall semester of 1949 and the spring semester of 1950 as part of the design studio instructed by Richard Buckminster Fuller, Carl Koch, Ralph Rapson and Burnham Kelly at the MIT School of Architecture. The archival number for the crate containing the dome fragments is 1986.083.0012³⁰ and the complete collection of documents regarding this geodesic dome is completed by a set of 43 photos (1986.083.002-044) and one blueprint drawing (1986.086.045). The crate that encloses the main physical object of this archival set contains all of the structural supports for the dome and partial remains of the covering _ The dome structure was entirely built out of lumber, two by fours were used as struts, joints were wooden discs, and only some minor galvanized steel pieces, such as bolts and screws, were needed to hold the wooden pieces together. Karl Zane Yost, who was a student at MIT during fall 1949 and part of the team that made the geodesic dome, was the one who made the donation to the MIT Museum after having enjoyed the dome for over 30 years. The dome was transported from MIT to Zane Yost's parents' property in Gilmanton, New Hampshire,

Photo of the reconstructed dome in New Hampshire in 1952 (Document '1986.083.0(4)

³¹ US Patent number 2,682,235. Concession of patent June 29, 1954.

³² See BALDWIN, J. Bucky Works. John Wiley & sons, Inc. New York. 1996. p.131.

³³ See WONG, Yunn Chii. The Geodesic Works of Richard Buckminster Fuller, 1948-68 (The Universe as a Home of Man). HTC in Architecture PhD Thesis. Massachusetts Institute of Technology. June 1999. pp. 235.

³⁴ A 'necklace dome' is a type of dome that is constructed out of straight tubes. Each tube contains a cable inside its hollow cavity to tie the parts together.

³⁵ R. Buckminster Fuller liked to start his lectures saying: 'I'd like to introduce myself as the world's most successful failure' (See BALDWIN, J. Bucky Works. John Wiley & sons, Inc. New York: 1996. pp. 2.) and he referenced on multiple occasions the necessity of failure as means of advancement and evolution.

in 1952, where it was re-erected and served as a guesthouse until they sold the property in 1986. Then, Zane Yost, her wife, Megan Owen Yost, and a classmate of MIT dismantled the dome and sent the remains to the MIT Museum.

The 12th of December of 1951³¹, a couple of months after the MIT wooden dome was built in the lab, Buckminster Fuller fired a patent of invention application for the geodesic dome. The dome that is archived at MIT is one of the early prototypes developed by Fuller in order to research among different types of construction techniques and materials that could implement the design principles contained in the patent. According to the notes in the MIT Museum archive, the dome is the first geodesic dome made out of wood. Although, they also point out that the dome that was made at MIT was the second dome ever erected, it is more likely to be the third. Some author's place the first attempt³² to erect a large geodesic dome in the Black Mountain College (BMC) 1949 summer experiment with venetian blind slats. Nevertheless, Fuller had already been able to build a dome during the end of the fall semester of 1948 at the New Bauhaus (ID-Chicago)³³ This dome had a diameter of 14 foot and was made out of aluminum tubes that were held together by a system of cables, hubs and screws. Fuller called these types of domes the 'necklace domes'³⁴ and, by that time, he had also successfully manufactured one of these in less than three hours in the Pentagon garden.

As Wong suggests, the further rigorous research on different construction methods was pushed by the success of the Pentagon Dome and the suggestion of Maj. Gen. Grandison Gardner to push the design to more challenging conditions. Maybe this was why Fuller forced his design to fail³⁵ in the BMC experiment made a couple of months later. He was looking for a way of optimizing weight and costs and pushed the

Photo of the Black Mountain college geodesic 'failure' of 1949

³⁶See PAWLEY, Martin. Buckminster Fuller. Trefoil Publications, London. 1990. pp. 93-97.

material properties to the limit of their capacity to see the behavior of the system in space-time. The dome erected at MIT between 1949 and 1950 had a diameter of 24 foot, that was 10 more than the one erected in Chicago a year before.

The work of Fuller on the geodesic domes was inscribed in a project to produce military settlements that could be easily delivered and constructed wherever they were needed that had started with the Dymaxion Deployment Unit or DDO that were used as emergency accommodation for radar crews during the end of World War II³⁶. In this sense, capacity, efficient cost limitation, assembly and construction time, and weight reduction were primary goals. In order to multiply the research possibilities to search for improvements in these variables of the design and its fabrication, Fuller undertakes various experiments with students in multiple schools around the United States where different variations of the geodesic dome are tested. From the cardboard experiments in the University of Michigan and North Carolina to the fiberglass tensegrity dome made in the University of Minnesota, student labor was used as a means to geodesic dome optimization through physical fabrication and ground testing. While the cardboard experiments centered in the reduction of cost of the dome, the tensegrity one looked for structural optimization. Nevertheless, in both cases, the amount of manual labor that was needed to achieve rigidity of the whole, by cutting and folding the material in the case of cardboard, and by building compressed fiberglass struts and connecting pieces together in the tensegrity dome, made this types disappear over time due to manufacturing complexity. In the case of the MIT dome, the dome was produced in wood with very simple woodworking processes and the number of different elements of the system was reduced to four: three different struts and one joint.

Magnesium framed fabric storage dome for Marine Corps¹⁴

³⁷ See US Patent number 2,682,235. .

³⁸ Since the early works (1928 4D TimeLock and beyond) Fuller links his understanding of human existence medium to the one contained in Einstein's special theory of relativity.

It is not casual that the geodesic dome patent text starts with the statement: 'My invention relates to a framework for enclosing space'³⁷. Buckminster Fuller's conceptualization of space was related to relativistic space-time where the three dimensions of space and time are intertwined within each other³⁸ (Minkowsky space) forming an ever-changing reality where events happen. There was no place for Euclidean geometry or the 'golden mean' as tools for stylistic placement of building elements in space in this universal conceptualization. Geometry should evolve towards a tool for wider understanding of the Universe and its principles in order to help the definition of frameworks that will enclose events. For this purpose, Fuller conceptualizes a wider extension of geometry linked to the major principles of the New Physics in his Energy Geometry metaphorical cognitive construction that would help achieve the materialization of event framework design. In the case of the geodesic domes, the geometrical complexity of their design was a way of reducing the need of energy consumption in the building process by means of increasing the rigidity of the structure while reducing weight.

Energy consumption reduction in geodesic domes was simultaneously fulfilling Fuller's approach to design philosophy and the pragmatic need for efficiency demanded by the US Army. The MIT dome is a well-balanced example of construction efficiency. It does not push preexisting knowledge on geodesic design towards the limits of failure but it simplifies the processes that are needed to construct a geodesic dome by emphasizing pre-existing construction materials and tools: standard lumber profiles, bolts and conventional saws, drills and wrenches. And here is where the value of the MIT dome is: it is simple. And simplification of processes is also a way of energy reduction. The kind of dome made at MIT can be made without sophisticated technical skills. Just wood planks, a saw and some screws and bolts are needed to

Parts for the geodesic dome waiting for assemblage on top of a desk at HIT Lab. 1950

³⁹ See PAWLEY, Martin. Buckminster Fuller. Trefoil Publications, London. 1990. pp. 40-41.

⁴⁰ The construction systems for Marine Corps ranged from magnesium frame domes to inflatable fabric domes that could be erected in seconds. See PAWLEY, Martin. Buckminster Fuller. Trefoil Publications, London. 1990. pp. 130-146.

make it. This makes this kind of dome deliverable through its design principles and not through its material pieces. Wherever you have wood you can make a dome if you have the plans and know the dimensions. In the case of the archival material at the MIT Museum, the only drawing of the set does not correspond to the dome that was built at MIT, but it is a drawing of Fuller's home built in Carbondale in 1966³⁹ so it is not a helpful document in order to unveil the geometrical structure of the dome and its built dimensions. But by the application of geodesic calculation and the reproduction of the details that were used in the original 1952 dome new construction documents could be developed to reactivate the geodesic game of easy construction of a dome. Construction of a dome will be to play with some sticks and some disks to enclose space within its boundaries placing in this way the act of playing not as a mere ludic activity but as a response to efficiency in (cognitive) energy consumption.

It is worth noting that only two main families survived the manufacturing evolution of domes for non-military purposes⁴⁰: the metallic tube family (aluminum necklace domes and steel tube with spherical joints among others) and the wooden domes. The simplicity in the detailing and manufacturing of the wooden dome is maybe the key to its proliferation. While metallic domes (steel and aluminum types) need of precise industrial tools to be manufactured, the wooden dome parts can be made with cheap and handy carpenter tools. This difference is not trivial, and is at the origin of its conception. Although it is not precisely documented, this key factor might have been introduced by Ralph Rapson and Carl Koch while Buckminster Fuller was out of residence during the evolution of the project during the academic year.

Ralph Rapson had been teaching at the department of Architecture at the New Bauhaus (Institute of

Parts for the geodesic dome waiting for assemblage on top of a desk at HIT Lab. 1950

⁴¹ See KING HESSION, Jane, RAPSON, Rip, WRIGHT, Bruce N. *Ralph Rapson: Sixty Years of Modern Design*. Afton Historical Society Press. Afton, Minnesota. 1999. pp. 51-61.

⁴² Ibid. pp. 68

⁴³ See KOCH, Carl. *At home with Tomorrow*. Rinehart & Co. Inc. New York. 1958. p.46. "My own introduction to prefabrication, in fact, came in Sweden in 1938, while I was abroad on a fellowship. I remember being somewhat intrigued by the do-it-yourself aspects of the thing - families working on weekends to put together wood-panel walls, and roofs on walls."

⁴⁴ See KOCH, Carl. *At home with tomorrow*, Rinehart & Co. Inc. New York. 1958. p.18. "A house is: 5. Buildable, makeable - the more easily so the better. This implies also obtainable, buyable, cheap"

⁴⁵ See KOCH, Carl. *Design the Industrialized House*. In *Design and the Production of Houses*. KELLY, Burnham (Ed.). McGraw-Hill Book Company. New York.: p.8 "Wood is suited to craft handwork. It is easily cut and fitted. There is no necessity and little advantage in taking many wood fabrication and finishing operations into a large, mechanized factory. Steel is another matter, it is hard and expensive to modify, cut and fit, by hand or even with light, portable machinery. Its production expense must be covered by high sales volumes.

⁴⁶ See KOCH, Carl. *At home with Tomorrow*. Rinehart .li Co. Inc. New York. 1958. p.45. "The pre-cut (wood-frame) house represents the simplest practical aspect of prefabrication"

Design in Chicago), in close contact with Moholy-Nagy⁴¹, before arriving at MIT in 1946, the same institution where the first 14-foot 'necklace' dome was erected in 1948. By 1949 he had developed multiple projects that had been conceived around prefabrication concepts and that used simple 2 by 4 lumber for their construction, such as the "4/16 competition" project designed with John van der Meulen in 1938 for Architecture Forum magazine. At MIT, it was Rapson who proposed in 1949 to William R. Wurster to organize "The Industrialized House"⁴², a year course that focused on industrial design, instructed by Rapson and Carl Koch with the assistance of Burnham Kelly, the Director of the Bemis Foundation of the Prefabrication Industry in the USA. The idea was to integrate the research that was being developed at the Bemis Foundation at MIT into a practical studio that would enable the students apply the principles of prefabrication they learnt through research and lectures in specific design projects. Buckminster Fuller was invited as guest lecturer to this course due to its radical approach in the prefabrication of houses carried out in the Dymaxion Deployment Unit project and the Wichita House project (Dymaxion House) among others. On the other hand, at the time Carl Koch was teaching at MIT, when Buckminster Fuller arrived, he had already finished Snake Field (1941) housing complex, where he searched for a quality and affordable building system, and the Acorn House project (1948), that was his first prefabricated assembly. Carl Koch developed his entire career around the principles of prefabrication and was interested in the easiness of assemblage and the possibility to demount and reconfigure buildings. His interest in prefabrication had flourished from his curiosity on the do-it-yourself culture he noticed in Sweden in 1938⁴³. For Koch prefabrication was linked with the notion of simplicity, facility of construction and cheapness⁴⁴, and the only material that had the potentiality to unite all this principles was wood⁴⁵, especially in the form of wood-frame construction⁴⁶.

General view of Drop City, c. 1969

⁴⁷ See SCOTT, Felicity D., *Architecture or Techno Utopia*. The MIT Press, Cambridge. 2007. p. 155.

The MIT dome was a type 3-frequency geodesic dome with a diameter of 24 foot (7,32 meters). The chosen frequency implied that there were three different strut measures (approximately 4' 2", 4' 10" and 4' 11") and fifteen four-way connectors, six five-way connectors and twenty-five six-way connectors would be needed. The angles in each type of connector would vary also. As a way of simplifying the system, the same wooden disc was used as a joint and the struts were screwed to this disc by means of a thin galvanized steel plate that could be bended to the required angle. As a result, forty-six identical discs could be used, thus streamlining the connection between the struts. Even in further developments of self-constructed wooden domes, such as the ones erected in Drop City, the type of joints that were employed required a more accurate sewing of the angles of the struts than the discs used at MIT. Unfortunately the details of the construction process were not documented, and no drawings of the junction between the struts were made to transmit this knowledge to further dome manufacturers.

Simplicity is what made this kind of dome proliferate within the popular culture. The easiness of construction permitted that people without precise dexterity in construction could build up their own geodesic dome as if they were dealing with a construction toy. Furthermore, they were able to erect the fascinating kind of spaces they had seen on TV with the same tools they had been using to build or fix the wood-framed houses they had inhabited their entire life. Geodesic domes were the image of American technological prosperity during the times of cold war, as they not only served the army for pragmatic purposes (storage or sheltering), but also became the foreign architectural face of the U.S. State Department⁴⁷, eventually culminating in the construction of the United States pavilion in Montreal in 1967.

⁴⁸ See GROSSMAN, Joan and MACCOURT, Tom. Drop City documentary film (<http://dropcitydoc.com>).

Geodesic domes represented, not only a sample of technological richness of American industry, but also a global understanding of the way human being dwelled in the Universe: we were all crewmembers of spaceship Earth. This Fullerian view of existence evoked in the people a feeling of belonging to a wider reality, a reality that extended beyond the boundaries of national borders or political and economical interests. This feeling of belonging to a wider reality had a deep ontological difference in relation to the feeling of nationhood and patriotism, and was adopted by the counterculture of the Vietnam conflict times as a response to political violence, as a way of escaping political and economical establishment.

Drop City, a commune that was open to anyone that wanted to scape from the war consciousness of those times and wanted to merge life, art and action together, adopted the geodesic dome as the form of the architecture they inhabited. Although the original idea was to start Drop City in an isolated spot in the southern Nile riverbed, it finally emerged near Trinidad, Colorado, where it could feed itself from the detritus of mass consumption and also benefit from its low cost and high quality industrial products. Indeed, it seems that for some droppers the key factor to that decision came from something as simple as bending with a hammer some low quality nails that had been bough in Morocco on their way to the ideal African spot⁴⁸. To isolate themselves from political and economical establishment it was not necessary to escape out of the boundaries of the nation but it was easier to build a bubble within it; it was enough to buy six acres of rural land and fill it out with 'unconventional' spaces to live in.

Nevertheless, it is a paradox that the geodesic dome could be read as the architectural form that best represented the ideas and lifestyle of late 60's American counterculture, while on the other hand was being

DOME

COOKBOOK

by Steve Baer

3rd printing - December 1969
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published by
cookbook fund - Lama Foundation
 Holly Baer secretary
 Box 422 Corrales N.M.

New Reviewer
 Fox Shot 25
 Sam To De
 Published
 184
 TIME LOCK
 4-D
 11 JANUARY 1970

\$70.48

also published
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 25 SHOT I
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⁵⁰ Ibid. pp. 161-166.

⁵¹ Vic Muniz paints with trash selected at the dumping site. See *Wasteland* film (<http://www.wastelandmovie.com/vik-muniz.html>).

⁵² The facade of the Museum of Automation in Madrid is planned to be built as a massive ashlar wall made out of recycled car cubes. See *El Croquis magazine* n. 161, p. 238-249

used by the Army and the government of the United States as the image of technological power and great part of the technical development of the system was due to the funding Buckminster Fuller had received from the U.S. Army since 1948. While the military showed off their control on technological complexity, the droppers were proud to inhabit spaces that were different to those dwelled by their neighbors; it was especially uplifting that those spaces were entirely made by themselves outside the manufacturing chain of capitalism.

That same feeling of pride and satisfaction on their independence on the manufacturing of their built environment is what made the droppers write down on paper their experience and knowhow on geodesic structures, something the Bemis Foundation had not done about fifteen years before. Steve Baer's "Dome Cookbook", published in 1968 with funds from the Lama Foundation, had the aim to transmit Drop City's understanding of geodesic domes, its applied math and possible technologies to fabricate them, to anyone who was interested in the self assemblage of the framework of the environment where their activities took place in. But Baer's cookbook was written also as an anti Euclidean manifesto against the rectangular grid that constrained every urban settlement in America⁴⁹ and offered reuse principles⁵⁰ to build the domes that were quite ahead of their time. For instance, the use of recycled car tops, which were literally chopped out of the car with an axe, was anticipating the critical sustainable reuse that today artists and architects, such as Vic Muniz⁵¹ or Mansilla and Tuñón in the Museum of Automotion⁵², are making of industrial detritus in their work.

Drop City - Steve Baer device to redirect solar radiation made with recycled rearview mirrors

⁵³ If we just search in Youtube or Google, multiple entries will take us to contemporary fabrications that will not differ greatly from the first large wooden geodesic dome made at MIT in 1950.

However, the do-it-yourself manuals edited by Lloyd Kahn in 1970 and 1971 Domebook One and Domebook 2 were those that triggered the final proliferation of domes in mass culture and are still today cited in many amateur, and even professional manufacturer dome web pages as the reference to understand geodesic dome construction. The propagation of wooden geodesic domes has survived even when the technical problems that rapid propagation unchained in the beginning of the 70' when the fact that domes leak was not only recognized by many authors (such as Lloyd Kahn or J. Baldwin) but by Buckminster Fuller himself. Today geodesic domes are still being made around the world and their anonymous manufacturers still like to tell us how they did so⁵³.

Drop City's contributions to a way of living committed to reducing impact on the planet not only correspond to the use of wooden geodesic domes. Steve Baer is an active inventor, supporter of reusing obsolete objects and discarded material to reactivate matter into appliances that improve living conditions through the use of alternative energy sources, mainly solar energy. By studying the basic physical laws and understanding of solar impact on earth he is able to design multiple appliances that use solar energy as a source for improvement of habitat.

Baer invented and manufactured solar panels from pipes, boxes lined with insulation and glass that could generate the greenhouse effect, solar chimneys that acclimatize the social interaction and common activities dome of Drop City by reusing windshields scrapped out of cars and he even invented somehow comical devices for the redirection of solar radiation from recycled rearview mirrors. All, or almost all, of these inventions are subsequently collected, described, and their physical principles explained in the book

Ant Farm – Ben Holmes in Dream Cloud parachute-1969

Sunspots - a kind of manual independent from consumerism halfway from a DIY survival manual and an energy architecture handbook. Is also noteworthy that Steve Baer is also the author of the famous handbook for geodesic dome construction 'Dome Cookbook', which was the reference for a whole generation to easily build his or her own geodesic dome.

Blowing towards architecture activation

Following the model of that handbook for geodesic dome construction, the American group Ant Farm published their famous book Inflatocookbook in 1972, a manual for simple construction of pneumatic structures. This book spread at great speed the prolific use of pneumatic structures around the globe. That abounding use of pneumatic structures is closely linked to its ease of implementation, the low cost that these structures have, and consequently, the low energy consumption required to be erected.

On April 21, 1970 Ant Farm makes a theatrical act of protest on pollution of the planet. Their work Air Emergency is a happening that occurs inside and outside of a low-density polyethylene single membrane pneumatic structure inflated with some fans on the campus of the University of California Berkeley. The pneumatic structure measuring 50 feet by 50 feet was called Clean Air Pod. The members of the university community that entered the bubble were marked with a yellow circle sticker so a satellite monitoring system could track them, while those who decide not to enter receive a negative census form for them to be completed before they die. Ant Farm members also remain outside wearing gas masks to keep breathing the polluted air outside the bubble. One of them named F-310 (in the manner of a humanoid robot),

Ant Farm – Ben Holmes in Dream Cloud parachute-1969

assures to be programmed only to respond questions from the press. The action details were included in Inflatocookbook together with a newspaper front-page photomontage. In it the original content about the support of nuclear tests by the University of California Berkeley is replaced with the action undertaken by Ant Farm. The cover date is also modified in the pneumatic architecture handbook. (Scott, 2007).

This work contributes to the understanding by many communities that pneumatic structures were the best ones to respond to their temporary recreational needs, the ones that were more committed to the environment. In fact their pneumatic structures were fundamental part of many concerts, which include the festival of Altamont or others for the Rolling Stones. However, Reyner Banham and Francois Dellegrat had done a good work also with 'A Home is not a House'. Bubbles responded through direct action to the changeable desires of a part of society that had its will placed on technology, joy and love.

In the UK Cedric Price performs various research projects on pneumatic structures, compiling his findings in 1971 in 'Air Structures', a handbook on such structures. There, multiple referenced can be found, from the industrial applications of Hovercrafts to structural systems used by the military as an interesting removable bridge for vehicles that may be the predecessor of the 'bridge in a backpack' project developed at the University of Maine (<http://engineering.umaine.edu/departement-research/research-features/bridge-in-a-backpack/>). Price's interest is transferred to several active members of the architectural and cultural landscape of England. Archigram has several projects that use this type of technology including their project for an 'Instant City' - mentioned in a previous section of this text - in which they propose the use of an airship to which a set of curtains and electronic devices are added in order to enable urban spaces to carry out

Graham Stevens. Desert Cloud Solar heated floating inflatable structure

events. The intent of this project is the temporary activation of public space, disappearing after the eventual use. The shift towards air medium allows architectural structures to move easily from one place to another only remaining static at the precise moment in which they are being socially active, a recurring interest in the projects of the London group.

Graham Stevens another British artist, focuses much of his work in exploring the possibilities of pneumatic structures. His interest is in both the sensory experience of these types of structures and the ability to generate large volumes with minimal matter. Likewise he shows interest in the principles of buoyancy due to the density difference that occurs when heating the air that is contained within the structures, the original principle of this kind of structures contained on the 'Montgolfiers'. After being advised by Cedric Price and consult the book 'Direct use of the sun's energy' by Farrington Daniels (Architectural Review, April 2014, p. 106) he begins to explore the possibility of heating the interior of inflatable structures using direct sunlight radiation. To do this he places black plastic vertical ribs, the same ribs that reinforce the structure and control its form, which absorb sunlight transforming it into calorific energy. This energy heats the air inside of the structure, reducing its density, which culminates in the floatation of the structure in the air. In 1974 he makes a structure of this type in the desert of Kuwait; the strong sunlight at this location made the structure suspend in the air, an action he filmed for his movie 'Desert Cloud' which is part of the permanent collection of the FRAC Centre (Fonds Régional d'Art Contemporain) in Orleans, France.

Blur. Diller & Scofidio

Atmospheric Architecture: Blur

While the three generations of Japanese architects studied in the topology section, have tried to blur the boundaries of architecture and have overtly focused part of their architectural intentions on this issue, Toyo Ito even titled 'Blurring Architecture' the retrospective exhibition held at the Suermondt Ludwig Museum in Aachen in October 1999 to January 2000, on the other hand we can ensure that, until today, the most radical architectural act in terms of manipulation of the topological properties of architectural boundaries is the Blur project by Elisabeth Diller and Ricardo Scofidio in Switzerland.

This project is a pavilion built for the 2002 Swiss exhibition on Lake Neuchatel. In the words of its own architects it is atmospheric architecture. From the viewpoint of the analysis that is being carried out in this paper, we find a building whose boundary blurs and is materialized in an event in itself, it is no longer inert matter at rest but a dynamic suspension of water drops in the air. In fact the building's architectural materiality has nothing to do with the presence of it and of the experience of entering and crossing the dynamical boundary that defines it. In terms of construction the architects employ a 'tensegrity' structure, which minimizes the need for use of structural material, and 31,500 pressure water diffusers that return the water collected from the lake itself by drawing the diffuse boundary of the architectural act.

Blur. Diller & Scofidio

From the point of view of boundaries topological properties it is interesting the duality between the permeability at a level of translation through the building that is absolute while the building is visually imperious.

Blur is the material and living manifestation that shows how space-time reality has been assumed in architecture. Blur occurs in a given moment, it is changeable in time, it is not the same event one day than another, since the volatile boundary is reactive to the environmental conditions outside (wind, temperature...), and it disappears after a while and all it remains is the memory of an experience. The building is not executed following geometric guidelines (except for the 'tensegrity' structure and the plumbing system and water diffusers), but instead the performance parameters for the functioning of all diffusers are defined by computer programming in order to set the 'behaviour' of the building. In other words, instead of drawing the static position of building elements unpredictable (from an aesthetic point of view) weather events are encoded and programmed.

Save Our Planet. Save our Cities. R. Buckminster Fuller

CONCLUSIONS

Architecture seeks to sublimate through actions and material transformations the medium in which life happens. I stated it before: Architecture is about life. Everything else is circumstantial. This thesis has tried to trace the origin of certain recurring actions in contemporary architectural design. Such actions have been organized according to three research cores that have their origin in the changes that emerged from the theory of relativity in our way of understanding the world: contingency, topology and energy. Even though these research nuclei have been separated into separate sections, this simplification is merely a tool to facilitate the understanding of the processes involved. Life occurs, events happen and the becoming of space-time flows beyond our ability to understand it and adapt our actions to it. This flow is irreversible and runs just in one direction. This irreversibility of processes and events is what breaks time symmetry, as Ilya Prigogine explains in 'Order out of Chaos'. Irreversibility is what makes matter, space, time, events and energy to be united in a single reality.

If as architects we want to apprehend this reality and work on it, we ought to assume complexity and sophistication as essential to our practice. We should understand that architecture is not a formal academic discipline governed by a finite set of composition rules. In contrast, active architecture is an open system characterized by its ever growing level of complexity. As an open system, architecture provides topological links of relationship between an increasing number of layers of information that affect its behavior and the way in which creation and transformation of the environment decisions are taken. Thus architecture is always in constant transformation and adaptation as the parameters of the subsystems that comprise it are modified, allowing an organic adaptation in time.

City energy diagram. Howard T. Odum

Flow, continuity, porosity, permeability and ecosystem are terms that already belong and are assumed in the contemporary architectural glossary; terms that are linked to the adaptation of architecture to the scientific knowledge of its time. This new semantics is the evidence that this transformation in the conception of architecture is real and is being adopted by a growing number of architects. Other new terms imported from other systemic disciplines such as correspondence exergy, emergy or transformity will be gradually introduced in the common lexicon of architects, transforming their mindset and way of navigating the open system of active architecture. However, it is a priority to adapt the way architectural operating mode is transmitted to new generations of architects. To do this, it is of great importance to train and educate young architects in systems thinking so they can learn to relate, to connect, to establish degrees of interaction between sets of processes and events rather than thinking in solving finite problems in an engrossed closed system – be it a building, a city or furniture.

Systems thinking has enabled the inherent complexity of the world to be digested by our minds in order to adapt our actions to a narrow interpretation of events and actual processes rather than a mere intuition or arbitrary lax interpretation of simplifications of these processes. Only in this way could the Club of Rome could establish parameters for action in the famous “Limits to Growth” which since then has served as guide for the set of regulatory treaties that attempt to minimize the footprint of progress on the environment; only with systems we can safely control global air flow and telematic communications. Architecture, as long-lived complex discipline must abandon all simplistic and dogmatic thinking that seeks to force control over shape and tectonics, and learn to flow in the complexity and irreversibility of energy processes, active matter and space-time.

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